Evolution of plant attractiveness further threatens pollinator populations

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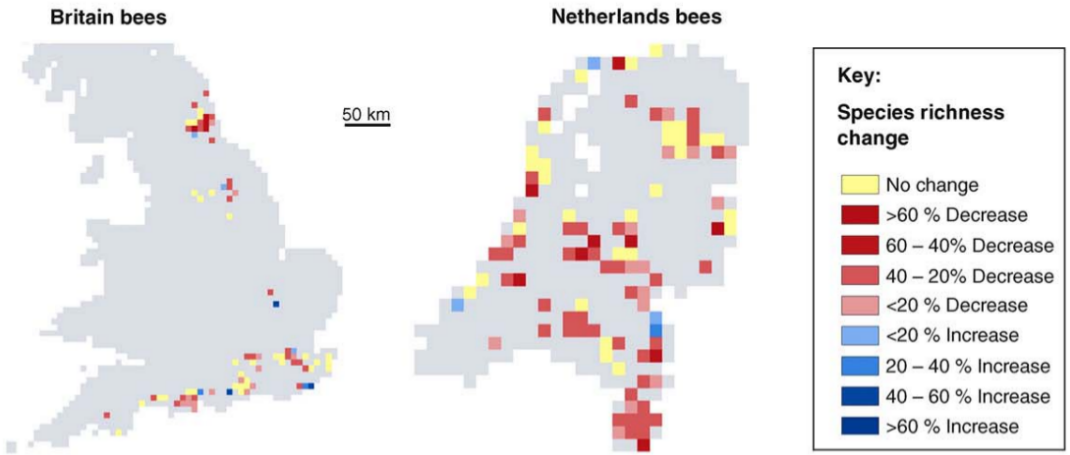
Modélisation Mathématique et Biodiversité

Recent **collapse of pollinator** populations (Biesmeijer *et al.* 2006)

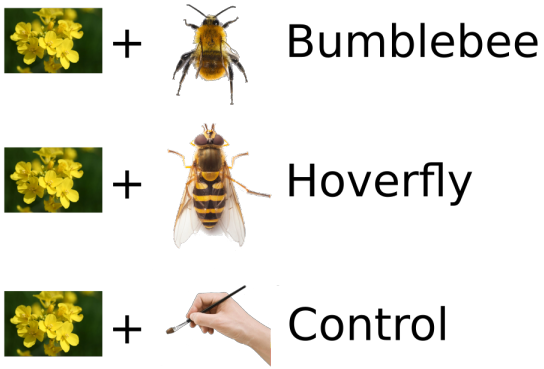


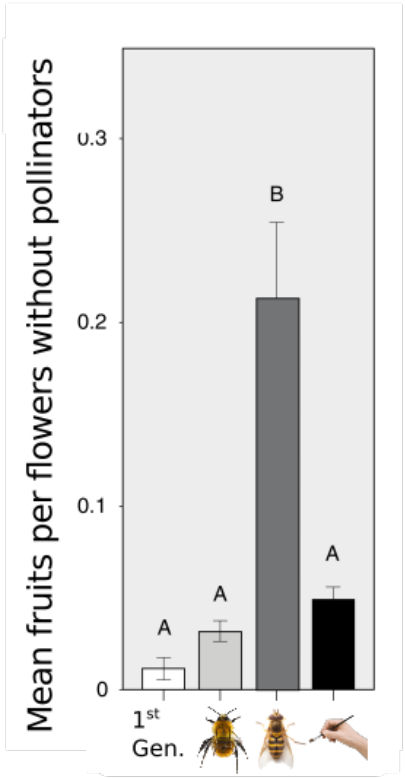
$\rightarrow$ plants adapt rapidly by shifting to other reproduction means

