Supplementary Information

Table S1. Comparative database of 45 extant carnivoran species used to define the dietary morphospace. “Sm.hyper” denotes small (< 20 kg) hypercarnivore; lg.hyper denotes large (≥ 20 kg) hypercarnivore.

Family	Genus	Species	Mass (kg)	RBL	RUGA	JD/DL	Diet	Diet references
Canidae	*Vulpes*	*lagopus*	4.9	0.622	0.851	0.145	sm.hyper	[1–4]
Canidae	*Atelocynus*	*microtis*	9.5	0.608	1.127	0.136	omnivore	[5,6]
Canidae	*Canis*	*adustus*	9.5	0.611	1.032	0.128	omnivore	[7–11]
Canidae	*Canis*	*aureus*	9	0.639	0.949	0.143	carnivore	[8,12,13]
Canidae	*Canis*	*latrans*	14	0.643	0.847	0.14	carnivore	[14–18]
Canidae	*Canis*	*lupus*	51.5	0.646	0.862	0.166	lg.hyper	[19,20]
Canidae	*Canis*	*mesomelas*	7.5	0.642	0.906	0.138	carnivore	[8,11,13,21]
Canidae	*Canis*	*simensis*	15.25	0.664	1.006	0.122	sm.hyper	[22–24]
Canidae	*Cerdocyon*	*thous*	6.5	0.59	1.104	0.138	omnivore	[25–29]
Canidae	*Chrysocyon*	*brachyurus*	21.5	0.624	1.112	0.131	omnivore	[25,30]
Canidae	*Cuon*	*alpinus*	19	0.681	0.731	0.168	lg.hyper	[31,32]
Canidae	*Lycalopex*	*culpaeus*	8.7	0.633	0.905	0.13	omnivore	[24,33–37]
Canidae	*Lycalopex*	*griseus*	3	0.617	1.03	0.122	omnivore	[28,34,35,38]
Canidae	*Lycalopex*	*gymnocercus*	5.35	0.628	1.028	0.122	omnivore	[28,29,33]
Canidae	*Lycalopex*	*sechurae*	3.6	0.617	1.133	0.12	omnivore	[39]
Canidae	*Lycalopex*	*vetulus*	4	0.566	1.288	0.125	omnivore	[40,41]
Canidae	*Lycaon*	*pictus*	27	0.659	0.932	0.16	lg.hyper	[42–45]
Canidae	*Nyctereutes*	*procyonoides*	7	0.612	1.059	0.136	omnivore	[21,46,47]
Canidae	*Speothos*	*venaticus*	6	0.636	0.922	0.171	sm.hyper	[25,26,48]
Canidae	*Urocyon*	*cinereoargenteus*	4.5	0.613	1.119	0.121	omnivore	[49]
Canidae	*Urocyon*	*littoralis*	4	0.577	1.116	0.12	omnivore	[50–52]
Canidae	*Vulpes*	*bengalensis*	2.5	0.666	1.192	0.111	omnivore	[53,54]
Canidae	*Vulpes*	*cana*	0.8	0.712	0.91	0.125	omnivore	[55–57]
Canidae	*Vulpes*	*chama*	3	0.676	1.127	0.111	omnivore	[24,58]
Canidae	*Vulpes*	*corsac*	5	0.693	0.837	0.133	sm.hyper	[24,59]
Canidae	*Vulpes*	*ferrilata*	7	0.738	0.859	0.118	sm.hyper	[24,60]
Canidae	*Vulpes*	*macrotis*	2.1	0.643	0.94	0.122	sm.hyper	[24,61]
Canidae	*Vulpes*	*pallida*	2.8	0.656	1.129	0.108	omnivore	[24]

