



Tooth wear - causes and (evolutionary) consequences review of the evidence

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NESCent Symposium 2011



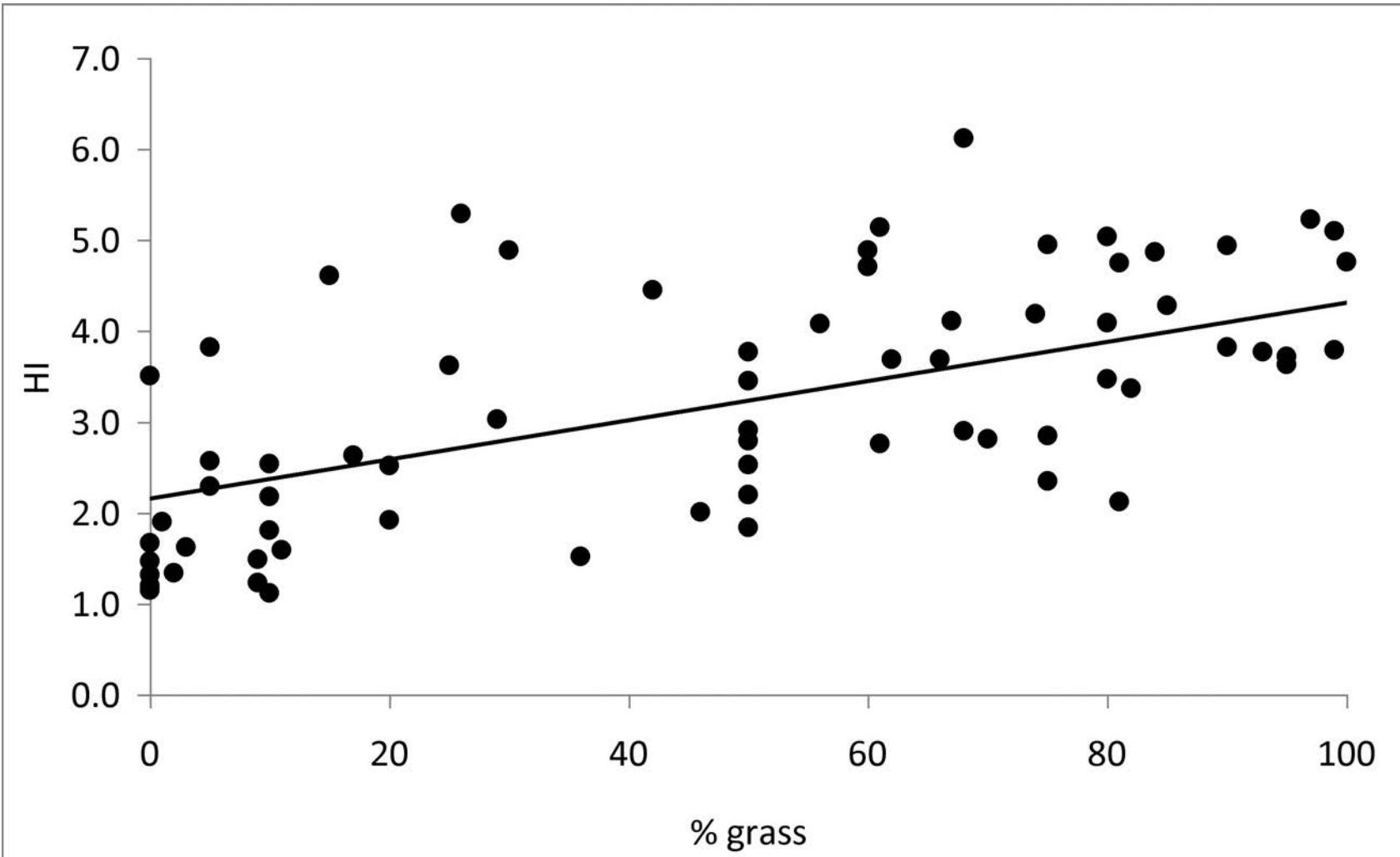


Tooth wear

- Do animals show adaptations to tooth wear?
- Do variations in tooth wear drive the quantitative expression of these adaptations?
- Hypsodonty, mesowear, tooth wear (height/volume per time)
- Diet abrasiveness



Hypsodonty and grass



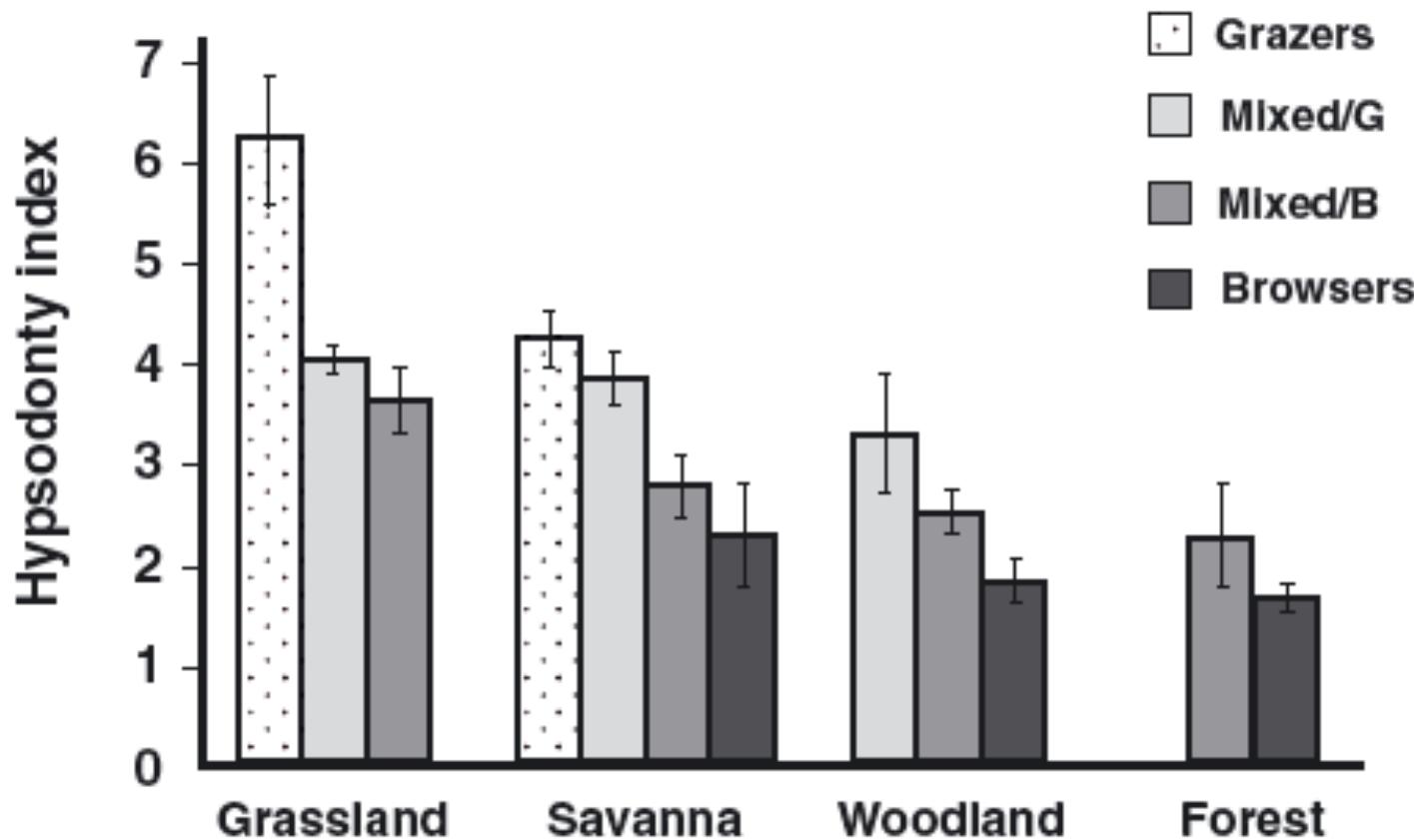
own evaluation, but similar findings published by Janis (1995), Perez-Barberia and Gordon (2001), Mendoza and Palmqvist (2008)



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

John Damuth^{1*} and Christine M. Janis²

Biol. Rev. (2011),

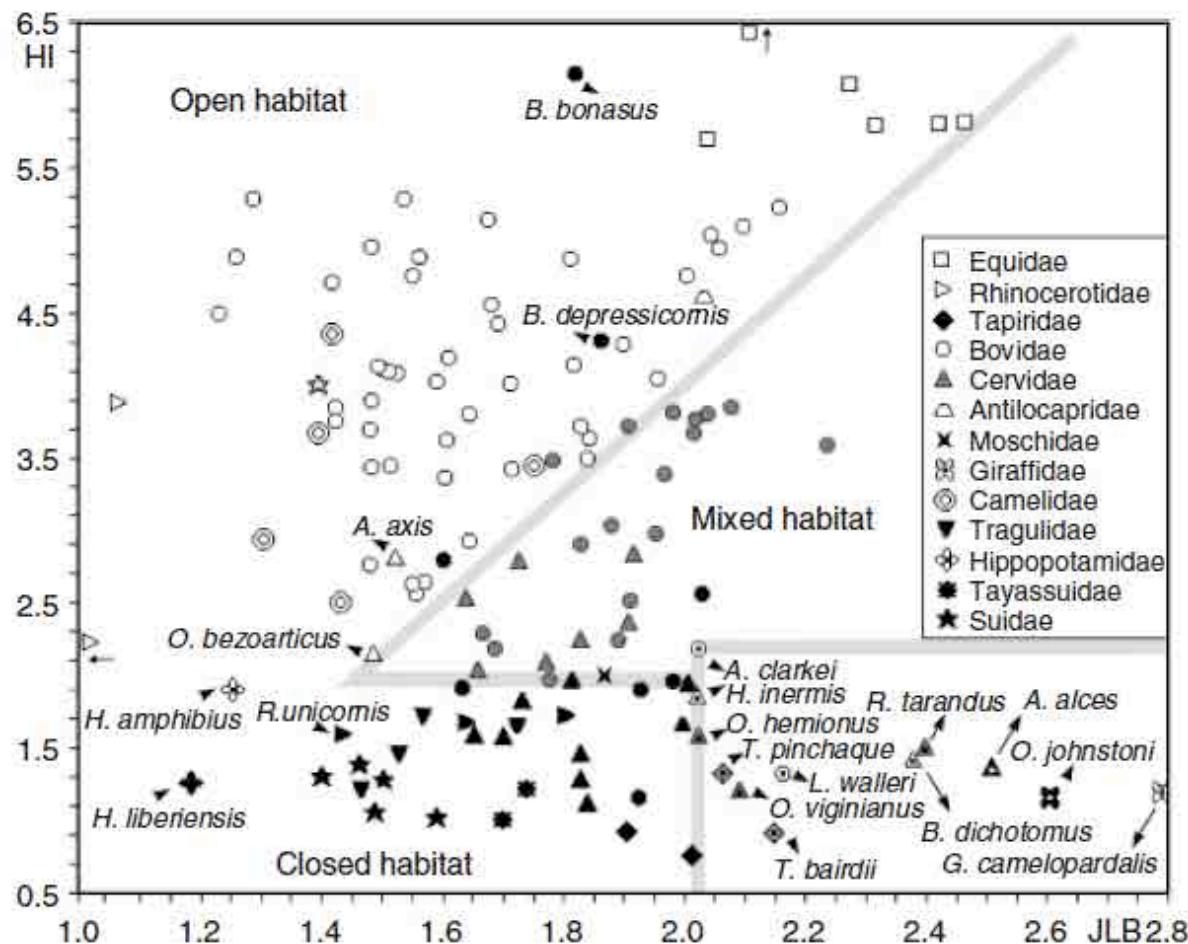




Hypsodonty in ungulates: an adaptation for grass consumption or for foraging in open habitat?

M. Mendoza¹ & P. Palmqvist²

Journal of Zoology 274 (2008) 134–142





Journal of Zoo and Wildlife Medicine 39(1): 69–75, 2008
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IRREGULAR TOOTH WEAR AND LONGEVITY IN CAPTIVE WILD RUMINANTS: A PILOT SURVEY OF NECROPSY REPORTS

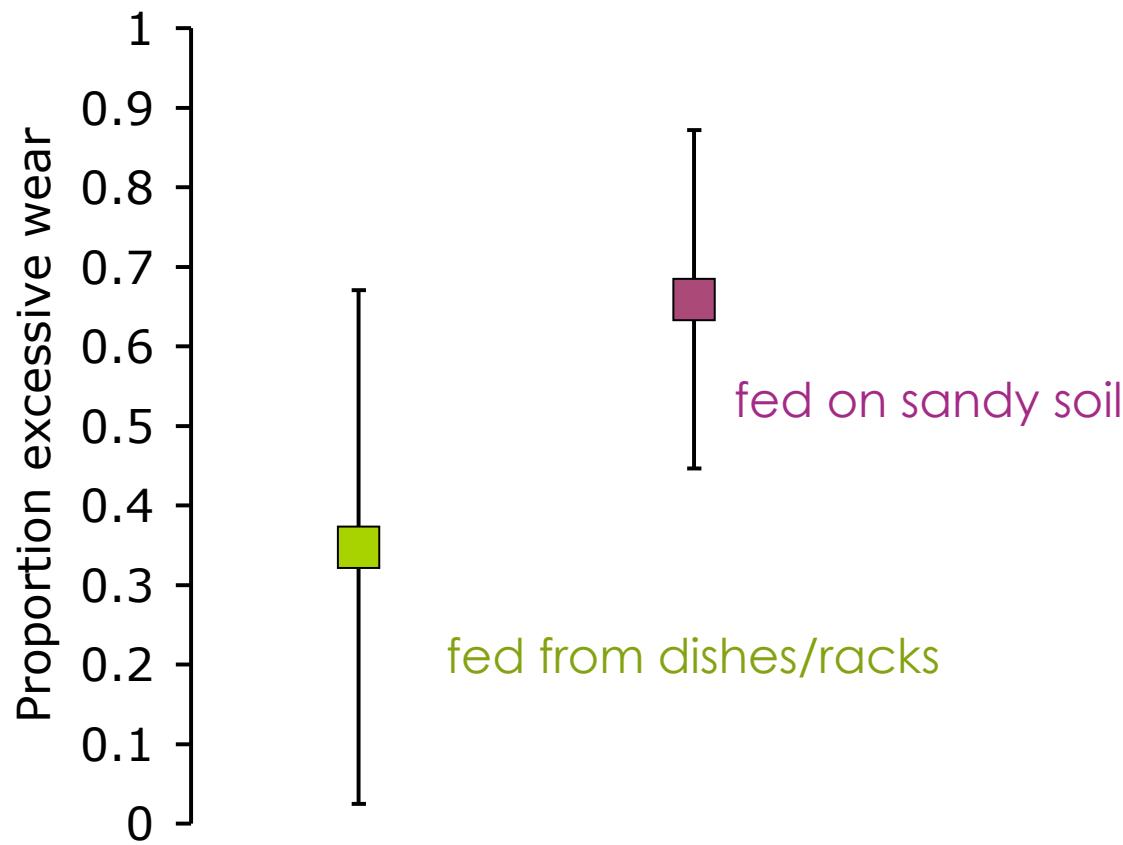
Olga Martin Jurado, med.vet., Marcus Clauss, M.Sc., Dr.med.vet., Dipl. E.C.V.C.N., W. Jürgen Streich, Dr.rer.nat., and Jean-Michel Hatt, M.Sc., Prof. Dr.med.vet., Dipl. E.C.A.M.S., Dipl. A.C.Z.M.



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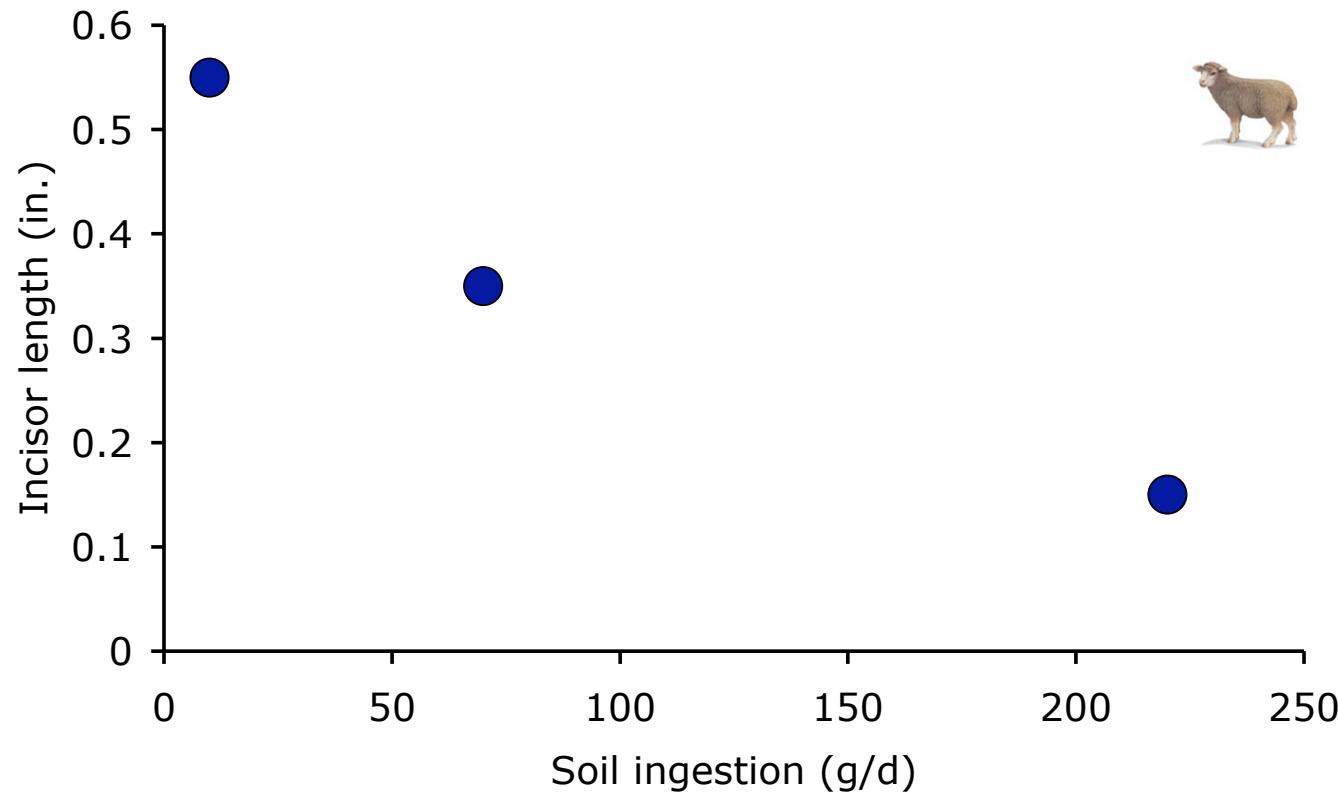
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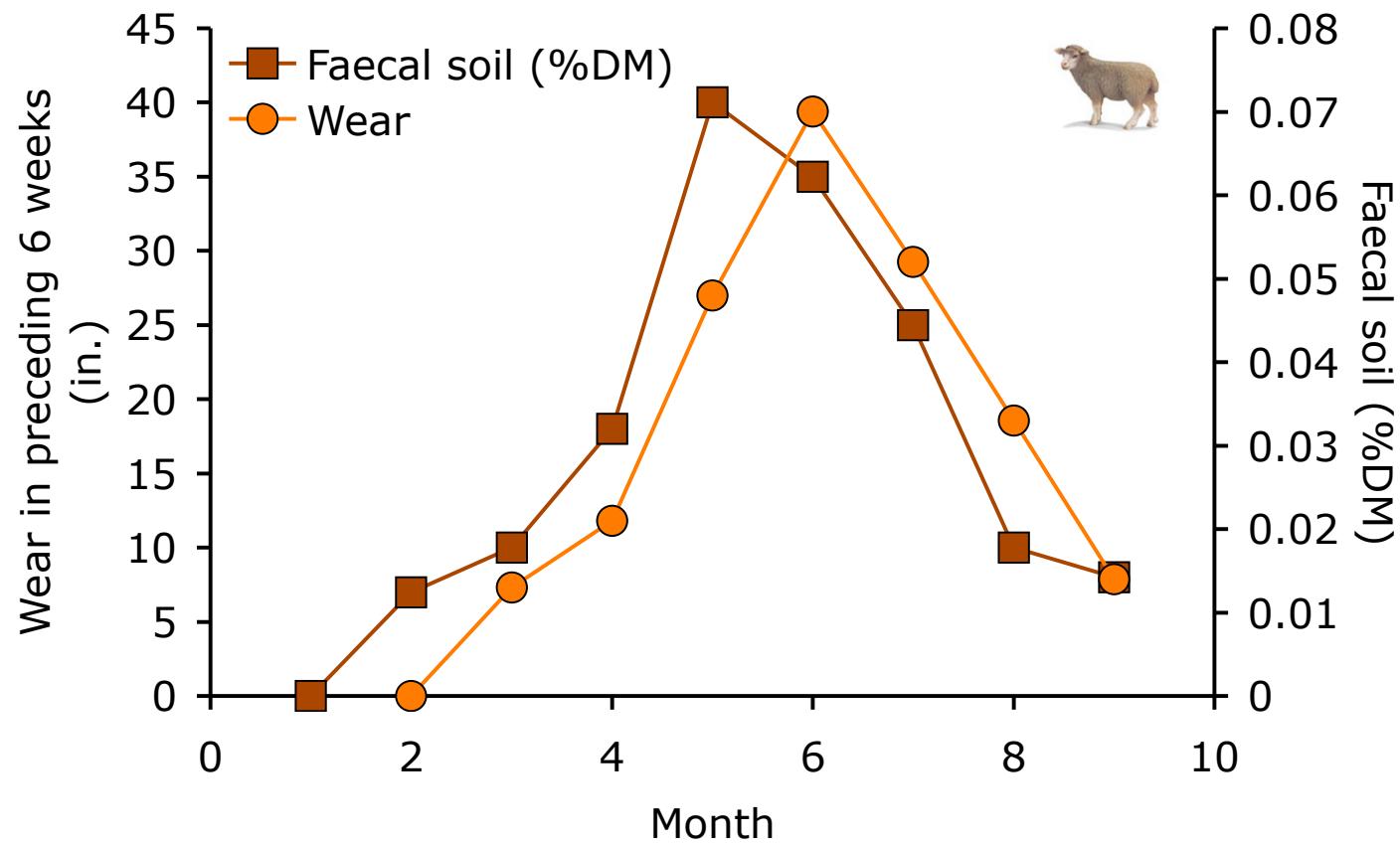
Soil ingestion and wear



from Healey et al. (1965)



Soil ingestion and wear



from Healey et al. (1966)



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



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Food item	n	AIA (%DM)		Source
		Mean	Range	
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
Alfalfa meal pellet	9	0.3	0.0–0.7	Castell ⁴
	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.



