Slight trait variation causes complex predator-prey oscillations

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Ecological complexity 31: 115-124

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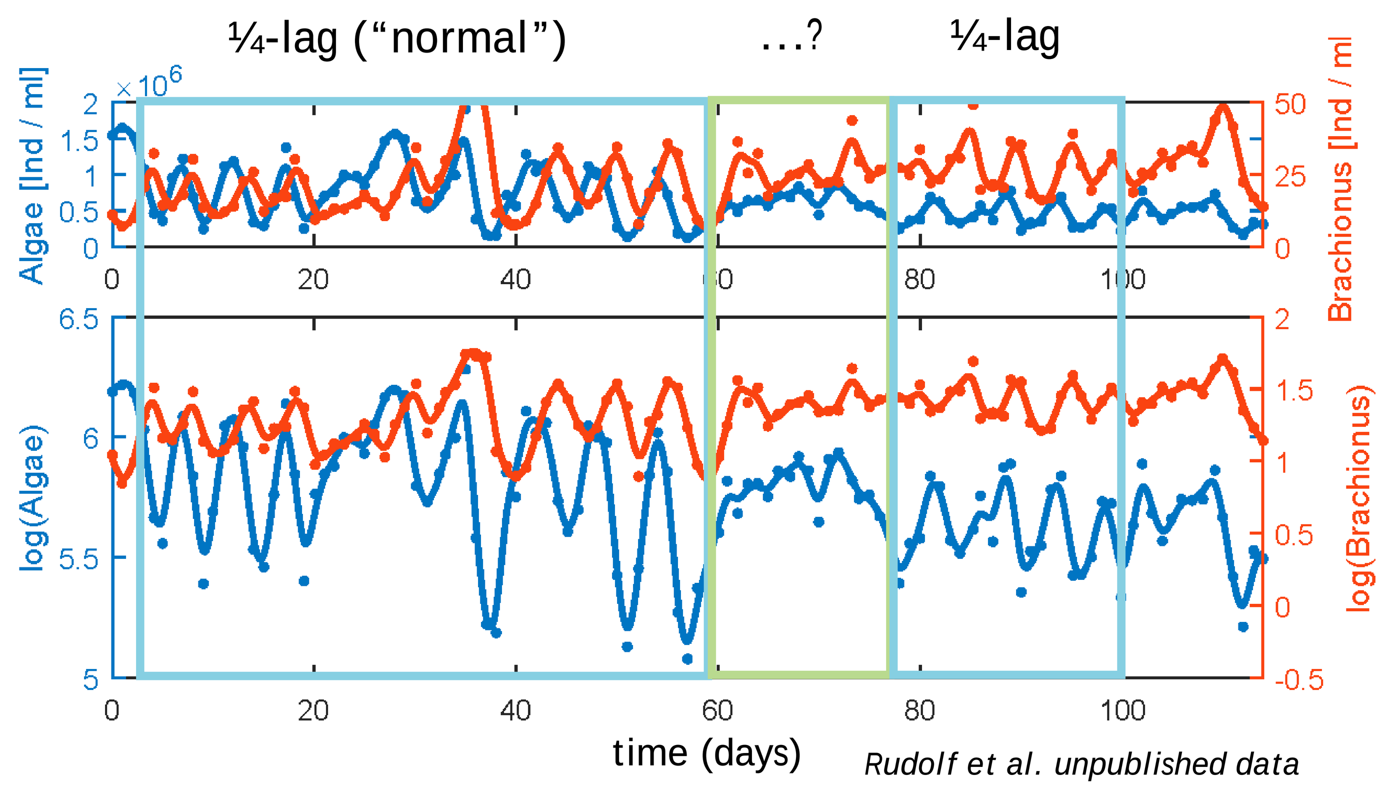
Complex chemostat dynamics

Long-term chemostat experiments often exhibit *intermittent cycles*: regular ¼-lag cycles are interrupted by periods with no clear patterns, before returning to ¼-lag cycles.

Due to the highly controlled nature of such chemostat experiments, it is unlikely that these interruptions are not caused by environmental noise or pronounced trait variation in prey or predators.

Finding the unknown mechanism responsible for such intermittent cycles can help us understand what drives complex predator-prey dynamics.



Rudolf et al. unpublished data

Hypothesis & Conclusion

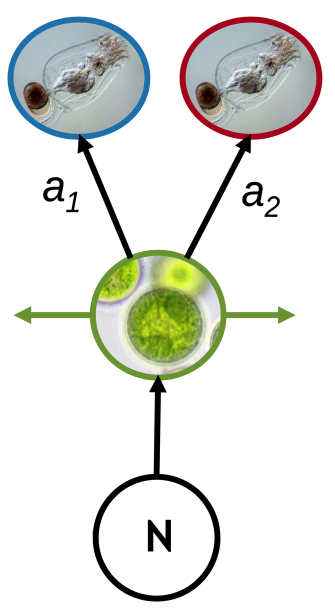
Intermittent cycles may be driven by **small trait variations in prey and predators,** e.g. variations in attack rate.

