Saving the World's Terrestrial Megafauna

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From the late Pleistocene to the Holocene, and now the so called Anthropocene, humans have been driving an ongoing series of species declines and extinctions (Dirzo et al. 2014). Large-bodied mammals are typically at a higher risk of extinction than smaller ones (Cardillo et al. 2005). However, in some circumstances terrestrial megafauna populations have been able to recover some of their lost numbers due to strong conservation and political commitment, and human cultural changes (Chapron et al. 2014). Indeed many would be in considerably worse predicaments in the absence of conservation action (Hoffmann et al. 2015). Nevertheless, most mammalian megafauna face dramatic range contractions and population declines. In fact, 59% of the world's largest carnivores ($\geq$ 15 kg, n = 27) and 60% of the world's largest herbivores ($\geq$ 100 kg, n = 74) are classified as threatened with extinction on the International Union for the Conservation of Nature (IUCN) Red List (supplemental table S1 and S2). This situation is particularly dire in sub-Saharan Africa and Southeast Asia, home to the greatest diversity of extant megafauna (figure 1). Species at risk of extinction include some of the world's most iconic animals—such as gorillas, rhinos, and big cats (figure 2 top row)—and, unfortunately, they are vanishing just as science is discovering their essential ecological roles (Estes et al.

2011). Here, our objectives are to raise awareness of how these megafauna are imperiled (species

in supplemental table S1 and S2) and to stimulate broad interest in developing specific

recommendations and concerted action to conserve them.

Megafauna provide a range of distinct ecosystem services through top-down biotic and knock-

on abiotic processes (Estes et al. 2011). Many megafauna function as keystone species and

ecological engineers, generating strong cascading effects in the ecosystems in which they occur.

These species also provide important economic and social services. For example, ecotourism is

the fastest growing subsector of tourism in developing countries (UNEP 2013), and megafauna

are a major draw for these tourists. Besides contributing considerable revenue to conservation,

wildlife-based tourism can contribute significantly to education, economies, job creation, and

human livelihoods.

Many of the surviving mammalian megafauna remain beset by long-standing and generally

escalating threats of habitat loss, persecution, and exploitation (Ripple et al. 2014, 2015). Large

mammals are extremely vulnerable to these threats due to their large area requirements, low

densities (particularly for carnivores), and relatively "slow" life history traits (Wallach et al.

2015). Various anthropogenic forces such as deforestation, agricultural expansion, increasing

livestock numbers, and other forms of human encroachment have severely degraded critical

habitat for megafauna by increased fragmentation or reduced resource availability. Although

some species show resilience by adapting to new scenarios under certain conditions (Chapron et

al. 2014), livestock production, human population growth and cumulative land use impacts can

trigger new conflicts or exacerbate existing ones, leading to additional declines. According to the

Food and Agriculture Organization, as of 2014, there were an estimated 3.9 billion ruminant

livestock on Earth compared with ~8.5 million individuals of 51 of 74 species of wild

megaherbivores for which population estimates are available within their native ranges (supplemental table S2), a magnitude difference of ~400 times.

The current depletion of megafauna is also due to overhunting and persecution: shooting, snaring, and poisoning by humans ranging from individuals to governments, as well as by organized criminals and terrorists (Darimont et al. 2015). Megafauna are killed for meat and body parts for traditional medicine and ornaments, or because of actual or perceived threats to humans, their crops or livestock. Meat and body parts are sold locally, to urban markets, or traded regionally and internationally. Striking instances include the slaughter of thousands of megafauna such as African elephants (*Loxodonta africana*) for their ivory, rhinoceroses for their horns, and tigers (*Panthera tigris*) for their body parts. In addition, many lesser-known megafauna species (figure 2, bottom row) are now imperiled (supplemental table S1 and S2). Most of the world's megaherbivores remain poorly studied and this knowledge gap makes conserving them even more difficult (Ripple et al. 2015).

