

Transparency and Minimalism:

Ecological Modeling of Late Pleistocene Megafaunal Extinctions

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Why Ecological Modeling Matters for Paleontologists

- Review by Barnosky *et al.* (2004)

Dual causation most likely, but to settle the details of Late Pleistocene extinctions we need firmer chronologies, **more realistic ecological models**, and regional paleontological insights

Two Necessary Questions

- What makes an extinction model ecologically realistic?

Involved species interact meaningfully

- What makes an extinction model “good”?

Number of component parameters minimized, not maximized

Maximally constrained parameters (ideally, empirically derived)

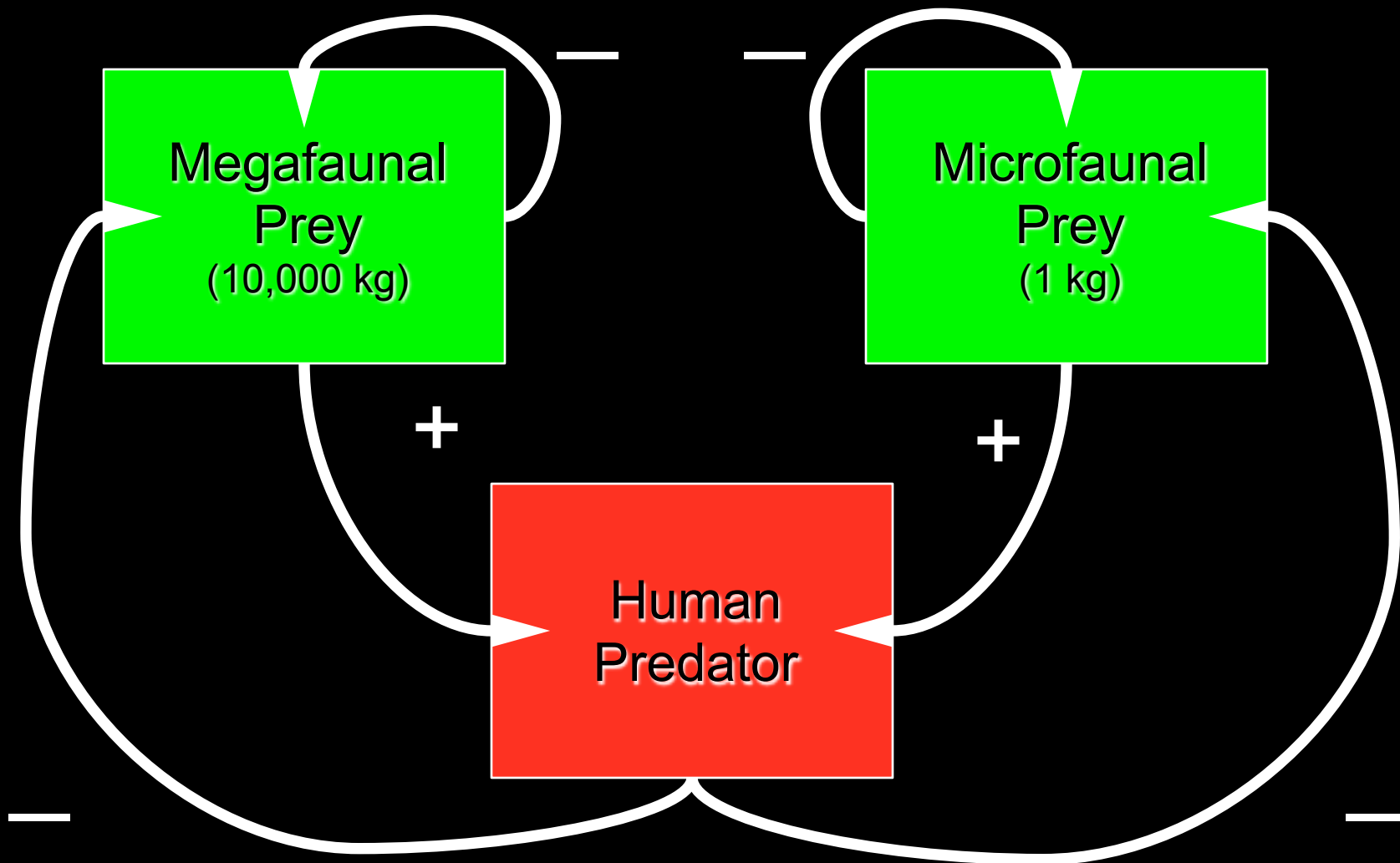
Note well! Simplification is unavoidable in modeling

Transparent, open-access intellectual resource, not a black box

Modeling Goals

- Ecologically Realistic Interactivity
- Known and Minimal Complexity
- Known and Maximal Constraint

