Scaling of cutting forces in leaf-cutter ants

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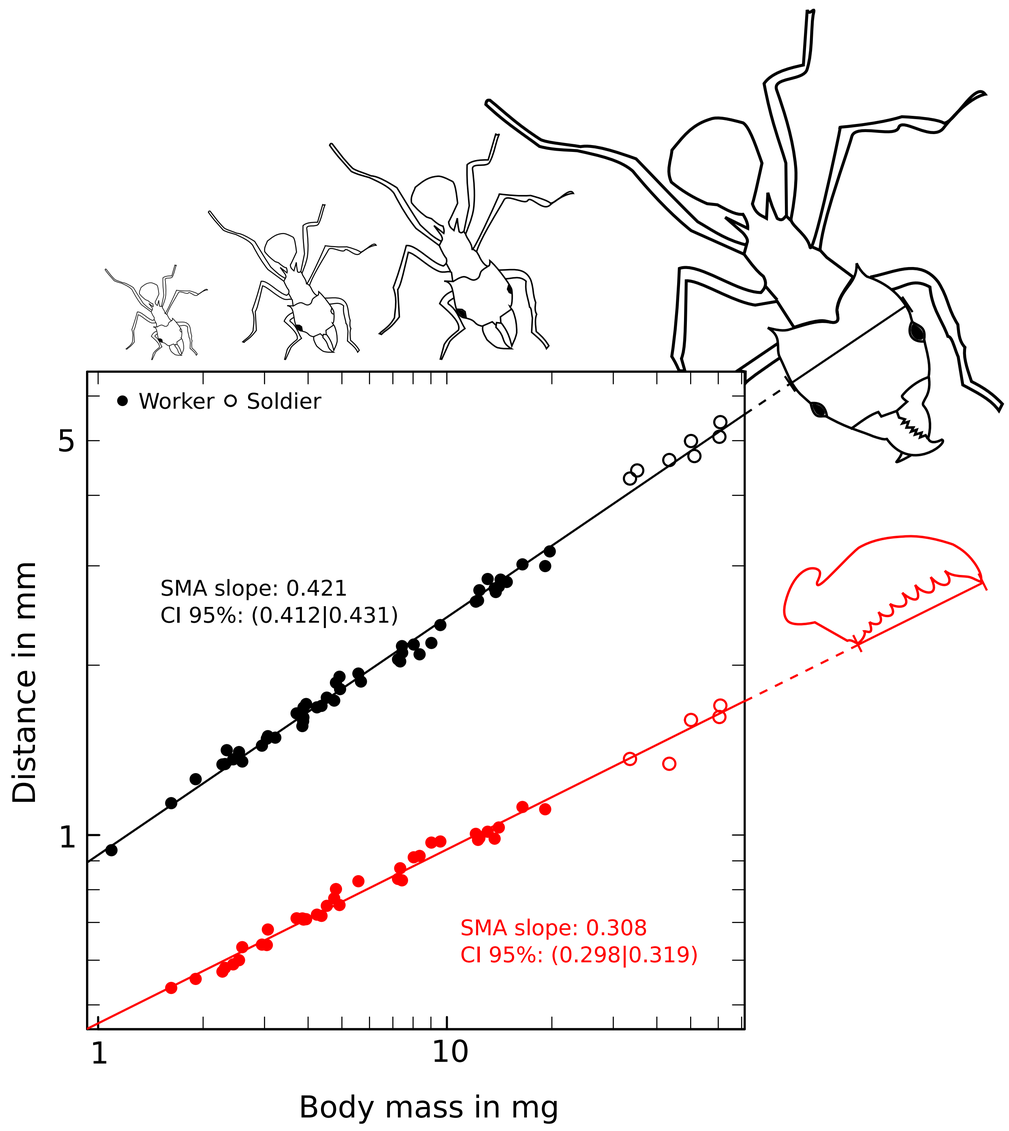
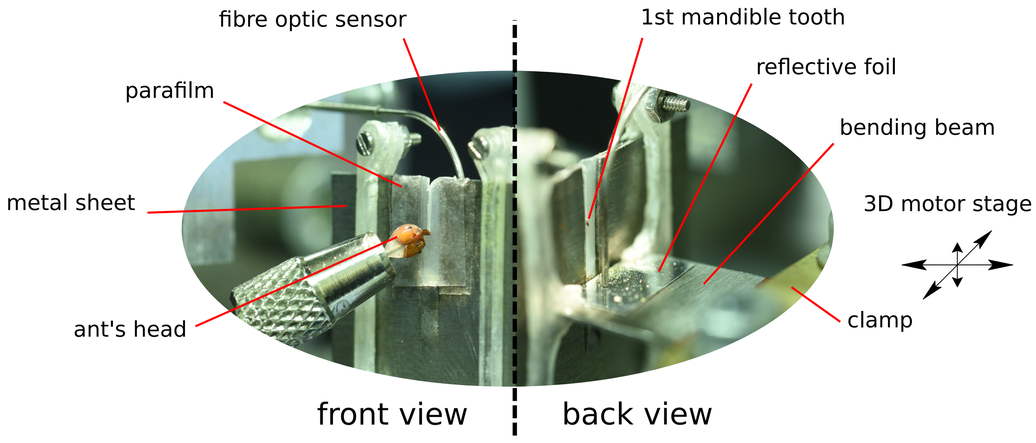
Leaf-cutter ants maintain a fungus garden, which is fed with leaves cut in the colony surroundings. Leaf-cutting is one of the most metabolically expensive activities insects engage in (second only to flight[1]), so ants of which size should be assigned to cutting in order to minimise metabolic costs at colony level?