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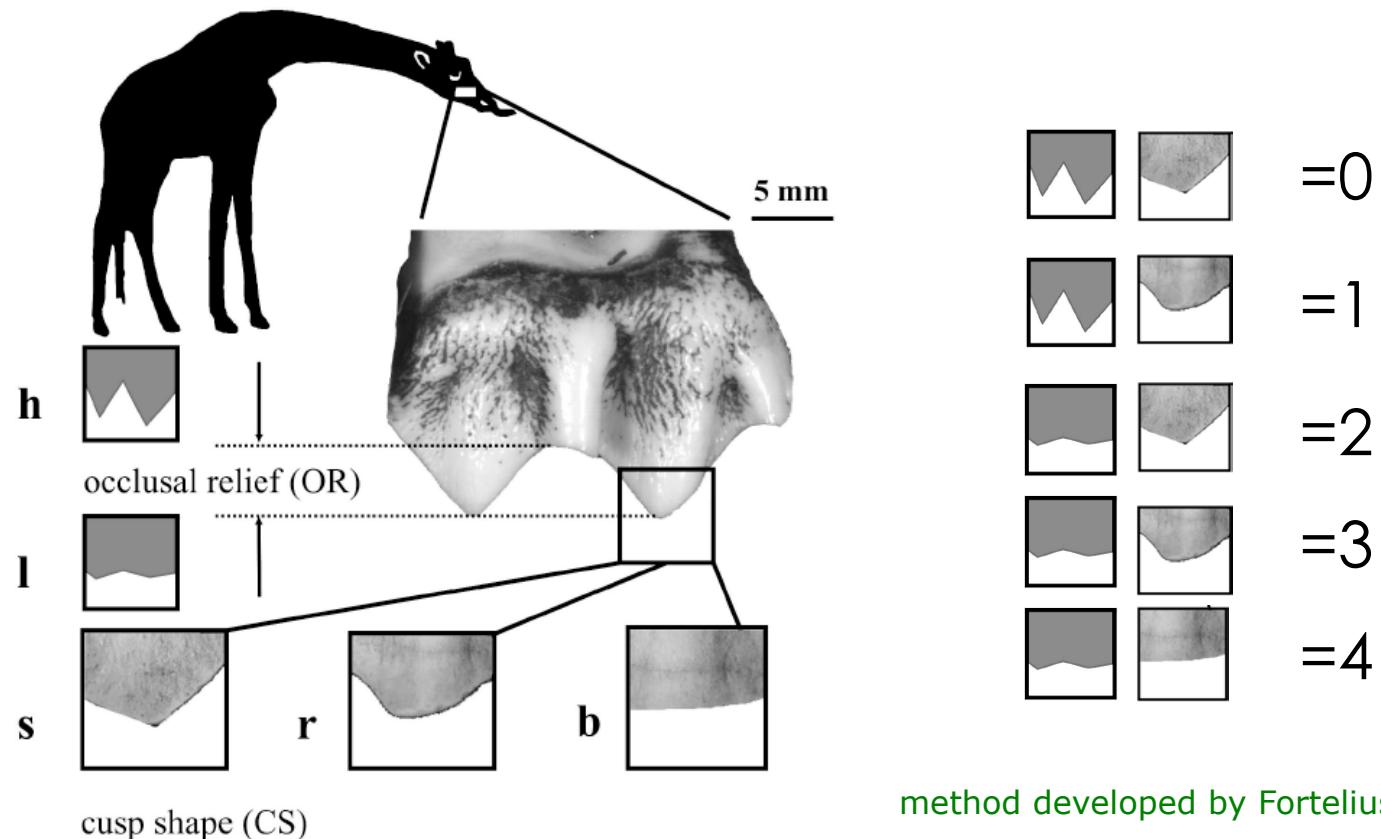


Foto: Johanna Castell



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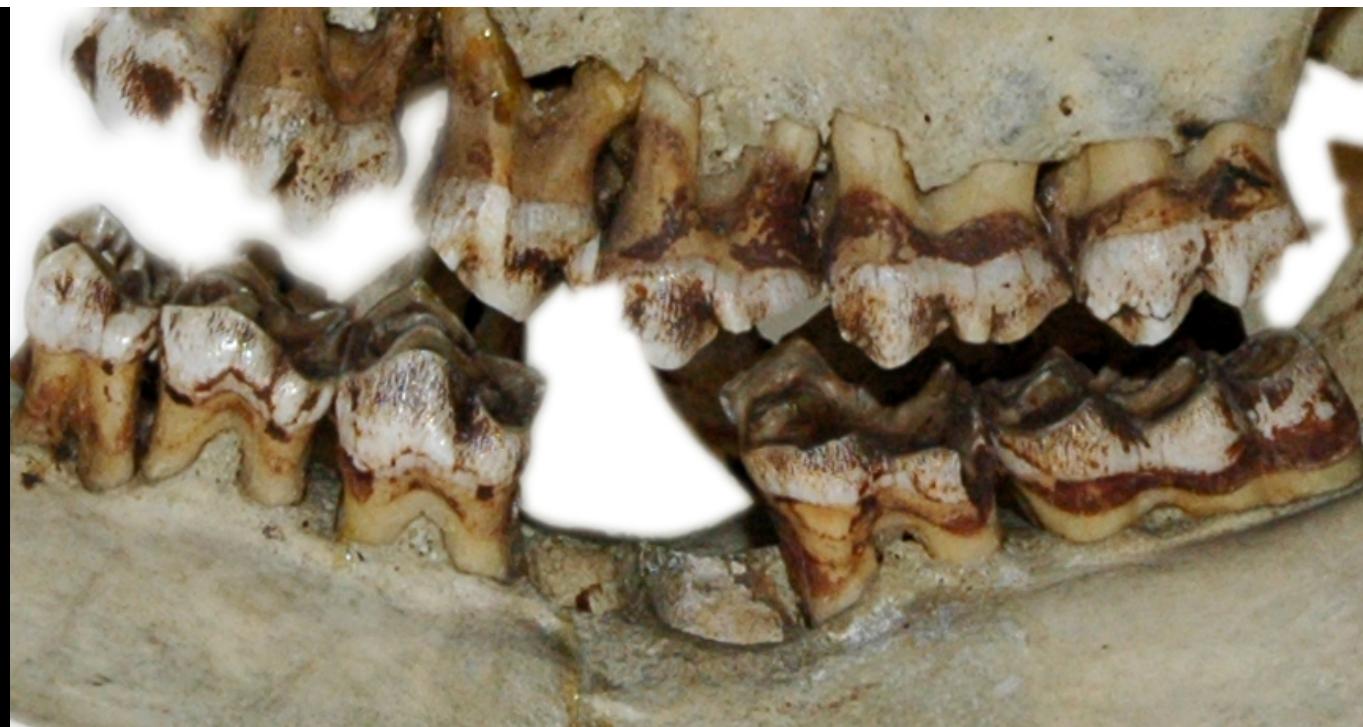




Free-ranging vs. captive giraffes



from Clauss et al. (2007)



from Clauss et
al. (2007)

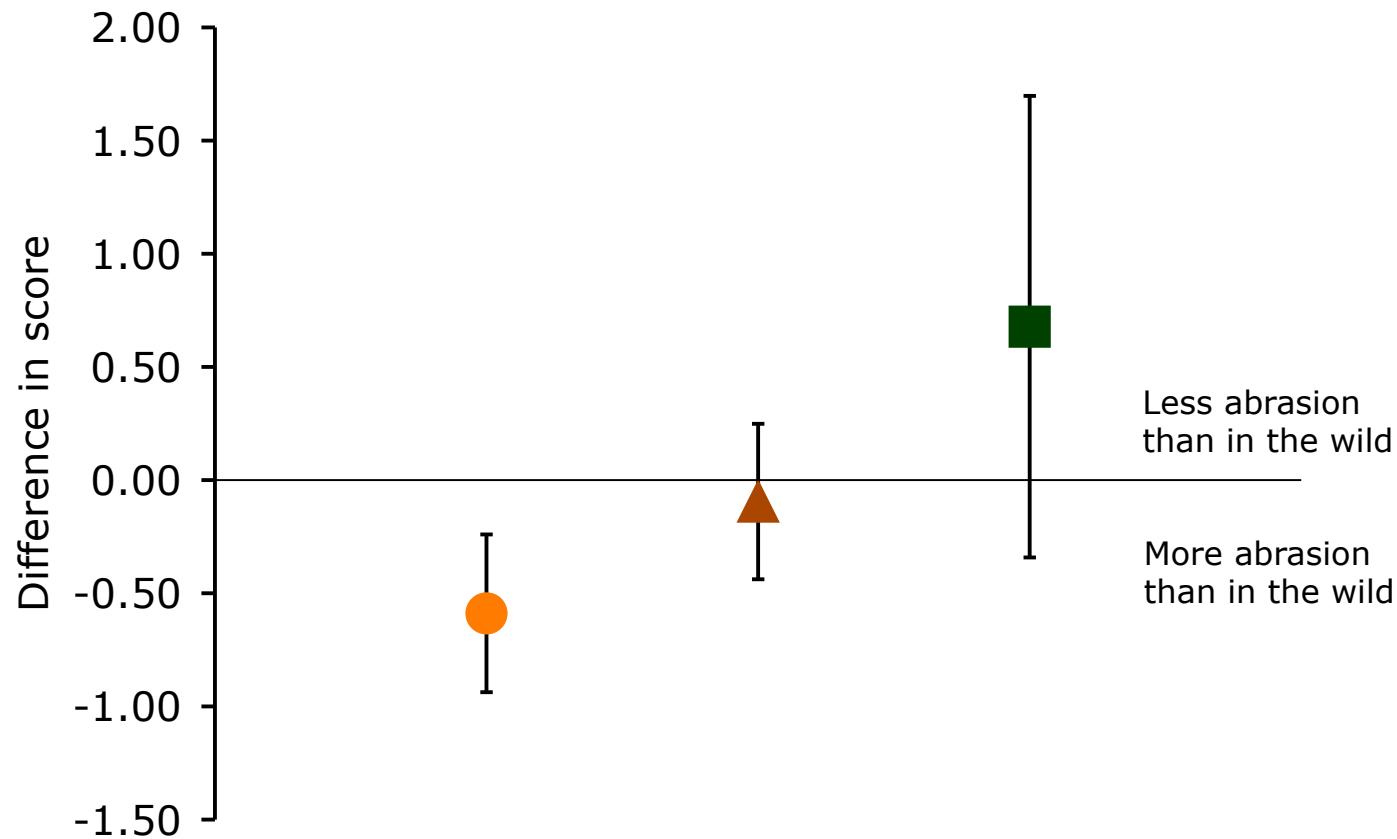
Giraf
Bel



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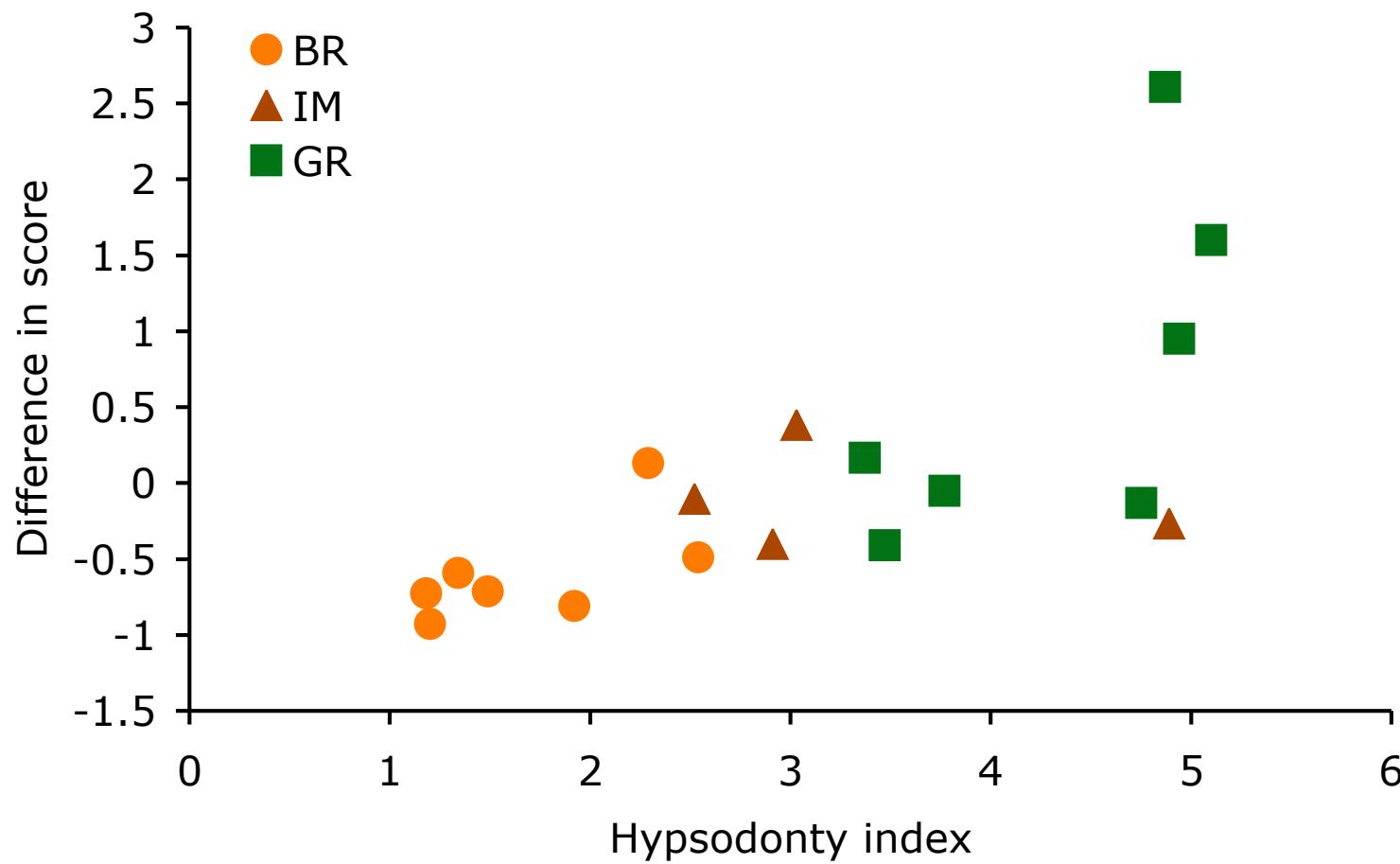




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Another one bites the dust: faecal silica levels in large herbivores correlate with high-crowned teeth

Jürgen Hummel^{1,*}, Eva Findeisen¹, Karl-Heinz Südekum¹,
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Proc. R. Soc. B (2011) 278, 1742–1747



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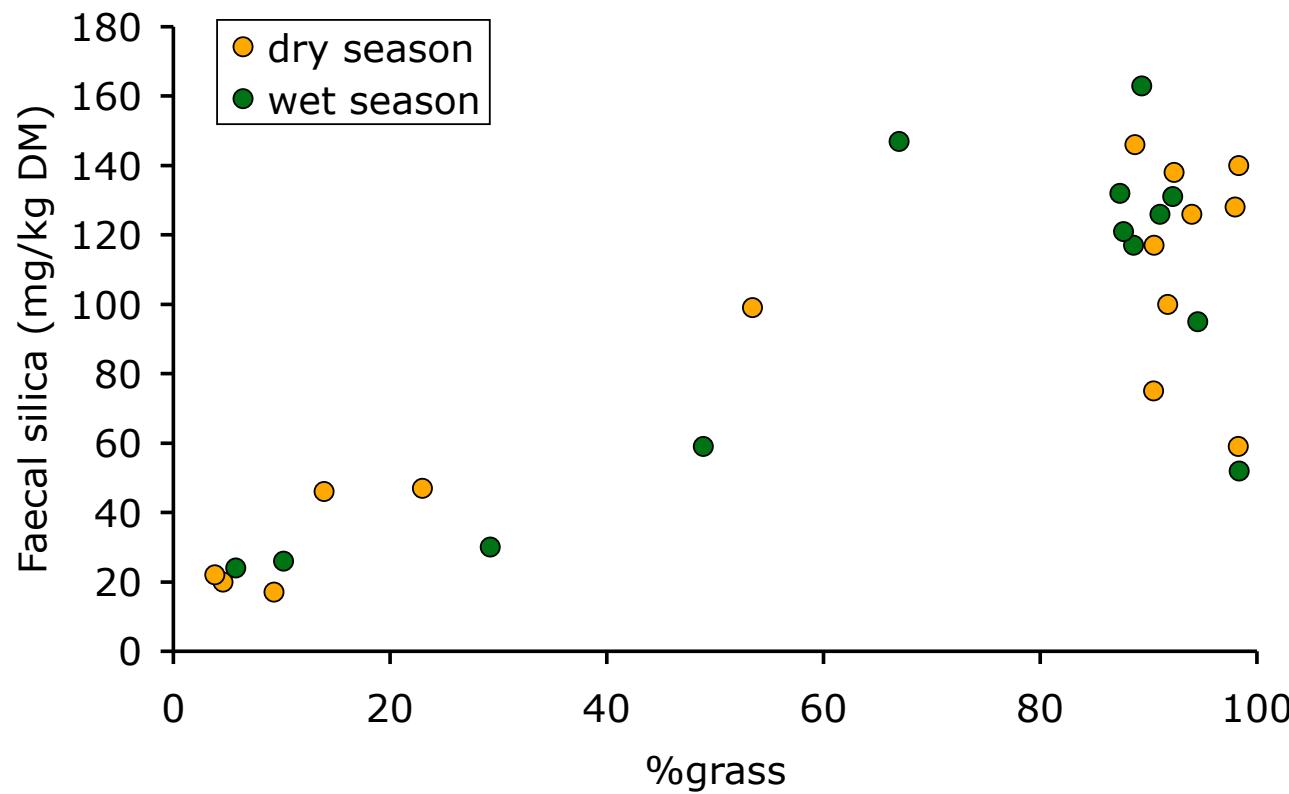




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ESTIMATES OF SOIL INGESTION BY WILDLIFE

W. NELSON BEYER, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, 12011 Beech Forest Road, Laurel, MD 20708-4041

ERIN E. CONNOR, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, MD 20708

SARAH GEROULD, U.S. Geological Survey, Mail Stop 412, 12201 Sunrise Valley Drive, Reston, VA 22092

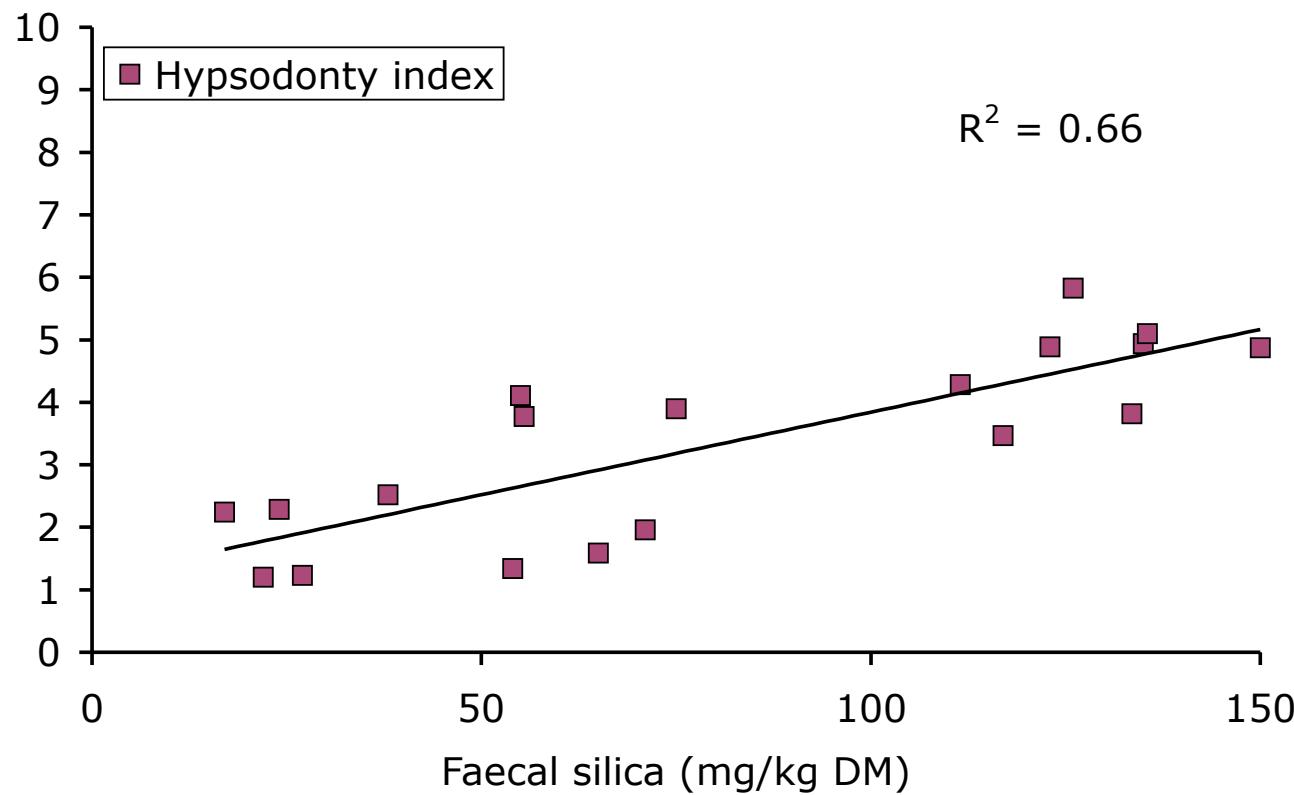
***J. WILDL. MANAGE.* 58(2):375–382**



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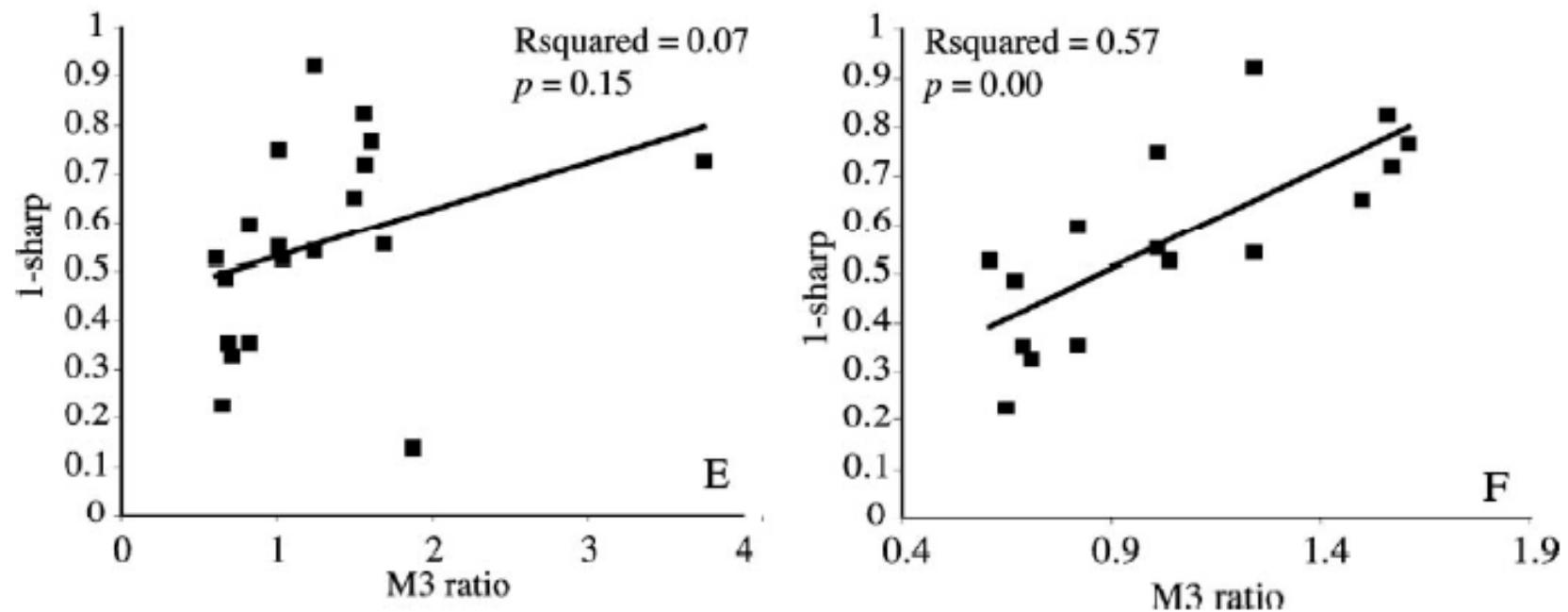




Coevolution of Tooth Crown Height and Diet in Oreodonts (Merycoidodontidae, Artiodactyla) Examined with Phylogenetically Independent Contrasts

