Zoo animal nutrition: typical health problems

Marcus Clauss

Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Switzerland

Belo Horizonte 2019

University of Zurich[UZH]

Clinic of Zoo Animals, Exotic Pets and Wildlife

Approach to zoo animal nutrition

+		-
	"do as we always did"	
based on experiences what has been working		sometimes 'experiences' are mistakes one has been making for long time
	"imitate the natural diet"	
best approach		depends on what you know about the natural diet, and what feeds are available
	"use a suitable domestic species as model"	
'scientific compromise' huge amount of knowledge		species-specific peculiarities are easily overlooked
	"based on studies in zoo animals"	
'scientific approach'		financially and logistically challenging, difficulty in summarizing knowledge

Zoo animal nutrition

zoo animal studies

Studies in zoo animals

- Case reports / case series
- Inventories of diets, pathological states, husbandry success
- Differences between free-range and zoo
- Epidemiological / controlled studies

Examples: case studies

DIETARY TAURINE SUPPLEMENTATION AND CARDIAC FUNCTION IN THE GIANT ANTEATER (*Myrmecophaga tridactyla*): PRELIMINARY FINDINGS

J. Andrew Teare, DVM, MS,[1] Alan D. Weldon, DVM, Dipl AVCIM,[2] and Nikolay Kapustin, DVM[1]*

2009 PROCEEDINGS AAZV AAWV JOINT CONFERENCE

TAURINE DEFICIENCY IN MANED WOLVES (*Chrysocyon brachyurus*) MAINTAINED ON TWO DIETS MANUFACTURED FOR PREVENTION OF CYSTINE UROLITHIASIS

Sara E. Childs-Sanford, DVM[1] and C. Roselina Angel, PhD[2]*

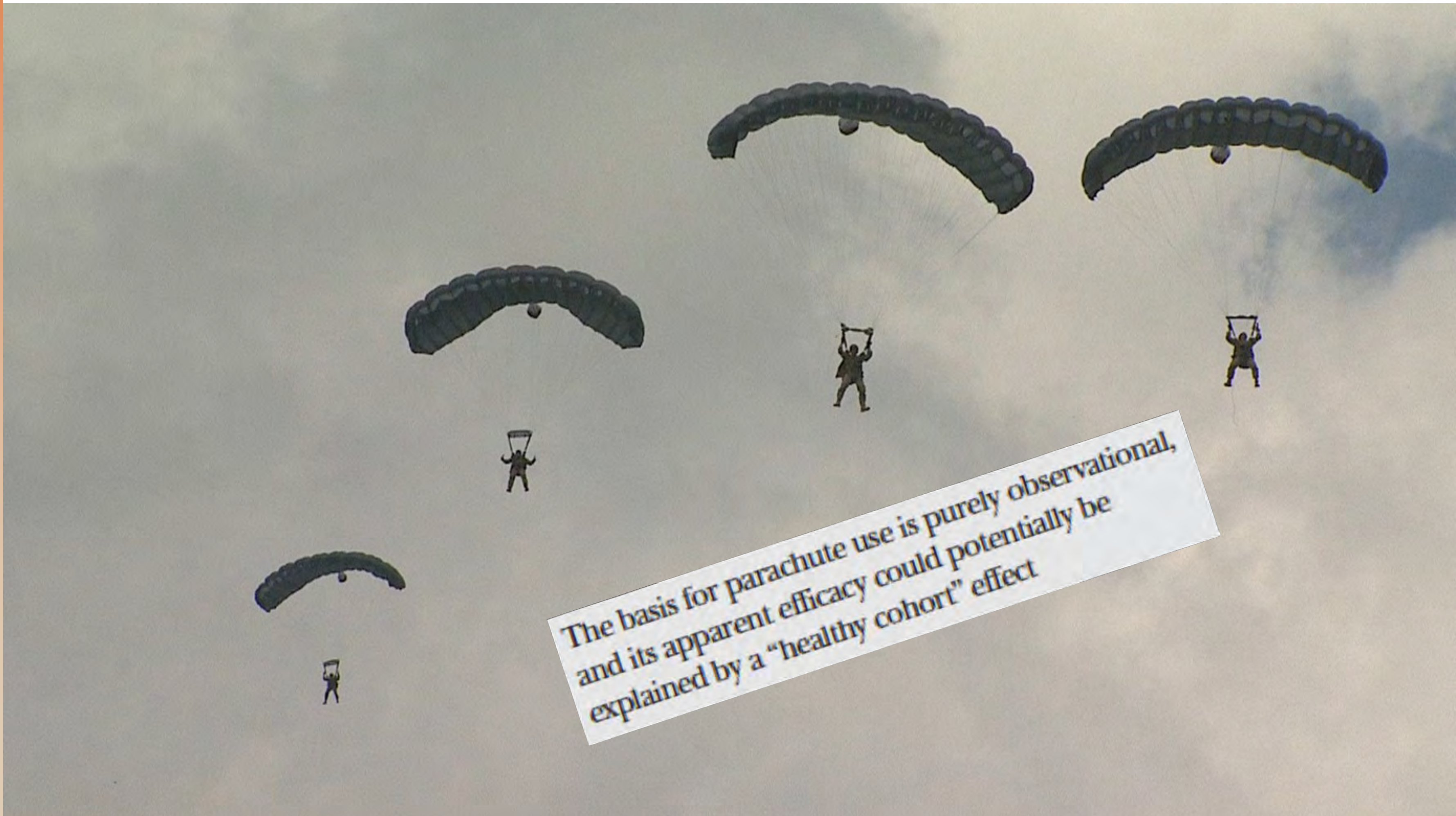
2004 PROCEEDINGS AAZV, AAWV, WDA JOINT CONFERENCE

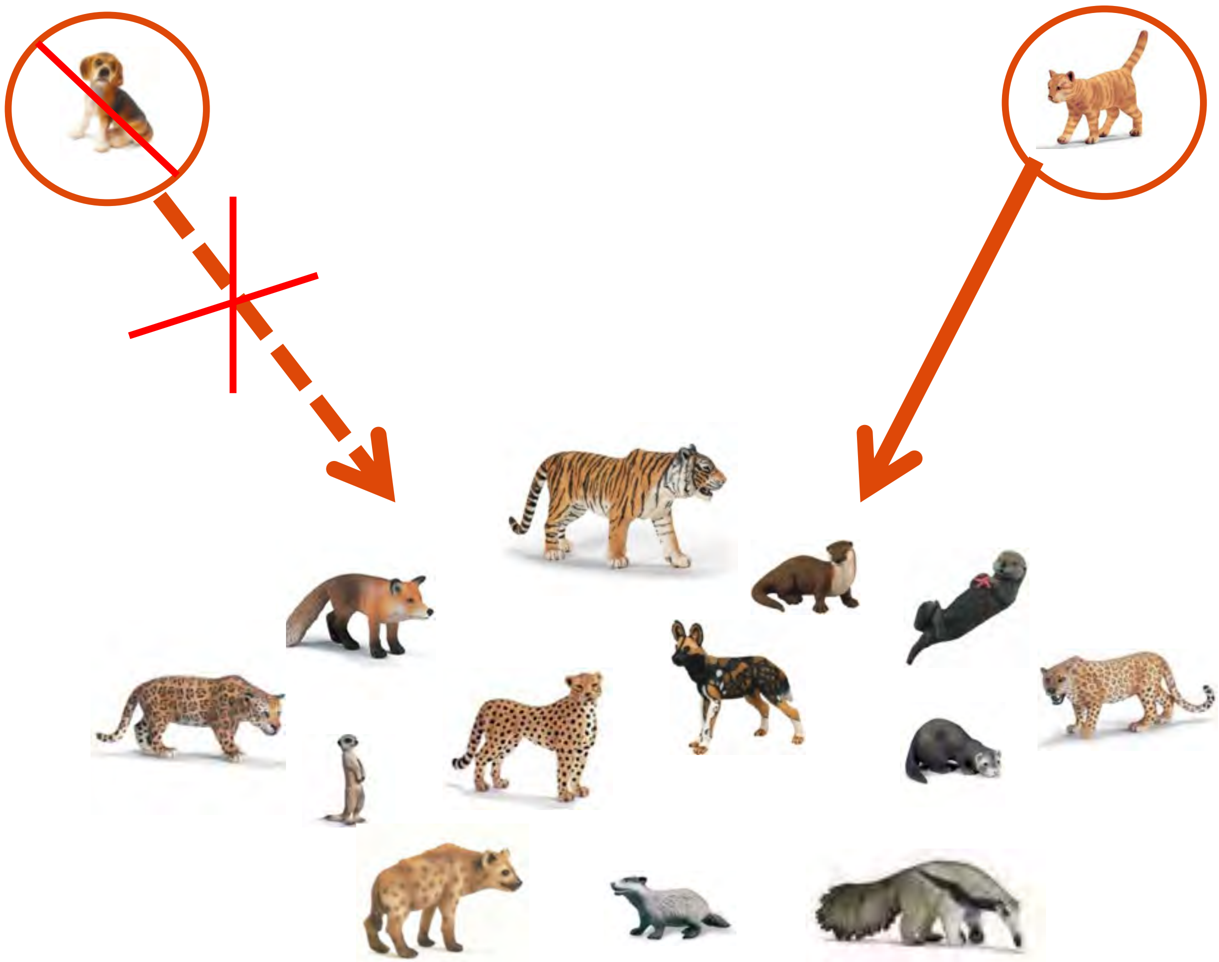
no control group

Parachute use to prevent death and major trauma related to gravitational challenge: systematic review of randomised controlled trials

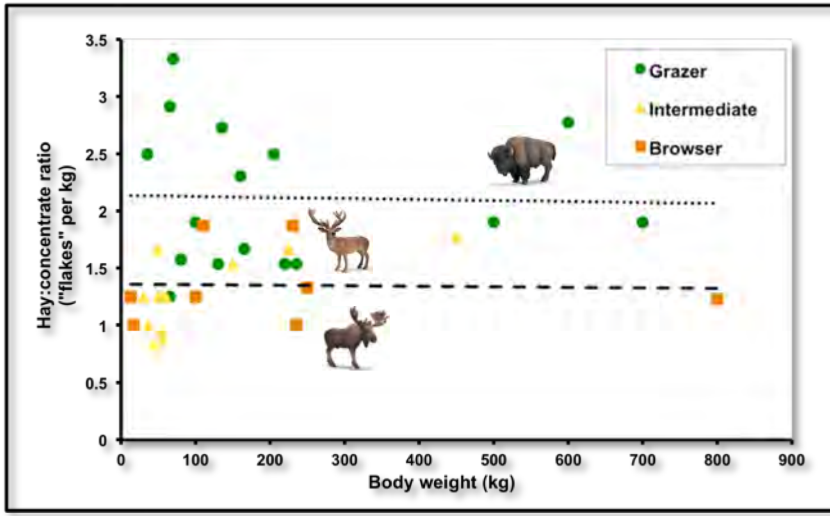
Gordon C S Smith, Jill P Pell

BMJ VOLUME 327 20–27 DECEMBER 2003





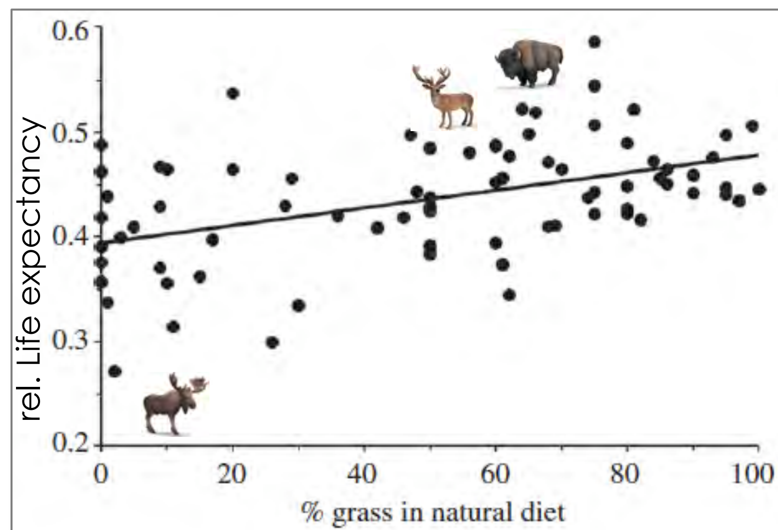
Examples: inventories



Grisham and Savage (1990)

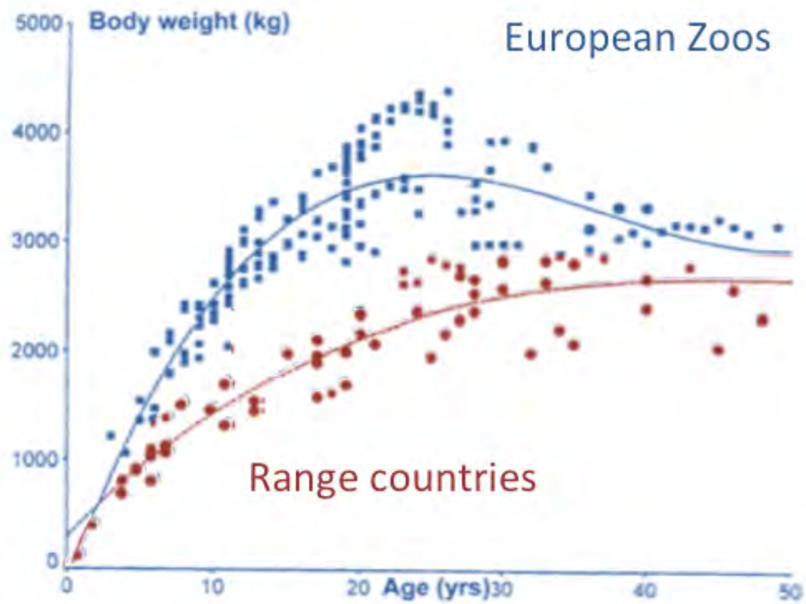
Feeding type	n	Acidotic changes of the rumen mucosa (%)
Grazer	13	23
Intermediate	30	27
Browser	24	83

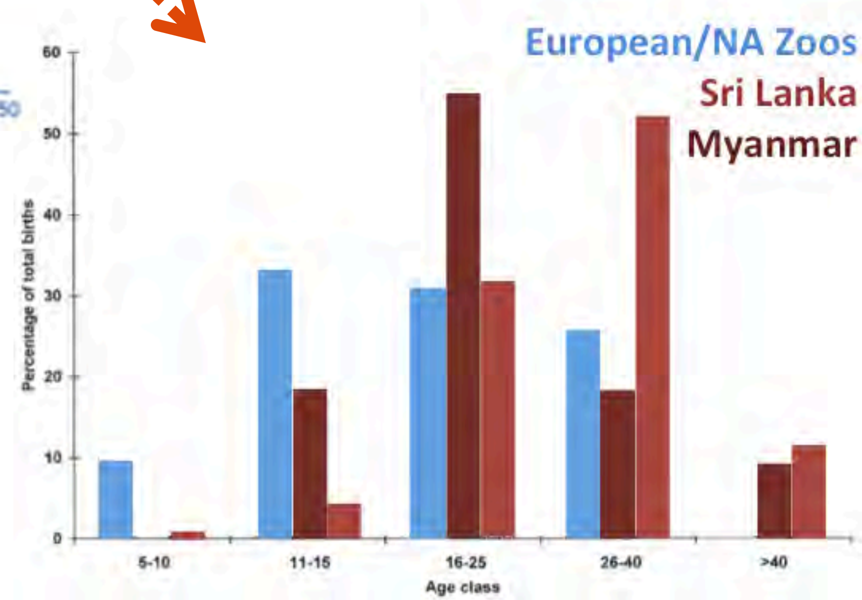
Marholdt (1991)



Müller et al. (2011)

Examples: inventories





Kibby Treiber - Plenary (2015)

Studies in zoo animals

- **Case reports / case series**
- **Inventories of diets, pathological states, husbandry success**
- **Differences between free-range and zoo**
- Epidemiological / controlled studies

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.

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]

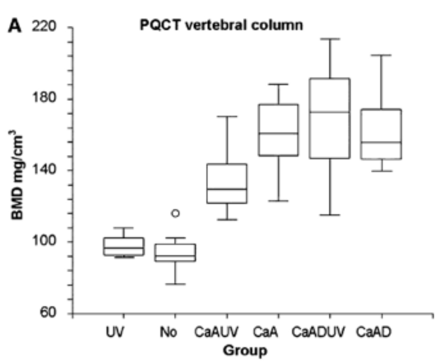
Examples: epidemiological/**controlled** studies

Nutritional Metabolic Bone Disease in Juvenile Veiled Chameleons (*Chamaeleo calyptratus*) and Its Prevention[1–3]

J. Nutr. 140: 1923–1931, 2010.

Stefan Hoby,[4,5] Christian Wenker,[5] Nadia Robert,[4] Thomas Jermann,[5] Sonja Hartnack,[6] Helmut Segner,[4] Claude-P. Aebischer,[8] and Annette Liesegang[7]*

Group	*n*	Body dimensions: Weight	Body dimensions: SVL
		g	*mm*
UV	10	26.7 (19.2–34.2)	100.1 (90.4–109.8)
No	10	13.5 (11.3–15.7)	74.4 (69.1–79.7)
CaAUV	9	58.2 (47.3–69.2)	144.2 (133.8–154.6)
CaA	9	60.5 (52.1–68.9)	144.2 (133.4–155.1)
CaADUV	9	54.3 (38.1–70.5)	138.2 (117.6–158.8)
CaAD	9	57.9 (38.2–77.6)	136.8 (117.8–155.7)



Controlled studies often put animals at risk

Nutritional Metabolic Bone Disease in Juvenile Veiled Chameleons (*Chamaeleo calyptratus*) and Its Prevention[1–3]

J. Nutr. 140: 1923–1931, 2010.

Stefan Hoby,[4,5] Christian Wenker,[5] Nadia Robert,[4] Thomas Jermann,[5] Sonja Hartnack,[6] Helmut Segner,[4] Claude-P. Aebischer,[8] and Annette Liesegang[7]*

Effects of starch and fibre in pelleted diets on nutritional status of mule deer (*Odocoileus hemionus*) fawns

S. McCusker[1], L. A. Shipley[1], T. N. Tollefson[1,2], M. Griffin[3,4] and E. A. Koutsos[4]

Journal of Animal Physiology and Animal Nutrition **95** (2011) 489–498

Laboratory Animal Science
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Vol 47, No 2
April 1997

Hepatic Hemosiderosis in Common Marmosets, *Callithrix jacchus*: Effect of Diet on Incidence and Severity

Georgina F. Miller,[1] Dennis E. Barnard,[1] Ruth A. Woodward,[1] B. Michael Flynn,[1] and Jeff W. M. Bulte[2]

Research in a zoo setting

- lack of risk for zoo animals is usually a prerogative for a zoo study to be allowed
- studies that shall have relevance for ***HEALTH*** mostly by definition require setups of more and less healthy options/treatments

- typical 'risk-free' nutrition studies in zoos with potential relevance: inventories, epidemiological studies
- typical 'risk-free' nutrition studies in zoos with less potential relevance: measuring digestibility and digesta passage on used diets

Comparisons with the wild

Examples: differences wild - zoo

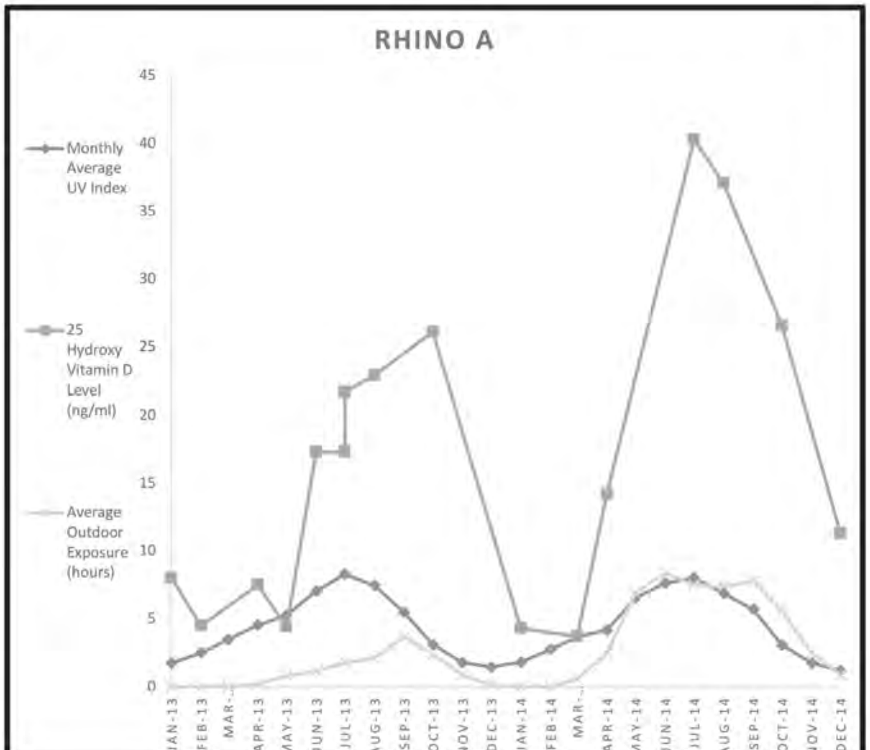
+ calcium in diets and body tissues & UV-B exposure -

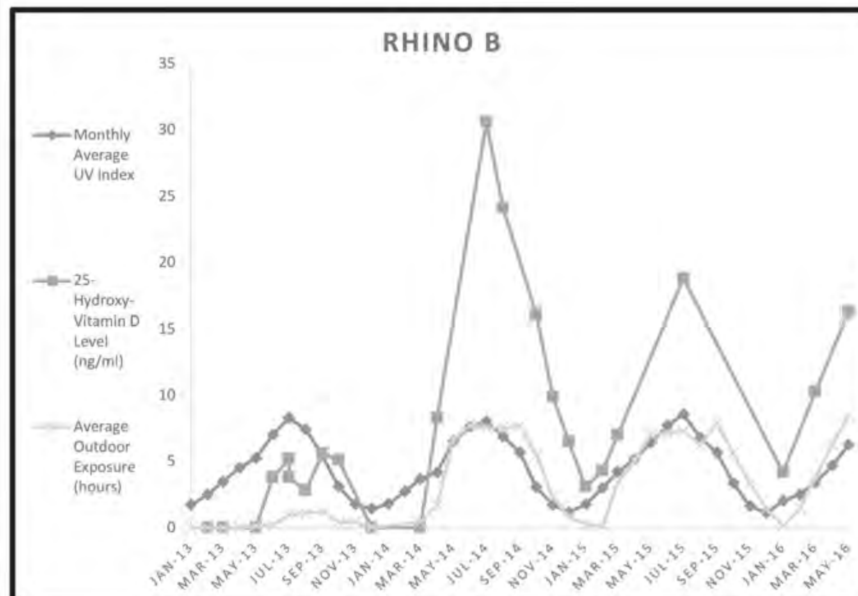
e.g. Herz & Kirberger (2004), Clauss et al. (2007)

SEASONAL VARIATION OF SERUM 25-HYDROXY-VITAMIN D IN TWO CAPTIVE EASTERN BLACK RHINOCEROS (*DICEROS BICORNIS MICHAELI*) HOUSED IN A NORTH AMERICAN ZOO

June Olds, D.V.M., Wes Oltman, B.S., Andrew J. Makowski, B.A., Hilary Householder, D.V.M., and Lou L. Keeley, M.S., B.S.

Journal of Zoo and Wildlife Medicine 49(4): 943–951, 2018





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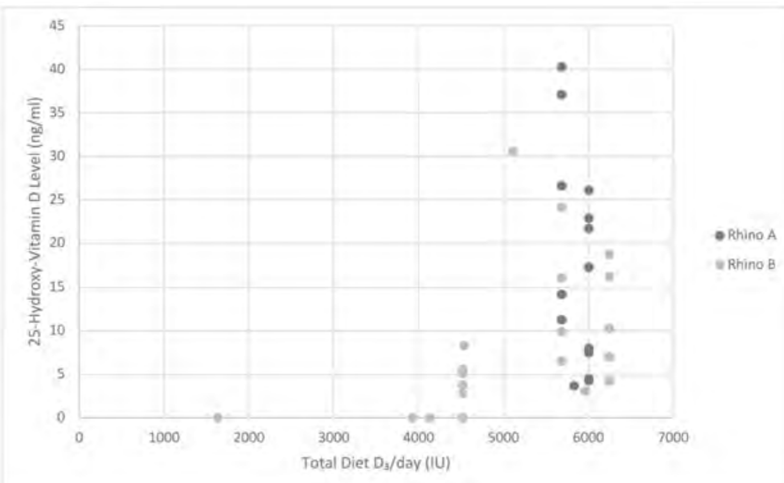

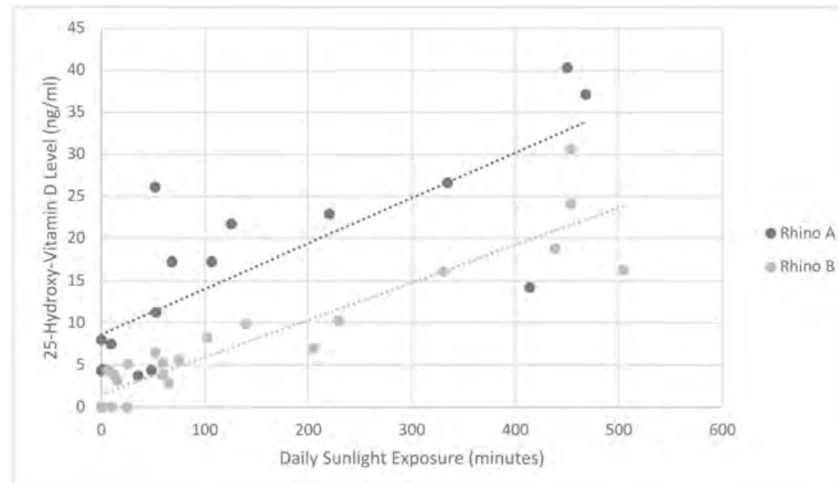

Examples: differences wild - zoo

wild		zoo
+	calcium in diets and body tissues & UV-B exposure	-
-	iron deposits in organs	+

e.g. Herz & Kirberger (2004), Clauss et al. (2007), Clauss & Paglia (2012)

CHAPTER 34

Iron Overload in the Animal Kingdom

LINDA J. LOWENSTINE
LINDA MUNSON

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

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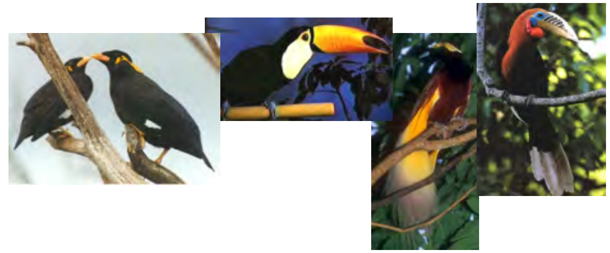
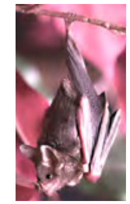
Susceptible species

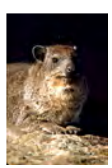
Definite candidates

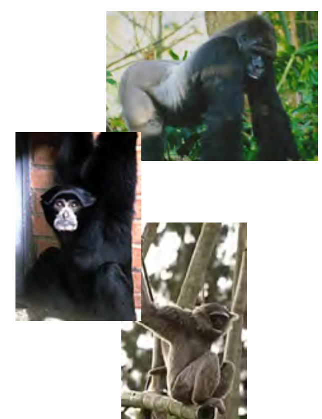




Definite candidates?

Potential candidates





Screening lemurs

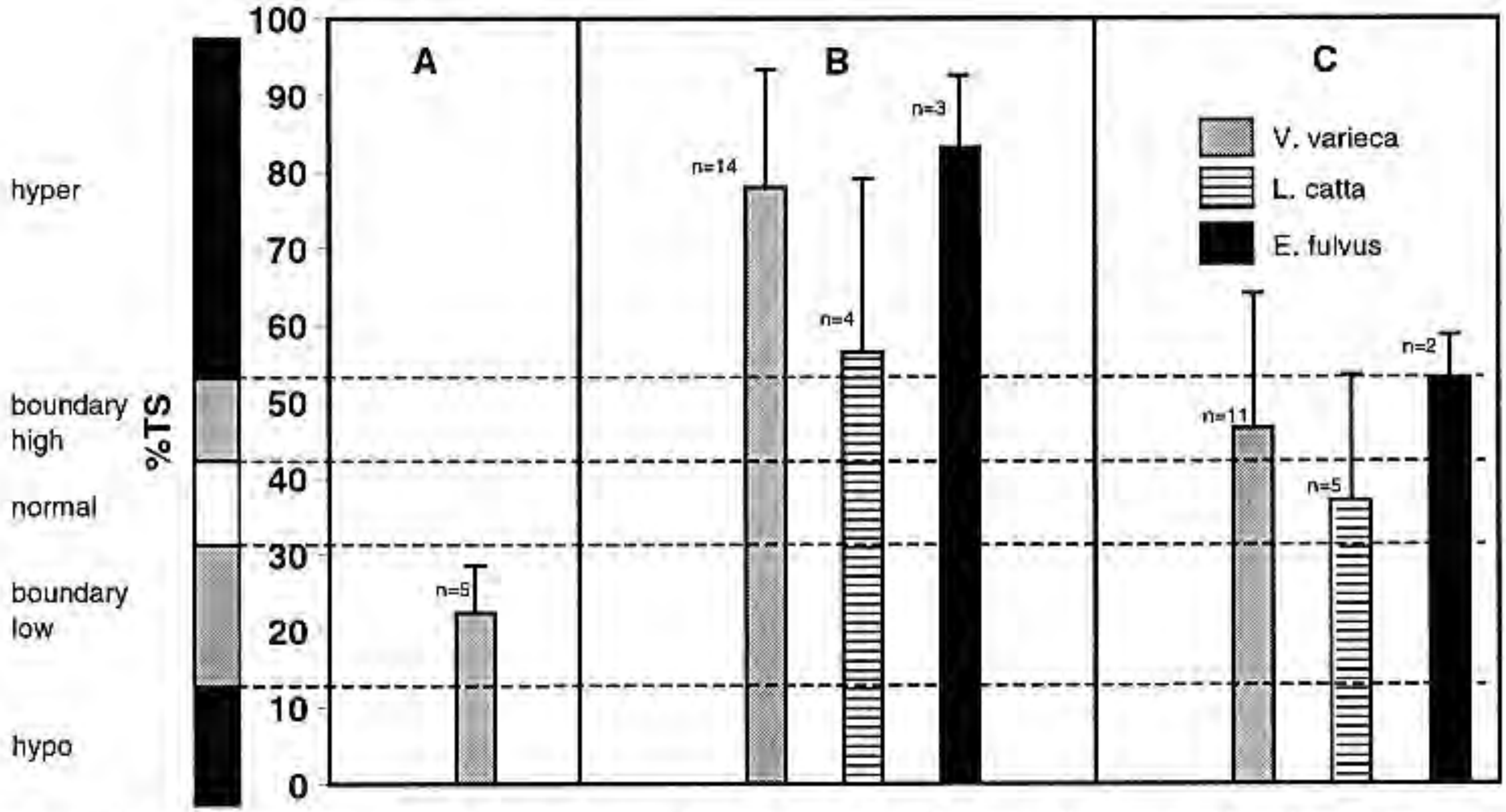


Fig. 1. Mean (SD) TS% in different captive lemur species: (A) weanling animals [Gonzales et al., 1984], (B) regular zoo diet, and (C) 8 weeks after dietary change (this study). Evaluation of data according to standards used in human medicine (c.f. Table I).

Wood et al. (2003); remember Benirschke et al. (1985)

ISD in lemurs: is it real?

Brygoo et al. (1964), Palotay (1978), Griner (1983), Clauss et al. (2002), Schwitzer et al. (2002) - individual cases

Gonzales et al. (1984), Benirschke et al. (1985), Spelman et al. (1989) - in up to 100% of investigated cases

Dutton et al. (2003) and several other more recent studies - lower iron status in free-ranging than in captive lemurs

Yet, in 2003, we were surprised by massive reviewer opposition to our manuscript Wood et al. (2003) which also addressed ISD in lemurs and suggested dietary measures

2003 Prosimian TAG Report on ISD in lemurs:

"unpublished data from Duke University suggests that the incidence of hemosiderosis in captive lemurs may not be as high as previously suspected and that there may be species and institutional differences in the tendency to develop hemosiderosis"

ISD in lemurs: is it real?

Retrospective Evaluation of the Incidence and Severity of Hemosiderosis in a Large Captive Lemur Population

KELLY M. GLENN[1], JENNIFER L. CAMPBELL[2*], DAVID ROTSTEIN[3], AND CATHY V. WILLIAMS[1]
[1]*Duke University Primate Center, Durham, North Carolina*
[2]*Department of Animal Biotechnology and Conservation, Delaware Valley College, Doylestown, Pennsylvania*
[3]*Department of Pathobiology, University of Tennessee College of Veterinary Medicine, Knoxville, Tennessee*

American Journal of Primatology 68:369–381 (2006)

Of the 153 reports examined, 49 (32%) of the animals were considered positive for the presence of hemosiderin in the liver, lymph node, duodenum, and kidney, with 36 of the 49 (73%) showing deposition of iron in the liver.

Examples: differences wild - zoo

+	calcium in diets and body tissues & UV-B exposure	-
-	iron deposits in organs	+
+	unsaturated (n-3) fatty acids in diets and body tissues	-

e.g. Herz & Kirberger (2004), Clauss et al. (2007), Clauss & Paglia (2012), Clauss et al. (2007)

Linseed

M. Clauss, E.J. Flach, K. Ghebremeskel,
C. Tack, J.-M. Hatt

Supplementing the diet of captive giraffe (*Giraffa camelopardalis*) with linseed extraction chips

Abstract

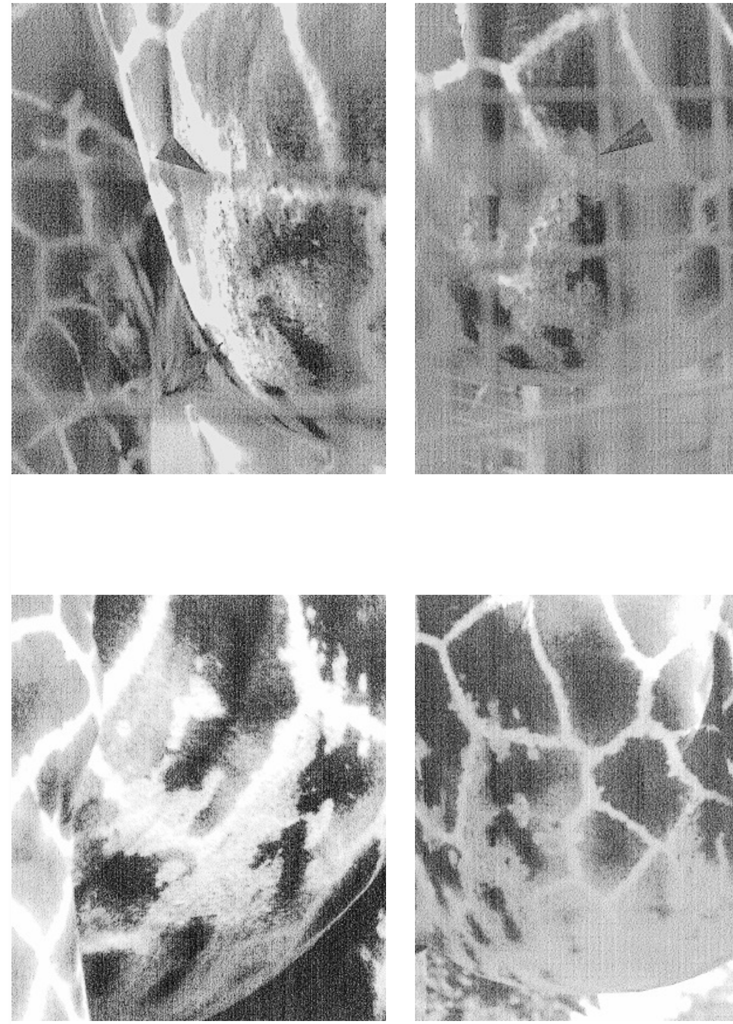
Captive giraffe (Giraffa camelopardalis) are reported to have low linolenic acid concentrations in body tissues in comparison with free-ranging individuals. However, it is not known whether this merely reflects a different diet, or whether it impairs body functions. As linseed contains significant amounts of linolenic acid, the feeding of linseed extraction chips might be a practical way of supplementation. Captive giraffe with low linolenic acid status in their blood lipids (compared to domestic ruminants) were introduced to a diet that included linseed extraction chips. Blood lipids of animals from which samples were available after the change in dietary regime (n = 2) showed an increase in linolenic acid content. One of the animals had a history of skin lesions resistant to treatment. The skin lesions improved markedly during the course of linseed supplementation. While long-term effects of either linolenic acid deficiency or linolenic acid supplementation in giraffe remain to be demonstrated, these results suggest that giraffe might benefit from the addition of linseed extraction chips to their diet.

