



Zoos as locations for scientific studies



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**University of
Zurich**^{UZH}



Clinic
of Zoo Animals, Exotic Pets and Wildlife



Why do research with zoo animals?

- interest in zoo-specific questions
- interest in an animal species that cannot be attained somewhere else



What kind of research is of interest?



Conservation of biodiversity is set as a main driver

**Developing
the research
potential of
zoos and aquaria**

The EAZA Research Strategy



What kind of research is of interest?



When considering the ethics of acquiring animals which may be subject to research there are issues concerning purpose and value, i.e. what serves the 'greater good' in conservational and/or welfare terms?

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What kind of research is of interest?



The European Council Directive 1999/22/EC relating to the keeping of wild animals in zoos (the EU Zoos Directive)

The Member States guarantee that all zoos will implement the following conservation measures:

- participating in research from which conservation benefits accrue to the species, and/or training in relevant conservation skills, and/or the exchange of information relating to species conservation and/or, where appropriate, captive breeding, repopulation or reintroduction of species into the wild;



What kind of research is of interest?

Identify research priorities

The scope for research is huge, and time and resources are always limited, so it is important to identify research priorities. There are several bases for this. For example:

- > degree of threat, where threatened species are high priorities (e.g. IUCN www.redlist.org);
- > species that are endemic to biodiversity hotspots (e.g. www.unep-wcmc.org);
- > problems identified by EAZA Taxon Advisory Groups, EEP Species Committees and other EAZA Groups;
- > biological issues in individual collections;
- > specialities and facilities of associated university departments;
- > specialities and expertise of staff.



What kind of research is of interest?

To the zoo / zoo community

- conservation-related issues
- issues related to animal welfare (i.e., captivity)

reproduction, diseases (diagnostics and intervention), management, biological characteristics, enrichment, nutrition

To many students / researchers

anything that allows
work with zoo
animals

- high 'adventure' factor
- pioneer situation
 - easy way to expertise position
 - perception of low failure risk
- automatic justification (at first)



Justifications?

**To the zoo /
zoo community**

**To many students /
researchers**



- conservation-related issues
- issues related to animal welfare (i.e., captivity)

anything that allows work with zoo animals

**XYZ is a highly endangered species ...
... more knowledge is essential for the
management of this endangered species ...**

reproduction, diseases (diagnostics and intervention), management, biological characteristics, enrichment, nutrition

- high 'adventure' factor
- pioneer situation
- easy way to expertise position
- perception of low failure risk
- automatic justification



Counting the books while the library burns: why conservation monitoring programs need a plan for action

David B Lindenmayer^{1*}, Maxine P Piggott¹, and Brendan A Wintle²

Conservation monitoring programs are critical for identifying many elements of species ecology and for detecting changes in populations. However, without articulating how monitoring information will trigger relevant conservation actions, programs that monitor species until they become extinct are at odds with the primary goal of conservation: avoiding biodiversity loss. Here, we outline cases in which species were monitored until they suffered local, regional, or global extinction in the absence of a preplanned intervention program, and contend that conservation monitoring programs should be embedded within a management plan and characterized by vital attributes to ensure their effectiveness. These attributes include: (1) explicit articulation of how monitoring information will inform conservation actions, (2) transparent specification of trigger points within monitoring programs at which strategic interventions will be implemented, and (3) rigorous quantification of the ability to achieve early detection of change.



What kind of research is of interest?



Assessing the *effectiveness* (or not) of specific conservation measures is a vital and challenging area of research.

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Does conservation need science ... or fences, guns & education ?





Counting the books while the library burns: why conservation monitoring programs need a plan for action

but if the library burns, taking stock of what
will be lost is interesting in its own right

David B Lindenmayer^{1*}, Martin D. Engelbrecht² and Brandon A. Wintle³

Conservation monitoring programs are critical for identifying many elements of species ecology and for detecting changes in populations. However, without articulating how monitoring information will trigger relevant conservation actions, conservation monitoring programs may be less effective than they could be. The primary goal of conservation: avoiding biodiversity loss. Here, we outline cases in which species were monitored until they suffered extinction. Our aim is to highlight the importance of articulating how monitoring information will be used to prevent extinction. We argue that conservation monitoring programs should be embedded within a management plan and characterized by vital attributes: (1) explicit articulation of how monitoring information will inform conservation actions, (2) transparent specification of trigger points within monitoring programs at which strategic interventions will be implemented, and (3) rigorous quantification of the ability to achieve early detection of change.



What kind of research is of interest?



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EAZA Research Project Example	Breeding biology and reintroduction of amphibians
Size and scale	Collaborative working group for breeding amphibians
Collaborators	Moscow Zoo; various research institutes
Disciplines	Natural history; <i>in situ</i> wildlife management
Summary	A special Working Group for breeding of endangered, exotic and problem amphibian species was established in the 1980's by scientists from Moscow Zoo, the Koltzov Institute of Developmental Biology and the State Research Centre's Institute of Biophysics. As a consequence of studying breeding biology, methods for hormone stimulation of amphibian reproduction and husbandry guidelines for all life stages have been developed. These methods made it possible to establish new wild populations of the banded newt <i>Triturus vittatus</i> and Eastern spadefoot toad <i>Pelobates syriacus</i> , within their natural habitats in the Caucasian Natural Reserve and Armenia respectively. These populations are still thriving and further reintroductions within the natural range of <i>P. syriacus</i> are underway. See also Amphibian Ark Project (Glossary).
Publication	Goncharov <i>et al.</i> (1989)
Illustration	
PHOTO: I. Serbinova	



What kind of research is of interest?



Wider needs and benefits As well as underpinning practical or applied science, zoo research can make a general, perhaps major contribution to fundamental or theoretical knowledge.

**Developing
the research
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zoos and aquaria**

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What kind of research is of interest?



AZA believes that contemporary animal management, husbandry, veterinary care and conservation practices should be based in science, and that a commitment to scientific research, both basic and applied, is a trademark of the modern zoological park and aquarium.

Types of Research

Research investigations, whether observational, behavioral, physiological, or genetically based, should have a clear scientific purpose with the reasonable expectation that they will increase our understanding of the species being investigated and may provide results which benefit the health or welfare of animals in wild populations.



What kind of research is done in zoos?



Research efforts on these topics will, in turn, typically draw on combinations of major scientific disciplines such as anatomy, anthropology, biochemistry, biogeography, bioinformatics, biotechnology, ecology, education, endocrinology, ethnology, ethology, evolution, forensics, genetics, genomics, information technology, nutrition, parasitology, pharmacology, physiology, population biology, psychology, sociology, taxonomy and veterinary medicine.

The EAZA Research Strategy



What kind of research is of interest?



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Appendix VIII. Zoo research: sample serial publications

This list provides examples of printed and online serial sources of research information and potential outlets for zoo-associated research papers. It has, with kind permission, been adapted and expanded from a list in the *World Zoo and Aquarium Conservation Strategy* (Chapter 3) but is by no means comprehensive. Please refer to the EAZA website (www.eaza.net) for updates.

Animal Behaviour
Animal Conservation
Animal Welfare
American Zoo and Aquarium Association Conference Proceedings (Annual and Regional)
Animal Keepers Forum
Applied Animal Behaviour Science
Aquarium Sciences and Conservation
Australasian Regional Association of Zoological Parks and Aquaria (ARAZPA Newsletter, website)
Bongo (Journal of the Berlin Zoo, contains scientific articles on animal husbandry and conservation)
British and Irish Association of Zoos and Aquaria (BIAZA Research Newsletter, BIAZA Research Symposium Proceedings, BIAZA Research Guidelines)
Conservation Biology
Copeia (American Society of Ichthyologists and Herpetologists)
Dodo (Journal of Durrell Wildlife Conservation Trust)
European Association of Zoos and Aquaria (EAZA Research Committee Newsletter, EAZA News, EAZA Conference Proceedings, EAZA website)
International Zoo News
International Zoo Yearbook
Journal of Applied Animal Welfare Sciences
Journal of Fish Biology
Journal of Herpetology
Journal of Mammalogy
Journal of Wildlife Management
Journal of Zoo and Wildlife Medicine
Oryx: The International Journal of Conservation
Pan African Association of Zoological Gardens, Aquaria and Botanic Gardens (PAAZAB News, website)
Ratel (publication of the Association of British Wild Animal Keepers)
Reproduction
South East Asian Zoos Association (scientific papers from conferences available on SEAZA website)
Thylacinus (Australasian Society of Zoo Keeping)
Turtle and Tortoise Newsletter (Chelonian Research Foundation)
Wildlife Information Network
World Association of Zoos and Aquaria (WAZA News, WAZA Conference Proceedings and website)
Zeitschrift des Kölner Zoo (Journal of Cologne Zoo)
Zoo Biology
Der Zoologische Garten (The Zoological Garden)
Zoo Vet News (American Association of Zoo Veterinarians)



Bureaucracy

Know the zoo organisations:

- WAZA, EAZA, AZA etc., e.g. BIAZA
- EEP / SSP – incl. their TAGs

Many zoos want to see the statement of some organisation before they will consider participating in a research project.

Many (esp. British) zoos have a bureaucratic procedure for research that is time-consuming and must be factored into any research plan.

Health & Safety



observations



Typical zoo biology: observations

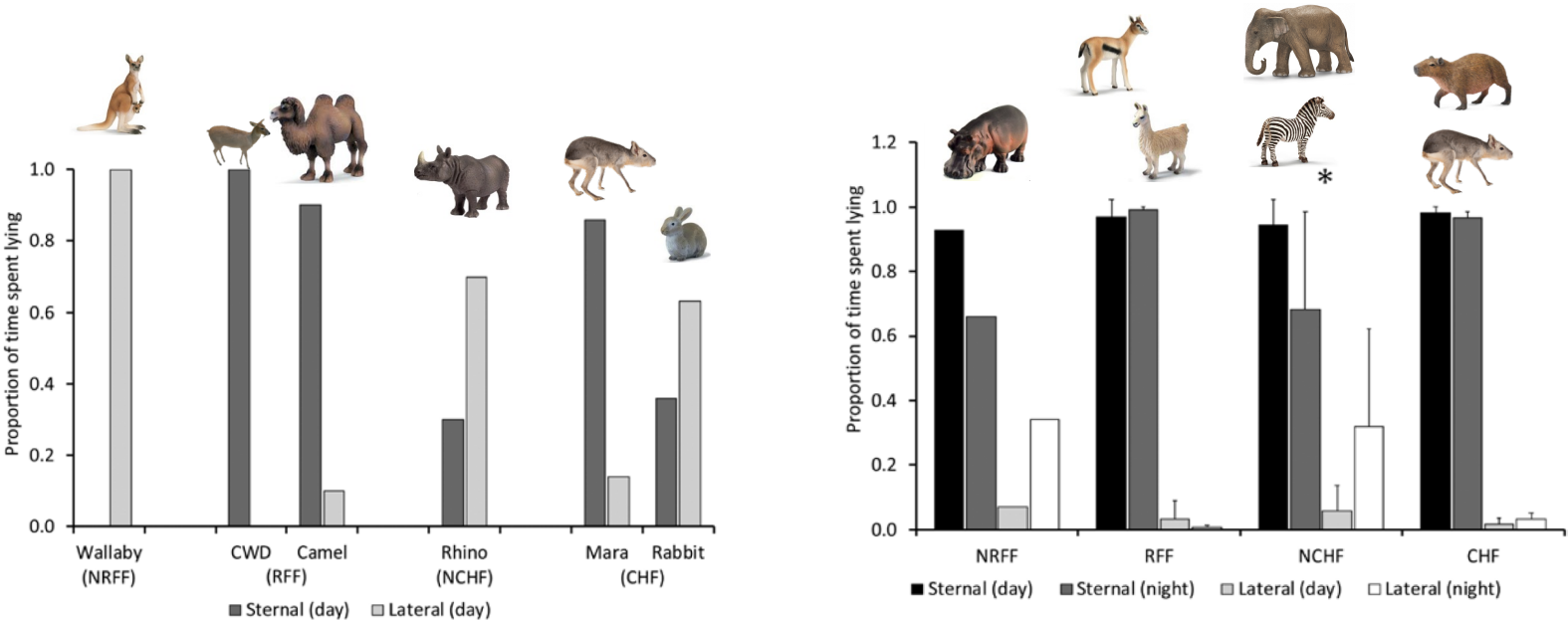


Journal of Mammalogy, XX(X):1–12, 2019
DOI:10.1093/jmammal/gyz044



Resting postures in terrestrial mammalian herbivores




ENDRE PUCORA, CHRISTIAN SCHIFFMANN, AND MARCUS CLAUSS*

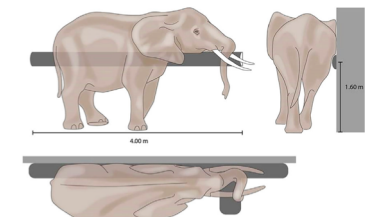
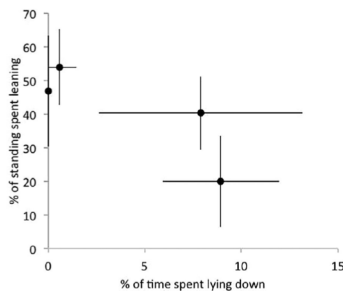
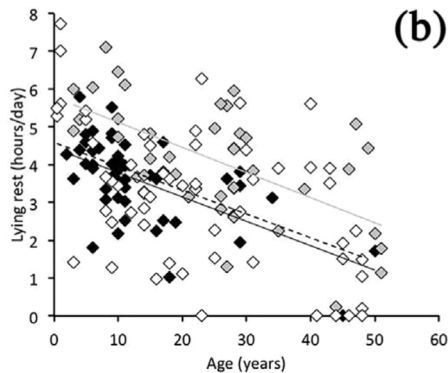


Exceptional zoo biology: very insightful observations

When elephants fall asleep: A literature review on elephant rest with case studies on elephant falling bouts, and practical solutions for zoo elephants

Zoo Biology. 2018;37:133–145.

