Modeling trade-offs between calcium and energy acquisition for reproducing songbirds in acidified forests


Ovenbird eggshell

Sarah E. Pabian, Department of Biology, Colorado State University
Fort Collins, CO

Calcium availability can limit bird productivity and abundances in forests impacted by acid rain

- Birds require a lot of Ca to make eggshells
- Insectivorous diets do not provide enough Ca for reproduction
- Birds must supplement their diets with Ca-rich food, like snail shells
- Acid rain causes Ca to leach from soils

Acid rain ➡ fewer snails ➡ not enough Ca for birds
birds lay eggs with thin eggshell and lay fewer eggs

Could a trade-off between calcium and energy acquisition explain reproductive problems in birds?

3 prey types

	Caterpillars	Millipedes	Snail shells
Energy (KJ/g)	6.	5.	0.5
Calcium (mg/g)	0.1	3.	90.
Handling (hrs/g)	0.0	0.035	0.10

Optimal Foraging Theory

$$\frac{E}{T} = \frac{T_s \sum_i \lambda_i E_i P_i}{T_s + T_s \sum_i \lambda_i h_i P_i} = \frac{\sum_i \lambda_i E_i P_i}{1 + \sum_i \lambda_i h_i P_i}$$

Predator gains total energy, E (kJ), while foraging for time, T (hr) composed of time spent searching T_s (hr), and time spent handling prey, h_i (hr). Predator encounters prey i at a rate λ_i (g/hr), and once encountered, eats the prey with a probability of P_i. Th ith prey has a net energy E_i (kJ/g), and handling time, h_i (hr).

$$\frac{E}{T} < \frac{E + \lambda_b E_b P_b}{T + \lambda_b h_b P_b}$$

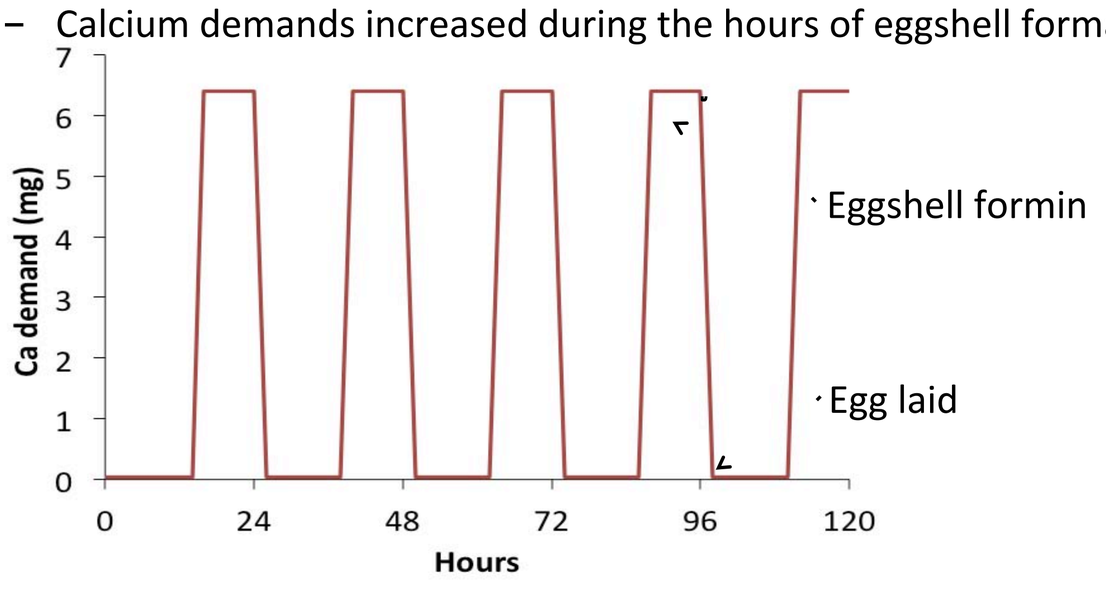
Adding a prey item, b, that does not follow the above rule will result in a decrease in the amount of energy/time that a bird gains