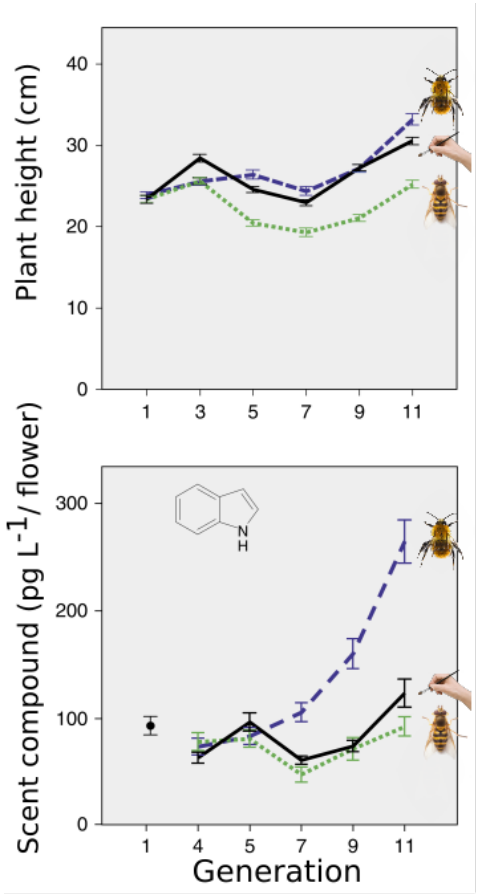
(Darwin 1862, Bodbyl Roels & Kelly 2011, Hopkins R & Rausher MD. 2012)

The rapid evolution of plants

Experiment on pollination-driven evolution of a plant:







adapted from Gervasi *et al.*, 2017

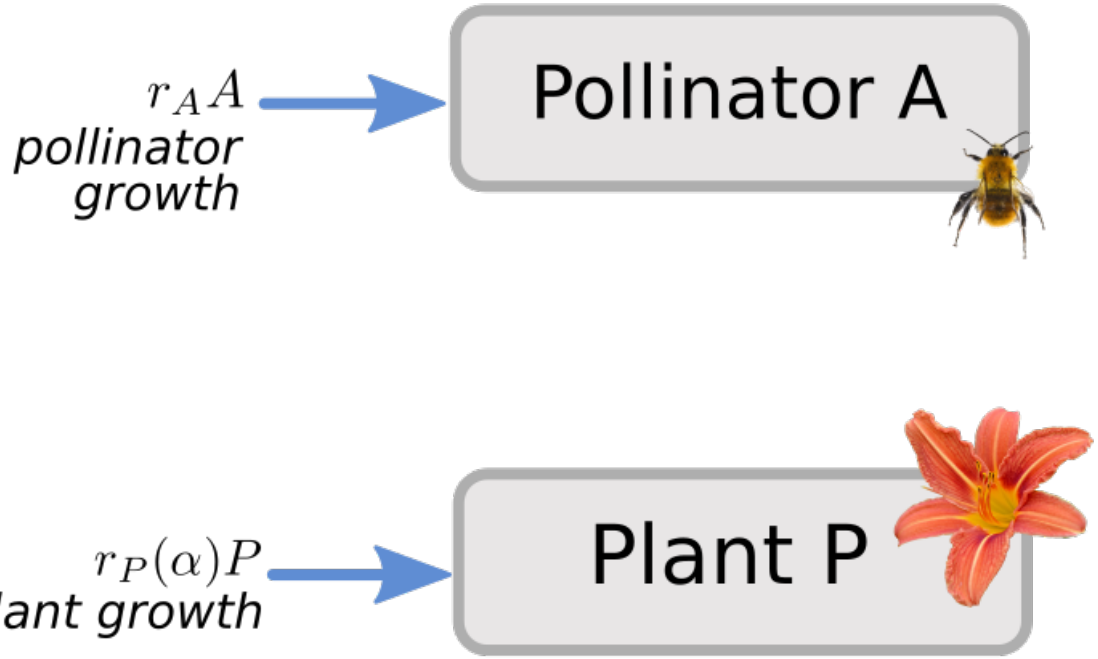
In the pollination context:

1. How does the plant **attractiveness evolve**?
2. How does this evolutionary process **impact plant and pollinator populations**?
3. How a **perturbation** (e.g. **pollinator populations decline**) might **alter** these ecological and evolutionary **equilibria**?

