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Late Quaternary Extinctions: State of the Debate
Koch and Barnosky

TABLE S1 Global list of extinct and extant megafaunal genera by continent.

STATUS	TAXON	TIME
	AFRICA	
	Mammalia	
	Carnivora	
	Felidae	
	Acinonyx	
	Panthera	
	Hyaenidae	
	Crocuta	
	Hyaena	
	Ursidae	
	Ursus[a]	
	Primates	
	Gorilla	
	Proboscidea	
	Elephantidae	
C	*Elephas*	<100
	Loxodonta	
	Perissodactyla	
	Equidae	
S	*Equus*	<100
E	*Hipparion*	<100
	Rhinocerotidae	
	Ceratotherium	
	Diceros	
E	*Stephanorhinus*	<100
	Artiodactyla	
	Bovidae	
	Addax	
	Ammotragus	
	Antidorcas	
	Alcelaphus	
	Aepyceros	
C	*Bos*	11.5-0
	Capra	
	Cephalopus	
	Connochaetes	
	Damaliscus	
	Gazella	
S	*Hippotragus*	<100
	Kobus	
E	*Rhynotragus/Megalotragus*	11.5-0
	Oryx	
E	*Pelorovis*	11.5-0
E	*Parmularius*[a]	<100
	Redunca	
	Sigmoceros	
	Syncerus	
	Taurotragus	
	Tragelaphus	
	Camelidae	
C	*Camelus*	<100

	Cervidae	
E	*Megaceroides*	<100
	Giraffidae	
S	*Giraffa*	<100
	Okapia	
	Hippopotamidae	
	Hexaprotodon	
	Hippopotamus	
	Suidae	
	Hylochoerus	
	Phacochoerus	
	Potamochoerus	
	Sus[a]	
	Tubulidenta	
	Orycteropus	
	AUSTRALIA	
	Reptilia	
	Varanidae	
E	*Megalania*	50-15.5
	Meiolanidae	
E	*Meiolania*	50-15.5
E	*Ninjemys*	<100
	Crocodylidae	
E	*Palimnarchus*	50-15.5
E	*Quinkana*	50-15.5
	Boiidae?	
E	*Wonambi*	100-50
	Aves	
E	*Genyornis*	50-15.5
	Mammalia	
	Marsupialia	
	Diprotodontidae	
E	*Diprotodon*	50-15.5
E	*Euowenia*	<100
E	*Euryzygoma*	<100
E	*Nototherium*	<100
E	*Zygomaturus*	100-50
	Macropodidae	
S	*Macropus*	100-50
E	*Procoptodon*	<100
E	*Protemnodon*	50-15.5
E	*Simosthenurus*	50-15.5
E	*Sthenurus*	100-50
	Palorchestidae	
E	*Palorchestes*	50-15.5
	Thylacoleonidae	
E	*Thylacoleo*	50-15.5
	Vombatidae	
S	*Lasiorhinus*	<100
E	*Phascolomys*	<100
E	*Phascolonus*	50-15.5
E	*Ramsayia*	<100

	EUROPE/NORTH ASIA	
	Mammalia	
	Carnivora	
	Canidae	
	Canis	
	Felidae	
	Acinonyx	
S	*Panthera*	11.5-0
	Hyaenidae	
C	*Crocuta*	15.5-11.5
	Ursidae	
S	*Ursus*	15.5-11.5
	Proboscidea	
	Elephantidae	
E	*Mammuthus*	11.5-0
E	*Palaeoloxodon*	50-15.5
	Perissodactyla	
	Equidae	
S	*Equus*	11.5-0
	Rhinocerotidae	
E	*Coelodonta*	15.5-11.5
C	*Stephanorhinus*	50-15.5
	Artiodactyla	
	Bovidae	
	Bos	
S	*Bison*	
	Capra	
C	*Ovibos*	11.5-0
	Ovis	
	Pseudois	
	Saiga	
E	*Spirocerus*	50-15.5
	Camelidae	
	Camelus	
	Cervidae	
	Alces	
	Cervus	
	Dama	
E	*Megaloceros*	11.5-0
	Rangifer	
	Hippopotamidae	
C	*Hippopotamus*	50-15.5
	Suidae	
	Sus	
	NORTH AMERICA	
	Mammalia	
	Xenarthra	
	Dasypodidae	
S	*Dasypus*	<100
	Glyptodontidae	
E	*Glyptotherium*	<100
	Megalonychidae	