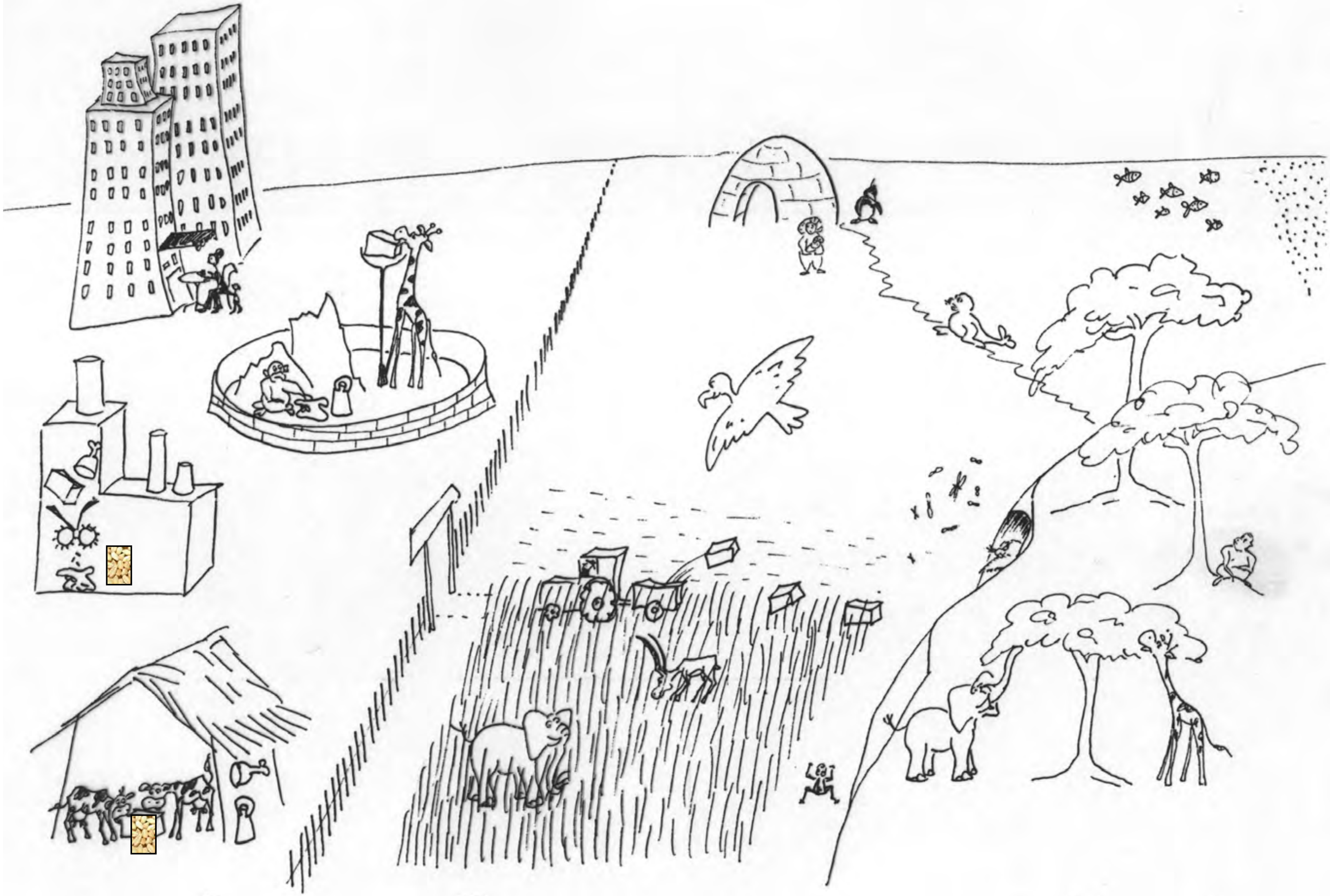
Keywords

polyunsaturated fatty acids, linolenic acid, skin lesion, peracute mortality syndrome

1. Introduction

It has been reported that captive giraffe (*Giraffa camelopardalis*) have a much lower content of polyunsaturated fatty acids (PUFA) in body tissues than

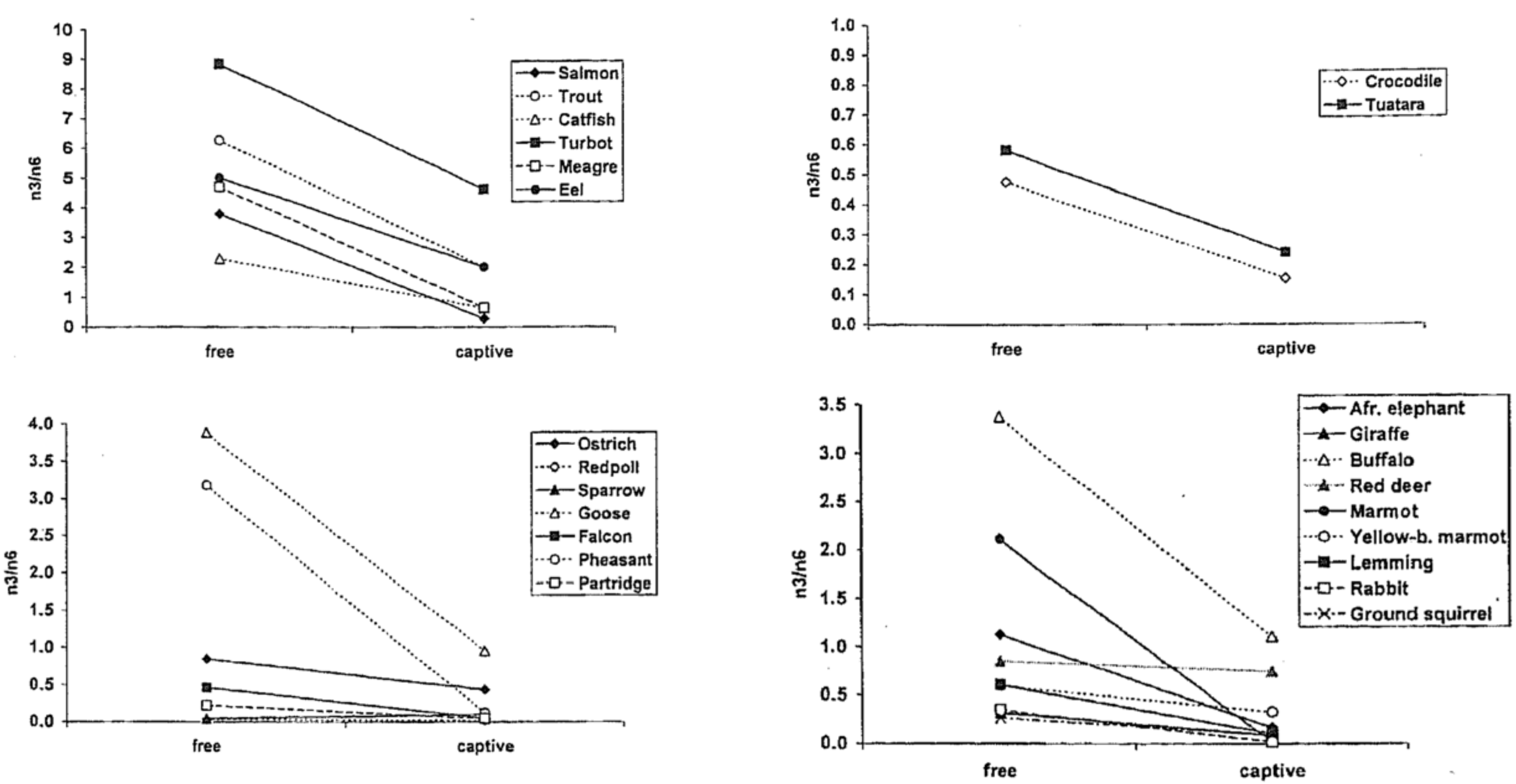




Fatty acid status of captive wild animals: a review

By Marcus Clauss, Christine Grum and Jean-Michel Hatt, Zurich

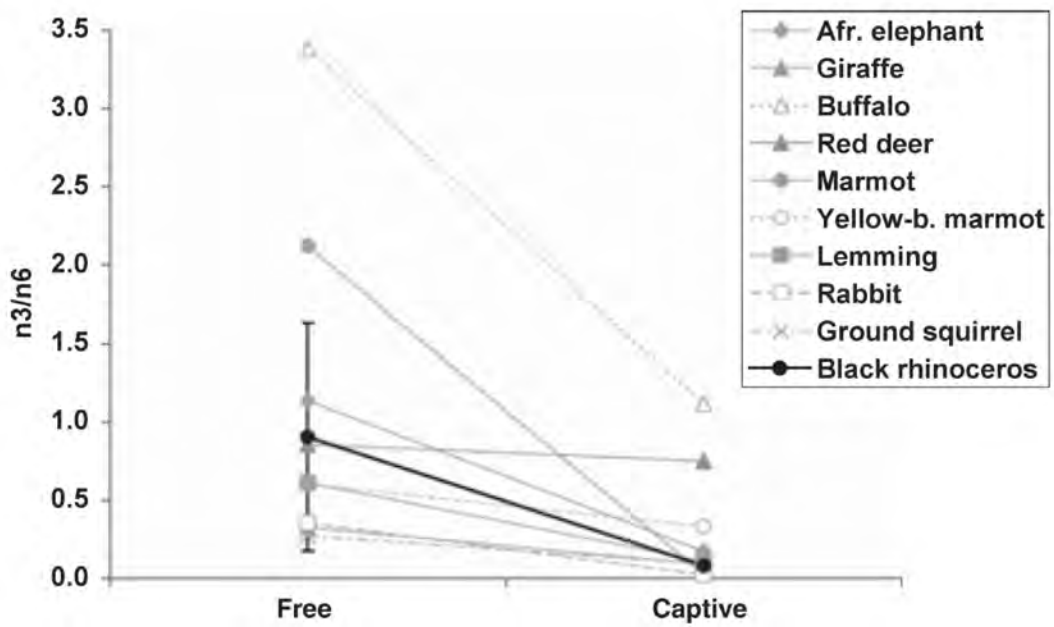
Zool. Garten N. F. **76** (2007) 5–6, S. 382–401



Fatty acid status in captive and free-ranging black rhinoceroses (*Diceros bicornis*)*

M. Clauss[1], E. S. Dierenfeld[2], K. E. Bigley[3], Y. Wang[4], K. Ghebremeskel[4], J.-M. Hatt[1], E. J. Flach[5], O. Behlert[6], J. C. Castell[7], W. J. Streich[8] and J. E. Bauer[3]

Journal of Animal Physiology and Animal Nutrition **92** (2008) 231–241



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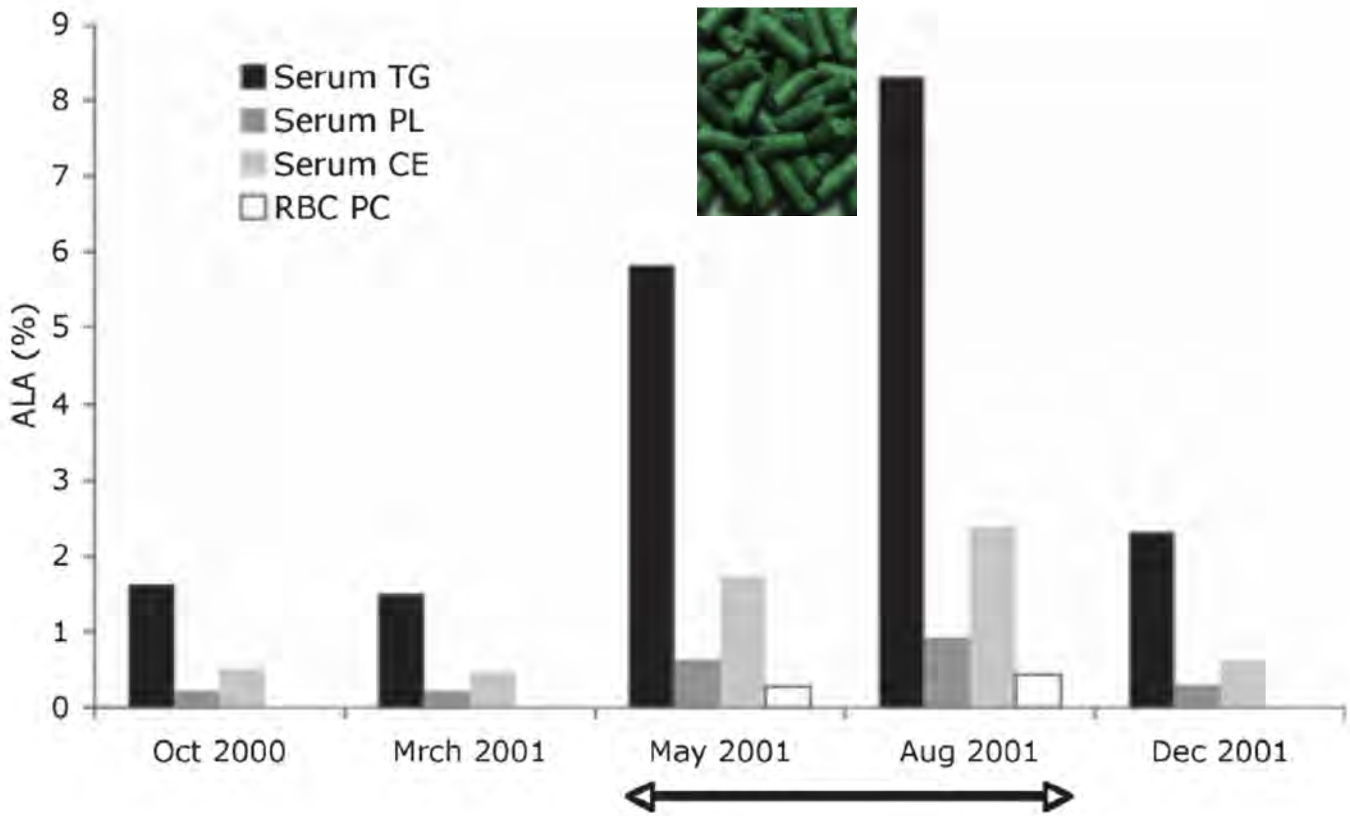

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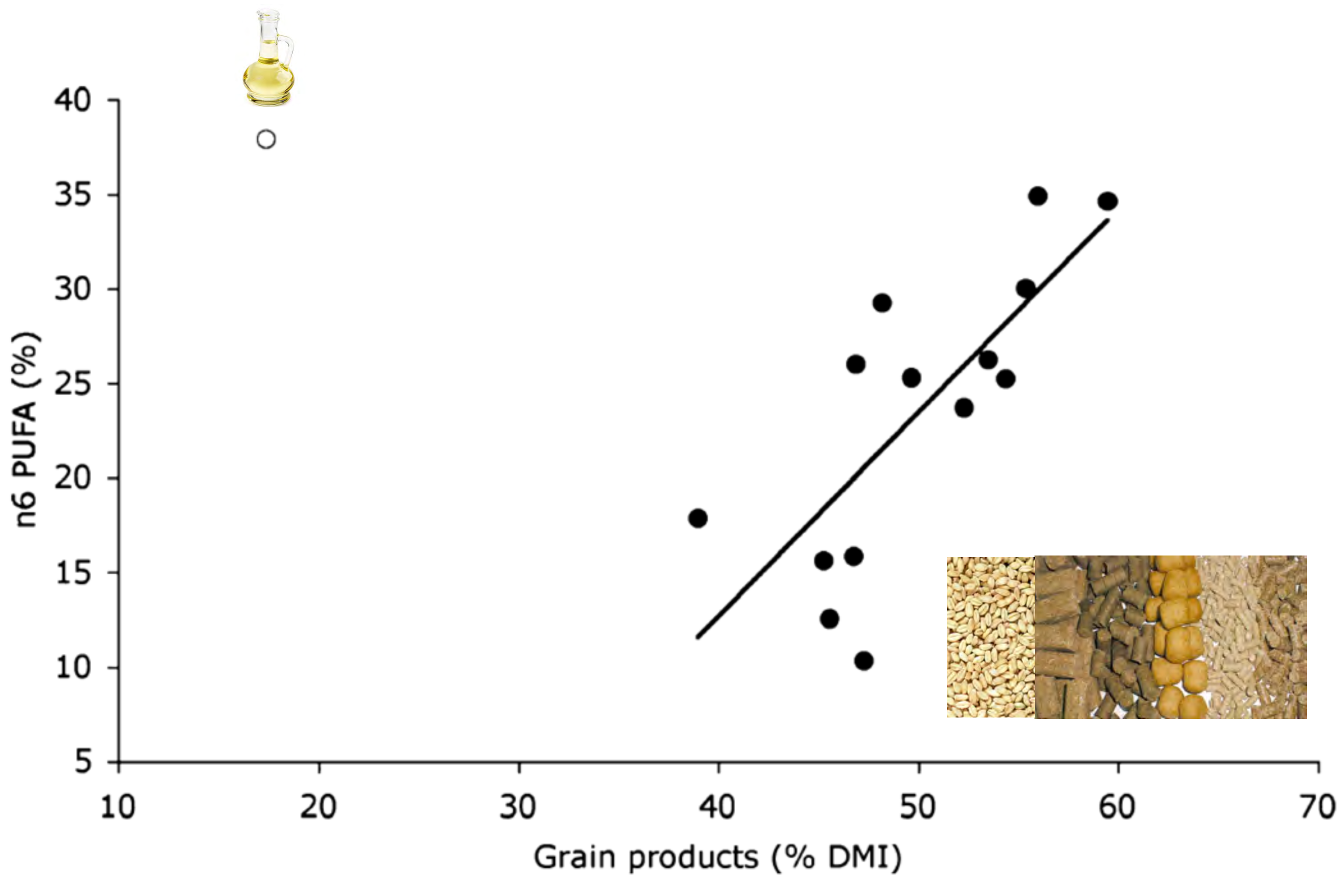


n3 >> n6 PUFA

n3 << n6 PUFA

Examples: differences wild - zoo

+	calcium in diets and body tissues & UV-B exposure	-
-	iron deposits in organs	+
+	unsaturated (n-3) fatty acids in diets and body tissues	-
+	carotenes and related substances in diet and intensive colouration	-

e.g. Herz & Kirberger (2004), Clauss et al. (2007), Clauss & Paglia (2012), Clauss et al. (2007), Ogilvy et al. (2012)

A brighter future for frogs? The influence of carotenoids on the health, development and reproductive success of the red-eye tree frog

V. Ogilvy[1], R. F. Preziosi[1] & A. L. Fidgett[2]

Animal Conservation **15** (2012) 480–488

Females fed a carotenoid post-metamorphic diet were significantly more likely to produce spawn than those fed a control post-metamorphic diet ($\chi^2 = 8.46$, degrees of freedom = 1, $P \leq 0.01$). Four out of the five carotenoid-

Examples: differences wild - zoo

+ dental calculus ++

e.g. De Clarke & Cameron (1998)

Hamburger-style diets

J. Zoo An. Med. 15: 142-146, 1984

Diet and Oral Health in Captive Amur Tigers (*Panthera tigris altaica*)

L. I. Haberstroh, D.V.M.*
D. E. Ullrey, Ph.D.**
J. G. Sikarski, D.V.M., M.S.*
N. A. Richter, D.V.M.***
B. H. Colmery, D.V.M.*
T. D. Myers, D.D.S.****

J. Zoo An. Med. 13: 104-107, 1982

A SOFT VERSUS HARD DIET AND ORAL HEALTH IN CAPTIVE TIMBER WOLVES (*Canis lupus*)

K.M. Vosburgh, B.S.*
R.B. Barbiers, B.S.*
J.G. Sikarskie, D.V.M., M.S.*
D.E. Ullrey, Ph.D.**

Dental calculus

Relationship between diet, dental calculus and periodontal disease in domestic and feral cats in Australia

DE CLARKE[a] and A CAMERON[b]

Aust Vet J 1998;76:690-693.

Results Dental calculus scores were significantly higher in domestic cats than in feral cats. There was no statistical difference in the prevalence of periodontal disease between the two groups.

Conclusion It can be inferred that diet may play a role in the accumulation of calculus, but a diet based on live prey does not protect cats against periodontal disease.

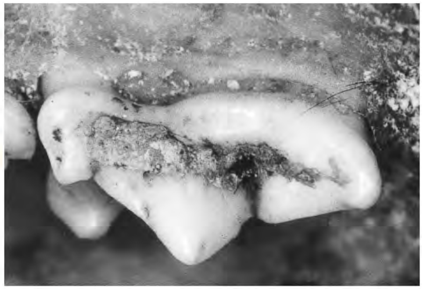


Figure 1. Calculus on the buccal surface of the upper fourth premolar tooth in a feral cat.

Examples: differences wild - zoo

+	dental calculus	++
-	tooth wear (browsers, bears)	+

e.g. De Clarke & Cameron (1998), Wenker et al. (1999), Clauss et al. (2007), Kaiser et al. (2009), Taylor et al. (2014)

Dental health in captivity

... a lot of work suggesting that the dental health of captive wild animals is not ideal ...

Dental health in captivity

Coyler (1936) primates in captivity have much more tooth problems than free-ranging primates (e.g. caries)

Hungerford et al. (1999) higher incidence of periodontosis and caries in raccoons from a city park than from the wild

Wenker et al. (1999) more dental calculus in captive than in free-ranging bears, and more leasions due to bar chewing in zoo bears

Dental health in captivity

... a lot of work suggesting that the dental health of captive wild animals is not ideal ...

... due to sugars (caries), texture (calculus), behavioural abnormalities (bar chewing) or genetics (malformed teeth)

... what about tooth wear (the loss of dental tissue for physical reasons)?

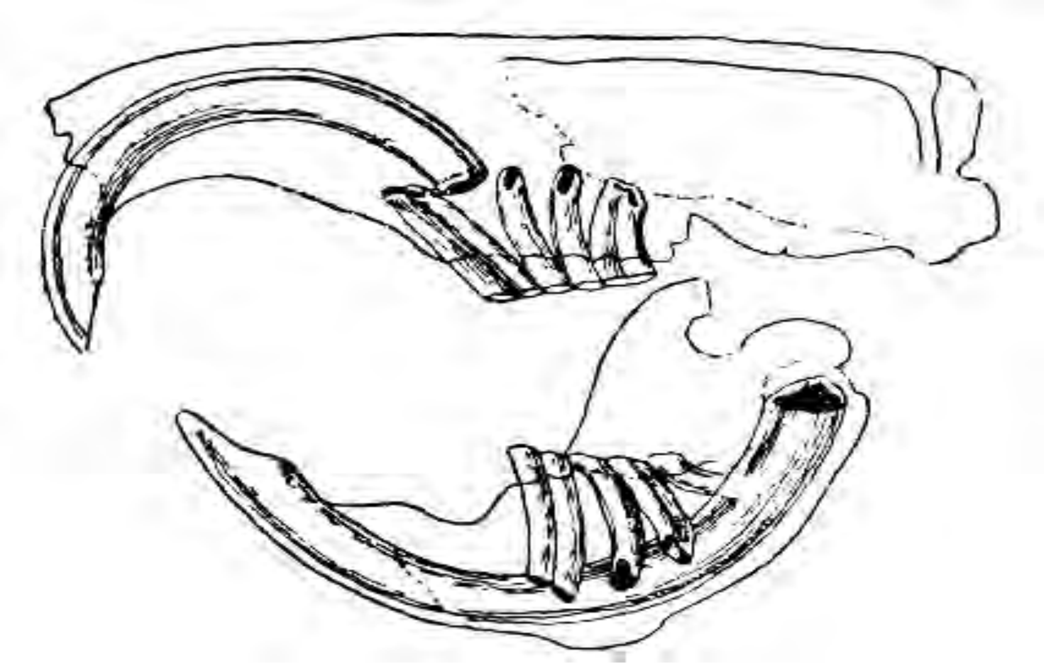
What wears down dental tissue?

- ~~diet 'hardness' (common perception: branches, twigs, sometimes even dry bread)~~

- diet abrasiveness

- tooth-to-tooth contact => chewing!

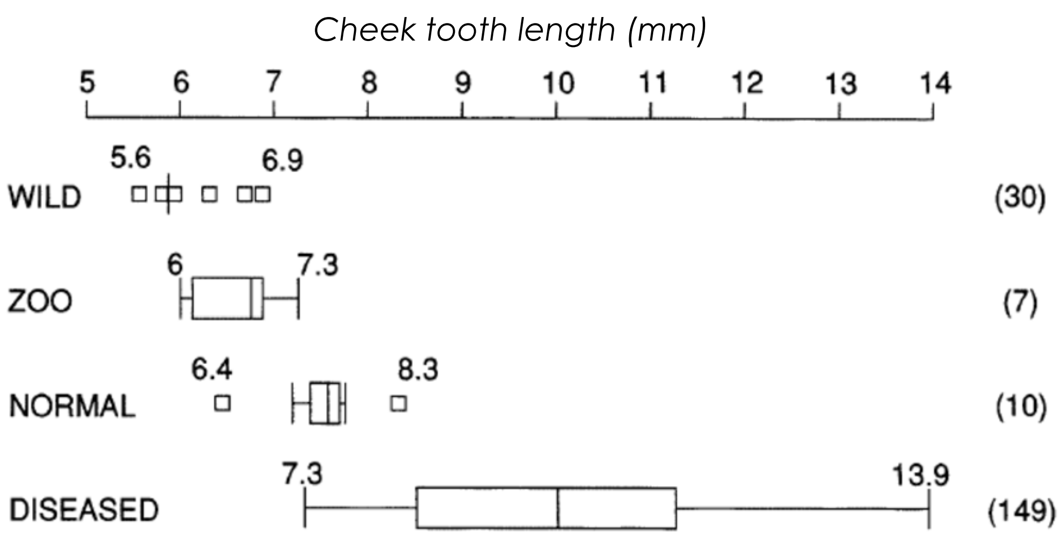
Hypseledont teeth



Skull size and cheek-tooth length in wild-caught and captive-bred chinchillas

David A. Crossley *, Maria del Mar Miguélez

Archives of Oral Biology 46 (2001) 919–928

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The way we taught it in the past …

"Growth is constant …

Growth (mm/week) of incisors

Species	Maxilla	Mandible
Rat	1.5-2.6	1.8-3.9
Chinchilla	1.3-1.7	1.1-2.2
Guinea pig	1.4-1.7	1.2-1.9
Dwarf rabbit	1.3-1.7	1.1-1.8

Kamphues (2001)

… and must be compensated by chewing-wear of a suitable food."

The way we taught it in the past …

"Growth is constant …

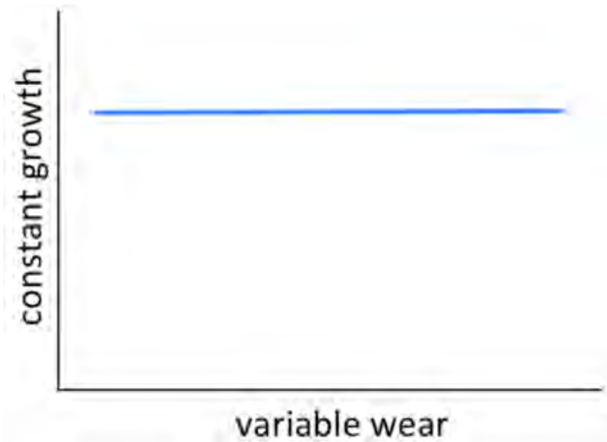
Time required for ingestion (min/g dry matter)

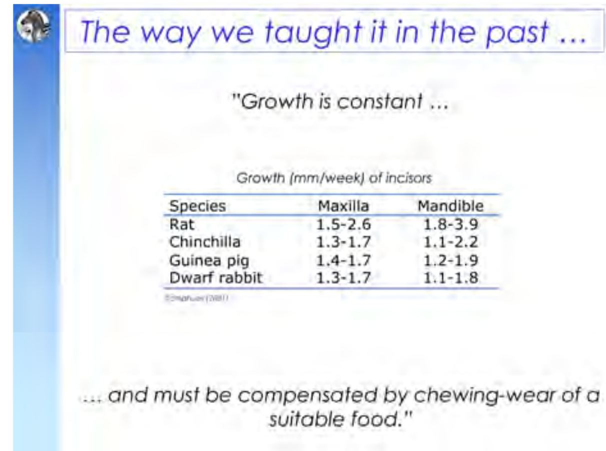
Food	Rabbit	Guinea pig	Chinchilla
Grass hay	5-12	8-14	14-20
Fresh grass	7	7	19
‚Müsli'	3	4	5
Pellets	1	5	4

Wenger (1997), Schröder (1999)

… and must be compensated by chewing-wear of a suitable food."

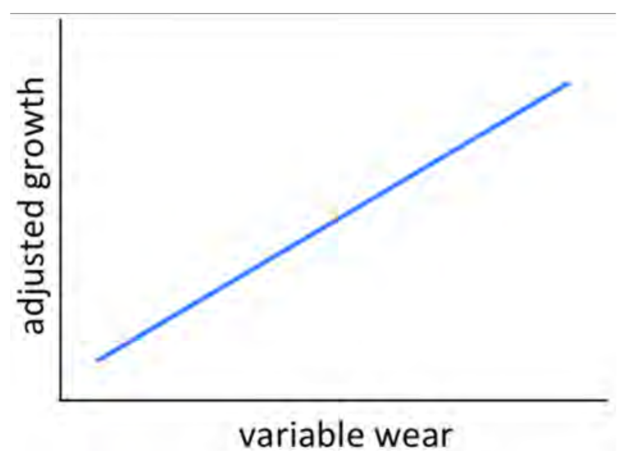
Growth


constant growth
variable wear


The way we taught it in the past …
"Growth is constant …
Growth (mm/week) of incisors

Species	Maxilla	Mandible
Rat	1.5-2.6	1.8-3.9
Chinchilla	1.3-1.7	1.1-2.2
Guinea pig	1.4-1.7	1.2-1.9
Dwarf rabbit	1.3-1.7	1.1-1.8

… and must be compensated by chewing-wear of a suitable food."


adjusted growth
variable wear

RESEARCH ARTICLE

Growth and Wear of Incisor and Cheek Teeth in Domestic Rabbits (*Oryctolagus cuniculus*) Fed Diets of Different Abrasiveness

JOURNAL OF EXPERIMENTAL ZOOLOGY
PART A
ECOLOGICAL GENETICS AND PHYSIOLOGY
A Journal of Integrative Biology

JACQUELINE MÜLLER[1], MARCUS CLAUSS[1]*, DARYL CODRON[1,2], ELLEN SCHULZ[3], JÜRGEN HUMMEL[4], MIKAEL FORTELIUS[5], PATRICK KIRCHER[6], AND JEAN-MICHEL HATT[1]

J. Exp. Zool. 321A:283–298, 2014

Journal of
Animal Physiology and Animal Nutrition

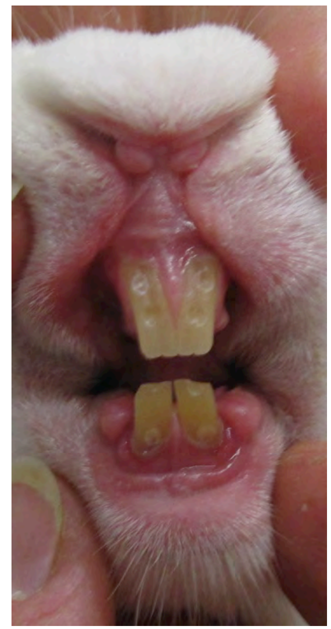
Journal of Animal Physiology and Animal Nutrition © 2014 DOI: 10.1111/jpn.12226

ORIGINAL ARTICLE

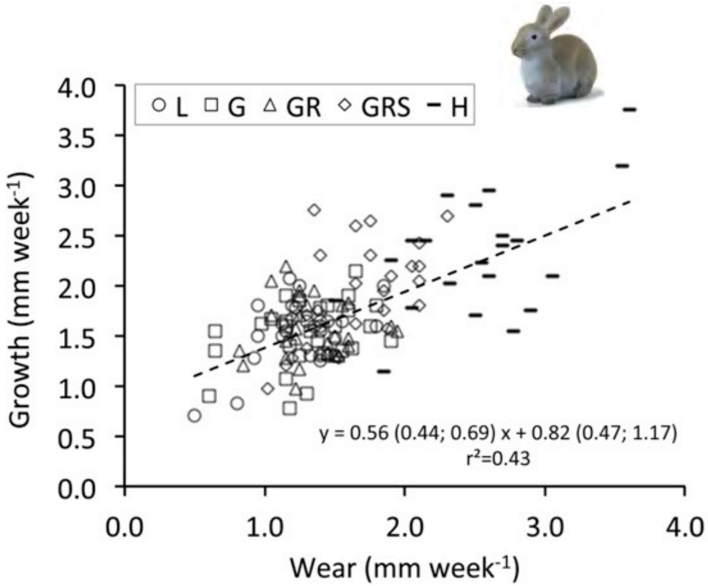
Tooth length and incisal wear and growth in guinea pigs (*Cavia porcellus*) fed diets of different abrasiveness

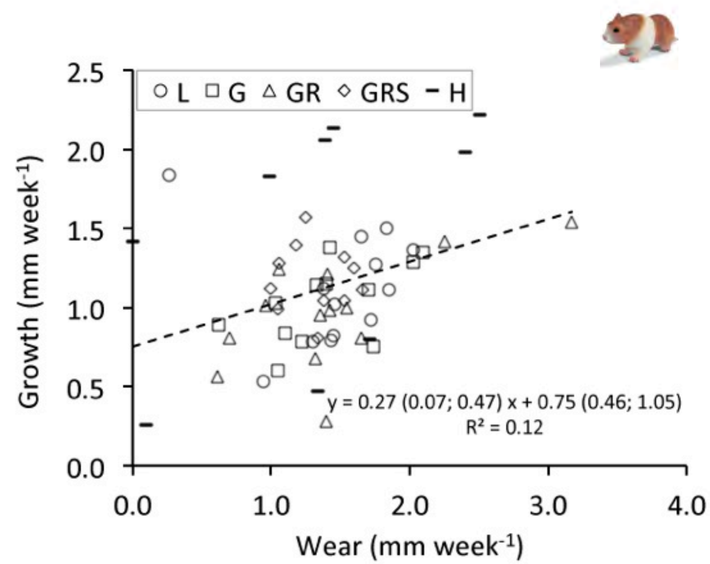
J. Müller[1], M. Clauss[1], D. Codron[1,2], E. Schulz[3,4], J. Hummel[5], P. Kircher[6] and J.-M. Hatt[1]

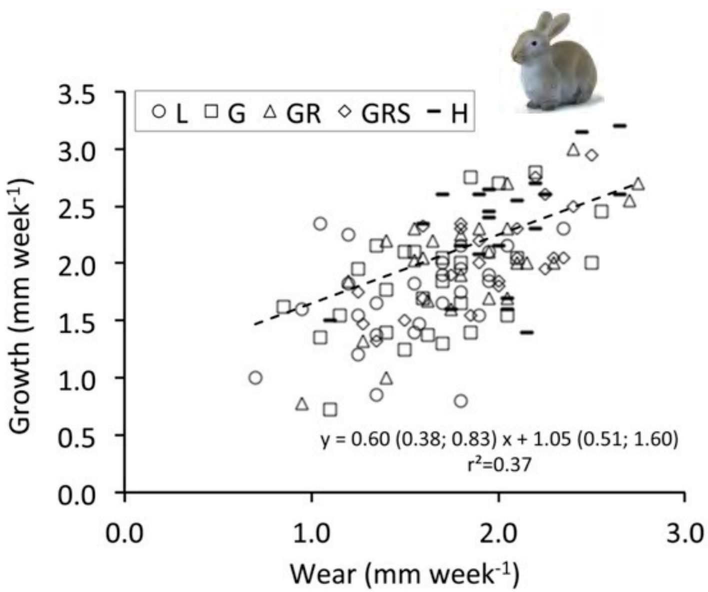
Rabbits

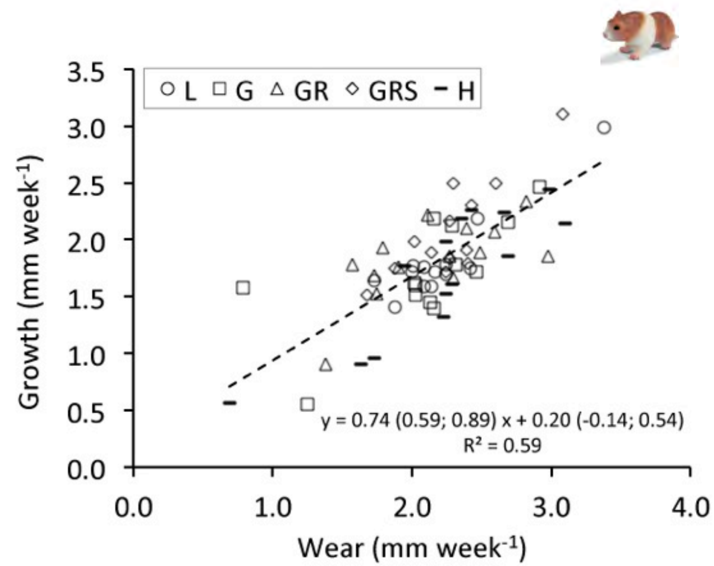


Wear and growth upper/lower incisor





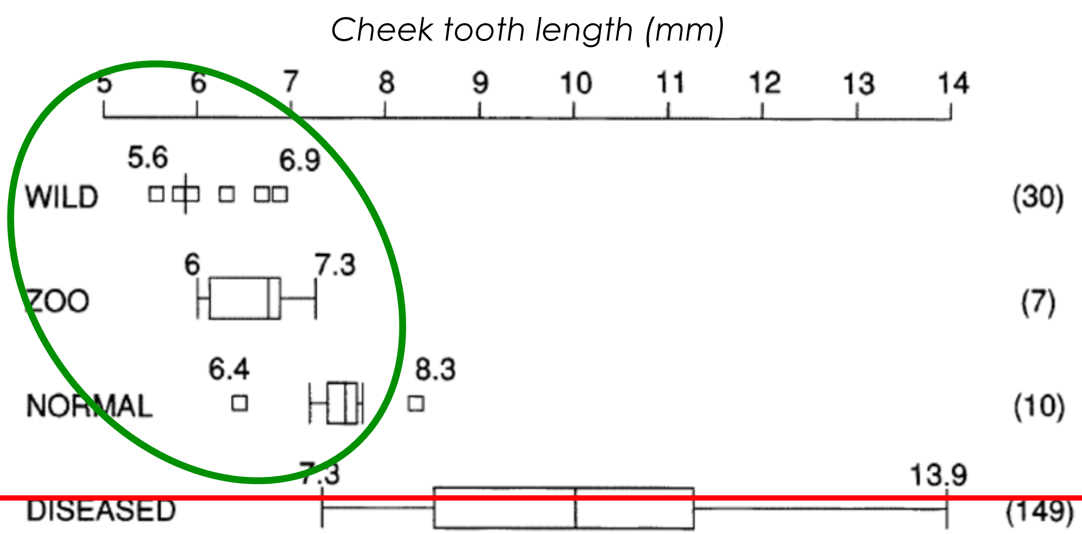




Skull size and cheek-tooth length in wild-caught and captive-bred chinchillas

David A. Crossley *, Maria del Mar Miguélez

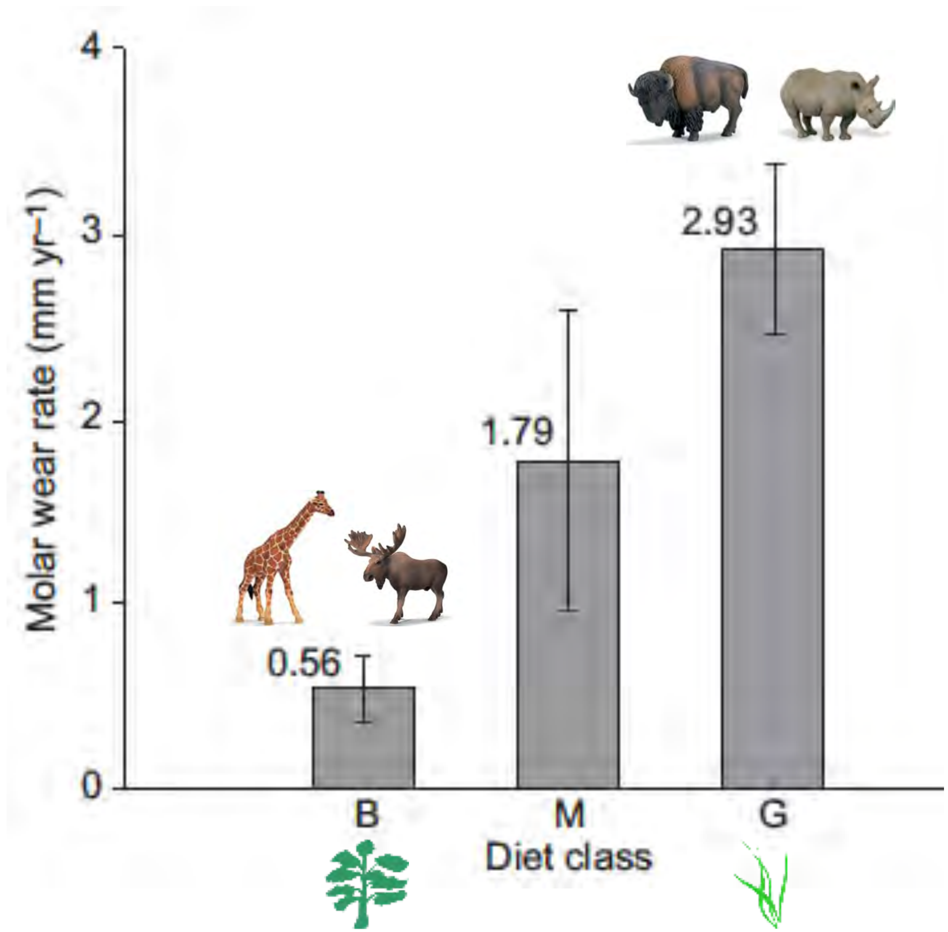
Archives of Oral Biology 46 (2001) 919–928



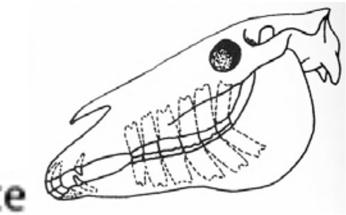
A comparison of observed molar wear rates in extant herbivorous mammals