Canidae	*Vulpes*	*rueppellii*	3.3	0.677	1.007	0.119	omnivore	[62]
Canidae	*Vulpes*	*vulpes*	6	0.629	0.883	0.133	carnivore	[24,63]
Canidae	*Vulpes*	*zerda*	1.2	0.655	1.06	0.113	omnivore	[13,64]
Hyaenidae	*Crocuta*	*crocuta*	62.5	0.817	0	0.218	lg.hyper	[65–68]
Hyaenidae	*Hyaena*	*brunnea*	53.4	0.807	0.243	0.22	carnivore	[57,69–71]
Hyaenidae	*Hyaena*	*hyaena*	35	0.766	0.316	0.237	carnivore	[66]
Mephitidae	*Conepatus*	*leuconotus*	1.8	0.53	1.274	0.156	omnivore	[72]
Mustelidae	*Eira*	*barbara*	4.8	0.658	0.611	0.244	carnivore	[73,74]
Mustelidae	*Gulo*	*gulo*	21.5	0.685	0.472	0.197	carnivore	[75–77]
Mustelidae	*Martes*	*pennanti*	3.4	0.642	0.68	0.197	carnivore	[78]
Mustelidae	*Meles*	*meles*	13	0.514	1.541	0.186	omnivore	[79–81]
Mustelidae	*Mellivora*	*capensis*	10.3	0.603	0.475	0.18	carnivore	[7,82,83]
Mustelidae	*Melogale*	*moschata*	2	0.647	0.635	0.148	omnivore	[84,85]
Mustelidae	*Taxidea*	*taxus*	8.4	0.629	0.979	0.164	carnivore	[57,72]
Procyonidae	*Nasua*	*narica*	5	0.531	1.424	0.157	insectivore	[86,87]
Procyonidae	*Nasua*	*nasua*	4.6	0.469	1.304	0.142	omnivore	[57,88]
Procyonidae	*Procyon*	*lotor*	6.5	0.632	1.427	0.17	omnivore	[57,72]

Table S2. Time intervals used for analysis of maximum geographic range area. Intervals follow the age bounds defined on the MIOMAP / FAUNMAP database, except for the Early / Late Clarendonian pair of intervals, which were assigned to be of equal size after preliminary analysis showed that using MIOMAP's original Early / Middle / Late Clarendonian subdivisions produced extreme unevenness in number of localities across the Clarendonian.

Interval name	Abbreviation	Lower bound (million years ago)	Upper bound (million years ago)
Early Early Arikareean	EEAK	30	27.9
Late Early Arikareean	LEAK	27.9	23.8
Early Late Arikareean	ELAK	23.8	19.5
Late Late Arikareean	LLAK	19.5	18.8
Early Hemingfordian	EHMF	18.8	17.5
Late Hemingfordian	LHMF	17.5	15.9
Early Barstovian	EBAR	15.9	14.8
Late Barstovian	LBAR	14.8	12.5
Early Clarendonian	ECLA	12.5	10.75
Late Clarendonian	LCLA	10.75	9
Early Early Hemphillian	EEHP	9	7.5
Late Early Hemphillian	LEHP	7.5	6.7
Early Late Hemphillian	ELHP	6.7	5.9
Late Late Hemphillian	LLHP	5.9	4.7
Blancan	BLAN	4.7	1.7
Irvingtonian	IRVI	1.7	0.45
Rancholabrean	RANC	0.45	0.01
Holocene	HOLO	0.01	0

Table S3. Median results from models of trait evolution fitted to 500 trees sampled at random from the Bayesian posterior distribution by Slater [89].