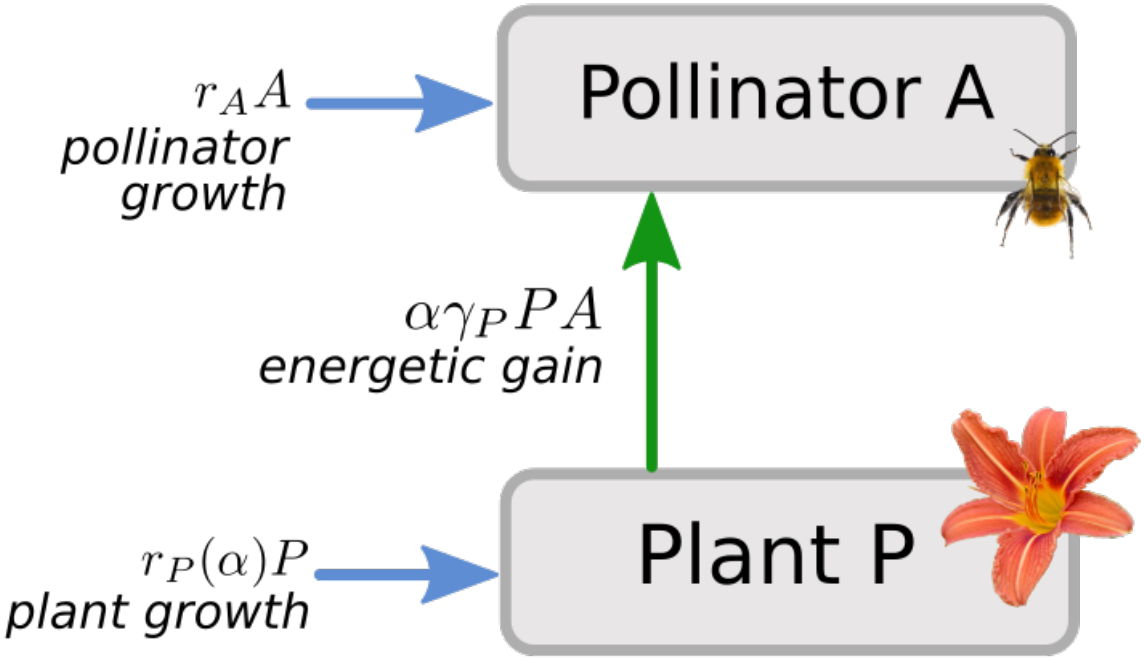
Pollinator A

Plant P

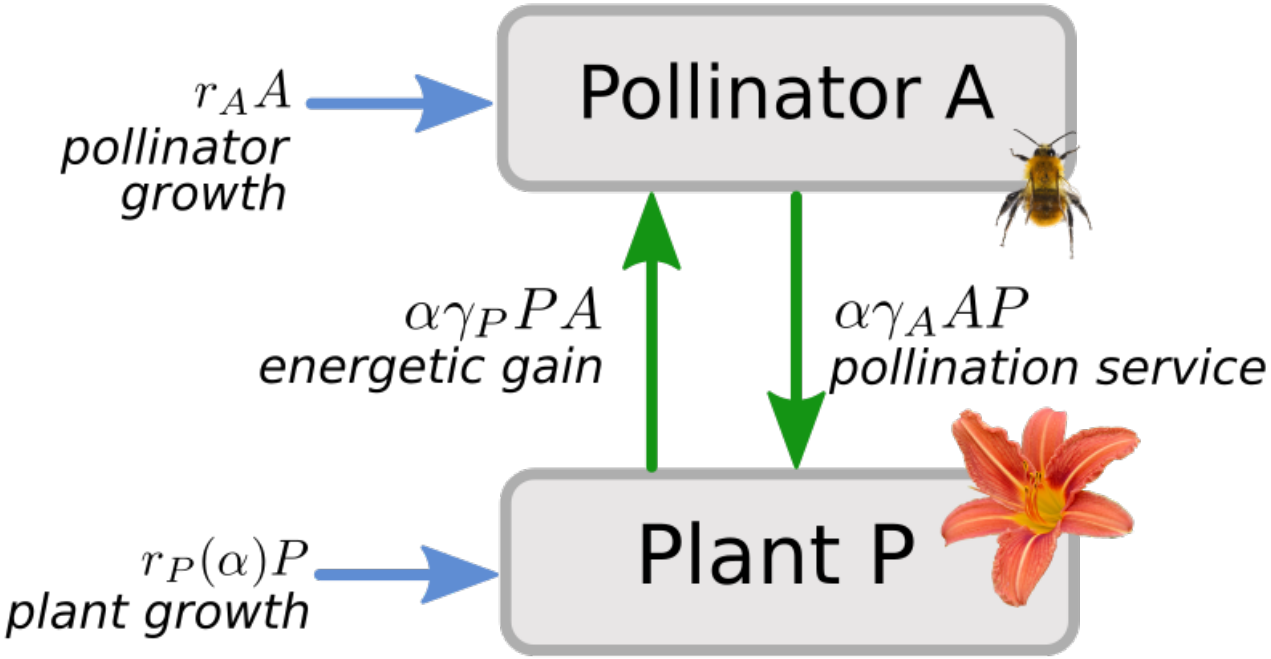
$$\begin{cases} \frac{dA}{dt} = \\ \frac{dP}{dt} = \end{cases}$$



