

SUPPLEMENTARY INFORMATION

Severe conservation risks of roads on apex predators

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All I.Q., E.F.C., J.D., M.A., D.M.M., F.M.F., B.R.S., F-J.R., conceived, designed, and wrote the manuscript. E.F.C. carried out spatial analysis and maps. I.Q. and E.F.C. designed and created indices. M.A., D.M.M., F.M.F., B.R.S., I.Q., and F-J.R. collected articles and extracted data for wildlife-vehicle collision.

Supplementary Table S1. Selected apex predator species including reference and justification. Note that “transition to apex predator” refers to the study by Wallach et al.¹ in which the transition from apex- to meso-predator occurred in species with an average body mass form 13-16 kg. Species that fall over this threshold but have a diet based mainly on plants (*e.g.* Panda and civet) and marine and semi-aquatic (*e.g.* polar bear, otters and pinnipeds) were excluded. Dingo was excluded from the analysis due to the lack of an available IUCN distribution map². Data for mass was obtained from Wallach et al.¹ and from Jonas et al.³ for the Tasmanian. ULBM= Upper limit body mass, and ABM= Average body mass.

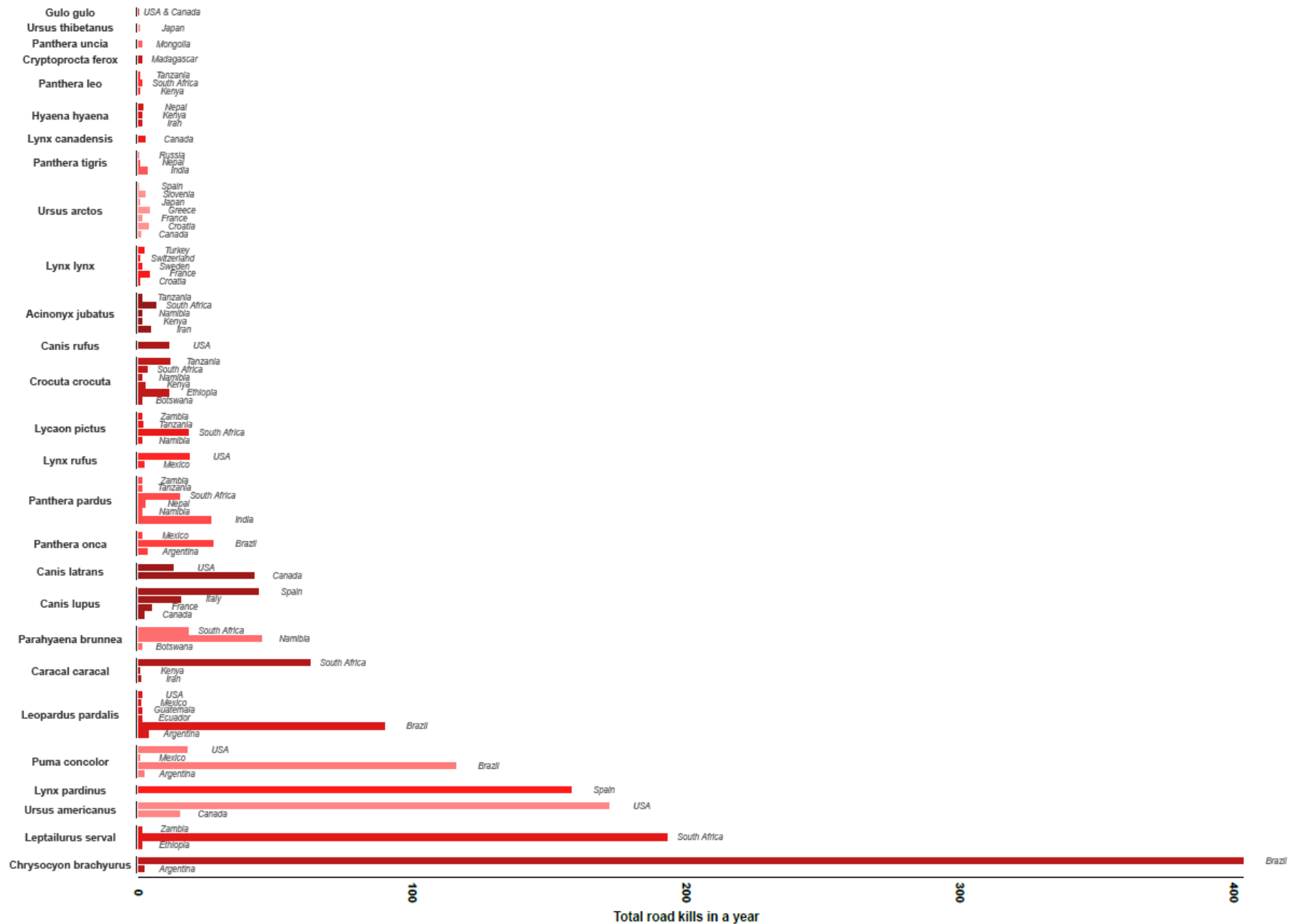
Family	Species name	Common name	Justification	ULBM (kg)	ABM (kg)
Canidae	<i>Canis latrans</i>	Coyote	Transition to apex predator ¹	34	13
Canidae	<i>Canis lupus</i>	Gray wolf	Apex predator ¹	80	27
Canidae	<i>Canis rufus</i>	Red wolf	Apex predator ¹	41	25
Canidae	<i>Canis simensis</i>	Ethiopian wolf	Transition to Apex predator ¹	20	15
Canidae	<i>Chrysocyon brachyurus</i>	Maned wolf	Apex predator ¹	25	22
Canidae	<i>Cuon alpinus</i>	Dhole	Apex predator ¹	25	18
Canidae	<i>Lycaon pictus</i>	African wild dog	Apex predator ¹	34	27
Dasyuridae	<i>Sarcophilus harrisii</i>	Tasmanian devil	Apex predator ⁴ despite being below ABM threshold.	NA	8.2
Eupleridae	<i>Cryptoprocta ferox</i>	Fossa	Apex predator in Madagascar (largest carnivore) ⁵ , despite being below ABM threshold.	12	10
Felidae	<i>Acinonyx jubatus</i>	Cheetah	Apex predator ¹	65	54
Felidae	<i>Caracal caracal</i>	Caracal	Transition to apex predator ^{1,6}	20	16
Felidae	<i>Catopuma temminckii</i>	Asiatic golden cat	Apex predator ¹	16	14
Felidae	<i>Leopardus pardalis</i>	Ocelot	Transition to Apex predator ¹ . Its density seems to not be affected by larger cats densities and affect the smaller ones in opposite trend ⁷	20	9