Matthew C. Mihlbachler^{1,2,3} and Nikos Solounias^{1,2}

Journal of Mammalian Evolution, Vol. 13, No. 1, March 2006

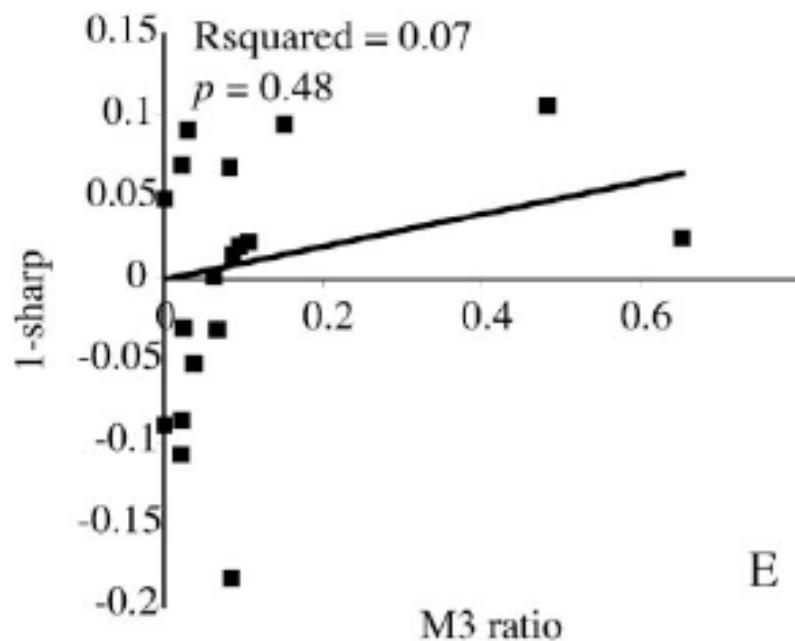




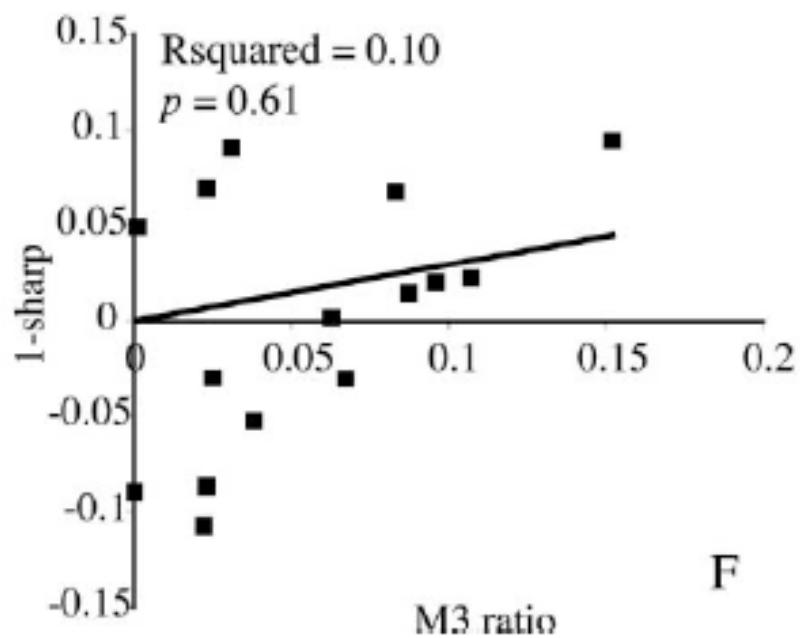
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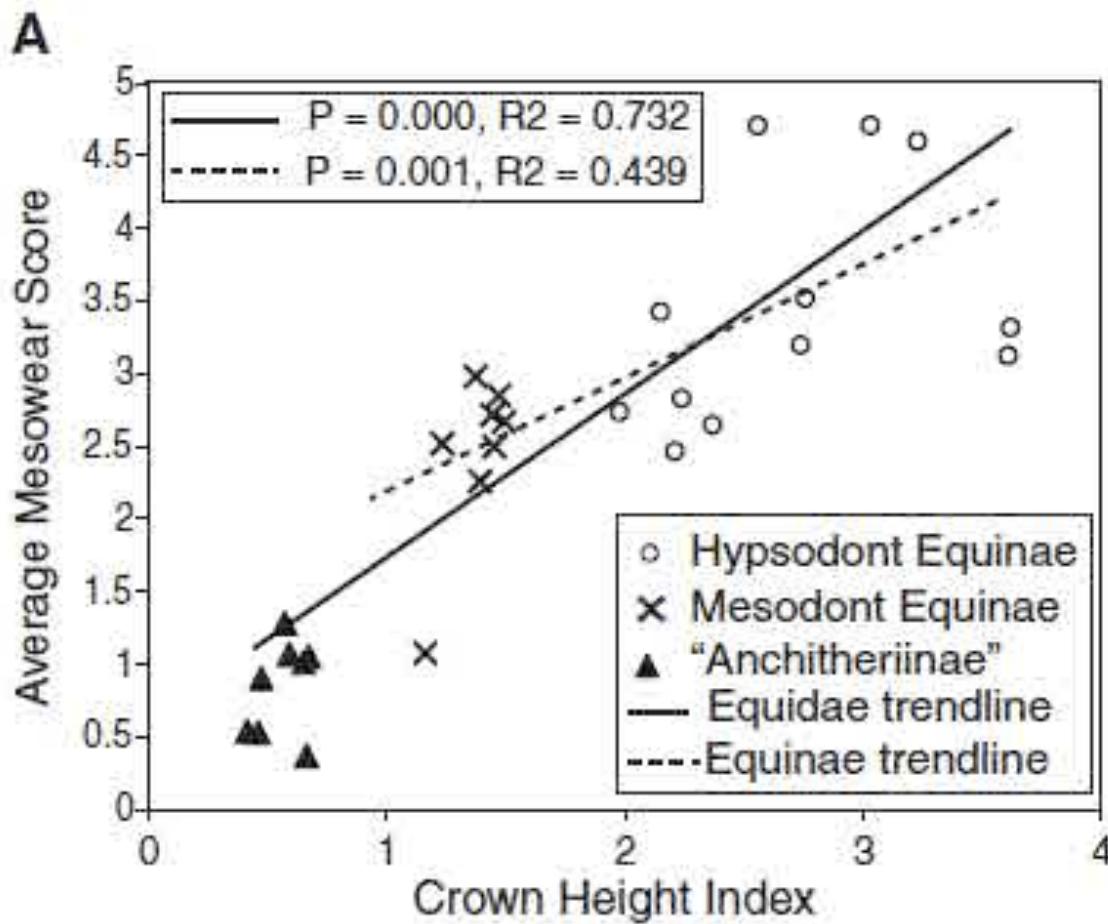
F



Dietary Change and Evolution of Horses in North America

Matthew C. Mihlbachler,^{1,2*} Florent Rivals,³ Nikos Solounias,^{1,2} Gina M. Semprebon⁴

4 MARCH 2011 VOL 331 SCIENCE

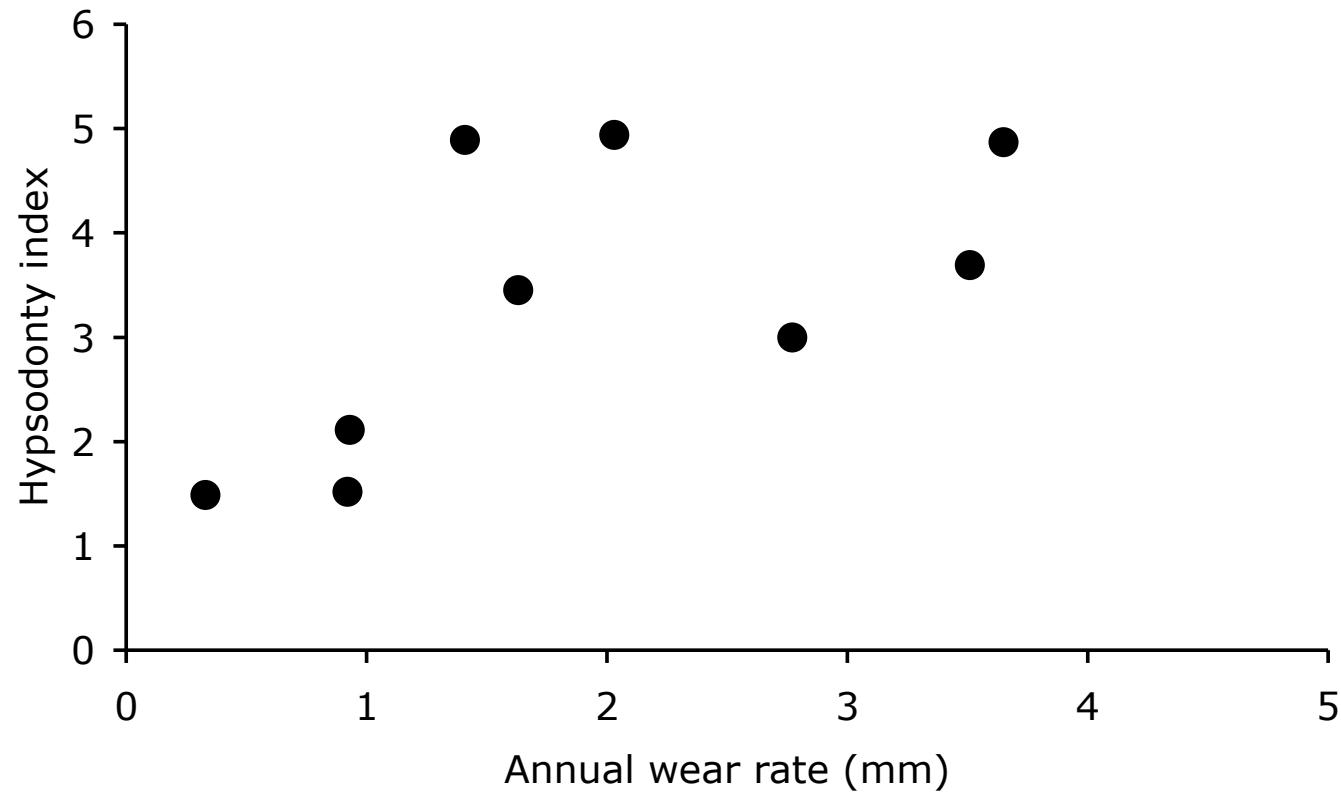




Molar wear rates in ruminants: a new approach

N. Solounias, M. Fortelius & P. Freeman

Ann. Zool. Fennici 31:219–227
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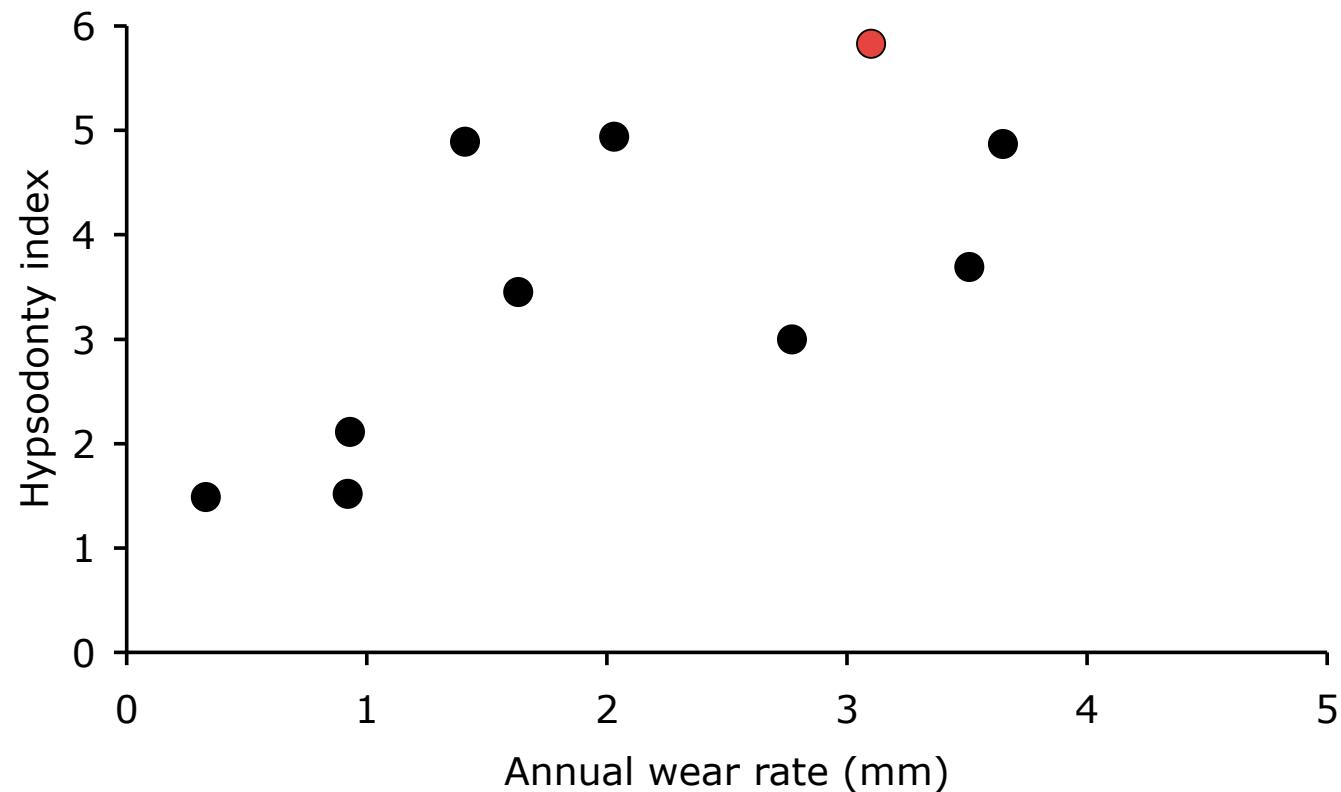




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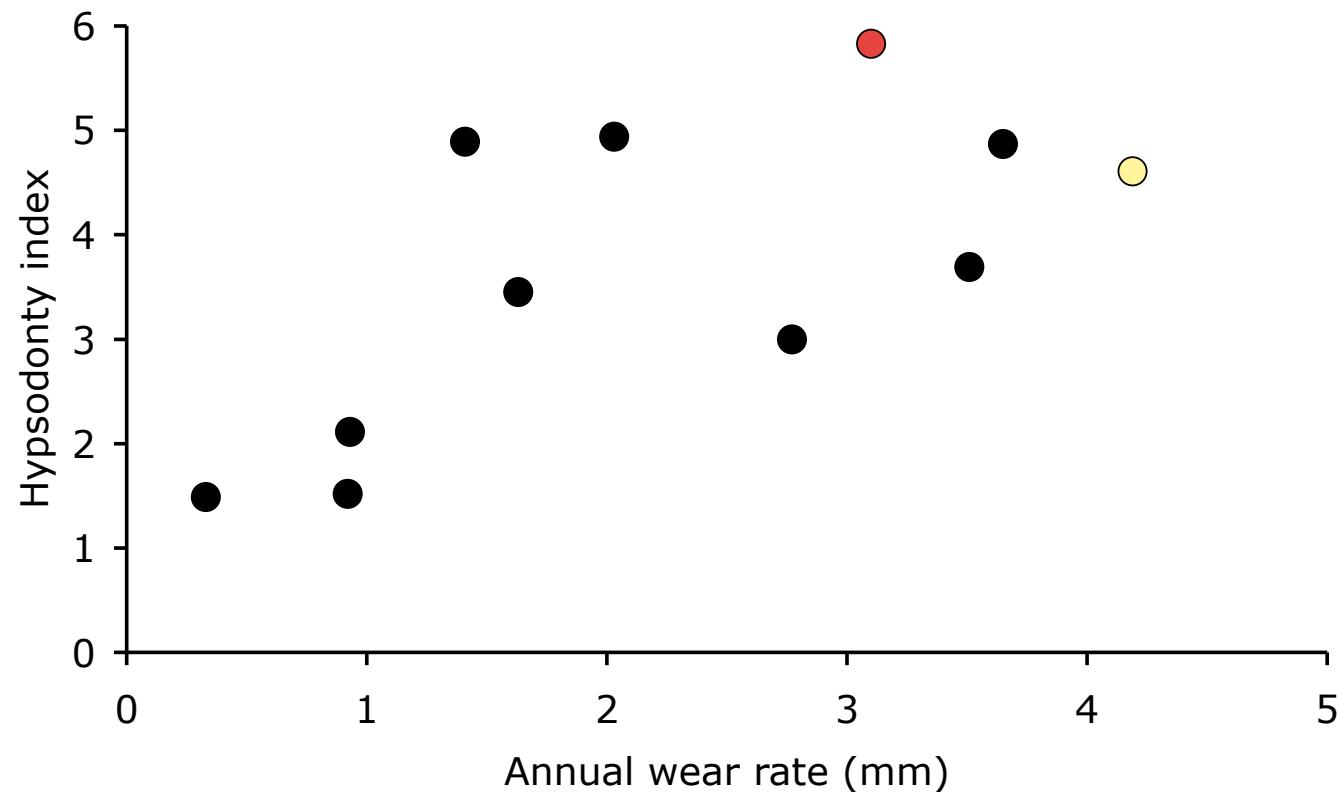




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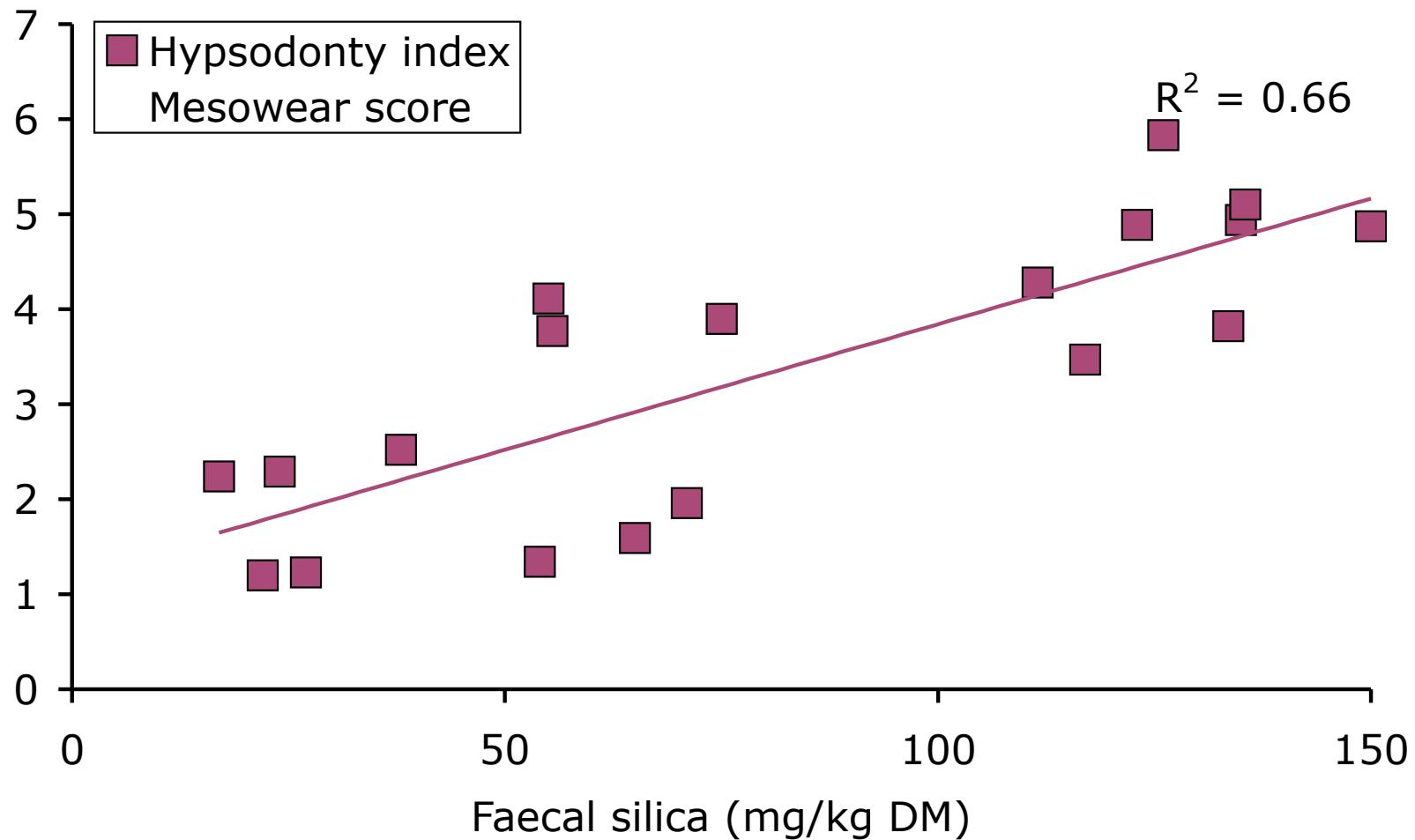


Testing the mesowear signal

- Species level (comparative)
- Calculating mesowear score from Fortelius & Solounias (2000) and the data collection of Kaiser; matching hypsodonty index from Janis (1988)
- Using %grass from own data collection
- Using habitat score from Mendoza & Palmqvist (2008)
- Using precipitation and other climate data from Pantheria
- Analyses with OLS and PGLS

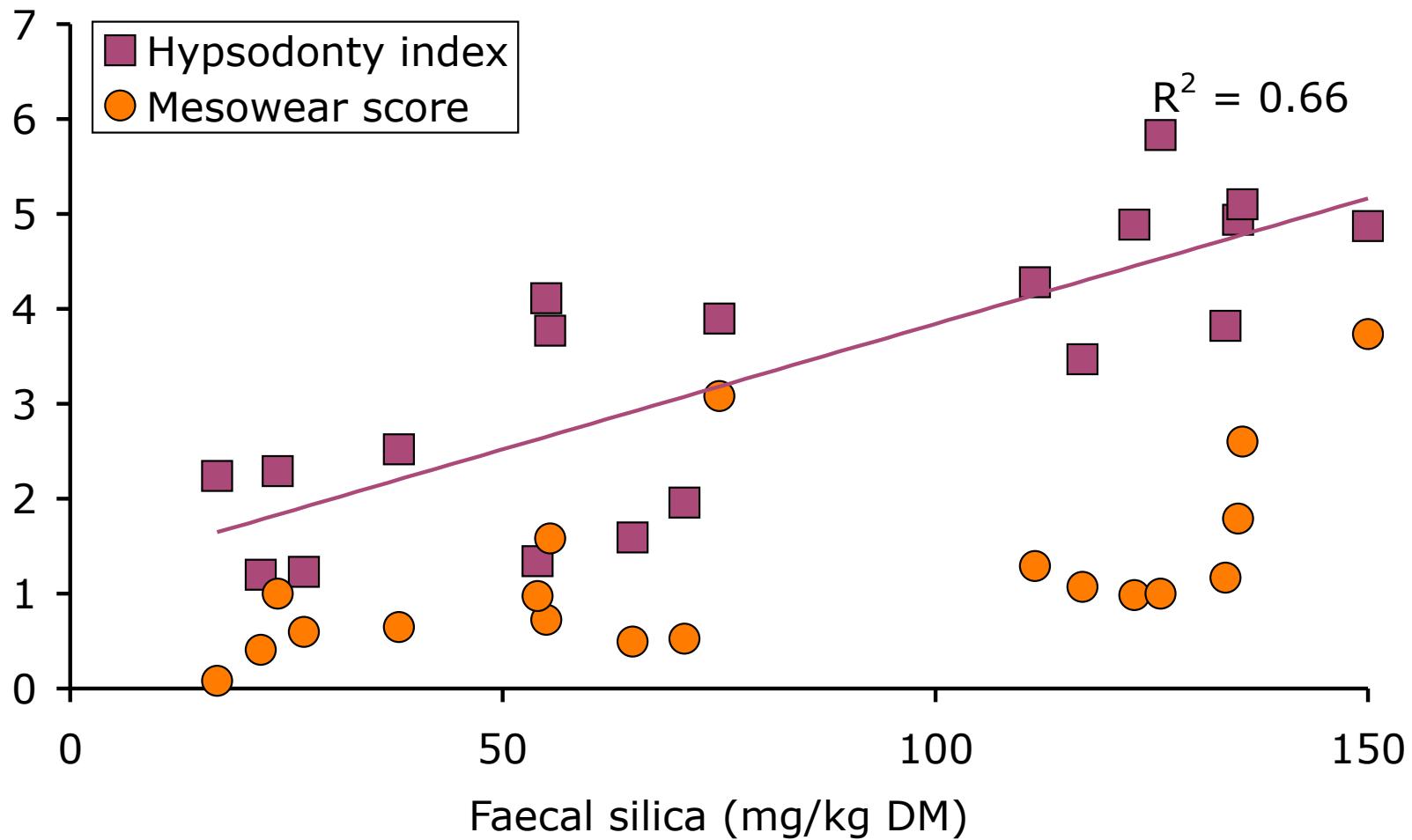


Is diet abrasiveness reflected in the mesowear score?