Under a business-as-usual scenario, conservation scientists will soon be busy writing obituaries for species and subspecies of megafauna as they vanish from the planet. In fact, this process is already underway: eulogies have been written for Africa's western black rhinoceros (*Diceros bicornis longipes*) and the Vietnamese subspecies of the Javan rhinoceros (*Rhinoceros sondaicus annamiticus*) (IUCN 2015). Epitaphs will probably soon be needed for scimitar-horned oryx (*Oryx dammah*), now extinct in the wild; the kouprey (*Bos sauveli*), last seen in 1988; and the northern white rhinoceros (*Ceratotherium simum cottoni*), which now numbers three individuals (IUCN 2015). The Sumatran rhino (*Dicerorhinus sumatrensis*) is already extinct in the wild in Malaysia and is very close to extinction in Indonesia with the population collapsing during the last 30 years from over 800 to fewer than 100 (supplemental table 2). The Javan rhino

(*Rhinoceros sondaicus*) is down to a single population of ~58 in a single reserve (supplemental table 2). The Critically Endangered Bactrian camel (*Camelus ferus*) and African wild ass (*Equus africanus*) are not far behind. Even in protected areas, megafauna are increasingly under assault. For example, in West and Central Africa, several large carnivores [including lions (*Panthera leo*), African wild dogs (*Lycaon pictus*), and cheetahs (*Acinonyx jubatus*)] have experienced recent severe range contractions and have declined markedly in many protected areas (IUCN 2015).

Although many of the general causes and mechanisms of declines are well identified and recognized, this understanding has not translated into adequate conservation action. Some of the existing mammal prioritization schemes could be incorporated into a comprehensive global strategy for conserving the largest mammals (Rondinini et al. 2011). Increasing prioritization and political will to conserve megafauna—and actions to restore or reintroduce them in areas where they have declined or been extirpated (such as plans to reintroduce scimitar-horned oryx into Chad and to rehabilitate the entire Gorongosa ecosystem in Mozambique)—are urgently needed. We suggest that the problem has two parts: i) a need to further and more effectively implement, expand, and refine current interventions at relevant scales and; ii) a need for large-scale policy shifts and global increases in funding for conservation to alter the framework and ways in which people interact with wildlife.

In order to save declining species, there is a need to increase global conservation funding by at least an order of magnitude (McCarthy et al. 2012). Without such a transformation, there is a risk that many of the world's most iconic species may not survive to the 22nd Century. We must not go quietly into this impoverished future. Rather, we believe it is our collective responsibility, as scientists who study megafauna, to act to prevent their decline. We therefore present a call to the

broader international community to join together in conserving the remaining terrestrial megafauna (see declaration in Box 1).

From declaration to action

Social and political commitment to provide sufficient protection across the vast landscapes needed for the conservation of the world's megafauna is increasingly required. International frameworks and conventions such as the Convention on Biological Diversity (CBD), the Convention on the Conservation of Migratory Species of Wild Animals (CMS), and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) have had some success in safeguarding species and regions. However, the decisions of these conventions are not always binding, and they will require substantially increased political will and financial support if they are to be effective in the critical task of securing the survival of the world's megafauna. Some regional legal instruments such as the CMS Gorilla Agreement and the Global Tiger Initiative incorporate environmental or biodiversity commitments, and are playing a growing role in protecting biodiversity. International agreements are often well-placed for enforcing regional frameworks for megafauna; examples include the African Elephant Action Plan and the regional conservation strategy for cheetahs and African wild dogs. However, implementation of such initiatives requires financial resources and capacity that are seldom available at those locations where the highest diversity of megafauna remains (figure 1). Therefore, the onus is on developed countries, which have long ago lost most of their megafauna, to not only embark on conservation and restoration programs on their own lands, but also support conservation initiatives in those nations where diverse megafauna still persist. For conservation efforts to be successful, actions should be taken at all levels by authorities that have the public interest in mind, and to work to secure the continued existence of these species.

Successfully conserving megafauna requires bold social, political, and financial commitments from nations around the world. Through understanding the value and importance of local human needs, and by combining international financial support with a coordinated multilateral approach to conservation, it may be possible to rescue megafauna from the brink of extinction. As biologists, ecologists and conservation scientists, we are mindful that none of our arguments are new, and that our prescriptions are far easier to write out than to accomplish. However, our objective in presenting them together here is to demonstrate a consensus of opinion amongst the global community of scientists who study and conserve these animals, thereby emphasizing to the wider world the gravity of the problem. Our hope is that this declaration, with the proposed actions and list of signatories, will attract the public and media attention that this issue requires to galvanize opinion, catalyze action, and establish new funding mechanisms. Comprehensive actions to save these iconic wildlife species will help to curb an extinction process that appears to have begun with our ancestors in the late Pleistocene.

