

Supplementary Information

Effects of phylogenetic associations on environmental and temporal niche partitioning among sympatric mammals

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Appendix A. Supplementary tables and figures

Table S1. Environmental layers used to classify camera stations into habitat groups, including the data source and original resolution.

Environmental variable	Resolution	Data provider	Data source
Digital elevation model	30 m.	Copernicus Land Monitoring Service	https://finder.creodias.eu
Land cover	10 m.	S2GLC project	https://finder.creodias.eu
NDVI ¹	10 m.	Copernicus Land Monitoring Service	https://finder.creodias.eu
Average annual temperature ²	30 arc sec (~1 km)	WorldClim	https://worldclim.org
Average annual precipitation ²	30 arc sec (~1 km)	CHELSA	https://worldclim.org
Roads ³	Vector	OpenStreetMap	https://planet.openstreetmap.org/

¹ W used the average of the dates 2019-07-02, 2019-07-17, 2019-07-25, 2019-08-09, 2019-08-11, 2019-08-19 and 2019-08-21. All of these dates had a local cloud cover of <5%.

² Average annual values from 1970-2000

³ We used only primary, secondary, and residential roads for our calculations.

Table S2. Cophenetic correlation between the original distance matrix and pair-wise distances in dendrograms created using seven different clustering algorithms.

Algorithm	R
Ward	0.56
Single linkage	0.65
Complete linkage	0.69
Unweighted centroid linkage	0.66
Weighted centroid linkage	0.53
Unweighted average linkage	0.73
Weighted average linkage	0.67

Table S3. Percent contribution of each of the 12 environmental variables on the first four dimensions in a principal component analyses on the environmental characteristics of individual camera stations.

	Dim.1	Dim.2	Dim.3	Dim.4
Deciduous forest	0.01	31.61	2.61	7.56
Coniferous forest	9.99	1.44	0.94	10.08
Herbaceous vegetation	2.08	18.71	18.50	0.17
Moorland	1.34	6.10	27.12	3.35
Land cover heterogeneity	2.34	17.00	4.76	10.39
NDVI	2.10	10.43	0.21	17.40
Precipitation	8.35	4.54	9.07	7.39
Temperature	26.46	0.09	0.35	0.06
Elevation	25.39	0.00	0.88	1.68
Terrain	3.65	1.91	32.26	0.90
Distance to road	17.80	0.01	0.48	0.65
Distance to water	0.50	8.18	2.82	40.38

Table S4. Estimated occupancy, naive occupancy (proportion of occupied sites) and number of observations for six groups of camera stations based on environmental characteristics.

	A			B			C			D			E			F			
	Occ.	Naive occ.	N	Occ.	Naive occ.	N	Occ.	Naive occ.	N	Occ.	Naive occ.	N	Occ.	Naive occ.	N	Occ.	Naive occ.	N	
<i>Canis lupus</i>	0.340	0.294	41	0.444	0.286	5	0.000	0.000	0	0.674	0.500	2	0.00	1	0.001	0	0.000	0.000	0
<i>Capreolus capreolus</i>	0.598	0.529	61	0.518	0.571	69	0.504	0.600	52	0.406	0.500	7	0.83	0	0.999	10	0.000	0.000	0
<i>Cervus elaphus</i>	0.527	0.471	11 8	0.693	0.714	57	0.374	0.400	21	0.474	0.500	17	0.79	9	1.000	10	0.000	0.000	0
<i>Felis silvestris</i>	0.134	0.118	5	0.542	0.143	1	0.000	0.000	0	0.872	0.500	19	0.00	0	0.000	0	0.000	0.000	0
<i>Hystrix cristata</i>	0.067	0.059	2	0.000	0.000	0	0.000	0.000	0	0.936	0.500	16	0.00	1	0.000	0	0.001	0.000	0
<i>Lepus sp.</i>	0.275	0.235	16	0.953	0.857	22	0.650	0.400	12	0.743	0.500	51	0.43	2	0.001	0	0.000	0.000	0
<i>Martes sp.</i>	0.260	0.235	49	0.330	0.143	4	0.655	0.400	5	0.897	0.750	60	1.00	0	1.000	14	0.001	0.000	0
<i>Meles meles</i>	0.140	0.118	6	0.542	0.143	1	0.000	0.000	0	0.875	0.500	12	0.41	6	0.000	0	0.000	0.000	0
<i>Sciurus vulgaris</i>	0.065	0.059	3	0.000	0.000	0	0.000	0.000	0	0.828	0.250	10	1.00	0	1.000	3	0.000	0.000	0
<i>Sus scrofa</i>	0.206	0.176	16	0.783	0.429	5	0.731	0.400	2	0.809	0.500	24	0.00	0	0.003	0	0.001	0.000	0
<i>Ursus arctos</i>	0.808	0.235	5	0.145	0.143	1	0.247	0.200	1	0.000	0.000	0	0.38	2	0.000	0	0.000	0.000	0
<i>Vulpes vulpes</i>	0.464	0.412	60	0.653	0.571	30	0.438	0.400	7	0.789	0.750	18	0.423	0	0.000	0	0.000	0.000	0