E	*Megalonyx*	15.5-11.5
	Megatheriidae	
E	*Eremotherium*	<100
E	*Nothrotheriops*	15.5-11.5
	Mylodontidae	
E	*Glossothrium*	50-15.5
	Pampatheriidae[b]	
E	*Holmensina*	<100
	Rodentia	
	Castoridae	
E	*Castoroides*	15.5-11.5
	Hydrochoeridae	
C	*Hydrochaeris*	<100
E	*Neochoerus*	<100
	Carnivora	
	Canidae	
S	*Canis*	15.5-11.5
	Felidae	
	Felis[c]	
E	*Homotherium*	50-15.5
E	*Miracinonyx*	15.5-11.5
S	*Panthera*	15.5-11.5
E	*Smilodon*	15.5-11.5
	Ursidae	
E	*Arctodus*	15.5-11.5
C	*Tremarctos*	15.5-11.5
	Ursus	
	Proboscidea	
	Gomphotheriidae	
E	*Cuvieronius*	
	Mammutidae	
E	*Mammut*	15.5-11.5
	Elephantidae	
E	*Mammuthus*	11.5-0
	Perissodactyla	
	Equidae	
C	*Equus*	15.5-11.5
	Tapiridae	
C	*Tapirus*	15.5-11.5
	Artiodactyla	
	Antilocapridae	
	Antilocapra	
E	*Stockoceros*	<100
E	*Tetrameryx*	<100
	Bovidae	
S	*Bison*	
E	*Bootherium*[d]	11.5-0?
C	*Bos*	<100
E	*Euceratherium*	11.5-0?
S	*Oreamnos*	15.5-11.5
	Ovibos	
	Ovis	
C	*Saiga*	<100

	Camelidae	
E	*Camelops*	15.5-11.5
E	*Hemiauchenia*	15.5-11.5
E	*Paleolama*	15.5-11.5
	Cervidae[e]	
S	*Alces*	<100
E	*Bretzia*[a]	<100
E	*Cervalces*	15.5-11.5
	Cervus	
E	*Navahoceros*	<100
	Odocoileus	
	Rangifer	
E	*Torontoceros*[a]	<100
	Tayassuidae	
E	*Mylohyus*	15.5-11.5
E	*Platygonus*	15.5-11.5
	SOUTH AMERICA	
	Mammalia	
	Xenarthra	
	Dasypodidae	
E	*Eutatus*	11.5-0?
	Priodontes	
E	*Propaopus*	11.5-0?
	Glyptodontidae	
E	*Chlamydotherium*	11.5-0?
E	*Doedicurus*	11.5-0?
E	*Glyptodon*	11.5-0?
E	*Heteroglyptodon*[a]	<100
E	*Hoplophorus*	11.5-0?
E	*Lomaphorus*	<100
E	*Neosclerocalyptus*	<100
E	*Neothoracophorus*	<100
E	*Panochthus*	<100
E	*Parapanochthus*[a]	<100
E	*Plaxhaplous*	<100
E	*Sclerocalyptus*	<100
	Megalonychidae	
E	*Valgipes*	<100
	Megatheriidae[f]	
E	*Eremotherium*	15.5-11.5
E	*Megatherium*	11.5-0?
E	*Nothropus*	<100
E	*Nothrotherium*	15.5-11.5
E	*Ocnopus*	<100
E	*Perezfontanatherium*[a]	<100
	Mylodontidae	
E	*Glossotherium*	15.5-11.5
E	*Lestodon*	15.5-11.5
E	*Mylodon*	15.5-11.5
	Pampatheriidae	
E	*Holmensina*	<100