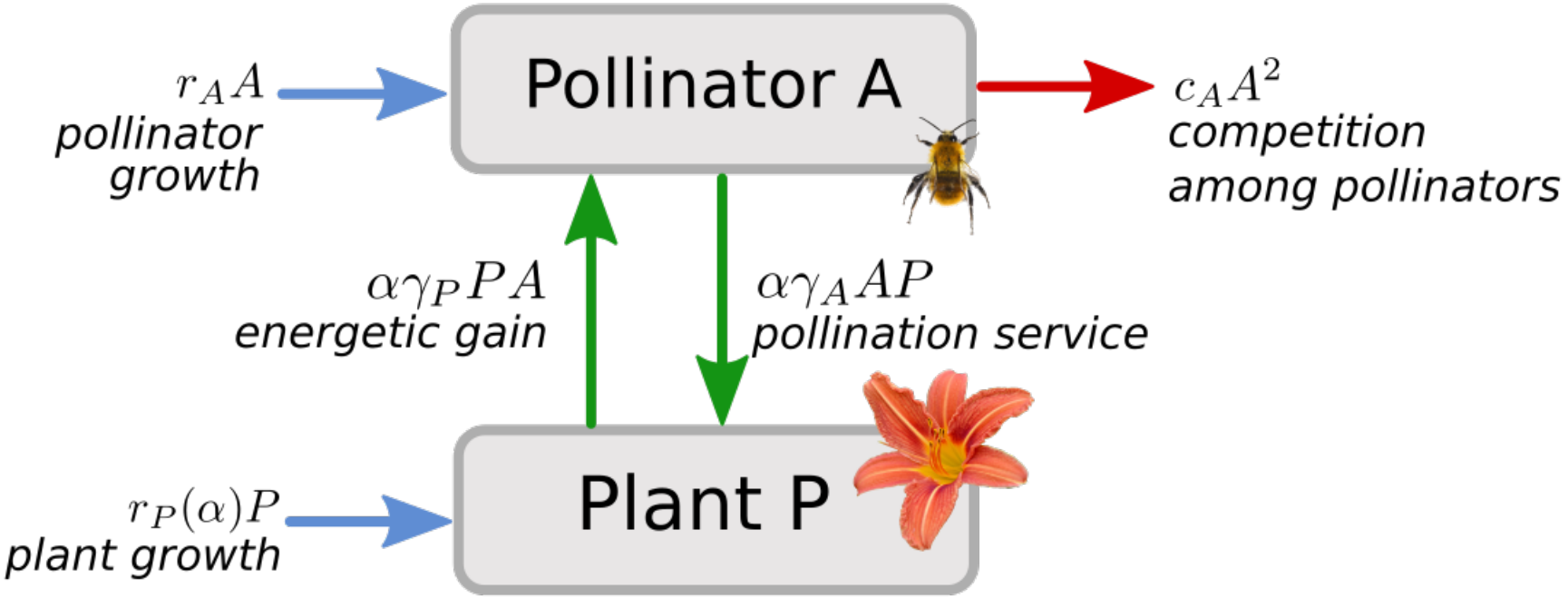
$$\begin{cases} \frac{dA}{dt} = A(r_A \qquad) \\ \frac{dP}{dt} = P(r_P \qquad) \end{cases}$$