Acknowledgements

Supplemental material

Supplemental table S1: The 27 large terrestrial carnivores (order Carnivora) with average masses of at least 15 kg. In addition to common and scientific names, average species masses (kg), estimated population sizes (sources: IUCN 2015, Ripple et al. 2014), IUCN Red List threat

category, population trends, and years assessed are shown. Red List categories are: LC (Least Concern), NT (Near Threatened), VU (Vulnerable), EN (Endangered), CR (Critically Endangered). Population trends are: Dec (decreasing), Stable, Inc (increasing), Unk (unknown).

Supplemental table S2: The 74 large terrestrial herbivores with average masses of at least 100 kg. In addition to common and scientific names, average species masses (in kg), estimated population sizes (sources: IUCN 2015, Ripple et al. 2015), IUCN Red List category, population trends, and years assessed are shown. IUCN Red List categories are: LC (Least Concern), NT (Near Threatened), VU (Vulnerable), EN (Endangered), CR (Critically Endangered), EW (Extinct in the Wild). Population trends are: Dec (decreasing), Stable, Inc (increasing), Unk (unknown).

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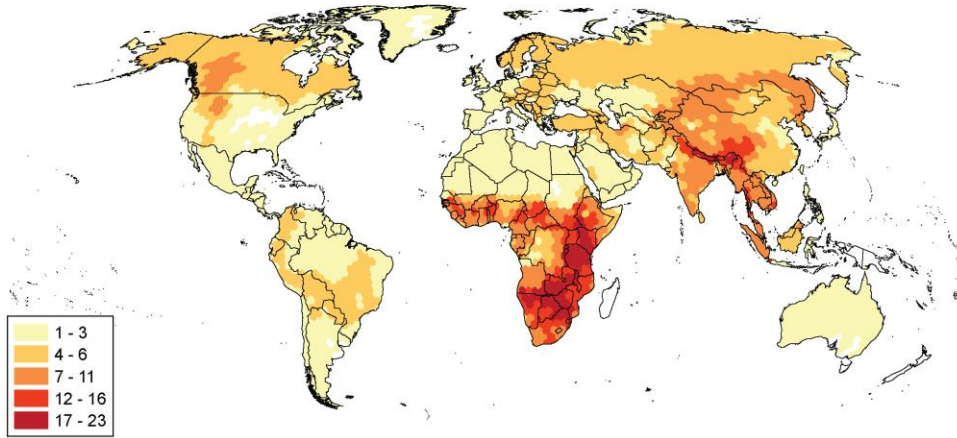
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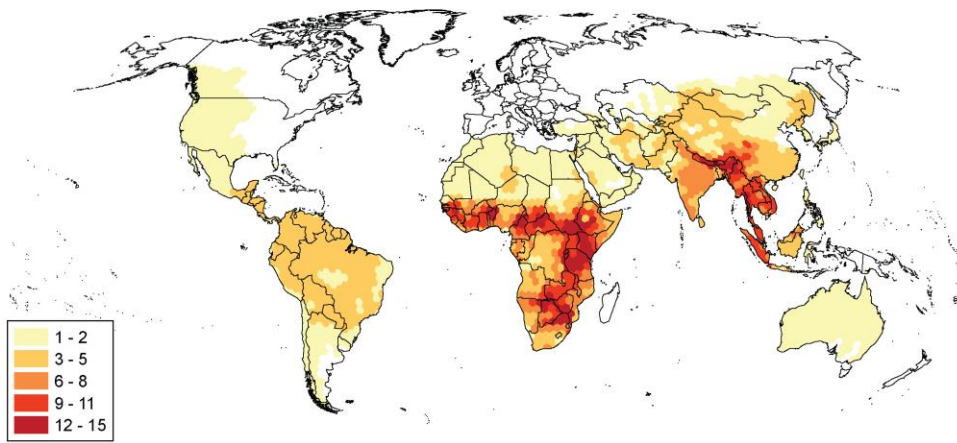
Figures

Figure 1. Richness map of (a) number of megafaunal species, (b) number of declining megafauna species, and (c) number of threatened megafaunal species in their native ranges. Megafauna are defined as terrestrial large carnivores (>15 kg) and large herbivores (>100 kg). Threatened includes all species categorized as Vulnerable, Endangered or Critically Endangered on the IUCN Red List (see supplemental tables).