Christian Schiffmann^{1,2}  | Stefan Hoby³ | Christian Wenker³ | Therese Hård⁴ | Robert Scholz⁵ | Marcus Clauss¹  | Jean-Michel Hatt¹ 





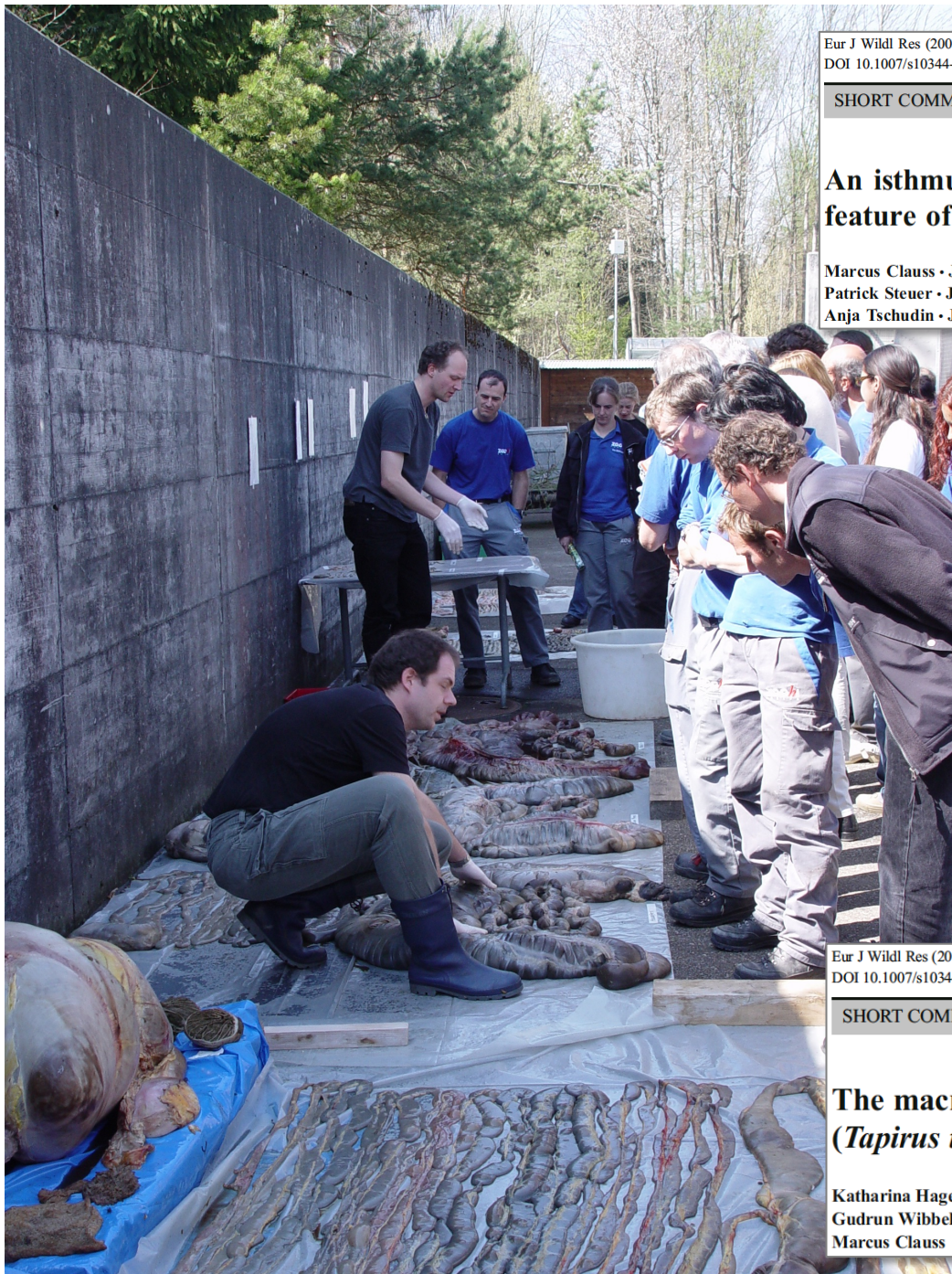
leftovers



What methods are used in zoo research?

As well as observational data, a wide variety of materials and methods may – subject to risk assessments, biosecurity and health and safety precautions – be utilised in studies of living zoological collections and associated products (e.g. tissue and blood samples, faeces, urine, bones, eggs, nests and feathers). For example, some substances such as hormones contained in faeces and urine are important in non-invasive studies of stress. All animals die eventually, and post-mortem material can be usefully studied and be deposited in museums and universities for future reference; especially material from threatened species.

Equally important are the computerised records and archives that zoos and aquaria maintain on breeding, e.g. parentage, clutch/litter size, inter-birth interval, infant survival, group composition, behaviour, medical issues etc.



Eur J Wildl Res (2008) 54:347–351

DOI 10.1007/s10344-007-0126-y

SHORT COMMUNICATION

An isthmus at the caecocolical junction is an anatomical feature of domestic and wild equids

Marcus Clauss • Jürgen Hummel • Angela Schwarm •
Patrick Steuer • Julia Fritz • Olga Martin Jurado •
Anja Tschudin • Jean-Michel Hatt

Eur J Wildl Res (2015) 61:171–176

DOI 10.1007/s10344-014-0870-8

SHORT COMMUNICATION

The macroscopic intestinal anatomy of a lowland tapir (*Tapirus terrestris*)

Katharina Hagen • Dennis W. H. Müller •
Gudrun Wibbelt • Andreas Ochs • Jean-Michel Hatt •
Marcus Clauss



experiments



Practical problems related to these approaches

- As well as observational data, a wide variety of materials and methods may – subject to risk assessments, biosecurity and health and safety precautions – be utilised in studies of living zoological collections and associated products (e.g. blood samples, feathers, eggs, etc.). For example, some substances such as hormones contained in faeces and urine are important in non-invasive studies of stress. All animals die eventually, and post-mortem material can be usefully studied and be deposited in museums and universities for future reference; especially material from threatened species.
- sample size
 - permits (CITES, internal and official animal welfare committees)
 - logistics of physically attaining the sample
 - logistics of sample storage and transport
- Equally important are the computerised records and archives that zoos and aquaria maintain on breeding, e.g. parentage, clutch/litter size, inter-birth interval, infant survival, group composition, behaviour, medical issues etc.



The most important methodological question

As well as observational data, a wide variety of materials and methods may – subject to risk assessments, biosecurity and health and safety precautions – be utilised in studies of living zoological collections and associated products (e.g. tissue and blood samples, faeces, urine, bones, eggs, nests and feathers). For example, some substances such as hormones contained in faeces and urine are important in non-invasive studies of stress. All animals die eventually, and post-mortem material can be usefully collected and be deposited in museums and universities for future reference, especially material from threatened species.

**Opportunistic sampling or
experimental design?**

Equally important are the computerised records and archives that zoos and aquaria maintain on breeding, e.g. parentage, clutch/litter size, inter-birth interval, infant survival, group composition, behaviour, medical issues etc.



Fundamental approach

Sodium metabolism in black rhinos across different dietary intakes?
Stress hormones in orangutans related to group size?

Opportunistic

- use inter-zoo variability (in diets, in group composition)

you need a lot of zoos that only have to give you access to the samples you need

Experimental

- change diets/group size within a constant group of animals

Sometimes taking the 'normal zoo data' requires methods that are in themselves 'experimental'

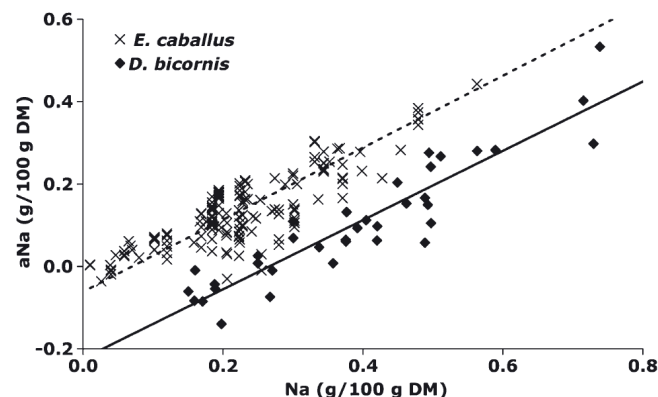




Mineral absorption in the black rhinoceros (*Diceros bicornis*) as compared with the domestic horse

M. Clauss¹, J. C. Castell², E. Kienzle², P. Schramel³, E. S. Dierenfeld⁴, E. J. Flach⁵, O. Behlert⁶, W. J. Streich⁷, J. Hummel^{6,8} and J-M. Hatt¹

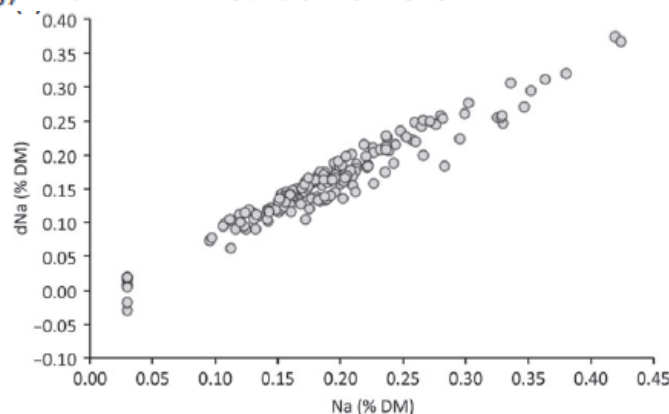
Journal of Animal Physiology and Animal Nutrition **91** (2007) 193–204



Organic matter and macromineral digestibility in domestic rabbits (*Oryctolagus cuniculus*) as compared to other hindgut fermenters

K. B. Hagen¹, A. Tschudin¹, A. Liesegang², J.-M. Hatt¹ and M. Clauss¹

Journal of Animal Physiology and Animal Nutrition © 2015

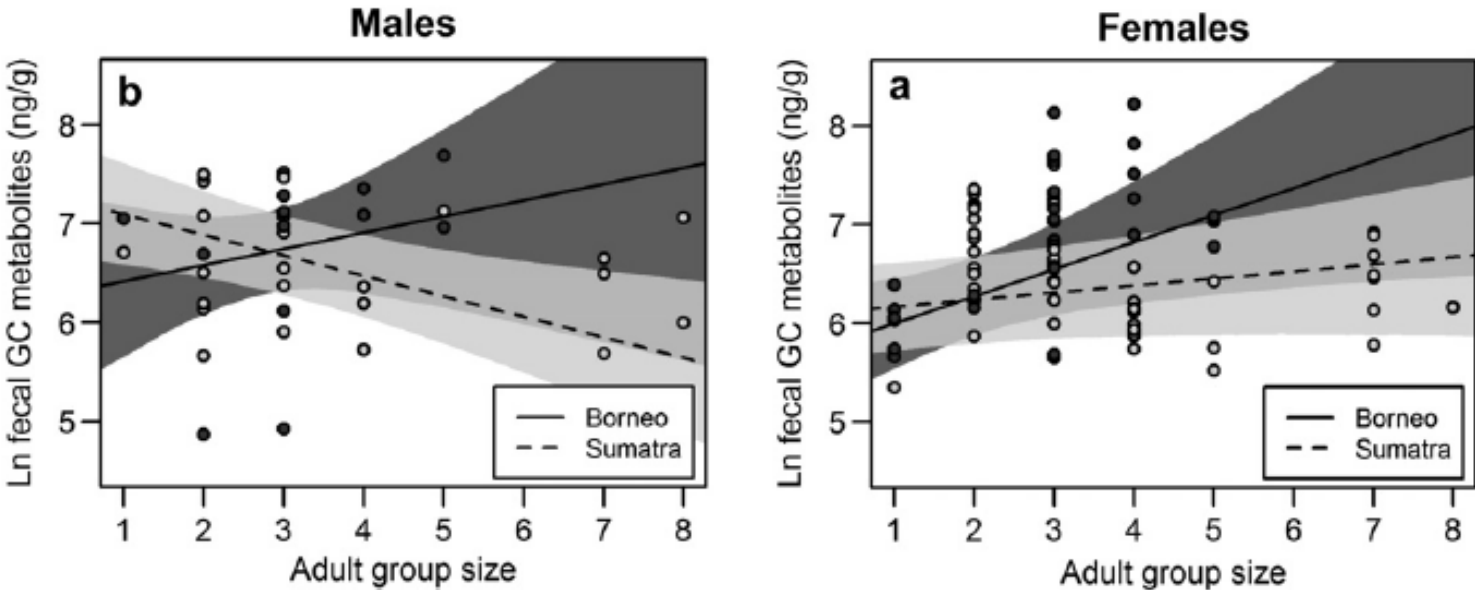




Species-specific patterns in fecal glucocorticoid and androgen levels in zoo-living orangutans (*Pongo* spp.)

Tony Weingrill^{a,*}, Erik P. Willems^a, Nina Zimmermann^b, Hanspeter Steinmetz^c, Michael Heistermann^d

General and Comparative Endocrinology 172 (2011) 446–457

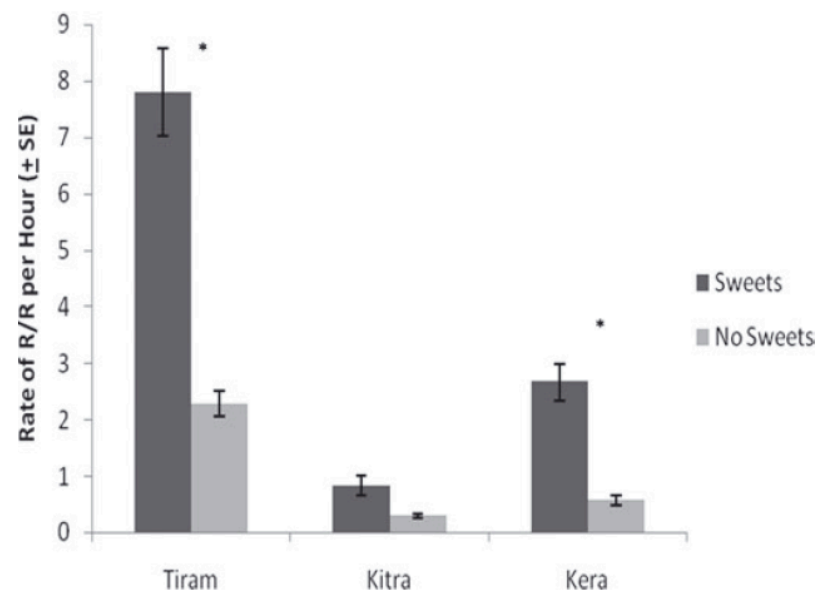
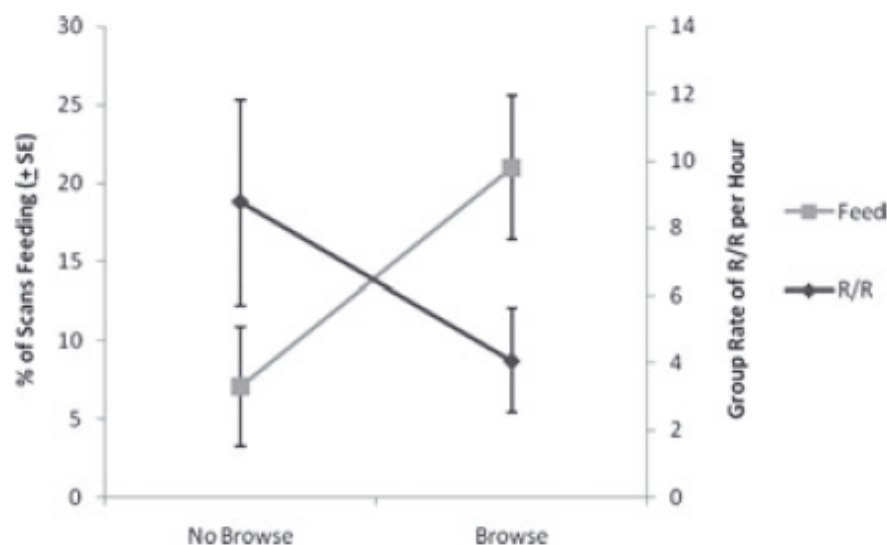
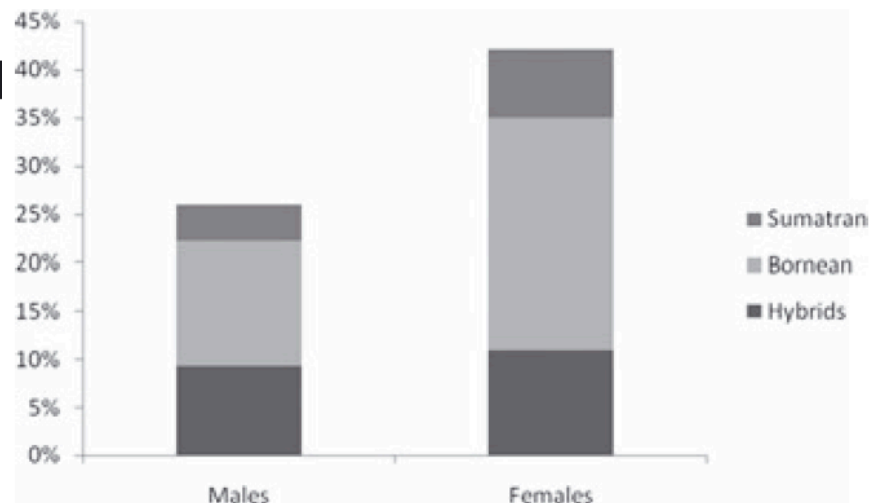




Prevalence of Regurgitation and Reingestion in Orangutans Housed in North American Zoos and an Examination of Factors Influencing its Occurrence in a Single Group of Bornean Orangutans

Christine M. Cassella,^{1,2*} Alyssa Mills,¹ and Kristen E. Lukas^{1,2}

Zoo Biology 31: 609–620 (2012)





surveys



And another method ...