E	*Pampatherium*	<100
	Scelidotheriidae[g]	
E	*Scelidotherium*	11.5-0?
	Rodentia	
	Hydrochoeridae	
	Hydrochaeris	
E	*Neochoerus*	11.5-0?
	Octodontidae	
E	*Dicolpomys*	<100
	Carnivora	
	Canidae	
C	*Canis*	<100
	Felidae	
	Felis	
	Panthera	
E	*Smilodon*	11.5-0?
	Ursidae	
E	*Arctodus*	<100
	Litopterna	
	Macraucheniidae	
E	*Macrauchenia*	<100
E	*Windhausenia*	<100
	Notoungulata	
	Toxodontidae	
E	*Mixotoxodon*	<100
E	*Toxodon*	15.5-11.5
	Probosicdea	
	Gomphotheriidae	
E	*Cuvieronius*	15.5-11.5
E	*Haplomastodon*	11.5-0?
E	*Notiomastodon*	<100
E	*Stegomastodon*	15.5-11.5
	Perissodactyla	
	Equidae	
C	*Equus*	15.5-11.5
E	*Hippidion*	15.5-11.5
E	*Onohippidion*	<100
	Tapiridae	
	Tapirus	
	Artiodactyla	
	Camelidae	
E	*Eulamaops*	<100
E	*Hemiauchenia*	15.5-11.5
E	*Paleolama*	11.5-0?
	Lama	
	Vicugna	
	Cervidae	
E	*Agalmaceros*	<100
E	*Antifer*[h]	<100
	Blastocerus	
E	*Charitoceros*	<100
	Hippocamelus	
	Mazama	
E	*Morenelaphus*	<100

	Odocoileus	
	Tayassuidae	
E	*Platygonus*	<100

The vetting of generic data and dates for extinct taxa is as described in Barnosky et al. (2004). The primary source for generic data on extant taxa was Smith et al. (2003). Northern Eurasia is Europe, Siberia, Mongolia, Manchuria, Kazakhstan, Tarim Basin, Korea and Japan. Under Status: E, globally extinct; C, extinct on continent; S, extinct species within genus; no code, extant. Time is in units of kyr BP.

[a] Not listed in Smith et al. (2003). [b] Excludes *Pampatherium*, considered a synonym of *Holmensina*. [c] *Puma* is a synonym of *Felis.* [d] *Symbos* is a synonym of *Bootherium.* [e] Excludes *Sangamona.* [f] Excludes *Paramegatherium,* considered a synonym of *Megatherium.* [g] Excludes *Scelidodon*, considered a synonym of *Scelidotherium.* [h] *Paraceros* is a synonym of *Antifer*

TABLE S2 Percent mammalian extinction at the species level by body mass

Body size (log_{10} gm)	N. America	S. America	Eurasia	Australia	Africa
6.5-7.0	100 (6)	100 (8)	100 (2)	na	50 (1)
6.0-6.5	100 (4)	100 (11)	100 (4)	100 (1)	25 (1)
5.5-6.0	83 (20)	100 (20)	45 (5)	100 (6)	29 (4)
5.0-5.5	77 (17)	79 (19)	8 (1)	100 (10)	11 (3)
4.5-5.0	50 (12)	38 (8)	7 (1)	95 (18)	7 (3)
4.0-4.5	20 (2)	33 (7)	6 (1)	30 (7); 5 (1)	0 (0)
3.5-4.0	8 (3)	3 (2)	nd	9 (3); 10 (3)	0 (0)
3.0-3.5	10 (3)	0 (0)	nd	0 (0); 7 (2)	0 (0)
2.5-3.0	5 (3)	0 (0)	nd	0 (0); 19 (5)	0 (0)