Table S5. Estimated occupancy, naive occupancy (proportion of occupied sites) and number of observations for six time bins based on the time of camera observation.

	Dawn			Early day			Late day			Dusk			Early night			Late night		
	Occ.	Naive occ.	N	Occ.	Naive occ.	N	Occ.	Naive occ.	N	Occ.	Naive occ.	N	Occ.	Naive occ.	N	Occ.	Naive occ.	N
<i>Canis lupus</i>	0.167	0.114	7	0.504	0.114	9	0.623	0.171	13	0.421	0.086	3	0.57	0.143	9	0.416	0.086	7
<i>Capreolus capreolus</i>	0.380	0.343	21	0.637	0.429	63	0.668	0.457	57	0.253	0.143	8	0.46	0.286	25	0.422	0.257	25
<i>Cervus elaphus</i>	0.336	0.286	17	0.527	0.314	43	0.527	0.314	56	0.327	0.171	13	0.52	0.314	51	0.562	0.343	43
<i>Felis silvestris</i>	0.000	0.000	0	1.000	0.029	1	1.000	0.086	4	1.000	0.057	2	1.00	0.086	7	1.000	0.086	11
<i>Hystrix cristata</i>	0.045	0.029	1	0.000	0.000	0	0.498	0.029	1	0.767	0.086	4	0.49	0.029	3	0.768	0.086	9
<i>Lepus sp.</i>	0.228	0.171	13	0.441	0.143	12	0.596	0.229	43	0.217	0.057	2	0.30	0.086	5	0.632	0.257	26
<i>Martes sp.</i>	0.093	0.086	7	0.691	0.171	16	0.641	0.143	21	0.500	0.086	11	0.79	0.257	36	0.763	0.229	41
<i>Meles meles</i>	0.038	0.029	1	0.000	0.000	0	0.499	0.029	2	0.000	0.000	0	0.82	0.114	5	0.766	0.086	11
<i>Sciurus sp.</i>	0.032	0.029	4	0.673	0.057	6	0.762	0.086	6	0.000	0.000	0	0.00	0.000	0	0.000	0.000	0
<i>Sus scrofa</i>	0.225	0.143	5	0.348	0.086	6	0.252	0.057	4	0.253	0.057	6	0.61	0.200	12	0.500	0.143	14
<i>Ursus arctos</i>	1.000	0.086	3	0.804	0.029	1	0.842	0.029	1	0.807	0.029	1	0.80	0.029	1	0.000	0.000	0
<i>Vulpes vulpes</i>	0.073	0.057	3	0.880	0.286	20	0.840	0.229	21	0.781	0.171	9	0.896	0.343	23	0.897	0.314	39

Table S6. Number of independent observations (photographs taken at different camera stations or at the same camera station >30 minutes apart) for the 12 species or taxa used in the study.

