Dynamical transitions in a pollination–herbivory interaction

Tomás Revilla[1]

[1]Centre for Biodiversity Theory and Modelling
Station d'Ecologie Expérimentale du CNRS à Moulis

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Outline

Interaction compass

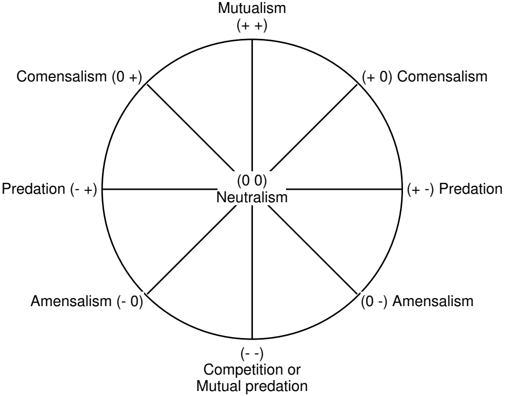

Figure from Holland & DeAngelis (2009)

Lotka–Volterra equations

$$\frac{dN_1}{dt} = r_1 N_1 + a_{11} N_1^2 + a_{12} N_1 N_2$$
$$\frac{dN_2}{dt} = r_2 N_2 + a_{22} N_2^2 + a_{21} N_1 N_2$$

Set the r_i and the a_{ij} according to the interaction of interest

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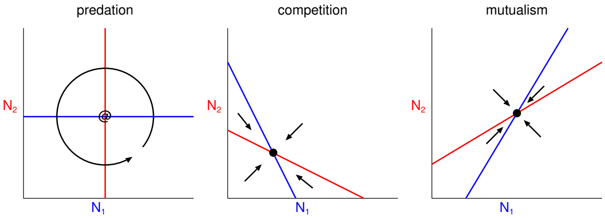
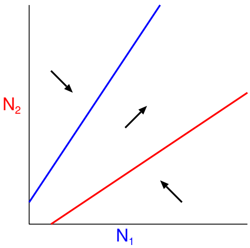


Lotka–Volterra models and mutualism

"orgy of mutual benefaction"



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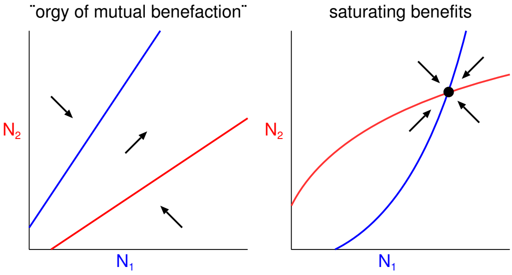

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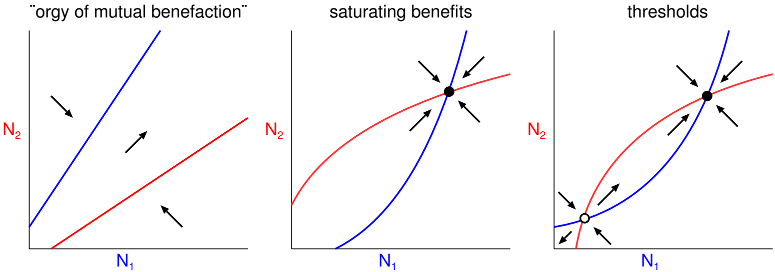

Variable interactions

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  - Malgas Island: Lobsters are abundant, they predate on snails
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- Cactus-Moth (several papers of Bronstein & collaborators):
  - Low moth density: pollination benefits overcomes seed parasitism
  - High moth density: seed parasitism overcomes pollination benefits

Holland & DeAngelis (2010) consumer–resource approach

$$\frac{dN_i}{dt} = N_i\left(r_i - d_i N_i + c_i\left[\frac{a_i N_j}{b_i + N_j}\right] - q_i\left[\frac{d_i N_j}{h_i + N_i}\right]\right)$$

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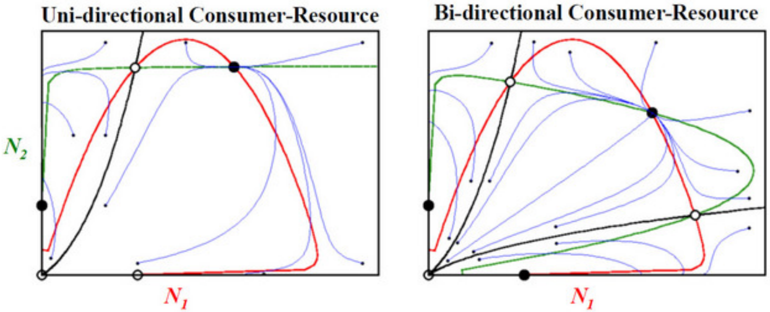

Outline

Friend or Foe?