Species counts and body-mass data are largely from Smith et al. (2003), with minor additions from Brook & Bowman (2004) and Johnson (2002). For data from Americas, Eurasia, and Africa, percent extinct is the first number, number of species extinct is in parentheses. While most animals on these continents became extinct in the latest Pleistocene, last occurrences for some extinct taxa are in the Holocene. For Australia percent extinct and number extinct (in parentheses) in Pleistocene is before the semi-colon, percent extinct and number extinct (in parentheses) in the Holocene is after the semi-colon. na, not applicable; nd, no data

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TABLE S3 Carbon isotope values for tooth enamel from Pleistocene mammals in North America

Genus	Common name	Texas	Florida	Missouri	S. West	$\%C_4$	$\delta^{13}C$ (‰)
Cuvieronius	gomphothere	-7.2, 1	-6.1, 1			95	2
Mammut	mastodon	-10.5±0.6, 25	-11.0±0.9, 41	-11.4±0.6, 37		89	1
Mammuthus	mammoth	-2.4±1.4, 64	-1.6±1.8, 29	-1.6±0.4, 6	-4.2±3.4, 18	82	0
Equus	horse	-3.4±2.0, 60	-4.0±3.2, 14	-2.0±0.8, 2	-4.2±2.8, 46	75	-1
Tapirus	tapir	-11.2±0.5, 7	-12.9±0.8, 9	-12.8±0.8, 2		69	-2
Mylohyus	pecarry	-9.9±0.1, 2	-10.3±1.4, 5			62	-3
Platygonus	pecarry	-9.0±0.2, 3	-8.3, 1			55	-4
Camelops	camel	-4.8±4.5, 17			-4.8±3.6, 26	49	-5
Hemiauchenia	llama		-8.5±4.4, 25			42	-6
Paleolama	llama	-11.1±0.8, 5	-14.8, 1			29	-8
Bison[a]	bison	-1.0±1.5, 22	-0.7±2.4, 8	-0.7±1.9, 2	-0.6±2.5, 14	22	-9
Bootherium	musk-oxen			-11.3±0.2, 5		15	-10
Cervalces	stag-moose			-12.1±0.3, 2		9	-11
Odocoileus[a]	deer	-12.2±1.2, 17	-13.6±1.4, 15	-14.4±0.3, 2	-10.8, 1	2	-12
Antilocapra[a]	pronghorn				-11.0, 1	-5	-13
Stockoceros	pronghorn				-11.6±0.6, 2		
Tetrameryx	pronghorn				-9.8±1.2, 3		
Casteroides	giant beaver	-11.3, 1					

Stable isotope data are from Connin et al. (1998), Koch et al. (1998, 2004, unpublished data) and Feranec (2003). Data are reported as the mean ± one standard deviation (in units of ‰ relative to VPDB), with number of samples indicated after the comma. $\%C_4$ was calculated from $\delta^{13}C$ values assuming a diet-to-apatite fractionation of 14‰ and a mixing model, assuming end-member $\delta^{13}C$ values of -26‰ for C_3 plants and -12‰ for C_4 plants.

[a] Genus survived in North America.