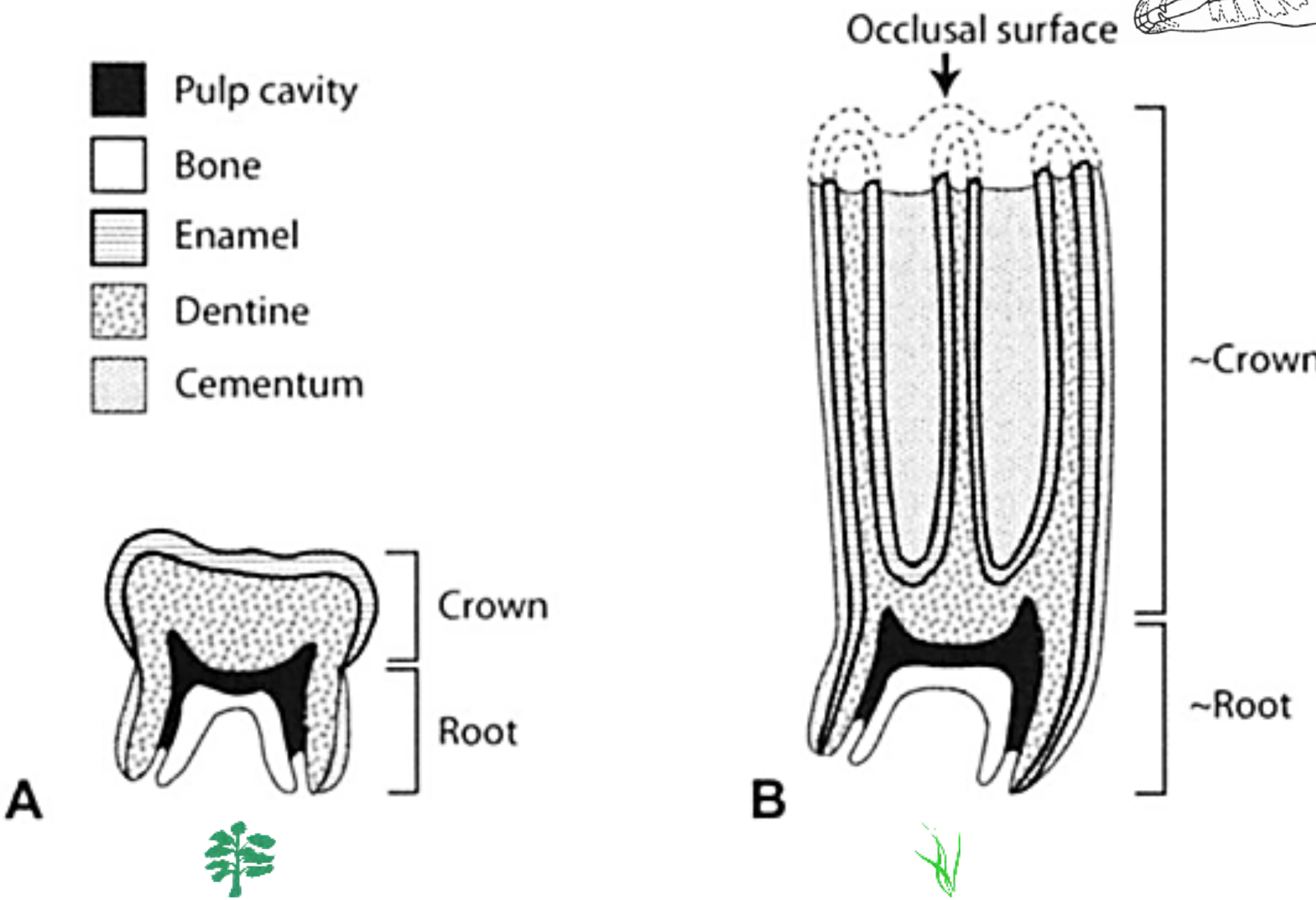
John Damuth[1] & Christine M. Janis[2]

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

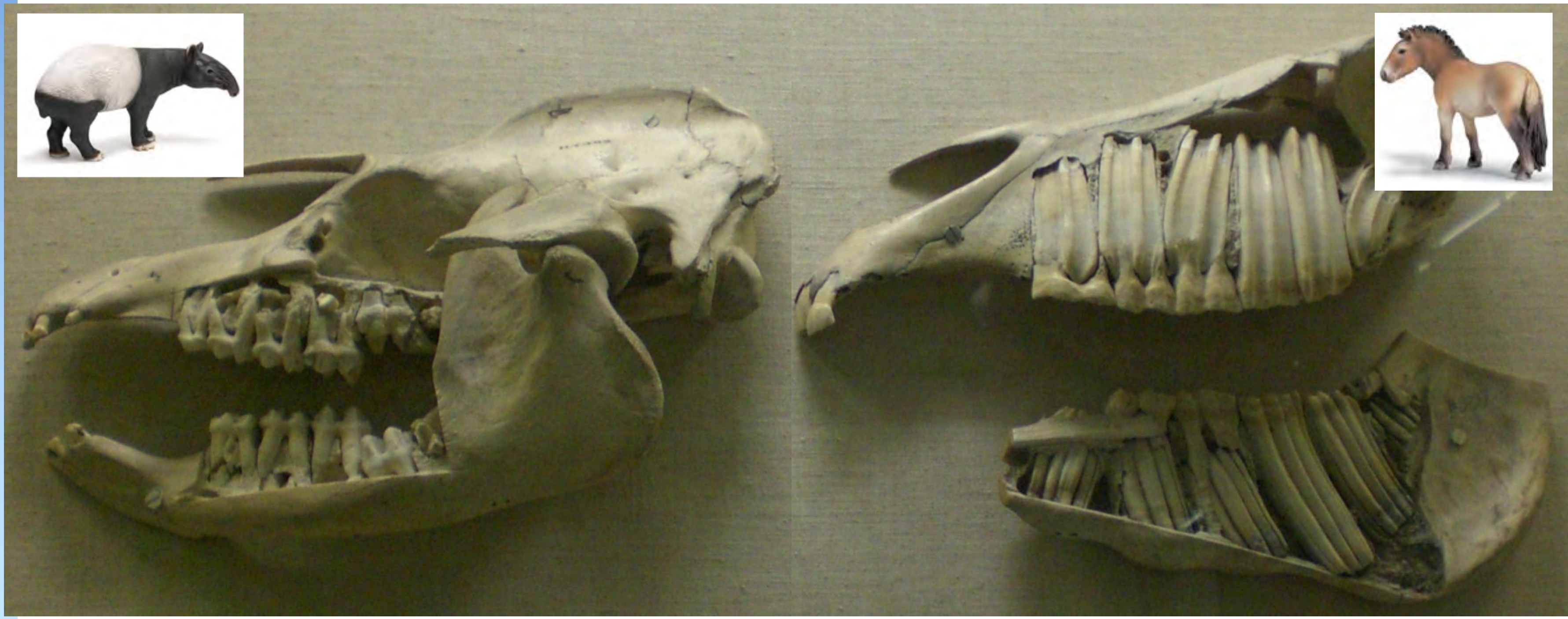


Hypsodonty




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

Hypsodonty

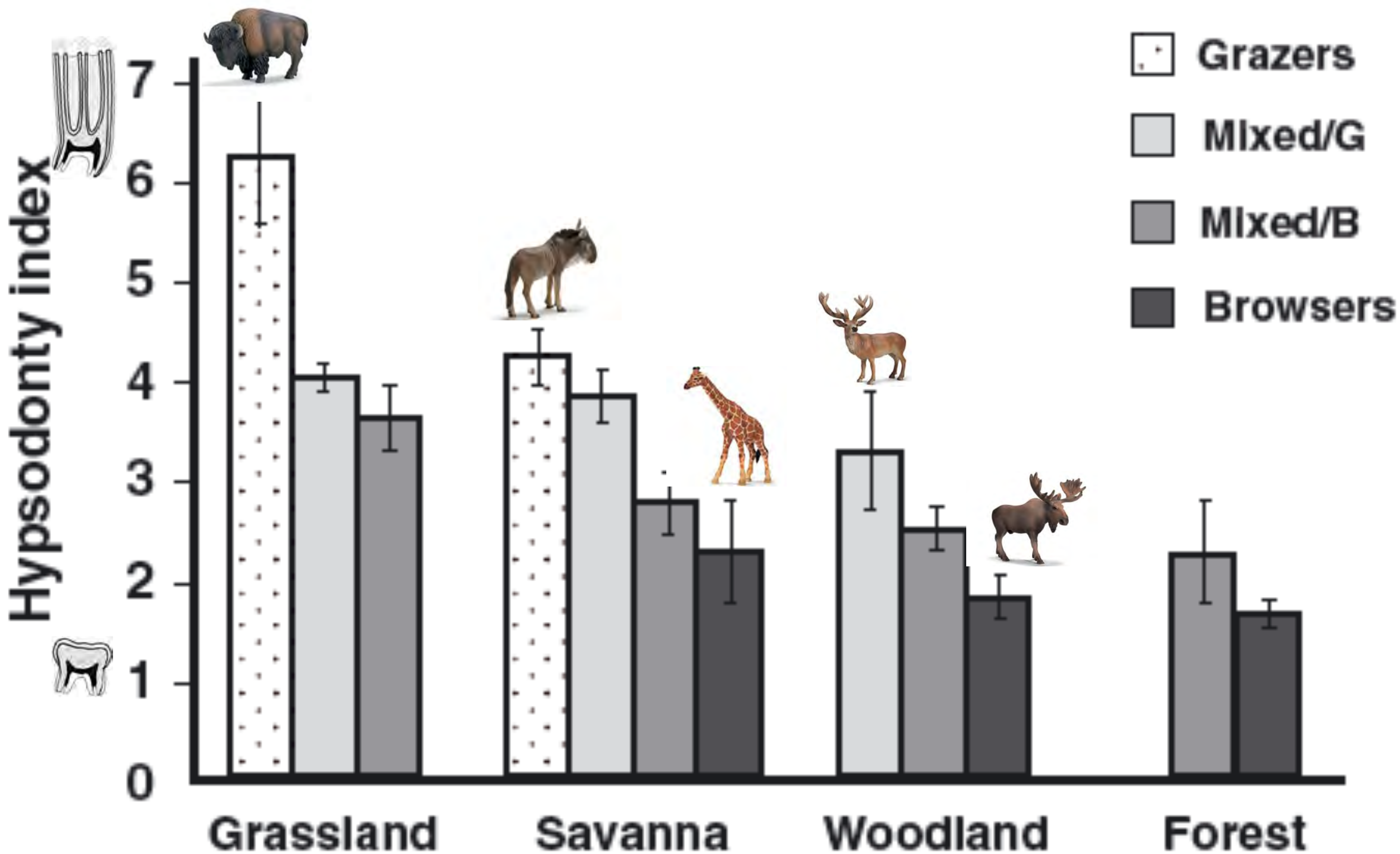


Hummel (unpubl.)

On the relationship between hypsodonty and feeding ecology in ungulate mammals, and its utility in palaeoecology

John Damuth[1]* and Christine M. Janis[2]

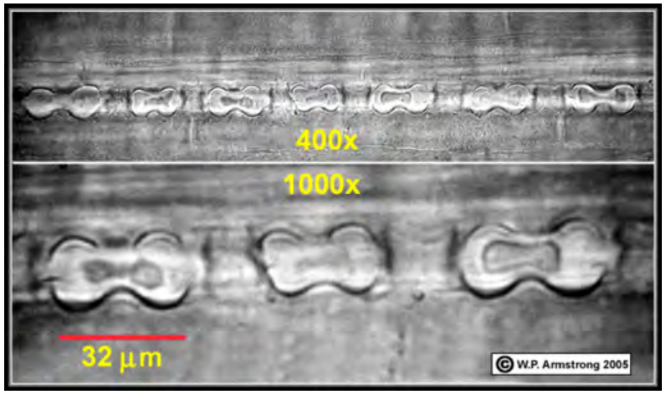
Biol. Rev. (2011).



Where does the silica come from?

- grit/dust (external abrasives)?

- phytoliths (internal abrasives)?



Does it matter for zoos?

Food item	n	AIA (%DM) Mean	Range	Source
Temperate browse	1	0.0	—	Clauss et al.[6]
	6	0.2	0.0–0.4	Castell[4]
Alfalfa hay	1	0.2	—	Baer et al.[1]
	1	0.2	—	Clauss et al.[6]
	9	0.3	0.0–0.7	Castell[4]
Alfalfa meal pellet	1	0.5	—	Castell[4]
Grass hay	13	2.0	0.3–5.1	Castell[4]
Fresh grass	2	2.0	1.8–2.2	Castell[4]
Grass meal pellet[a]	1	6.4	—	Castell[4]
Pelleted compound feed	2	0.9	0.2–1.5	Baer et al.[1]
	3	0.8	0.7–1.0	Clauss et al.[6]
	24	1.5	0.5–3.1	Castell[4]

[a] Young grass cut low, dried artificially, ground and pelleted.

animals adapted to browse but eating grass products should experience more wear than they are naturally adapted to

Clauss et al. (2007)

Journal of Zoo and Wildlife Medicine 38(3): 433–445, 2007

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.

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]

Mamm. biol. 74 (2009) 425–437

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

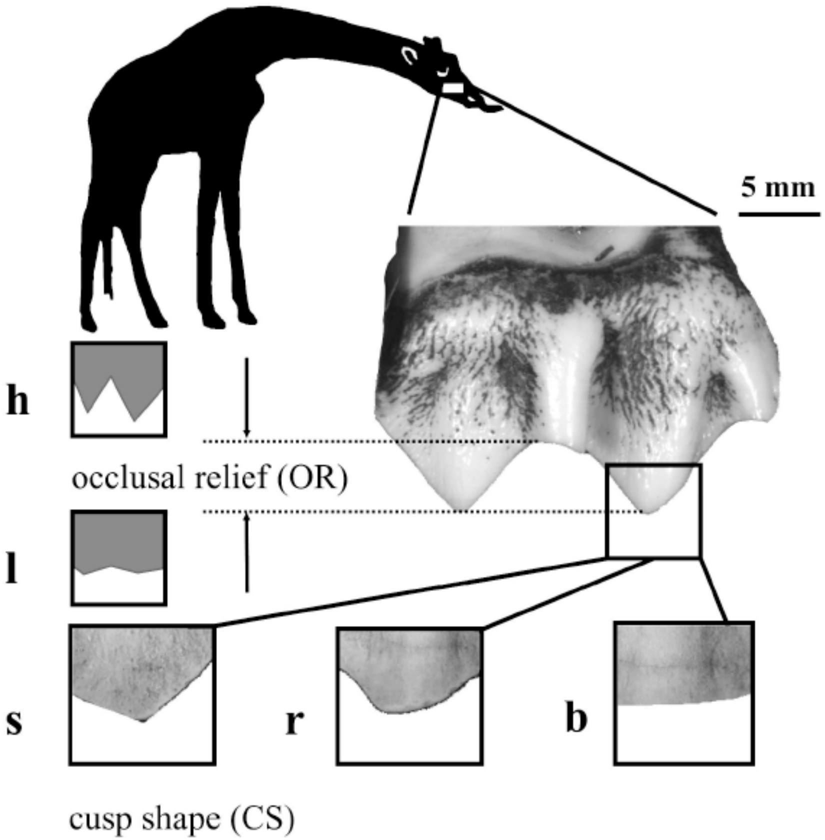
Tooth wear in captive rhinoceroses (*Diceros*, *Rhinoceros*, *Ceratotherium*: Perissodactyla) differs from that of free-ranging conspecifics

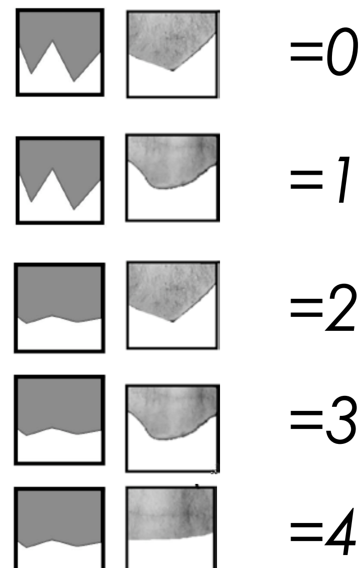
Lucy A. Taylor[1,2], Dennis W.H. Müller[3,4], Christoph Schwitzer[1], Thomas M. Kaiser[5], Daryl Codron[3,6], Ellen Schulz[5], Marcus Clauss[3,7]

Equine Veterinary Journal **48** (2016) 240–245

Comparative analyses of tooth wear in free-ranging and captive wild equids

L. A. TAYLOR[†‡], D. W. H. MÜLLER[§#], C. SCHWITZER[†], T. M. KAISER[¶], J. C. CASTELL[¥], M. CLAUSS[§] and E. SCHULZ-KORNAS*[¶††]





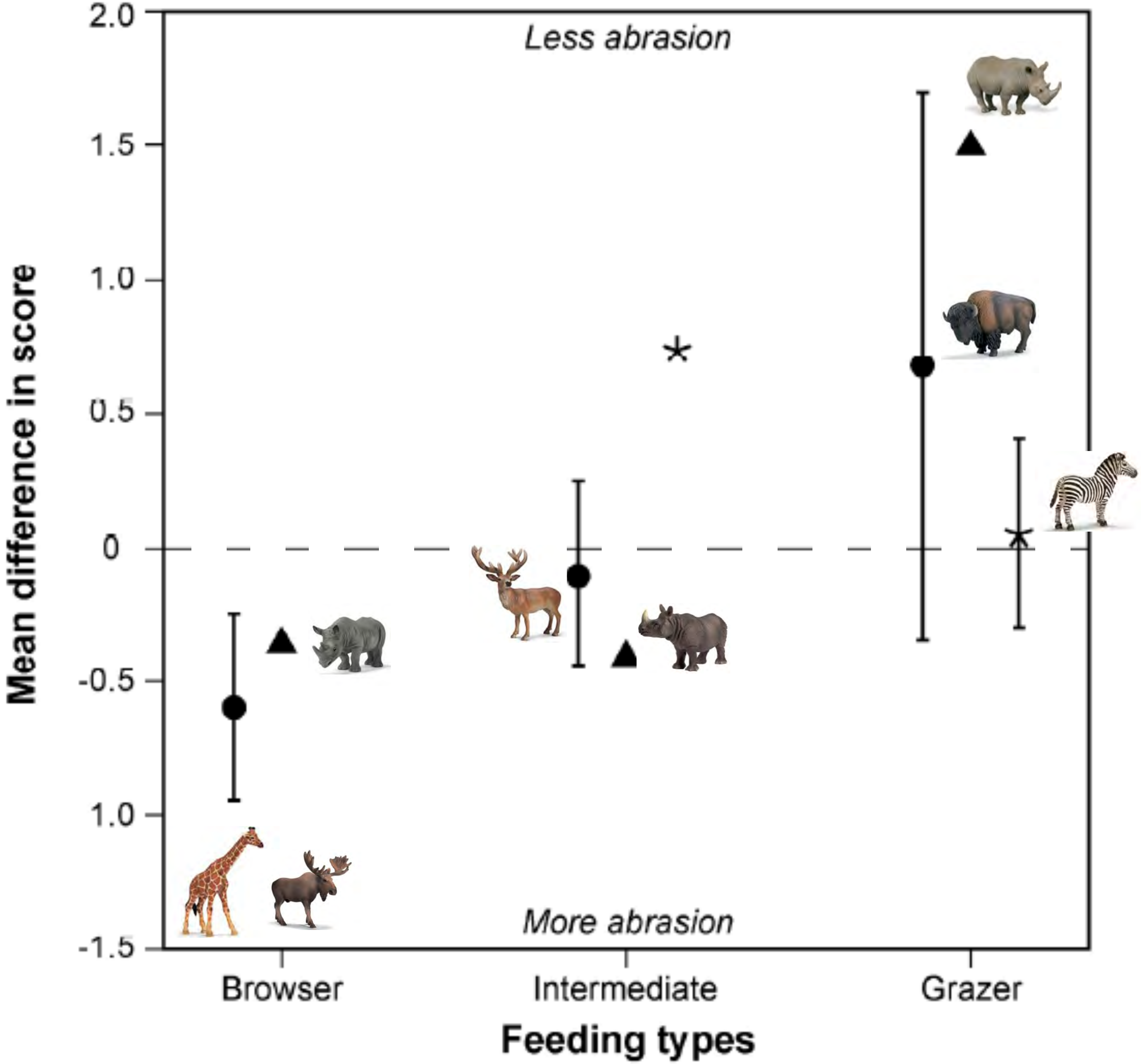
Fotos: Johanna Castell,

Free-ranging vs. captive giraffes

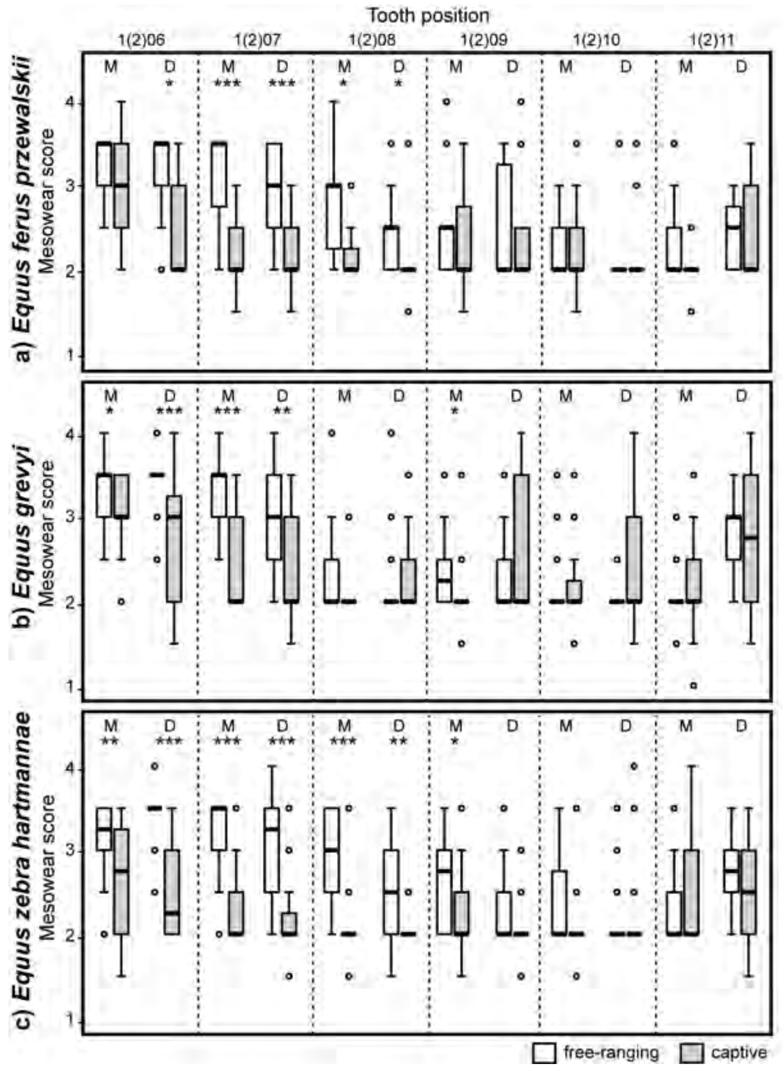
from Clauss et al. (2007)

Free-ranging vs. captive moose

from Kaiser et al. (2009)


2.0
1.5
1.0
0.5
0
-0.5
1.0
-1.5
Mean difference in score
Less abrasion
More abrasion
Browser
Intermediate
Grazer
Feeding types

The special case of equids



from Taylor et al. (2016)

The special case of equids

Wild

Zoo

from Taylor et al. (2015)

Feeding position?

Wild

Zoo

from Taylor et al. (2015)

Summary

Differences in wear patterns exist between zoos and the wild, indicating

❍	*less abrasion in grazers*	*due to feeding hygiene?*
✪	*more abrasion in browsers*	*due to the use of abrasive feeds (incl. phytoliths)?*

Summary

Less abrasion in grazers: only a problem in uneven wear => feeding position

Summary

Less abrasion in grazers: only a problem in uneven wear => feeding position

More abrasion in browsers: contributing to lower lifespan?; is it possible to avoid abrasive elements in both forages (dicot = lucerne) and pellets (no monocot products)?



Examples: differences wild - zoo

- undesired GIT bacteria +

e.g. Fujita & Kageyama (2007)

Polymerase chain reaction detection of *Clostridium perfringens* in feces from captive and wild chimpanzees, *Pan troglodytes*

Shiho Fujita[1] & Takashi Kageyama[2]

J Med Primatol **36** (2007) 25–32

Table 2 Detection of *Clostridium perfringens* in feces of captive chimpanzees

Subject	Sex	Age	Birth	No. of samples tested	First PCR	Nested PCR	Not detected
Ai[1]	Female	24 years	Wild	1	1	0	0
Pendesa	Female	23 years	Captive[2]	1	0	0	1
Chloé	Female	19 years	Captive[4]	4	3	1	0
Reo	Male	18 years	Captive[3]	2	0	1	1
Ayumu[1]	Male	5 months	Captive[3]	2	1	1	0
Total (%)				10	5 (50)	3 (30)	2 (20)

[1]Ai and Ayumu are a mother–infant pair.
[2]Japan Monkey Center.
[3]Primate Research Institute.
[4]Parc Zoologique de Paris.

Table 3 Detection of *Clostridium perfringens* in feces of wild chimpanzees

Site	Season	No. of samples tested	First PCR	Nested PCR	Not detected
Mahale	Dry	16	0 (0.0)[1]	1 (6.3)	15 (93.7)
	Wet (I and II)	65	0 (0.0)	0 (0.0)	65 (100.0)
	Total	81	0 (0.0)	1 (1.3)	80 (98.7)
Bossou	Dry	23	1 (4.3)	2 (8.7)	20 (87.0)
	Wet	30	5 (16.7)	4 (13.3)	21 (70.0)
	Total	53	6 (11.3)	6 (11.3)	41 (77.4)

[1]The values in parentheses show percentages.

Examples: differences wild - zoo

+ fibre in (herbivore) diets -

e.g. Taylor et al. (2013),, Mason et al. (2007)

Man-made diets: too little fibre

- *Human nutrition → gut health*
- *Pigs → piglet diarrhoea*
- *Beef cattle/ Dairy cattle*
- *Riding horses → crib biting*
- *Dogs/ Cats → faeces consistency*
- *Zoo animals → obesity*

Fibre content depends on intended use

Use		Fibre content*	Longevity
Beef cattle		12 %DM	app. 2 years
Dairy cattle		18 %DM	app. 4 years
Feral cattle		30 %DM	app. 25 years

*historical recommendations for ration design

Feeding herbivores

from Stevens und Hume (1995)

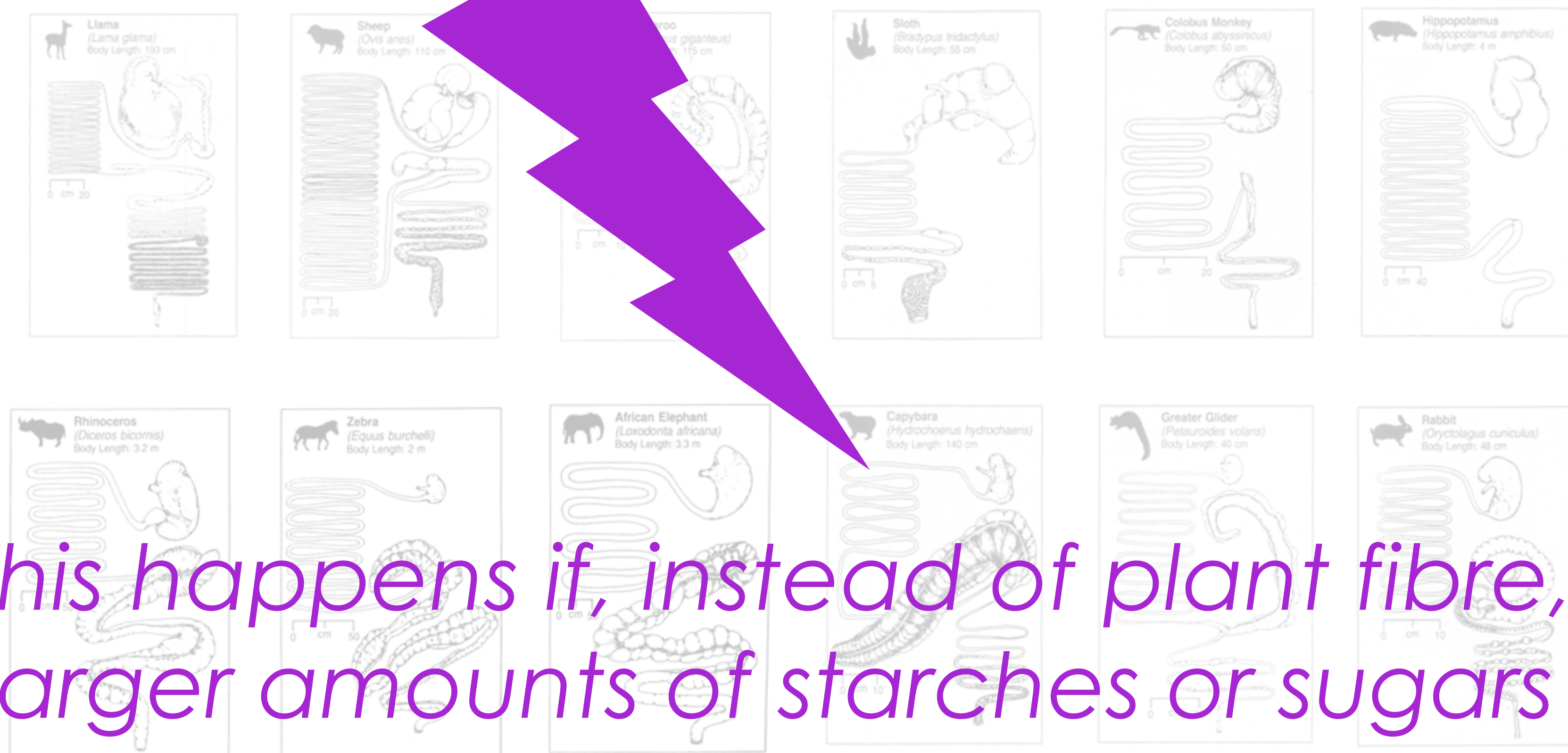
Feeding herbivores

Major goal of herbivore feeding:

Do not disturb the balance of the ‘fermentation chamber’!

from Stevens und Hume (1995)

Feeding herbivores



This happens if, instead of plant fibre, larger amounts of starches or sugars enter into the fermentation chamber!

from Stevens und Hume (1995)

Bacteria ferment all carbohydrates into volatile fatty acids (VFA)

plant fibres (cellulose, hemicellulose) are fermented ***slowly***

► *the VFA can be absorbed as they come*

► *the pH in the fermentation chamber remains stable*

sugars/starch are fer-mented ***rapidly (some even „explosively“)***

► *more VFA produced than can be absorbed*

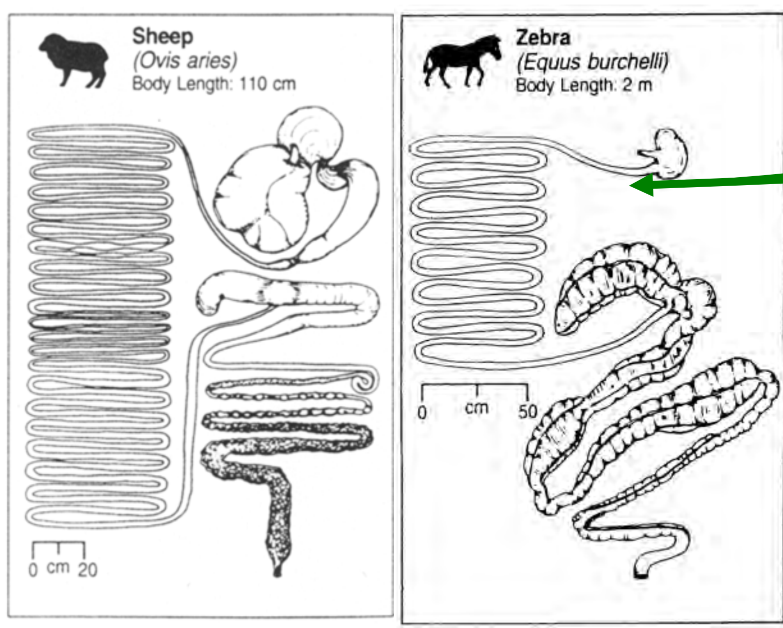
► *the pH in the fermentation chamber drops*

► ► ► ***ACIDOSis !***

Feeding high-sugar/starch diets





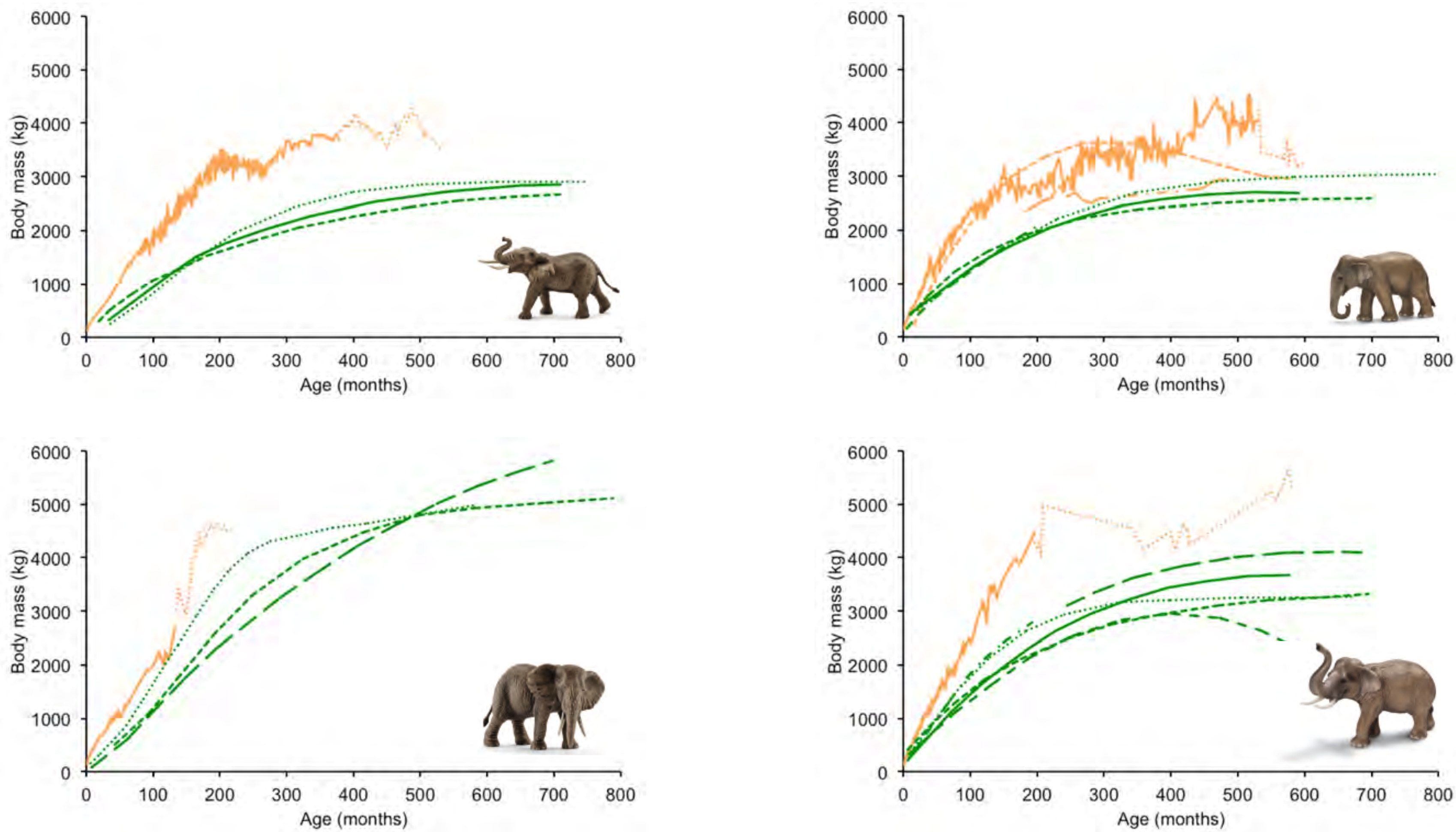


Easily digestible nutrients absorbed in small intestine => obesity

Clauss & Dierenfeld (2008)

Photo Jean-Michel Hatt

Elephant body mass



Schiffmann et al. (subm.)

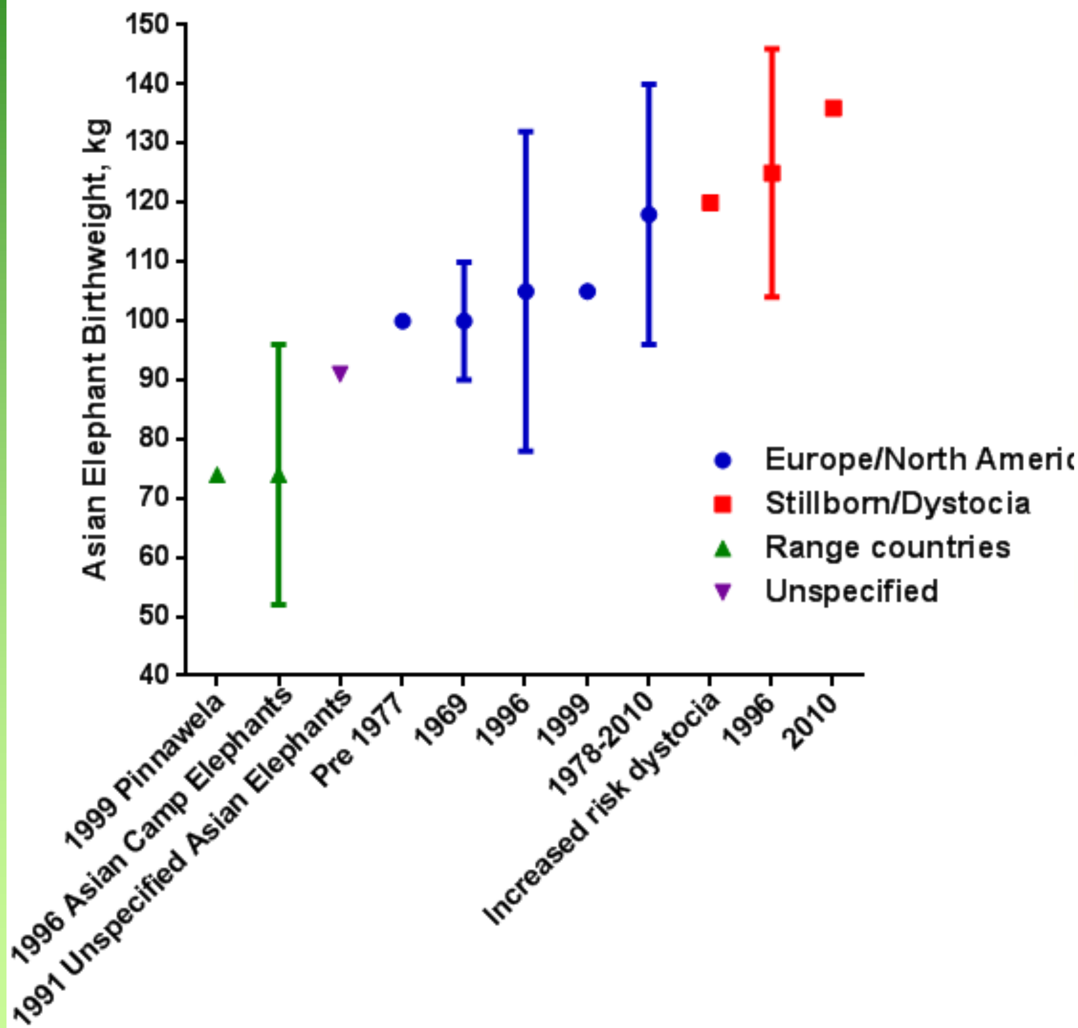
Fecundity and population viability in female zoo elephants: problems and possible solutions

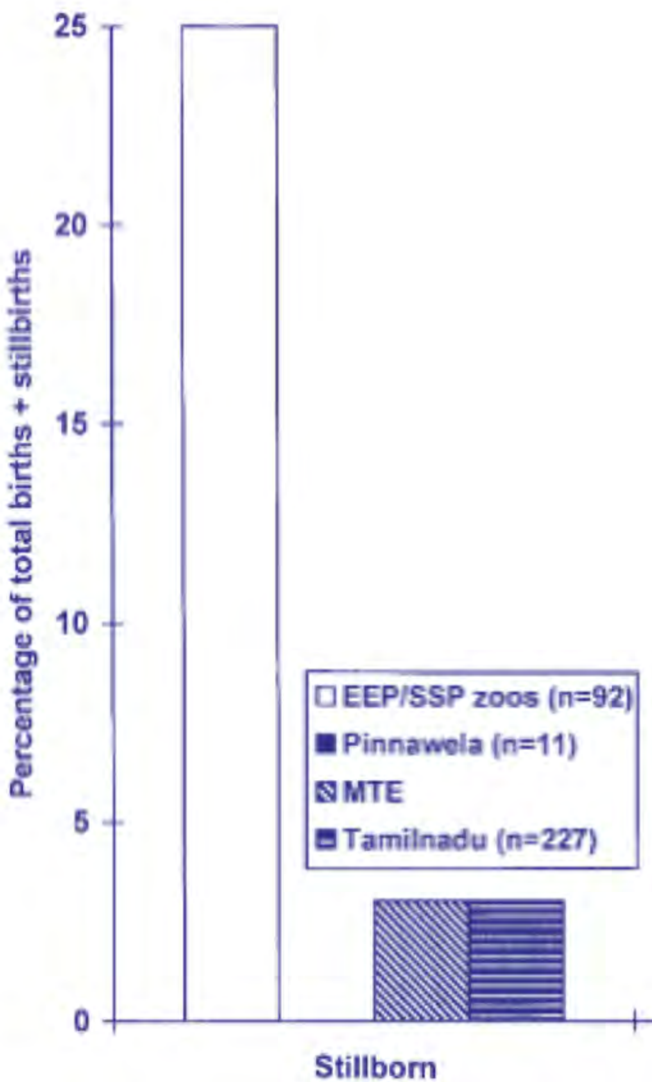
R Clubb[†], M Rowcliffe[‡], P Lee[§#], KU Mar[¶], C Moss[#] and GJ Mason[¥]*

Animal Welfare 2009, 18: 237-247

Group/measure	Population		Population difference	Data source/notes
	In situ	**Zoo**		
Birth weight	89.5 (± 6.3) kg (n = 5)	102.1 (± 9.6) kg (n = 63)	$F_{1,66} = 8.32$, $P = 0.005$	Hayssen *et al* 1993
	74.0 kg (n = 6)	105.6 kg (n = 40)	Reported in paper as significant	Kurt & Mar 1996 (sexes pooled)
	–	118.8 kg (n = 7)	n/a	ISIS 2002 (females only)

Risk of high birth weight ?