Questionnaires !

**If you want to do a survey,
travel & interview people
yourself and try to avoid
questionnaires.**

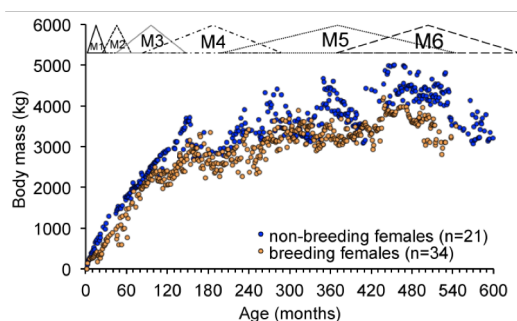
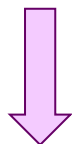
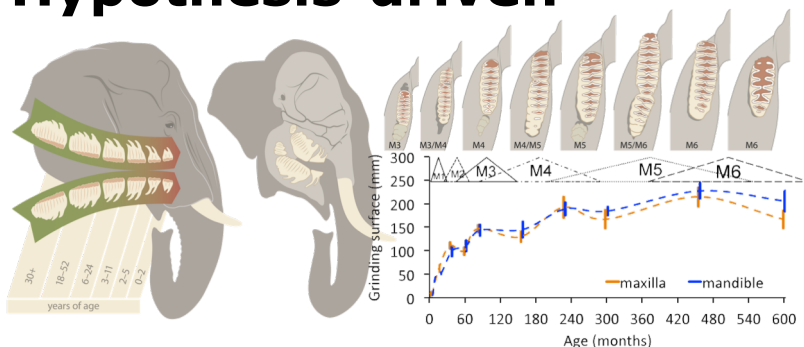
As well as observational data, a wide variety of materials and methods may – subject to risk assessments, biosecurity and health and safety precautions – be utilised in studies of living zoological collections and associated products (e.g. tissue and blood samples, faeces, urine, bones, eggs, nests and feathers). For example, some substances such as hormones contained in faeces and urine are important in non-invasive studies of stress. All animals die eventually, and post-mortem material can be usefully studied and be deposited in museums and universities for future reference; especially material from threatened species.

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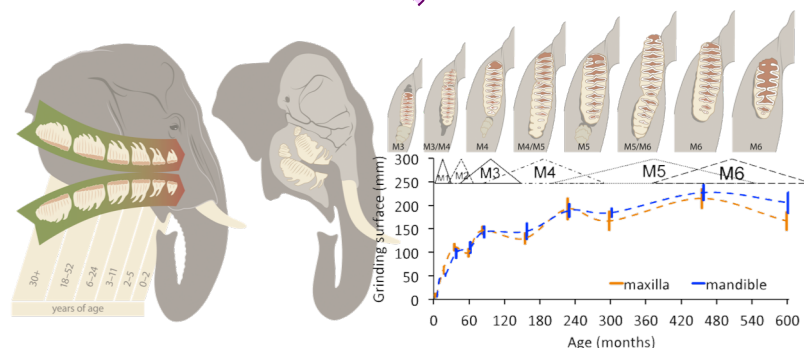
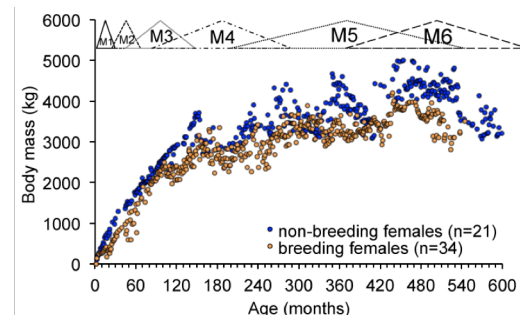
The myth of 'hypothesis-driven research': getting used to lying

Hypothesis-driven



"our hypothesis was confirmed"

Serendipity-driven



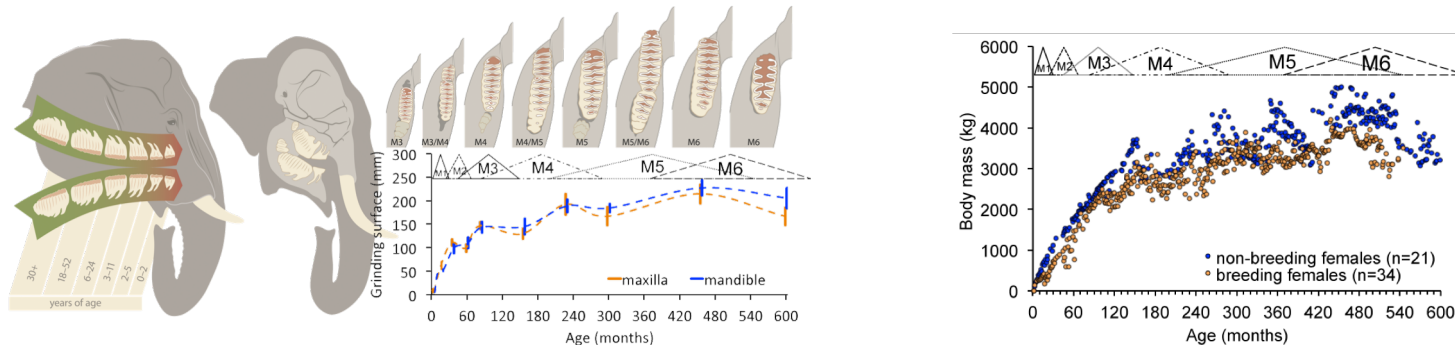
*"we stumbled across a pattern
and we think we can explain it"*



Elephant body mass cyclicity suggests effect of molar progression on chewing efficiency

Christian Schiffmann^{a, b}, Jean-Michel Hatt^a, Stefan Hoby^{c, d}, Daryl Codron^{e, f}, Marcus Clauss^{a, *}

Mammalian Biology xxx (2018) xxx-xxx



mass data. These data revealed a pattern corresponding to the considerations on molar progression above (which we had collated after identifying the pattern; this study therefore did not test a hypothesis, but reports a serendipitous result). We consider this an outstanding ex-

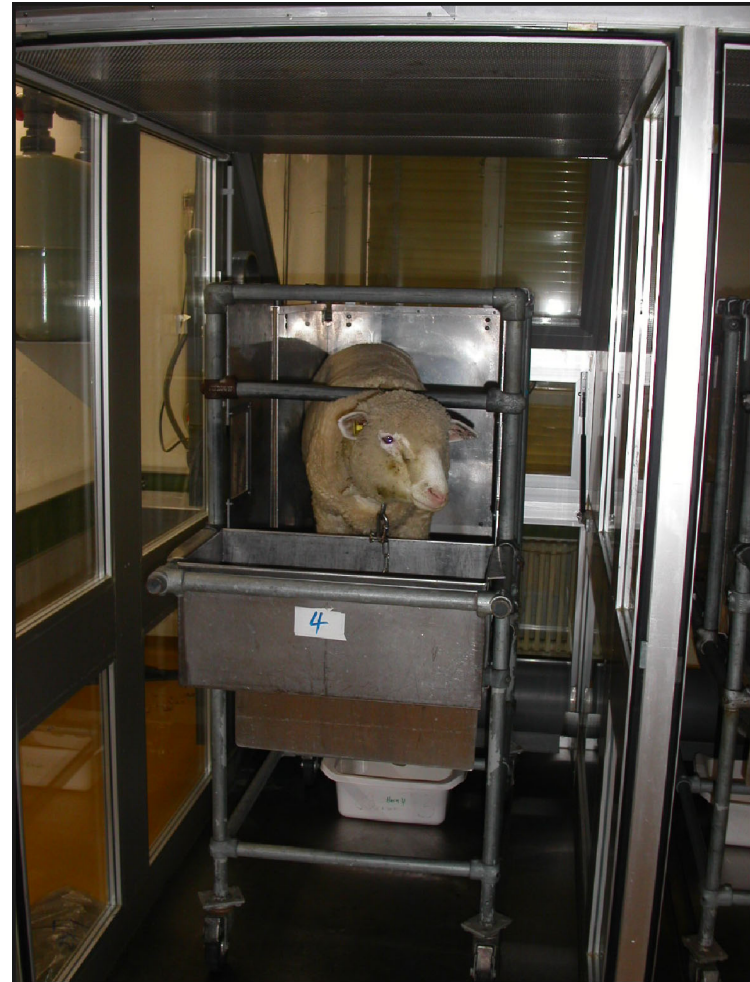


example:
digestion studies



Case example: digestion studies

What are the minimum conditions you need to perform reasonable studies on digestive physiology?





Case example: digestion studies

What are the minimum conditions you need to perform reasonable studies on digestive physiology?





Case example: digestion studies

What are the minimum conditions you need to perform reasonable studies on digestive physiology?



from Lechner et al. (2010)



Case example: digestion studies

What are the minimum conditions you need to perform reasonable studies on digestive physiology?

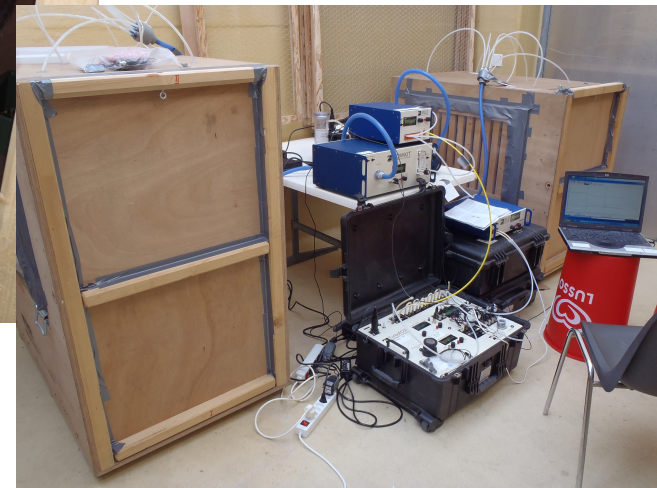


from Tschuor & Clauss (2008)



Case example: digestion studies

What are the minimum conditions you need to perform reasonable studies on digestive physiology?





Case example: digestion studies

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Case example: digestion studies

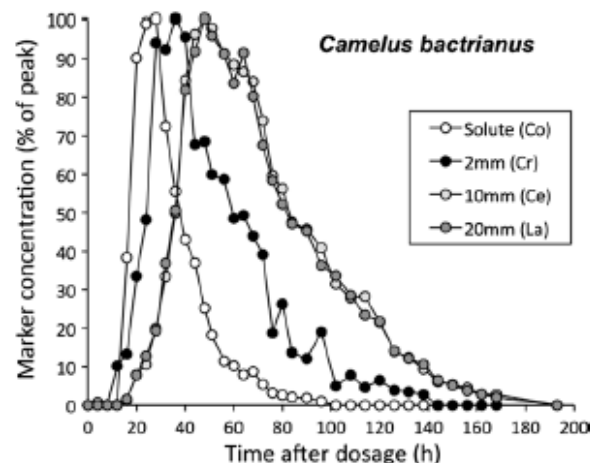
What are the minimum conditions you need to perform reasonable studies on digestive physiology?

J Comp Physiol B (2015) 185:559–573
DOI 10.1007/s00360-015-0904-x

ORIGINAL PAPER

Digesta retention patterns of solute and different-sized particles in camelids compared with ruminants and other foregut fermenters

Marie T. Dittmann^{1,2} · Ullrich Runge³ · Sylvia Ortmann⁴ · Richard A. Lang⁵ ·
Dario Moser⁶ · Cordula Galeffi⁷ · Angela Schwarm² · Michael Kreuzer² ·
Marcus Clauss¹

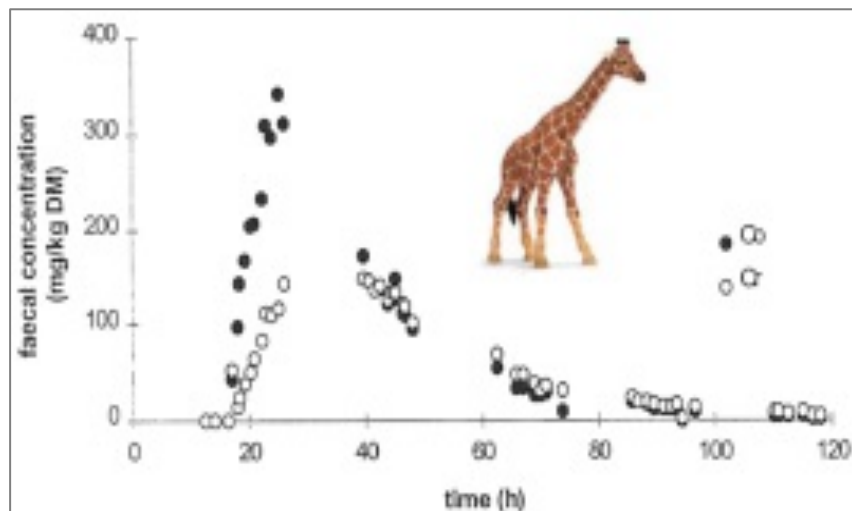




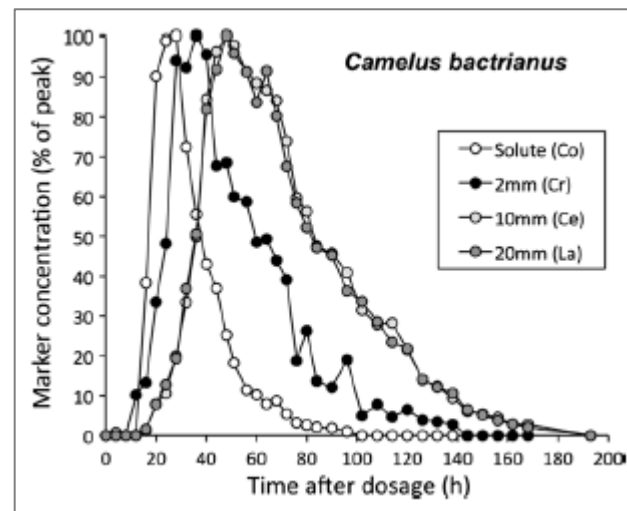
Case example: digestion studies

What are the minimum conditions you need to perform reasonable studies on digestive physiology?

Sampling frequency test



giraffe study



camel study

=> how much are you allowed and are you prepared to work?



Case example: digestion studies

What are the minimum conditions you need to perform reasonable studies on digestive physiology?

Rhinoceros faeces test: Crude ash content of sample

- sent in by zoo – 50 % dry matter
- taken by doctoral student – 18 % dry matter
- taken by postdoc supervisor – 9 % dry matter

=> how accurate do you work / how high do you rate personal comfort?



Case example: digestion studies

What are the minimum conditions you need to perform reasonable studies on digestive physiology?