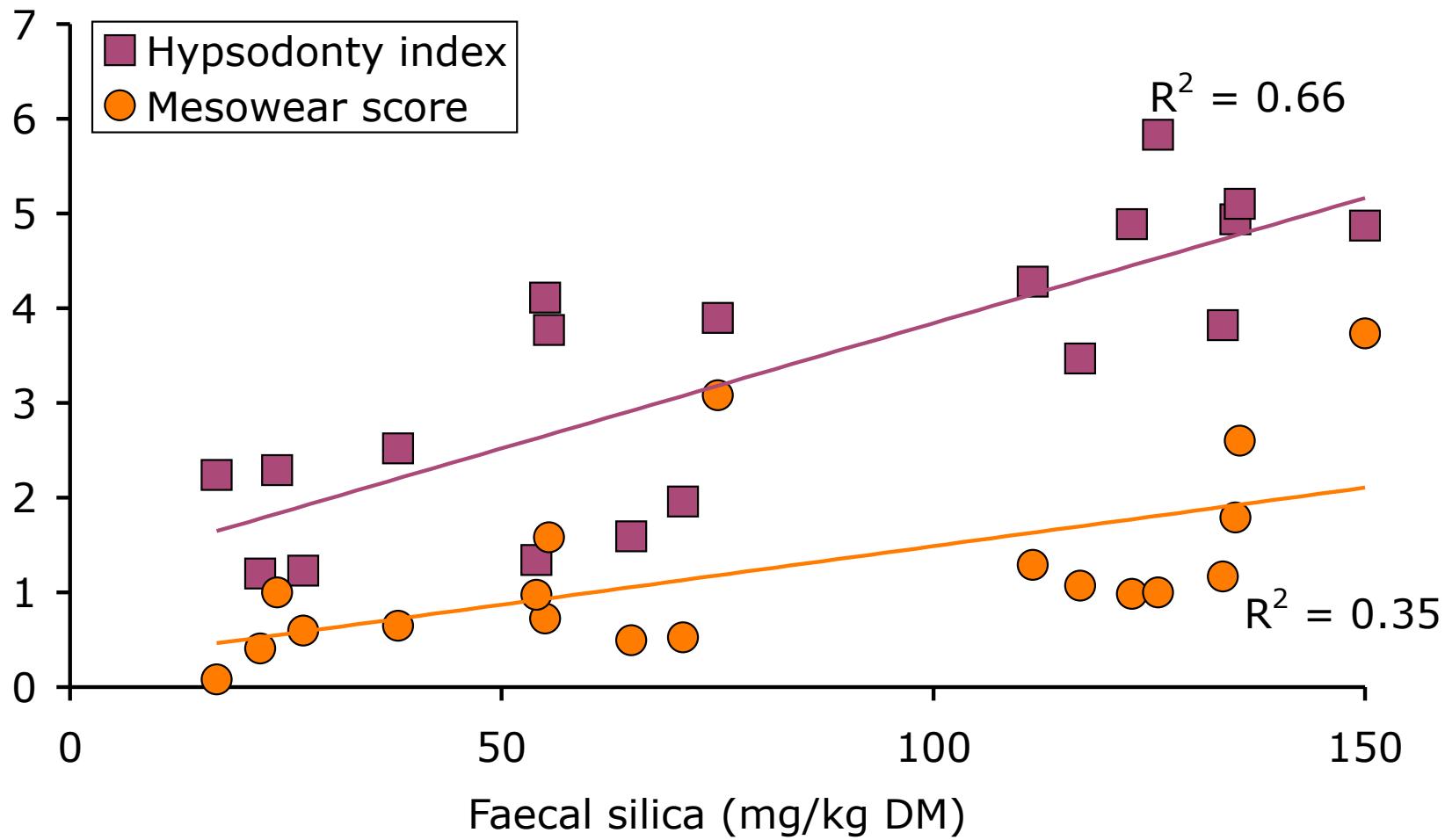


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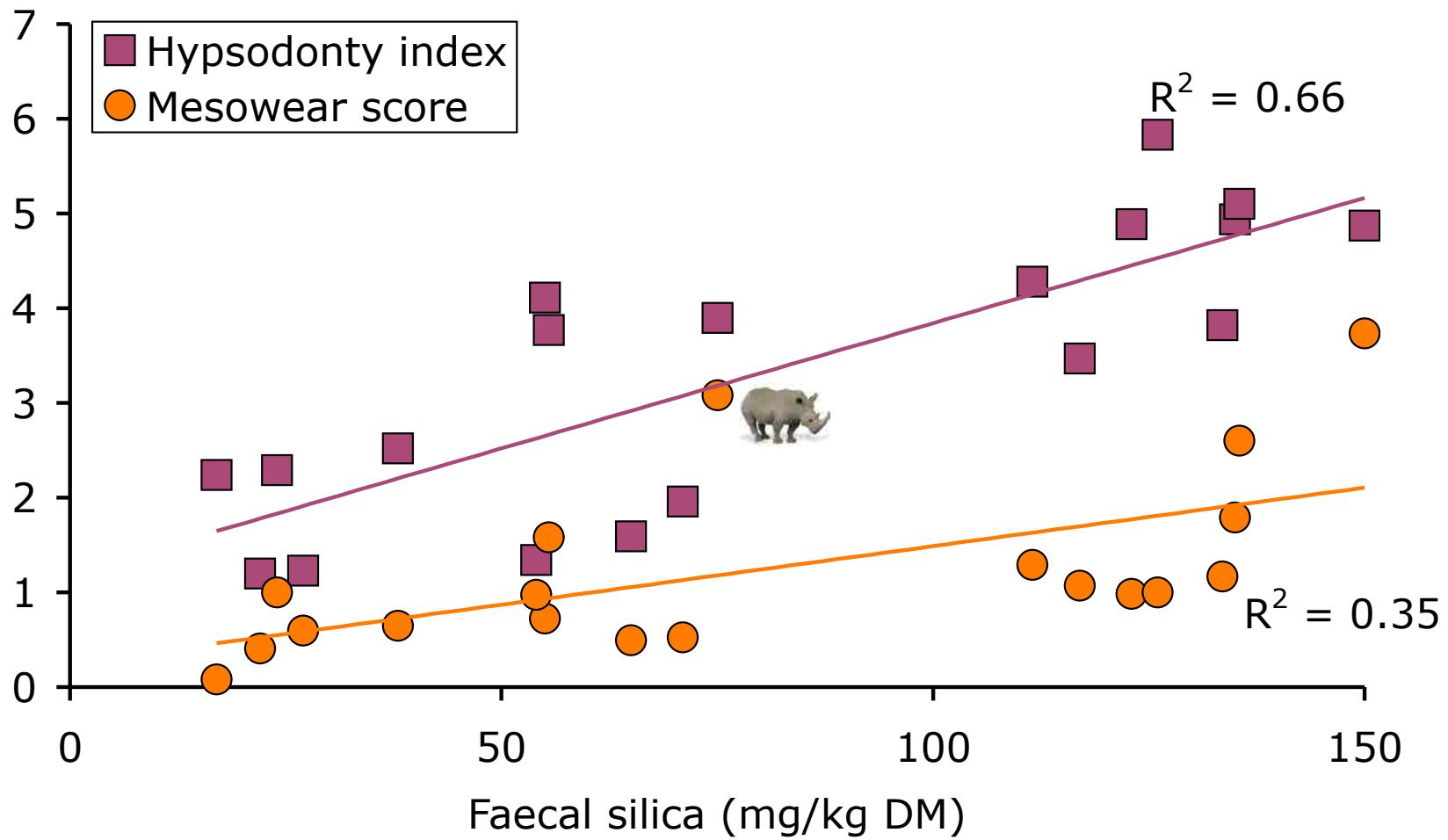


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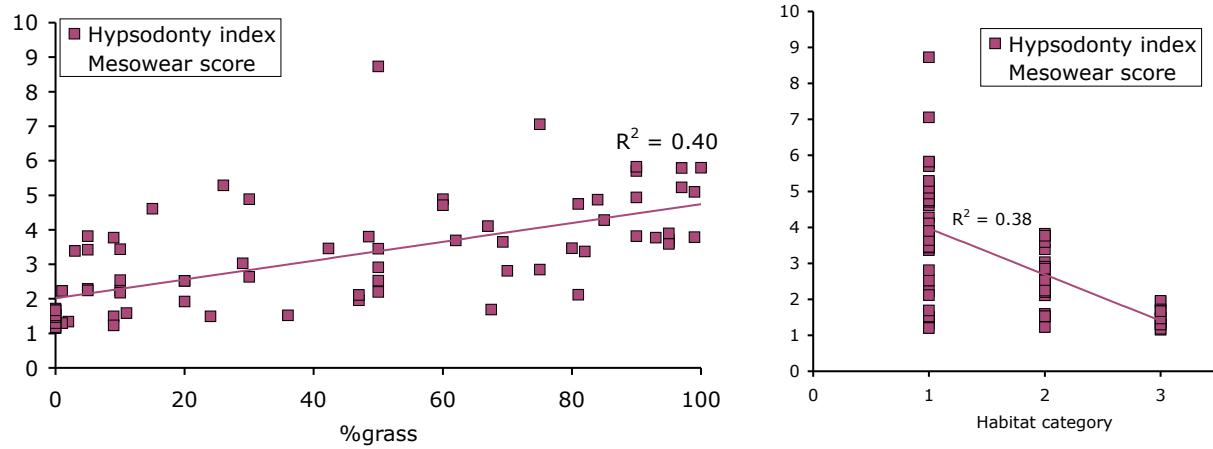


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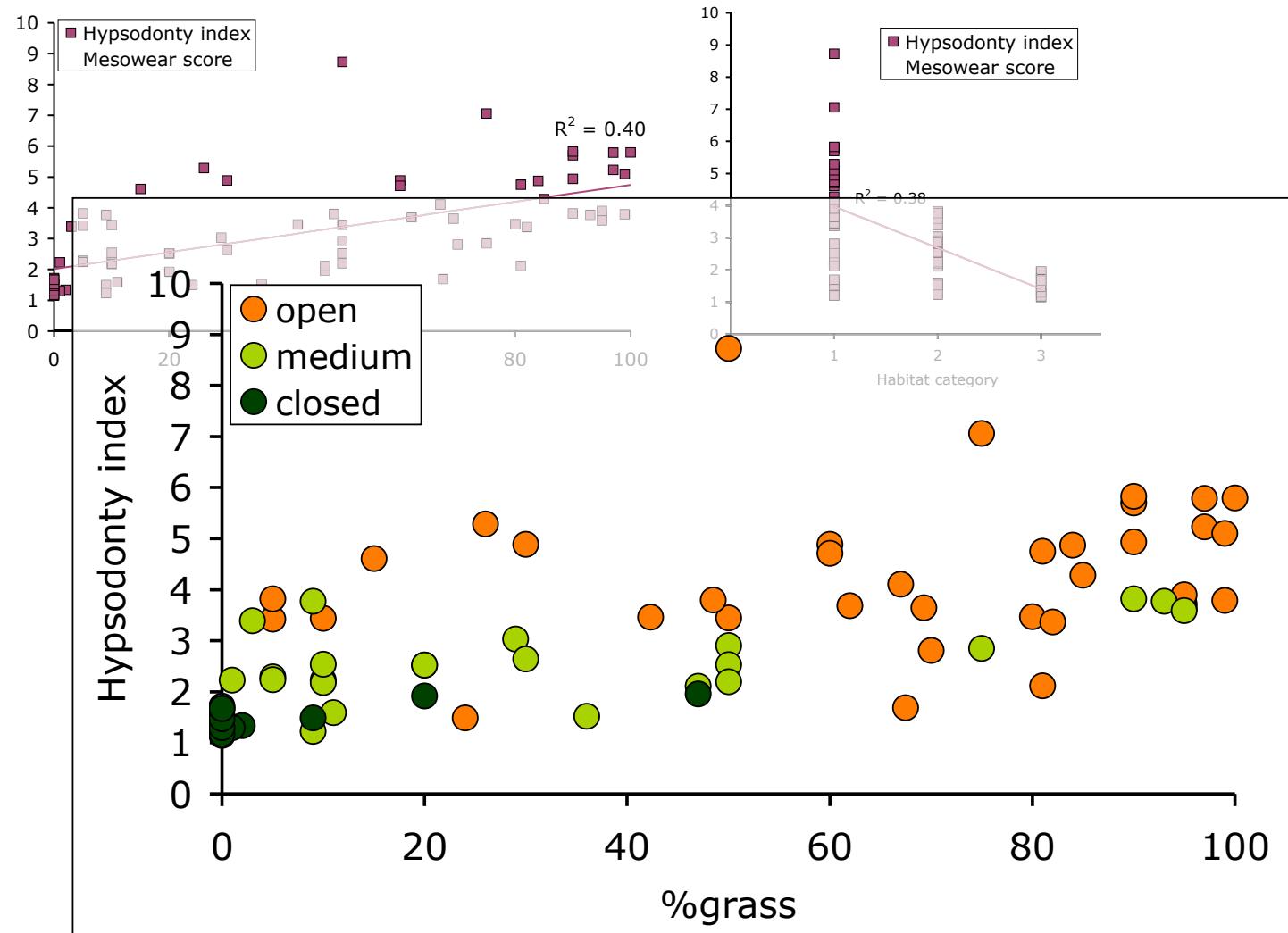
Mesowear score, diet and habitat





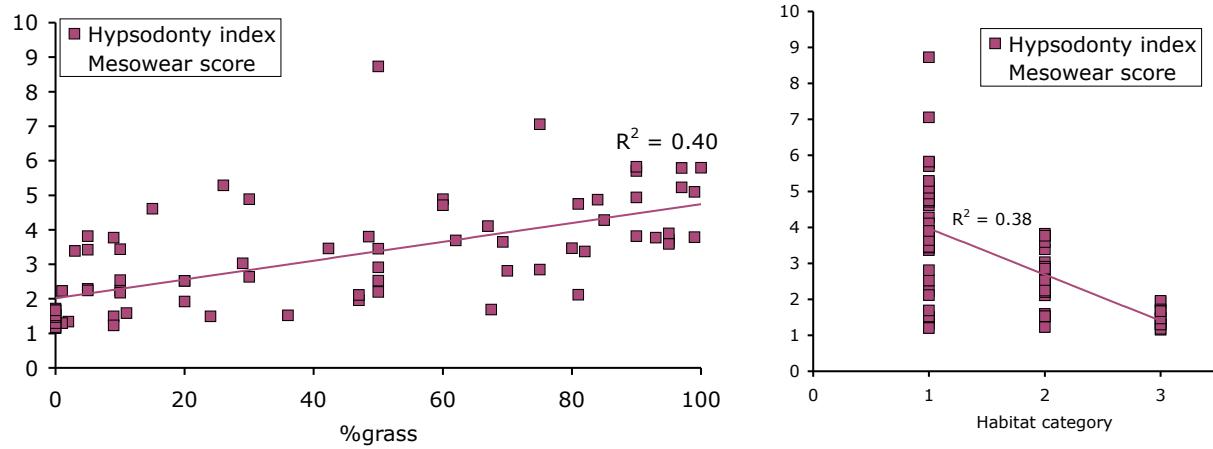
Mesowear score, diet and habitat

This shows that both %grass and habitat influence HI



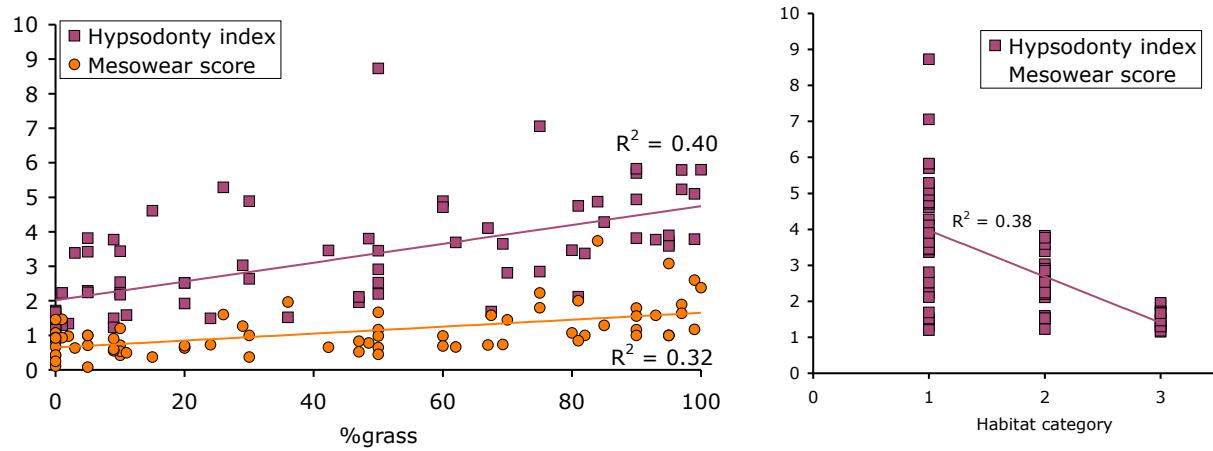


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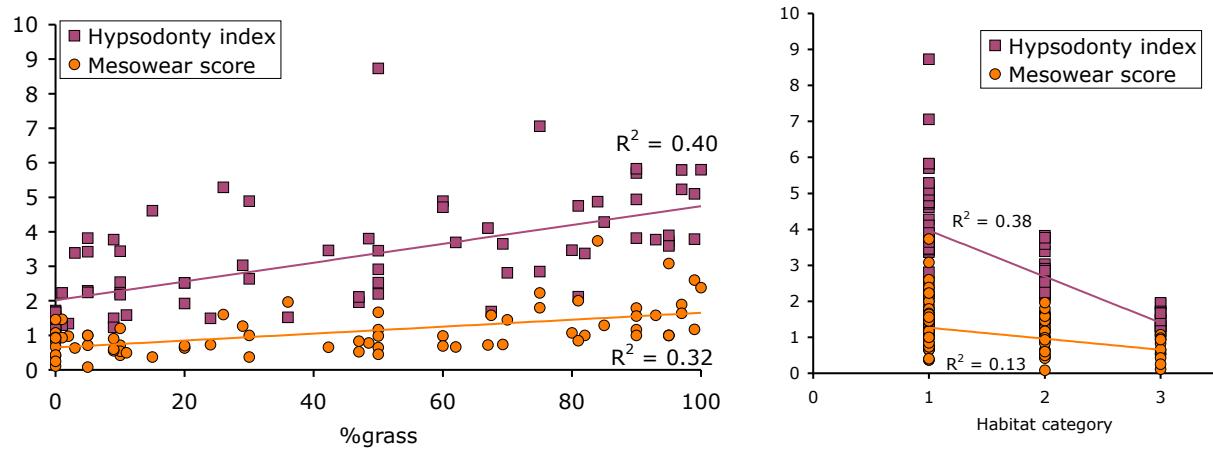


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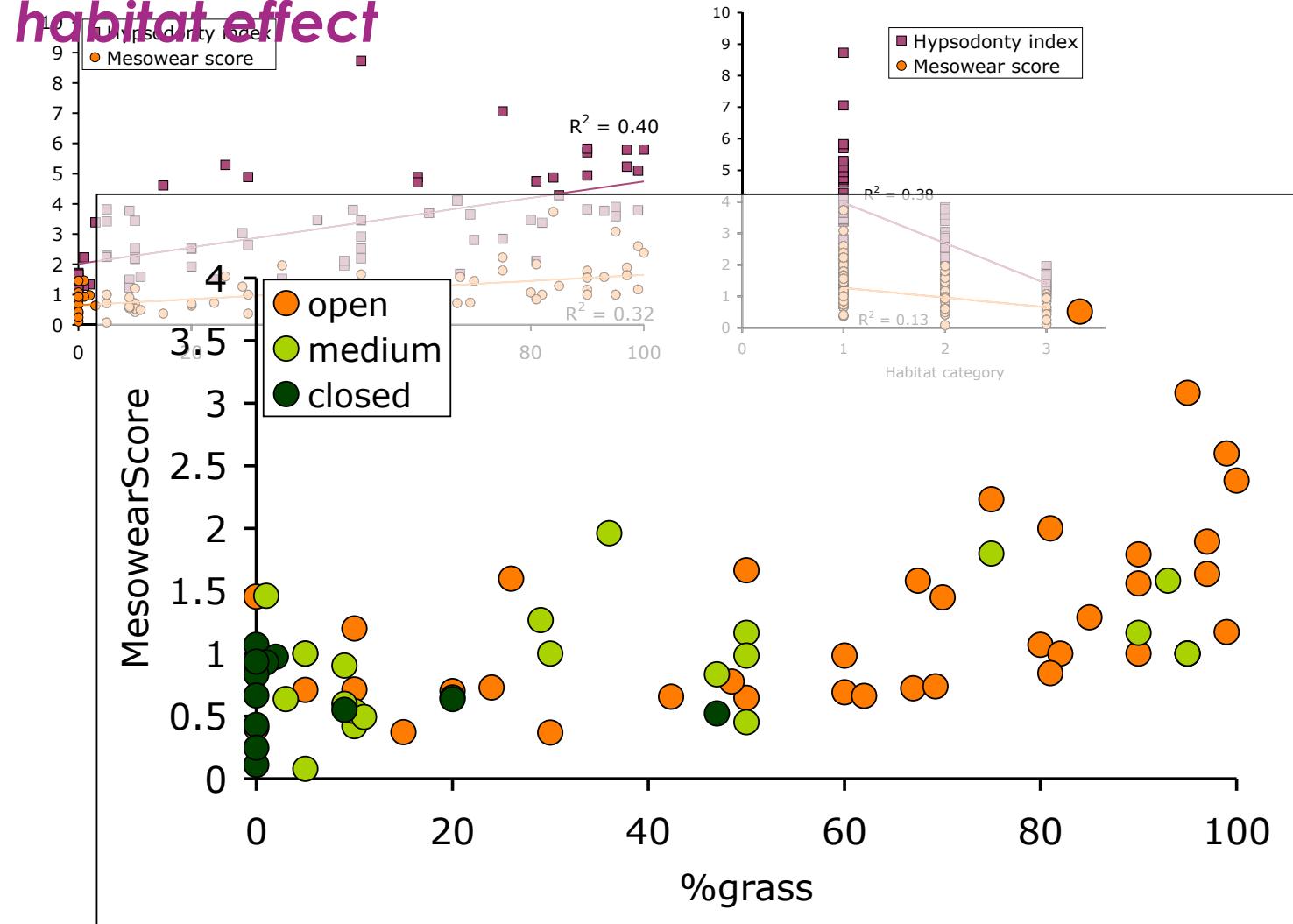
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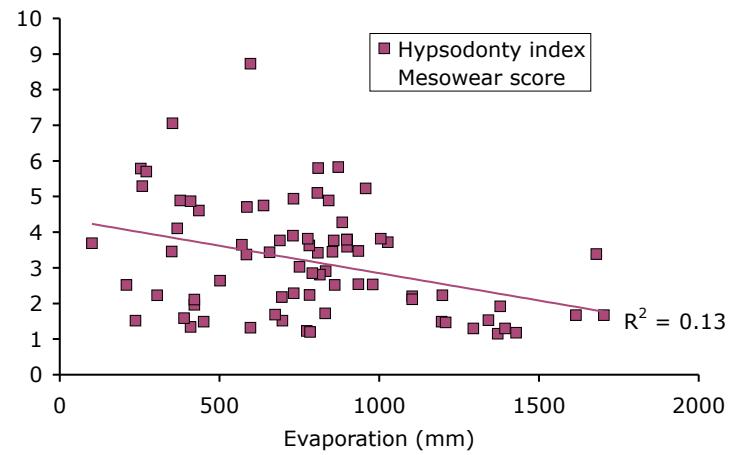
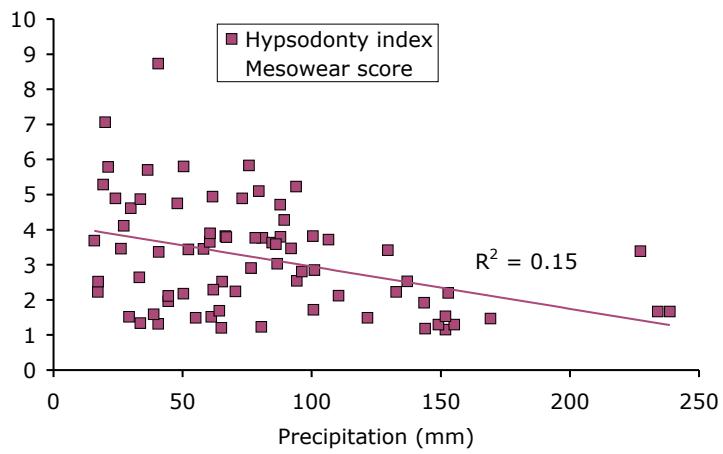
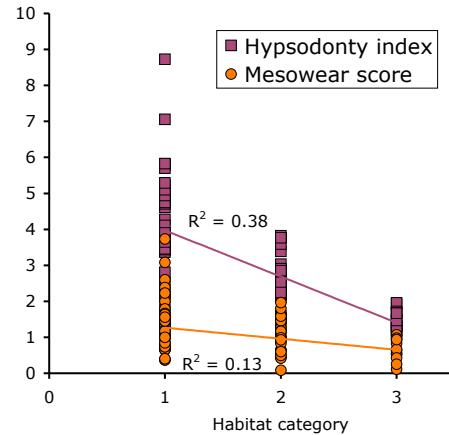
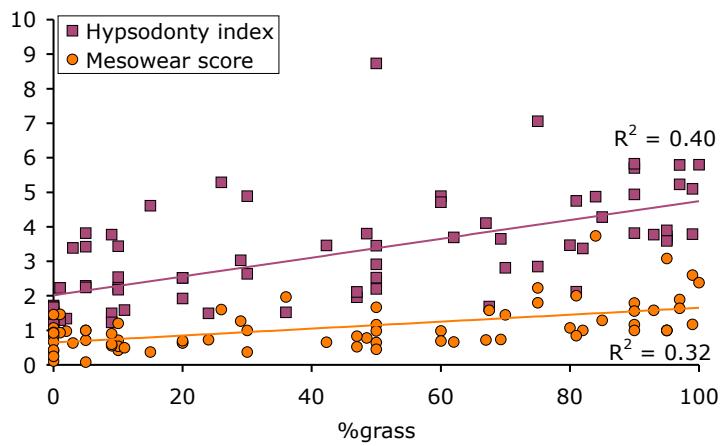
Mesowear score, diet and habitat