Such variations may be small enough to be empirically indetectable.

We incorporate small trait variations in a mathematical predator-prey chemostat model and confirm this hypothesis:

10-15% variation in attack rates (within measurement error) can be enough to generate intermittent cycles.

Predator-prey model with trait variation



Two rotifer clones with different but overlapping prey spectra feed on algal prey. (*eq.* (3), (4))

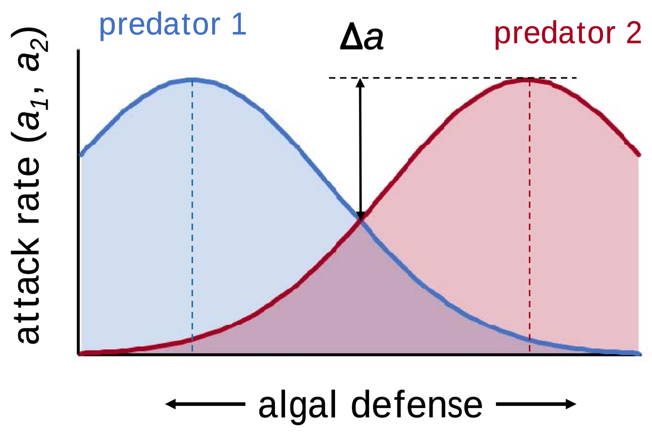
Prey can adjust trait to defend against predators. Better defense against one predator means higher vulnerability to the other. (*eq.* (2), (5))

Nutrients flow through the chemostat and are taken up by algae. (*eq.* (1))

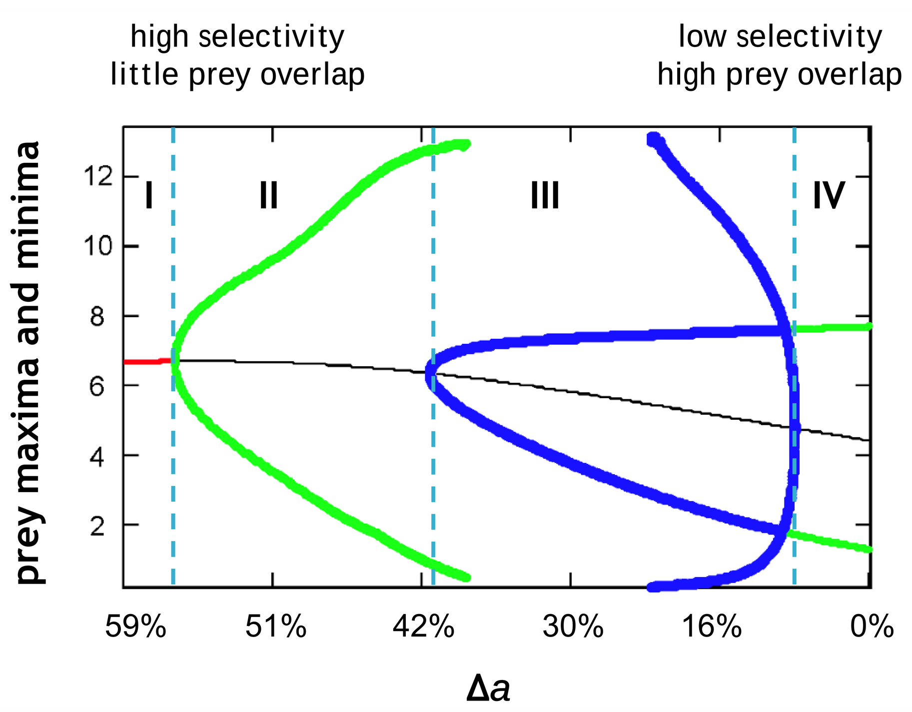
Prey adaptation causes temporal changes in predator attack rates a_1 and a_2.

Δa: temporal variation in attack rates

Minimal difference Δa required for intermittent cycles?