The Effectiveness of Indigestible Markers for Identifying Individual Animal Feces and Their Prevalence of Use in North American Zoos

Grace Fuller,^{1,2*} Susan W. Margulis,^{3,4} and Rachel Santymire³

Zoo Biology 30 : 379–398 (2011)

Species	Marker type	Dosage
Fishing cat, <i>Prionailurus viverrinus</i>	Liquid food coloring (green)	0.5–1.0 ml daily
	Sesame seeds	0.125 tsp
	Wilton paste food dye (Christmas red and kelly green)	Enough to color feed well
Giant panda, <i>Ailuropoda melanoleuca</i>	Corn, various colors	NR
Grey wolf, <i>Canis lupus</i>	Rice	1 Tbsp
	Finch seed	1 Tbsp
	Kernal corn	1 Tbsp
	Scratch	1 Tbsp
	Foil glitter	1 Tbsp
	Sweet potato	0.25 cup chunks
	Carrot	0.25 cup diced
	Fresh corn	1 ear
	Beets, chopped	NR



Case example: digestion studies

- can you keep animals individually
 - i.e. are there enough enclosures
 - will they cope with being isolated
 - will they fight when put together again
- how many can you keep individually at a time
- can you shift the animals to get at faeces regularly
- can you work 'after-hours'
- can you weigh the animals
- can you process your samples on site / is there freezer space
- can you manipulate the diet



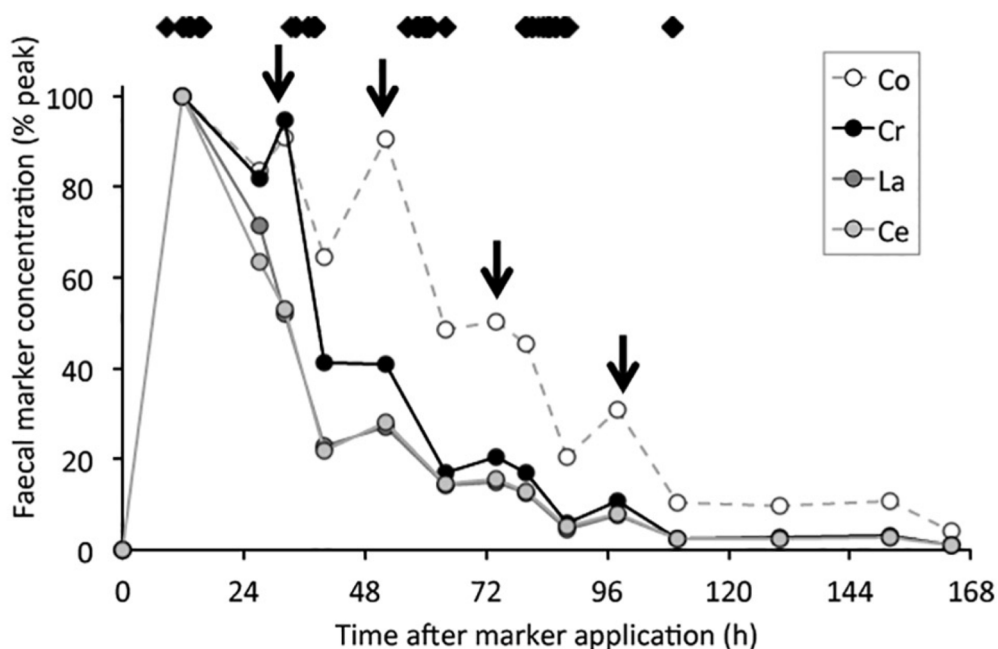


Patterns: secondary marker peaks

Effect of different feeding regimes on cecotrophy behavior and retention of solute and particle markers in the digestive tract of paca (*Cuniculus paca*)

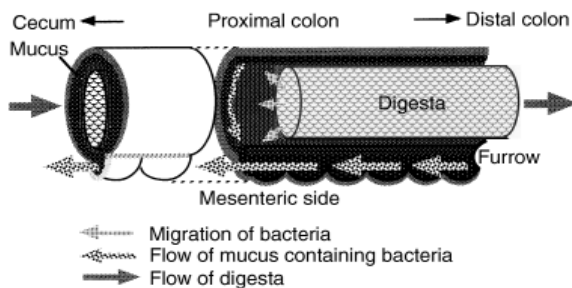
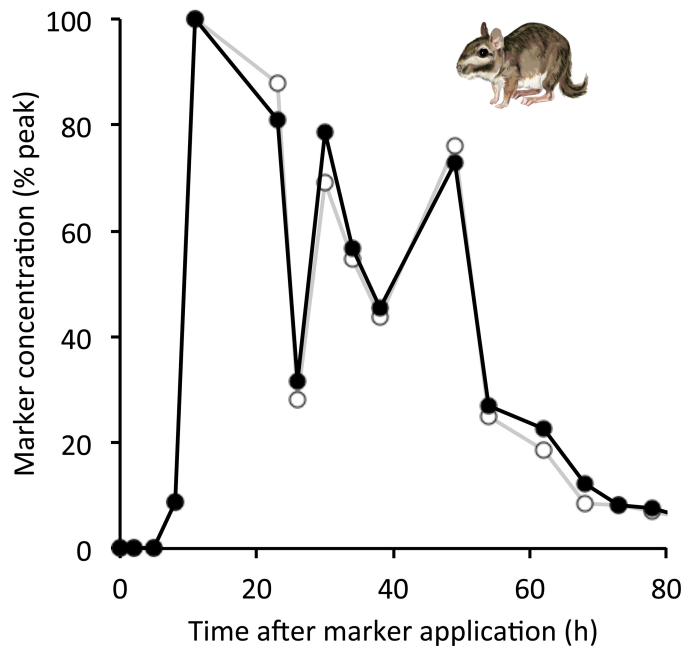
Letícia Guerra Aldrigui^a, Sérgio Luiz Gama Nogueira-Filho^a, Alcester Mendes^a,
Vanessa Souza Altino^a, Sylvia Ortmann^b, Selene Siqueira da Cunha Nogueira^a, Marcus Clauss^{c,*}

Comparative Biochemistry and Physiology, Part A 226 (2018) 57–65

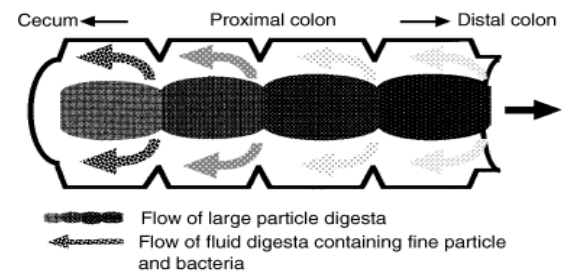
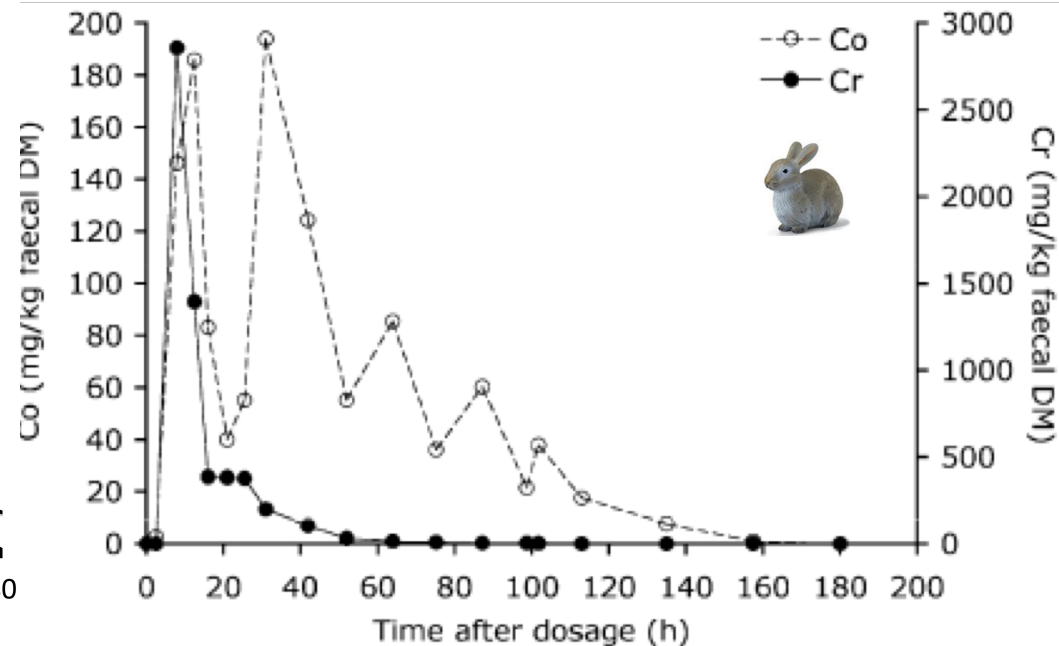


Sorting of ingesta for caecotroph formation

Mucus trap mechanism (Hystricomorph rodents)



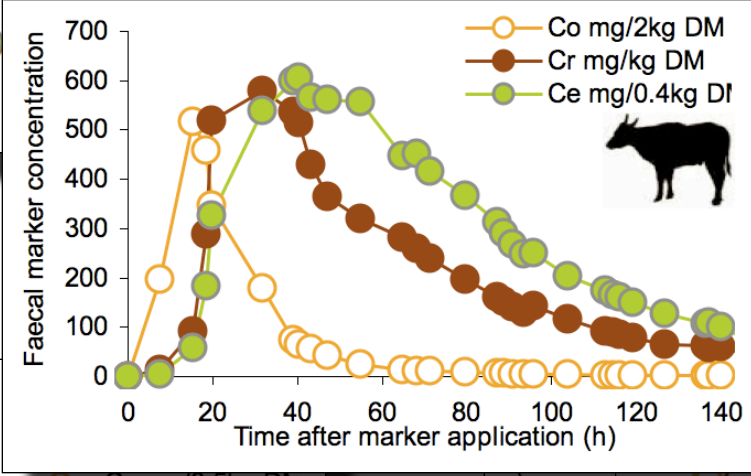
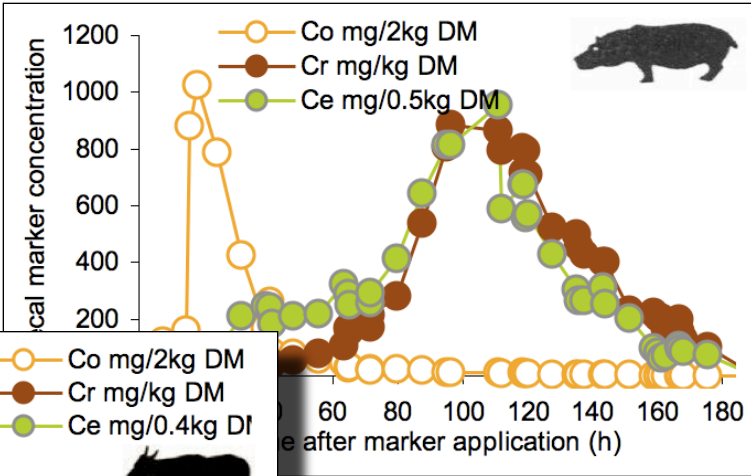
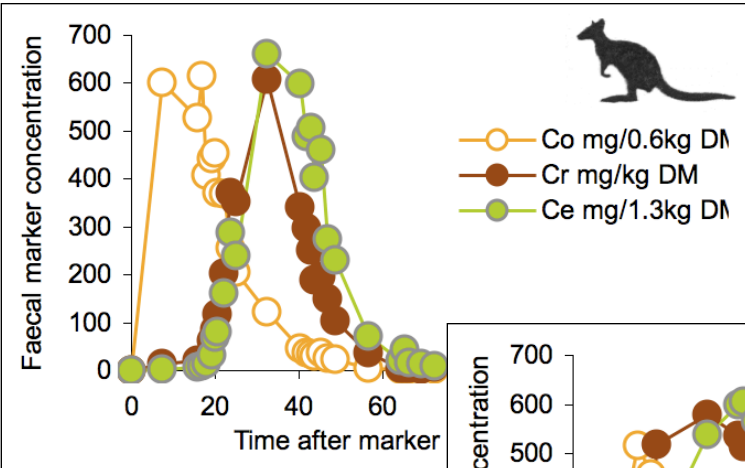
Wash back mechanism (Lagomorphs)



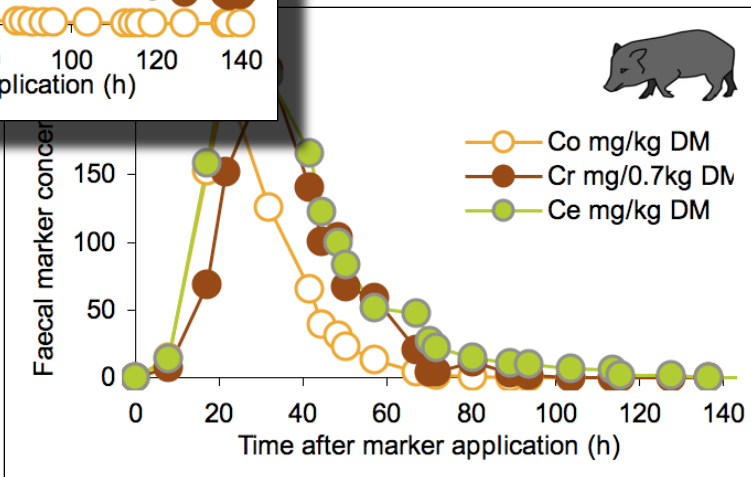
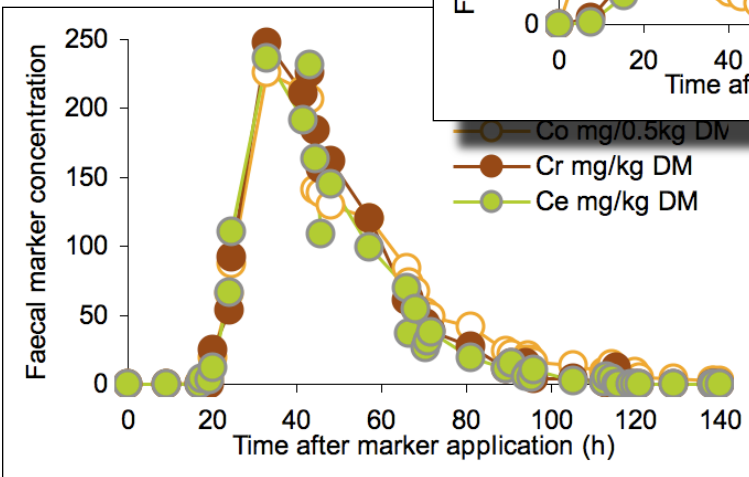
from Hagen et al. (2015), Sakaguchi & Hume (1991), Franz et al. (2011)



Ruminant vs. Nonruminant Foregut Fermentation

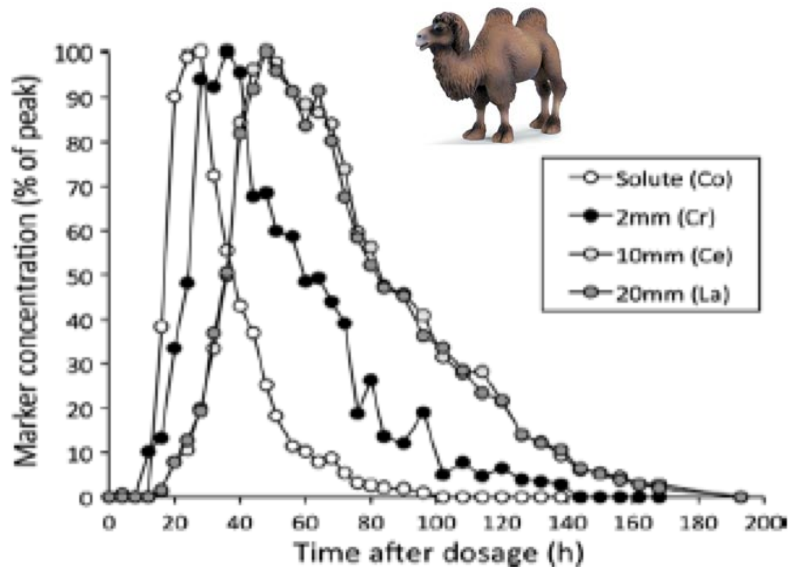
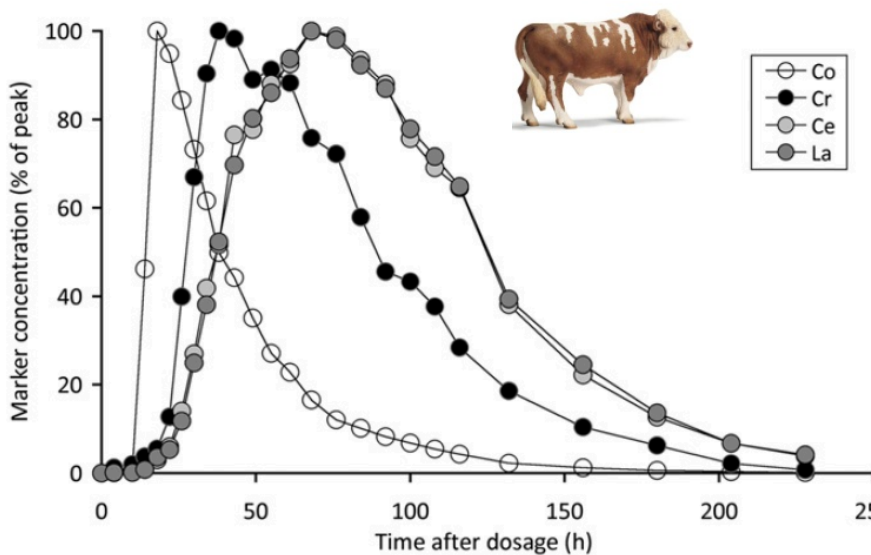