Model	Log likelihood	AICc	AICw	σ^2	parameter
A. All canids					
1. Body mass					
BM	44.66475	-85.21069	9.157756e-05	0.003137757	NA
ACDC	44.82939	-83.41878	3.961611e-05	0.002973134	2.162607e-03
Trend	44.19477	-82.14953	3.065730e-05	0.002961913	2.894189e-03
Drift	54.88301	-103.52601	9.997347e-01	0.002574601	1.827889e-02
Diversity	44.91393	-83.58786	4.295418e-05	0.002830693	6.421031e-06
OU	44.66091	-83.08183	3.446327e-05	0.003138818	5.638945e-11
2. Carnivory					
BM	-85.58034	175.3145	0.06286337	0.05542281	NA
ACDC	-82.93337	172.1784	0.30904457	0.02338048	3.757759e-02
Trend	-83.59806	173.5078	0.21499314	0.01879732	2.894189e-03
Drift	-84.89842	176.1085	0.04285114	0.05429989	2.199654e-02
Diversity	-82.93179	172.1753	0.29672574	0.03478219	4.402561e-04
OU	-85.15941	176.6305	0.03487011	0.06291428	5.638945e-11
B. Hesperocyoninae					
1. Body mass					
BM	10.72104	-16.89664	0.010247768	0.002784072	NA
ACDC	10.90481	-14.66677	0.003364927	0.003324918	-1.554880e-02
Trend	10.69501	-14.24717	0.002814115	0.003080303	-8.770118e-03
Drift	16.56953	-25.99621	0.975773477	0.001726929	2.229475e-02
Diversity	10.92228	-14.70171	0.003365869	0.003019731	-1.813923e-05
OU	10.73479	-14.32673	0.002868430	0.003019731	4.874302e-11
2. Carnivory					
BM	-16.80593	38.41185	0.32331540	0.03979974	NA
ACDC	-16.57325	40.86079	0.09059419	0.04690875	-1.791413e-02
Trend	-16.74146	41.19720	0.09059419	0.04389444	-8.770118e-03
Drift	-15.43745	38.58919	0.28213640	0.03413788	4.820888e-02
Diversity	-16.50592	40.72612	0.09957292	0.03664228	4.999463e-04
OU	-16.81839	41.35107	0.07754502	0.03981831	4.874302e-11
C. Borophaginae					
1. Body mass					
BM	24.40350	-44.58059	0.012110790	0.003053074	NA
ACDC	24.49023	-42.51892	0.004613334	0.002941919	1.023808e-03
Trend	24.06219	-41.66283	0.003805079	0.002739413	4.655062e-03
Drift	29.88019	-53.29883	0.968437135	0.002526532	2.142011e-02
Diversity	24.55110	-42.64065	0.004800221	0.002730486	1.277821e-05
OU	24.40370	-42.34586	0.004210236	0.003049184	3.025531e-11
2. Carnivory					
BM	-53.39299	111.05871	0.003421490	6.526654e-02	NA

ACDC	-46.60766	99.77347	0.754624015	4.906135e-03	1.062904e-01
Trend	-48.03736	102.63287	0.210585899	2.675498e-05	3.488621e-03
Drift	-52.81768	112.19350	0.001821449	6.379503e-02	3.459980e-02
Diversity	-50.36962	107.29738	0.020662595	3.881006e-02	8.624105e-04
OU	-52.30791	111.17395	0.003301093	8.701984e-02	4.405020e-11
D. Fossil Caninae					
1. Body mass					
BM	13.76979	-22.93958	0.09041973	2.941388e-03	NA
ACDC	14.99181	-22.72046	0.10259634	7.382779e-04	6.495250e-02
Trend	15.35436	-23.44556	0.15091620	4.799969e-06	5.096073e+01
Drift	16.86994	-26.47673	0.53512705	2.244663e-03	1.748150e-02
Diversity	14.52832	-21.79348	0.05662464	1.877707e-03	8.941093e-05
OU	13.76245	-20.26174	0.02399209	2.938599e-03	4.348186e-11
2. Carnivory					
BM	-11.22622	27.37552	0.4616176	0.03449126	NA
ACDC	-11.05996	30.11993	0.1138682	0.02490613	1.662639e-02
Trend	-11.19122	30.38243	0.1077072	0.02484354	5.096073e+01
Drift	-11.17205	30.34409	0.1037565	0.03419290	-2.057593e-03
Diversity	-11.08674	30.17349	0.1116702	0.02626673	1.116238e-03
OU	-11.21163	30.42325	0.1013317	0.03648666	4.348186e-11