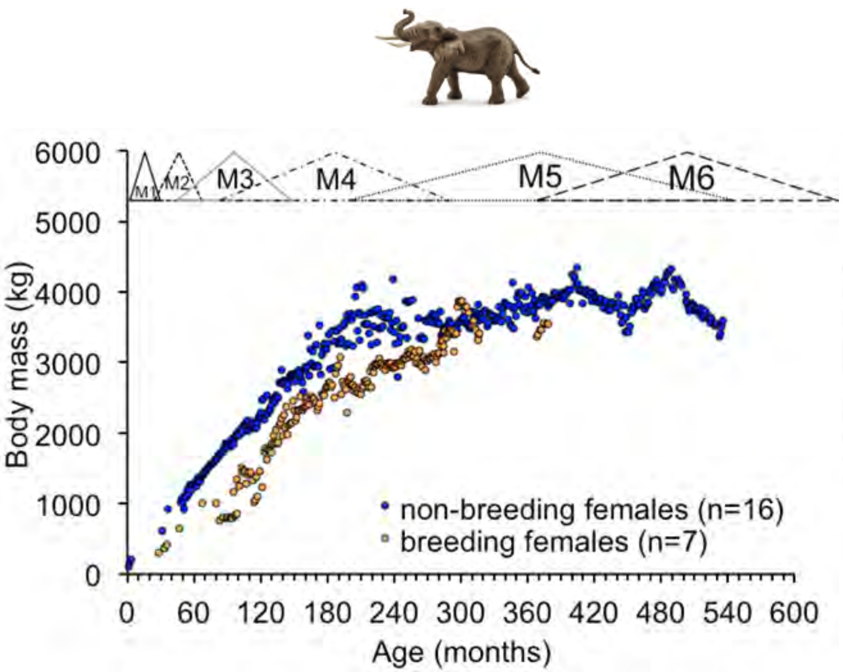


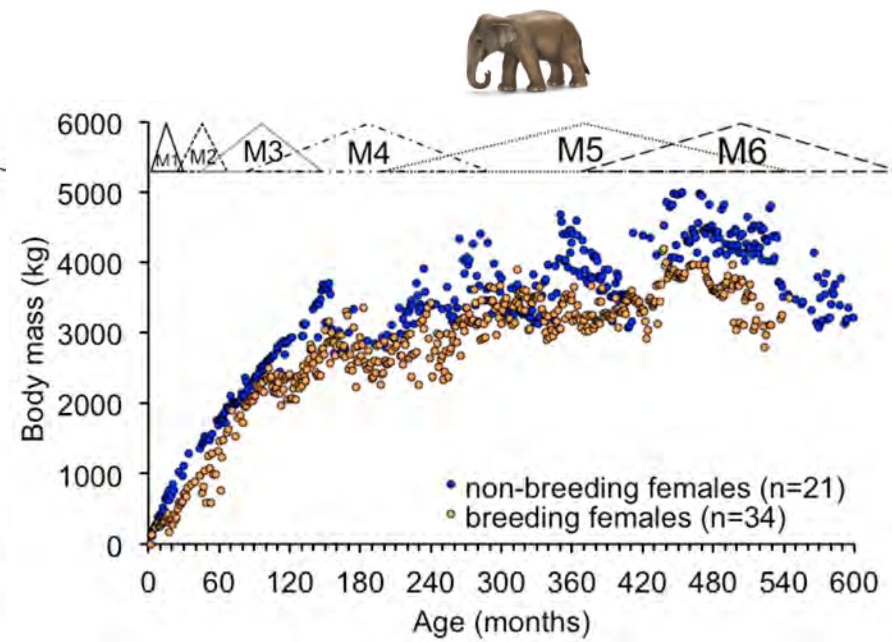


(Dale 2010; Kurt & Mar 1996; Hermes 2008; Doyle 1999; Reuther 1969; Lee 1991; Jayewardene 1999)

Slide courtesy of Kibby Treiber

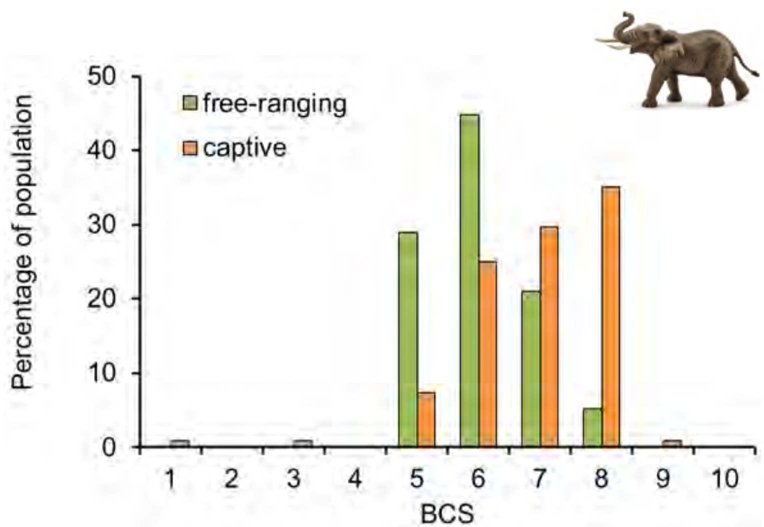
Female elephant body mass & breeding

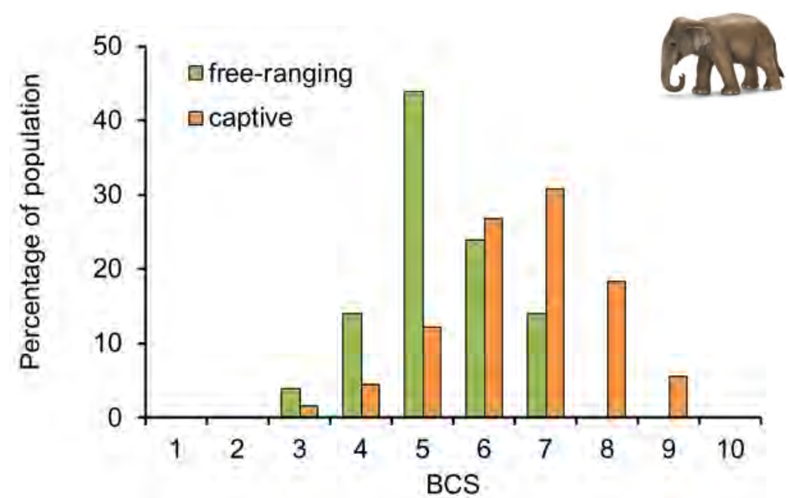




Schiffmann et al. (2019)

Body condition monitoring





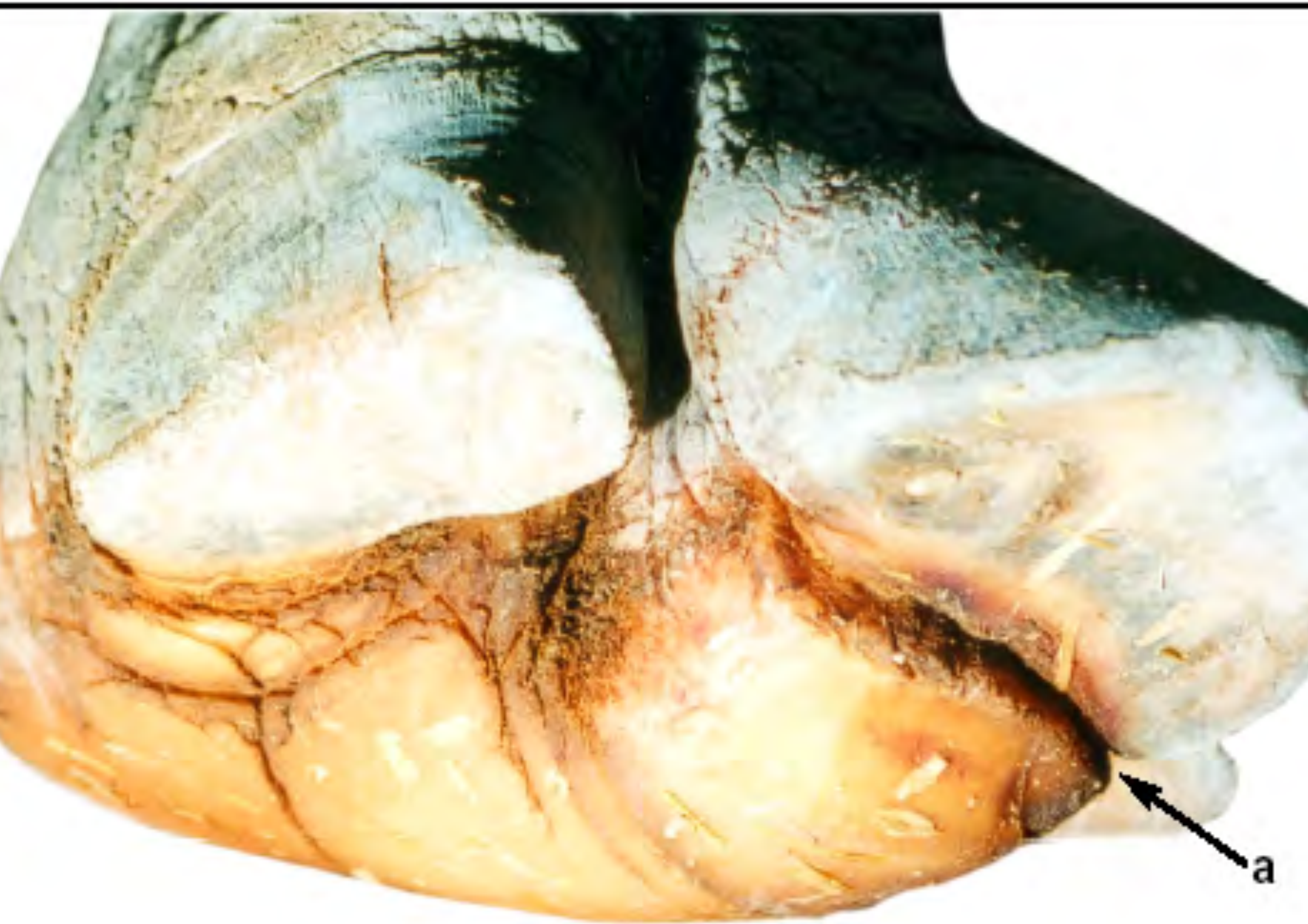
Hatt & Clauss (2006), Schiffmann et al. (2018)

Free-range vs. zoo

from various internet sources and own photo

Free-range vs. zoo

from Clauss & Hatt (2006)

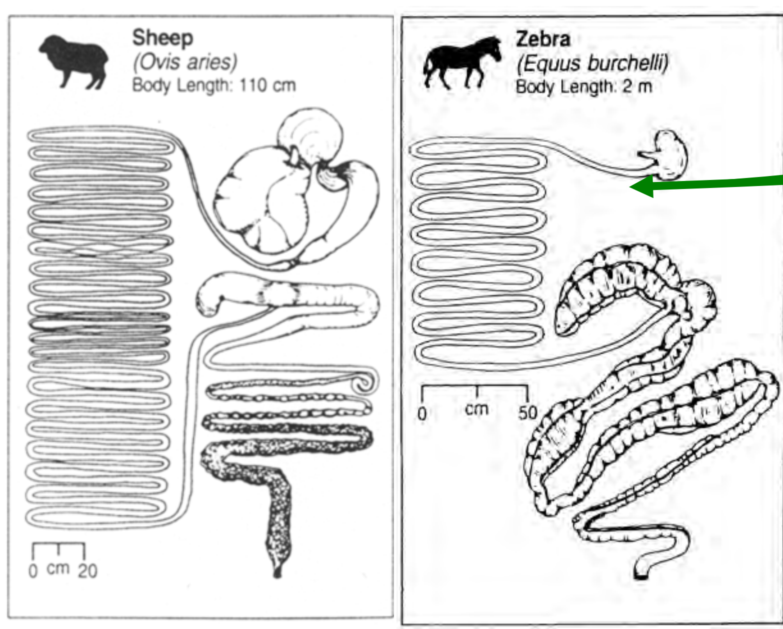


(Von Houwald 2016)

Feeding high-sugar/starch diets







Easily digestible nutrients absorbed in small intestine => obesity

Only at very excessive amounts: 'caecum acidosis', diarrhoea, laminitis

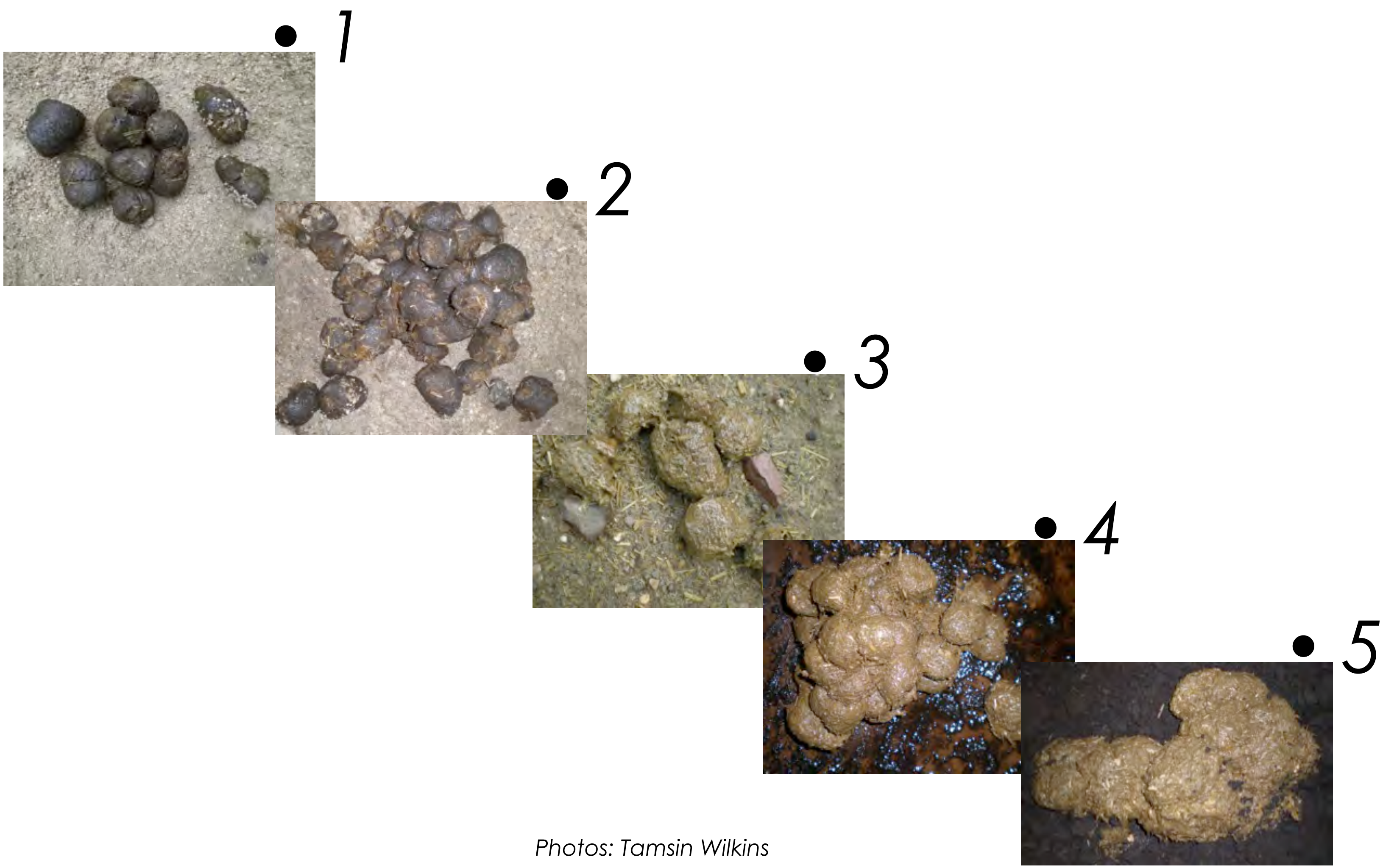
Tapir faeces

Free range

'traditional' zoo diets

Photos: Patricia Medici, Stefanie Lang-Deuerlein, J.-M. Hatt, M. Clauss

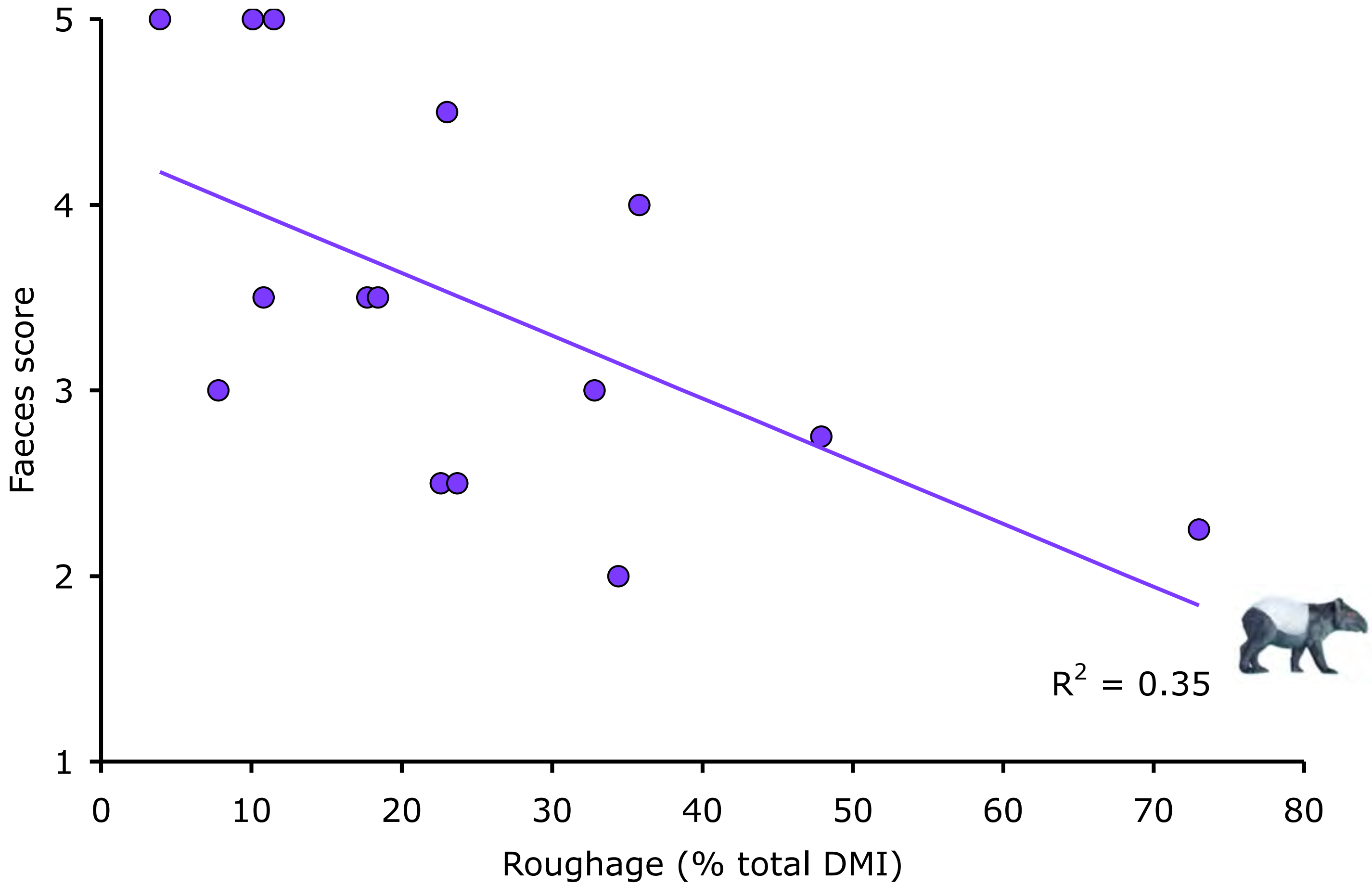
Faecal scores in tapirs



Photos: Tamsin Wilkins

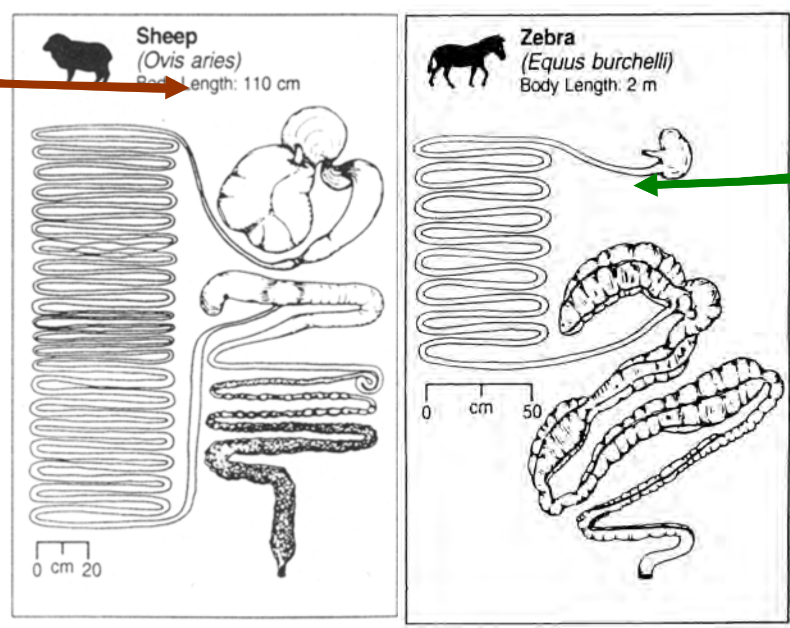
from Clauss et al. (2008)

Faecal scores in tapirs



from Clauss et al. (2009)

Feeding high-sugar/starch diets



(obesity)

Easily digestible nutrients absorbed in small intestine => obesity

Only at very excessive amounts: 'caecum acidosis', diarrhoea, laminitis

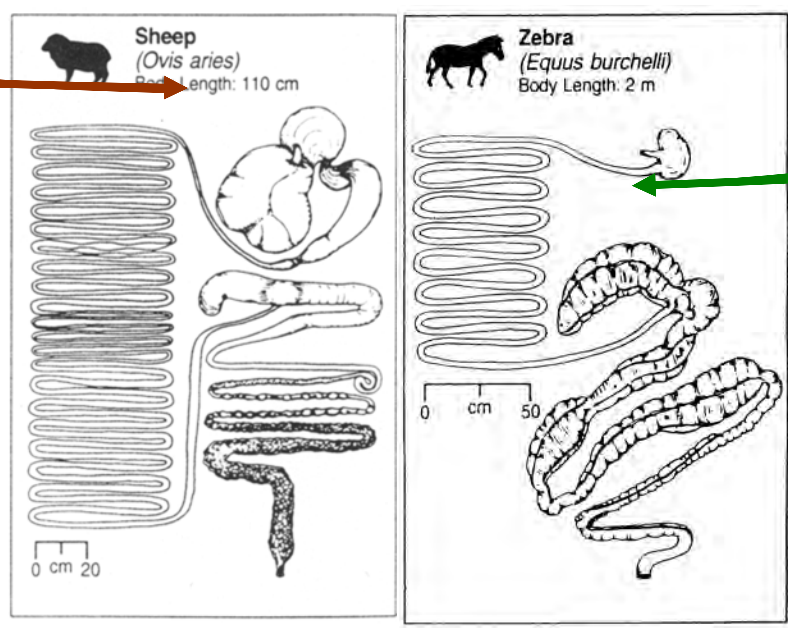
Clauss & Dierenfeld (2008)

Free-range vs. zoo

from Collen et al. (2011)

from Taylor et al. (2013)

Feeding high-sugar/starch diets



(obesity)

Easily digestible nutrients enter the fermentation chamber
⇒'malfermentation'

Low food intake
Laminitis
Liver abscess
Reduced lifespan?
Diarrhoea
Oral stereotypies

Easily digestible nutrients absorbed in small intestine
=> obesity

Only at very excessive amounts: 'caecum acidosis', diarrhoea, laminitis

Clauss & Dierenfeld (2008)

Ruminal pH in cattle (*Bos primigenius* f. *taurus*) and moose (*Alces alces*) under different feeding conditions: a pilot investigation

Julia Ritz[1], Daryl Codron[2], Sandra Wenger[2], E. Eberhard Rensch[2], Jean-Michel Hatt[2], Ueli Braun[1] and Marcus Clauss[2*]

Journal of Zoo and Aquarium Research 2(2) 2014

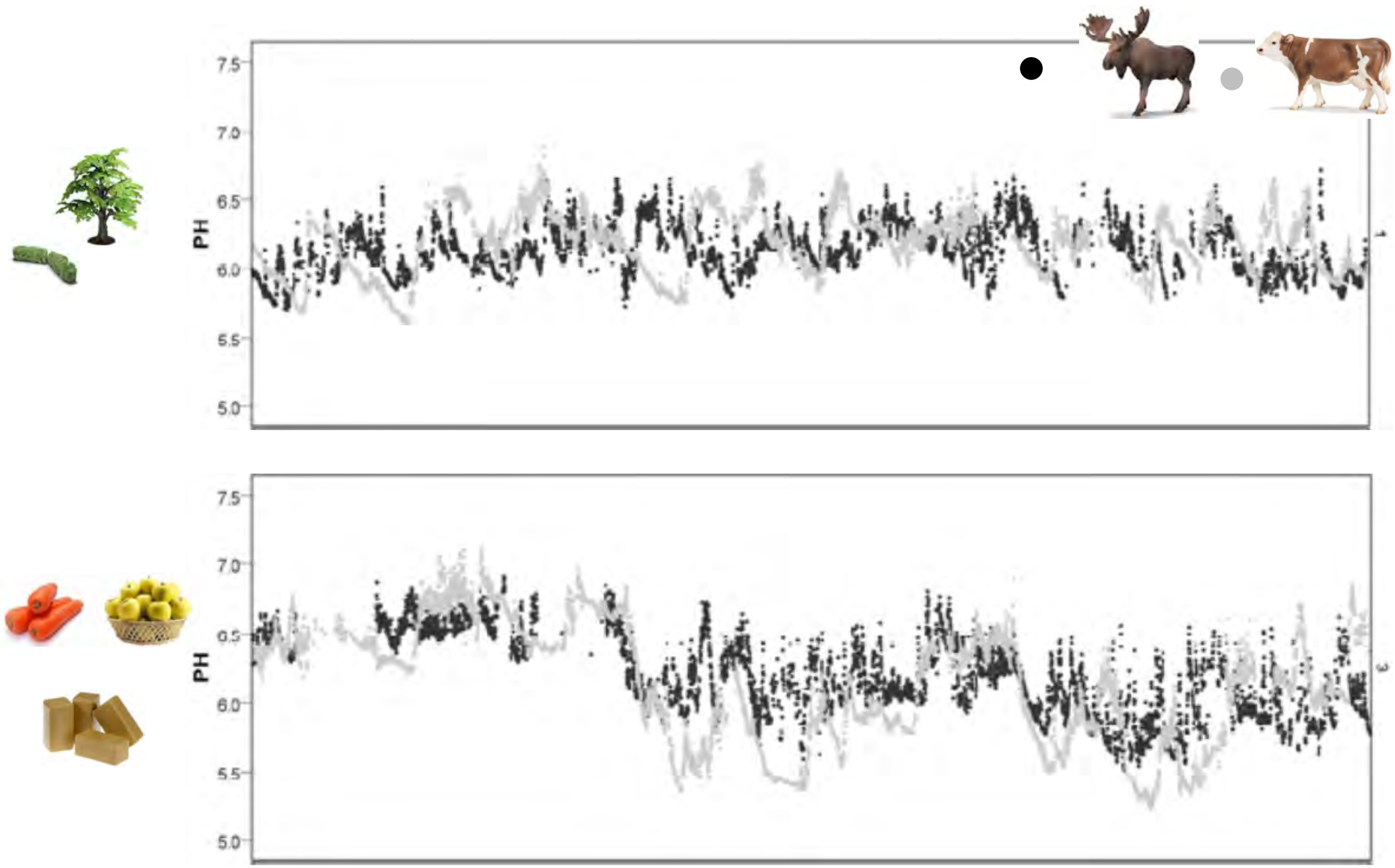
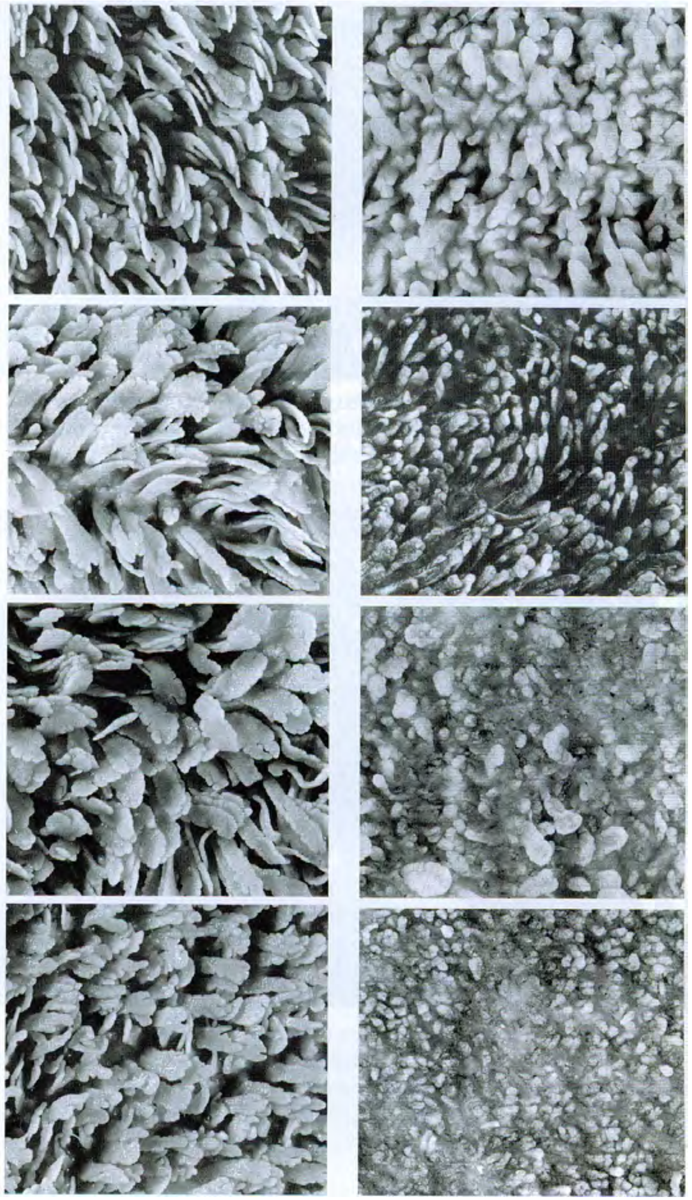



Foto: Marcus Clauss

Rumen mucosa of moose

Finnish moose



captive moose

(Whipsnade Zoo)

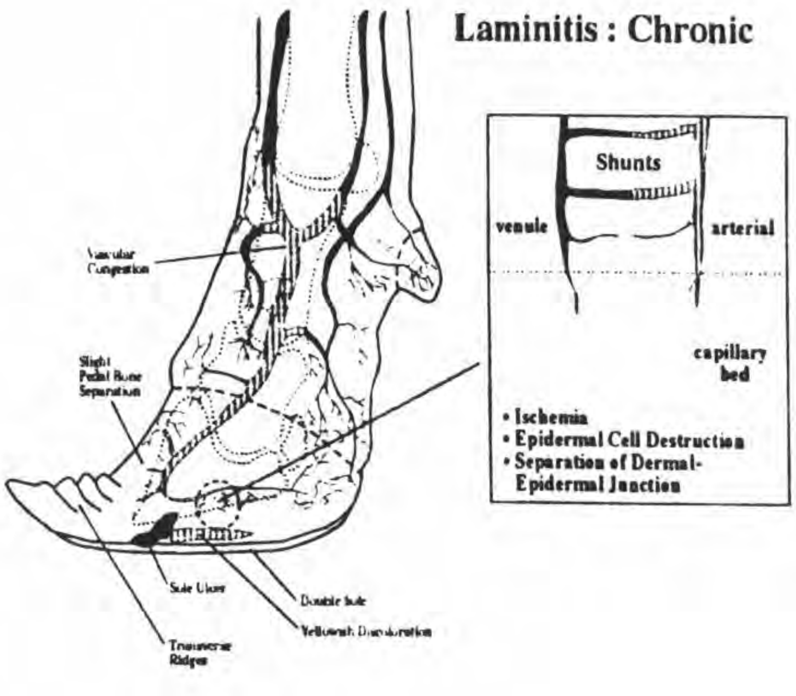
from Hofmann & Nygren (1992)

Changes in rumen mucosa indicating ruminen acidosis

Feeding type	n	Acidotic chanes of the rumen mucosa (%)
Grazer	13	23
Mixed feeder	30	27
Browser	24	83

Data from Marholdt (1991)

Hoof overgrowth / chronic laminitis



from Nocek (1997)

Photo: W. Zenker

Hoof overgrowth - 'anecdotes'

Giraffe survey: *Zoos with hoof problems fed more fruits/bread/grains than zoos without such problems* *(Hummel et al. 2006)*.

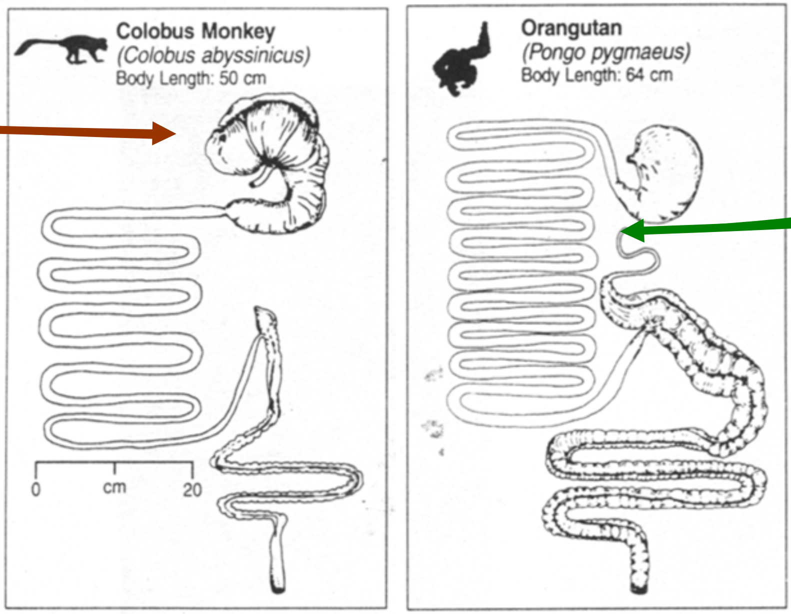
Moose survey: *Zoos with hoof problems fed more non-roughages (incl. fruits) than zoos without such problems* *(Clauss et al. 2002)*.

Comparing *two wild ruminant herds, the one with a higher proportion of concentrates had a lower rumen pH and worse claws* *(Zenker et al. 2009)*.

Primates as a prime example







(obesity)

Easily digestible nutrients enter the fermentation chamber
⇒'malfermentation'

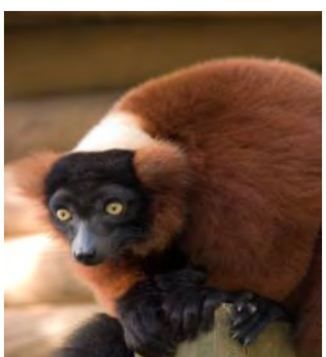
Low food intake
Laminitis
Liver abscess
Reduced lifespan?
Diarrhoea
Oral stereotypies



Obesity in primates

- Gorillas (Cousins 1972, Leigh 1992)
- Orangutans: wild ♀ 38.7 kg, ♂ 86.3 kg
  zoo ♀ up to 81 kg, ♂ up to 189 kg; (Schmidt 2004)
- Chimpanzees: 10.5% ♀♀ obese
  (Videan et al. 2007)

- Macaques: 7-23% obese
  (Walike et al. 1977, Schwartz et al. 1993, Chen at al. 2002)
- Marmosets
  (Savage et al. 1993, Encarnación & Heymann 1998, Araújo et al. 2000)



- Lemurs (Schaaf & Stuart 1983, Schwitzer & Kaumanns 2001, Taylor et al. 2012)

Examples: differences wild - zoo

obesity

A Survey of Diabetes Prevalence in Zoo-housed Primates

C. W. Kuhar,* G. A. Fuller, and P. M. Dennis

Zoo Biology 32: 63–69 (2013)

Nearly 30% of responding institutions reported at least one diabetic primate in their current collection. Although the majority of reported cases were in Old World Monkeys (51%), all major taxonomic groups were represented. Females represented nearly 80% of the diagnosed cases. A wide variety of diagnosing, monitoring, and treatment techniques were reported. It is clear from these results diabetes should be considered prominently in decisions relating to diet, weight and activity levels in zoo-housed primates, as well as discussions surrounding animal health and welfare.

Hypertension Increases With Aging and Obesity in Chimpanzees (*Pan troglodytes*)

John J. Ely,* Tony Zavaskis, and Michael L. Lammey

Zoo Biology 32: 79–87 (2013)

Cardiovascular disease is a primary cause of morbidity and mortality in captive chimpanzees. For females, obesity was a significant determinant of BP.