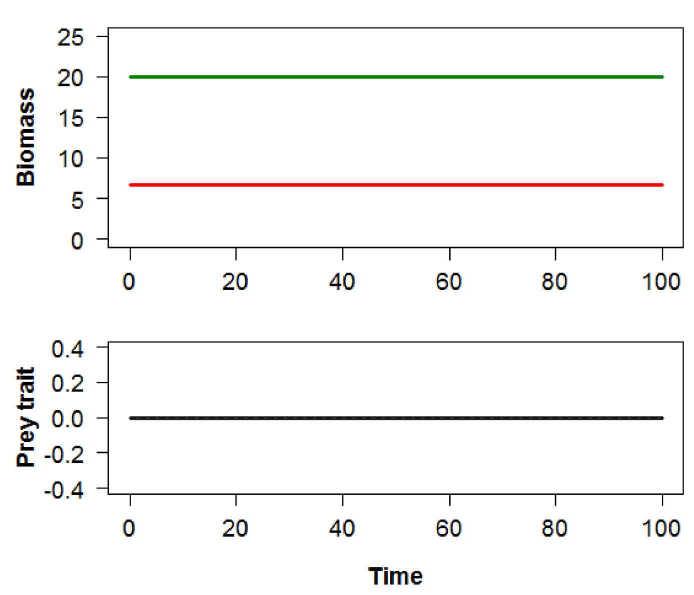
Results (I): bifurcation analysis

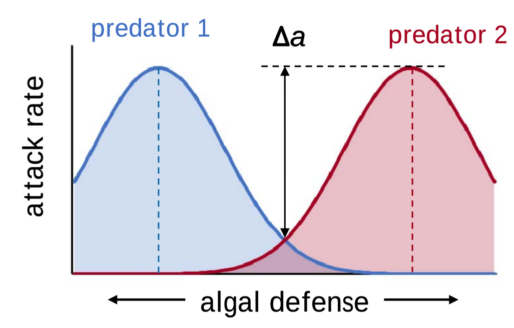


I	trait cycles	NO
	¼-lag cycles	NO
II	trait cycles	YES
	¼-lag cycles	NO
III	trait cycles	YES
	¼-lag cycles	YES
IV	trait cycles	NO
	¼-lag cycles	YES

Results (II): predator-prey dynamics

I: little overlap (Δa > 56%)

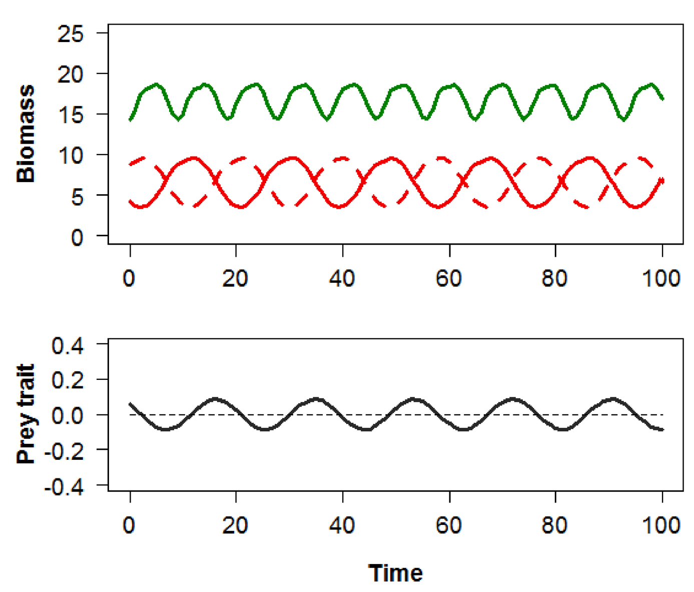


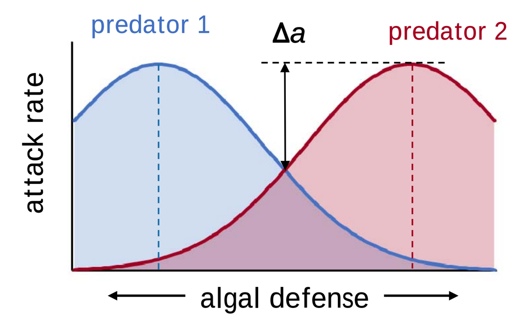


Prey well-defended against both predators → no adaptation

Low attack rates → no ¼-lag cycles

II: intermediate overlap (40% < Δa < 56%)