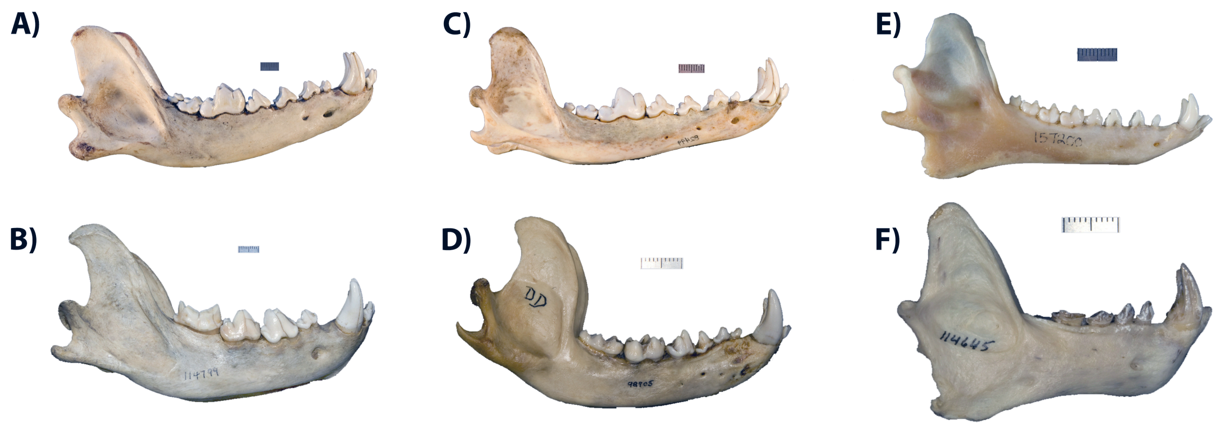

Figure S1. Lower jaws of representative extant carnivoran species across the hypercarnivory-mesocarnivory-hypocarnivory spectrum. **A, B,** hypercarnivores; **C, D,** mesocarnivores; **E, F,** hypocarnivores. **A,** grey wolf, *Canis lupus*; **B,** spotted hyena, *Crocuta crocuta*; **C,** coyote, *Canis latrans*; **D,** raccoon, *Procyon lotor*; **E,** bat-eared fox, *Otocyon megalotis*; **F,** kinkajou, *Potos flavus*. To highlight the differences in skeletal proportions corresponding to functional and dietary divergence among these animals, the lower jaws have been scaled to the same length from mandibular condyle to anterior end. Scale bars = 10 mm. Original specimen photos from Animal Diversity Web: https://animaldiversity.org.