Adding snails comes at the expense of energy

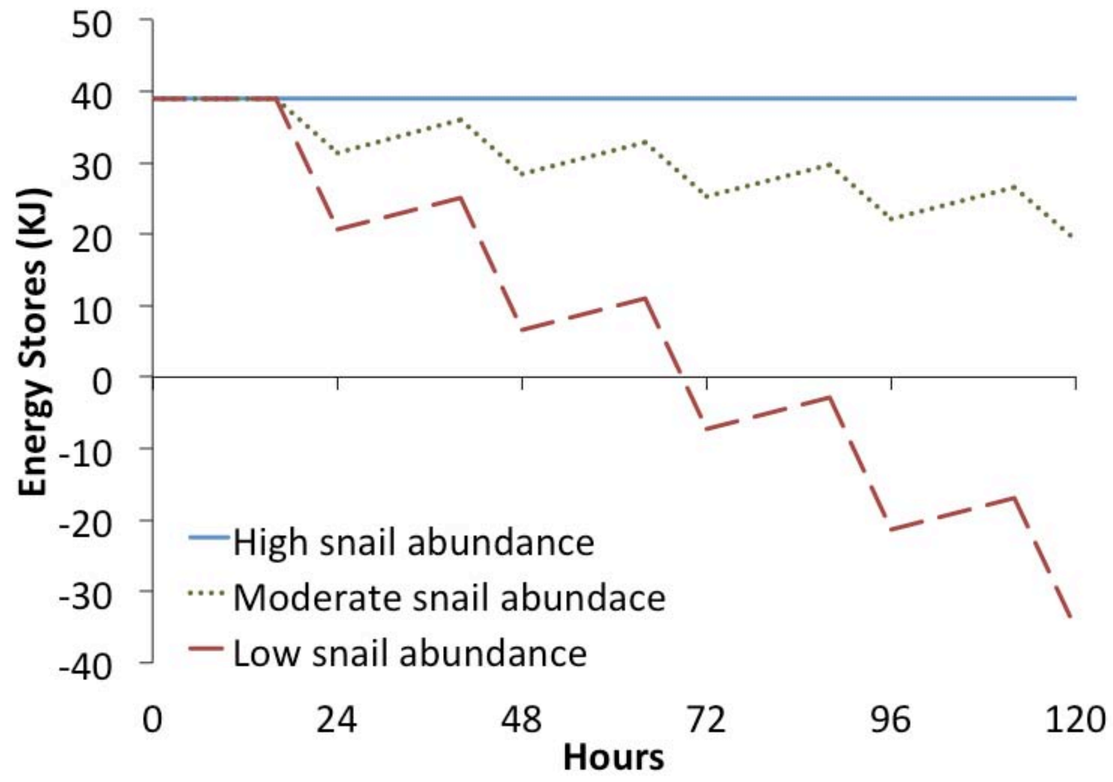
Snail shells have low energy (E_b), high handling time (h_b), and low availability (λ_b) in acidified forests.

Tracking E and Ca in a model bird

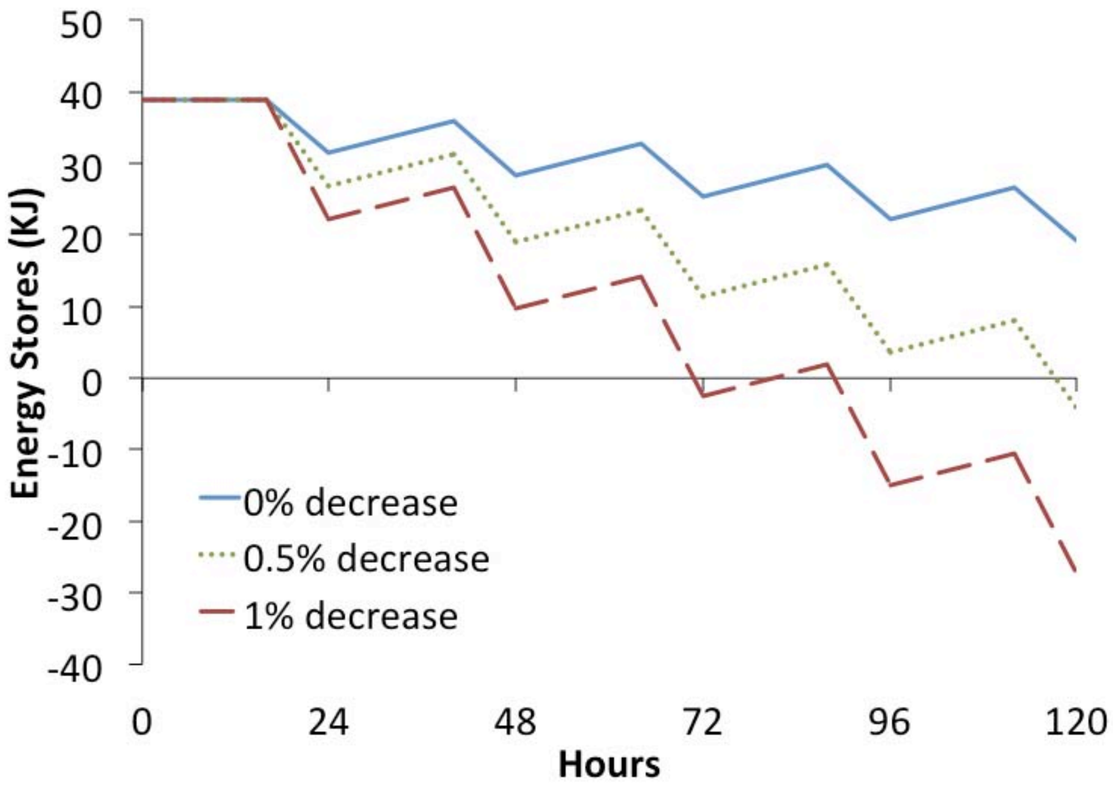
- We tracked E/T and Ca/T using the above model
- E/T was optimized under conditions that Ca demands were met
- Every 24 hours, the bird layed an egg
- The bird stored no Ca for reproduction
- The bird could store up to 39 KJ of energy (= 1 g of fat)
- Energy demand remains constant at 5.36 KJ/hour
- The eggshell is formed 8 hours before each egg is laid
- Calcium demands increased during the hours of eggshell formation