Il faut bien que je supporte deux ou trois chenilles si je veux connaître les papillons

Le Petit Prince – Antoine de Saint-Exupéry

Problem

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- The net outcome of an interaction will depend on population structure, e.g. how many larvae vs. how many adults
- And why a net outcome? why not an alternation:

  mutualism -> antagonism -> mutualism -> antagonism ...

Goals

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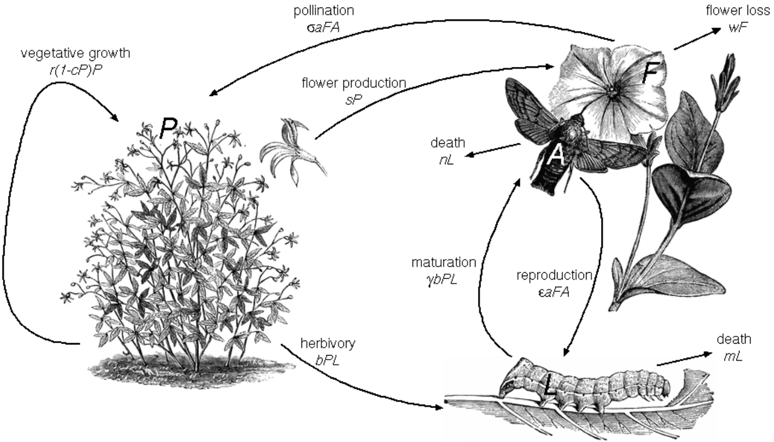
- Predict potential, indirect effects, of other plants in the cots/benefit balances

Outline

Interaction mechanism



Interaction dynamics

Differential equations for plant, flower, larva and adult biomasses

$$\frac{dP}{dt} = rP(1-cP) + \sigma aFA - bPL$$
$$\frac{dF}{dt} = sP - wF - aFA$$
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- But plant conversion rates σ can be larger than 1

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Flower dynamics

Nous ne notons pas les fleurs, dit le géographe
Pourquoi ça ! c'est le plus joli !
Parce que les fleurs sont éphémères

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Assumption

Flower (or nectar) dynamics is much faster than population dynamics. Let us assume that flowers attain a sort of steady-state, compared with plants and insects

$$F \approx \frac{sP}{w + aA}$$

The PLA model

Now everything is in terms of population biomasses

$$\frac{dP}{dt} = rP(1 - cP) + \sigma \left[\frac{asA}{w + aA} \right] P - bPL$$

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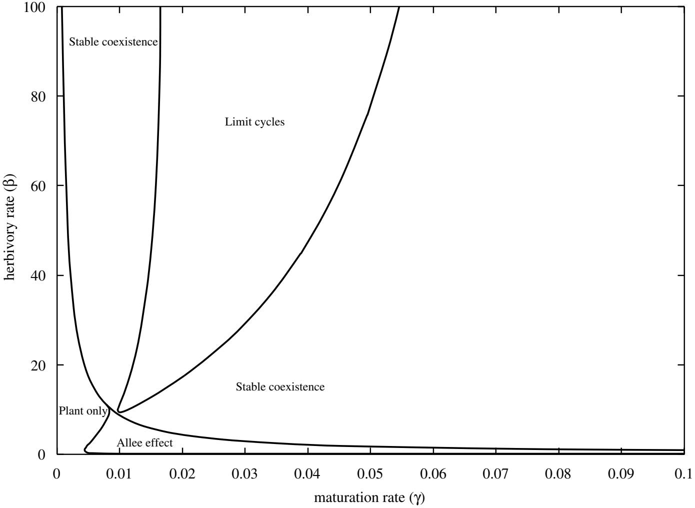
- Pollination benefits saturate with pollinator biomass
- Insects engage in competition for pollination resources
- Let's vary the herbivory rate (b) and the maturation rate (γ), this changes the balance between mutualism and antagonism

Outline

Parameter space. Herbivory (b) vs. Maturation rate (γ)