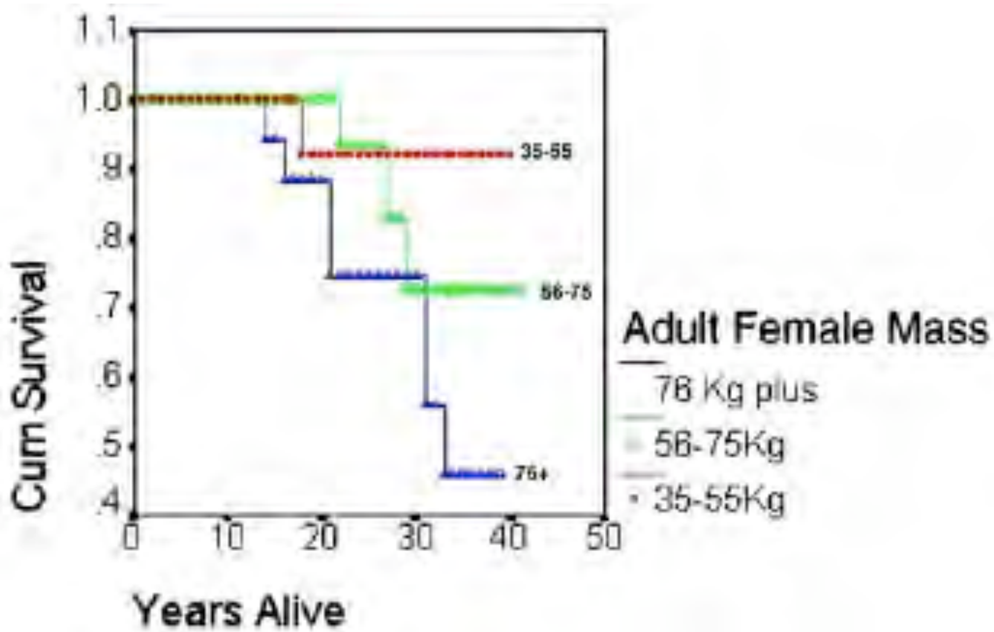
Obesity in orangutans

Int J Primatol (2007) 28:429–440
DOI 10.1007/s10764-007-9117-9

Factors Influencing the Well-Being and Longevity of Captive Female Orangutans

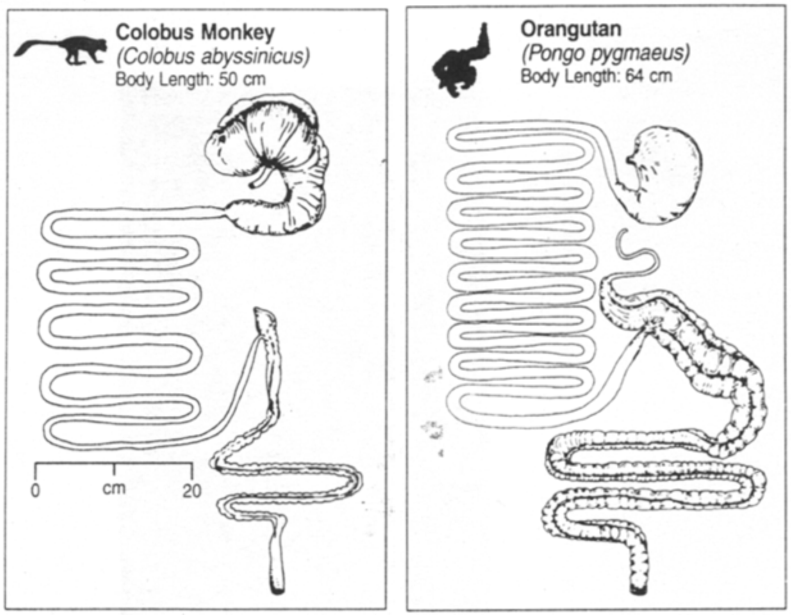
Leif Cocks

Fig. 12 Survival vs. female weight.



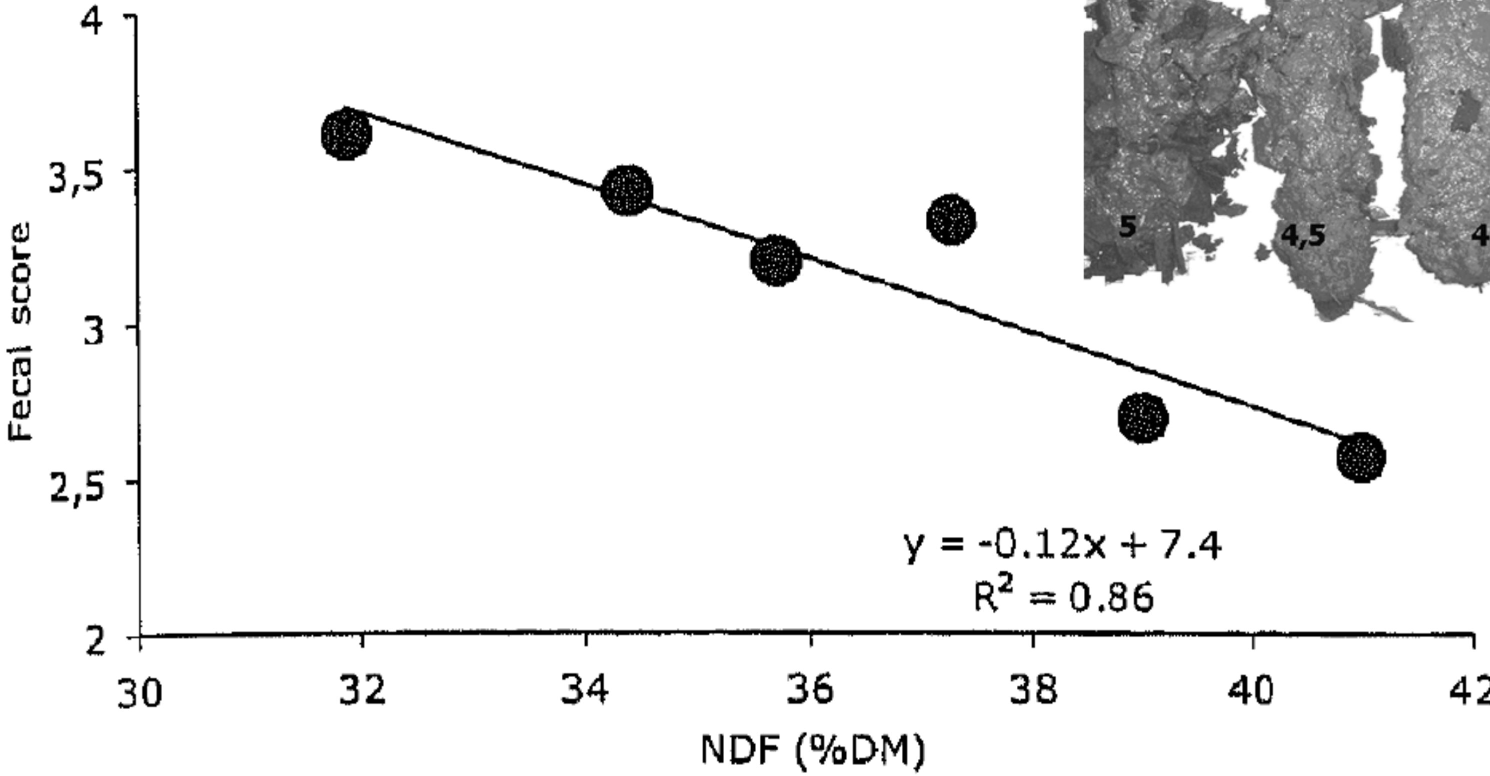
Primates as a prime example

langurs with bad condition, diarrhoea, short lifespan



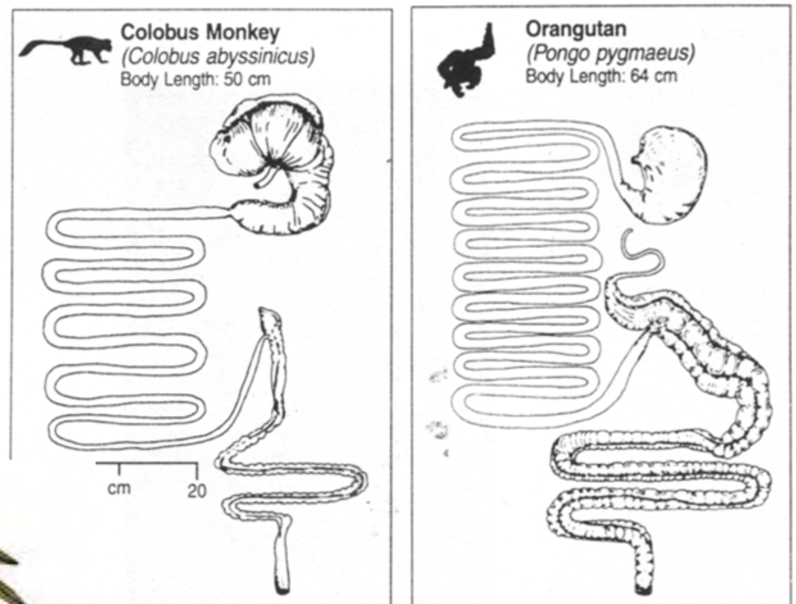
obese lemurs

Fibre and faeces consistency in langurs



Nijboer et al. (2006)

Primates as a prime example



Examples: differences wild - zoo

+	fibre in (herbivore) diets	-
-	feeding-related dysbehaviour	+

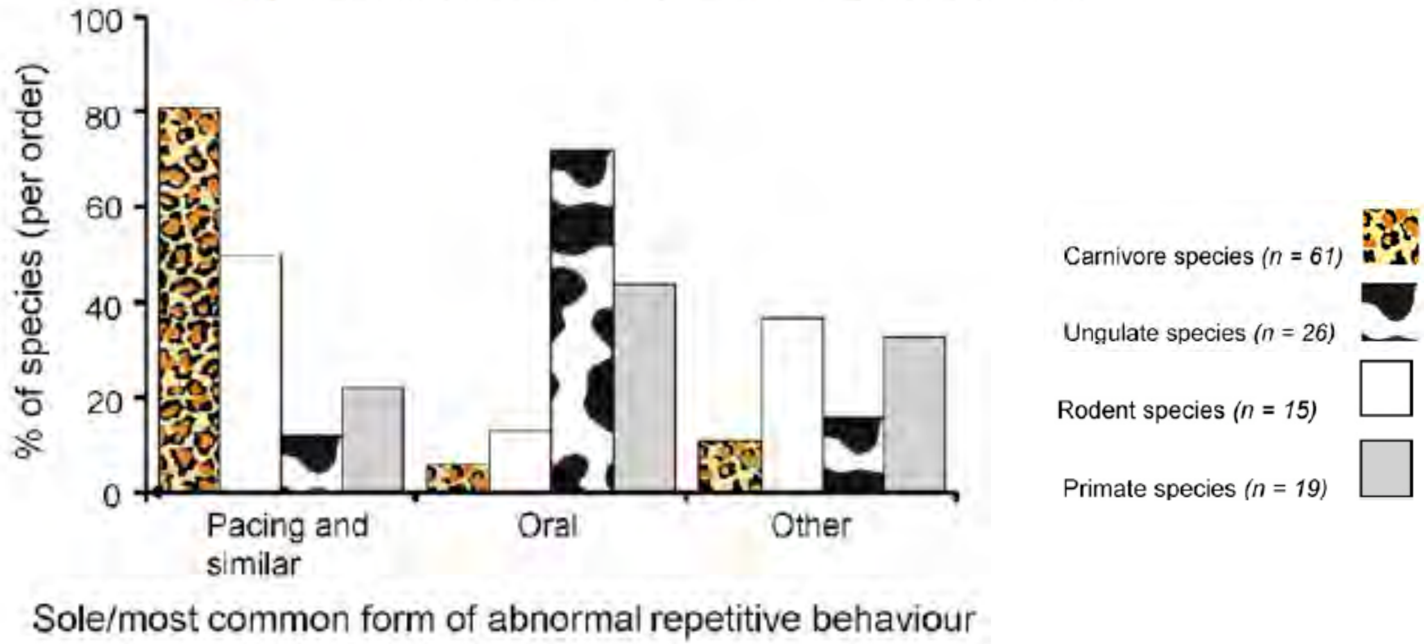
e.g. Taylor et al. (2013),, Mason et al. (2007)

Stereotypies

Why and how should we use environmental enrichment to tackle stereotypic behaviour?☆

G. Mason *, R. Clubb, N. Latham, S. Vickery

Applied Animal Behaviour Science 102 (2007) 163–188



Oral Stereotypies in Giraffe

Photo: Daniela Schaub

A review of nutritional and motivational factors contributing to the performance of regurgitation and reingestion in captive lowland gorillas (*Gorilla gorilla gorilla*)

Kristen E. Lukas *

Applied Animal Behaviour Science 63 (1999) 237–249

Despite findings that provision of browse and removal of fruit from the diet reduces R/R (Loeffler, 1982; Gould and Bres, 1986a; Ruempler, 1992; Wiard, 1992; Velderman, 1997), no one has yet documented the elimination of this behavior from an individual's repertoire. Ruempler (1992), however, reported that one gorilla's R/R had completely ceased for over a year after removing all but huge portions of vegetables and browse (18 kg per adult animal per day) from the diet at Cologne Zoo in Germany. For comparison, an adult male gorilla consumes approximately 6 kg/day at Zoo Atlanta (G. Hamor, personal communication), 13 kg/day at Brookfield Zoo (C. Demitros, personal communication), and 30 kg/day in the wild (*G.g. beringei*, Goodall, 1977). Unfortu-

Removing Milk from Captive Gorilla Diets: The Impact on Regurgitation and Reingestion (R/R) and Other Behaviors

Kristen E. Lukas,[1,2,3*] Gloria Hamor,[3] Mollie A. Bloomsmith,[2,3]
Charles L. Horton,[3] and Terry L. Maple[2,3]

Zoo Biology 18:515 - 528 (1999)

TABLE 6. Comparisons of gorilla behavior between conditions in Phase 2

	Baseline (32 oz milk)	Treatment 32 oz diluted (fruit juice)	Baseline (32 oz milk)	Hypothesis test: baselines vs. treatment	Probability ($\alpha = 0.05$)
Scan data (percentage of time)					
R/R	5.9%	3.7%	6.3%	F = 8.508	*P* = 0.010
Eat hay	1.3%	1.6%	0.3%	F = 0.767	ns
Inactive	45.5%	46.6%	46.3%	F = 0.115	ns
Drink water	3.4%	3.3%	2.9%	F = 0.011	ns
Social (affiliative)	8.4%	8.0%	11.7%	F = 1.221	ns
Other undesirable	1.0%	1.2%	2.0%	F = 0.594	ns
Self-directed behavior	17.1%	17.5%	13.9%	F = 1.681	ns
Social (agonistic)	0.1%	0.3%	0.4%	F = 0.136	ns
Other active behavior	16.0%	16.7%	15.0%	F = 0.605	ns
All-occurrence data (no. per 5 - min)					
R/R attempts	0.022	0.017	0.011	F = 0.000	ns
R/R bouts	0.428	0.256	0.422	F = 4.684	*P* = 0.045
Feed on another's regurgitant	0.061	0.061	0.072	F = 0.239	ns
Examine another engaging in R/R	0.056	0.056	0.072	F = 0.221	ns
Agonistic behavior	0.089	0.111	0.233	F = 1.342	ns

An analysis of regurgitation and reingestion in captive chimpanzees

Kate C. Baker [a,*], Stephen Phillip Easley [b]

Applied Animal Behaviour Science 49 (1996) 403–415

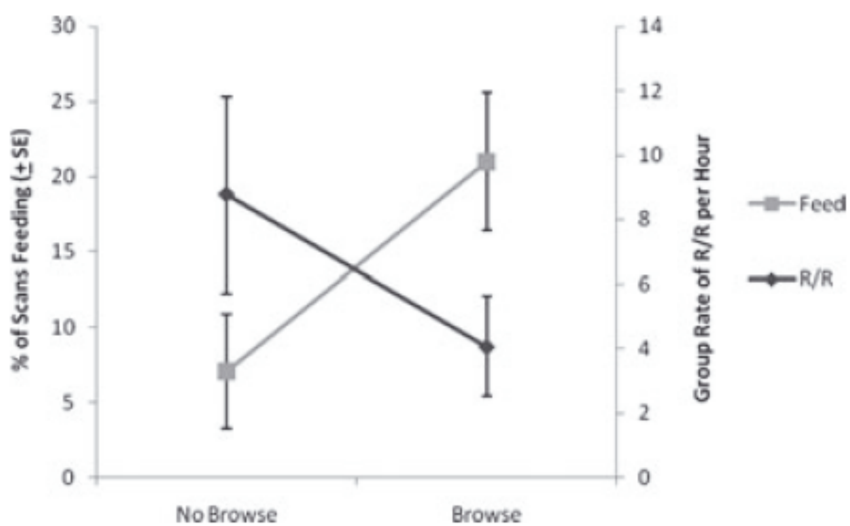
of cagemates or housing history; nor were sex differences detected. Meal composition was not found to effect the time devoted to R/R. Statistical tests did show a strong positive relationship between rates of R/R and elapsed time since feeding. These results suggest that increasing meal frequency or providing consistently available edible material may prove more broadly effective than altering meal composition. Temporal distributions of R/R differed from those of abnormal

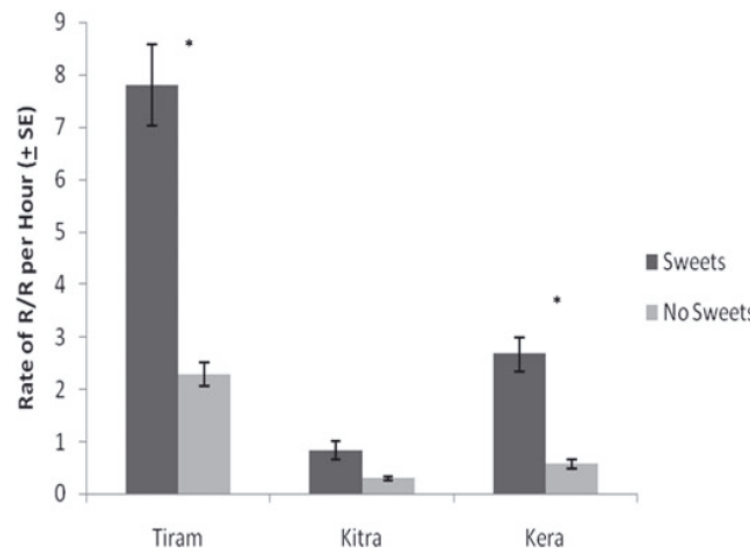
old male) (Morgan et al., 1993). That study found that R/R occurred within minutes of each meal, and was most frequent following meals consisting of fruit. Reductions in R/R occurred during behavioral training sessions and when more browse was provided.

Prevalence of Regurgitation and Reingestion in Orangutans Housed in North American Zoos and an Examination of Factors Influencing its Occurrence in a Single Group of Bornean Orangutans

Zoo Biology 31: 609–620 (2012)

Christine M. Cassella,[1,2*] Alyssa Mills,[1] and Kristen E. Lukas[1,2]





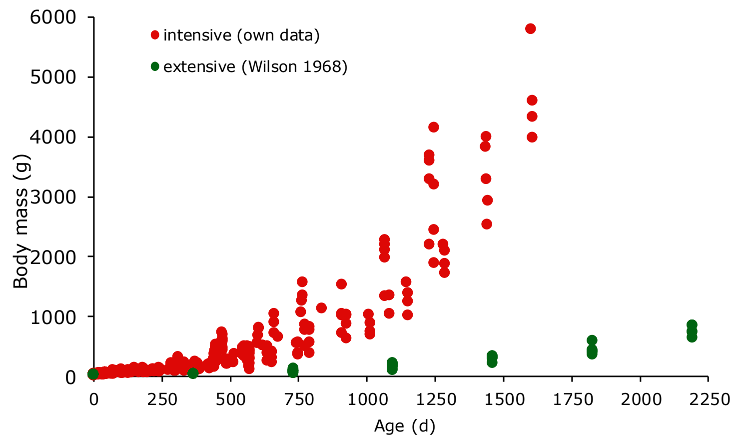
Examples: differences wild - zoo

+	fibre in (herbivore) diets	-
-	feeding-related dysbehaviour	+
-	***obesity***	++

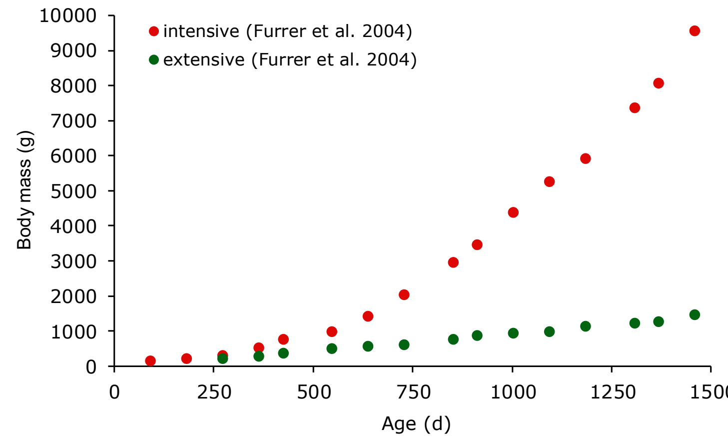
e.g. Taylor et al. (2013),, Mason et al. (2007), Schwitzer & Kaumanns (2001)

Tortoise growth

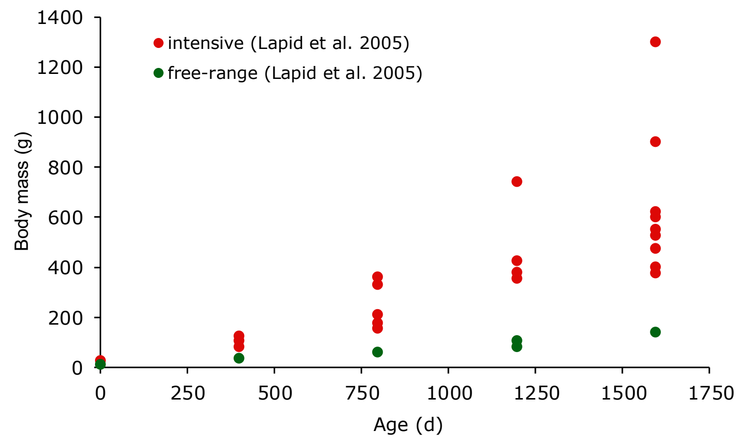
Geochelone pardalis



Geochelone nigra



Testudo graeca



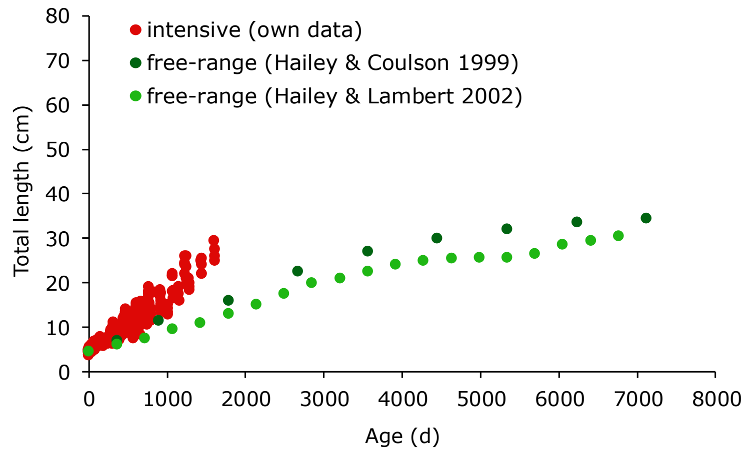
extensive or free-range

intensive

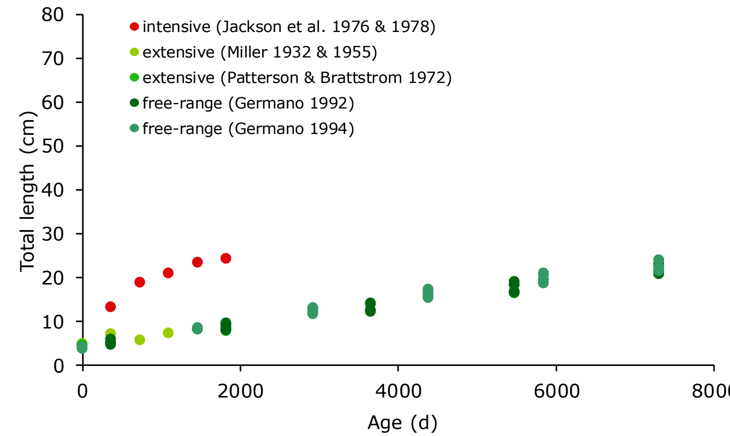
Ritz et al. (2010ab, 2012)

Tortoise growth

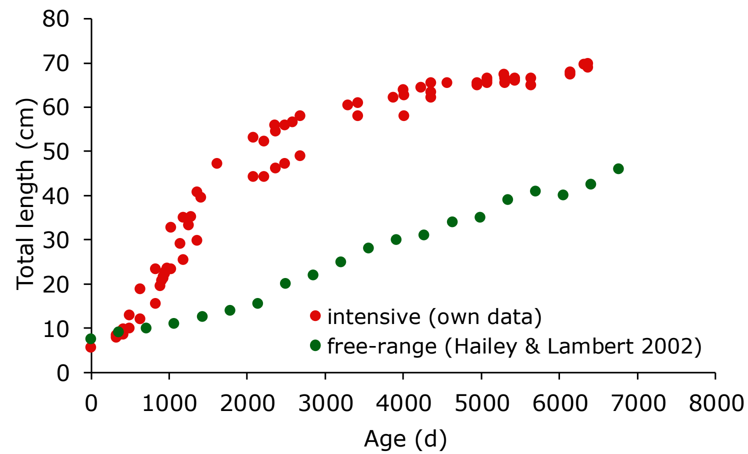
Geochelone pardalis



Gopherus agassizi



Geochelone sulcata



extensive or free-range

intensive

Ritz et al. (2010ab, 2012)

BCS giant anteater

BCS2

BCS3

BCS4

Clark et al. (2013)

Results: Body mass, BCS, food offer

Species	Body mass in adult free-ranging individuals, kg	Body mass, kg	BCS	Dry matter offered, g/d	Relative dry matter offered, $g/kg^{0.75}/d$
Giant anteater (*M. tridactyla*) 	31–45[1]	49.0±7.6 (38.5–62.5) n=12	2.9±0.5 (2.0–4.0) n=26	611±214 (270–1170) n=24	30±12 (16–53) n=10

Zoo giant anteaters:
Higher body masses than in the wild have been reported repeatedly. Does this have relevance?
Wide range of body masses and BCS.

Clark et al. (2013)

Large hairy armadillo
(Chaetophractus villosus)

BCS 3

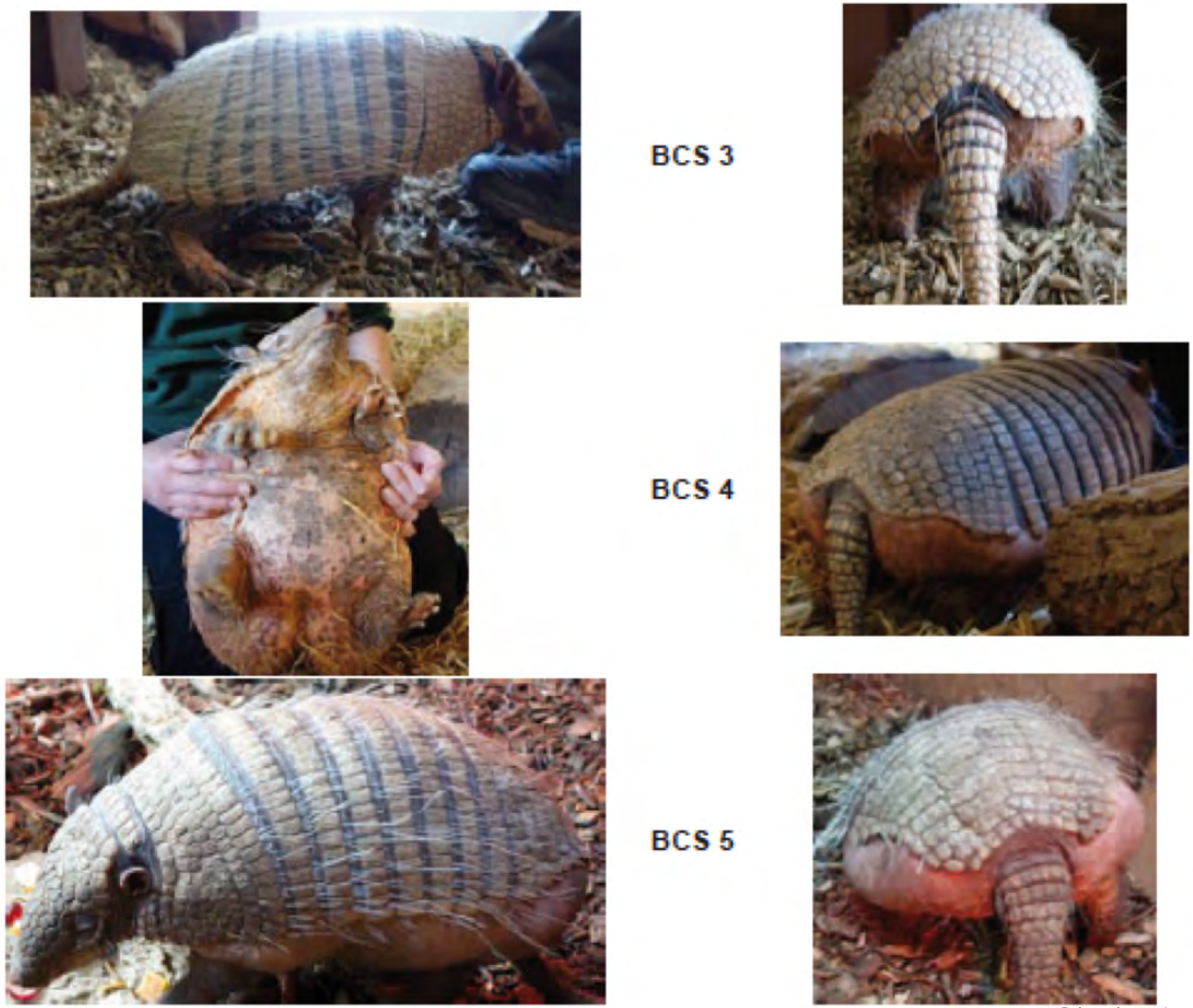
BCS 4

BCS 5

Clark et al. (2013)

Six-banded armadillo

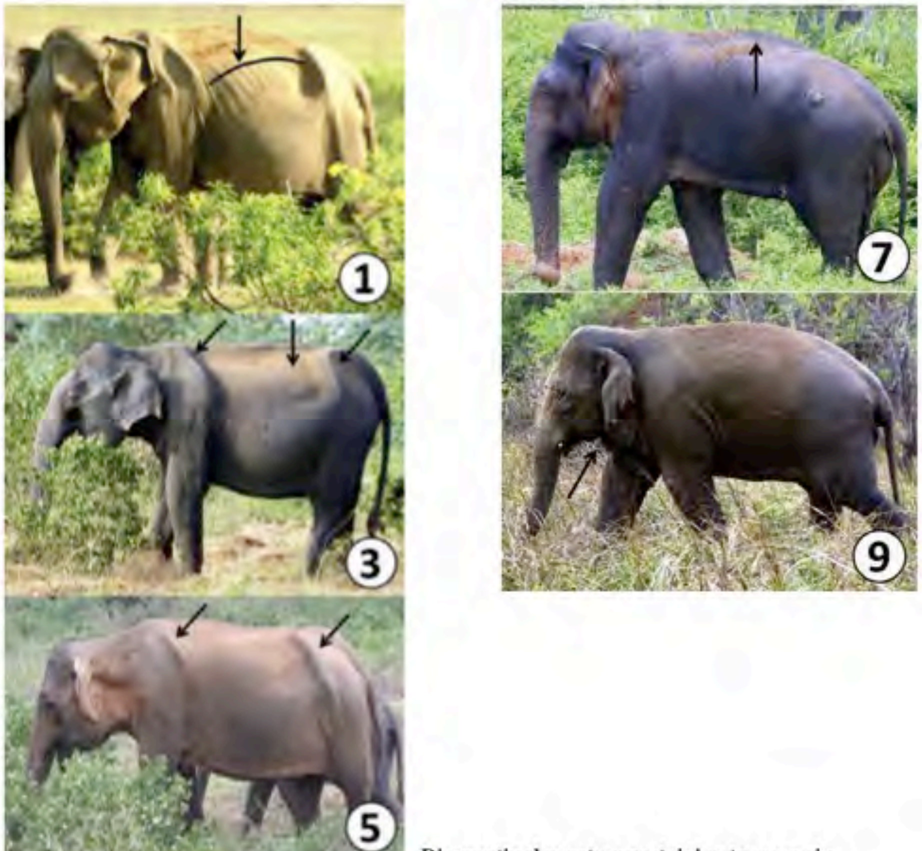
(*Euphractus sexcinctus*)



Clark et al. (2013)

Monitoring body condition

Body Condition Index Scores

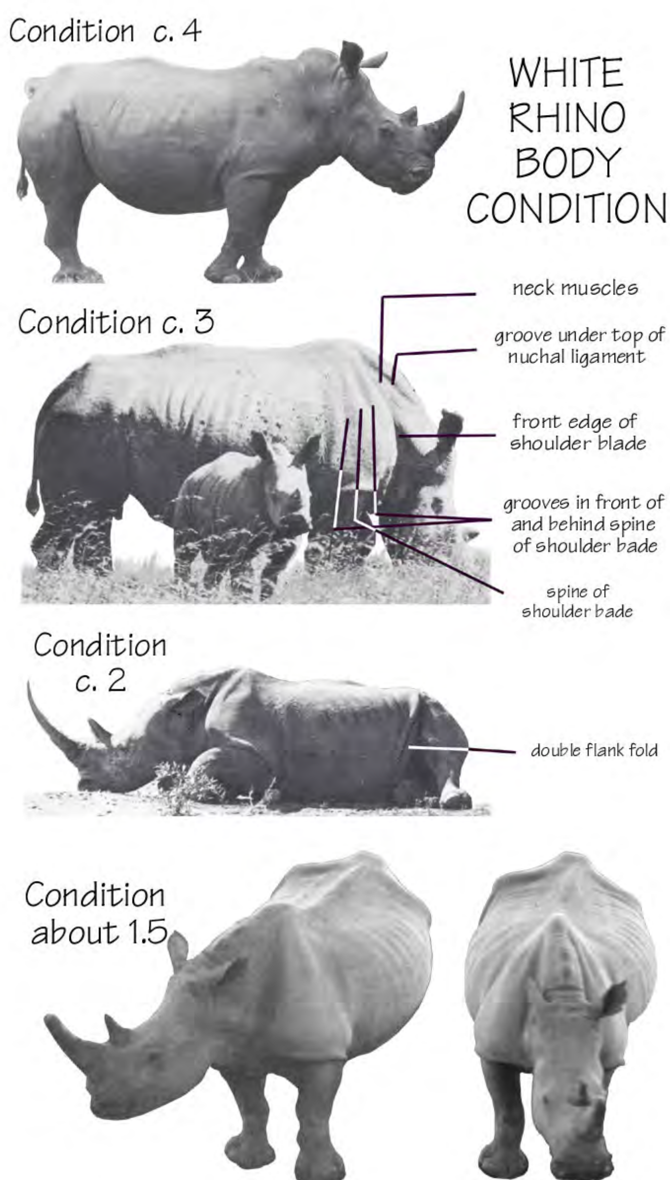


Diagnostic characters pertaining to scores in photographic scale.

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

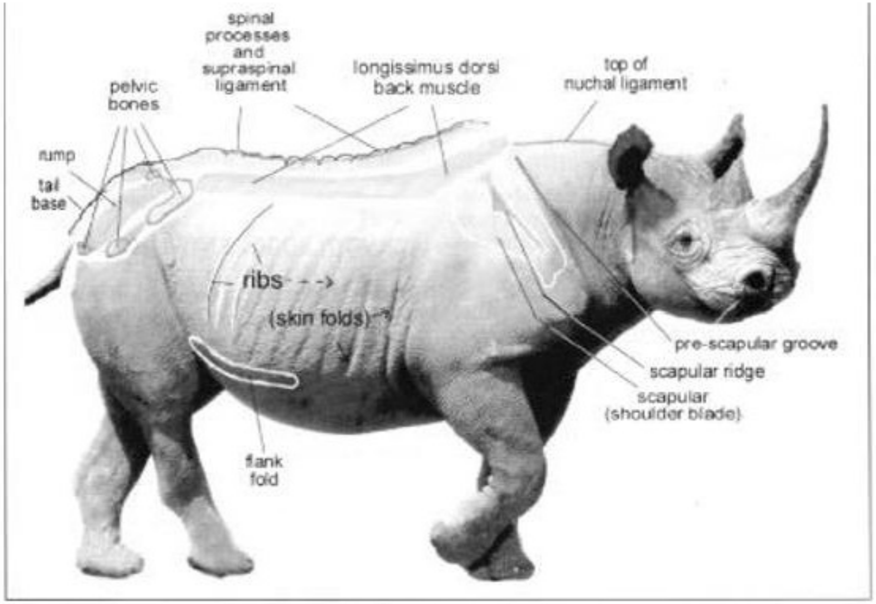
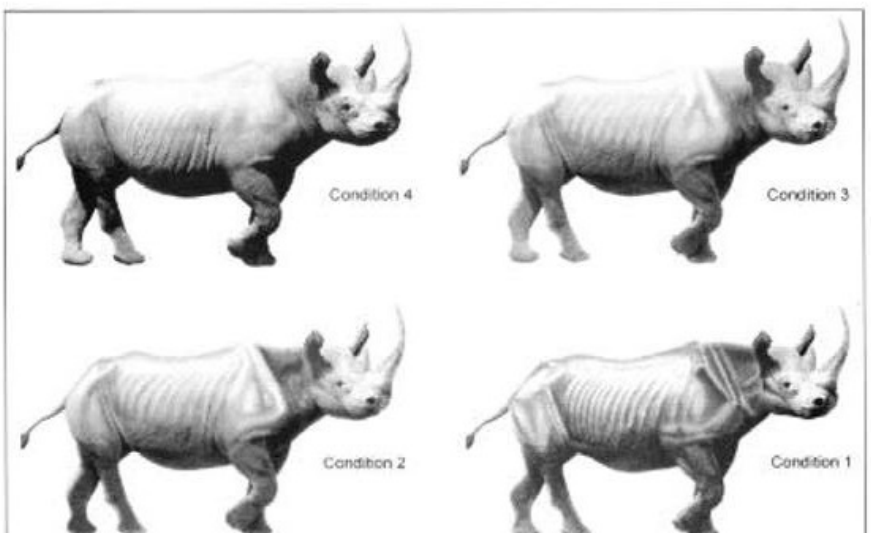


Figure 1. The body regions and specific anatomical features to be observed when assessing a rhino's condition.



from Reuter & Adcock (1998)

Monitoring body condition

BCS 5

BCS 4

BCS 3

BCS 2

BCS 1

from Heidegger et al. (2016)

Monitoring body condition

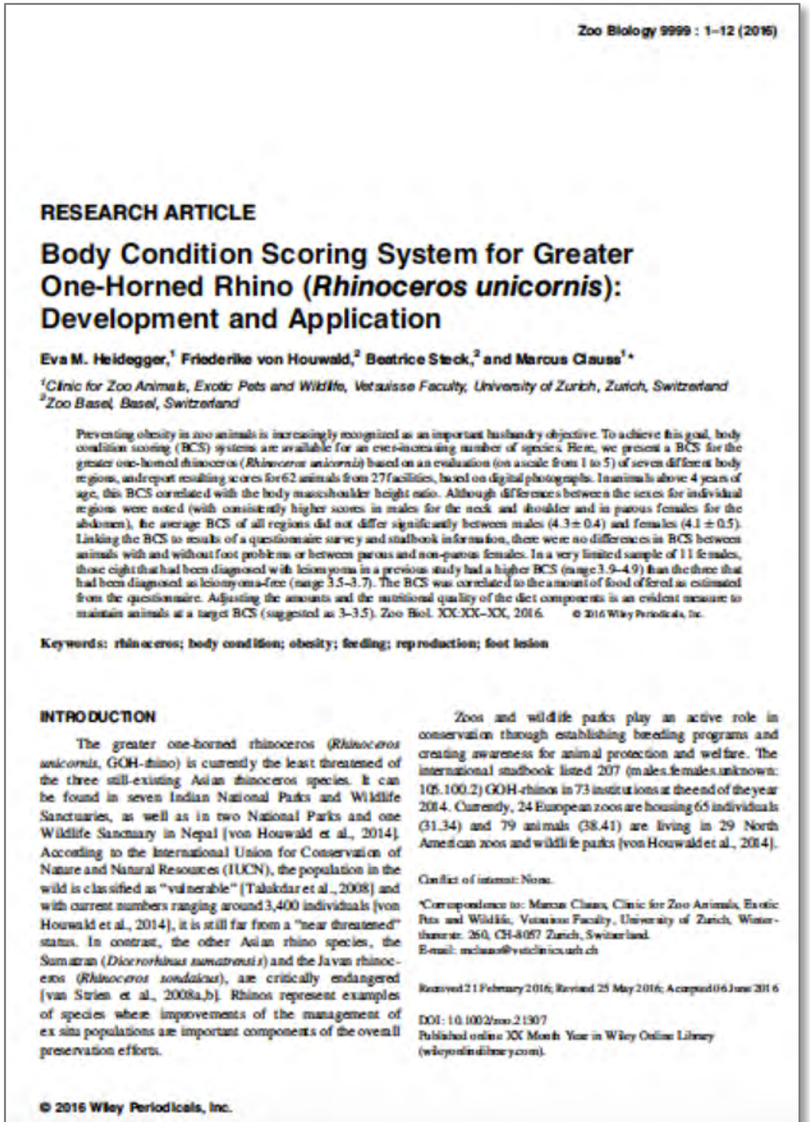
Irregular ovarian activity, body condition and behavioural differences are associated with reproductive success in female eastern black rhinoceros (*Diceros bicornis michaeli*)

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



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. © 2016 Wiley Periodicals, Inc.