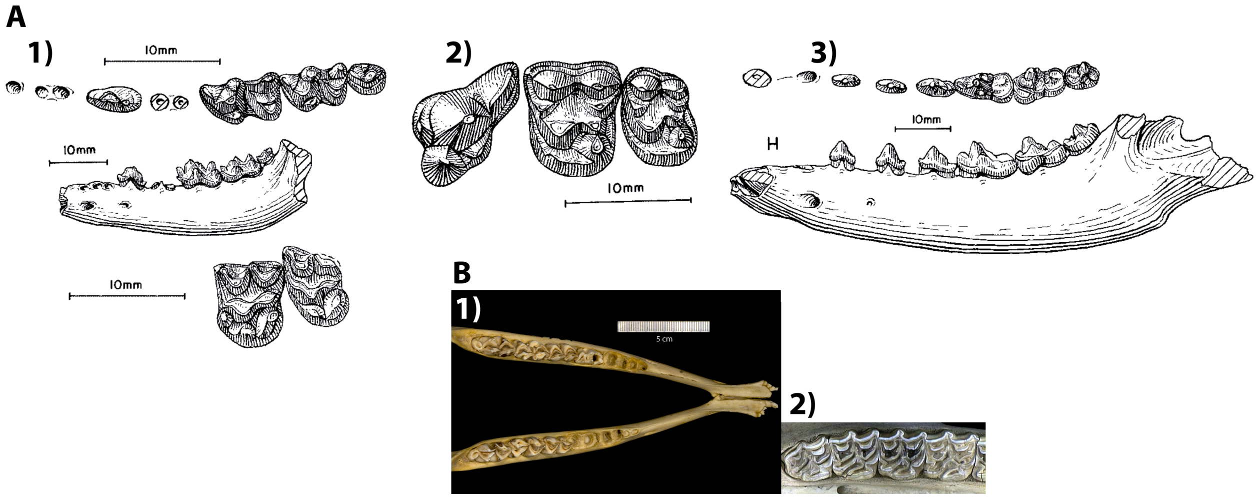

Figure S2. Comparison of the dentition of putatively hypocarnivorous fossil canids **(A)** with the dentition of known extant herbivorous ungulates **(B)**. **A, 1)** *Cynarctoides emryi*: occlusal view of lower dentition (top), labial view of lower jaw (middle), and occlusal view of upper molars (bottom); **2)** *Phlaocyon achoros*: occlusal view of upper carnassial and molars; **3)** *Cynarctus crucidens*, occlusal view of lower dentition (top) and labial view of lower jaw (bottom). **B, 1)** occlusal view of lower jaw of impala, *Aepyceros melampus*, and 2) occlusal view of dentition of horse, *Equus caballus*. Putatively hypocarnivorous fossil canids exhibit ecomorphological specialization in their teeth, with dental wear creating ridges converging on ungulate selenodont or bunodont dental morphology. Fossil-canid illustrations are from Wang *et al.* [90] and included with permission; extant-ungulate specimen photographs are from Animal Diversity Web (https://animaldiversity.org).