Model Structure



Allometric Constraint

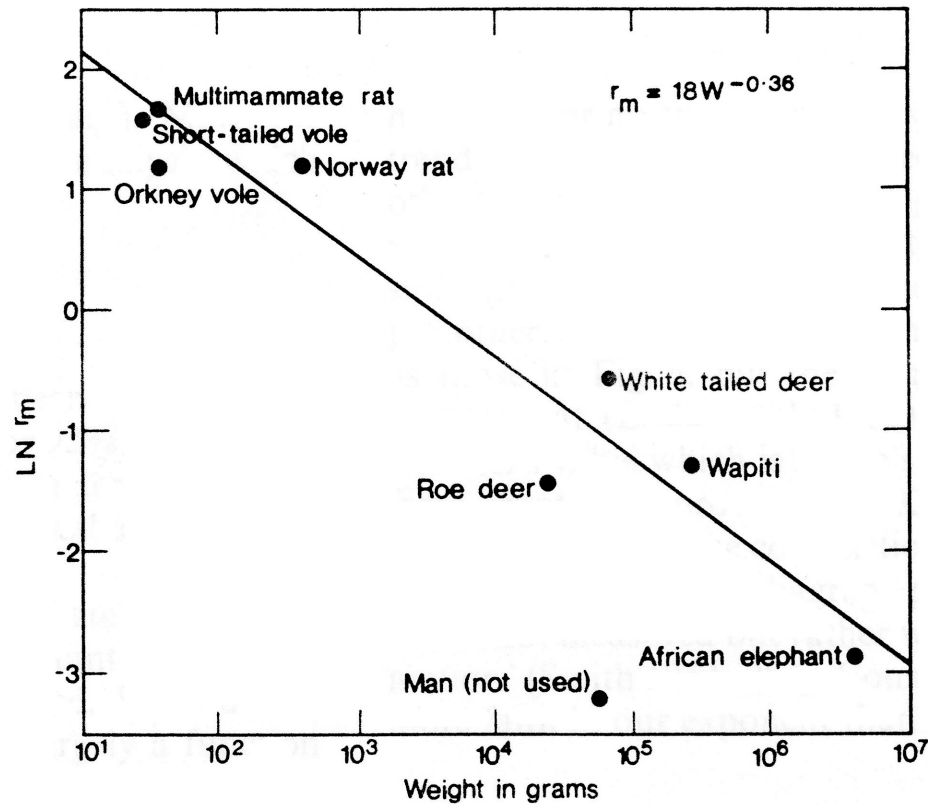


Fig. 6. Regression of intrinsic rate of increase against body weight

Caughley and Krebs 1983

Allometric Constraints Used

Parameter	Allometric Power Assumed	Source
r_m (maximal rate of population increase)	- 0.36	Caughley and Krebs 1983
K (carrying capacity)	- 0.75	Damuth 1987
e (conversion efficiency)	1.0	Assumption: all herbivore flesh has equal per kg nutritional value
h (handling time)	1.0	Assumption: time to prepare and digest herbivore flesh is proportional to its mass
α	Unknown	The parameter our model explores

Allometric Assumption	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-0	-0	-0	-0	-0	-0	-0	-0	0
Capture Efficiency (megafauna)	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0.1	0.2	0.3	0.5	0.8	1.3	2	3.2	5
Capture Efficiency (microfauna)	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Match to Historical Outcome?	FA LS E	FA LS E	FA LS E	FA LS E	FA LS E	FA LS E	FA LS E	FA LS E	FA LS E	FA LS E	FA LS E	FA LS E	FA LS E	FA LS E	TR UE	TR UE	TR UE	TR UE	TR UE	TR UE	TR UE

Prey dependent model

sensitivity analysis: open to interpretation, since we lack empirical grounding to constrain the parameter

Rather than picking a point and reporting model success/failure, we're providing the whole continuum of sensitivity analysis.

Model Context: Why Another Model?

Problems with Existing Models

- Decoupling Predator and Prey Interactivity (Budyko 1967, 1974; Choquenot and Bowman 1998)
- Models of Unknown Complexity (Alroy 2001)
- Model Transparency (Alroy 2001)

If a simple model can embrace ecological realism and transparency, why resort to an approach that dispenses with any of these necessary traits of good modeling?

Future Directions

Increase Ecological Realism/Robustness

- Additional Prey Species
- Niche Overlap (i.e., competition between prey species)
- Additional Predator Species

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Basic Equations:

$$\frac{dN_M}{dt} = r_M N_M (1 - N_M/K) - f_M(\bullet) P$$

$$\frac{dN_R}{dt} = r_R N_R (1 - N_R/K) - f_R(\bullet) P$$

$$\frac{dP}{dt} = e P [f_M(\bullet) + f_R(\bullet)] - \mu P$$

Asymptotic Functional Responses:

$$f(N) = \frac{\alpha N}{1 + \alpha h N}$$

(Holling 1965)

$$f(N/P) = \frac{\alpha N/P}{1 + \alpha h N/P}$$

(Arditi and Ginzburg 1989)

Prey Parameters

(one for each prey species included – units are per year)

- carrying capacity, K
- maximal intrinsic rate of population growth, r_m
- capture efficiency, i.e., how effective predator is at finding and capturing prey, α
- handling time, i.e., time it takes predators to process and consume one individual, h
- conversion efficiency, i.e., number of predator offspring resulting from the the consumption of one individual, e

Predator Parameters

- death rate in the absence of prey, μ
- predation determines predator intrinsic rate of population increase, r , and carrying capacity, K