Figure 2. Photos of **well-known species**, top row left to right: Western gorilla (*Gorilla gorilla*) (CR), black rhino (*Diceros bicornis*) (CR), Bengal tiger, (*Panthera tigris tigris*) (EN); and **lesser-known species**, bottom row left to right: African wild ass (*Equus africanus*) (CR), Visayan warty pig (*Sus cebifrons*) (CR), banteng (*Bos javanicus*) (EN). Photo credits: Julio Yeste, Four Oaks, Dave M. Hunt, Mikhail Blajenov, KMW Photography, and Kajornyot.

(a) Number of Megafauna

1 - 3
4 - 6
7 - 11
12 - 16
17 - 23

(b) Number of Declining Megafauna

1 - 2
3 - 5
6 - 8
9 - 11
12 - 15

(c) Number of Threatened Megafauna
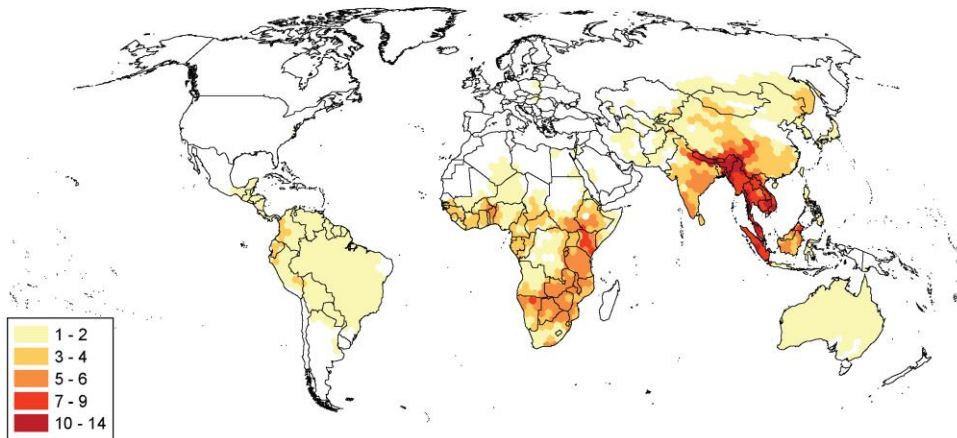

1 - 2
3 - 4
5 - 6
7 - 9
10 - 14

Figure 1.

Figure 2.

Box 1. A declaration to save the world's terrestrial megafauna.

We conservation scientists:

1 Acknowledge that most of the terrestrial megafauna species are threatened with extinction and have declining populations. Some megafauna species that are not globally threatened nonetheless face local extinctions or have critically endangered subspecies.

2 Appreciate that 'business as usual' will result in the loss of many of the Earth's most iconic species.

3 Understand that megafauna have ecological roles that directly and indirectly affect ecosystem processes and other species throughout the food-web; failure to reverse megafaunal declines will disrupt species interactions with negative consequences for ecosystem function, biological diversity, and the ecological, economic, and social services that these species provide.

4 Realize that megafauna are epitomized as a symbol of the wilderness, exemplifying the public's engagement in nature, and that this is a driving force behind efforts to maintain the ecosystem services they can provide.

5 Recognize the importance of integrating and better aligning human development and biodiversity conservation needs through engagement and support of local communities in developing countries.

6 Propose that funding agencies and scientists increase conservation research efforts in developing countries, where most threatened megafauna occur. Specifically, there is a need to increase the amount of research directed at finding solutions for the conservation of megafauna, especially for lesser-known species.

7 Request the help of individuals, governments, corporations, and nongovernmental organizations to stop practices that are harmful to these species and to actively engage in helping to reverse declines in megafauna.

8 Strive for increased awareness among the global public of the current megafauna crisis using traditional media as well as social media and other networking approaches.