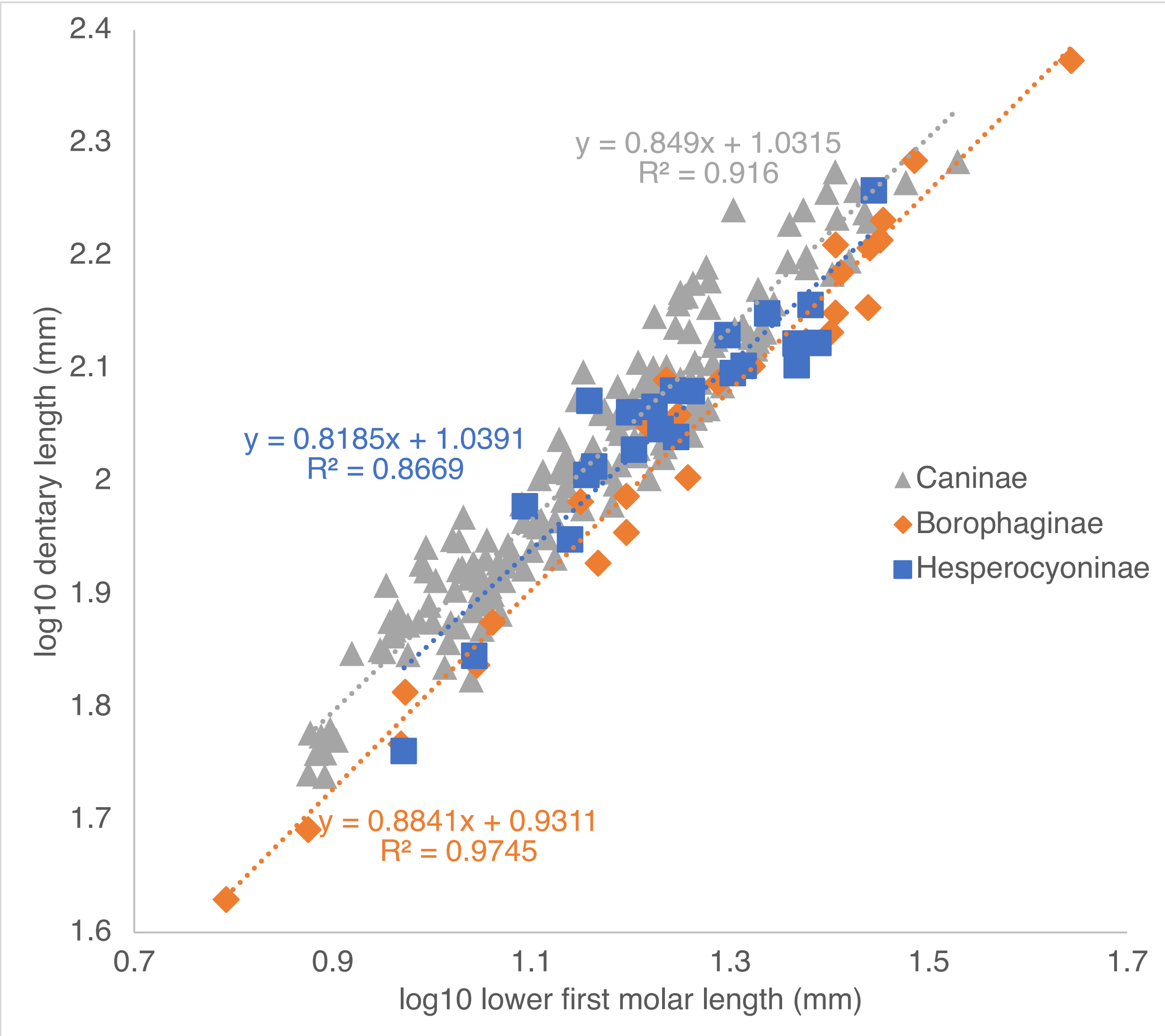

Figure S3. Per-subfamily regressions of $\log_{10}$ dentary length on $\log_{10}$ lower first molar length used to estimate dentary length of fragmentary fossil species, based on intact dentaries of 24 hesperocyonine individuals, 27 borophagine individuals, and 175 canine (extinct and extant) individuals. Borophagine dentaries tend to be shorter for a given molar length than dentaries of other subfamilies, even for borophagines of smaller body size that would not be expected to use a robust dentary to process bone.