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.

*Correspondence to: Marcus Clauss, Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Winterthurerstr. 260, CH-8057 Zurich, Switzerland.
E-mail: mclauss@vetclinics.uzh.ch

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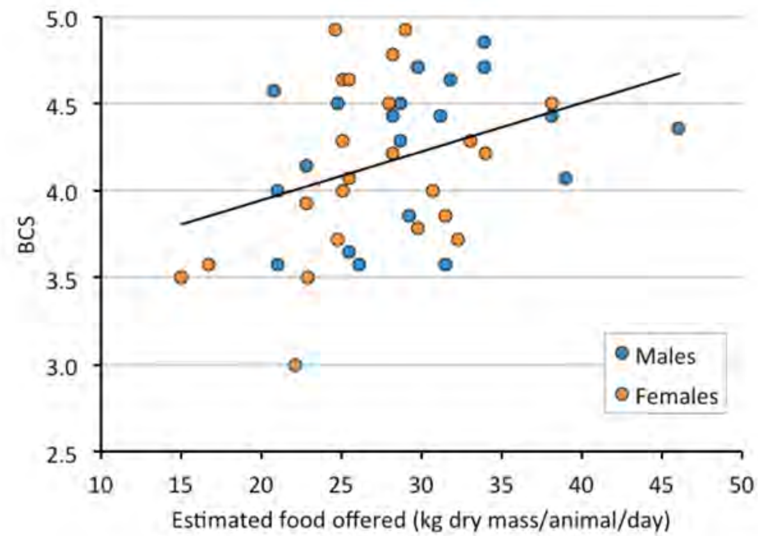


Ways to generate obesity

(too little exercise)

High-energy feeds

Too much of medium-energy feeds

Birthday cakes

Birthday cakes

Zoo nutrition problems

- historical development

The classic problem repertoire

Carnivore → *Red meat* → ?

The classic problem repertoire

Carnivore → *Red meat* → *Calcium deficiency*

The classic problem repertoire

Carnivore → *Red meat* → ~~*Calcium deficiency*~~

+

The classic problem repertoire

Carnivore → *Red meat* → ~~*Calcium deficiency*~~

 + 

The classic problem repertoire

Carnivore → *Red meat* → ~~*Calcium deficiency*~~

 + 

⇢ *Dental calculus, behavioural deficiencies*

The classic problem repertoire

Carnivore → *Red meat* → ~~*Calcium deficiency*~~

+

+

⇢ ~~*Dental calculus, behavioural deficiencies*~~

The classic problem repertoire

Carnivore → *Red meat* → ~~*Calcium deficiency*~~

 + 

- - → ~~*Dental calculus, behavioural deficiencies*~~

 + 

The classic problem repertoire

Carnivore → *Red meat* → ~~*Calcium deficiency*~~

 ~~+~~ 

 ~~+~~  - - → ~~*Dental calculus, behavioural deficiencies*~~

 + *adequate presentation*

The classic problem repertoire

Carnivore → *Red meat* → ~~*Calcium deficiency*~~

 + 

 + 

--→ ~~*Dental calculus, behavioural deficiencies*~~

 +

adequate presentation = ***enrichment !!***

The classic problem repertoire

Insectivore → *Meat, fruit, insects* → ?

The classic problem repertoire

Insectivore → *Meat, fruit, insects* → *Calcium and Vitamin A deficiency*

The classic problem repertoire

Insectivore → *Meat, fruit, insects* → ~~Calcium and Vitamin A deficiency~~




+


- - → *Obesity, aggression, abnormal behaviour*

The classic problem repertoire

Insectivore → *Meat, fruit, insects* → ~~*Calcium and Vitamin A deficiency*~~

⇢ ~~*Obesity, aggression, abnormal behavior*~~*, dental calculus*

The classic problem repertoire

Insectivore → *Meat, fruit, insects* → ~~Calcium and Vitamin A deficiency~~

- - → ~~Obesity, aggression, abnormal behavior, dental calculus~~

The classic problem repertoire

Insectivore → *Meat, fruit, insects* → ~~Calcium and Vitamin A deficiency~~

⇢ ~~Obesity, aggression, abnormal behavior, dental calculus~~


+

\+ *adequate presentation*

The classic problem repertoire

Insectivore → *Meat, fruit, insects* → ~~Calcium and Vitamin A deficiency~~

--> ~~Obesity, aggression, abnormal behavior, dental calculus~~

+

+ *adequate presentation =* ***enrichment !!***

The classic problem repertoire

Fish-Eater → *Thawed fish* → ?

The classic problem repertoire

Fish-Eater → *Thawed fish* → *Sodium- and vitamin B deficiency*

The classic problem repertoire

Fish-Eater → *Thawed fish* → ~~*Sodium and vitamin B deficiency*~~

 + 

\+ *adequate thawing regime*

The classic problem repertoire

Fish-Eater → *Thawed fish* → ~~*Sodium and vitamin B deficiency*~~

 + 

\+ *adequate thawing regime* ⇢ *abnormal behavior, skin/eye problems*

The classic problem repertoire

Fish-Eater → *Thawed fish* → ~~*Sodium and vitamin B deficiency*~~

 + 

+ *adequate thawing regime* ⇢ ~~*abnormal behavior,*~~ *skin/eye problems*

+ *adequate presentation*

The classic problem repertoire

Fish-Eater → *Thawed fish* → ~~*Sodium and vitamin B deficiency*~~

 + 

\+ *adequate thawing regime* ⇢ ~~*abnormal behavior,*~~ *skin/eye problems*

\+ *adequate presentation =* ***enrichment !!***

The classic problem repertoire

Fish-Eater → *Thawed fish* → ~~Sodium and vitamin B deficiency~~

 + 

+ *adequate thawing regime* ⇢ ~~abnormal behavior, skin/eye problems~~

+ *adequate presentation =* ***enrichment !!***

+ *salt water bath*
(e.g. 1x/week)

The classic problem repertoire

Primate → *Fruits & vegetables* → ?

The classic problem repertoire

Primate → *Fruits & vegetables* → *Calcium deficiency*

The classic problem repertoire

Primate → *Fruits & vegetables* → ~~*Calcium deficiency*~~

+

The classic problem repertoire

Primate → *Fruits & vegetables* → ~~*Calcium deficiency*~~

   + 

- - → *Obesity, caries, aggression, abnormal behaviour*

The classic problem repertoire

Primate → *Fruits & vegetables* → ~~*Calcium deficiency*~~

~~*Obesity, caries, aggression, abnormal behaviour*~~

The classic problem repertoire

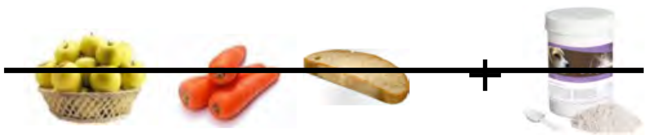
Primate → *Fruits & vegetables* → ~~*Calcium deficiency*~~

~~*Obesity, caries, aggression, abnormal behaviour*~~

\+ *adequate presentation*

The classic problem repertoire

Primate → *Fruits & vegetables* → ~~*Calcium deficiency*~~



- - → ~~*Obesity, caries, aggression, abnormal behaviour*~~

\+ *adequate presentation =* ***enrichment !!***

The classic problem repertoire

Herbivore → *Hay, fruits & grains* → ?

The classic problem repertoire

Herbivore → *Hay, fruits & grains* → *Vitamin E- and calcium deficiency*

The classic problem repertoire

Herbivore → *Hay, fruits & grains* → ~~*Vitamin E and calcium deficiency*~~

+

The classic problem repertoire

Herbivore → *Hay, fruits & grains* → ~~*Vitamin E and calcium deficiency*~~

\+

The classic problem repertoire

Herbivore → *Hay, fruits & grains* → ~~*Vitamin E and calcium deficiency*~~

\+ 

→ *Obesity, malfermentation, abnormal behaviour*

The classic problem repertoire

Herbivore

Hay, fruits & grains

+

~~*Vitamin E and calcium deficiency*~~

~~*Obesity*~~*,* ~~*malfermentation (acidosis)*~~*,* ~~*abnormal behaviour*~~

(

)

The classic problem repertoire

Herbivore

Hay, fruits & grains

+

~~Vitamin E and calcium deficiency~~

~~Obesity~~, ~~malfermentation (acidosis)~~, ~~abnormal behaviour~~

()

+ adequate presentation

The classic problem repertoire

Herbivore → *Hay, fruits & grains* → ~~*Vitamin E and calcium deficiency*~~

+

~~*Obesity*~~*,* ~~*malfermentation (acidosis)*~~*,* ~~*abnormal behaviour*~~

\+ *adequate presentation =* ***enrichment !!***

Basic feeding approach

Animal group → *Agriculture / human-taste diets* → *Classic deficiencies*

Basic feeding approach

Animal group → *Agriculture / human-taste diets* + *supplement* → ~~*Classic deficiencies*~~

Basic feeding approach

Animal group → *Agriculture / human-taste diets* → ~~*Classic deficiencies*~~

\+ *supplement*

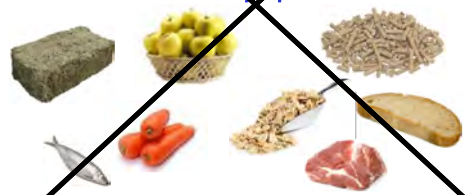
⇢ *'Civilisation diseases'* *(obesity, malfermentation)*, *abnormal behavior* *(stereotypies, aggression)*

Basic feeding approach

Animal group

Agriculture / human-taste diets

\+ *supplement*



~~Classic deficiencies~~

'Civilisation diseases'

(obesity, malfermentation),

abnormal behavior

(stereotypies, aggression)

Basic feeding approach

Animal group

Agriculture / human-taste diets

\+ *supplement*

~~*Classic deficiencies*~~

~~'Civilisation diseases'~~

~~*(obesity, malfermentation),*~~

~~*abnormal behavior*~~

~~*(stereotypies, aggression)*~~

Diets that resemble natural diets in structure and nutrient composition

Basic feeding approach

Animal group

→ ~~*Agriculture / human-taste diets + supplement*~~

→ ~~Classic deficiencies~~

⇢ ~~'Civilisation diseases' (obesity, malfermentation), abnormal behavior (stereotypies, aggression)~~

Diets that resemble natural diets in structure and nutrient composition

+ *adequate presentation*

Basic feeding approach

Animal group

Agriculture / human-taste diets

+ *supplement*

~~Classic deficiencies~~

~~'Civilisation diseases'~~
~~(obesity, malfermentation),~~
~~abnormal behavior~~
~~(stereotypies, aggression)~~

Diets that resemble natural diets in structure and nutrient composition

+ *adequate presentation =* ***enrichment !!***

Basic feeding approach

Animal group →

~~*Agriculture / human-taste diets*~~

~~+ *supplement*~~

→ ~~Classic deficiencies~~

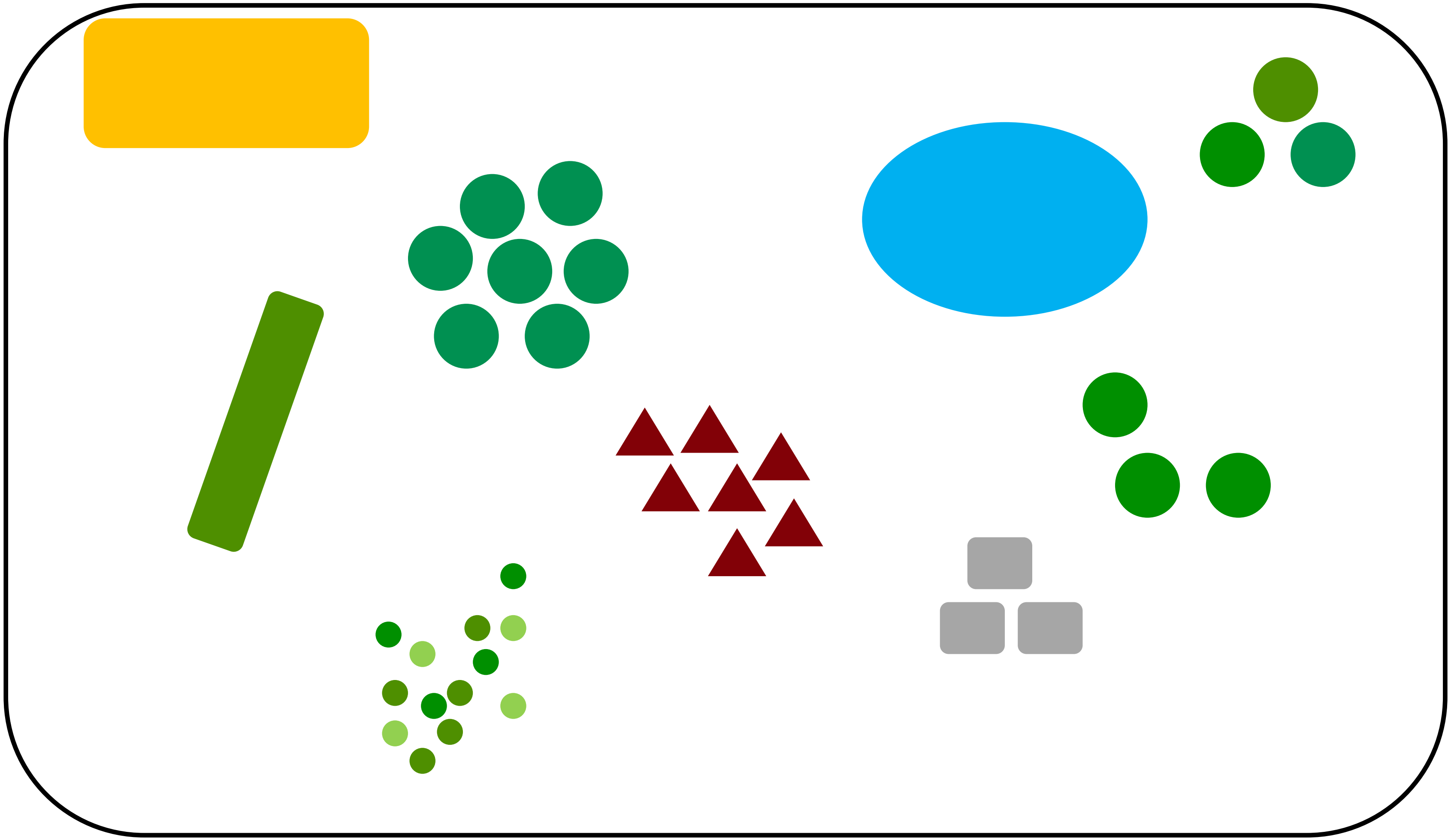
⇢ ~~'Civilisation diseases' (obesity, malfermentation), abnormal behavior (stereotypies, aggression)~~

Diets that resemble natural diets in structure and nutrient composition

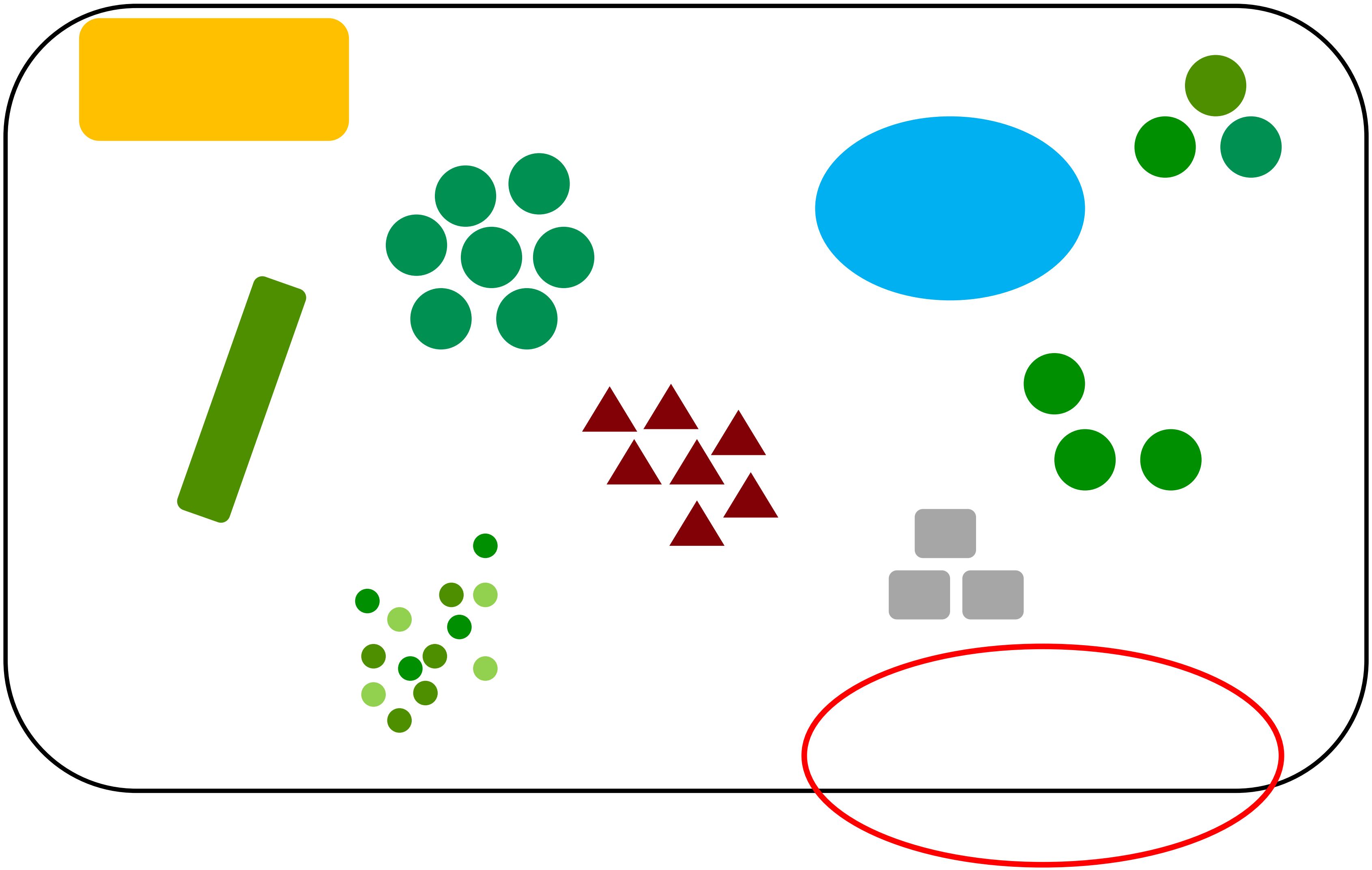
+ *adequate presentation =* ***enrichment !!***

Enrichment should ***not*** *be* ***the addition of something*** *(like human-taste items) but the presentation of the diet an a* ***challenging*** *and* ***meaningful way*** *!*

Enclosure design



Enclosure design and use



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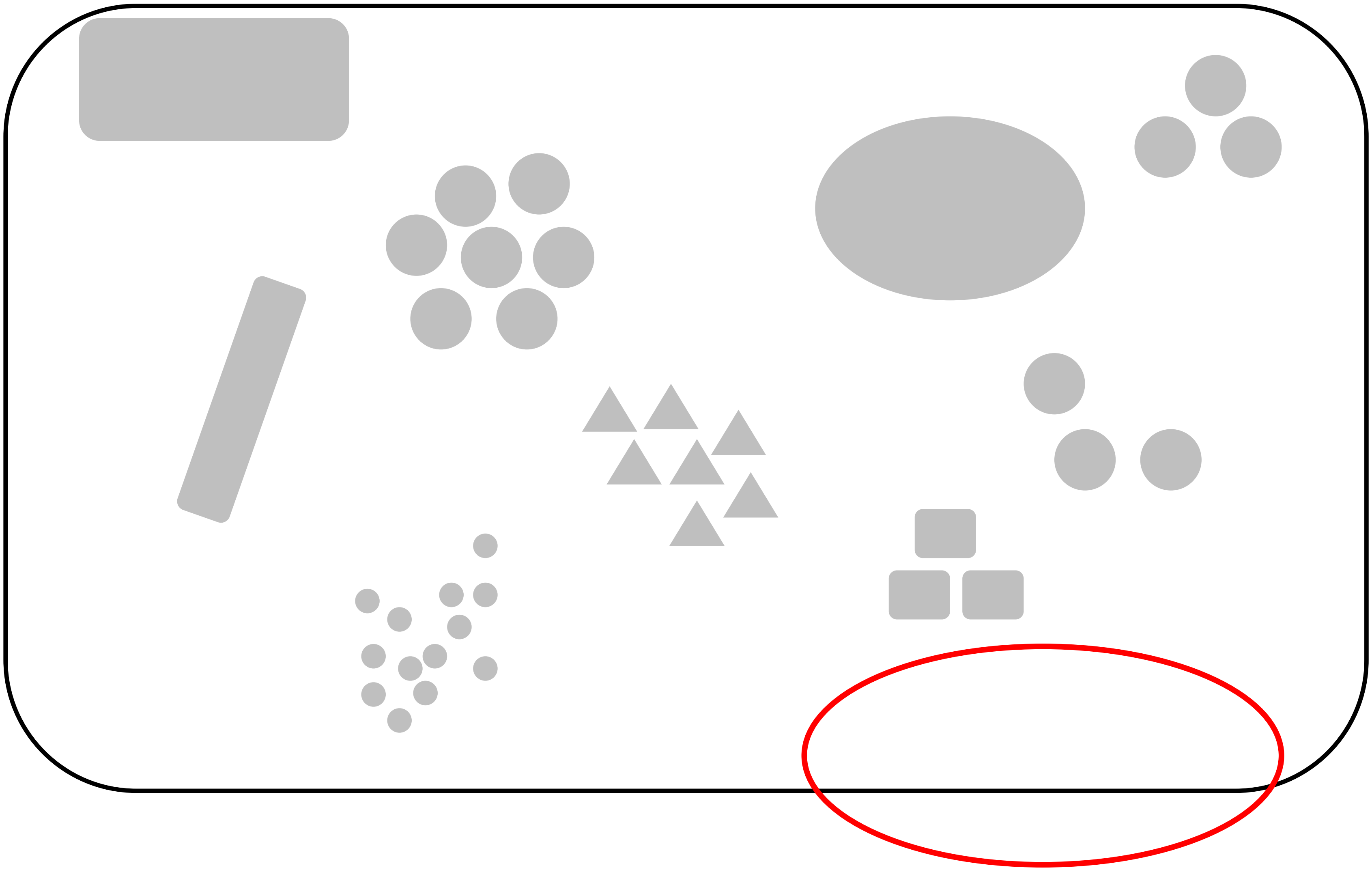
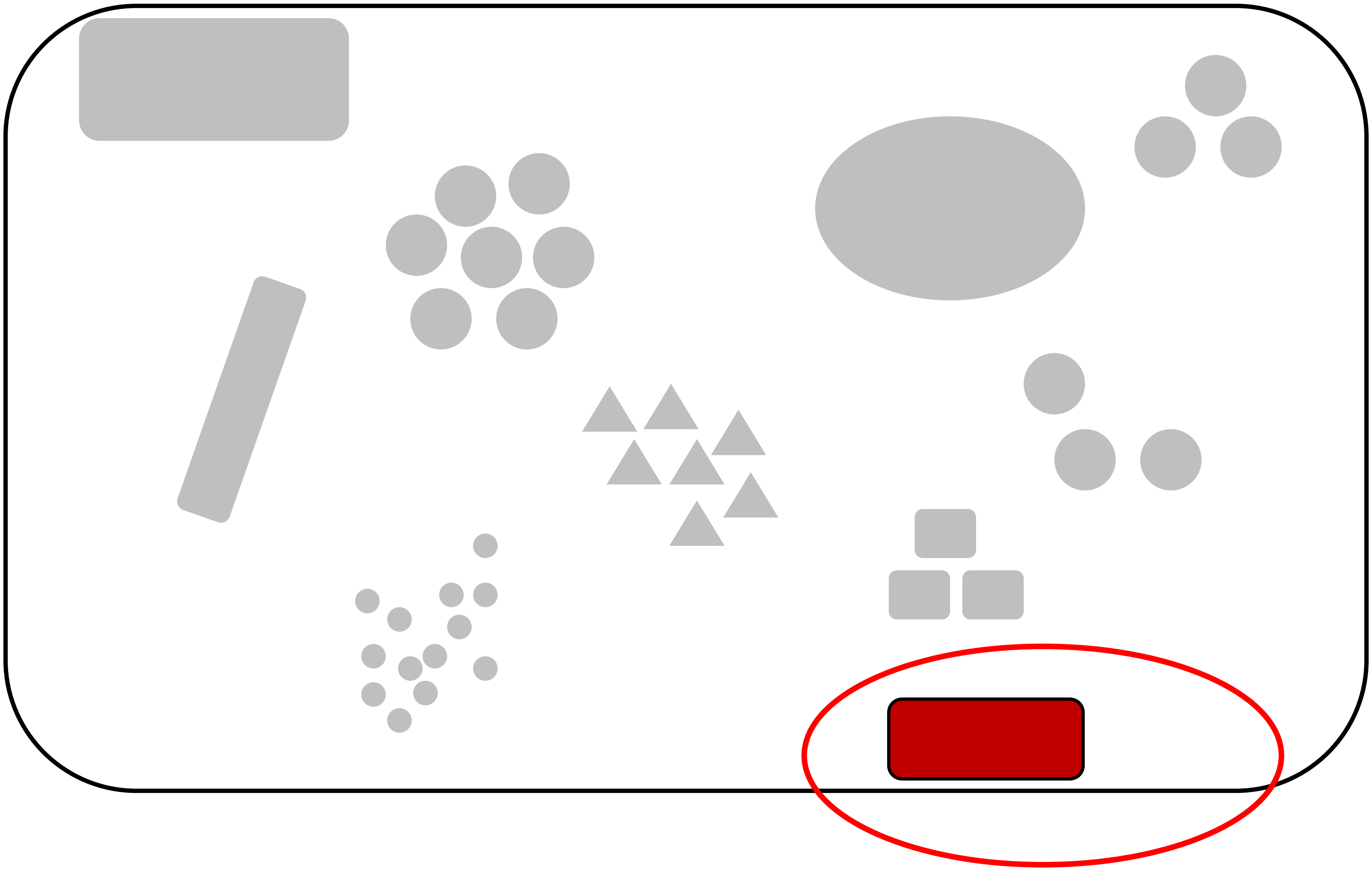


Enclosure design and use



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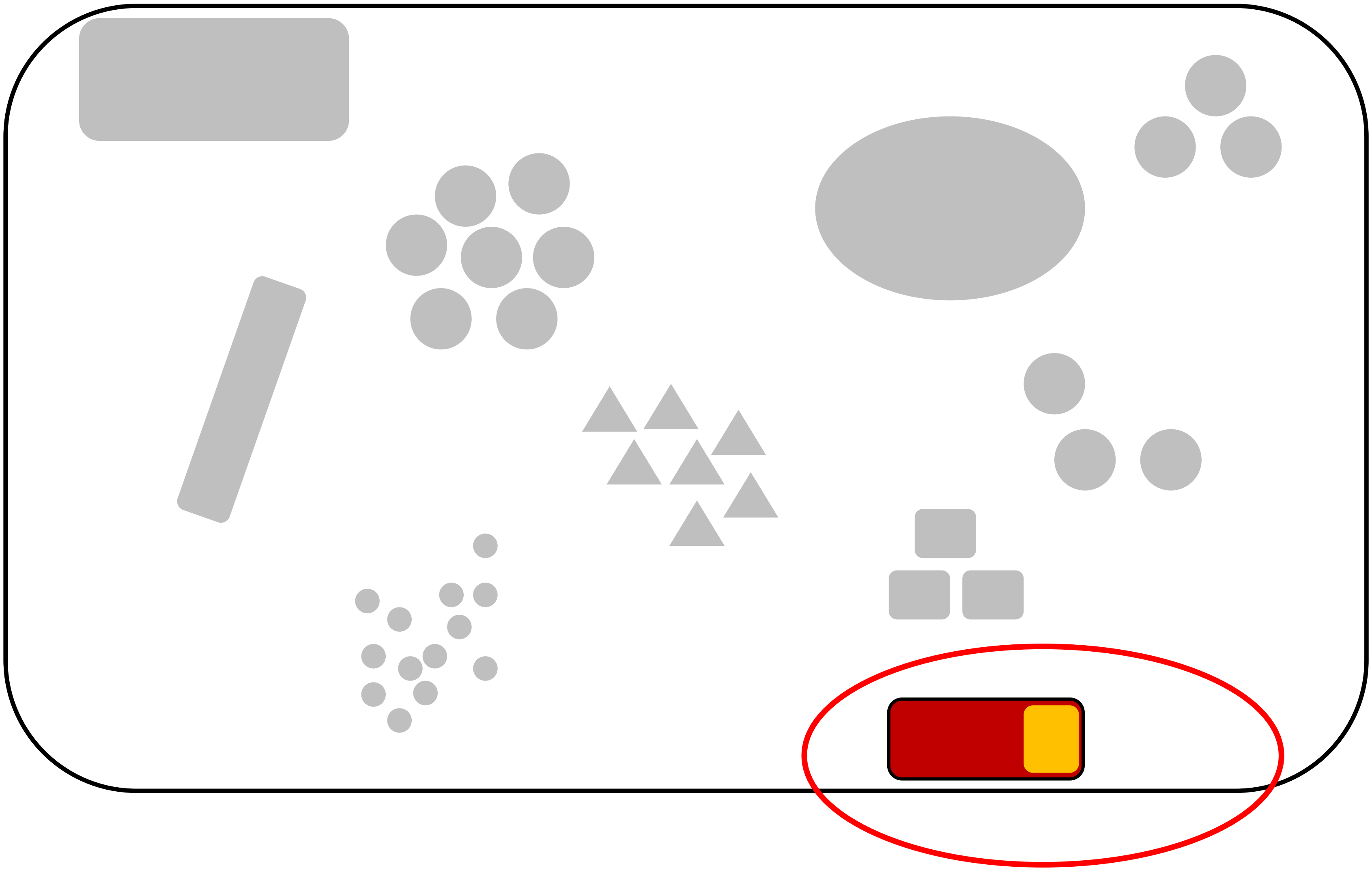
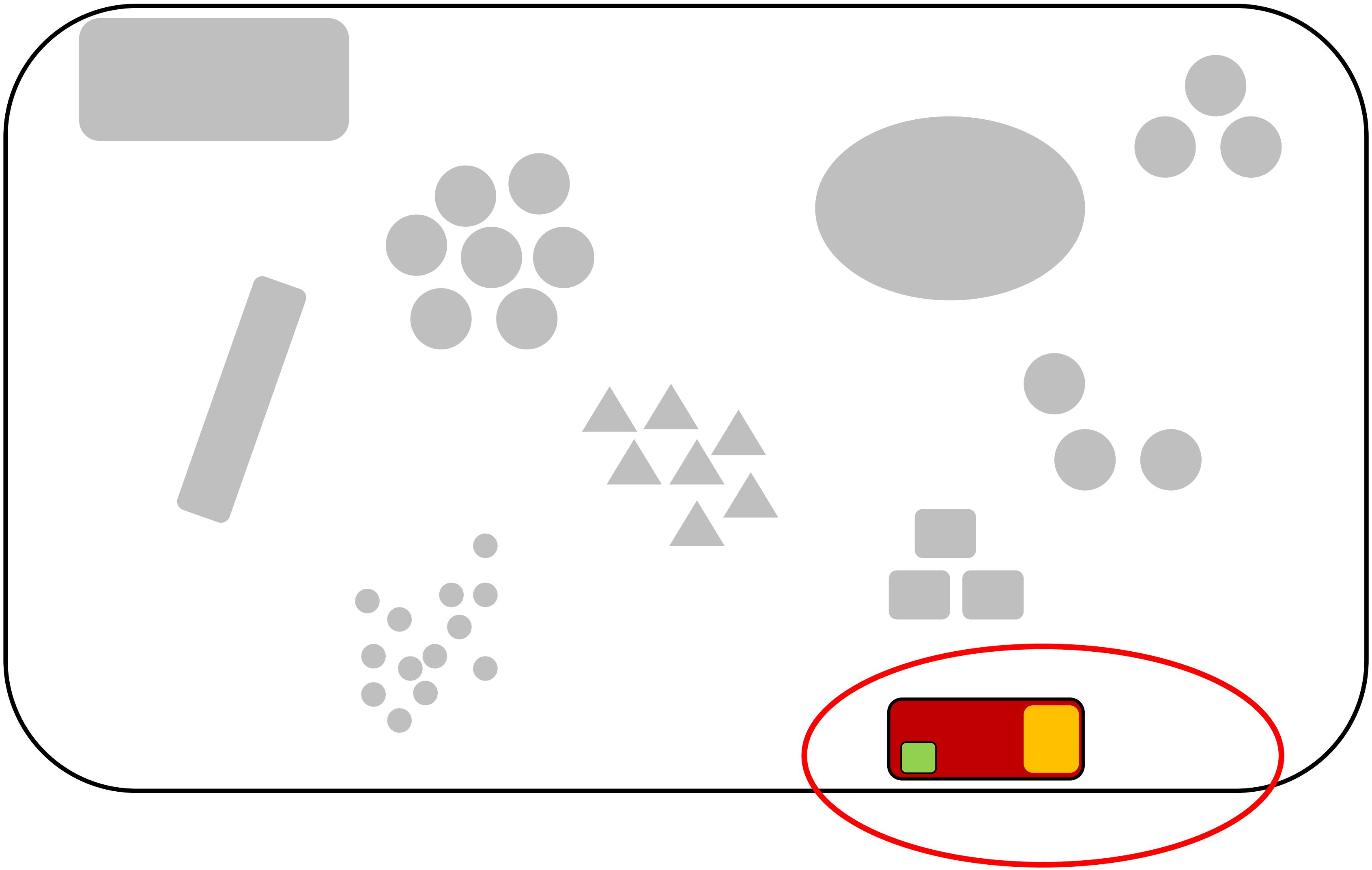


Enclosure design and use



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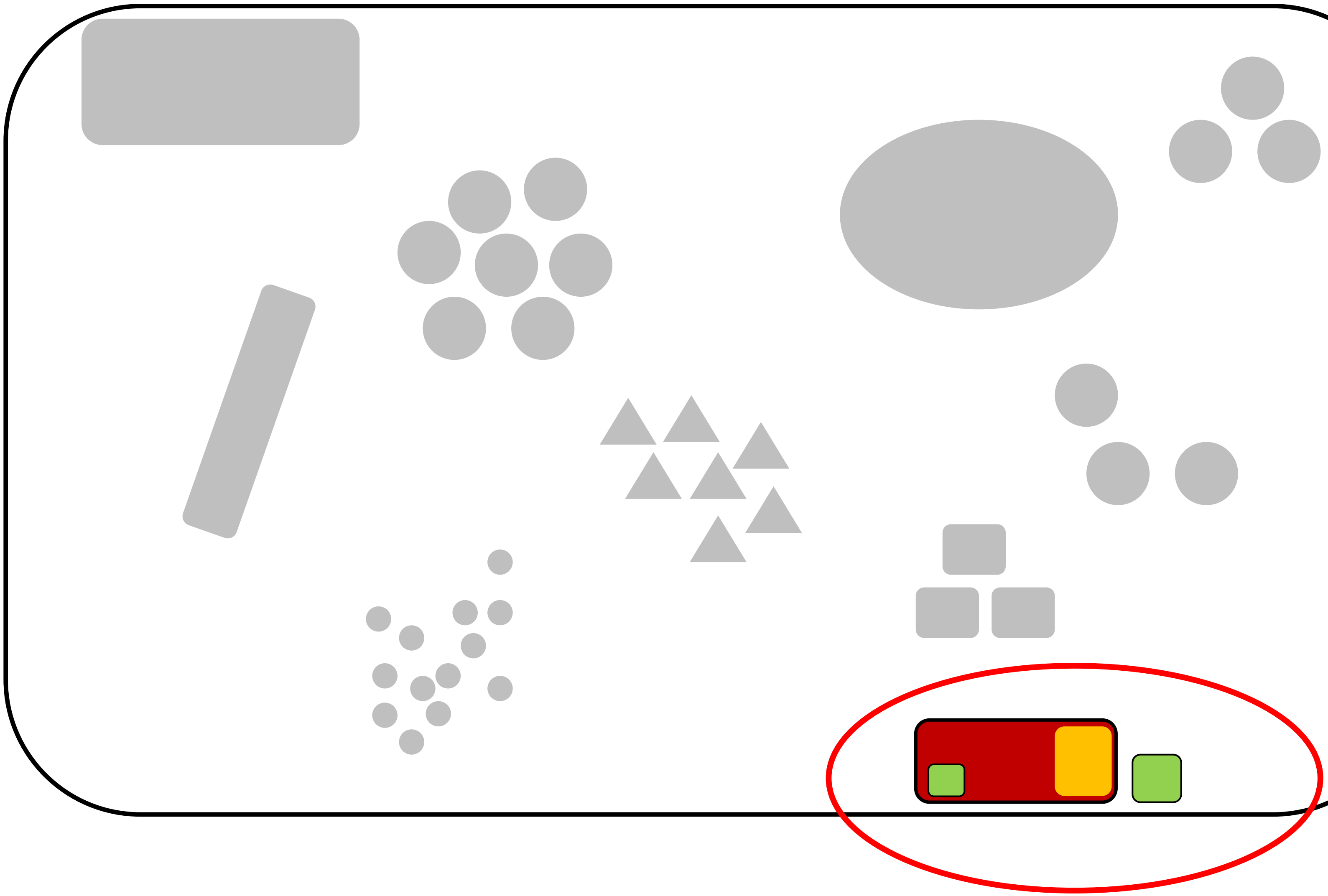