Schwarm et al. (2008,2009)



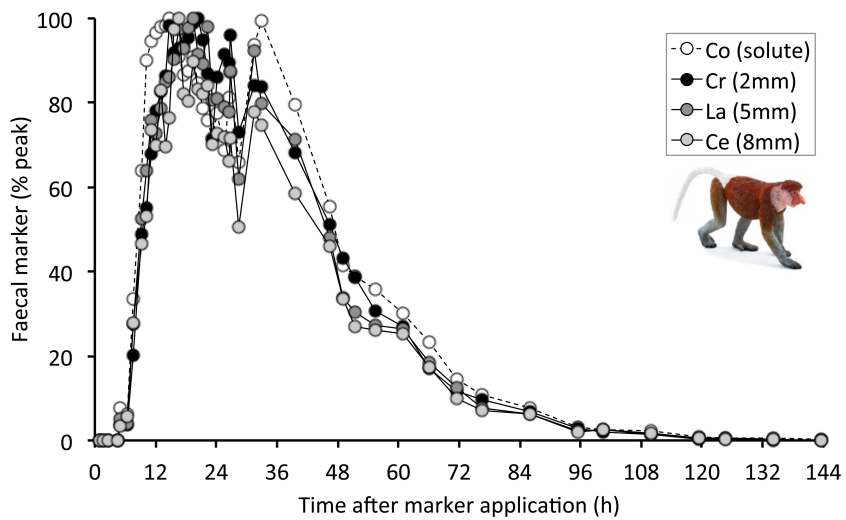
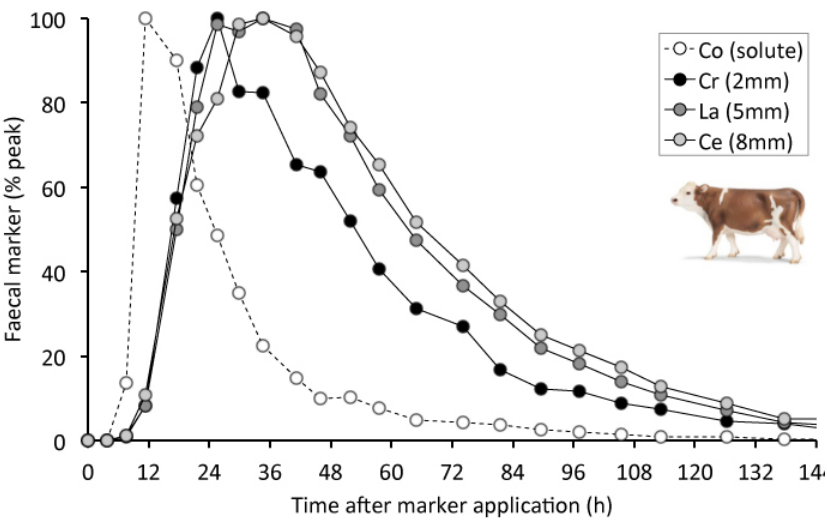


Rumination I: convergence



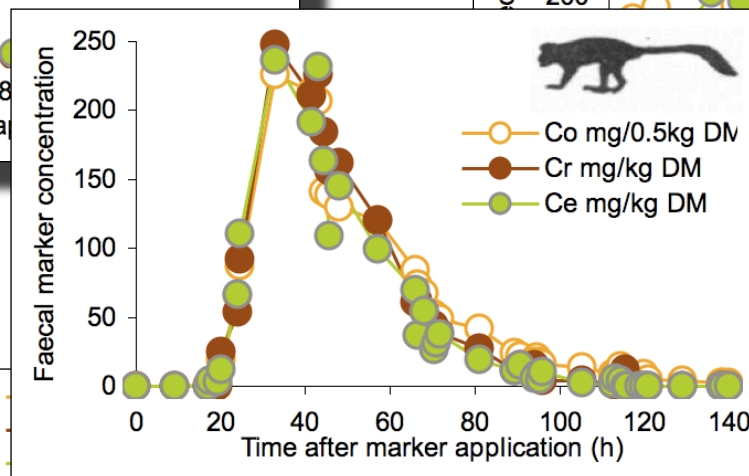
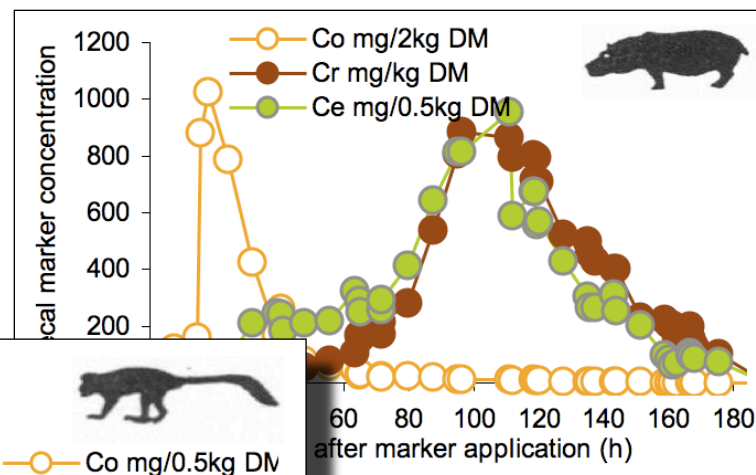
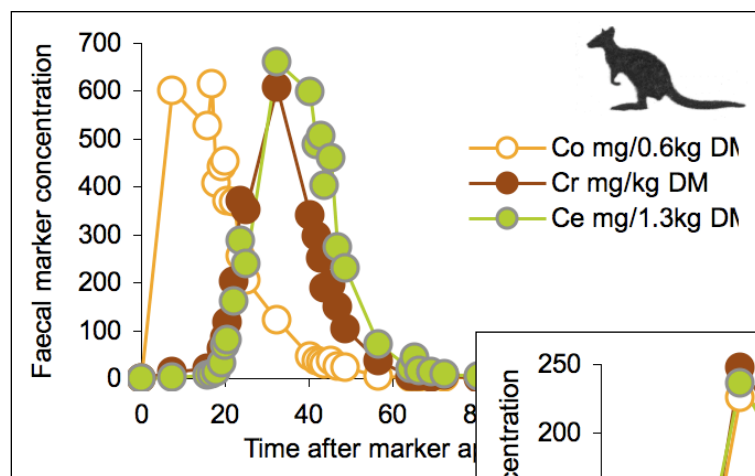


Rumination II: no convergence

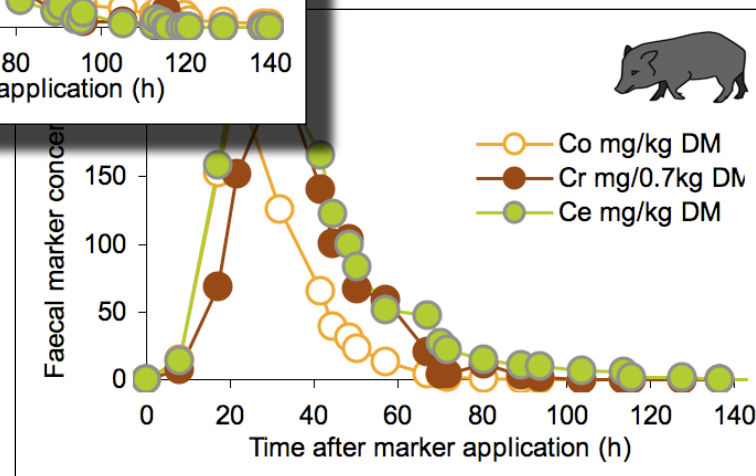
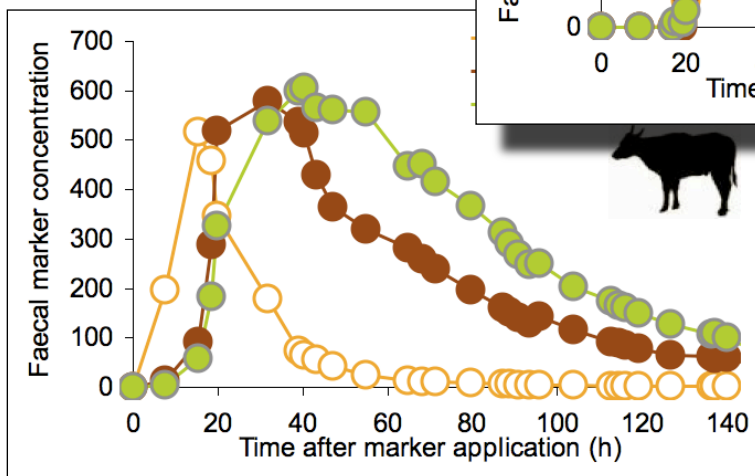




Fluid vs. particle retention

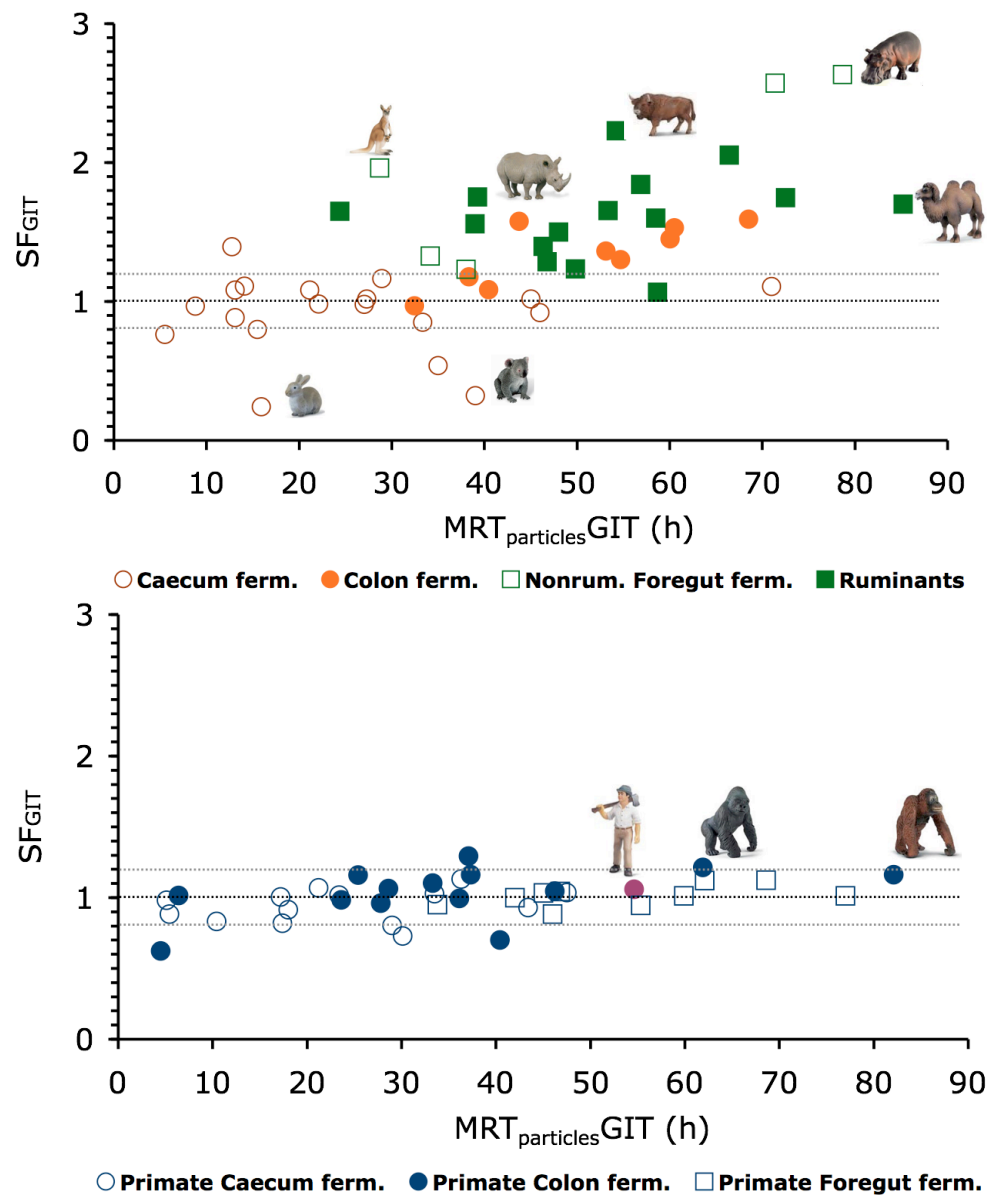


Schwarm et al. (2008,2009)





Fluid vs. particle retention



from Müller et al. (2011)



An old question:

Do larger herbivores ingest lower-quality diets, and are they physiologically equipped for a 'better' digestion of such diets?



An old question:

Functional Ecology



Functional Ecology 2014, **28**, 1127–1134

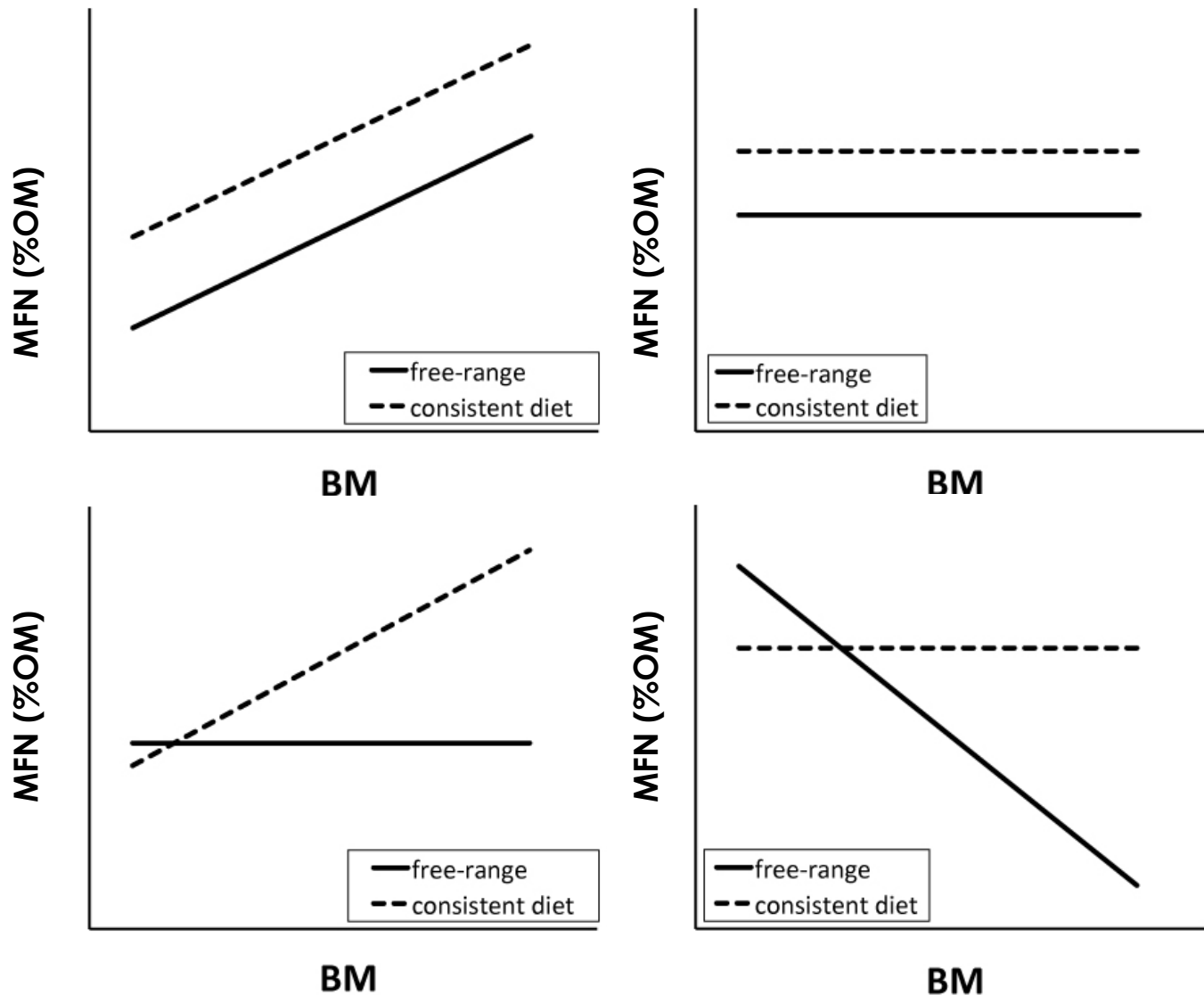
doi: 10.1111/1365-2435.12275

Does body mass convey a digestive advantage for large herbivores?