Order	Taxon	N _{obs}
Carnivora	<i>Canis lupus</i>	48
Carnivora	<i>Vulpes vulpes</i>	115
Carnivora	<i>Ursus arctos</i>	7
Carnivora	<i>Meles meles</i>	19
Carnivora	<i>Martes</i> sp.	132
Carnivora	<i>Felis silvestris</i>	25
Cetartiodactyla	<i>Capreolus capreolus</i>	199
Cetartiodactyla	<i>Cervus elaphus</i>	223
Cetartiodactyla	<i>Sus scrofa</i>	47
Lagomorpha	<i>Lepus</i> sp.	101
Rodentia	<i>Hystrix cristata</i>	18
Rodentia	<i>Sciurus vulgaris</i>	16

Table S7. Observed and random expectations of degree centrality, closeness centrality and specialization of each species in uni-partite networks projected from a tri-partite network describing combined environmental and temporal niche use as well as bi-partite networks describing environmental and temporal niche use. Significant deviations from random expectations, based on 1000 randomly shuffled interaction matrices, are indicated in bold font.

Species	Environmental and temporal niche use				Environmental niche use				Temporal niche use			
	Obs	Exp	Z	P	Obs	Exp	Z	P	Obs	Exp	Z	P
	<u>Degree centrality</u>											
<i>Canis lupus</i>	103.24	112.47	-0.82	0.414	39.99	46.49	-0.78	0.438	63.25	66.17	-0.40	0.693
<i>Capreolus capreolus</i>	120.09	113.21	0.61	0.539	55.66	46.31	1.09	0.277	64.43	66.73	-0.31	0.755
<i>Cervus elaphus</i>	120.35	113.49	0.59	0.553	56.08	46.91	1.08	0.278	64.26	66.23	-0.27	0.785
<i>Felis silvestris</i>	127.09	113.08	1.31	0.191	40.88	46.28	-0.68	0.500	86.20	66.40	2.66	0.008
<i>Hystrix cristata</i>	97.41	113.38	-1.39	0.164	35.44	46.63	-1.30	0.195	61.97	66.46	-0.61	0.539
<i>Lepus sp</i>	111.98	112.98	-0.09	0.929	51.61	46.30	0.61	0.541	60.36	66.29	-0.82	0.415
<i>Martes sp</i>	127.82	112.16	1.33	0.182	56.83	46.54	1.22	0.224	70.99	66.59	0.59	0.553
<i>Meles meles</i>	98.42	113.13	-1.30	0.193	40.98	46.14	-0.63	0.530	57.44	66.36	-1.22	0.221
<i>Sciurus vulgaris</i>	95.21	113.10	-1.56	0.119	44.33	46.52	-0.25	0.803	50.88	66.56	-2.15	0.031
<i>Sus scrofa</i>	108.85	112.33	-0.30	0.764	50.72	46.97	0.45	0.654	58.12	66.01	-1.06	0.291
<i>Ursus arctos</i>	116.19	112.89	0.29	0.771	37.39	46.35	-1.07	0.283	78.80	66.29	1.73	0.083
<i>Vulpes vulpes</i>	128.71	113.11	1.43	0.152	48.84	47.34	0.17	0.862	79.87	66.50	1.81	0.070
<u>Closeness centrality</u>												
<i>Canis lupus</i>	0.01	0.01	-0.81	0.418	0.02	0.02	-0.69	0.491	0.03	0.03	-0.47	0.638
<i>Capreolus capreolus</i>	0.01	0.01	0.46	0.649	0.03	0.02	0.89	0.371	0.03	0.03	-0.43	0.667
<i>Cervus elaphus</i>	0.01	0.01	0.42	0.675	0.03	0.03	0.86	0.388	0.03	0.03	-0.41	0.685
<i>Felis silvestris</i>	0.02	0.01	1.45	0.148	0.02	0.02	-0.66	0.507	0.10	0.03	6.21	0.000
<i>Hystrix cristata</i>	0.01	0.01	-1.13	0.256	0.02	0.02	-0.96	0.335	0.03	0.03	-0.58	0.560
<i>Lepus sp</i>	0.01	0.01	-0.22	0.825	0.03	0.02	0.31	0.757	0.03	0.03	-0.76	0.445
<i>Martes sp</i>	0.02	0.01	1.41	0.159	0.03	0.02	1.09	0.275	0.04	0.03	0.33	0.741
<i>Meles meles</i>	0.01	0.01	-1.05	0.294	0.02	0.02	-0.63	0.529	0.02	0.03	-0.92	0.358
<i>Sciurus vulgaris</i>	0.01	0.01	-1.24	0.215	0.02	0.02	-0.38	0.705	0.02	0.03	-1.23	0.217
<i>Sus scrofa</i>	0.01	0.01	-0.40	0.689	0.03	0.03	0.18	0.860	0.02	0.03	-0.85	0.395
<i>Ursus arctos</i>	0.01	0.01	0.07	0.944	0.02	0.02	-0.87	0.382	0.05	0.03	2.02	0.043