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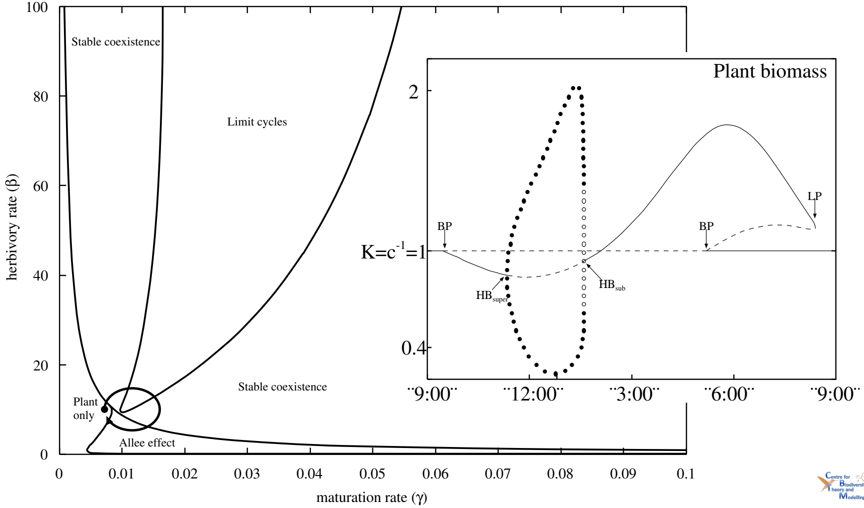
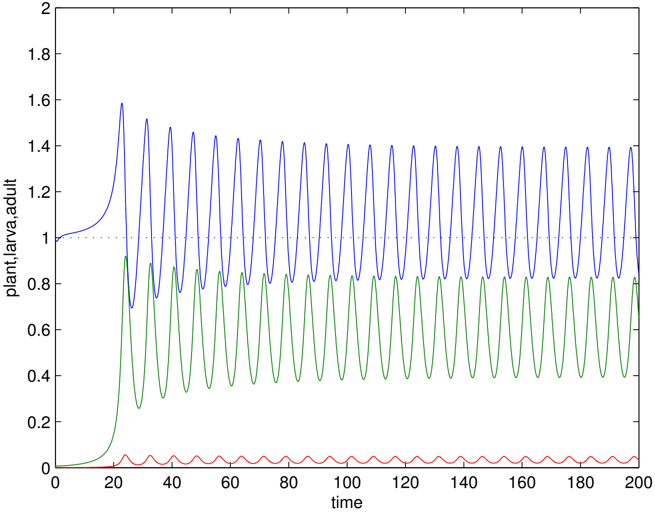


Outline

Plants can oscillating around the carrying capacity



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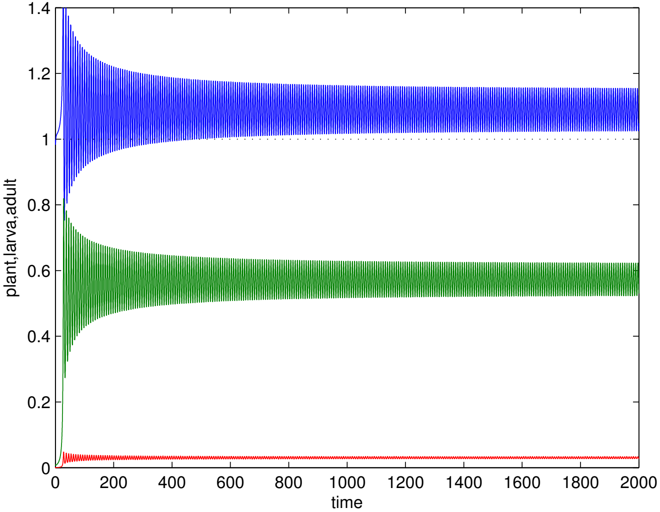

Outline

Alternative food sources

Suppose that the adults can pollinate other plants

$$\frac{dP}{dt} = rP(1-cP) + \sigma\left[\frac{asA}{w+aA}\right]P - bPL$$
$$\frac{dL}{dt} = gA + \varepsilon\left[\frac{asP}{w+aA}\right]A - \gamma bPL - mL$$
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$g > 0$: growth rate due to pollination of plants different than species "P"

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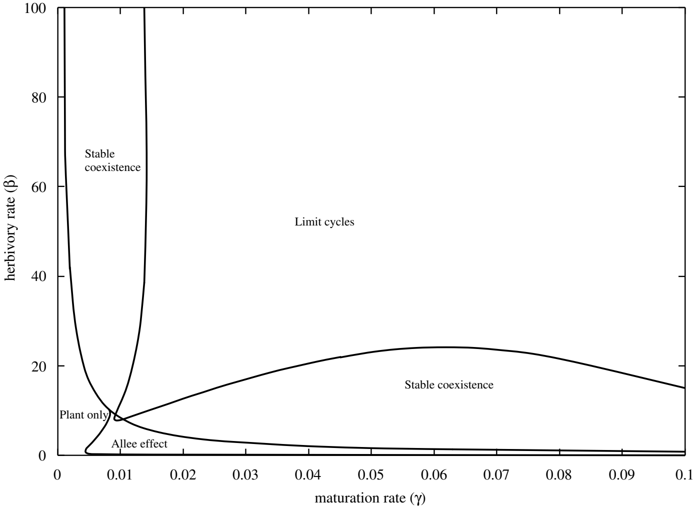

Summary

- Population structure determines the balance between the costs of herbivory and the benefits of mutualism
  - The faster the larvae turn into adults, the more stable the association (dynamically)
  - Changes in population structure can be triggered by multiple factors such as temperature, chemicals, food quality

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    - Plants can oscillate **entirely above** their carrying capacities: favored by mutualism (demographically), but with the dynamics of exploitation
- Pollination of other plants increases reproduction, leading to more larvae and loss of stability, i.e. victim-exploiter cycles

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Děkuji!