This shows that the mesowear signal is not catching a habitat effect



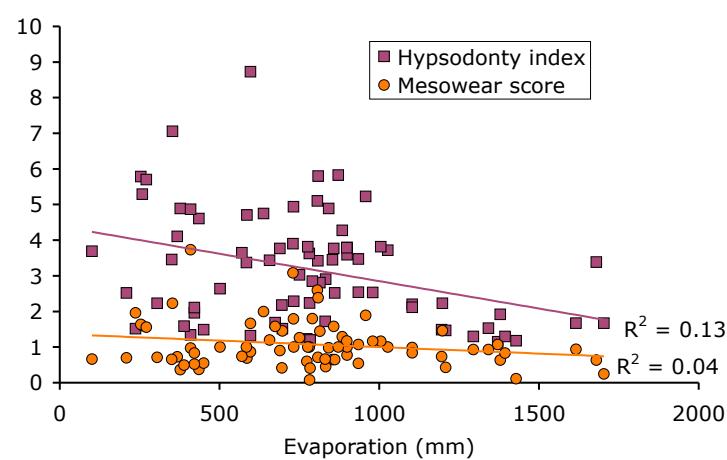
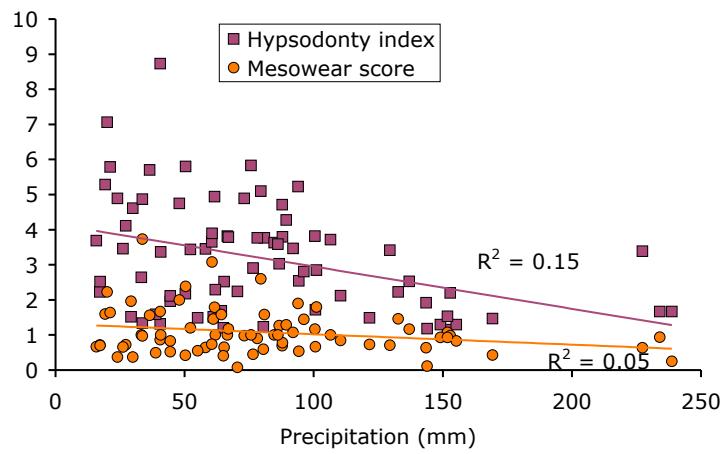
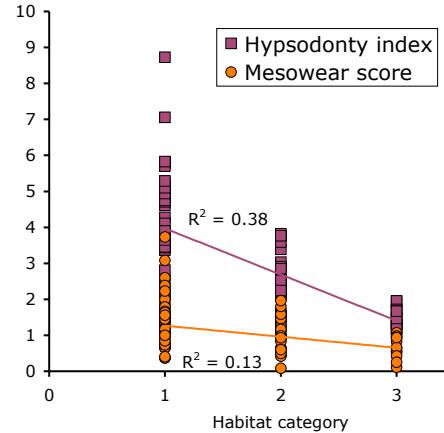
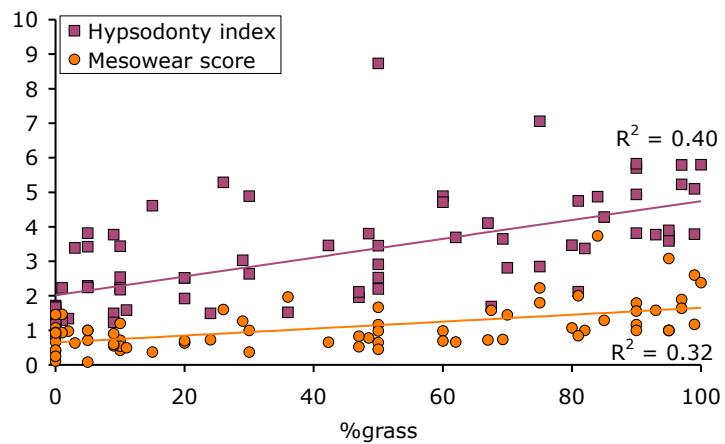


Mesowear score, diet and habitat



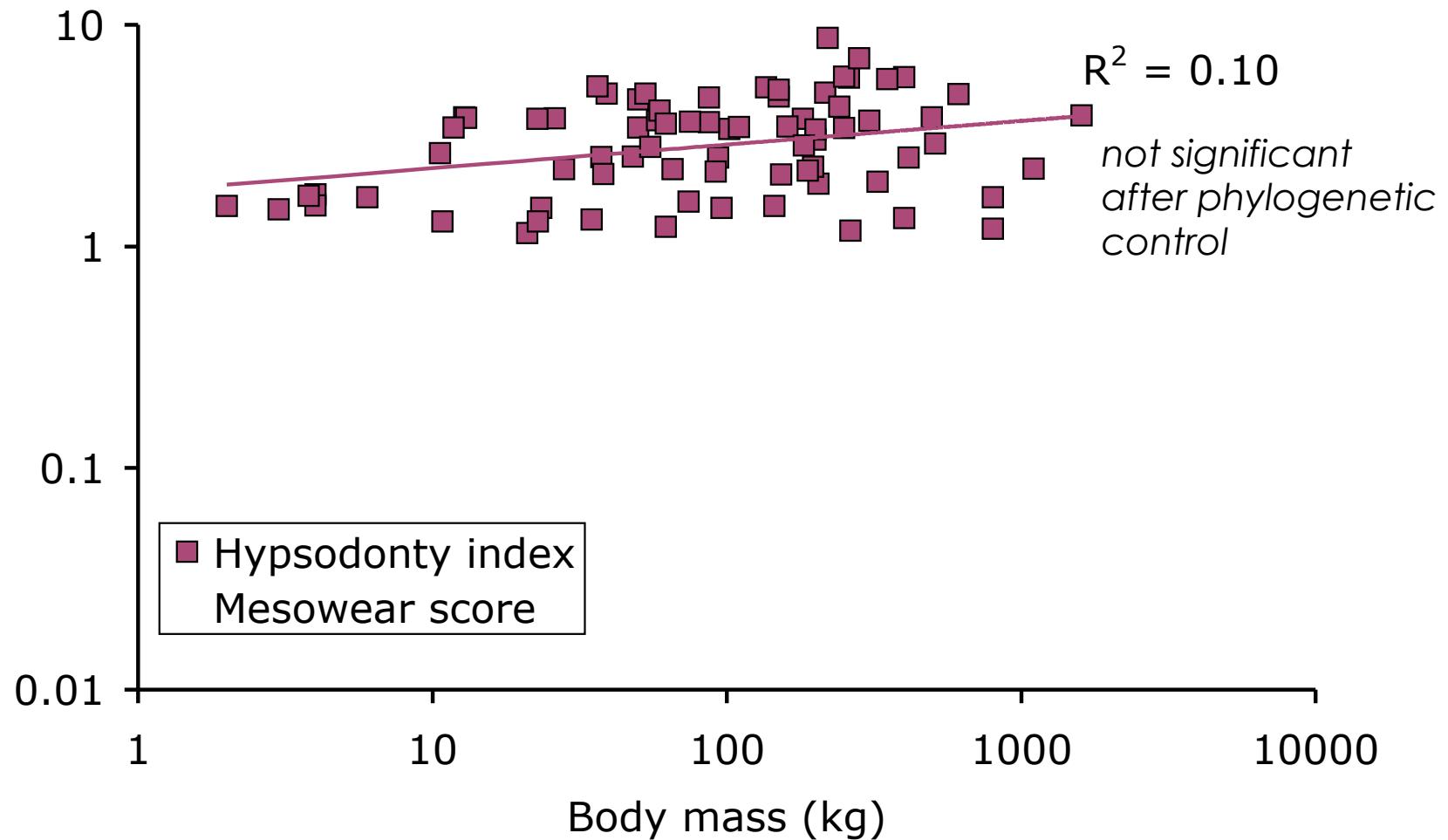


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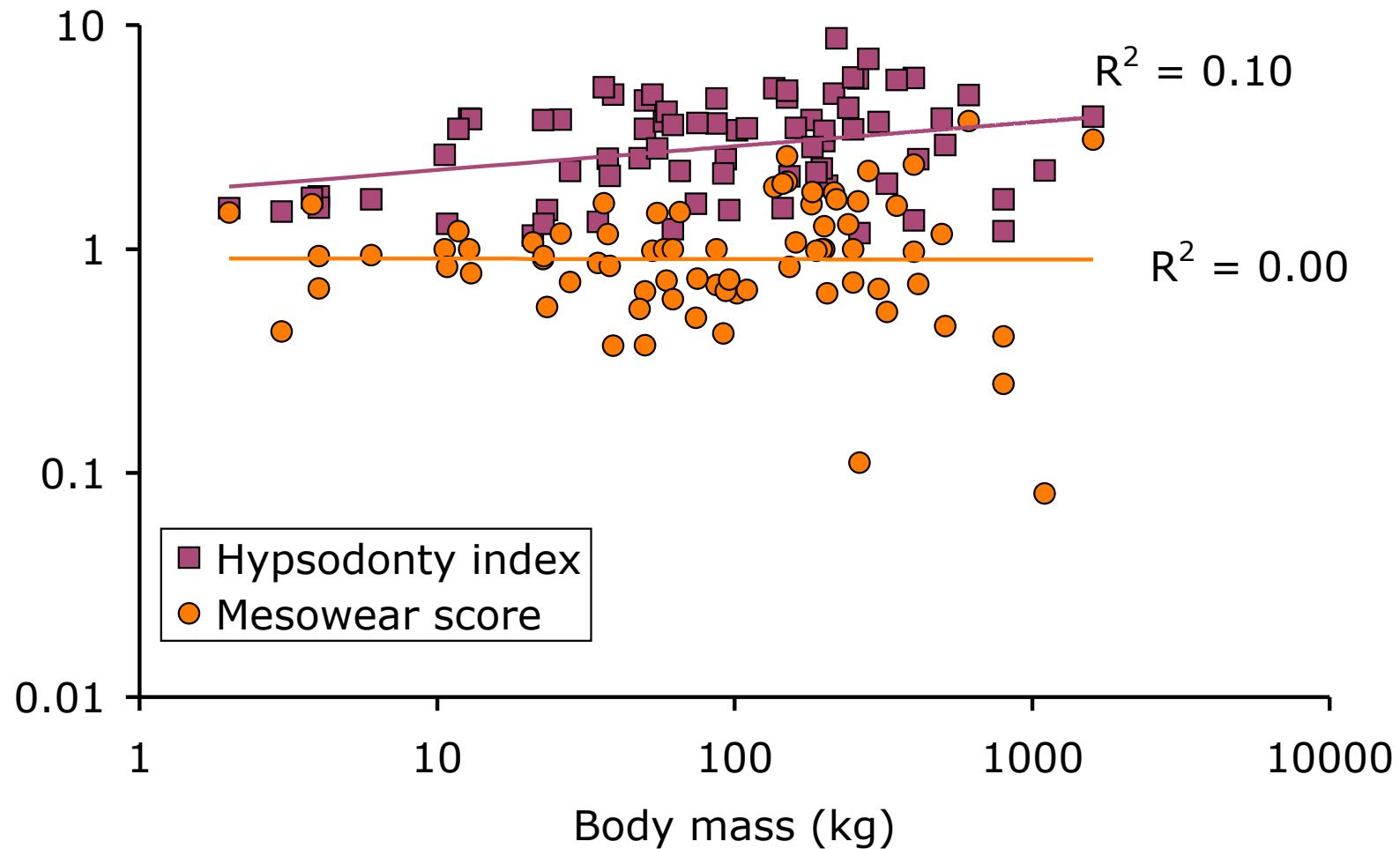


Mesowear score and body mass



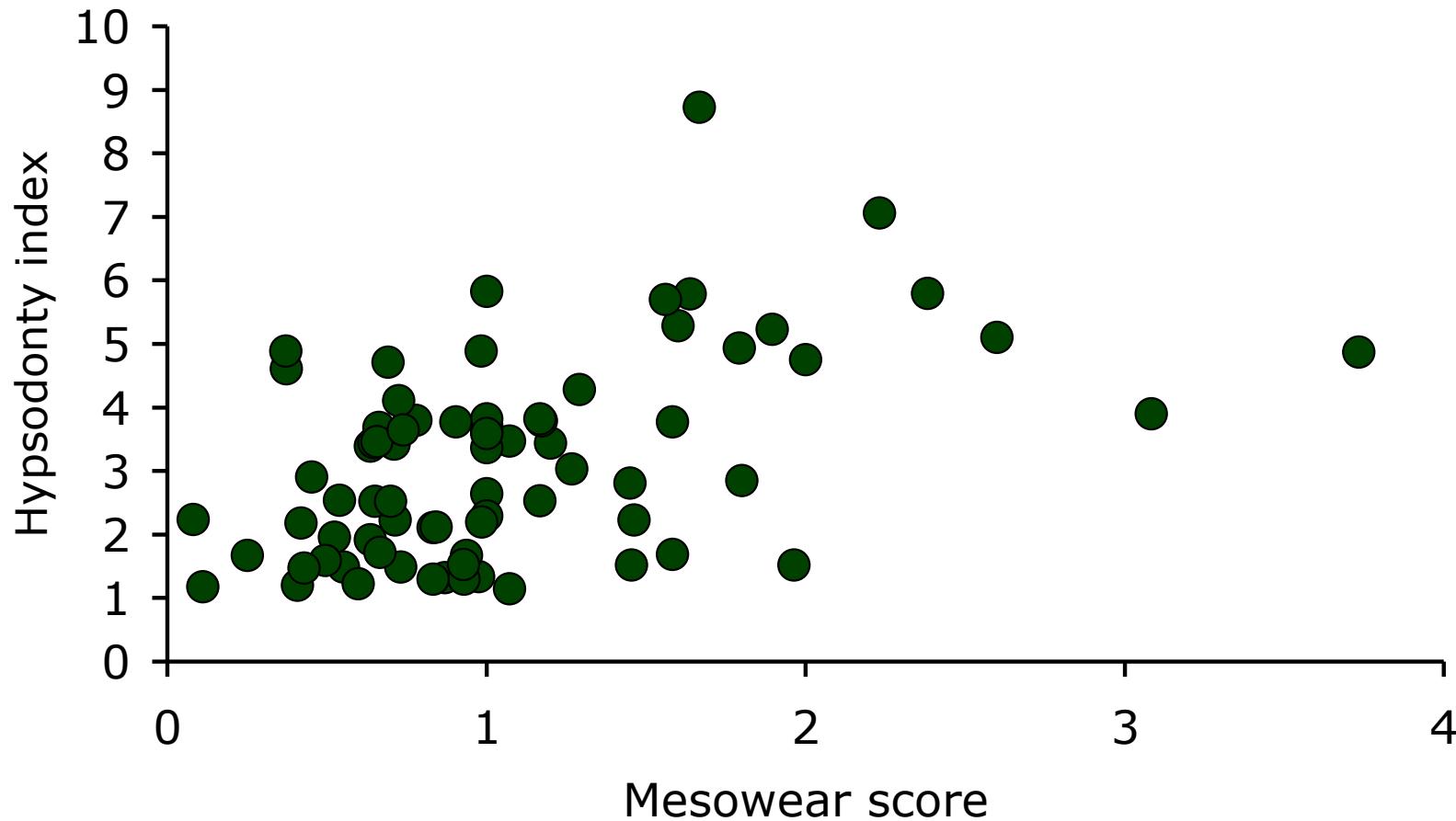


Mesowear score and body mass





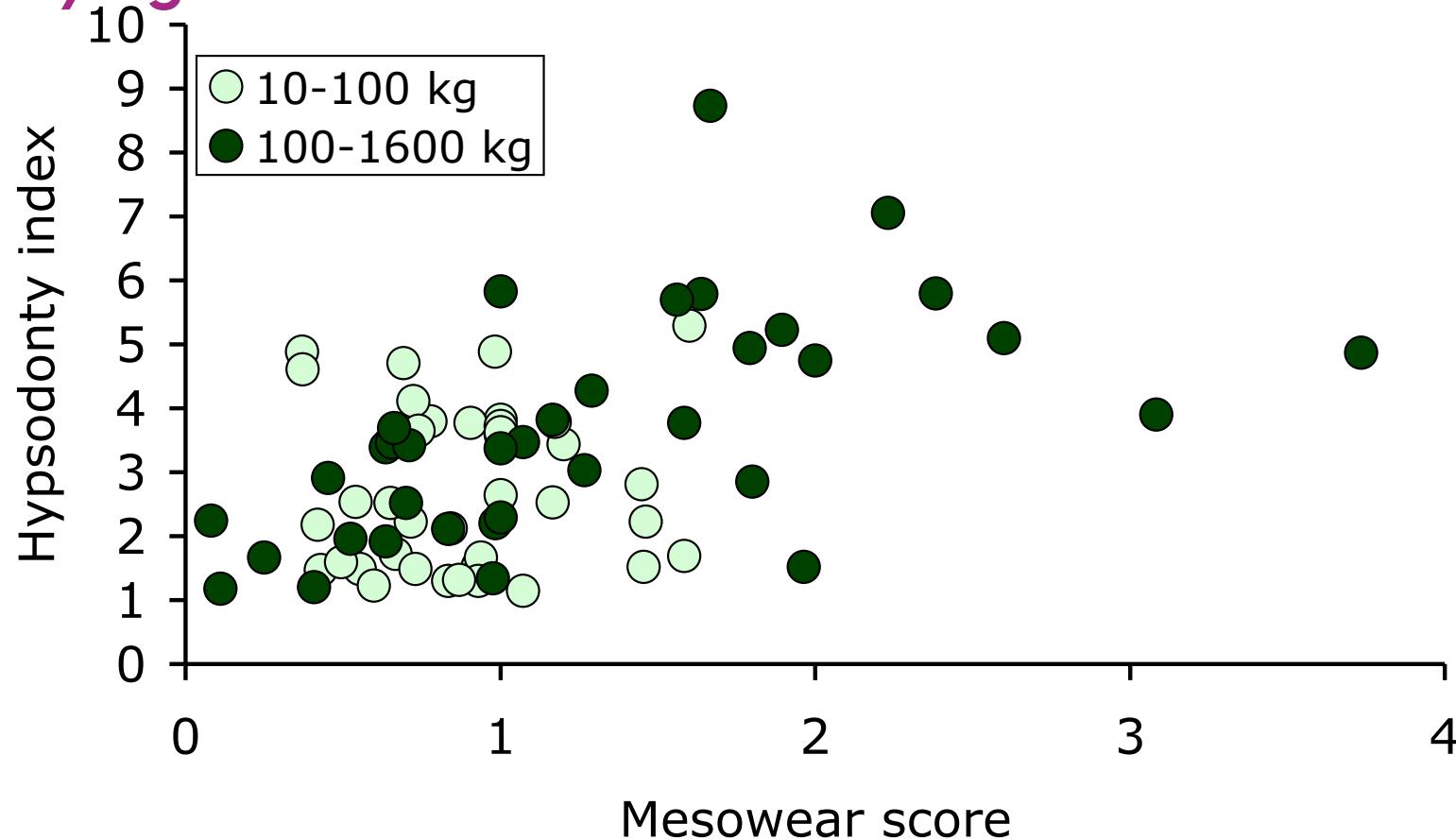
Does tooth wear drive the evolution of hypsodonty?





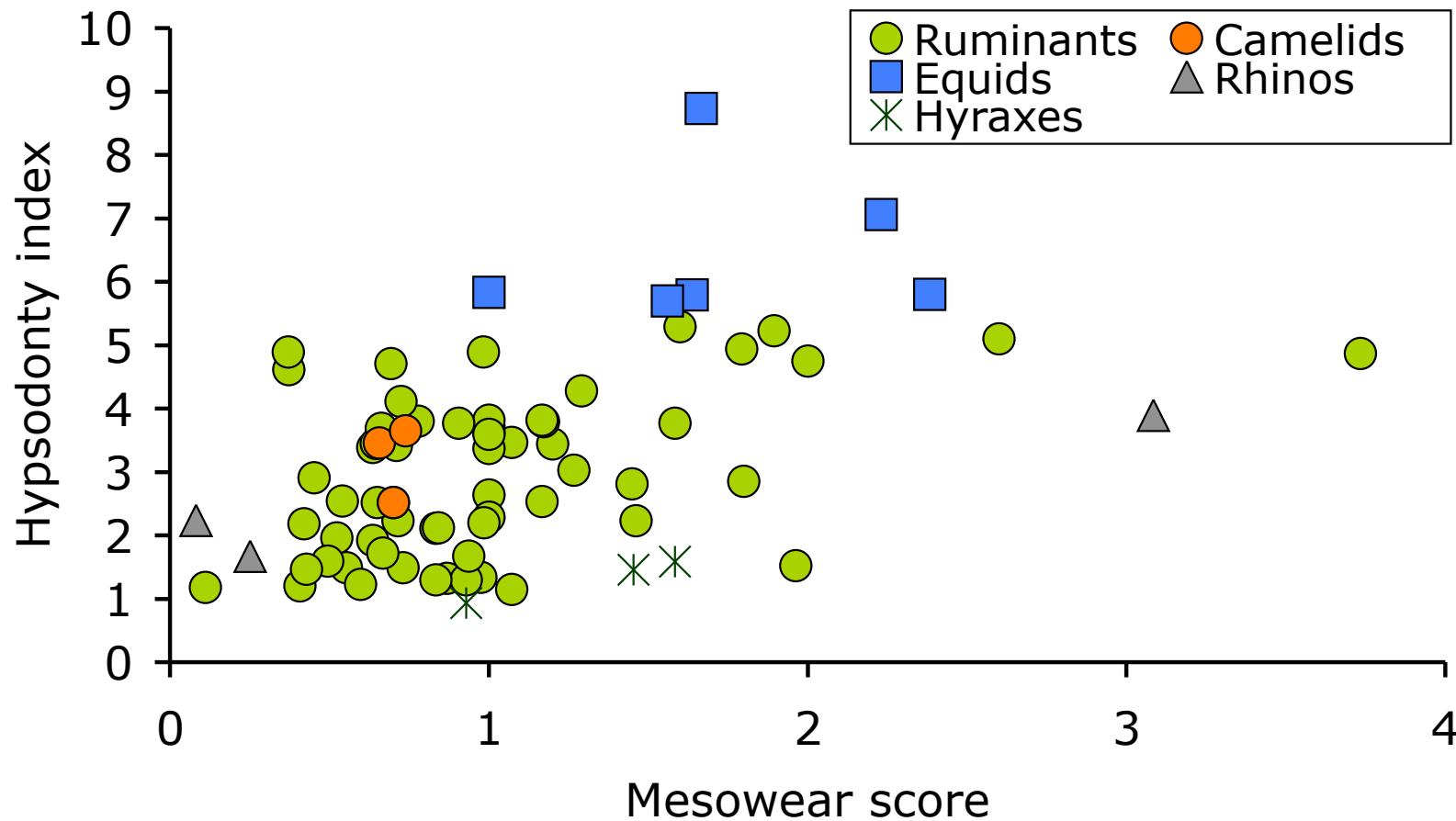
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Influence of body mass not significant with phylogenetic control