Are head width and mandible length isometric?

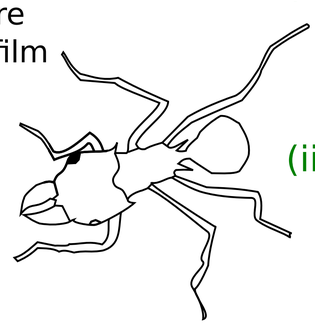


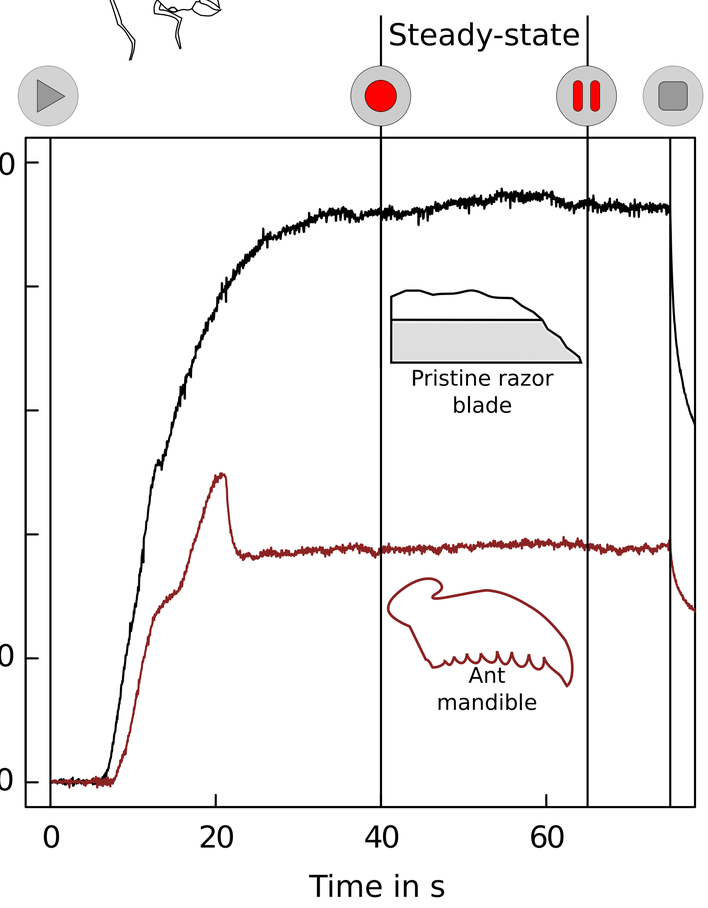
Relative to their size, larger ants have shorter mandibles, but wider heads - *should large workers do the bulk of the cutting?*

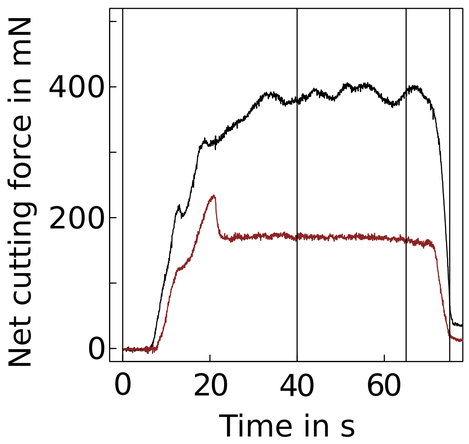
Do cutting forces change with mandible size?

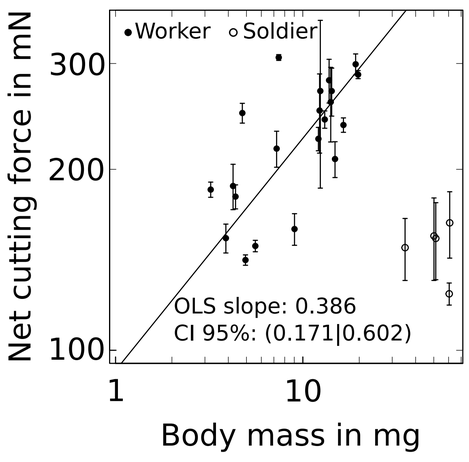


Steady-state cutting forces of individual mandibles were measured using a fibreoptics force-transducer and parafilm as a model substrate.