Patrick Steuer¹, Karl-Heinz Südekum¹, Thomas Tütken^{2,†}, Dennis W. H. Müller^{3,4}, Jacques Kaandorp⁵, Martin Bucher⁶, Marcus Clauss³ and Jürgen Hummel^{*,1,7}



... or larger animals eat lower quality diets



from Steuer et al. (2014)



Digesta retention allometry

Comparative Biochemistry and Physiology, Part A 164 (2013) 129–140



Contents lists available at SciVerse ScienceDirect

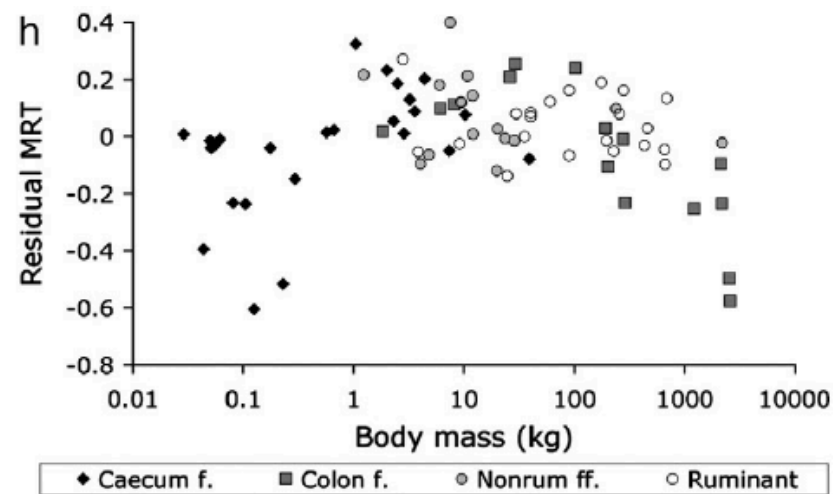
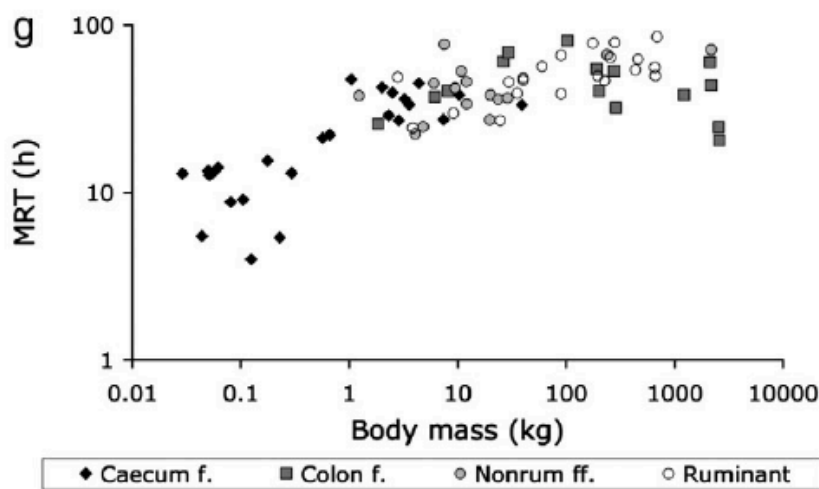
Comparative Biochemistry and Physiology, Part A

journal homepage: www.elsevier.com/locate/cbpa



Assessing the Jarman–Bell Principle: Scaling of intake, digestibility, retention time and gut fill with body mass in mammalian herbivores

Dennis W.H. Müller^{a,b}, Daryl Codron^{a,c}, Carlo Meloro^d, Adam Munn^e, Angela Schwarm^f,
Jürgen Hummel^{g,h}, Marcus Clauss^{a,*}





Vital skills I

- do an internship in a zoo to learn basic routines such as
 - handling brooms (use broom and shovel simultaneously)
 - handling & closing doors
 - understanding zoo logistics
- be able to communicate your topic and study goals
- know your animals (but rather listen than talk about what you know)



Vital skills II

- don't come to work later than those who shall help you (e.g., keepers)
- ensure nobody has to wait for you
- if you need help, ensure everybody realizes that you are reciprocating by helping back
- never expect anyone to do extra work for you because you need it or find it interesting
- never act as if a certain task is below your level of dignity that is part of the work of someone who shall help you
- always wash your dishes immediately
- bring your own food, tea, sugar from day 1



zoo data



Demographic data

PROCEEDINGS
— OF —
THE ROYAL
SOCIETY **B**

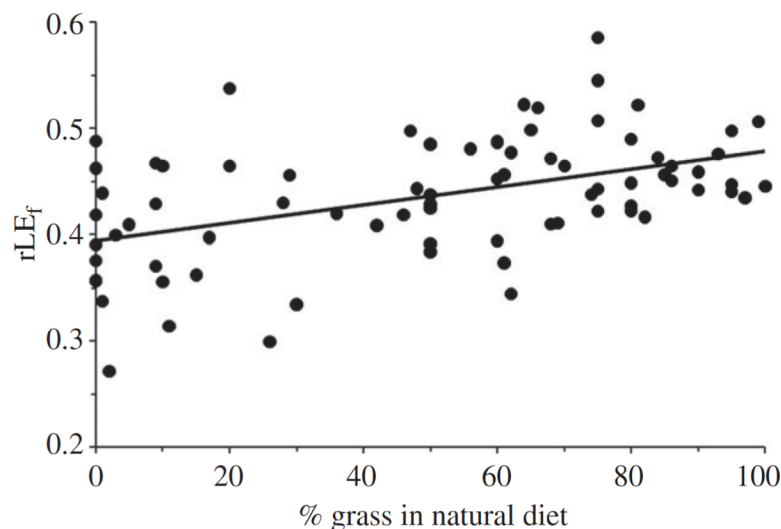
Proc. R. Soc. B (2011) **278**, 2076–2080

doi:10.1098/rspb.2010.2275

Published online 8 December 2010

Mating system, feeding type and *ex situ* conservation effort determine life expectancy in captive ruminants

**Dennis W. H. Müller^{1,*}, Laurie Bingaman Lackey²,
W. Jürgen Streich³, Jörns Fickel³, Jean-Michel Hatt¹
and Marcus Clauss¹**





Demographic data

BIOLOGICAL
REVIEWS

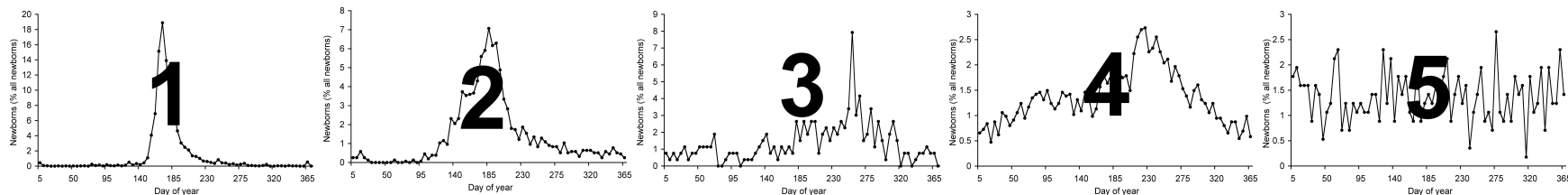
Cambridge
Philosophical Society

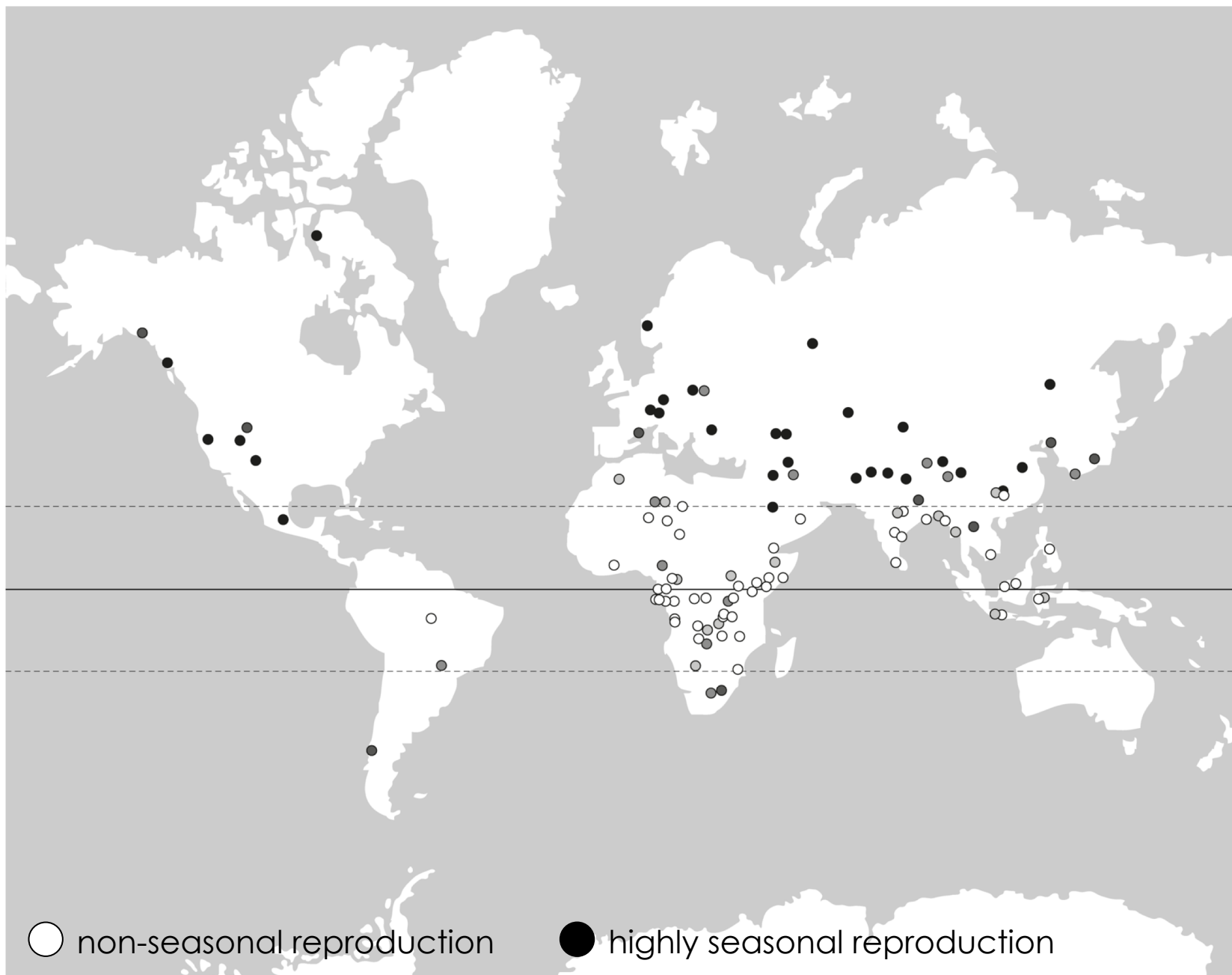
Biol. Rev. (2012), 87, pp. 965–990.
doi: 10.1111/j.1469-185X.2012.00238.x