9 Seek a new and comprehensive global commitment and framework for conserving megafauna. The international community should take necessary action to prevent mass extinction of the world's megafauna and other species.

10 Urge the development of new funding mechanisms to transfer the current benefits accrued through existence values of megafauna into tangible payments to support research and conservation actions in the places where highly valued megafauna must be preserved.

11 Advocate for interdisciplinary scientific interchange between nations to improve social and ecological understanding of the drivers of the decline of megafauna, and to increase capacity for megafauna science and conservation.

12 Recommend the reintroduction and rehabilitation of degraded megafauna populations whenever possible, following accepted IUCN guidelines, the ecological and economic importance of which is evidenced by a growing number of success stories, from Yellowstone's wolves (*Canis lupus*), to the Père David's deer (*Elaphurus davidianus*) in China, to various megafauna species of Gorongosa National Park in Mozambique.

13 Affirm an abiding moral obligation to protect the earth's megafauna.

Supplemental material

Supplemental table S1: The 27 large terrestrial carnivores (order Carnivora) with masses of at least 15 kg. In addition to common and scientific names, species masses (kg), estimated population sizes (sources: IUCN 2015, Ripple et al. 2014), IUCN Red List threat category, population trends, and years assessed are shown. Red List categories are: LC (Least Concern), NT (Near Threatened), VU (Vulnerable), EN (Endangered), CR (Critically Endangered). Population trends are: Dec (decreasing), Stable, Inc (increasing), Unk (unknown). We did not include predominantly marine Carnivora in the analysis (e.g. polar bear (*Ursus maritimus*), pinnipeds).

Common	Species	Mass	Status	Trend	Population	Year
Canidae						
Gray wolf	*Canis lupus*	33	LC	Stable	168,000-183,000	2008
Red wolf	*Canis rufus*	25	CR	Inc	<150	2014
Maned wolf	*Chrysocyon brachyurus*	23	NT	Unk	23,600	2015
African wild dog	*Lycaon pictus*	22	EN	Dec	6,600	2012
Dhole	*Cuon alpinus*	16	EN	Dec	4,500-10,500	2015
Dingo	*Canis dingo*	15	VU	Dec	Uncertain	2008
Ethiopian wolf	*Canis simensis*	15	EN	Dec	360-440	2011
Felidae						
Tiger	*Panthera tigris*	161	EN	Dec	3,159	2014
Lion	*Panthera leo*	156	VU	Dec	18,726-31,395[1]	2015
Jaguar	*Panthera onca*	87	NT	Dec	Uncertain	2008
Cheetah	*Acinonyx jubatus*	59	VU	Dec	6,674	2014
Leopard	*Panthera pardus*	53	NT	Dec	Uncertain	2008
Puma	*Puma concolor*	52	LC	Dec	Uncertain	2014
Snow leopard	*Panthera uncia*	33	EN	Dec	4,080-6,590	2008
Clouded leopard	*Neofelis nebulosa*	20	VU	Dec	Uncertain	2014
Sunda clouded leopard	*Neofelis diardi*	20	VU	Dec	4,500	2015
Eurasian lynx	*Lynx lynx*	18	LC	Stable	Uncertain	2014
Hyaenidae						
Spotted hyena	*Crocuta crocuta*	52	LC	Dec	27,000-47,000	2014
Brown hyena	*Hyaena brunnea*	43	NT	Dec	5,000-8,000	2014
Striped hyena	*Hyaena hyaena*	27	NT	Dec	5,000-14,000	2014
Ursidae						
Brown bear	*Ursus arctos*	299	LC	Stable	>200,000	2008
Giant panda	*Ailuropoda melanoleuca*	134	EN	Dec	1,600	2008
American black bear	*Ursus americanus*	111	LC	Inc	~900,000	2008
Andean black bear	*Tremarctos ornatus*	105	VU	Dec	5,000-30,000	2008
Asiatic black bear	*Ursus thibetanus*	104	VU	Dec	Uncertain	2008
Sloth bear	*Melursus ursinus*	102	VU	Dec	20,000	2008
Sun bear	*Helarctos malayanus*	46	VU	Dec	Uncertain	2008

[1] There is some uncertainty about the population of the lion, and the latest IUCN Red List assessment in 2015 stated "With all these considerations, we have greater confidence in an estimate of closer to 20,000 Lions in Africa than in a number over 30,000". For further detailed information from the Red List about the lion population see 15951_Panthera_leo_2015_4.pdf.