<i>Vulpes vulpes</i>	0.02	0.01	1.59	0.111	0.02	0.03	-0.07	0.941	0.06	0.03	2.55	0.011
<u>Specialization (d')</u>												
<i>Canis lupus</i>	0.05	0.13	-1.50	0.135	0.12	0.16	-0.44	0.660	0.00	0.09	-1.63	0.103
<i>Capreolus capreolus</i>	0.05	0.12	-1.34	0.179	0.07	0.16	-1.00	0.319	0.02	0.09	-1.23	0.218
<i>Cervus elaphus</i>	0.04	0.12	-1.53	0.125	0.06	0.16	-1.12	0.261	0.01	0.09	-1.43	0.152
<i>Felis silvestris</i>	0.10	0.12	-0.39	0.698	0.15	0.17	-0.16	0.870	0.04	0.09	-0.83	0.406
<i>Hystrix cristata</i>	0.18	0.13	0.99	0.322	0.28	0.16	1.56	0.118	0.11	0.09	0.38	0.704
<i>Lepus sp</i>	0.07	0.13	-1.14	0.254	0.11	0.16	-0.64	0.522	0.02	0.09	-1.32	0.186
<i>Martes sp</i>	0.04	0.13	-1.72	0.086	0.07	0.16	-1.07	0.284	0.01	0.09	-1.40	0.160
<i>Meles meles</i>	0.16	0.12	0.77	0.439	0.15	0.16	-0.12	0.903	0.17	0.09	1.43	0.154
<i>Sciurus sp</i>	0.28	0.12	3.35	0.001	0.27	0.16	1.29	0.197	0.27	0.09	3.18	0.001
<i>Sus scrofa</i>	0.07	0.12	-1.00	0.320	0.11	0.15	-0.56	0.573	0.02	0.09	-1.26	0.209
<i>Ursus arctos</i>	0.22	0.12	1.96	0.050	0.33	0.16	1.96	0.050	0.14	0.09	0.94	0.349
<i>Vulpes vulpes</i>	0.04	0.12	-1.57	0.116	0.07	0.16	-0.98	0.329	0.02	0.09	-1.32	0.186