Felidae	<i>Leptailurus serval</i>	Serval	Apex predator ¹	19	13
Felidae	<i>Lynx canadensis</i>	Canada lynx	Apex predator ⁸ despite being below ABM threshold.	11	10
Felidae	<i>Lynx lynx</i>	Eurasian lynx	Apex predator ¹	38	23
Felidae	<i>Lynx pardinus</i>	Iberian lynx	Apex predator ⁹ despite being below ABM threshold.	15	11
Felidae	<i>Lynx rufus</i>	Bobcat	Apex predator ¹⁰ despite being below ABM threshold.	14	9
Felidae	<i>Neofelis diardii</i>	Clouded leopard	Apex predator ¹	23	20
Felidae	<i>Neofelis nebulosa</i>	Clouded leopard	Apex predator ¹	23	20
Felidae	<i>Panthera leo</i>	African lion	Apex predator ¹	272	175
Felidae	<i>Panthera onca</i>	Jaguar	Apex predator ¹	125	81
Felidae	<i>Panthera pardus</i>	Leopard	Apex predator ¹	70	54
Felidae	<i>Panthera tigris</i>	Tiger	Apex predator ¹	350	120
Felidae	<i>Panthera uncia</i>	Snow leopard	Apex predator ¹	50	50
Felidae	<i>Puma concolor</i>	Puma	Apex predator ¹	105	63
Hyaenidae	<i>Crocuta crocuta</i>	Spotted hyena	Apex predator ¹	86	63
Hyaenidae	<i>Hyaena hyaena</i>	Striped hyena	Apex predator ¹	55	40
Hyaenidae	<i>Parahyaena brunnea</i>	Brown hyena	Apex predator ¹	73	42
Mustelidae	<i>Gulo gulo</i>	Wolverine	Apex predator ¹	35	16
Ursidae	<i>Helarctos malayanus</i>	Sun bear	Apex predator ¹	70	45
Ursidae	<i>Melursus ursinus</i>	Sloth bear	Apex predator ¹	190	100
Ursidae	<i>Tremarctos ornatus</i>	Spectacled bear	Apex predator ¹	200	118
Ursidae	<i>Ursus</i>	American	Apex predator ¹	400	154

	<i>americanus</i>	black bear			
Ursidae	<i>Ursus arctos</i>	Brown bear	Apex predator ¹	680	278
Ursidae	<i>Ursus thibetanus</i>	Asiatic black bear	Apex predator ¹	200	104

Supplementary References

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Supplementary Fig. S1. Collated wildlife-vehicle collision data. Total number of individuals killed in a year for each species in each country is shown.

Supplementary Table S2. Variables used for the calculation of the species vulnerability to roads (SVR) index for each of the 36 apex predator species. High-impact roads include highway, primary and secondary roads, whereas low-impact roads include tertiary and local roads. Proportion of area was calculated dividing the respective area by the total distribution area of each species. IUCN category was categorized as: Least Concern (LC =1), Near Threatened (NT =2), Vulnerable (VU =3), Endangered (EN =4) and Critically Endangered (CR =5). Total number of threats were calculated by adding the different types of threats listed in the IUCN. For body mass category the average body mass of each species was categorized as: Very large predators (>100 kg) =4, large predators (25-100 kg) =3, medium predators (15-25 kg) =2, small predators (8-15 kg) =1.