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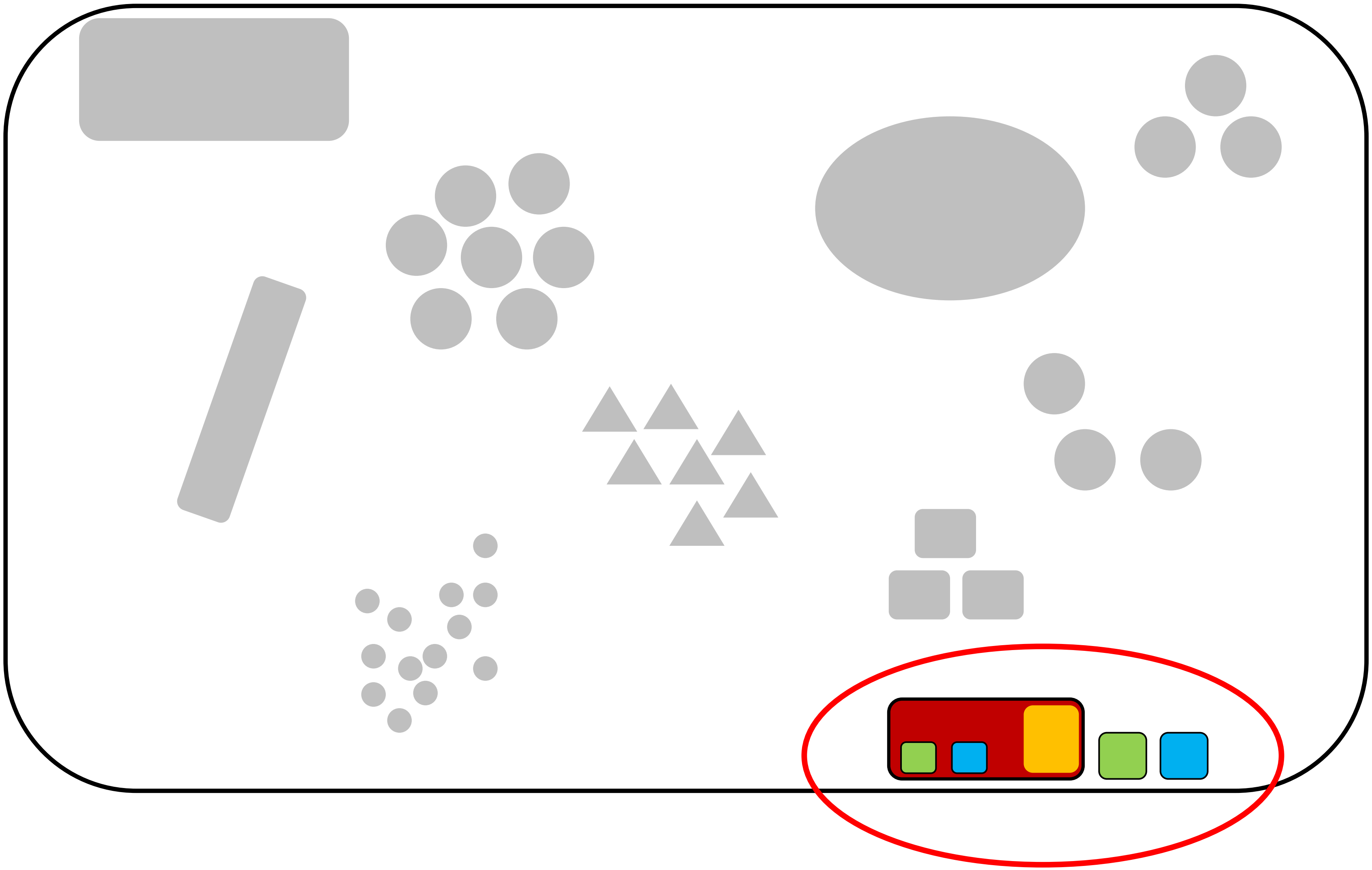

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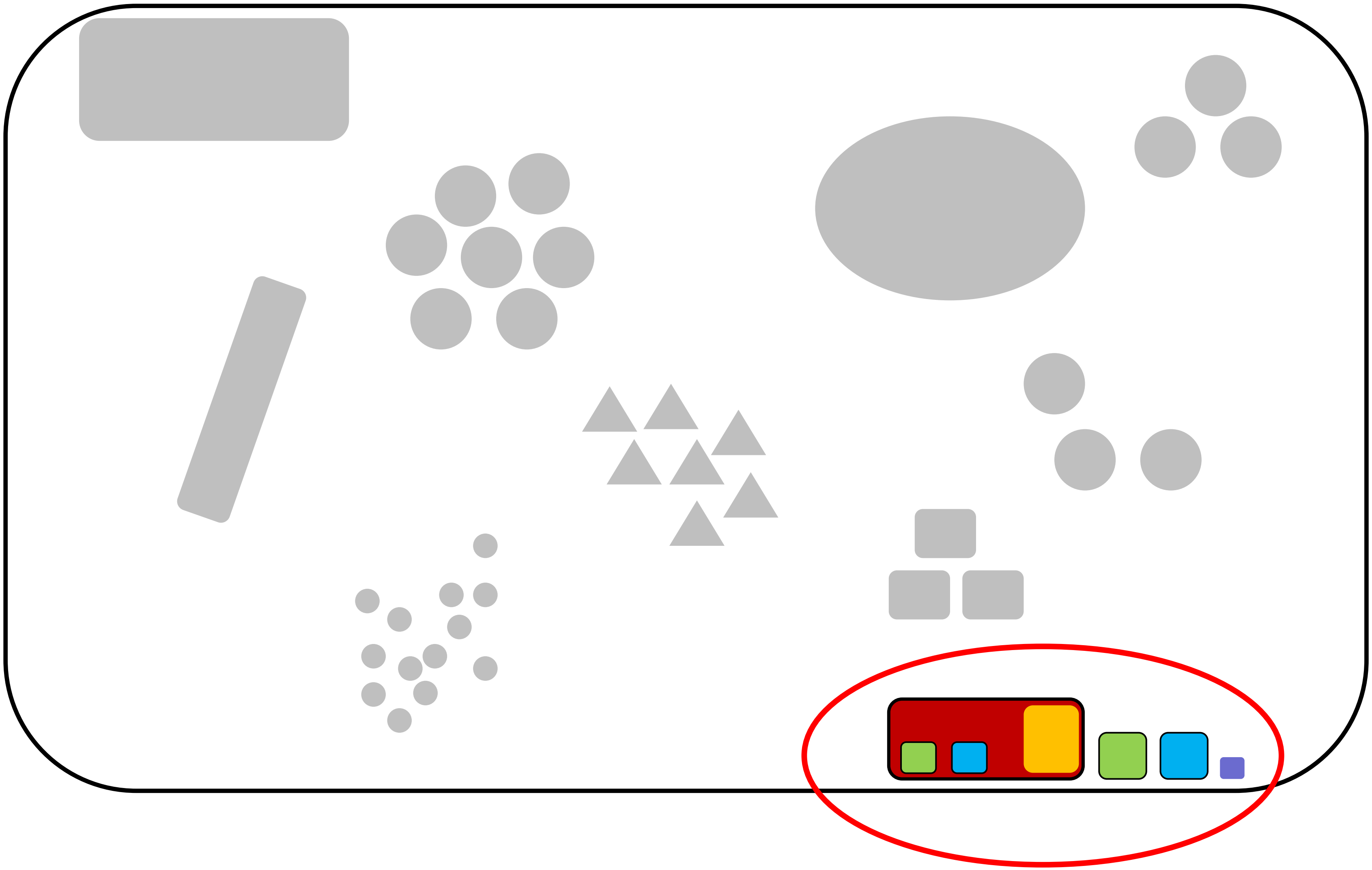

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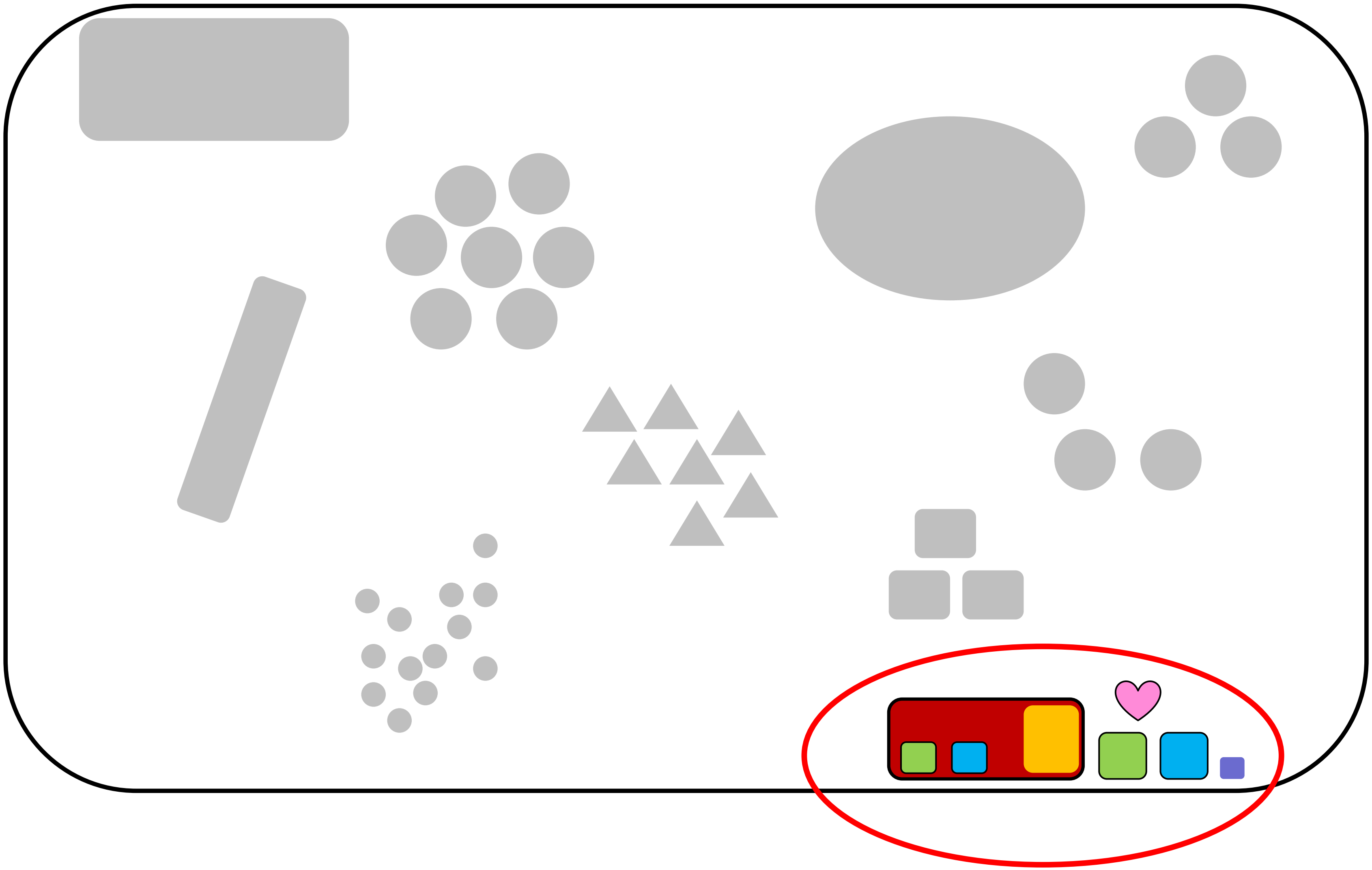

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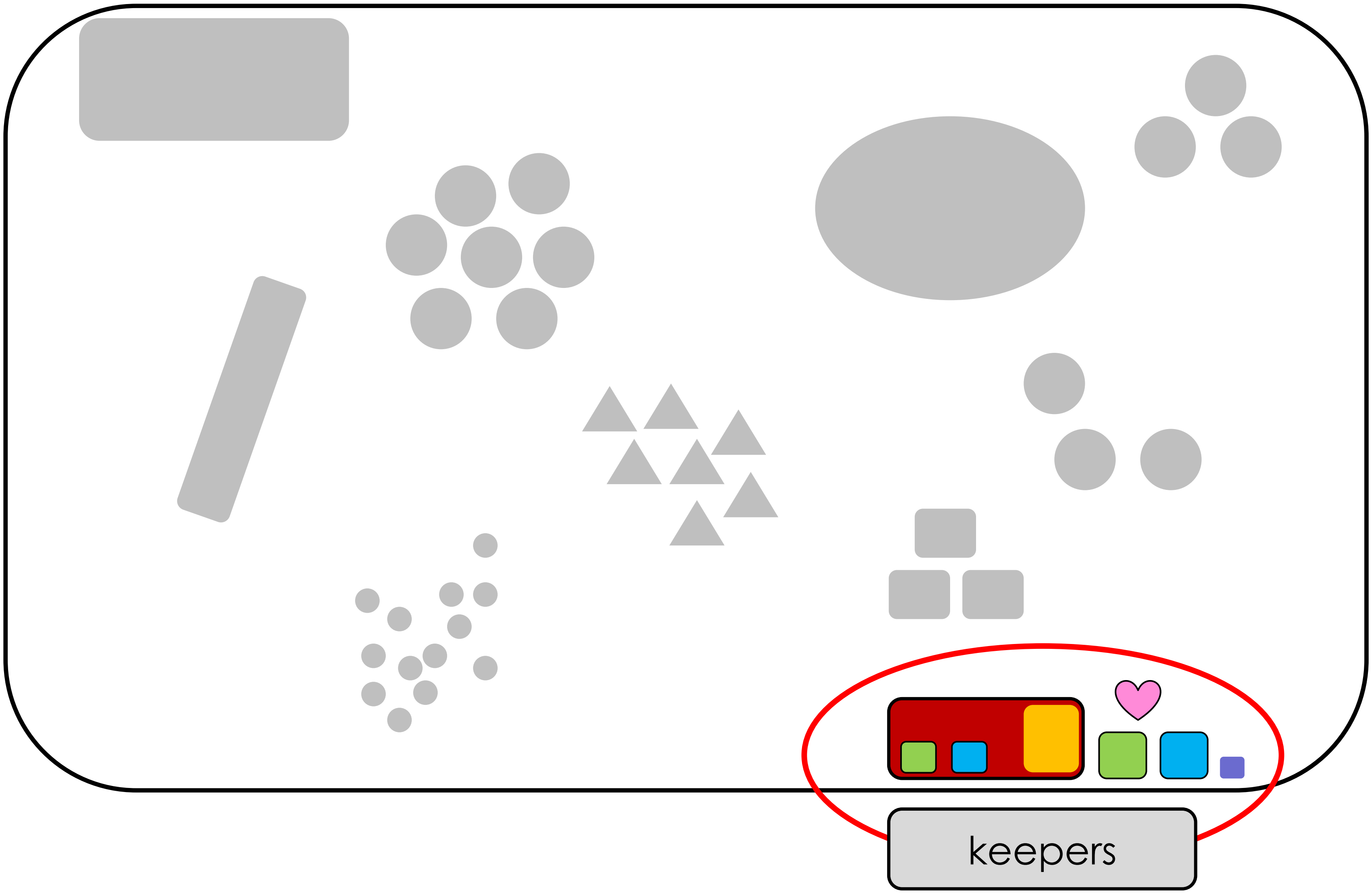
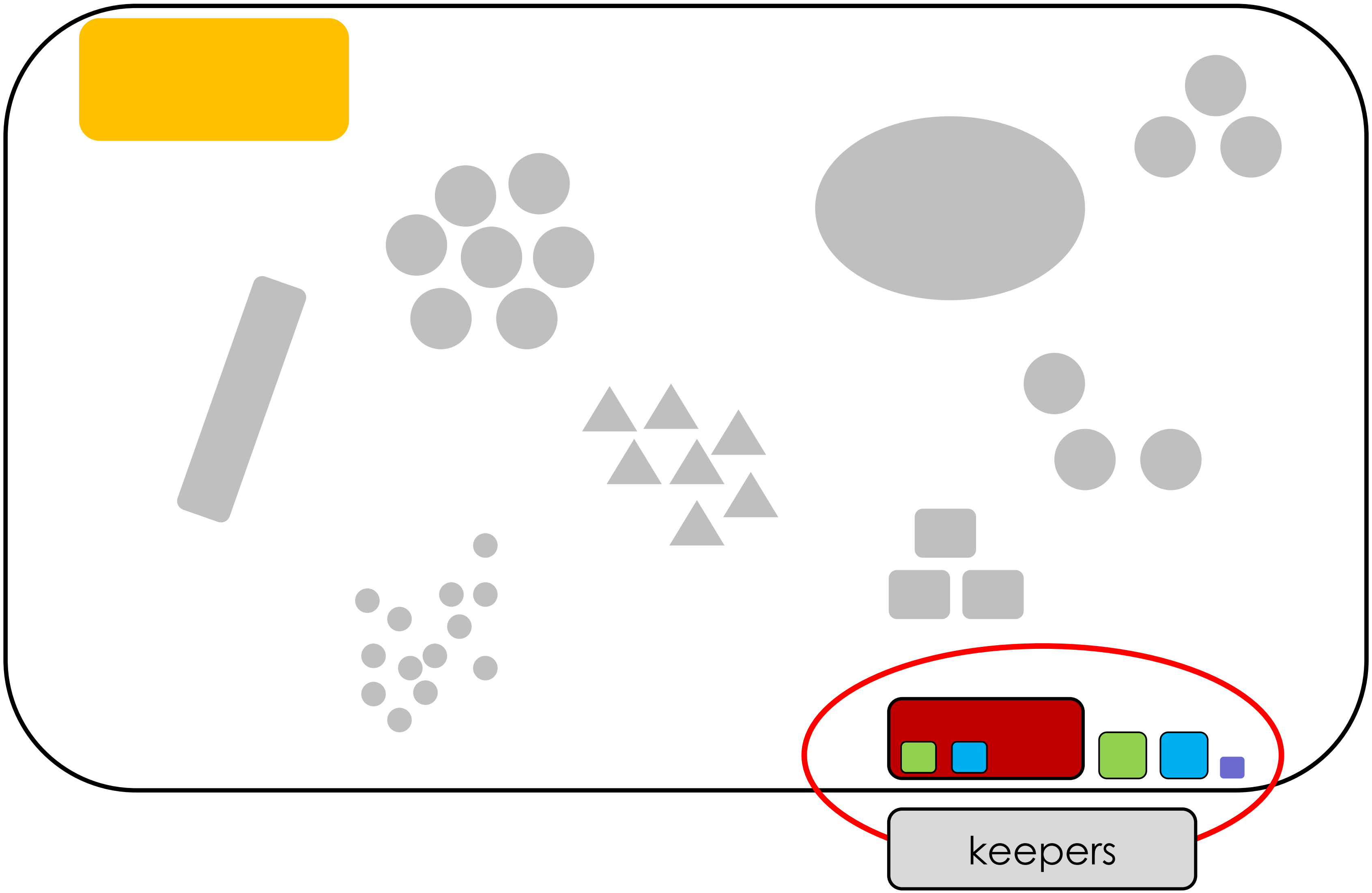


Enclosure management



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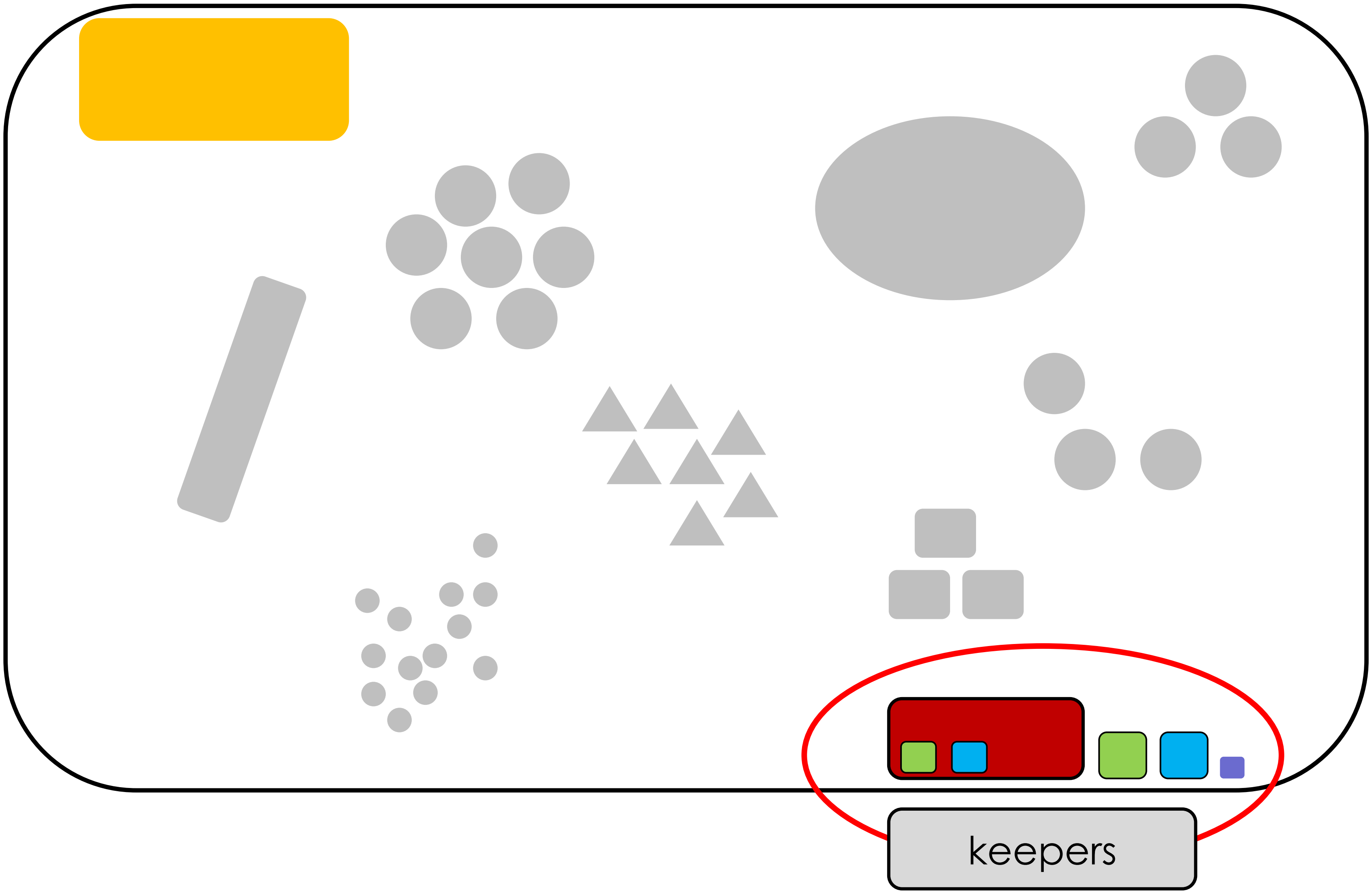

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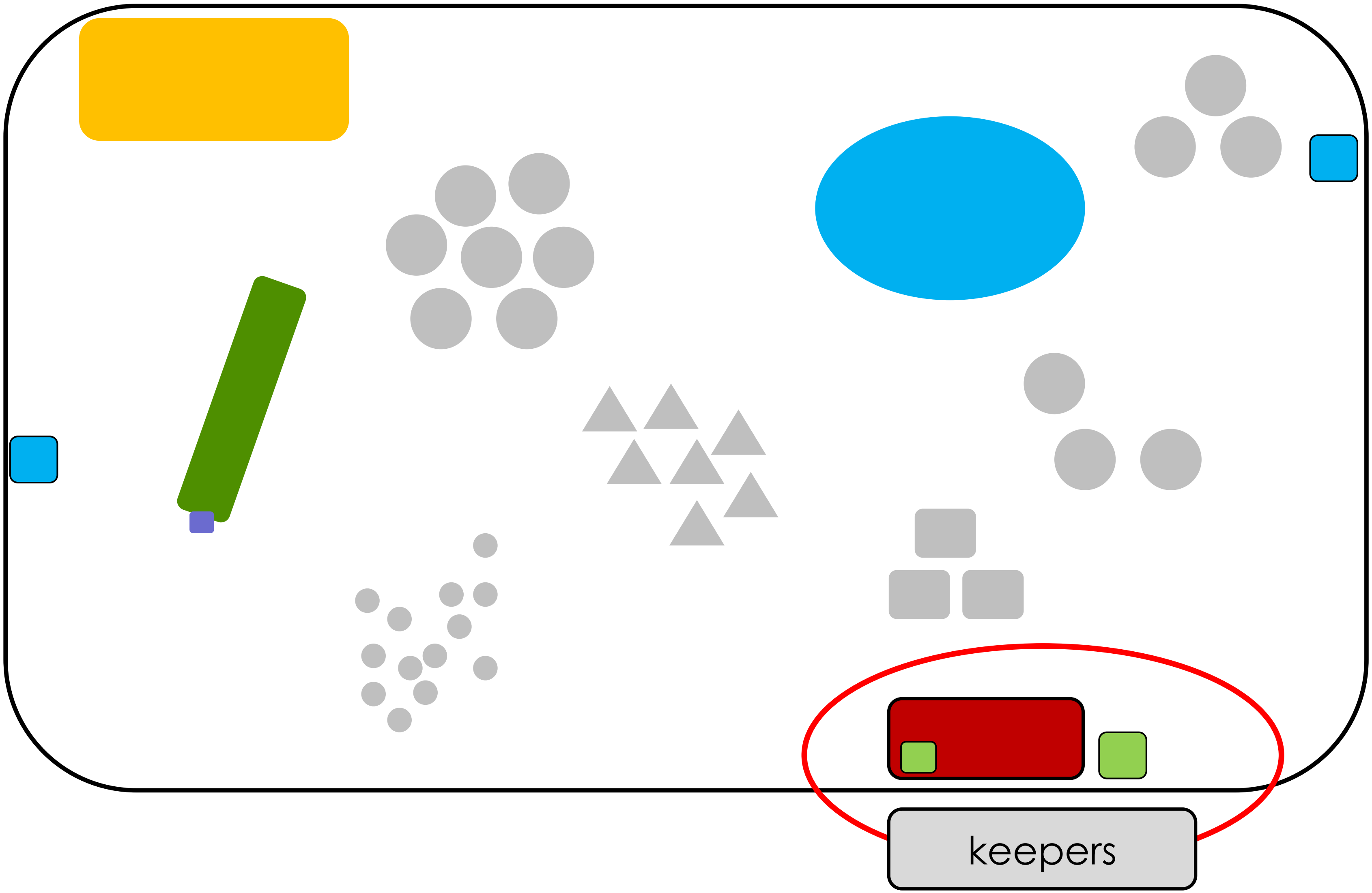

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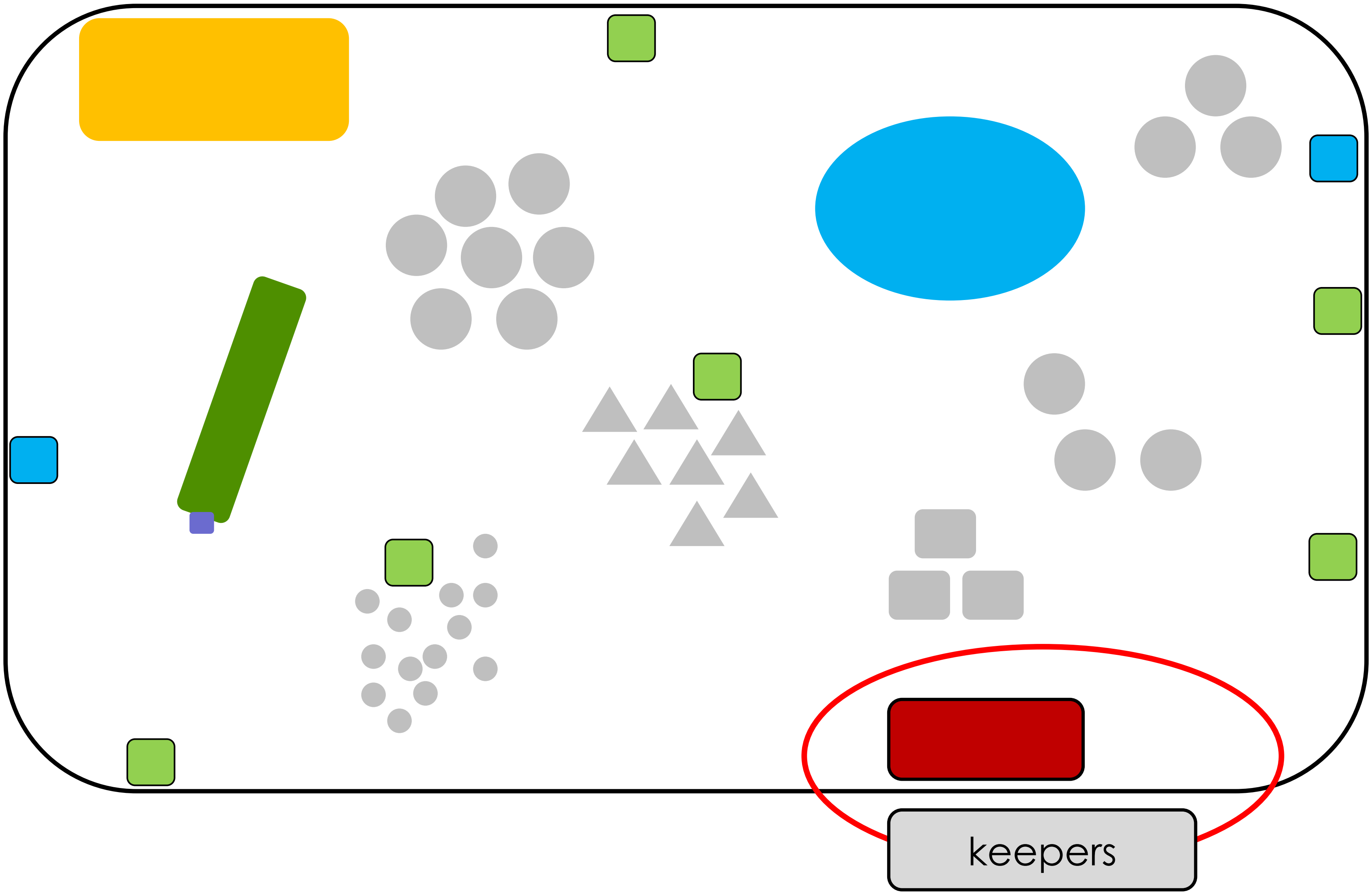
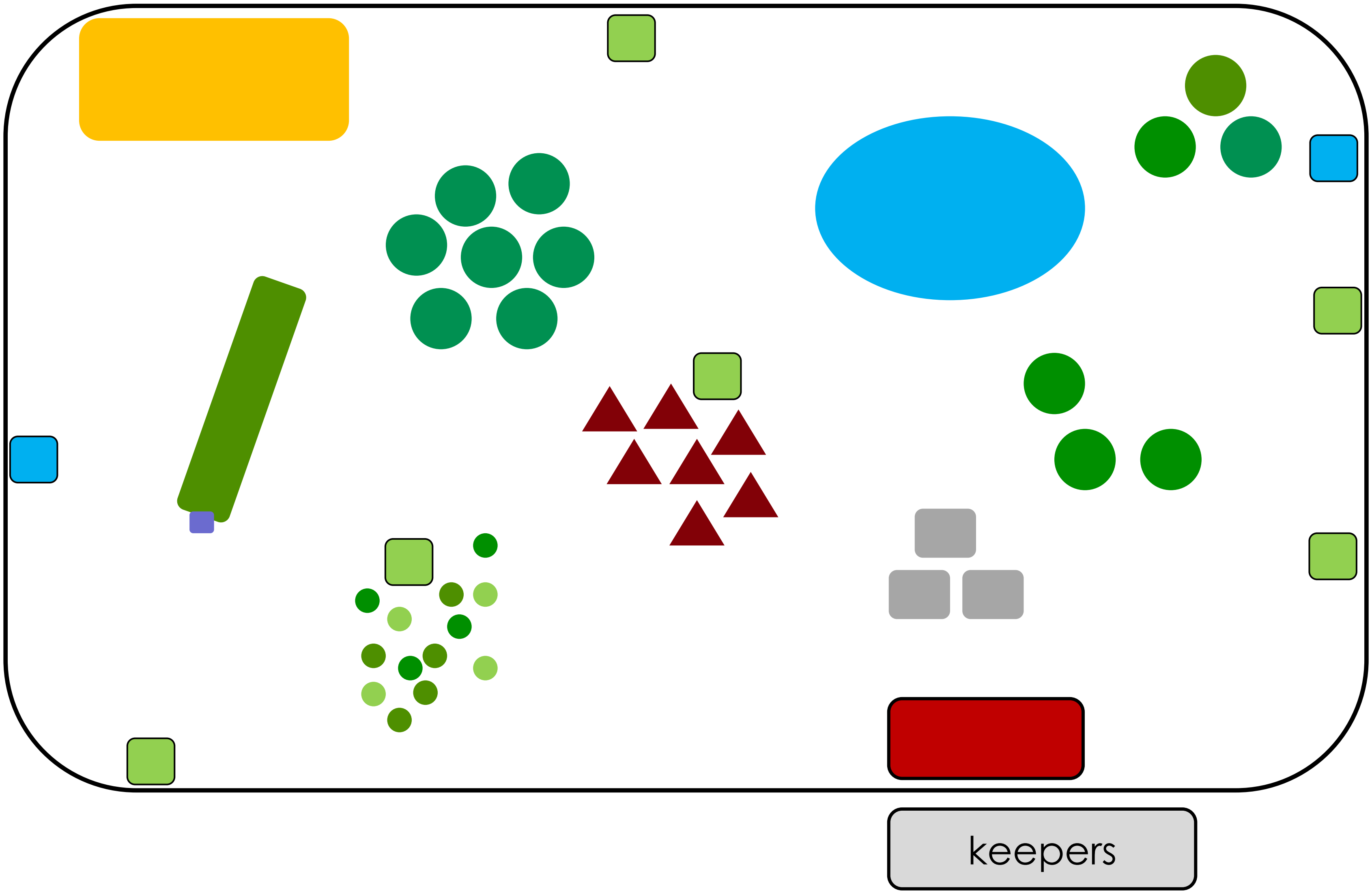
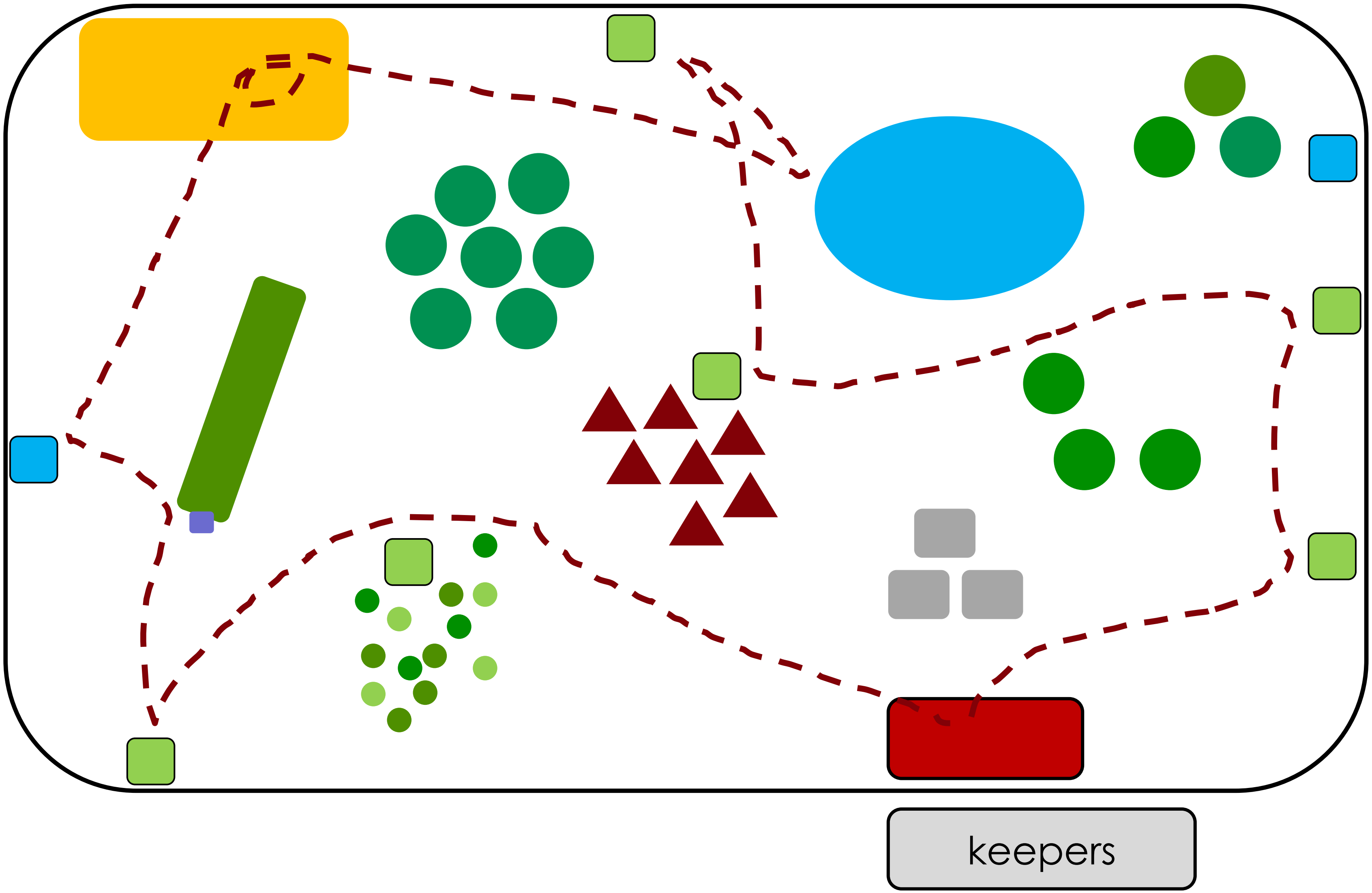


Enclosure management



Enclosure management = **enrichment**

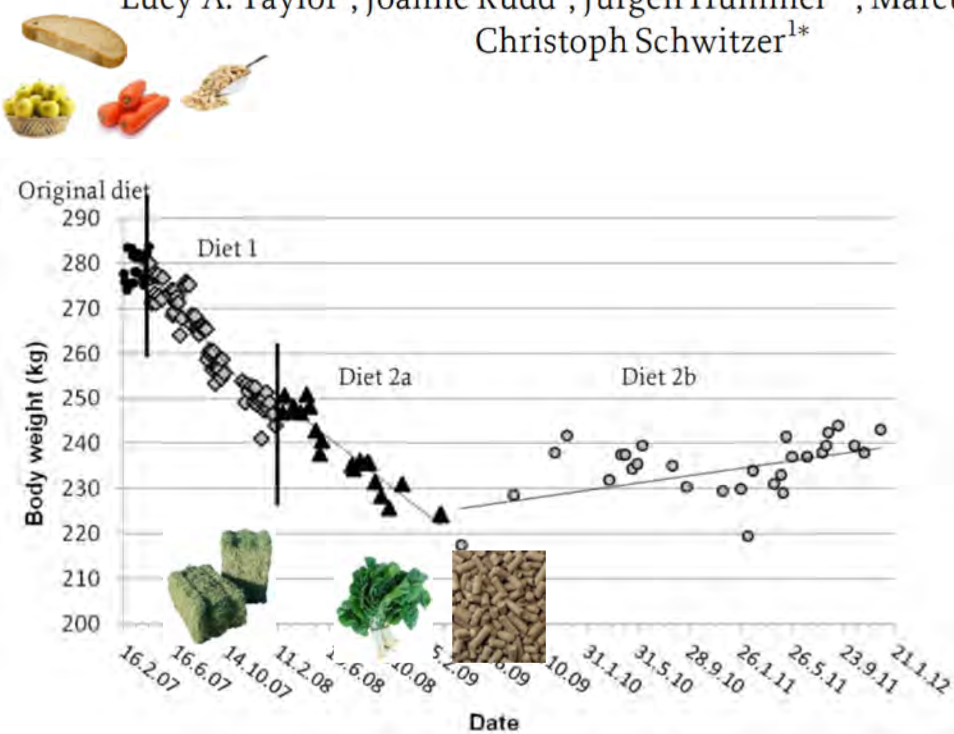


Real-life examples of diet changes

Reports: Hippos at Bristol

Weight loss in pygmy hippos (*Choeropsis liberiensis*)

Lucy A. Taylor[1], Joanne Rudd[2], Jürgen Hummel[3,4], Marcus Clauss[5] and Christoph Schwitzer[1*]



Reports: Ungulates at Chester

-existing rations seemed overly complicated

-against diet change: no health problems, established work routine, known providers

-for diet change: rations without biological logic, high potential for mistakes, inventory/stores management, costs

-aim: reduce fruits/vegetables, roughage as staple diet item, nutrient/mineral guaranteed via pelleted feeds

-February 2007: 4 week of transition for new rations

-fruits/vegetables stopped completely

-re-evaluation in 2009: keepers' evaluation incl. body condition scores and photo documentation

-no negative experiences, distinct cost reduction

courtesy Andrea Fidgett

Reports: Primates at Paignton

JZAR JOURNAL OF ZOO AND AQUARIUM RESEARCH
www.jzar.org
Journal of Zoo and Aquarium Research 1(2) 2013

Research article

Diet review and change for monkeys at Paignton Zoo Environmental Park

Amy Plowman

Reports: Primates at Paignton

-trigger: frequent dental treaments

-for diet change: reduction of sugar (high proportion of fruits), reduction of obesity, rations without biological logic, rations against current fibre recommendations, costs

-aim: reduction of fruits, bread, grain mixes

-as of 2004: diet changes for various primate groups (colobus, baboons, macaques, spider monkeys, meerkats)

-fruits stopped completely

-3-vegetable-system

courtesy Amy Plowman

3-vegetable-system

Group A	Group B	Group C
Green leaf	**“other”**	**Starch/Sugar**
spinach	green beans	carrot
cabbage	broccoli	corn
lettuce	cauliflower	parsnip
chard	celery	turnip
collards	cucumber	swede
greens	leek	squash
watercress	onion	pumpkin
	peas	tomato
		sweet potato
		pepper

flexible feeding plans allow to use seasonal availability

courtesy Amy Plowman

Reports: Primates at Paignton

-trigger: frequent dental treaments

-for diet change: reduction of sugar (high proportion of fruits), reduction of obesity, rations without biological logic, rations against current fibre recommendations, costs

-aim: reduction of fruits, bread, grain mixes

-as of 2004: diet changes for various primate groups (colobus, baboons, macaques, spider monkeys, meerkats)

-fruits stopped completely

-3-vegetable-system

-less dental treatments, better faecal consistency, little weight loss, cost reduction, better sustainability, less aggression

courtesy Amy Plowman

Reports: Primates at Paignton

Diet review and change for monkeys at Paignton Zoo Environmental Park

Journal of Zoo and Aquarium Research 1(2) 2013

Amy Plowman

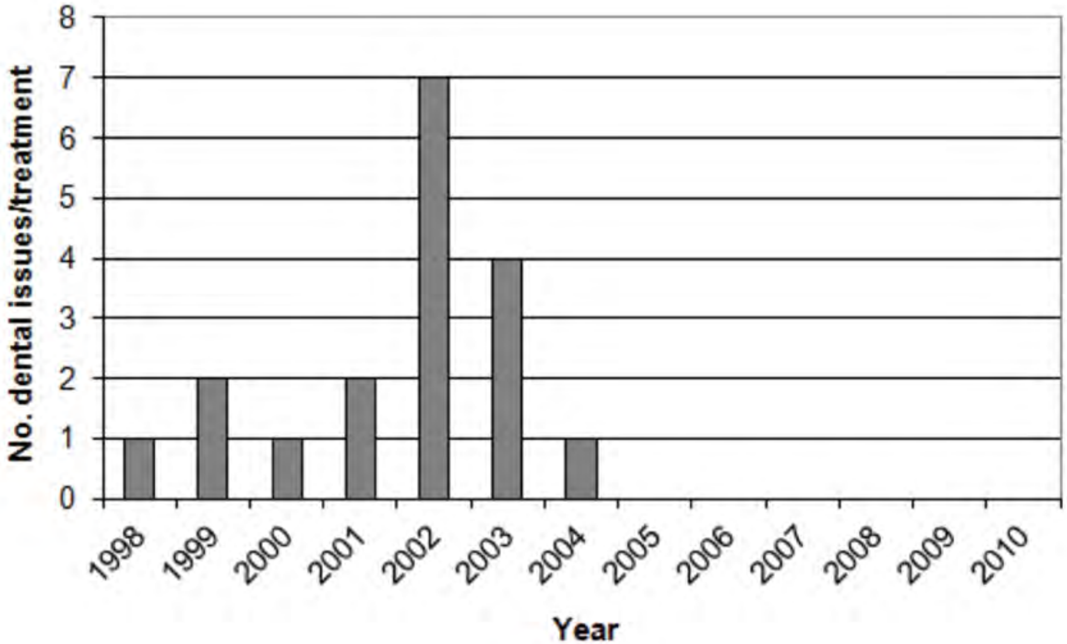


Figure 1. Frequency of dental issues identified or treatment required for six species of primate at Paignton Zoo Environmental Park before and after the initiation of diet improvements to reduce dietary sugar (March 2003).