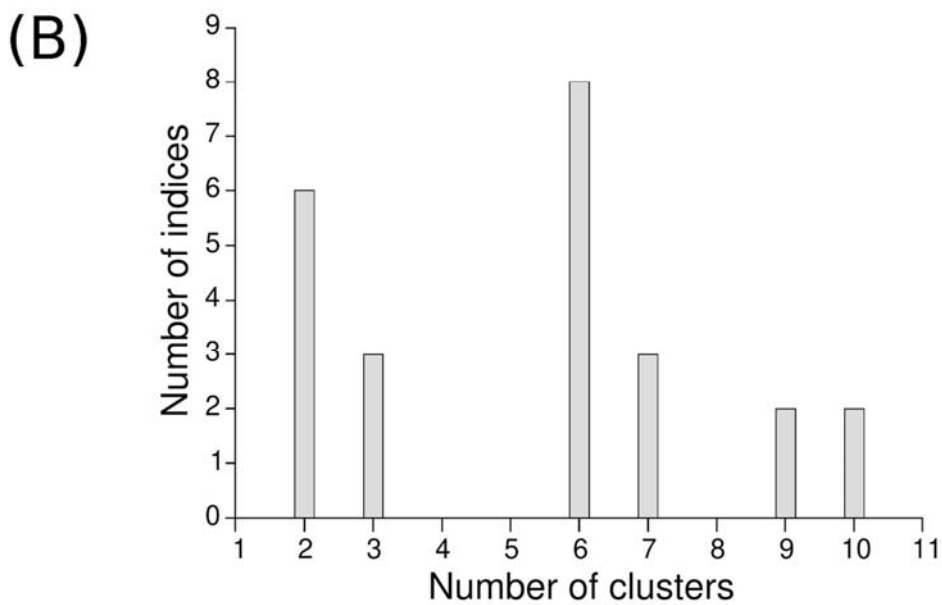
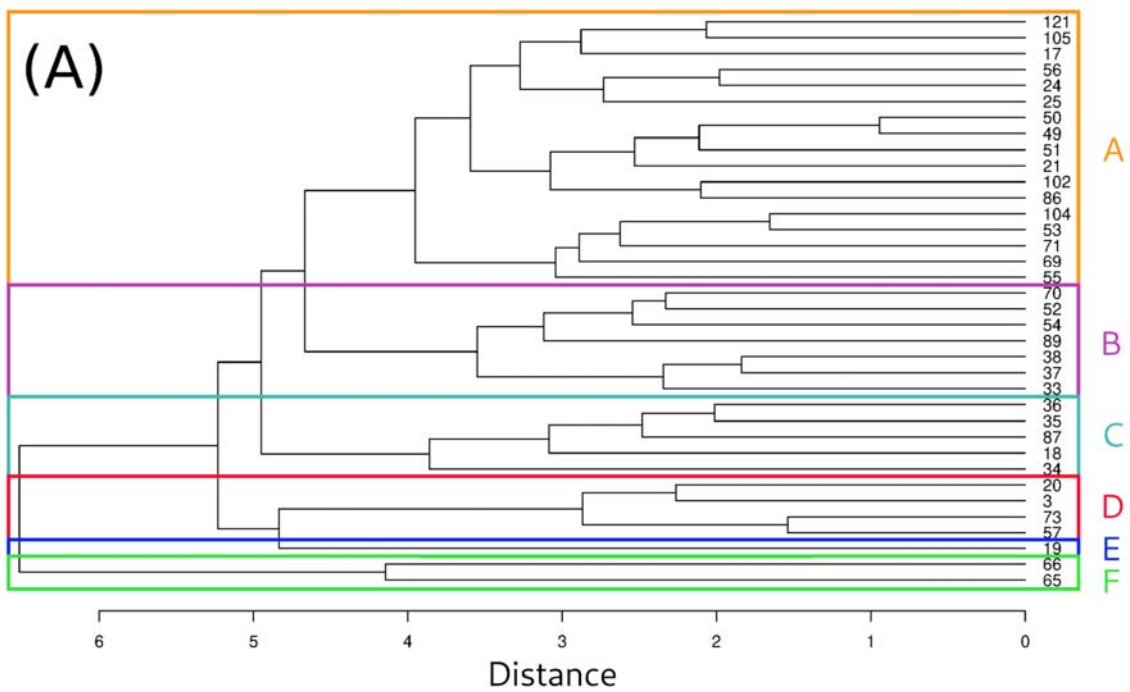


Figure S1. Dendrogram describing environmental differences between camera stations and their subsequent clusters (A), as well as the frequency of indices favoring a particular number of clusters ranging from 2 to 10 among 30 candidate indices following Charrad et al. (2014) (B).