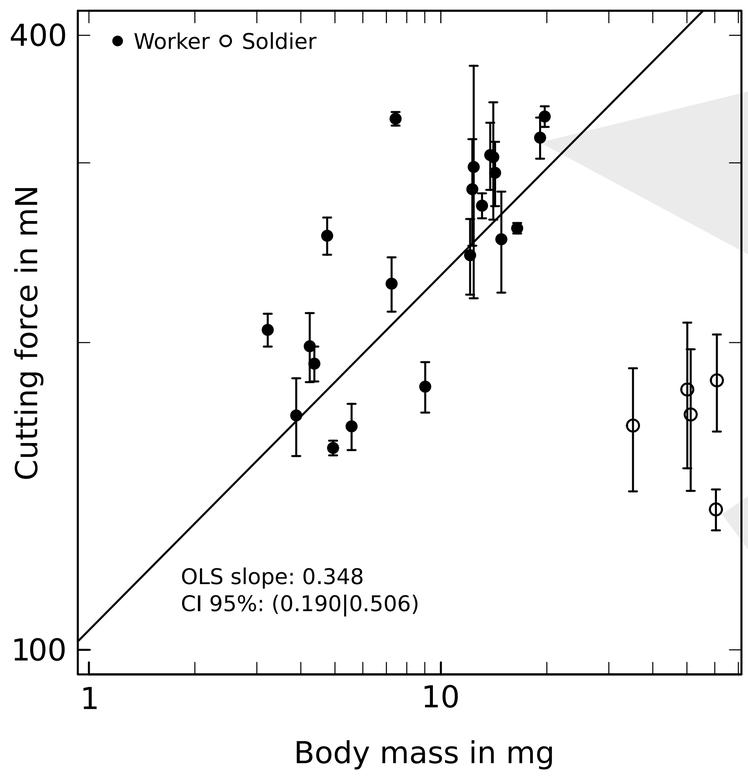


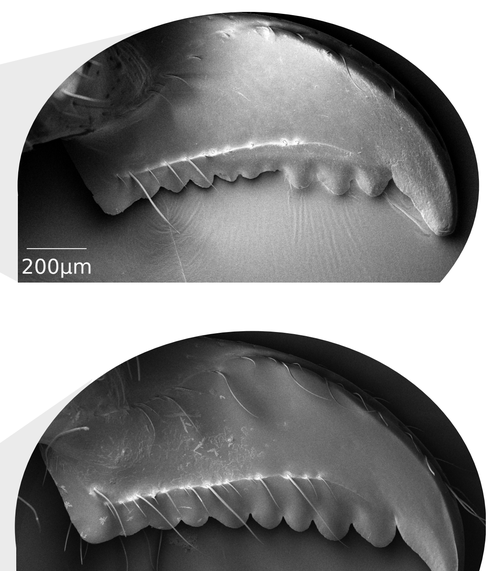






Net cutting forces are the difference between the total cutting forces and the forces due to friction, measured by drawing the mandibles through the cut a second time.[2]





Worker mandibles appear to be more worn!

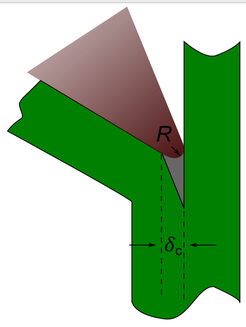
Cutting forces among workers scale as $m^{1/3}$, but soldier mandibles cut at forces comparable to small worker mandibles - *should smaller ants do the bulk of cutting*?

Why do cutting forces change with mandible size?

Cutting force is independent of blade radius if:[3]

Radius of cutting edge $R \leq \delta_c = \frac{G}{\sigma}$ Strain energy release rate and yield strength of cut material

Crack tip radius



Do cutting forces increase as a result of mandible wear?

Conclusions:

(i) The allometry of mandible length and head width implies that larger workers are specifically well-suited for cutting.

(ii) The scaling of cutting forces suggests that larger workers may need to produce larger forces to cut, presumably due to mandible wear.

(iii) The increase in available bite force predicted from mandible and head allometry is more than sufficient to balance the size-dependence of the cutting force, so that large workers should do the bulk of the cutting.

[1] Roces F & Lighten JR (1995). Nature. 373(2): 392

[2] Atkins, T (2009). Butterworth-Heinemann. Oxford. UK

[3] Blackman B, Hoult T, Patel Y & Williams J (2013): Eng Fract Mech. 101:47-58