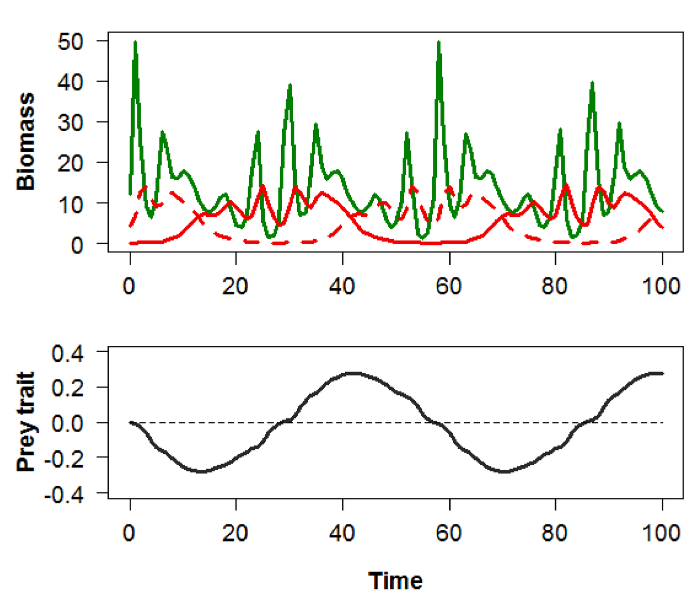


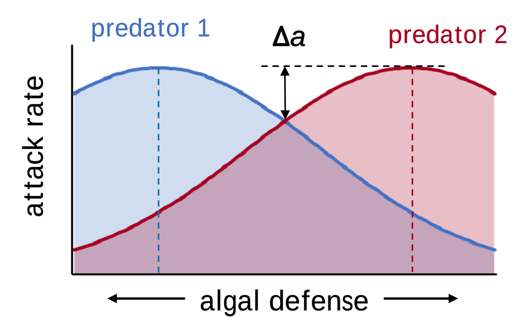


Prey adapts slightly to most abundant predator → predators taking turns

Low attack rates → no ¼-lag cycles

III: large overlap (8% < Δa < 40%)



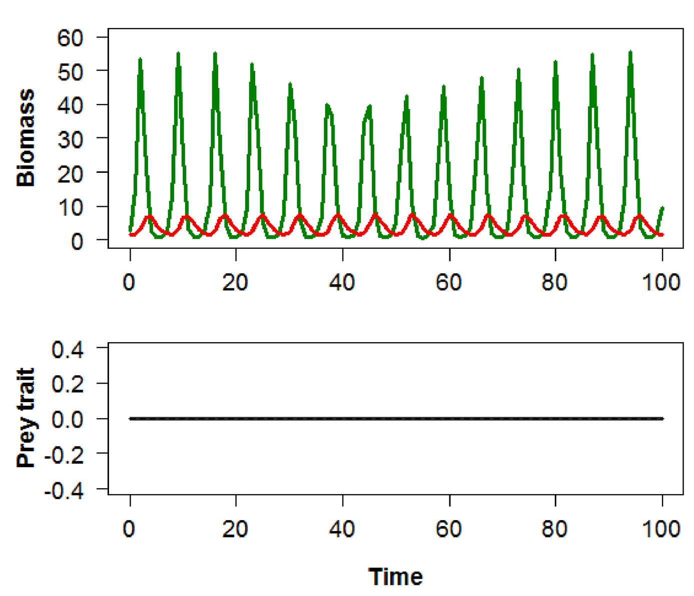


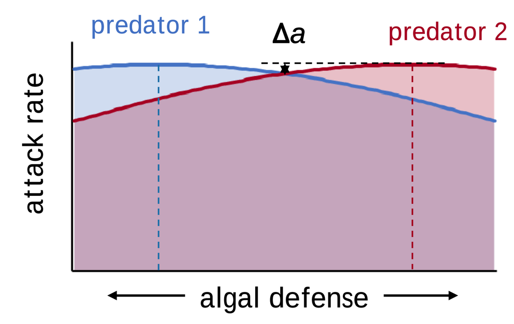
High attack rates → ¼-lag cycles

Stronger prey adaptation → cycles are interrupted when predators take turns

→ intermittent cycles in total biomass

IV: very large overlap (Δa < 8%)





Very weak selection on prey trait → no adaptation

High attack rates → ¼-lag cycles

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Model equations

$$\frac{dN}{dt} = \delta\left(N_0 - N\right) - r\frac{NM}{K_M + N} \quad (1)$$

$$\frac{dM}{dt} = \left(\frac{rN}{K_M + N} - \frac{a_1(\Phi)P_1}{1 + a_1(\Phi)hM} - \frac{a_2(\Phi)P_2}{1 + a_2(\Phi)hM} - \delta\right)M \quad (2)$$

$$\frac{dP_1}{dt} = \left(\varepsilon\frac{a_1(\Phi)M}{1 + a_1(\Phi)hM} - \delta\right)P_1, \quad \frac{dP_2}{dt} = \left(\varepsilon\frac{a_2(\Phi)M}{1 + a_2(\Phi)hM} - \delta\right)P_2 \quad (3)$$

$$a_i\left(\Phi\right) = a_i^{(0)}\exp\left(-\frac{\left(\Phi_{i,0} - \Phi\right)^2}{s_i}\right) \quad (4)$$

$$\frac{d\Phi}{dt} = \nu\frac{\partial\left(\frac{1}{M}\frac{dM}{dt}\right)}{\partial\Phi} + \mu\left(\Phi\right), \quad \mu\left(\Phi\right) = c\left(\frac{1}{\left(b_l - \Phi\right)^2} - \frac{1}{\left(b_r - \Phi\right)^2}\right) \quad (5)$$