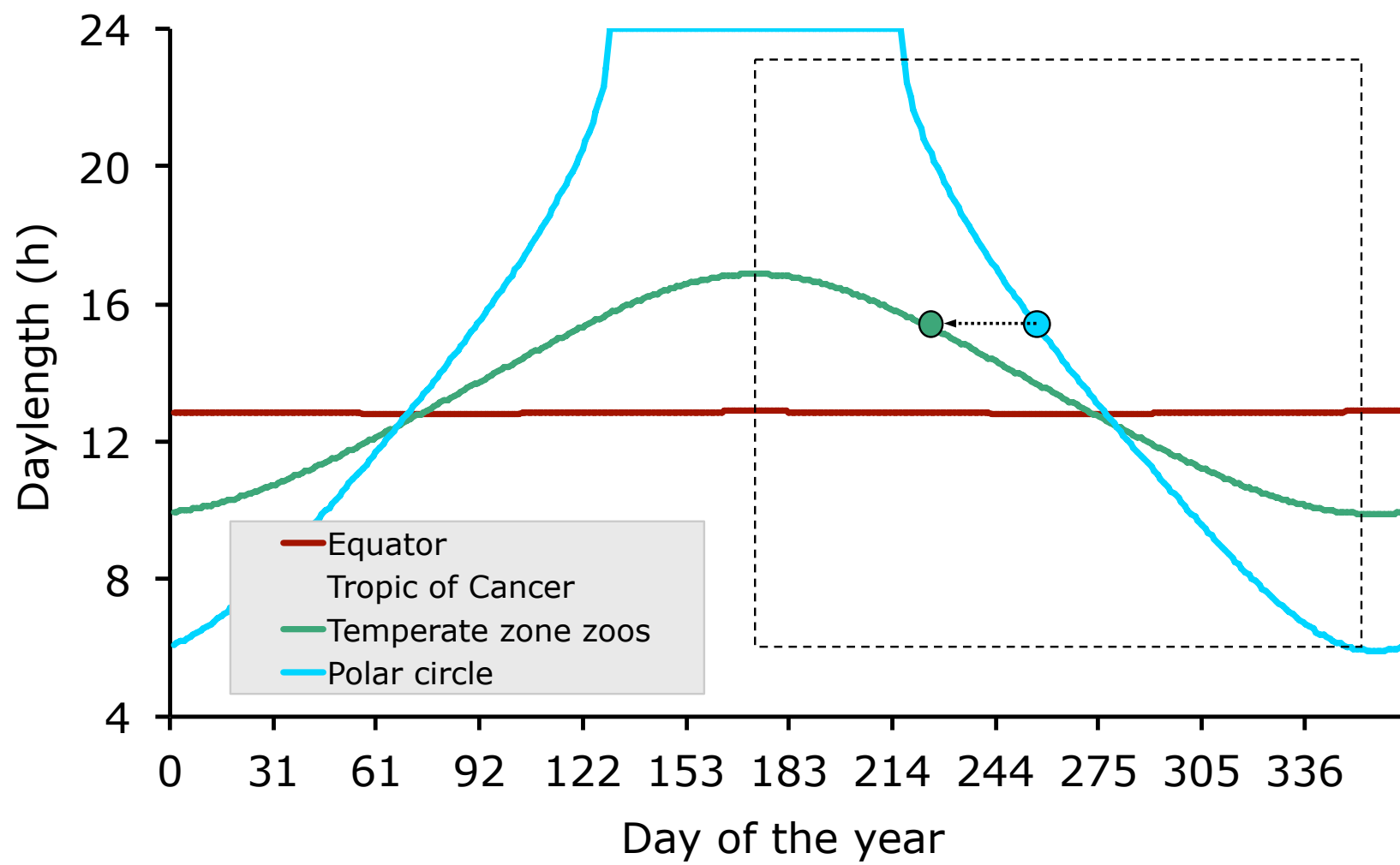
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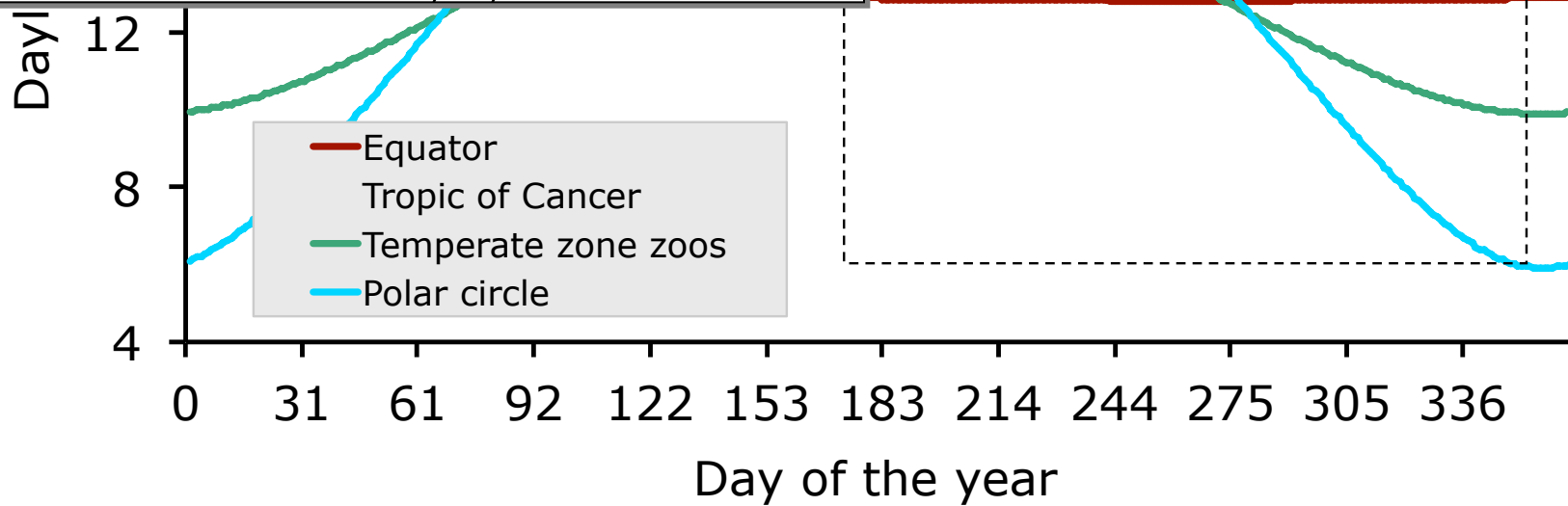
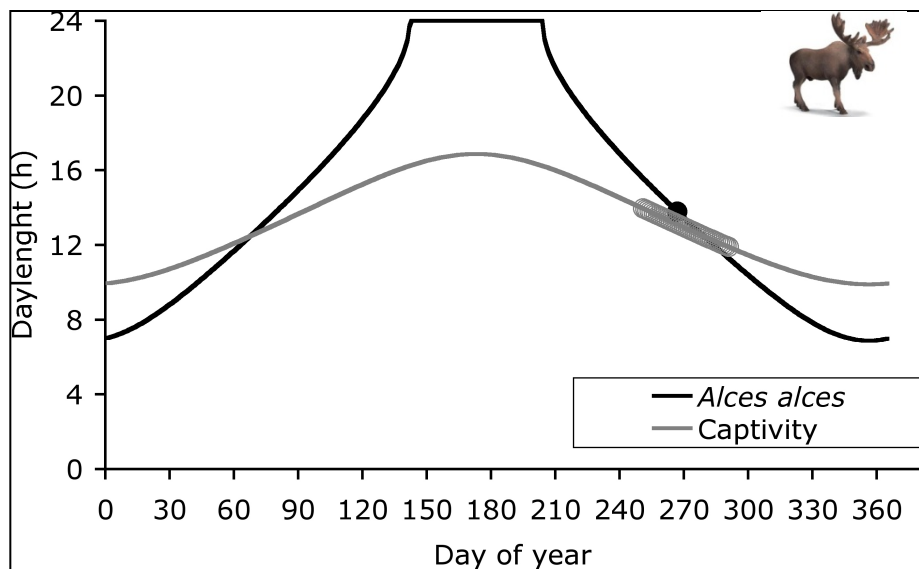
Reproductive seasonality in captive wild ruminants: implications for biogeographical adaptation, photoperiodic control, and life history

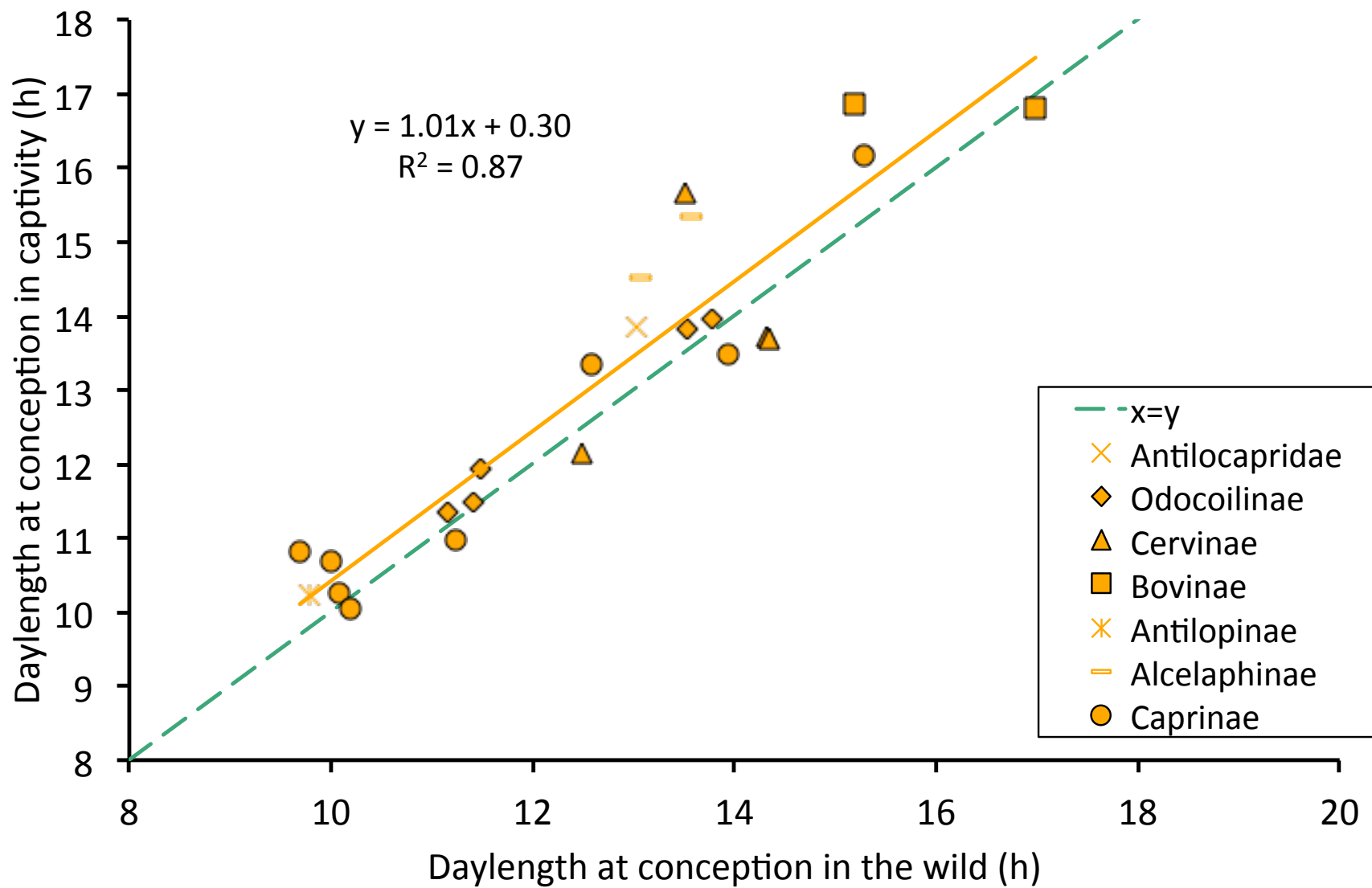
Philipp Zerbe^{1,2}, Marcus Clauss^{1,*}, Daryl Codron^{1,3,4,5}, Laurie Bingaman Lackey⁶, Eberhard Rensch¹, Jürgen W. Streich⁷, Jean-Michel Hatt¹ and Dennis W. H. Müller^{1,8}













*how do you tell
your story ?*

Compromised Survivorship in Zoo Elephants

Ros Clubb,¹ Marcus Rowcliffe,² Phyllis Lee,^{3,4} Khyne U. Mar,^{2,5} Cynthia Moss,⁴ Georgia J. Mason^{6*}

Wild animals can experience poor welfare when held captive (1), an effect with ethical and practical implications. In zoos, the welfare of African elephants (*Loxodonta africana*) and Asian elephants (*Elephas maximus*) has long caused concern. Infanticide, *Herpes*, tuberculosis, lameness, infertility, and stereotypic behavior are prevalent (2), and zoo elephant populations are not self-sustaining without importation (3). We compiled data from over 4500 individuals to compare survivorship in zoos with protected populations in range countries. Data representing about half the global zoo population (1960 to 2005) came from European "studbooks" and the European Elephant Group (4). We focused on females as relevant to population viability ($N = 786$, both wild-caught and captive-born; 302 African and 484 Asian). African elephants in Amboseli National Park, Kenya ($N = 1089$), and Asian elephants in the Burmese logging industry (Myanmar Timber Enterprise, M.T.E., $N = 2905$, wild-caught and captive-born) acted as well-provisioned reference populations [for details, see (2) and (5)].

For African elephants, median life spans (excluding premature and still births) were 16.9 years [95% confidence interval (CI) 16.4 to unknown; upper estimate for median not reached] for zoo-born females and 56.0 years (95% CI 51.5 to unknown) for Amboseli females undergoing natural mortality (35.9 years with human-induced deaths, 95% CI 33.8 to 40.3). Neither infant nor juvenile mortality differed between populations (Fig. 1A and tables S1 and S2), but adult females died earlier in zoos than in Amboseli (Fig. 1B and table S2). Zoo adult African survivorship has improved in recent years [$z = -2.75$, $P < 0.01$ (5)], but mortality risks in our data set's final year (2005) remained 2.8 times higher (95% CI 1.2 to 6.5) than that of Amboseli females undergoing natural mortality.

For Asian elephants, median life spans (excluding premature and still births) for captive-born females were 18.9 years in zoos (95% CI 17.7 to 34.0) and 41.7 years in the M.T.E. population (95% CI 38.2 to 44.6). Zoo infant mortality rates were high

(over double those of M.T.E.): A female's first pregnancy therefore had only a 42% chance of yielding a live year-old in zoos compared with 83% in M.T.E.

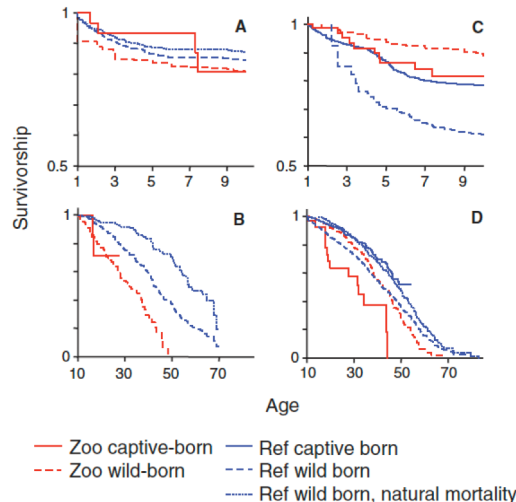


Fig. 1. Kaplan-Meier survivorship curves for female African (A and B) and Asian (C and D) elephants aged 1 to 10 juveniles in (A) and (C) and 10+ years [adults in (B) and (D)]. For wild-born reference (Ref, Amboseli or M.T.E.) populations, natural mortality excludes human-caused deaths; all mortality includes them (5). Results of statistical comparisons are given in table S2.

(table S1). Rates have not significantly improved over time (e.g., live births controlling for parity: $z = 1.19$, $P > 0.10$). For juveniles, captive-born survivorship did not significantly differ between populations, whereas wild-born survivorship was poorer in Burma (Fig. 1C and table S2) because of after-effects of capture (5). In adulthood, however, survivorship was lower in zoos (Fig. 1D and table S2), with no detectable improvement in recent years ($z = -1.48$, $P > 0.10$).

Within zoos, captive-born Asians have poorer adult survivorship than wild-born Asians (Fig. 1D and table S2). This is a true birth origin effect: Whereas zoo-born elephants are more likely to have been born recently and to primiparous dams, neither dam parity ($z = 0.86$, $P > 0.10$) nor recency ($z = -1.48$, $P > 0.10$) predict adult survivorship (controlling for recency makes birth origin more significant: $z = -3.52$,

$P < 0.001$). Because the median importation age of wild-born females was about 3.4 years, this suggests that zoo-born Asians' elevated adult mortality risks are conferred during gestation or early infancy.

Interzoo transfers also reduced Asian survivorship (see supporting online text), an effect lasting 4 years posttransfer ($z = -2.10$, $P < 0.05$, controlling for birth origin). Additionally, survivorship tended to be poorer in Asian calves removed from mothers at young ages ($z = -1.92$, $P < 0.10$) (5).

Overall, bringing elephants into zoos profoundly impairs their

viability.

1. R. Clubb, G. Mason, A Review of the Welfare of Zoo Elephants in Europe (RSPCA, Horsham, UK, 2002).
2. M. Hutchins, M. Keele, *Zoo Biol.* 25, 219 (2006).
3. European Elephant Group, "Elephants in zoos and safari parks Europe" (European Elephant Group, Grünwald, Germany, 2002).
4. Methods and supplementary results are available as supporting material on Science Online.
5. G.J.M. thanks the Natural Science

Overall, bringing elephants into zoos profoundly impairs their viability.

is a visiting professor at The Royal Veterinary College, London, UK. K.U.M. has received funding from Prospect Burma Foundation, Charles Wallace Burma Trust, Three Oaks Foundation, Whitney-Laing Foundation (Rutford Small Grants), Toyota Foundation, Fantham Memorial Research Scholarship, and University College London. K.U.M. has been a paid consultant for Woburn Safari Park, UK. G.J.M. has been a paid consultant to Disney's Animal Kingdom, USA.