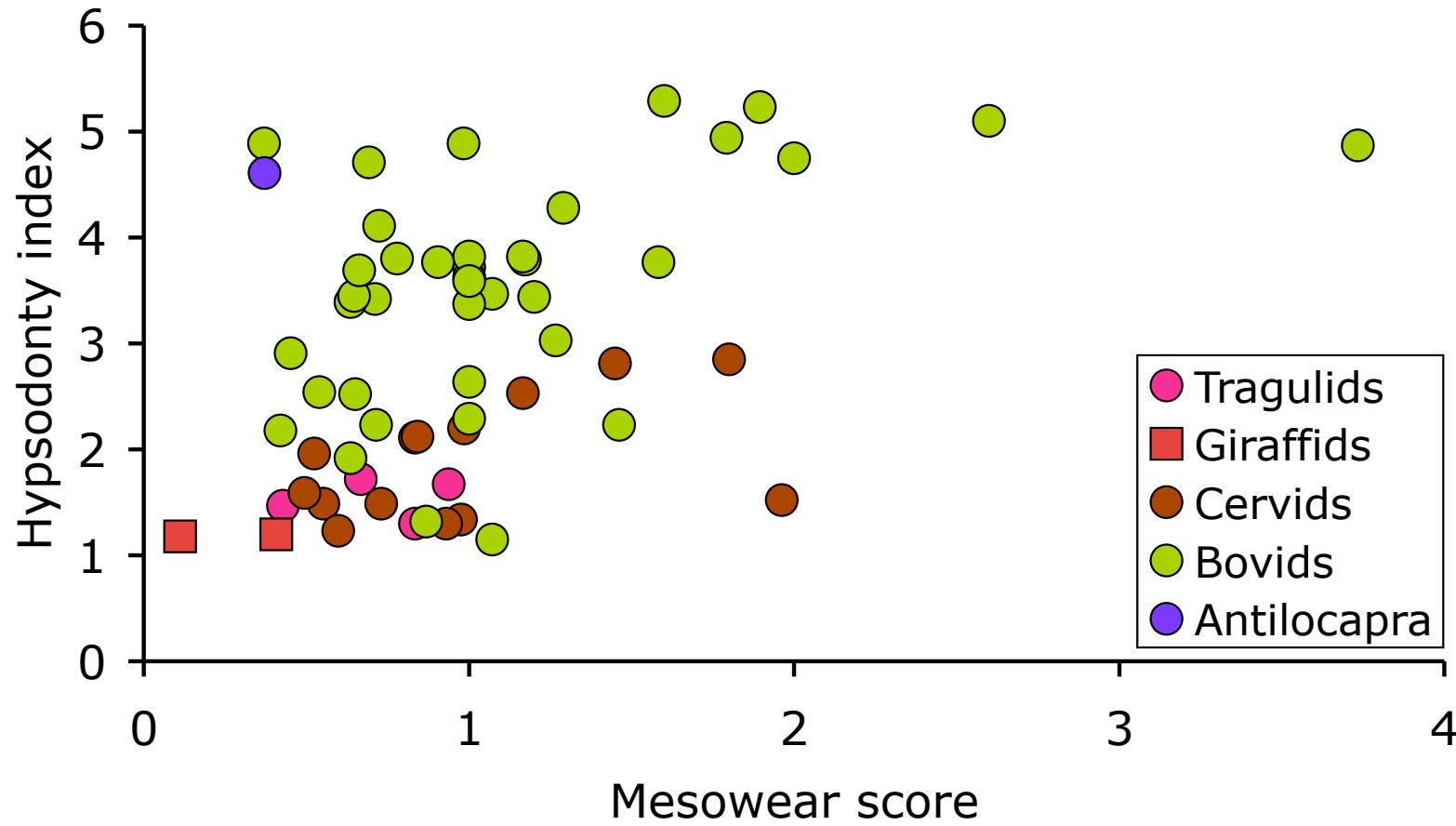


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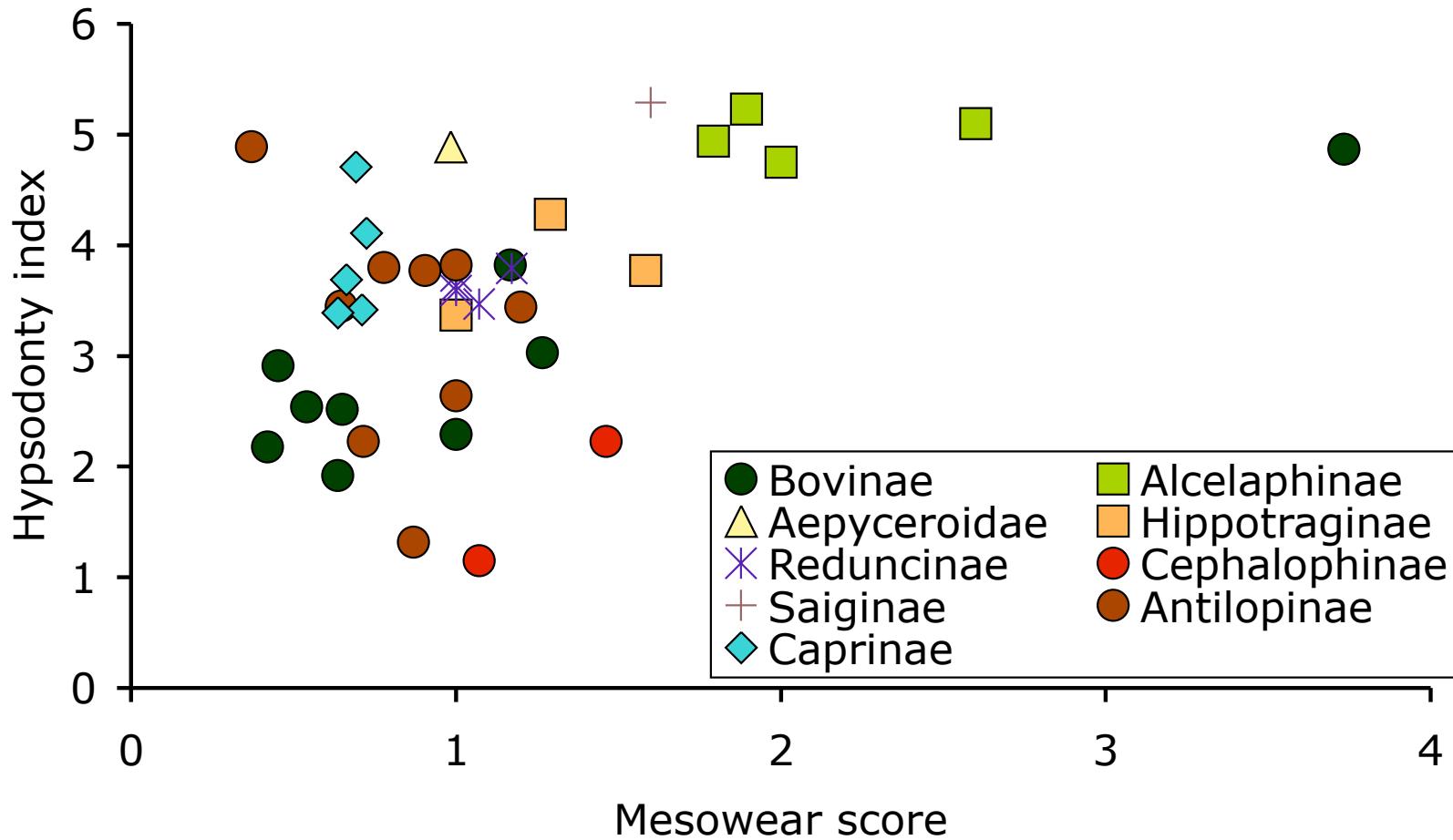


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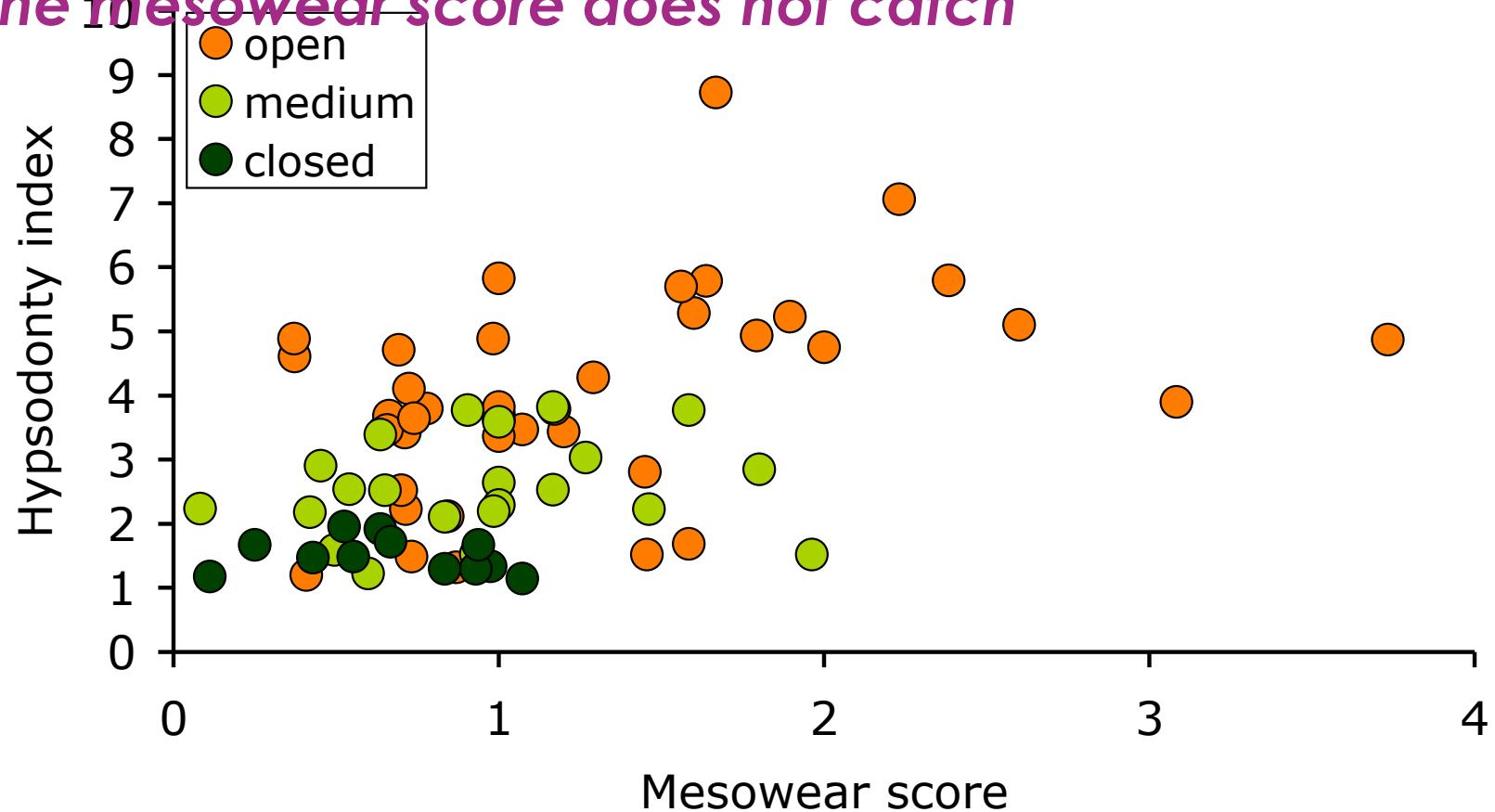
Does tooth wear drive the evolution of hypsodonty?





Does tooth wear drive the evolution of hypsodonty?

This shows that both mesowear and habitat influence HI - again showing that there is something in habitat that the mesowear score does not catch





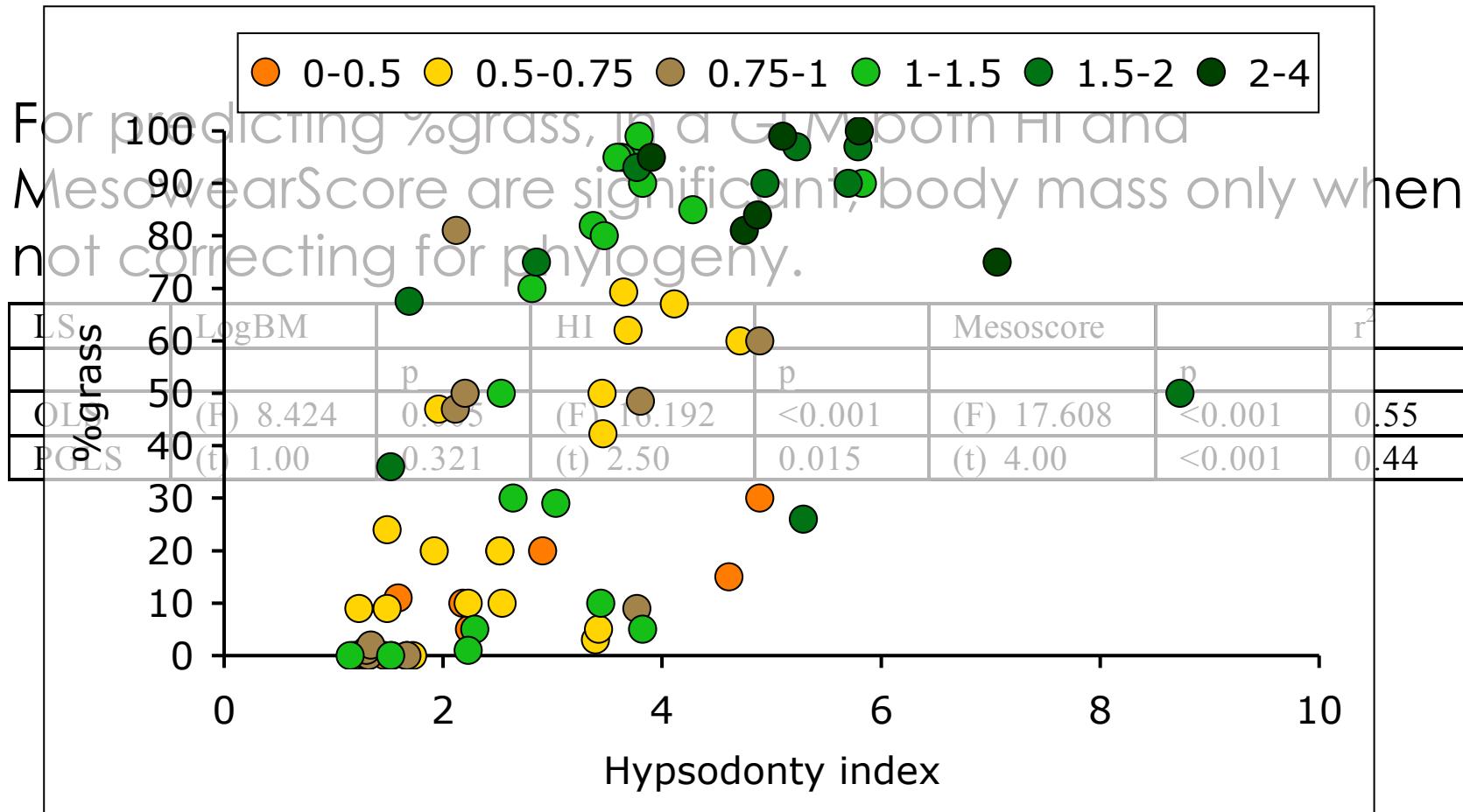
Predicting %grass / precipitation

For predicting %grass, in a GLM both HI and MesowearScore are significant; body mass only when not correcting for phylogeny.

LS	LogBM		HI		Mesoscore		r^2
		p		p		p	
OLS	(F) 8.424	0.005	(F) 16.192	<0.001	(F) 17.608	<0.001	0.55
PGLS	(t) 1.00	0.321	(t) 2.50	0.015	(t) 4.00	<0.001	0.44



Predicting %grass / precipitation



This shows that the mesowear score (colour-coded) specifies the HI-based prediction of %grass



Predicting %grass / precipitation

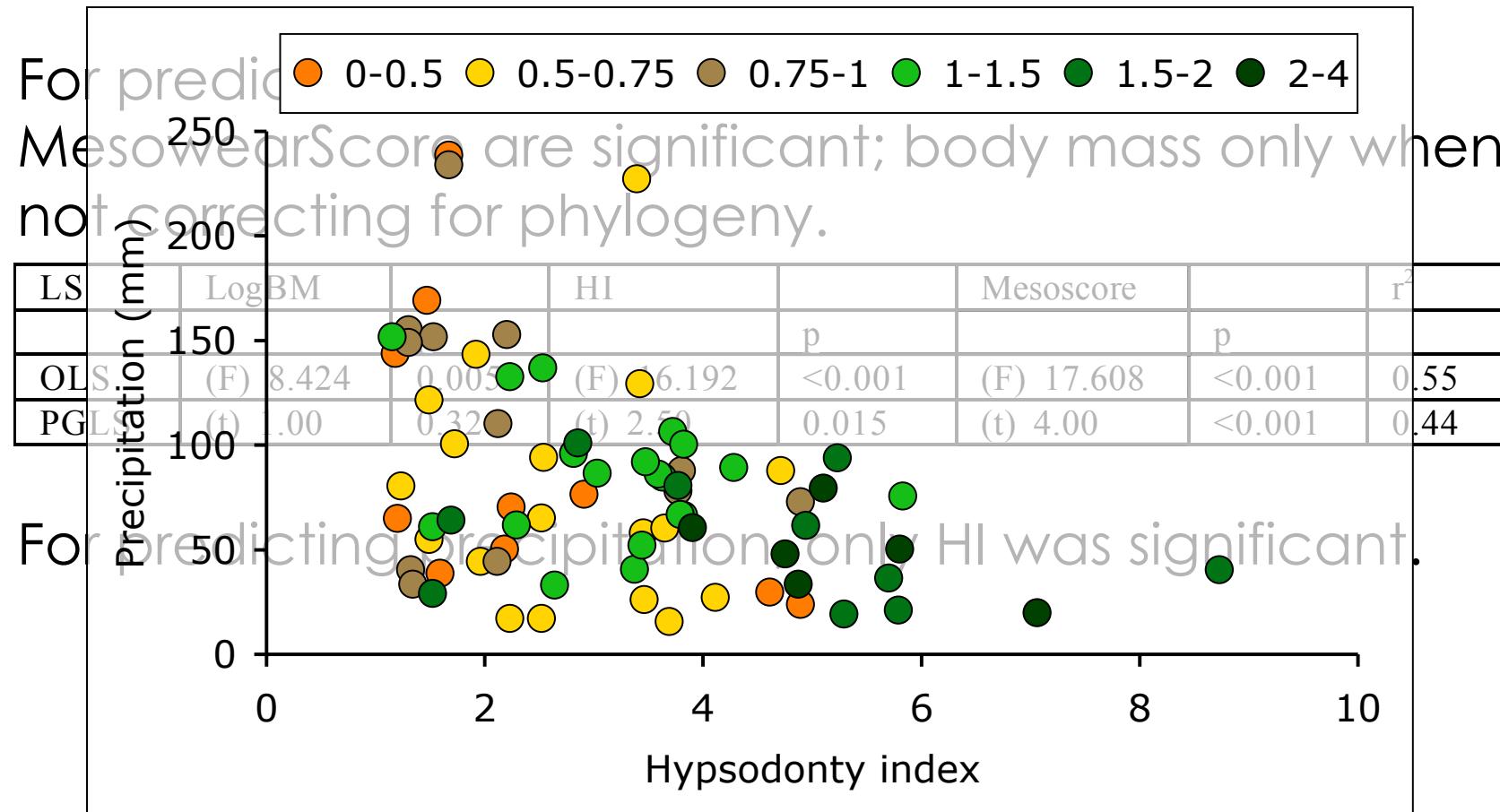
For predicting %grass, in a GLM both HI and MesowearScore are significant; body mass only when not correcting for phylogeny.

LS	LogBM	p	HI	p	Mesoscore	p	r ²
OLS	(F) 8.424	0.005	(F) 16.192	<0.001	(F) 17.608	<0.001	0.55
PGLS	(t) 1.00	0.321	(t) 2.50	0.015	(t) 4.00	<0.001	0.44

For predicting precipitation, only HI was significant.



Predicting %grass / precipitation



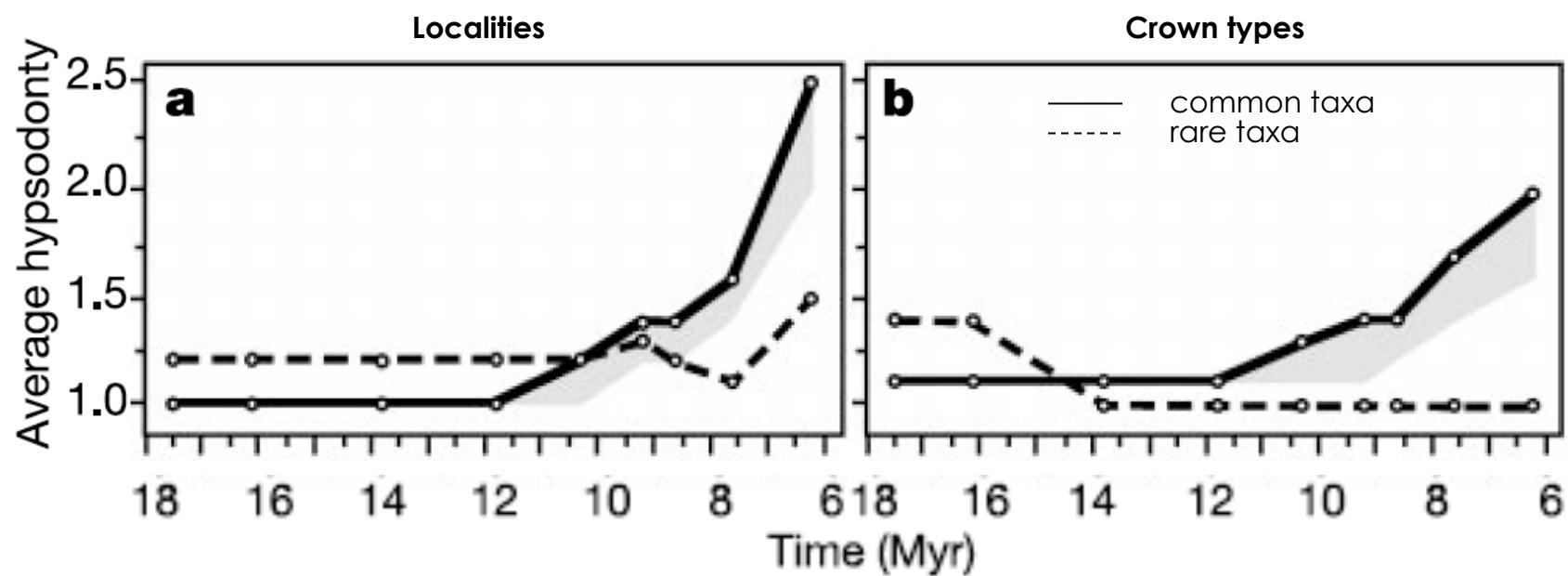
The mesowear score does not specify the HI-based prediction of precipitation



Common mammals drive the evolutionary increase of hypsodonty in the Neogene

Jukka Jernvall*† & Mikael Fortelius‡

NATURE | VOL 417 | 30 MAY 2002 |





Explaining patterns in modern ruminant diversity: contingency or constraint?

JAMES J. N. HEYWOOD*

Biological Journal of the Linnean Society, 2010, **99**, 657–672.

Deer did not evolve into ‘coarse food giants’ with huge grinding teeth.

Geist (1998: 1)

... it is unclear why no cervid evolved ... to be a specialised grazer.

Janis (2008: 41)

CONRAINT II: ‘THE CUSP
FUSION HYPOTHESIS’



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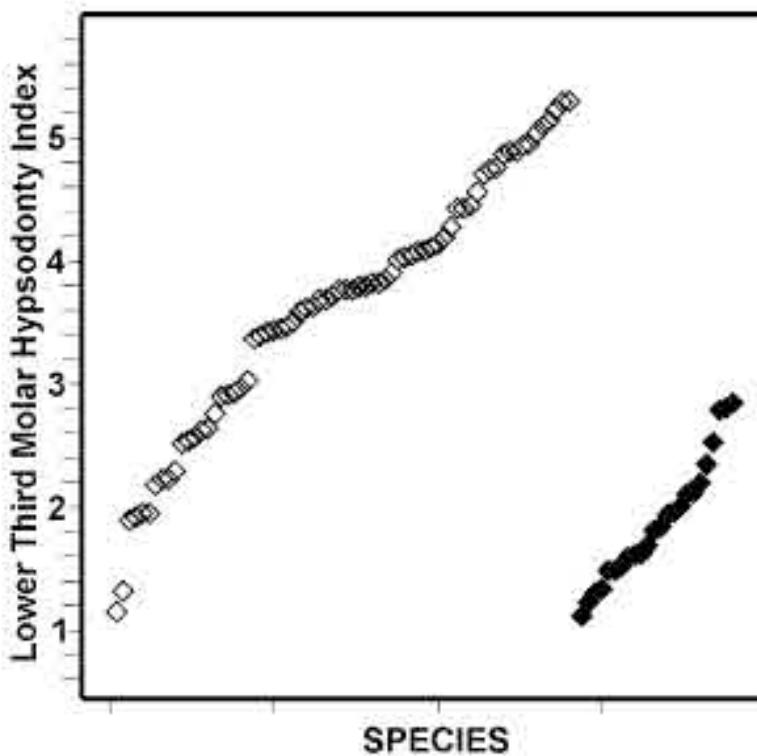


Figure 1. Lower third molar hypsodonty indices of extant ruminants. ◇, Bovidae; ♦, Cervidae. Data from Janis (1988) and Mendoza & Palmqvist (2008).