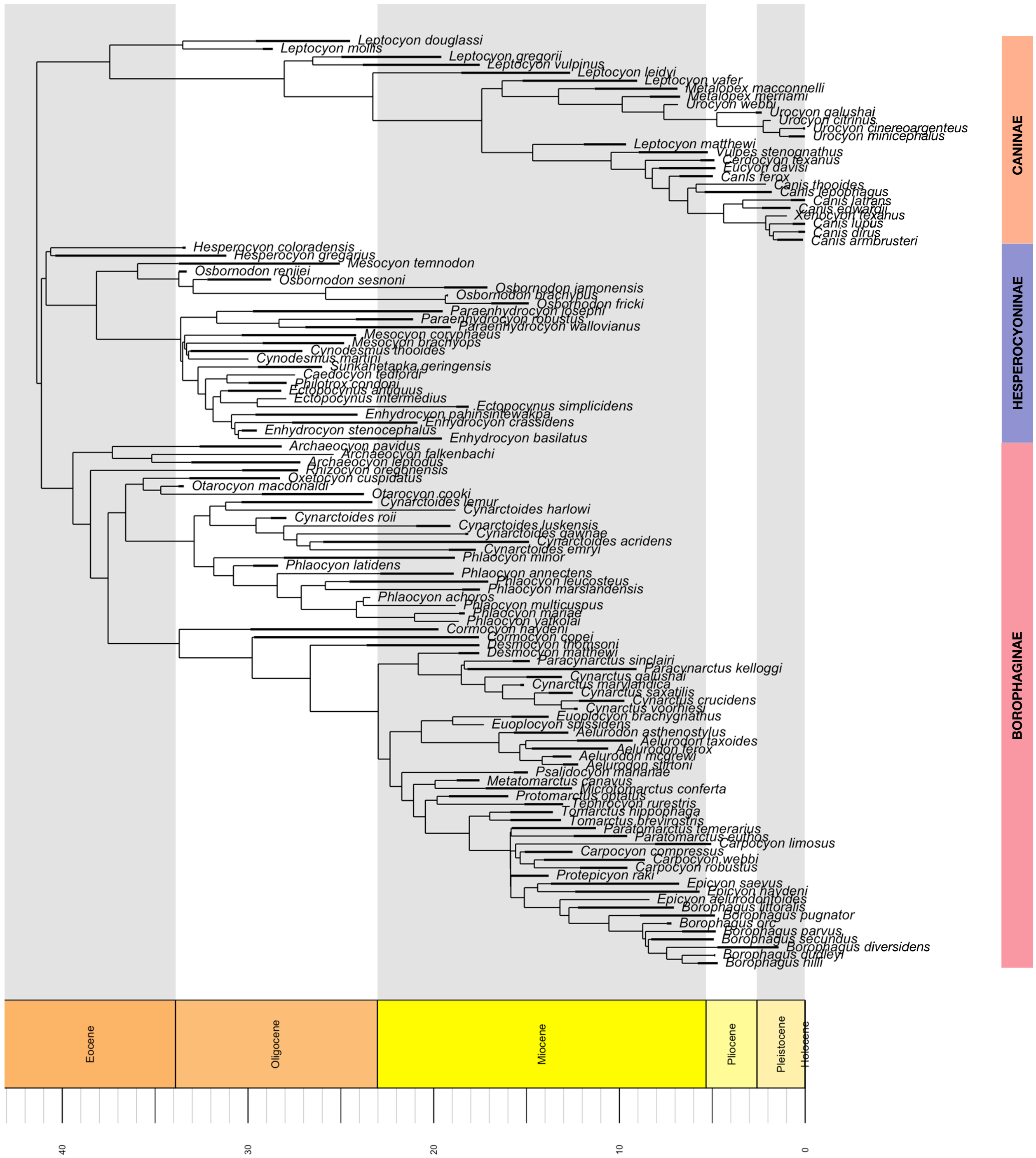

Figure S4. Time-scaled canid tree; topology from tree with the highest log-likelihood from the Bayesian posterior probability distribution of Slater [89]. Black bars on branches indicate stratigraphic range recorded by occurrences. Branches lacking black bars indicate singletons, or species with only one occurrence. Time units are millions of years ago.