Supporting Online Material

www.sciencemag.org/cgi/content/full/322/5908/1649/D1

Materials and Methods

SOM Text

Tables S1 and S2

References

6 August 2008; accepted 22 September 2008
10.1126/science.1164298

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*To whom correspondence should be addressed. E-mail: gmason@uoguelph.ca

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Comparative analyses of longevity and senescence reveal variable survival benefits of living in zoos across mammals

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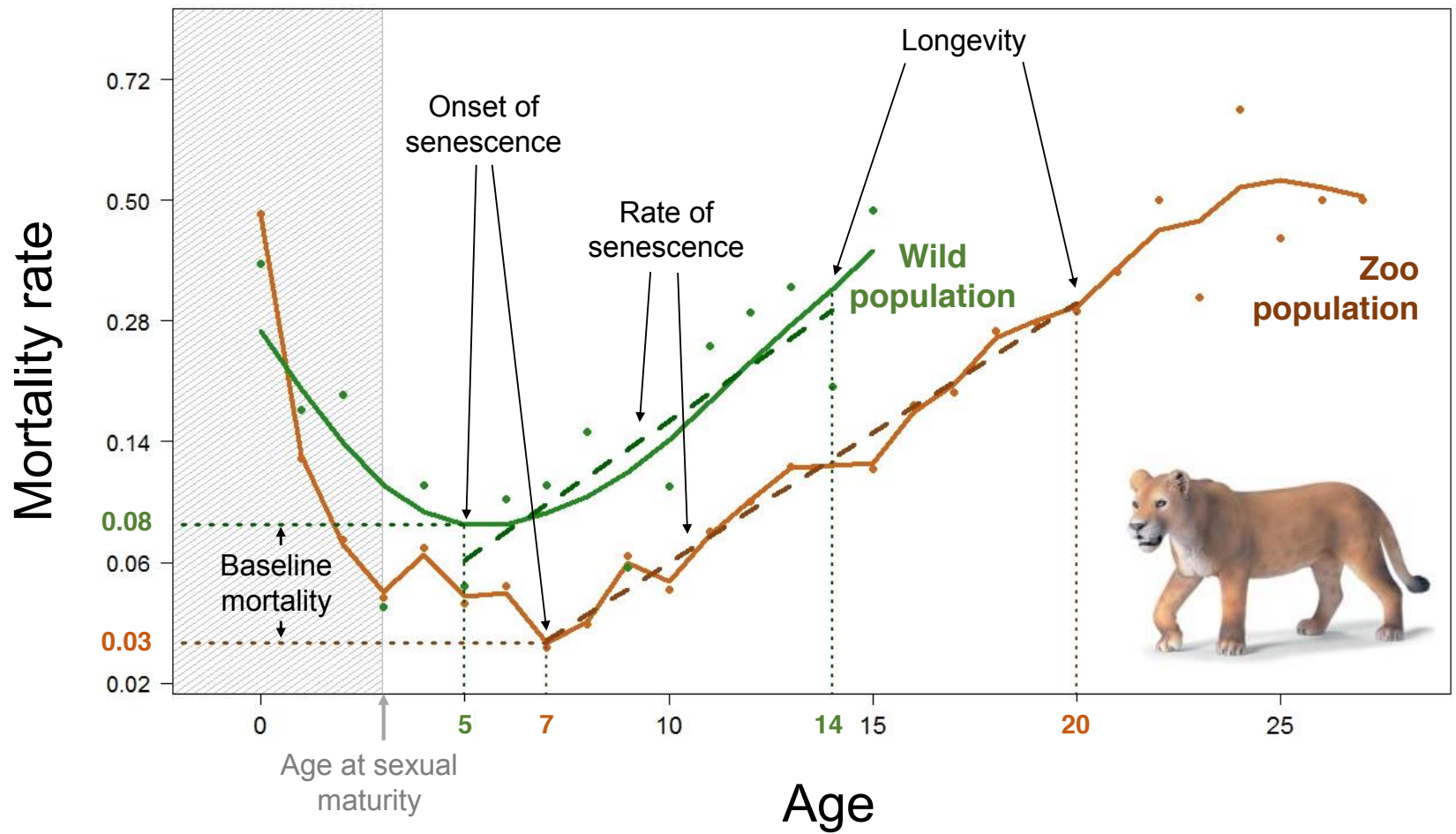
Morgane Tidière¹, Jean-Michel Gaillard¹, V  r  ne Berger¹, Dennis W. H. M  ller², Laurie Bingaman Lackey³, Olivier Gimenez⁴, Marcus Clauss⁵ & Jean-Fran  ois Lema  tre¹

While it is commonly believed that animals live longer in zoos than in the wild, this assumption has rarely been tested. We compared four survival metrics (longevity, baseline mortality, onset of senescence and rate of senescence) between both sexes of free-ranging and zoo populations of more than 50 mammal species. We found that mammals from zoo populations generally lived longer than their wild counterparts (84% of species). The effect was most notable in species with a faster pace of life (i.e. a short life span, high reproductive rate and high mortality in the wild) because zoos evidently offer protection against a number of relevant conditions like predation, intraspecific competition and diseases. Species with a slower pace of life (i.e. a long life span, low reproduction rate and low mortality in the wild) benefit less from captivity in terms of longevity; in such species, there is probably less potential for a reduction in mortality. These findings provide a first general explanation about the different magnitude of zoo environment benefits among mammalian species, and thereby highlight the effort that is needed to improve captive conditions for slow-living species that are particularly susceptible to extinction in the wild.

Zoological gardens represent artificial environments in which animals are maintained, bred and displayed. By doing so, zoos achieve a diversity of goals beyond their visitors' recreation: basic zoological and conservation education reaches 700 million visitors per year all over the world¹. Continuing research and expertise building by many thousands of zoo staff worldwide continuously improves knowledge of animal, population and ecosystem management. Zoos also aim to maintain viable *ex situ* insurance populations of endangered species that can be used for re-introduction to the wild^{2,3}. Zoo staff manages and generates funding for *in situ* conservation projects^{1,4}. Finally, zoos facilitate opportunities for researchers to increase expertise in a large variety of areas, from basic zoology to applied husbandry and molecular biology.

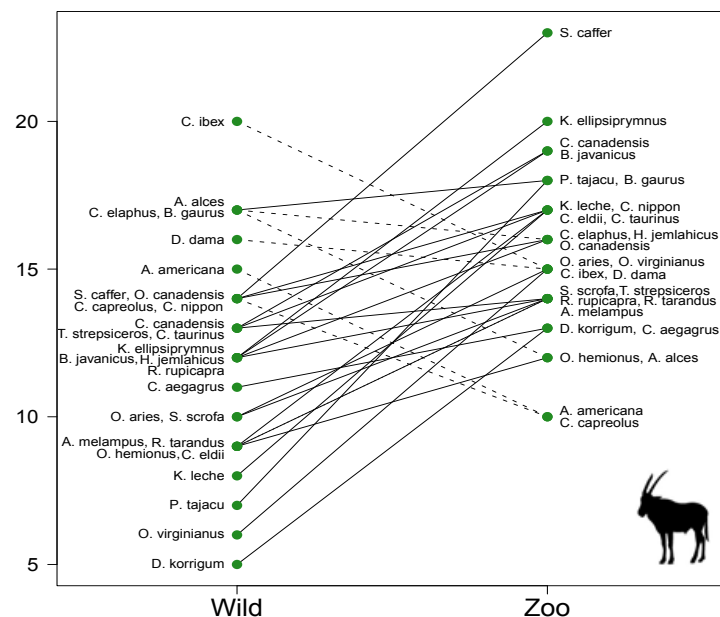
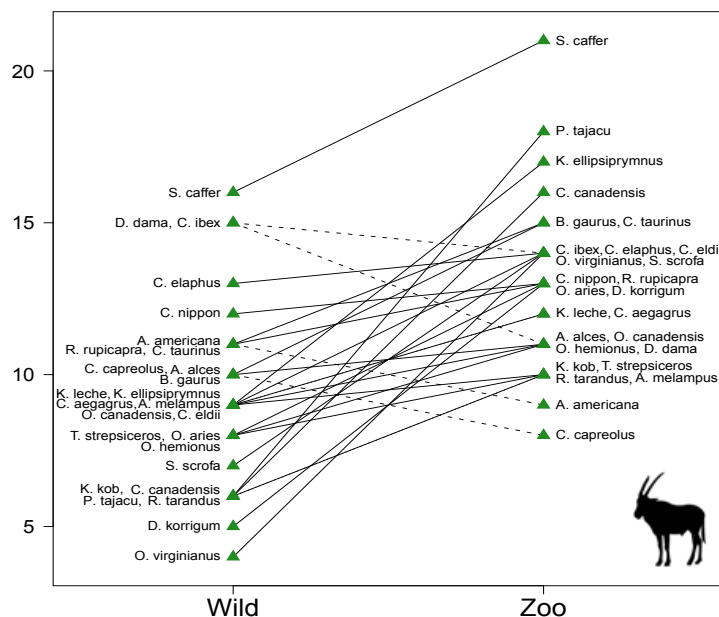
When assessing the justification of holding nondomestic species in zoos, the welfare of the individual animals housed in captivity is a critical ethical issue that has to be weighed against these aims⁵. There is no single proxy to measure the welfare of animals. Indicators typically employed include measures of survival (such as longevity, annual survival, or ageing rate), reproduction (such as fertility or litter size), physiology (such as stress hormones or the occurrence of specific diseases) and behavior (such as stereotypies)^{5,6}. It is typically believed that zoo animals live longer than their free-ranging conspecifics due to the consistent provision of food, water, and shelter from harsh climates, the absence of predation and management to minimize violent intraspecific encounters and accidents, as well as veterinary prophylactic and therapeutic intervention. However, zoo animals may be subject to behavioral deficits⁶. While an increasing number of comparative studies have demonstrated species-specific differences in the response to zoo-conditions^{7–9}, and a few species-specific comparisons of survival metrics between free-ranging and captive specimens have been published^{10,11}, large-scale inter-specific comparisons of captive and

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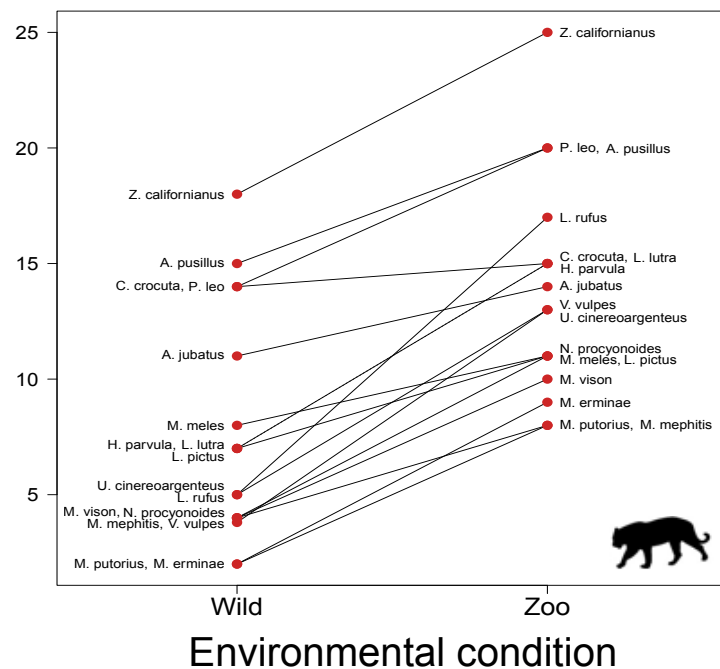
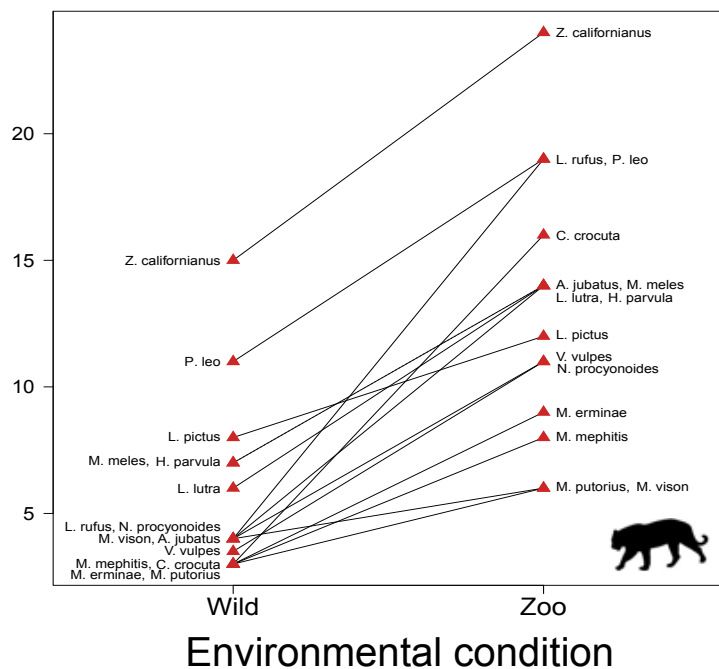


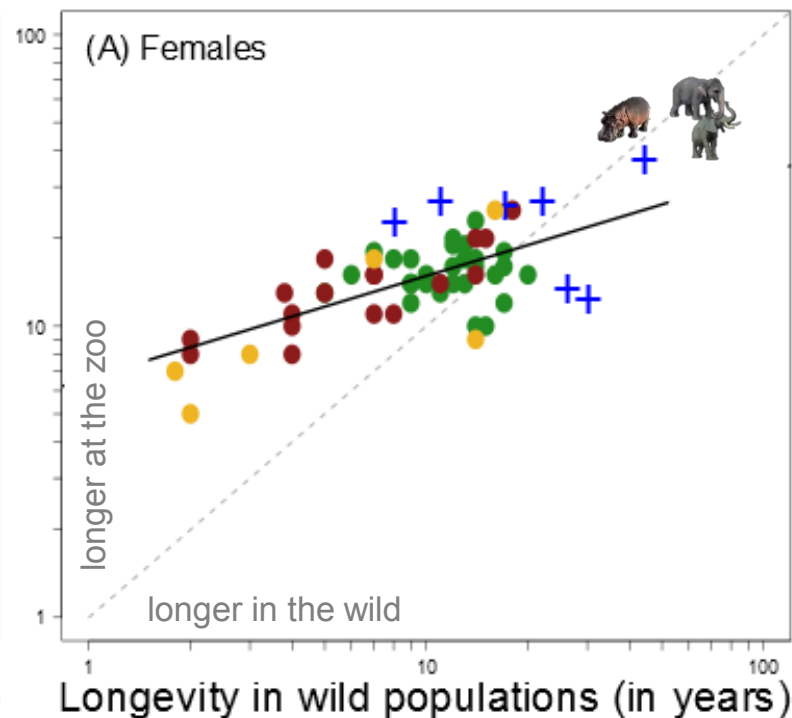
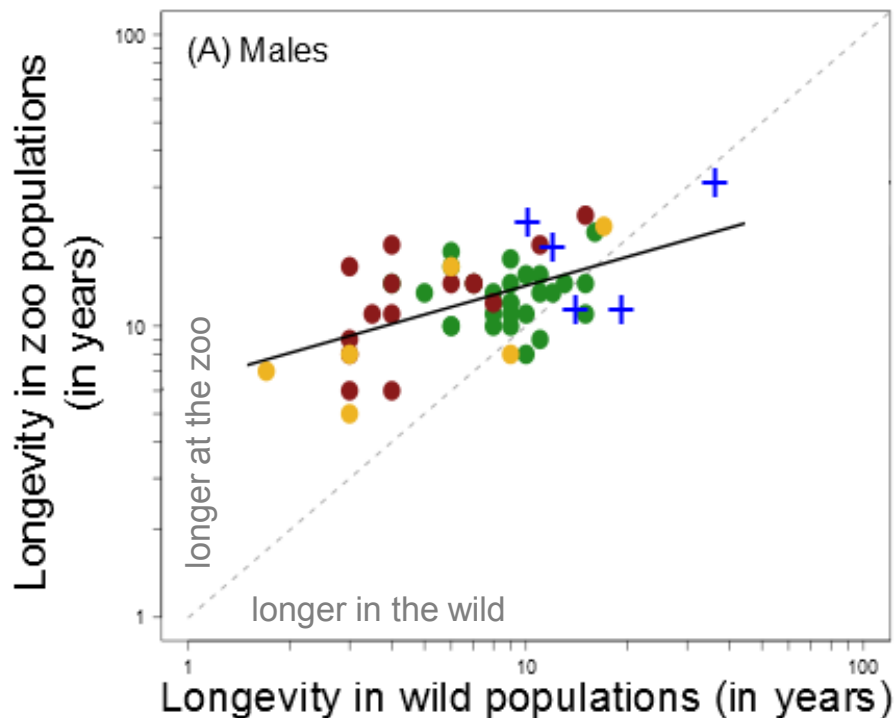


Longevity according to environmental condition for Artiodactyla species (in years)



Longevity according to environmental condition for Carnivora species (in years)





These findings provide a first general explanation about the different magnitude of zoo environment benefits among mammalian species, and thereby highlight the effort that is needed to improve captive conditions for slow-living species that are particularly susceptible to extinction in the wild.