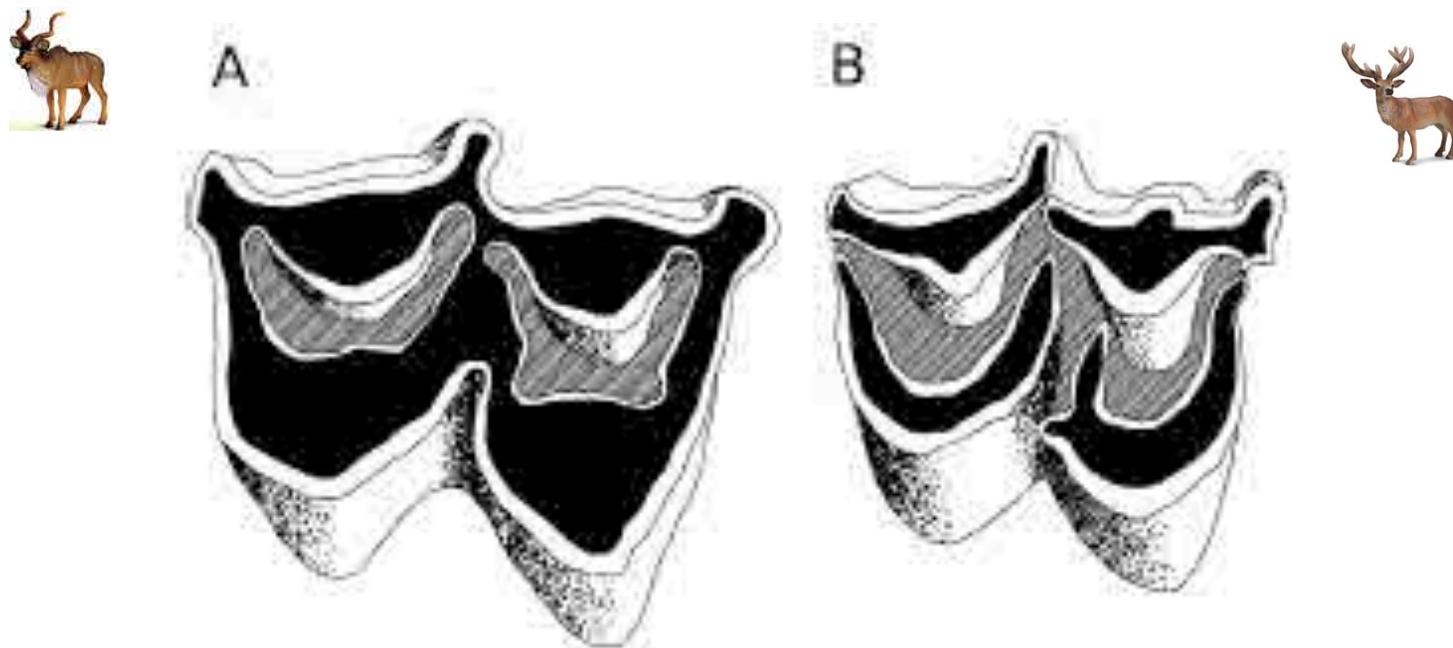


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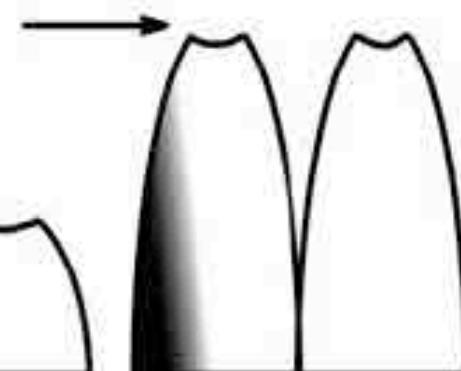
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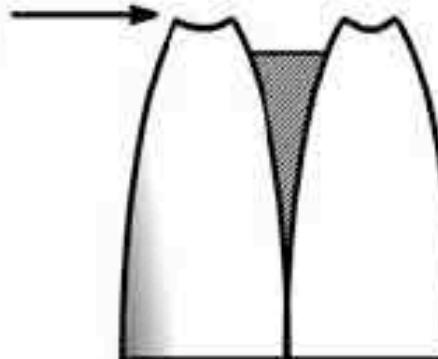
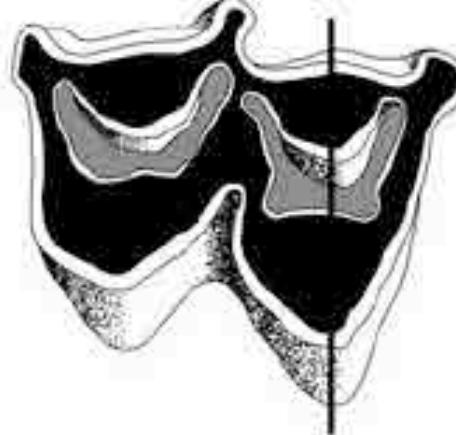
Biological Journal of the Linnean Society, 2010, **99**, 657–672.

CONSTRAINT II: 'THE CUSP FUSION HYPOTHESIS'

A



B





Enamel ridge alignment in upper molars of ruminants in relation to their natural diet

Journal of Zoology 281 (2010) 12–25

T. M. Kaiser¹, J. Fickel², W. J. Streich², J. Hummel³ & M. Clauss⁴

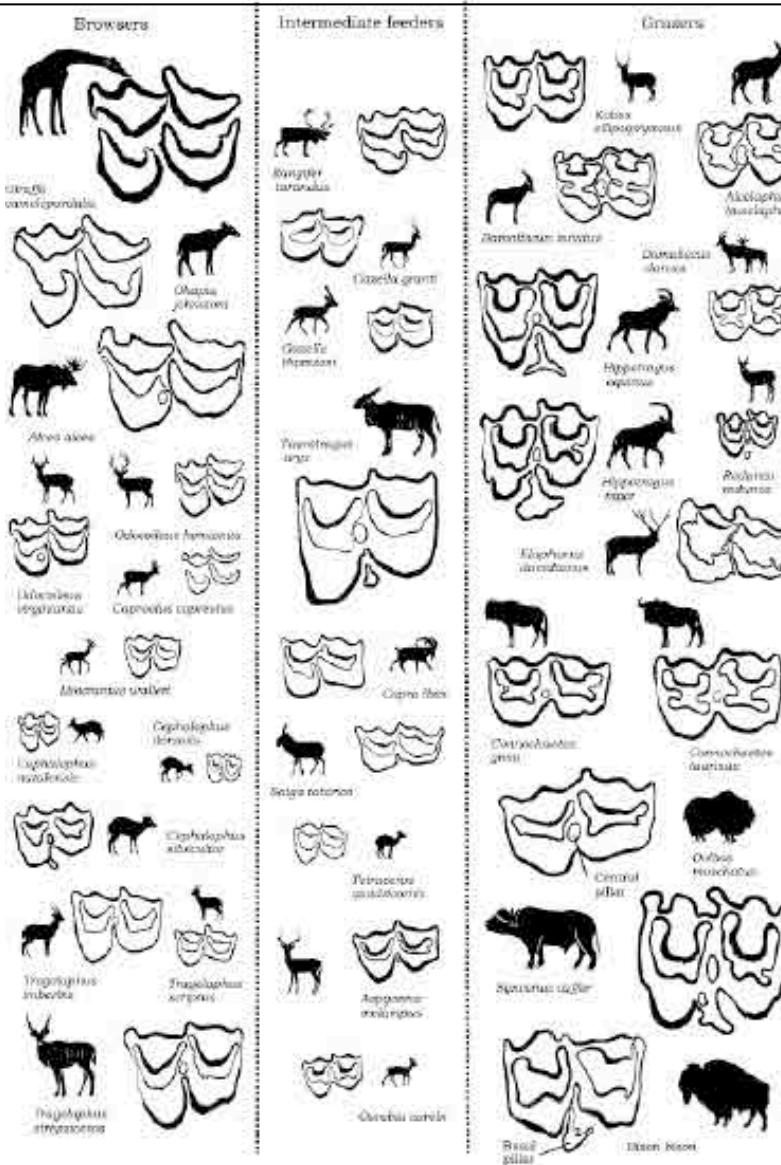


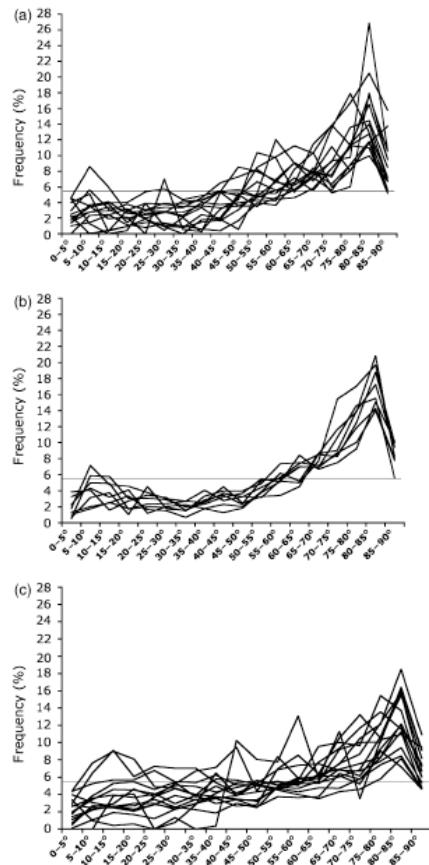
Figure 2 Upper second molar occlusal surfaces of some of the species included in this study. The occlusal enamel ridge pattern of a typical specimen is shown in original size. The buccal side of the molar is directed towards the top of the page, and the lingual side towards the bottom. Note the presence of central and basal pillars in some species. Animal pictograms are partly adapted from Marchini & Carter (1971).



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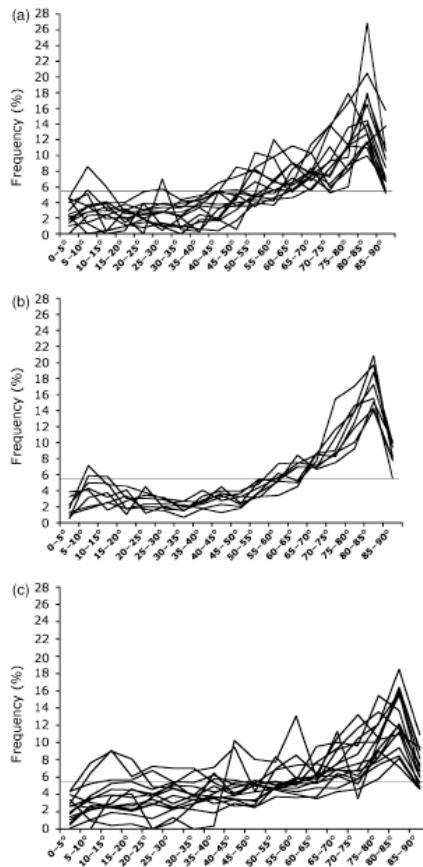




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Functional anatomy of bovid upper molar occlusal surfaces with respect to diet

Journal of Zoology 281 (2010) 1–11

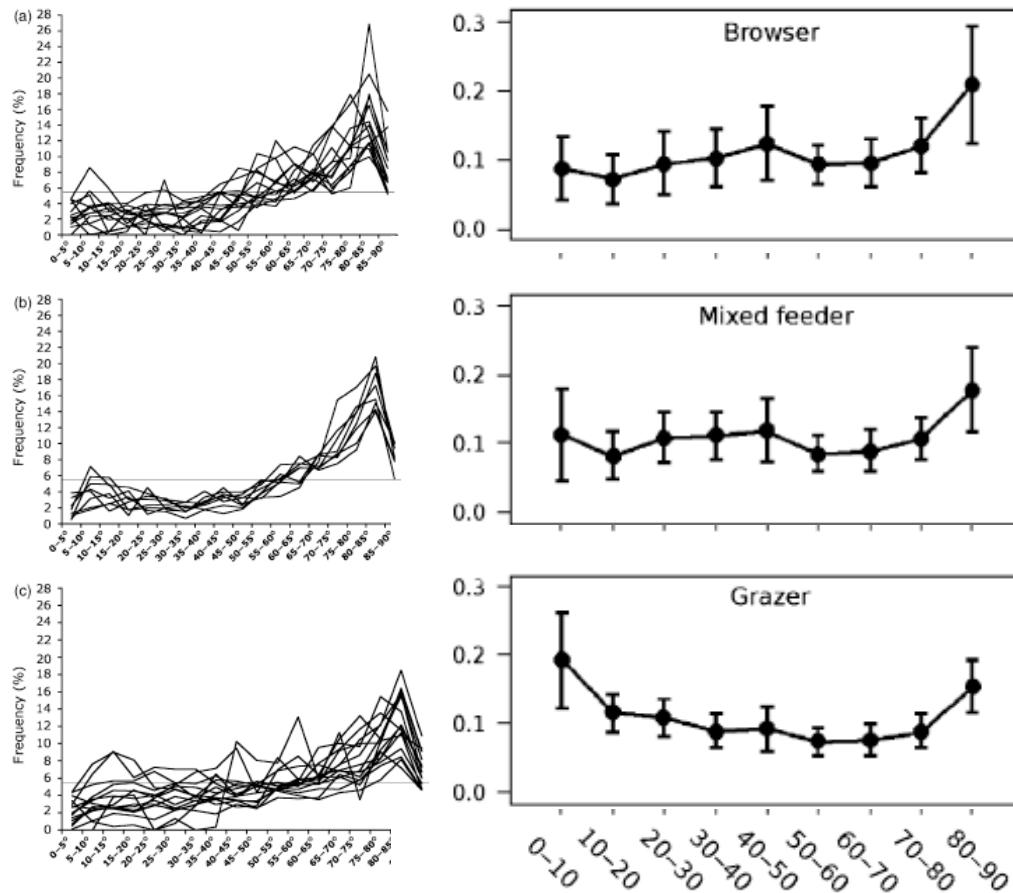
J. J. N. Heywood



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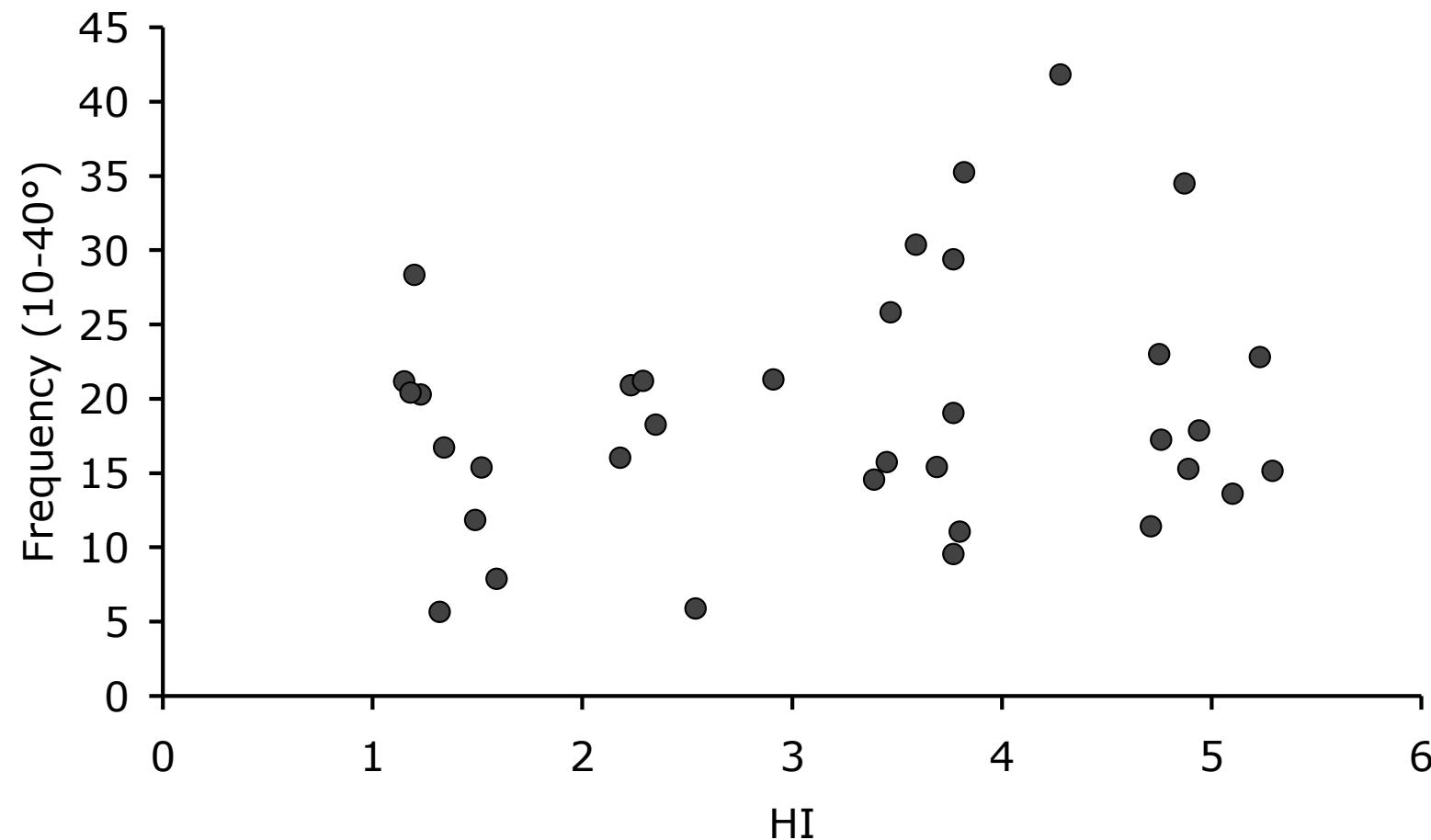
J. J. N. Heywood



Relationship HI - enamel ridge alignment?



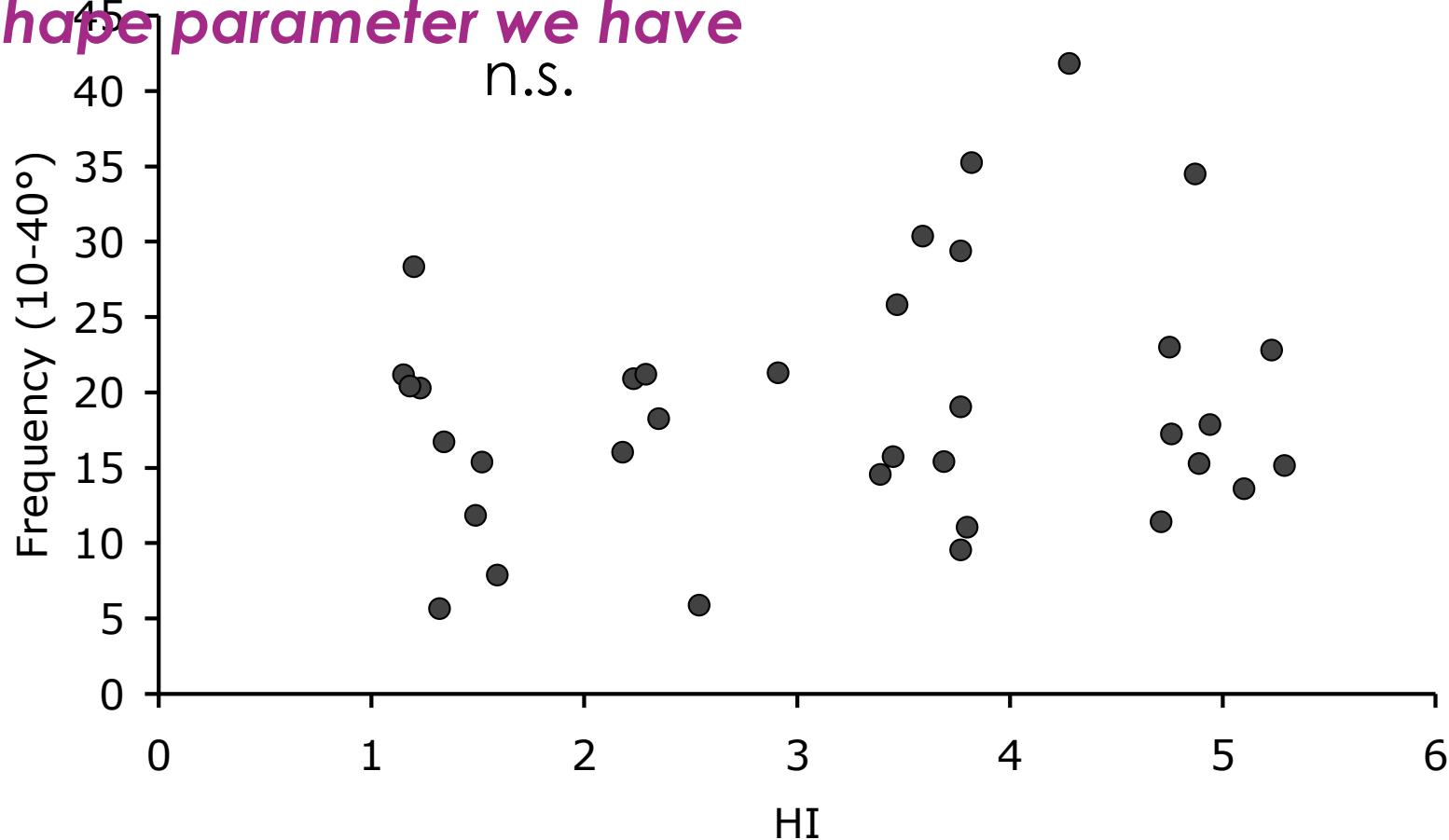
Relationship HI - enamel ridge alignment?





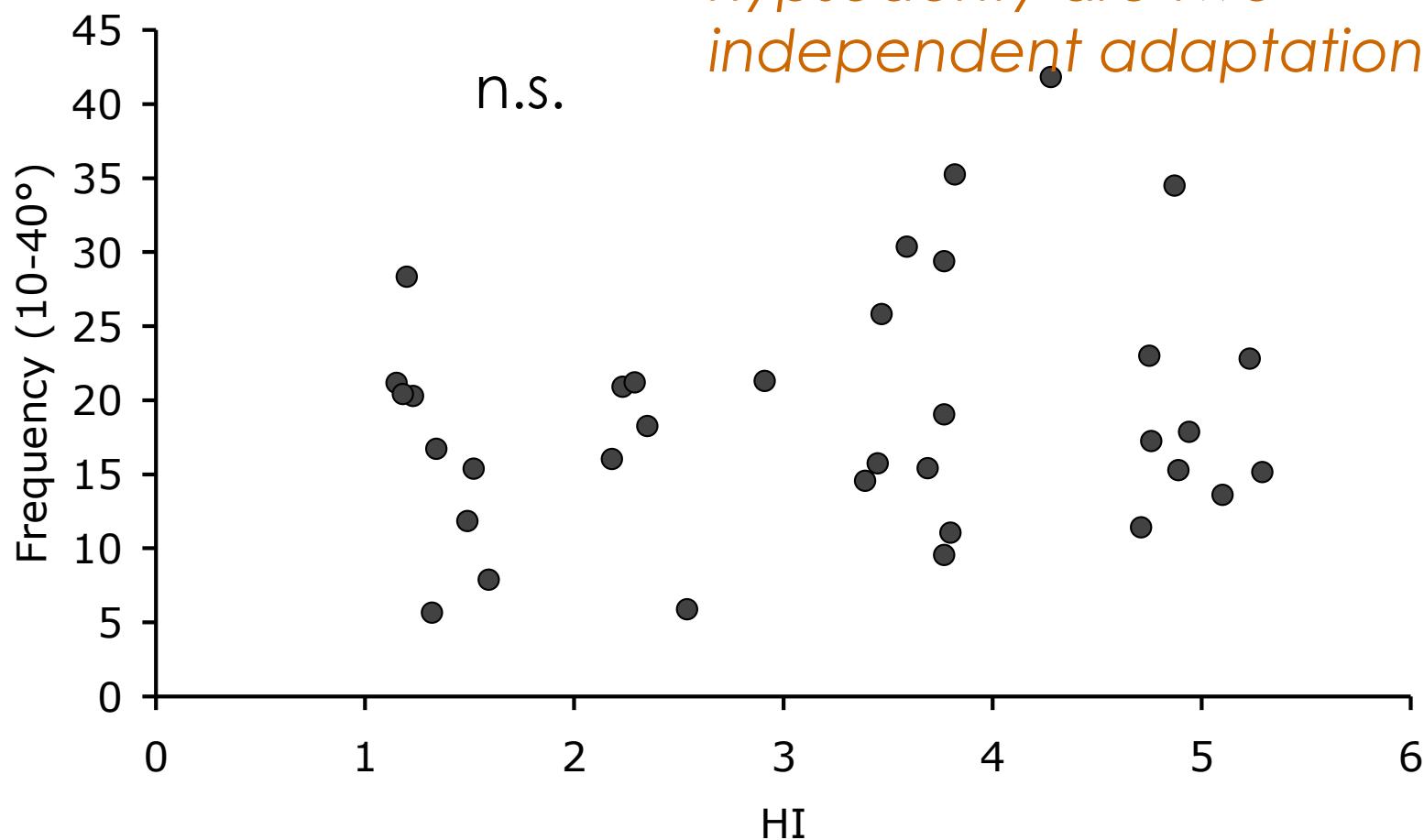
Relationship HI - enamel ridge alignment?