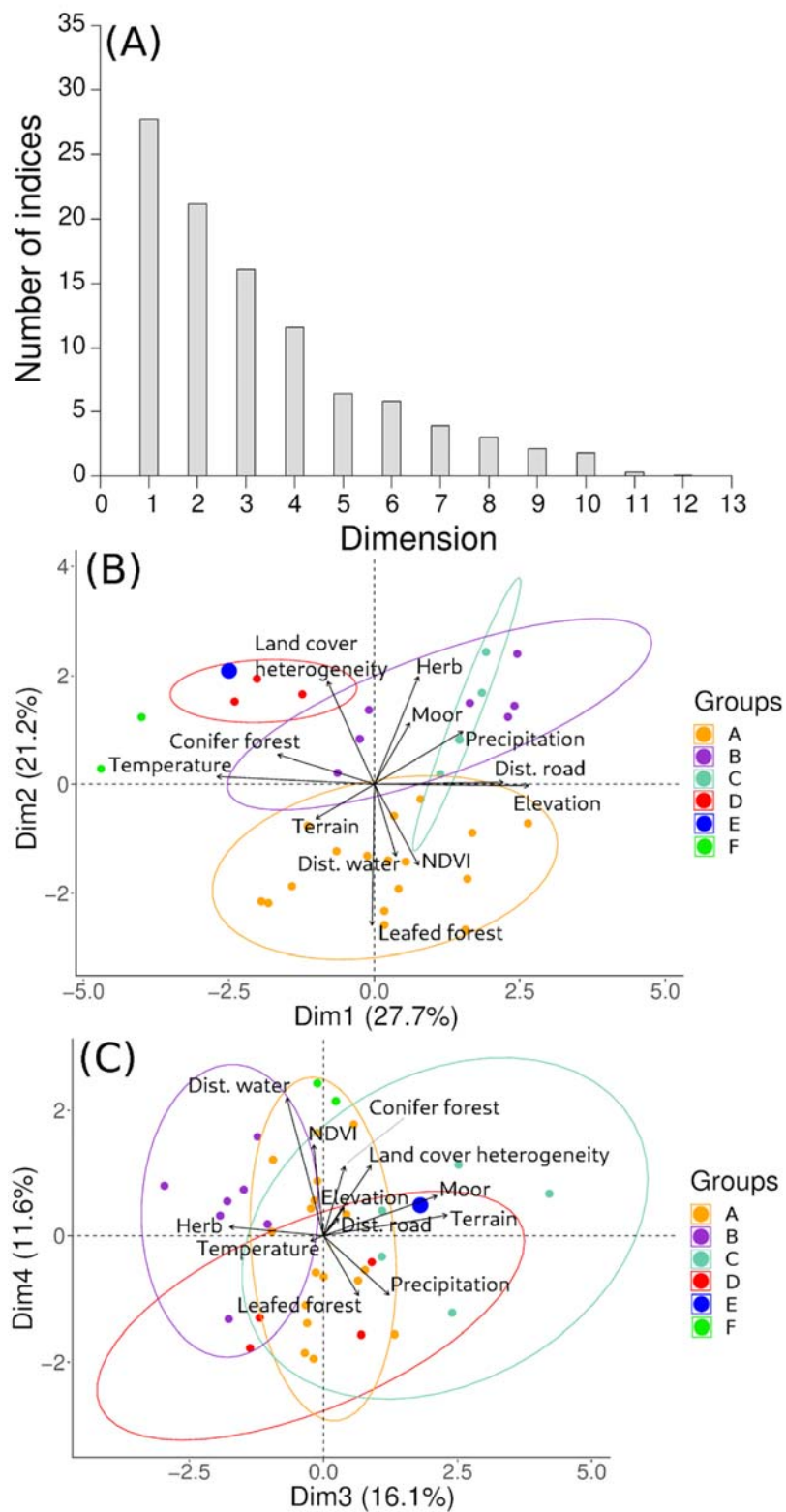


Figure S2. Scree plot showing the percentage of explained variation by the first 10 dimensions from a Principal Component Analyses on differences in environmental characteristics between camera stations (A), and bi-plots showing the spacing of individual camera stations within the first four dimensions as well as the influence of the environmental variables on each dimension (B, C).