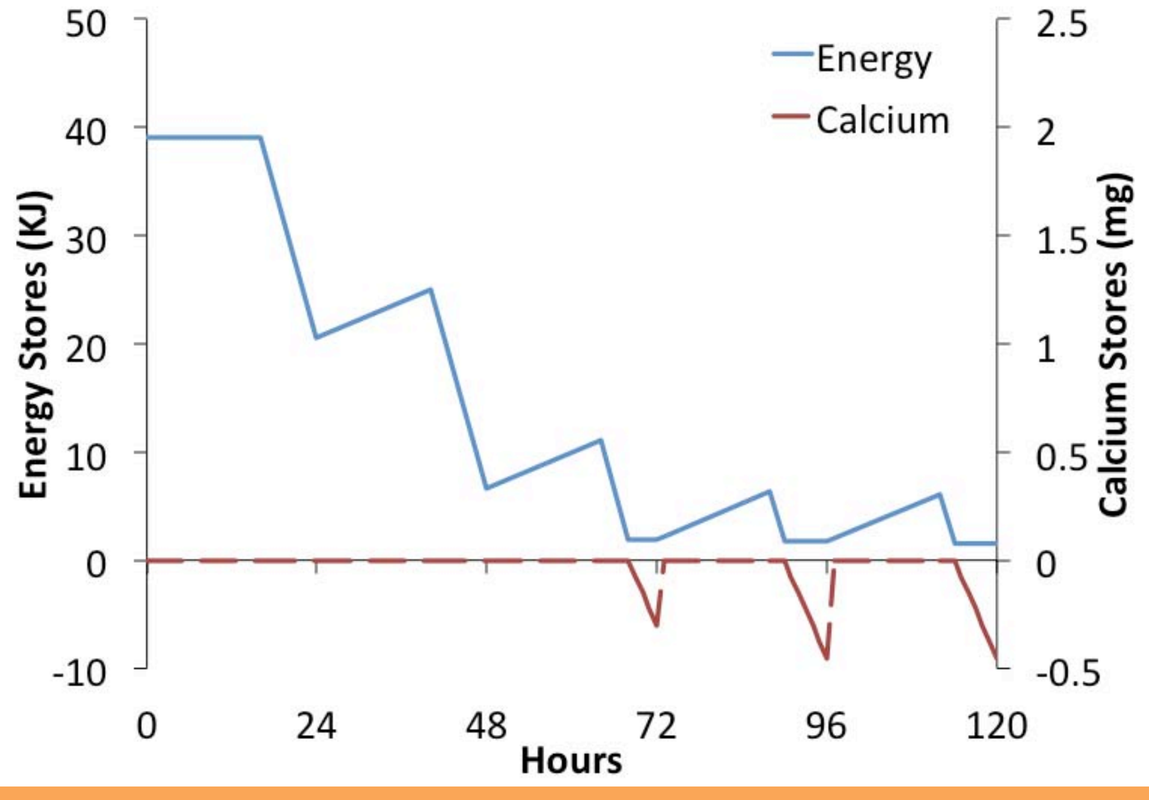
What happens to energy stores when the encounter rate for snail shells changes?



What happens to energy stores when the calcium content of prey changes?



To maintain energy levels above zero, the bird can reduce calcium use by laying eggs with thin eggshells



Conclusions

The trade-off between energy and calcium is important when calcium-rich food items have low abundances, low energy content and high handling tim

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