No link between HI and enamel ridge alignment - no relationship between HI and one quantitative tooth shape parameter we have





Relationship HI - enamel ridge alignment?





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

John Damuth^{1*} and Christine M. Janis²

Biol. Rev. (2011),

(2) Persistence of brachydont forms

Brachydonty is not merely the primitive condition for ungulates and mammals in general, but the brachydont teeth of ungulates may also represent optimal morphologies for an ungulate consuming a non-abrasive (or an only moderately abrasive) diet (Fortelius, 1985).

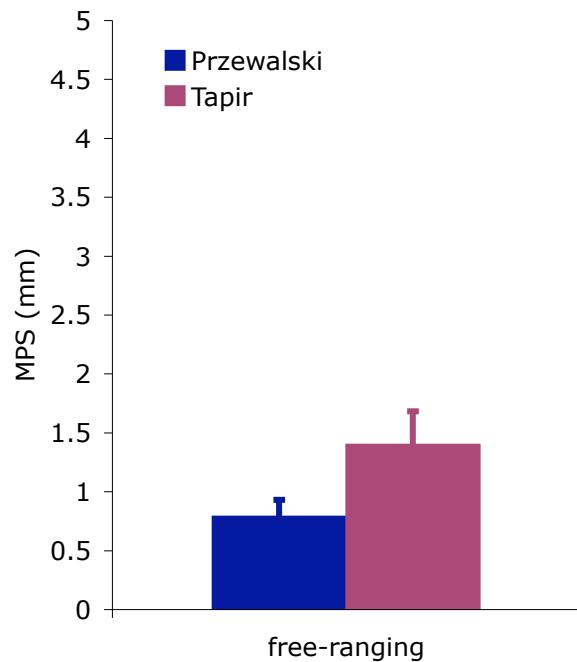
Some brachydont teeth do good things ...



Differences in Fecal Particle Size Between Free-ranging and Captive Individuals of Two Browser Species

Jürgen Hummel,^{1*} Julia Fritz,² Ellen Kienzle,² E. Patricia Medici,³ Stefanie Lang,² Waltraut Zimmermann,⁴ W. Jürgen Streich,⁵ and Marcus Clauss⁶

Zoo Biology 27:70–77 (2008)

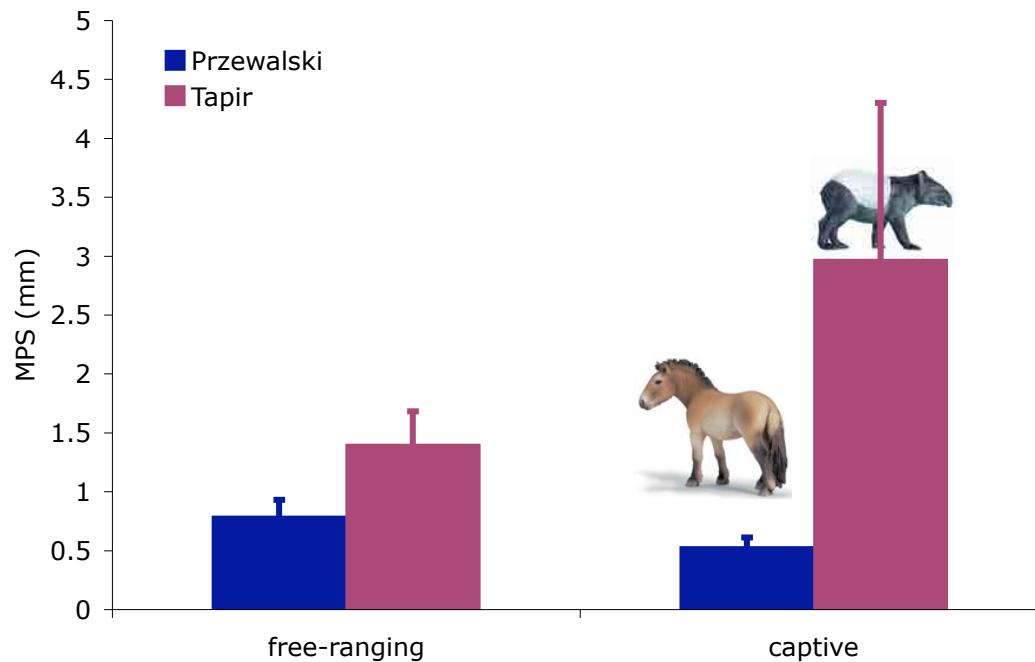




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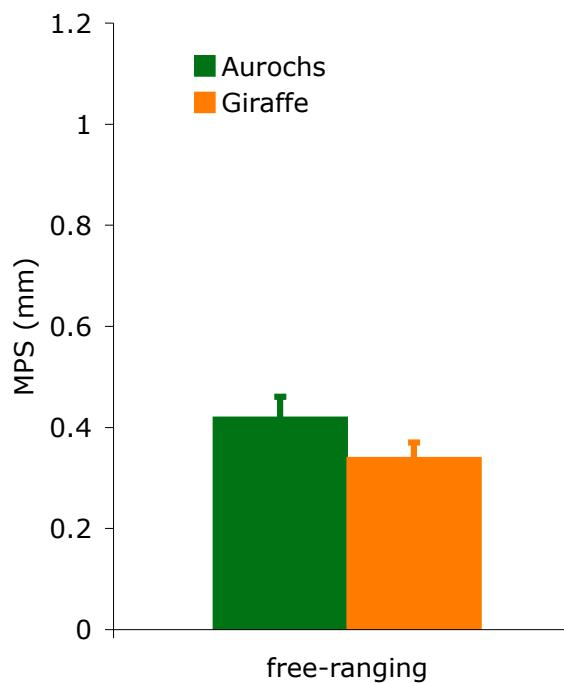




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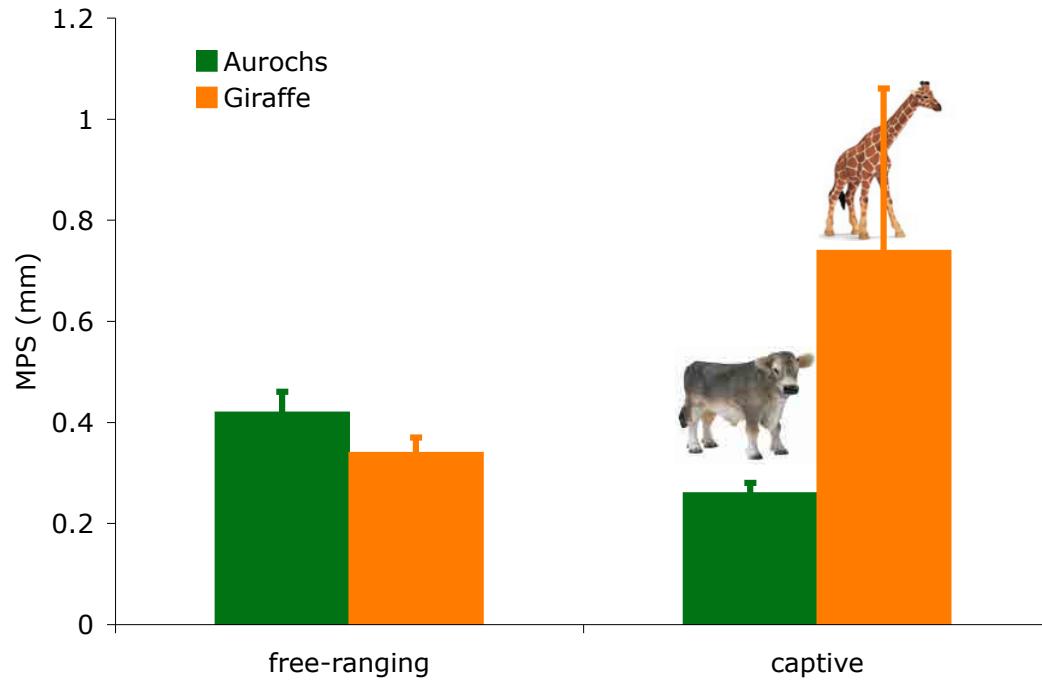




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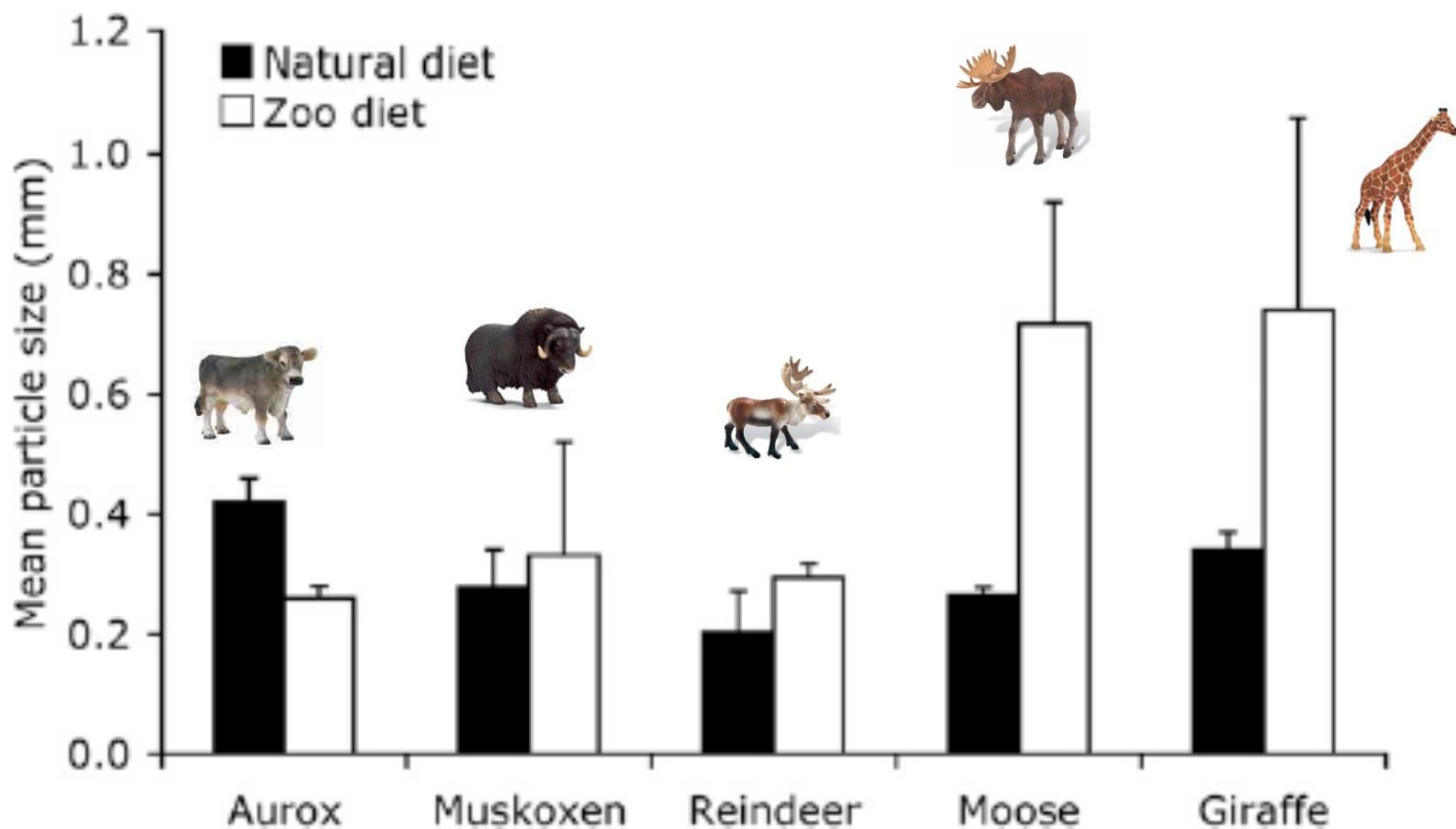




Differential passage of fluids and different-sized particles in fistulated oxen (*Bos primigenius f. taurus*), muskoxen (*Ovibos moschatus*), reindeer (*Rangifer tarandus*) and moose (*Alces alces*): Rumen particle size discrimination is independent from contents stratification

Isabel Lechner^a, Perry Barboza^b, William Collins^c, Julia Fritz^d, Detlef Günther^e, Bodo Hattendorf^e, Jürgen Hummel^f, Karl-Heinz Südekum^f, Marcus Clauss^{a,*}

Comparative Biochemistry and Physiology, Part A 155 (2010) 211–222

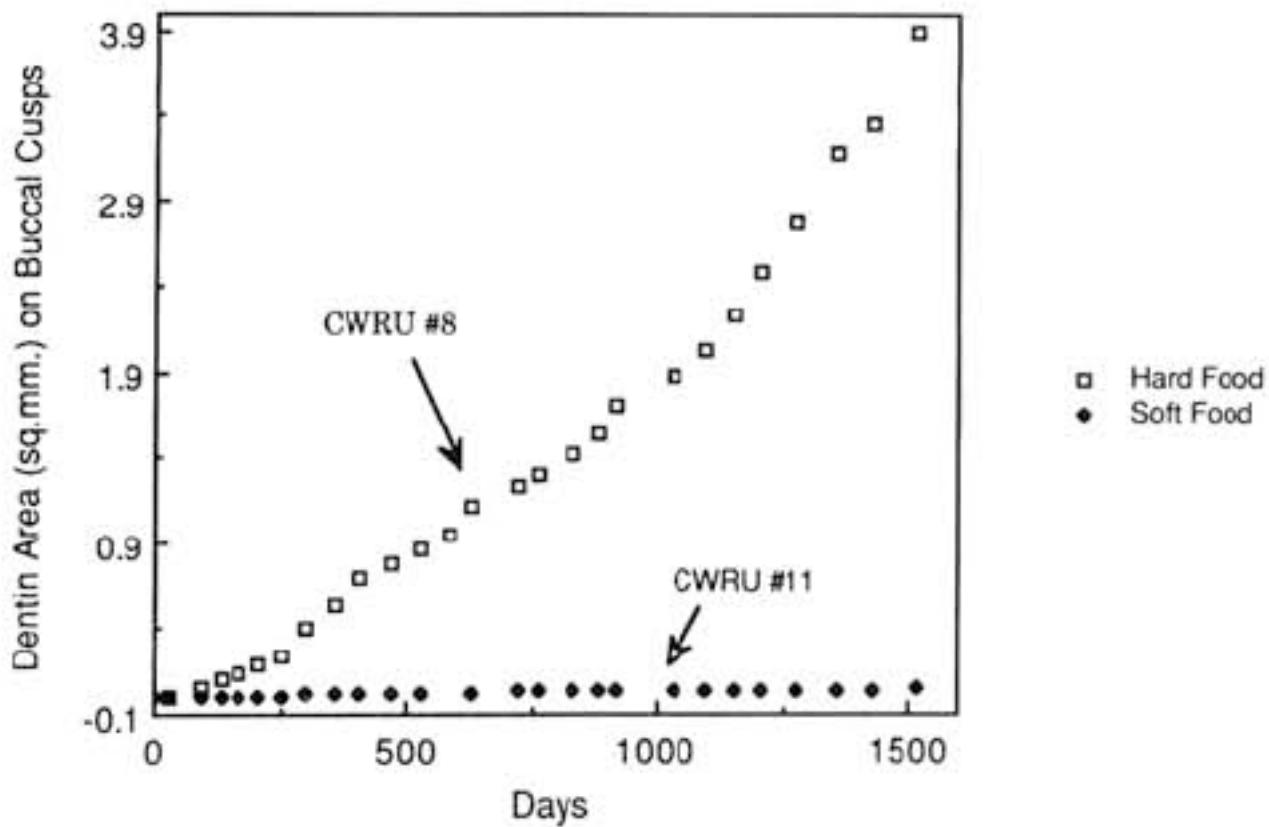




Differences in the Rate of Molar Wear between Monkeys Raised on Different Diets

M.F. TEAFORD and O.J. OYEN¹

J Dent Res 68(11):1513–1518, November, 1989

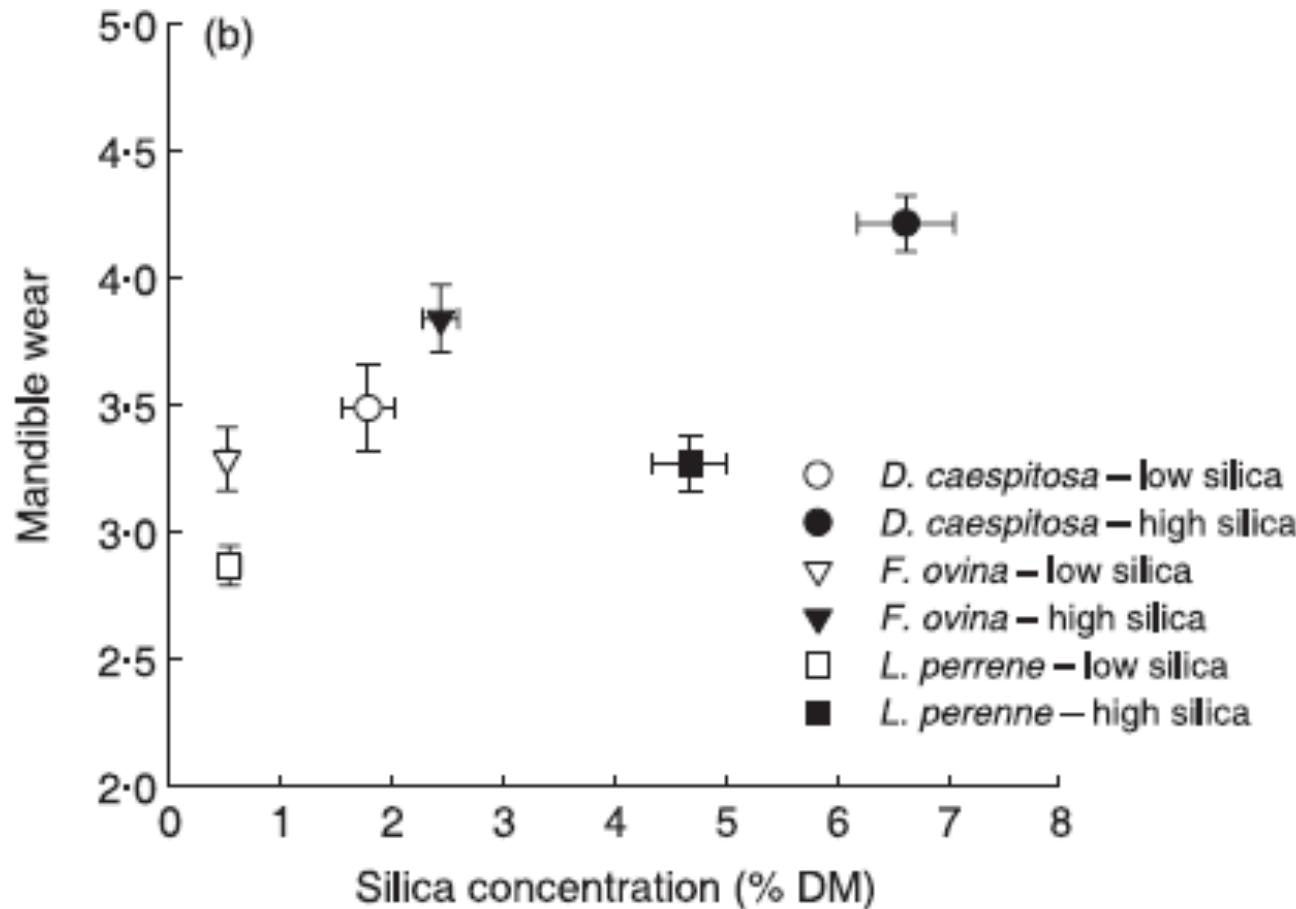




Physical defences wear you down: progressive and irreversible impacts of silica on insect herbivores

Fergus P. Massey* and Sue E. Hartley

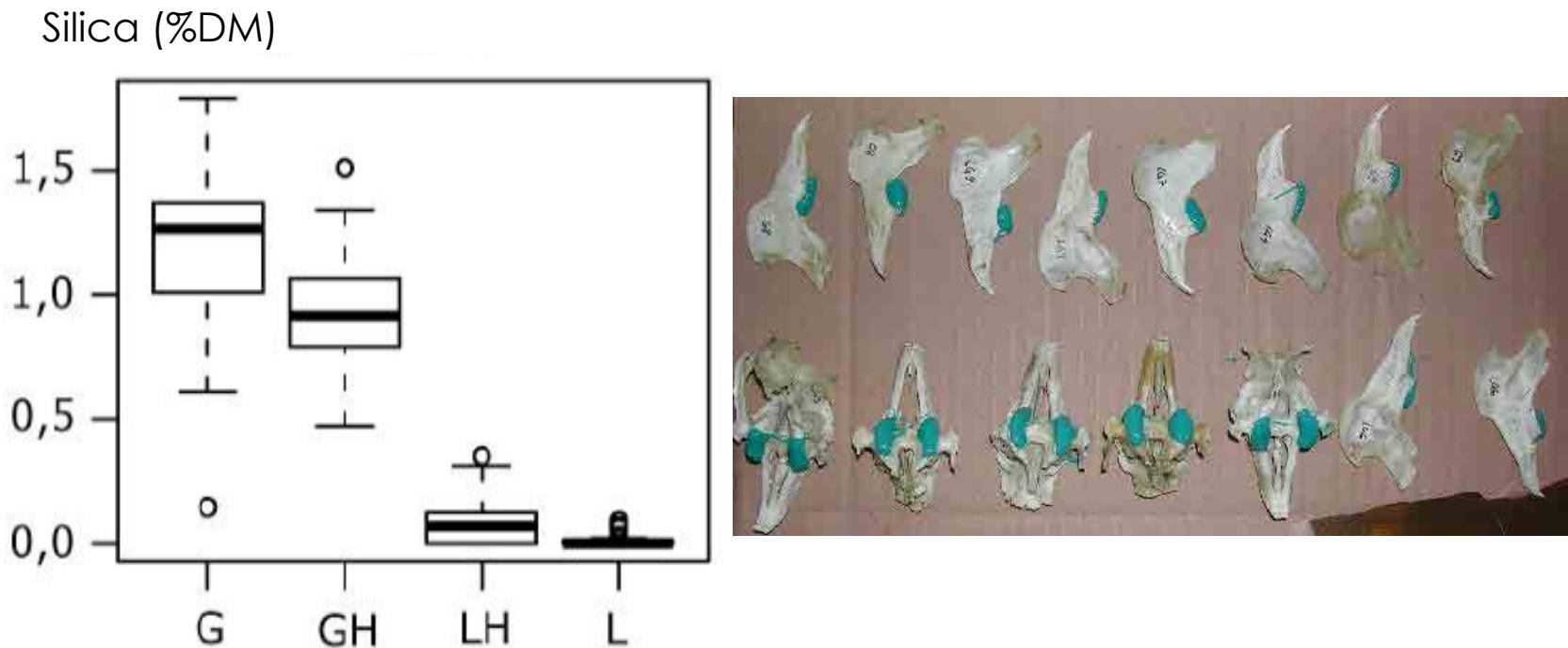
Journal of Animal Ecology 2009, 78, 281–291





Where do all the pits come from? – The effects of abrasive silica particles on tooth wear and its implications for palaeodietary interpretations

Schulz E.¹, Piotrowski V.¹, Clauss M.², Merceron G.³, Kaiser T.M.¹



Based on both methods the GG group have with a high amount of scratches the most abrasion dominated signature and the LL group with a high amount of pits the most attrition dominated signature. Therefore the silica content is identified as causing variable for scratching the surfaces. But additionally high amounts of pits are observed in the GG group too. This is linked to higher chewing pressure used for the highly tough grasses. We therefore conclude that pitting is not only a measure for browse.



Summary

- Hypsodonty can most logically be explained as a adaptation to tooth wear
- Abrasiveness of diet is mostly a concept and not an empirical measure
- Differences in wear can be demonstrated under different situations
- Important differences in the signal of hypsodonty (evolutionary) and mesowear (individual's lifetime)
- Quantitative effects of diet on tooth wear are needed



Summary

The mesowear score as in our collection does not reflect climate/habitat to the same extent as HI. HI is an evolutionary signal. MesoScore is a signal from an individual animal that may be exposed to different conditions than the animal was during its evolution of HI.

This does not mean that at lower-scale comparisons (e.g. within one group of herbivores only) the MesoScore is more linked to climate parameters.