Species name	Distribution area (km ²)	Total area covered by roads (km ²)	Area covered by high-impact roads (km ²)	Area covered by low-impact roads (km ²)	Non protected area (km ²)	Proportion of area covered by total roads	Proportion of area covered by high-impact roads	Proportion of area covered by low-impact roads	Proportion of area non protected	IUCN category	Total number of threats	Body mass category
<i>Melursus ursinus</i>	800042	774700	576979	628423	712236	0.97	0.72	0.79	0.89	3	7	4
<i>Cuon alpinus</i>	3621031	2670418	1698083	2216485	3229226	0.74	0.47	0.61	0.89	4	4	2
<i>Panthera tigris</i>	1026853	669064	415285	507818	777491	0.65	0.40	0.49	0.76	4	7	4
<i>Ursus thibetanus</i>	4038636	2618101	1759550	1992110	3572126	0.65	0.44	0.49	0.88	3	4	4
<i>Canis rufus</i>	4033	2712	2712	69	2295	0.67	0.67	0.02	0.57	5	3	3
<i>Neofelis nebulosa</i>	2052145	1338939	970575	971771	1827178	0.65	0.47	0.47	0.89	3	4	2
<i>Lynx pardinus</i>	4931	3378	2502	2904	1624	0.68	0.51	0.59	0.33	4	6	1
<i>Chrysocyon brachyurus</i>	4412522	3215387	1788915	2407401	3916405	0.73	0.41	0.55	0.89	2	4	2
<i>Lynx rufus</i>	9910174	6645115	6073076	2698850	9030750	0.67	0.61	0.27	0.91	1	5	1

<i>Parahyaena brunnea</i>	2331868	1575323	880193	1406651	1653511	0.68	0.38	0.60	0.71	2	2	3
<i>Panthera pardus</i>	9253624	4967570	2560558	3782841	6599835	0.54	0.28	0.41	0.71	3	7	3
<i>Helarctos malayanus</i>	1501780	919083	330614	817153	1164757	0.61	0.22	0.54	0.78	3	5	3
<i>Tremarctos ornatus</i>	348488	185273	84656	159392	234163	0.53	0.24	0.46	0.67	3	5	4
<i>Puma concolor</i>	21291518	11937238	7577894	8522000	16535384	0.56	0.36	0.40	0.78	1	7	3
<i>Sarcophilus harrisii</i>	64423	42850	20972	35271	37572	0.67	0.33	0.55	0.58	4	2	1
<i>Hyaena hyaena</i>	23487689	11746377	5735220	9092178	21288145	0.50	0.24	0.39	0.91	2	4	3
<i>Panthera uncia</i>	3481403	1141068	566233	790593	3151268	0.33	0.16	0.23	0.91	3	8	3
<i>Cryptoprocta ferox</i>	480076	377553	49572	364046	415606	0.79	0.10	0.76	0.87	3	4	1
<i>Canis simensis</i>	13560	6644	4889	2427	6699	0.49	0.36	0.18	0.49	4	5	2
<i>Leopardus pardalis</i>	14666314	7553291	4676693	5556292	10757128	0.52	0.32	0.38	0.73	1	8	1
<i>Catopuma temminckii</i>	602650	348696	202142	286064	318570	0.58	0.34	0.47	0.53	2	4	1
<i>Ursus arctos</i>	25234972	6526139	5292200	2261299	22115185	0.26	0.21	0.09	0.88	1	9	4

<i>Neofelis diardi</i>	629757	348644	46181	330294	540623	0.55	0.07	0.52	0.86	3	3	2
<i>Crocota crocuta</i>	14479050	8709991	3312801	7366699	11859497	0.60	0.23	0.51	0.82	1	1	3
<i>Leptailurus serval</i>	12646085	7657489	3289241	6343509	10232184	0.61	0.26	0.50	0.81	1	4	1
<i>Acinonyx jubatus</i>	3163284	1279582	447918	1066359	2053816	0.40	0.14	0.34	0.65	3	5	3
<i>Caracal caracal</i>	17506735	10118606	4502126	8215361	14509860	0.58	0.26	0.47	0.83	1	2	2
<i>Lycaon pictus</i>	1428318	590580	149151	534903	480641	0.41	0.10	0.37	0.34	4	8	3
<i>Canis latrans</i>	17049824	8216153	7369569	3453998	14975488	0.48	0.43	0.20	0.88	1	0	1
<i>Panthera onca</i>	9476699	3278772	1707032	2399899	5933615	0.35	0.18	0.25	0.63	2	8	3
<i>Ursus americanus</i>	10898763	3099560	2805265	1011119	9437110	0.28	0.26	0.09	0.87	1	4	4
<i>Panthera leo</i>	1955803	775849	264460	652299	797580	0.40	0.14	0.33	0.41	3	6	4
<i>Lynx lynx</i>	20842247	7012367	5764533	2515290	18781042	0.34	0.28	0.12	0.90	1	5	2
<i>Canis lupus</i>	51219910	17405031	12848675	8786961	46322782	0.34	0.25	0.17	0.90	1	2	3
<i>Gulo gulo</i>	24290288	3816281	3185869	846966	21237585	0.16	0.13	0.03	0.87	1	5	2
<i>Lynx canadensis</i>	8192520	1040668	807247	257291	6906792	0.13	0.10	0.03	0.84	1	7	1