TABLE S4 Summary of simulations designed to test the overkill model

Study by:	# of prey[a]	Coupled Dynamics?[b]	Do the results support overkill?
Budyko (1967): Evaluates the impact of human population growth on Eurasian mammoths.	1[c]	Yes, with exponential human population growth	Yes, but exponential population growth makes extinction inevitable.
Mosimann & Martin (1975): Studies the first entry of Clovis hunters into coterminous USA.	1[c]	Yes, with logistic human population growth and a fixed carrying capacity	Yes, with blitzkrieg under certain assumptions. Model fails stability tests so extinction inevitable under most conditions.
Whittington & Dyke (1984): A sensitivity test of Mosiman & Martin (1975) model across a wide range of parameter values.	1[c]	Yes, with logistic human population growth and a fixed carrying capacity	Yes, with blitzkrieg under limited conditions and gradual overkill under a wide set assumptions. Model fails stability tests so extinction inevitable under most scenarios.
Belovsky (1988): An optimal-foraging model for North America with sophisticated treatments of environmental controls on primary production, animal digestion, energetics, and foraging.	2 hunted vs. gathered food	Yes, with human population growth determined by an energetic model	No. Assumes a relatively high *r* for prey that may reduce extinctions. Predicts megafaunal extinction in areas of high available primary production, because human population growth is subsidized by gathered food. Megafauna survive in areas of low production. Yields general result that extinction results not from megafaunal specialization but rather from population growth of omnivores.
Winterhalder et al. (1988): An optimal foraging model of population dynamics of hunter-gatherers and prey (with varied reproductive and nutrient traits). A general model, not tied to a particular location.	1 to 2	Yes, with human population growth determined by an energetic model	No. Human populations stabilize or crash after wild oscillations if too much time is spent hunting. Prey persist in either scenario. Yields general result that predators in very simple systems are unlikely to drive prey to extinction; the reverse is more likely.
Anderson (1989): A model of predation on moas in New Zealand	1[c]	No, exponential growth at plausible rate	Yes, for blitzkrieg, but claims there are too few moa remains. No consideration of taphonomic process that might affect this claim.

Winterhalder & Lu (1997): An optimal foraging model of population dynamics of hunter-gatherers and prey (with varied reproductive and nutrient traits). Not tied to a particular location, but used to discuss conservation in Amazonia and Pleistocene overkill.	Up to 4	Yes, with human growth determined by energetic model	Overkill in many cases for slow-breeding prey, particularly if subsidized by a fast-breeding species. Slow breeders are not vulnerable to large game specialists.
Choquenot & Bowman (1998): Simulates Aboriginal impacts in a hypothetical tract of north Australian *Eucalyptus* savanna on single prey (varied reproductive traits).	1[c]	No, varied human densities	Mostly no. Varied hunting efficiency and human densities. Found that smaller megafauna would have been more readily exterminated than larger megafauna, a result dictated by use of low human densities and typical levels of hunting efficiency. Overkill would require higher human densities.
Holdaway & Jacomb (2000): Simulates predation on moas in New Zealand.	1[c]	No, exponential growth at plausible rate	Yes, consistent with blitzkrieg, predicts extinction of 11 species of moas in < 100 years.
Alroy (2001a,b): Simulates first entry of Clovis hunters into conterminous USA.	42	Yes	Overkill under many conditions in less than 1000 years for most species. Correctly predicts fates of 73% of the species.
Brook & Bowman (2002): An evaluation of some aspects of the Alroy simulations (2001a, 2001b) with a focus on understanding the effects of prey naïveté.	1[c]	No, varied human densities	Mostly no. Results are dependent on assumptions about prey naïveté/human hunting efficiency. Not directly comparable to Alroy (2001a, 2001b) because it used lower human densities and simulated predation on a single prey.
Brook & Bowman (2004): A sensitivity analysis of the model used in Brook & Bowman (2002), with a comparison of results to the size selectivity of extinction at a global level. Varied prey and human population dynamics, prey naïveté, hunting success, and habitat quality.	1[c]	No, logistic growth to equilbrium density	Yes. Overkill under many combinations of parameters, with a best fit to body size data for moderate levels of predation, some loss of naïveté, and moderate declines in habitat quality. Median time to extinction between 700 and 800 years.

[a] "# of prey" refers to how many species of prey were explicitly included in the simulation.
[b] "Coupled Dynamics?" indicates whether or not changes in human population density were linked to changes in prey density.
[c] These models implicitly assume humans switch to another food as prey becomes scarce.

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