Supplemental table S2: The 74 large terrestrial herbivores with masses of at least 100 kg. In addition to common and scientific names, species masses (in kg, based on the recorded average of male and female body mass; Ripple et al. 2015), estimated population sizes (sources: IUCN 2015, Ripple et al. 2015), IUCN Red List category, population trends (as reported on the Red List), and years assessed are shown. IUCN Red List categories are: LC (Least Concern), NT (Near Threatened), VU (Vulnerable), EN (Endangered), CR (Critically Endangered), EW (Extinct in the Wild). Population trends are: Dec (decreasing), Stable, Inc (increasing), Unk (unknown).

Common	Species	Mass	Status	Trend	Population	Year
Bovidae						
Indian water buffalo	*Bubalus arnee*	950	EN	Dec	<4,000	2008
Gaur	*Bos gaurus*	825	VU	Dec	13,000-30,000	2008
Kouprey	*Bos sauveli*	791	CR	Unk	0-20	2008
European bison	*Bison bonasus*	676	VU	Inc	3,200	2008
Wild yak	*Bos mutus*	650	VU	Dec	15,000	2008
Giant eland	*Tragelaphus derbianus*	646	LC	Dec	15,000-20,000	2008
Banteng	*Bos javanicus*	636	EN	Dec	8,000	2008
American bison	*Bison bison*	625	NT	Stable	30,000	2008
African buffalo	*Syncerus caffer*	593	LC	Dec	890,000	2008
Common eland	*Tragelaphus oryx*	563	LC	Stable	136,000	2008
Muskox	*Ovibos moschatus*	313	LC	Stable	140,000	2008
Takin	*Budorcas taxicolor*	295	VU	Dec	Uncertain	2008
Bongo	*Tragelaphus eurycerus*	271	NT	Dec	28,000	2008
Roan antelope	*Hippotragus equinus*	264	LC	Dec	76,000	2008
Lowland anoa	*Bubalus depressicornis*	257	EN	Dec	2,500	2008
Tamaraw	*Bubalus mindorensis*	254	CR	Dec	300	2008
Sable antelope	*Hippotragus niger*	236	LC	Stable	75,000	2008
Mountain nyala	*Tragelaphus buxtoni*	215	EN	Dec	3,300	2008
Greater kudu	*Tragelaphus strepsiceros*	206	LC	Stable	482,000	2008
Waterbuck	*Kobus ellipsiprymnus*	204	LC	Dec	200,000	2008
Beisa oryx	*Oryx beisa*	201	NT	Dec	67,000	2008
Scimitar-horned oryx	*Oryx dammah*	200	EW		Uncertain	2008
Common wildebeest	*Connochaetes taurinus*	199	LC	Stable	1,550,000	2008
Gemsbok	*Oryx gazella*	188	LC	Stable	373,000	2008
Mountain anoa	*Bubalus quarlesi*	182	EN	Dec	<2,500	2008
Nilgai	*Boselaphus tragocamelus*	182	LC	Stable	Uncertain	2008
Hartebeest	*Alcelaphus buselaphus*	161	LC	Dec	360,000	2008
Black wildebeest	*Connochaetes gnou*	157	LC	Inc	>18,000	2008
Topi	*Damaliscus lunatus*	136	LC	Dec	300,000	2008
Siberian ibex	*Capra sibirica*	130	LC	Unk	Uncertain	2008
Argali	*Ovis ammon*	114	NT	Dec	Uncertain	2008
Sumatran serow	*Capricornis sumatraensis*	111	VU	Dec	Uncertain	2008
Walia ibex	*Capra walie*	100	EN	Inc	500	2008
Camelidae						
Bactrian camel	*Camelus ferus*	555	CR	Dec	950	2008
Guanaco	*Lama guanicoe*	128	LC	Stable	535,750–589,750	2008
Cervidae						
Moose	*Alces americanus*	541	LC	Stable	Uncertain	2008
Eurasian elk	*Alces alces*	462	LC	Inc	1,500,000	2008
Red deer	*Cervus elaphus*	241	LC	Inc	Uncertain	2008
Sambar	*Rusa unicolor*	178	VU	Dec	Uncertain	2014