Reports: Primates at Paignton

Diet review and change for monkeys at Paignton Zoo Environmental Park

Journal of Zoo and Aquarium Research 1(2) 2013

Amy Plowman

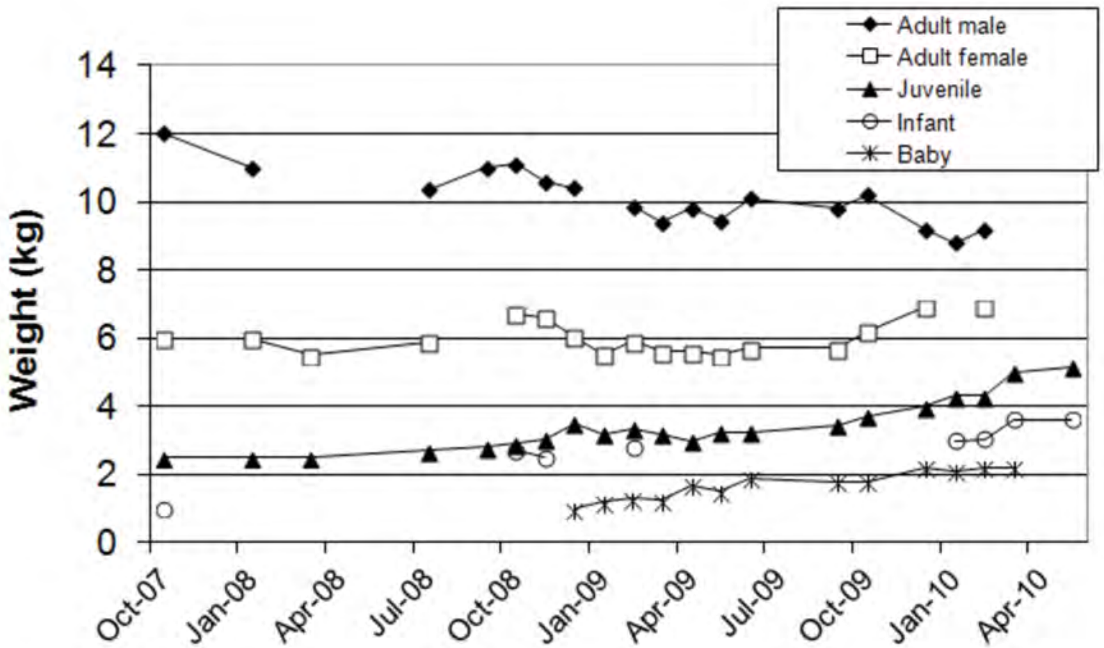


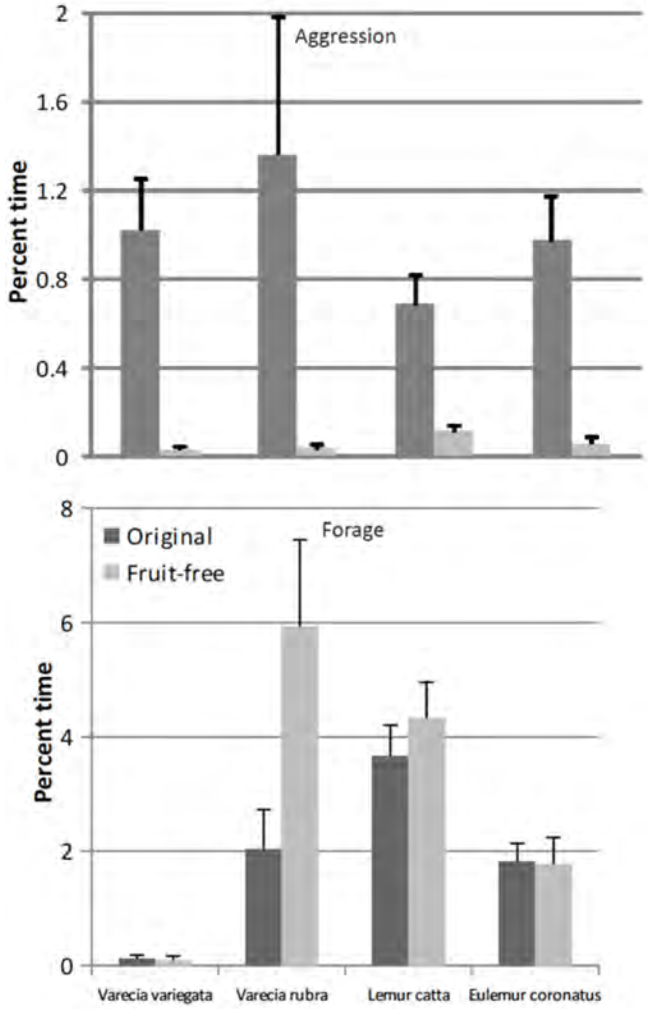
Figure 2. Body weights of a group of Diana monkeys at Paignton Zoo Environmental Park following a diet review that prompted a change from a fruit-based to a vegetable-based diet. The removal of all fruit occurred in April 2007; other changes were completed in September 2007 immediately before the first weights were obtained.

Reports: Primates at Paignton

Aggression and self-directed behaviour of captive lemurs (*Lemur catta, Varecia variegata, V. rubra* and *Eulemur coronatus*) is reduced by feeding fruit-free diets

Stephanie Britt[1], Katherine Cowlard[1], Kathy Baker[2] and Amy Plowman[3*]

Journal of Zoo and Aquarium Research 3(2) 2015



Reports: Bears at Zurich Zoo

Reports: Bears at Zurich Zoo

Bears at Zurich Zoo were considered obese when compared to reported body mass for species (male: 180 vs. 140 kg, female: 115 vs. 75 kg)

Diet offered contained 2x the amount of ME (calculated as for dogs) compared to estimated requirements at ideal body weight.

Challenge: feeding a group where some individuals should lose weight, some should keep weight, and one should continue to grow!

Reports: Bears at Zurich Zoo

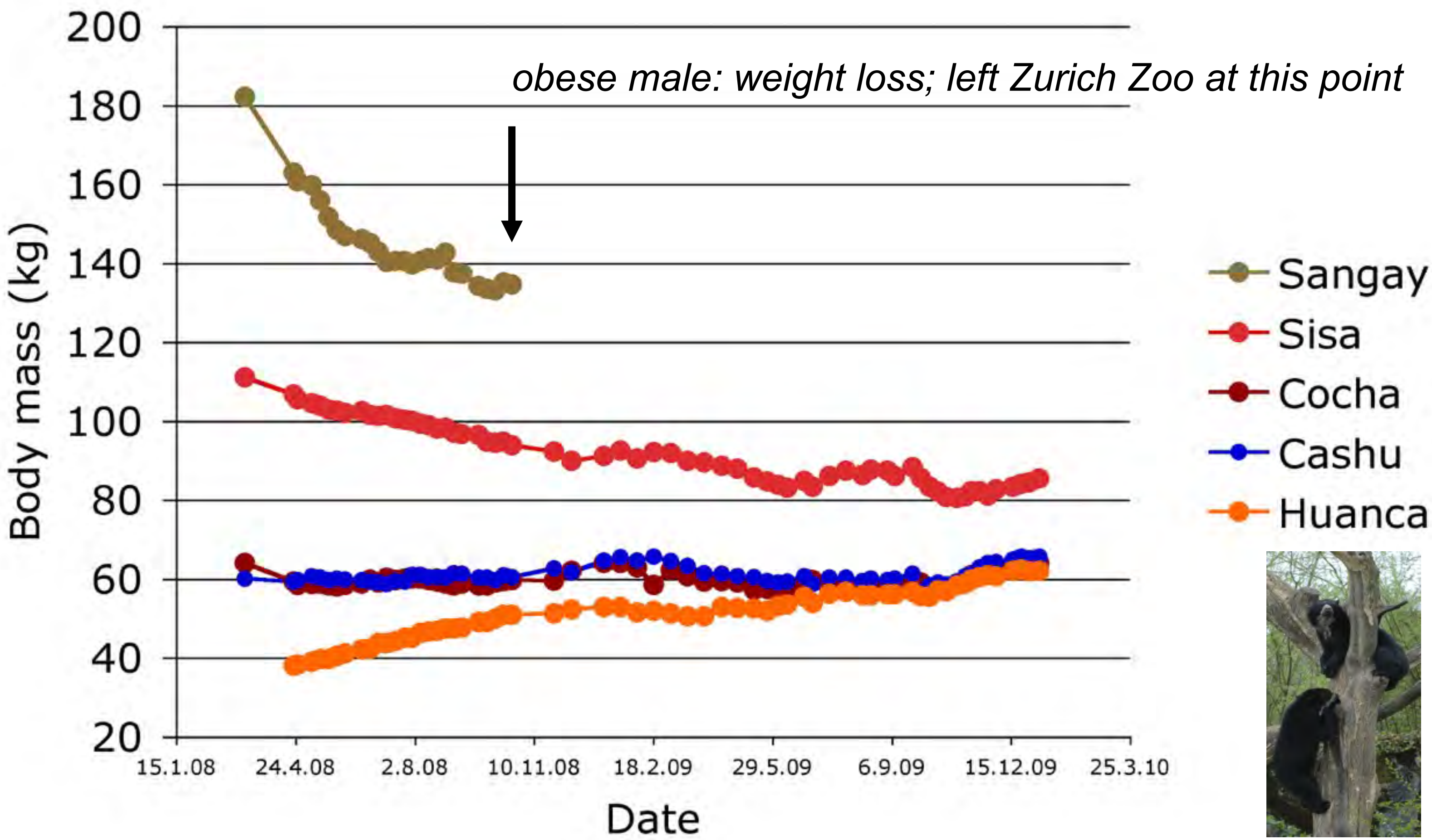
Amount of food was reduced (to what was calculated as the total requirement on ideal body weight).

Bread was excluded, fruits reduced, additional vegetables introduced.

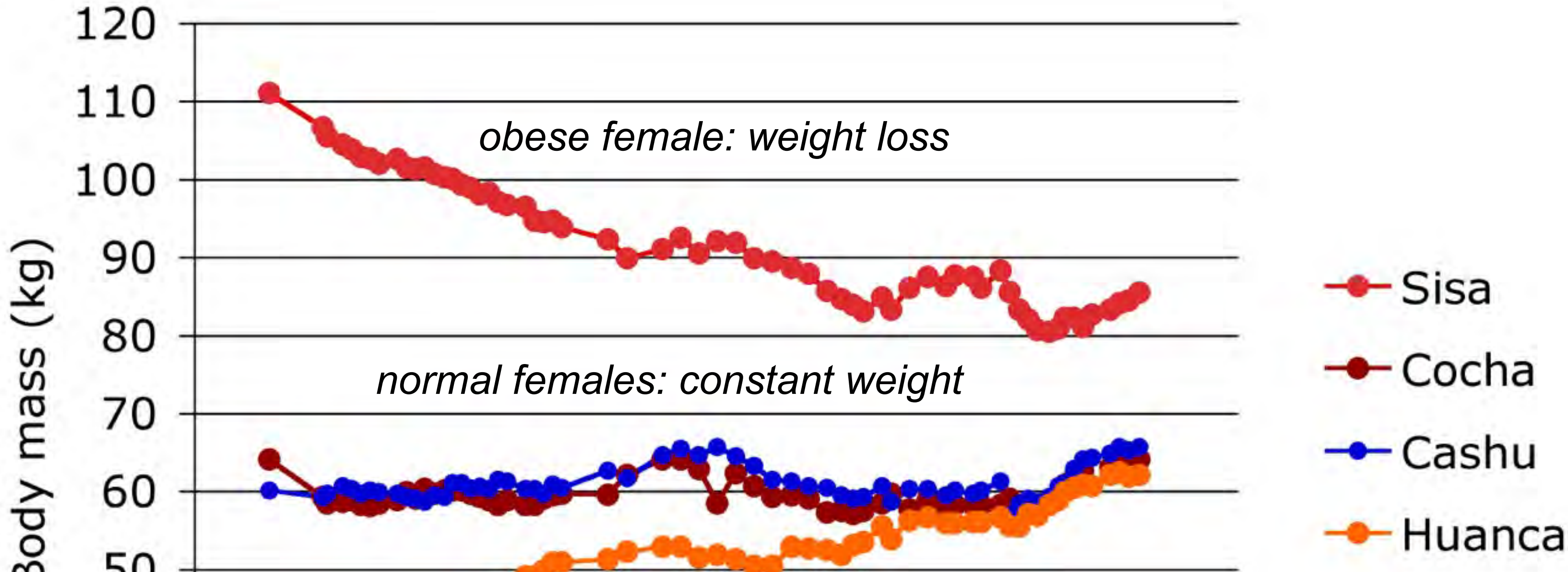
Regular weighing (every second week).

The most important task was to have all personnel involved agree on goals of weight loss and diet change to a more 'natural' diet (in terms of nutrient composition).

Reports: Bears at Zurich Zoo



Reports: Bears at Zurich Zoo



Reports: Bears at Zurich Zoo

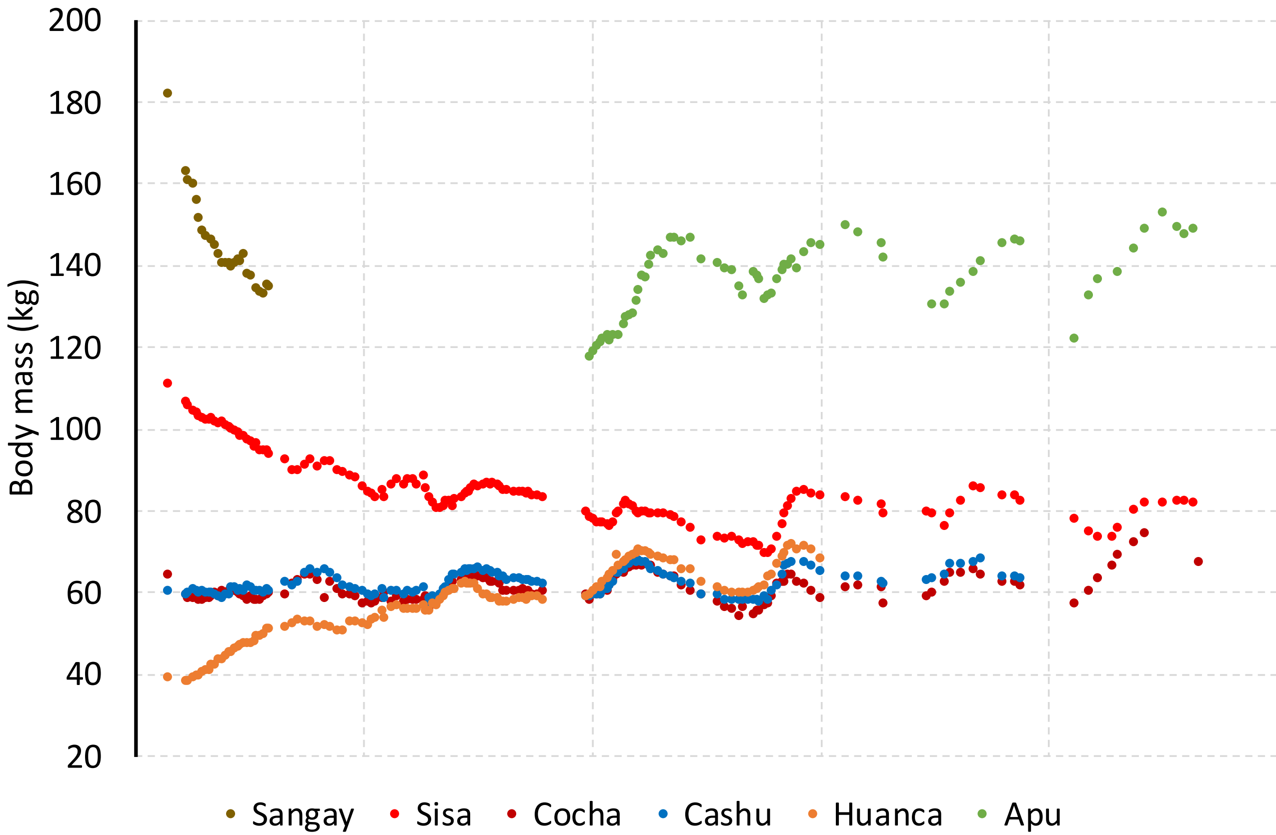
The most important accomplishment is the creation of a situation where everyone involved now considers regular weighing, and constant adjustment of diet amounts based on the results of weighing, a normal procedure.

Reports: Bears at Zurich Zoo

Seasonal body mass changes and feed intake in spectacled bears (*Tremarctos ornatus*) at Zurich Zoological Garden

Journal of Zoo and Aquarium Research 4(3) 2016

Kerstin Gerstner[1], Annette Liesegang[1], Jean-Michel Hatt[2], Marcus Clauss[2*] and Cordula Galeffi[3]



Reports: Viscachas at Zurich

OCCURRENCE OF CATARACT AND FATTY LIVER IN CAPTIVE PLAINS VISCACHAS (*LAGOSTOMUS MAXIMUS*) IN RELATION TO DIET

Jessica Gull, med. vet., Hanspeter Steinmetz, Dr. med. vet., M.Sc., Marcus Clauss, P.D. Dr. med. vet., Dipl. E.C.V.C.N., Dorothea Besselmann, Dr. med. vet., Pete Ossent, Dr. med. vet., Christian J. Wenker, Dr. med. vet., and Jean-Michel Hatt, Prof. Dr. med. vet., Dipl. A.C.Z.M., Dipl. E.C.A.M.S.
Journal of Zoo and Wildlife Medicine 40(4): 652–658, 2009

	Born before diet change (5 May 1992–4 May 2000)	Born after diet change (5 May 2000–4 May 2008)
No. of animals	56 (100%)	121 (100%)
Cataract[a]	16 (29%)	2 (1.65%)
Fatty liver	11 (20%)	0 (0%)

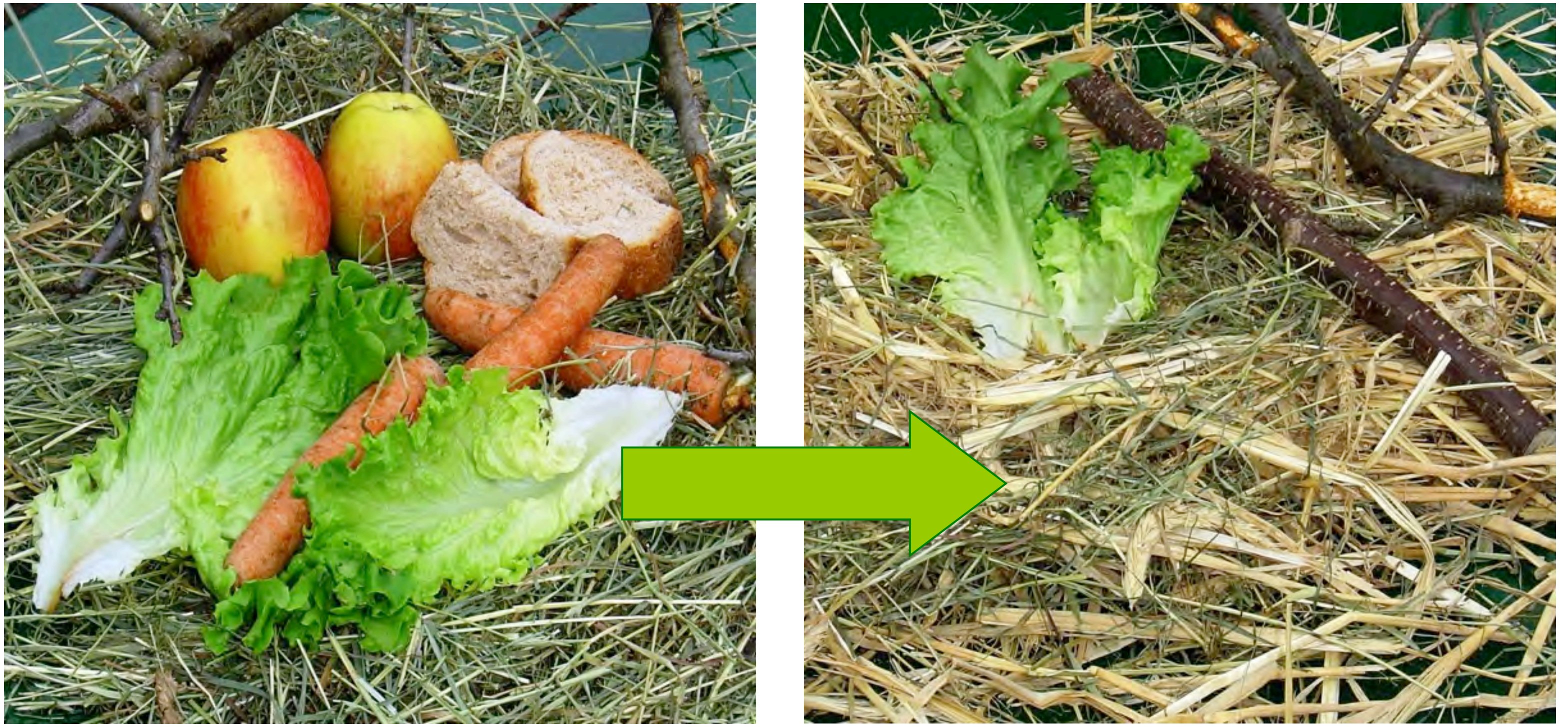
Reports: Viscachas at Zurich

Diet change in 2001/2 because of high incidence of cataracts (linked to diabetes)

Gull et al. (2009)

Reports: Viscachas at Zurich

Diet change in 2001/2 because of high incidence of cataracts (linked to diabetes)



Drastic reduction of the occurrence of new cataracts!

Gull et al. (2009)

Reports: Lesser kudu at Basle

Reports: Lesser kudu at Basle

JUVENILE MORTALITY IN CAPTIVE LESSER KUDU (*TRAGELAPHUS IMBERBIS*) AT BASLE ZOO AND ITS RELATION TO NUTRITION AND HUSBANDRY

Dorothea Besselmann, Dr. med. vet., Daniela Schaub, Dr. med. vet., Christian Wenker, Dr. med. vet., Jürg Völlm, Dr. med. vet., Nadia Robert, Dr. med. vet., Claude Schelling, P.D., Dr. med. vet., Hanspeter Steinmetz, M.Sc., Dr. med. vet., and Marcus Clauss, M.Sc., Dr. med. vet., Dipl. E.C.V.C.N.

Journal of Zoo and Wildlife Medicine 39(1): 86–91, 2008

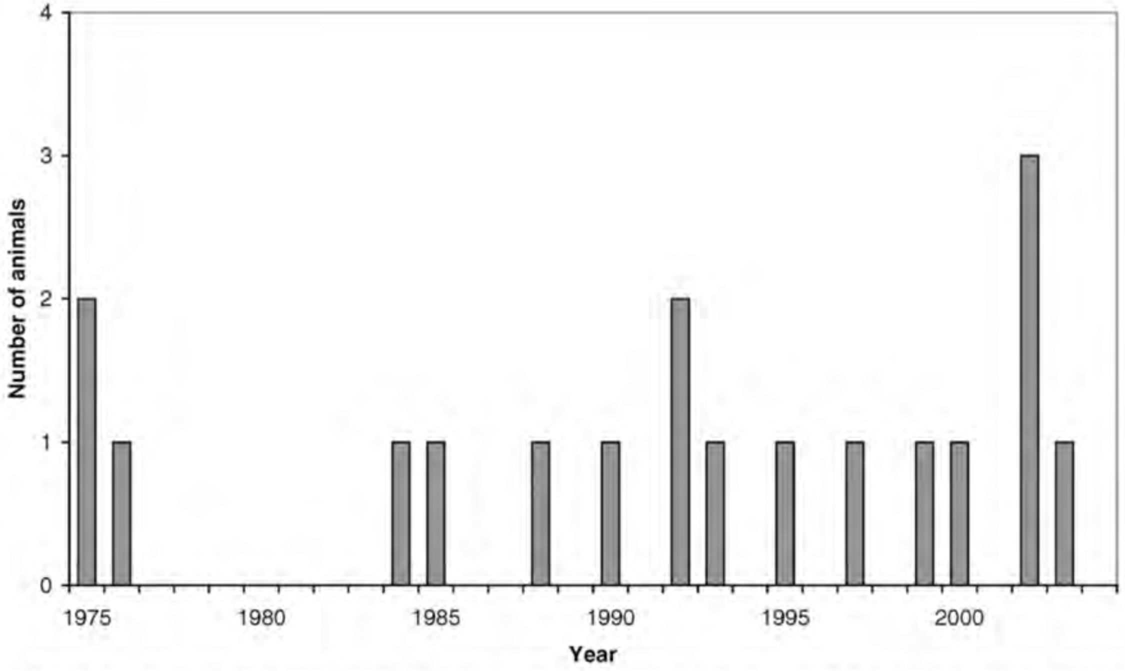


Figure 1. Number of juvenile deaths in lesser kudu (*Tragelaphus imberbis*) attributed to white muscle disease between 1975 and 2004.

Reports: Lesser kudu at Basle

JUVENILE MORTALITY IN CAPTIVE LESSER KUDU (*TRAGELAPHUS IMBERBIS*) AT BASLE ZOO AND ITS RELATION TO NUTRITION AND HUSBANDRY

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Journal of Zoo and Wildlife Medicine 39(1): 86–91, 2008

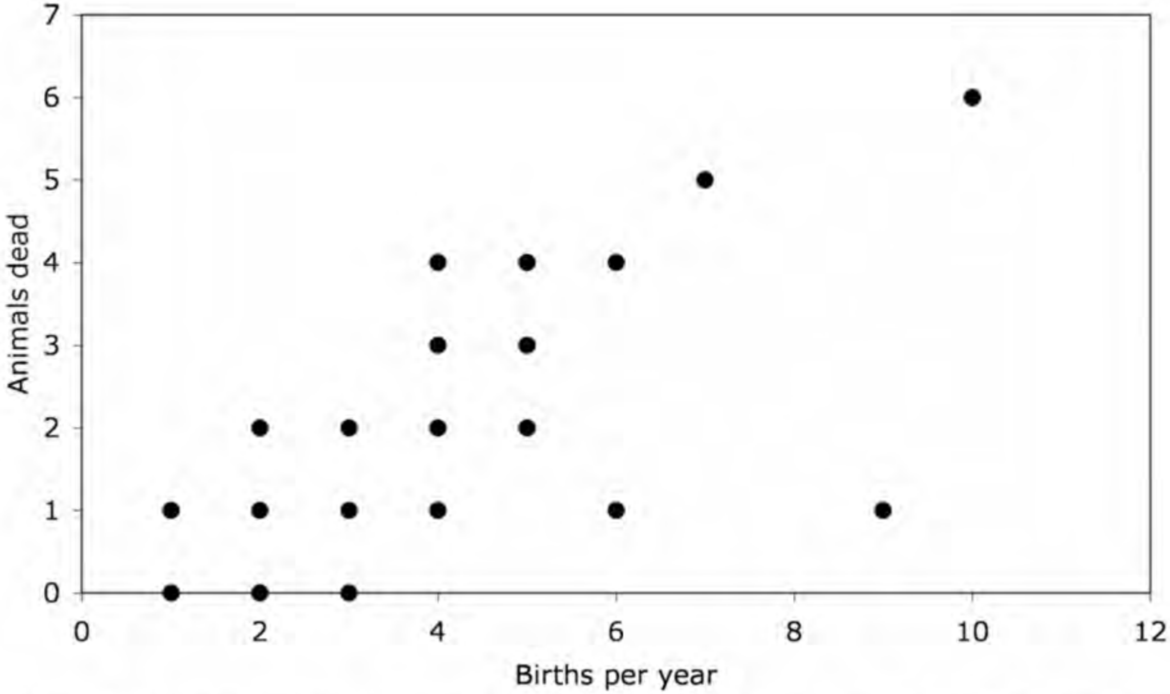


Figure 2. Correlation between the number of births per year and the total cases of mortality in lesser kudu (*Tragelaphus imberbis*) younger than 6 mo.

Lessons from the Lesser kudu

You can solve a problem – today.
Tomorrow, you have to solve it again.
You cannot trust that someone else will solve it for you tomorrow.
You have to instigate measures that ensure a solution is used day after day.

Every problem has the right to have several causes.

Fruits and vegetables at Zurich

Provide nutrient tables in 2006

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

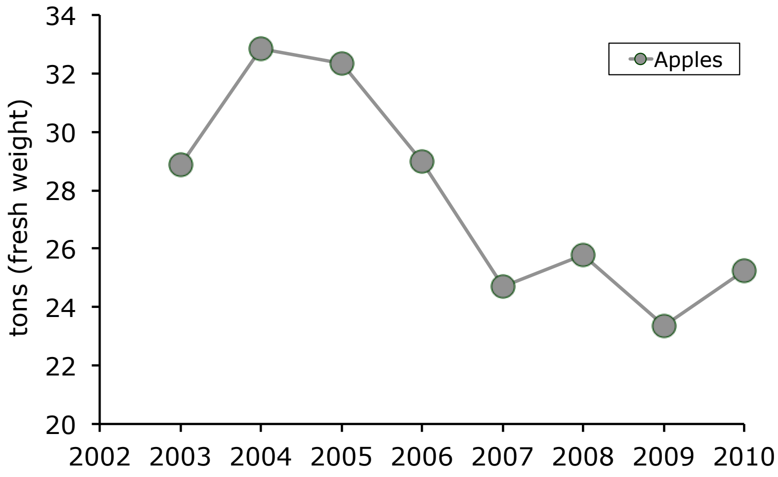
	Water	Rest	protein	available carbohydrates	calcium	phosphorus
		"dry matter"	%		‰	
	%	%	-------------------- dry matter --------------------			
Sweet potato	69.2	30.8	5.3	94.0*	1.1	1.5
Manioc/Tapioca	63.1	36.9	2.7	86.9	1.0	1.0
Beetroot	88.8	11.2	13.7	76.9	2.6	4.0
Potato raw/cooked	77.8	22.2	9.2	69.4	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

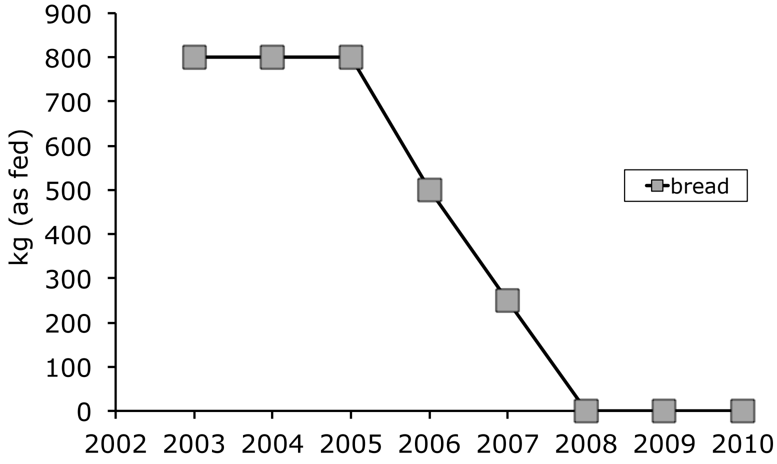
*minimum

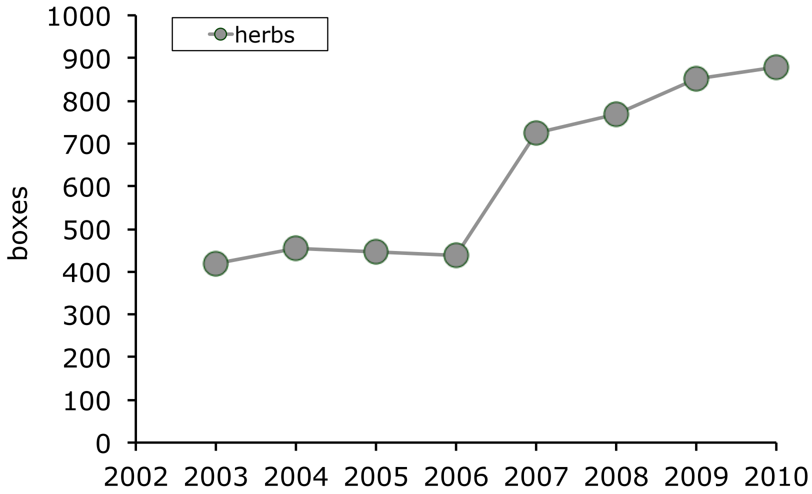
Source: Souci/Fachmann/Kraut „Die Zusammensetzung der Lebensmittel – Nährwert-Tabellen 1989/90". 4. Auflage, Wiss. Verlagsgesellschaft Stuttgart

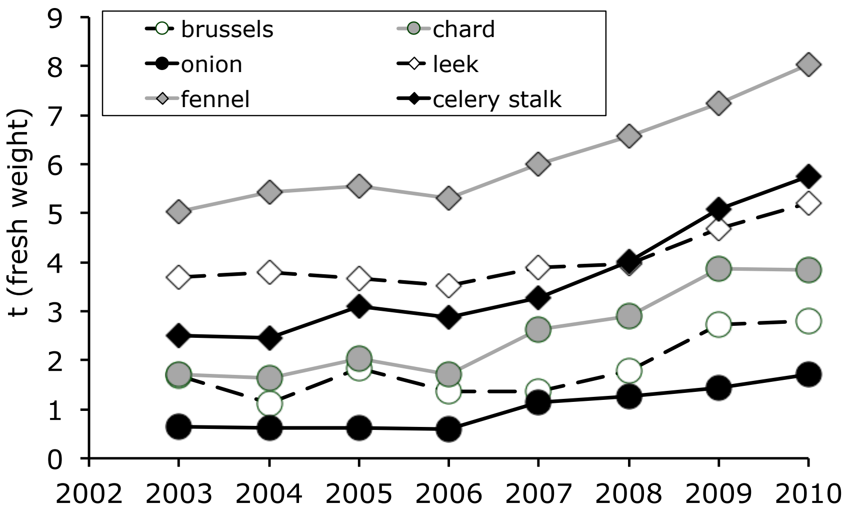
Fruits and vegetables at Zurich

Changes in food turnover









Changing a tapir diet I

- *strawberries*
- *mangos*
- *plums (w/o stones)*
- *apricots/peaches (w/o stones)*
- *apples*
- *pears*
- *ananas*
- *leek*
- *lettuce*
- *tomatoes*
- *cooked pasta/cooked rice with raisins*
- *oat flakes*
- *dry bread*
- *yoghurt*
- *minced meat (1x/week)*
- *... and grass hay ad libitum (is hardly eaten)*

Changing a tapir diet II

- *<u>morning</u>:*
  Lucerne hay ad libitum (for the whole day)
  and one lettuce, one bunch of leek, one bunch of celery stalks
  handful of pelleted feed (for minerals)

- *<u>afternoon (alterating)</u>:*
  20 carrots or
  2 pieces of barley sprouts or
  2 cucumbers

- *always fresh browse (twigs with leaves)*

from Clauss et al. (2008)

Changing a tapir diet III

- <u>*Alfred Brehm (1864)*</u>*:*
  „It always costs them quite an effort to rise up from their inactivity and phlegm."

Changing a tapir diet III

- *<u>Alfred Brehm (1864)</u>:*

  „It always costs them quite an effort to rise up from their inactivity and phlegm."

- *<u>one year after the diet change</u>:*

  animals did not starve!

  animals are more active, alert, lively, ingest food (lucerne hay) throughout the day, easier to handle for keepers (more responsive)

  animals are less obsese

from Clauss et al. (2008)


Foto: Jean-Michel Hatt