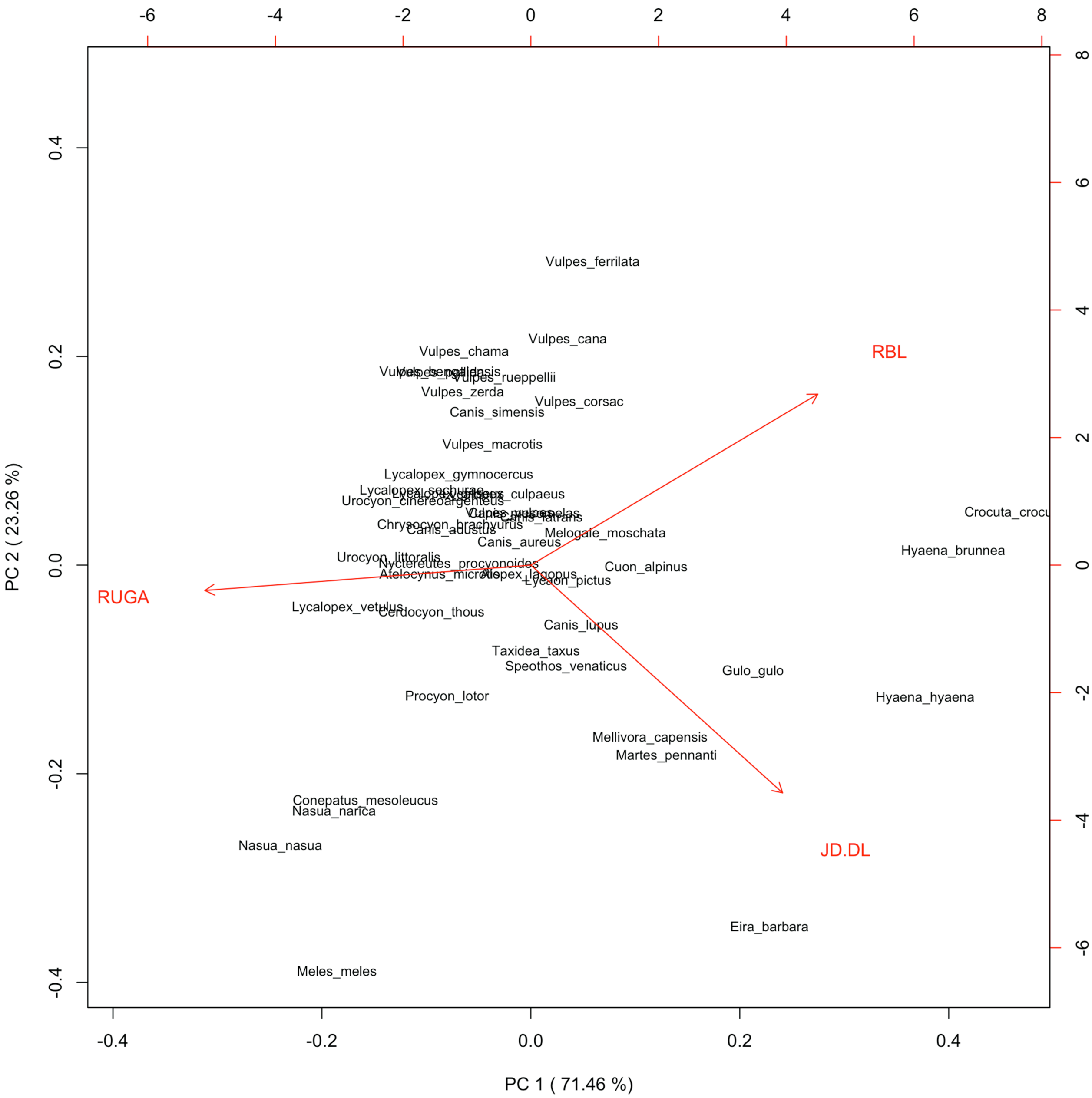

Figure S5. Principal component analysis of 45 extant caniform and hyaenid species only, with direction and magnitude of loadings superimposed.

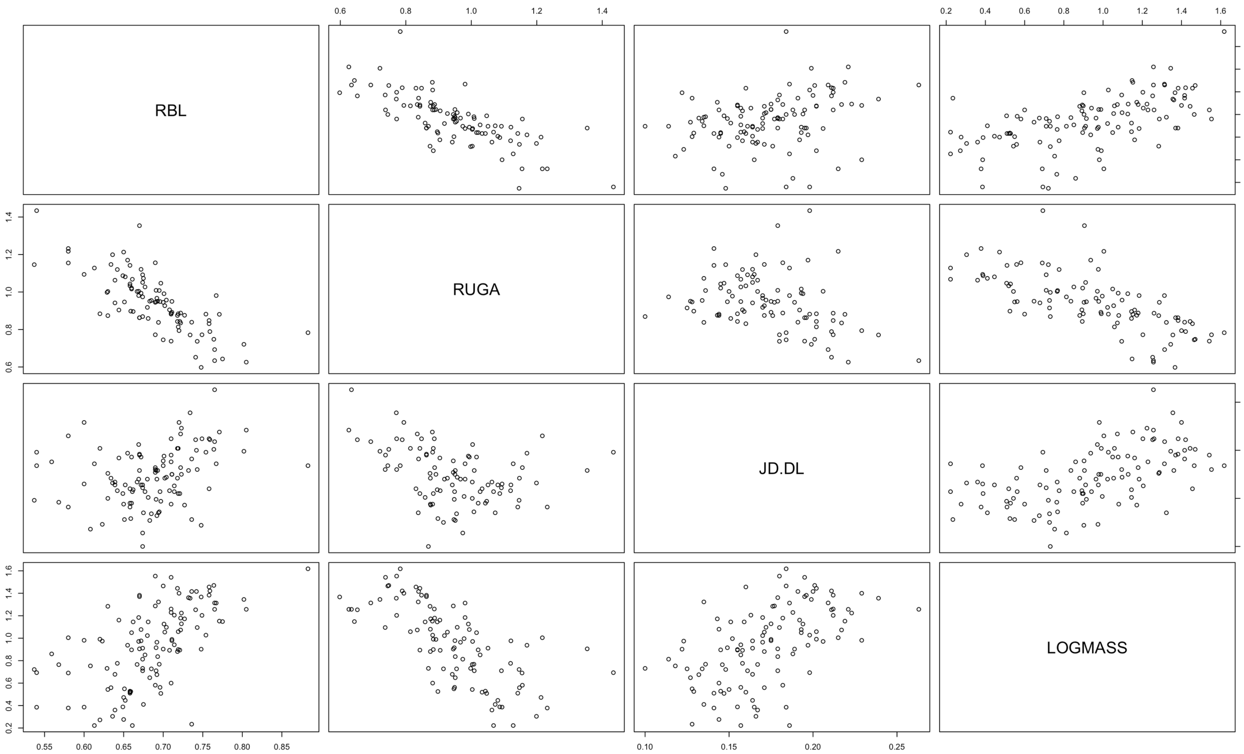

Figure S6. Bivariate plots showing correlated patterns among dietary measures and body mass.

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