Barasingha	*Rucervus duvaucelii*	171	VU	Dec	3,500-5,100	2015
Père David's deer	*Elaphurus davidianus*	166	EW	Inc	Uncertain[1]	2008
White-lipped deer	*Przewalskium albirostris*	162	VU	Unk	Uncertain	2014
Marsh deer	*Blastocerus dichotomus*	113	VU	Dec	Uncertain	2008
Reindeer	*Rangifer tarandus*	109	LC	Stable	Uncertain	2008
Elephantidae						
African elephant	*Loxodonta africana*	3825	VU	Inc	500,000[2]	2008
Asian elephant	*Elephas maximus*	3270	EN	Dec	41,410–52,345	2008
Equidae						
Grevy's zebra	*Equus grevyi*	408	EN	Stable	1,966-2,447	2008
Plains zebra	*Equus quagga*	400	LC	Stable	660,000	2008
Mountain zebra	*Equus zebra*	282	VU	Unk	15,000	2008
Kiang	*Equus kiang*	281	LC	Stable	60,000-70,000	2015
African wild ass	*Equus africanus*	275	CR	Dec	600	2014
Przewalski's horse	*Equus ferus*	250	EN	Inc	178	2014
Asiatic wild ass	*Equus hemionus*	235	EN	Dec	45,470-47,419	2015
Giraffidae						
Giraffe	*Giraffa camelopardalis*	965	LC	Dec	>80,000	2010
Okapi	*Okapia johnstoni*	230	NT	Stable	43,000	2015
Hippopotamidae						
Hippopotamus	*Hippopotamus amphibius*	1536	VU	Dec	125,680-149,230	2008
Pygmy hippopotamus	*Choeropsis liberiensis*	235	EN	Dec	2,500	2015
Hominidae						
Eastern gorilla	*Gorilla beringei*	149	EN	Dec	Uncertain	2008
Western gorilla	*Gorilla gorilla*	113	CR	Dec	Uncertain	2008
Rhinocerotidae						
White rhinoceros	*Ceratotherium simum*	2286	NT	Inc	20,170	2011
Indian rhinoceros	*Rhinoceros unicornis*	1844	CR	Inc	2,575	2008
Javan rhinoceros	*Rhinoceros sondaicus*	1750	CR	Unk	40-603[3]	2008
Sumatran rhinoceros	*Dicerorhinus sumatrensis*	1046	CR	Dec	220-275[4]	2008
Black rhinoceros	*Diceros bicornis*	996	CR	Inc	4,880	2011
Suidae						
Forest hog	*Hylochoerus meinertzhageni*	198	LC	Dec	Uncertain	2008
Visayan warty pig	*Sus cebifrons*	191	CR	Dec	Uncertain	2008
Oliver's warty pig	*Sus oliveri*	191	EN	Dec	Uncertain	2008
Philippine warty pig	*Sus philippensis*	191	VU	Dec	Uncertain	2008
Bearded pig	*Sus barbatus*	136	VU	Dec	Uncertain	2008
Palawan bearded pig	*Sus ahoenobarbus*	136	VU	Dec	Uncertain	2008
Tapiridae						
Malayan tapir	*Tapirus indicus*	311	EN	Dec	Uncertain	2008
Baird's tapir	*Tapirus bairdii*	294	EN	Dec	<5,500	2008
Lowland tapir	*Tapirus terrestris*	169	VU	Dec	Uncertain	2008

[1] The Père David's deer now has several well-established reintroduced populations in China.

[2] African elephant, white rhinoceros, and black rhinoceros were increasing at the time of their last IUCN Red List assessment in 2008, 2011, and 2011 respectively, but these species are now declining mostly due to recent intense poaching (Wittemyer et al. 2014; Ripple et al. 2015)

[3] It appears that the Javan rhino is down to a single population of ~58 in a single reserve (Haryono et al. 2015).

[4] The population estimate for Sumatran rhinoceros appears to be high and actual population for this species was recently estimated at <100 (Nardelli 2014).

| Mountain tapir | *Tapirus pinchaque* | 157 | EN | Dec | <2,500 | 2008 |

References for supplement

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