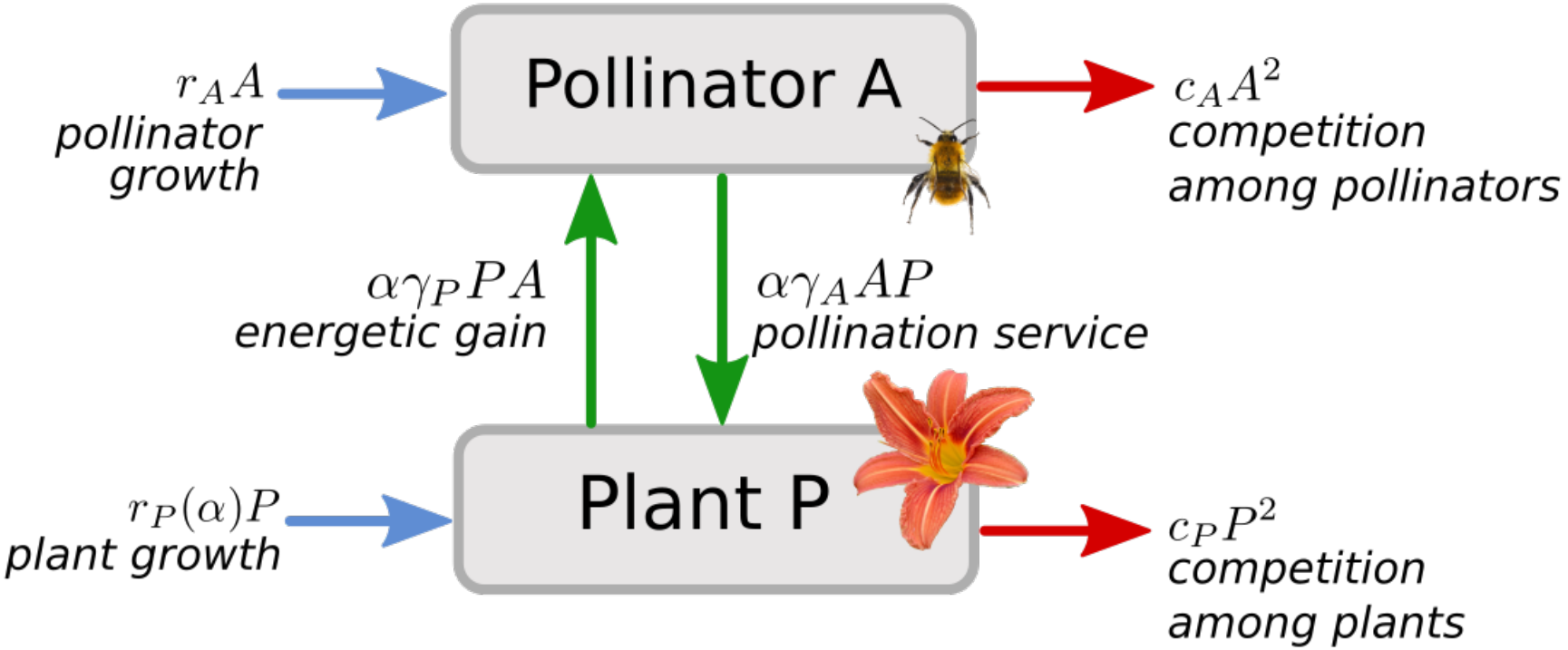
$$\begin{cases} \frac{dA}{dt} = A(r_A \qquad\qquad + \alpha\gamma_P P) \\ \frac{dP}{dt} = P(r_P \qquad\qquad\quad) \end{cases}$$



$$\begin{cases} \frac{dA}{dt} = A(r_A + \alpha\gamma_P P) \\ \frac{dP}{dt} = P(r_P + \alpha\gamma_A A) \end{cases}$$



$$\begin{cases} \dfrac{dA}{dt} = A\left(r_A - c_A A + \alpha\gamma_P P\right) \\ \dfrac{dP}{dt} = P\left(r_P \qquad\quad + \alpha\gamma_A A\right) \end{cases}$$



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Evolution of **plant attractiveness** α




We considered the following **energetic trade-off**:

$$\underbrace{\left(\frac{r_P}{r_{Pmax}}\right)^s}_{\text{growth rate}} + \underbrace{\left(\frac{\alpha}{\alpha_{max}}\right)^s}_{\text{attractiveness}} = 1$$

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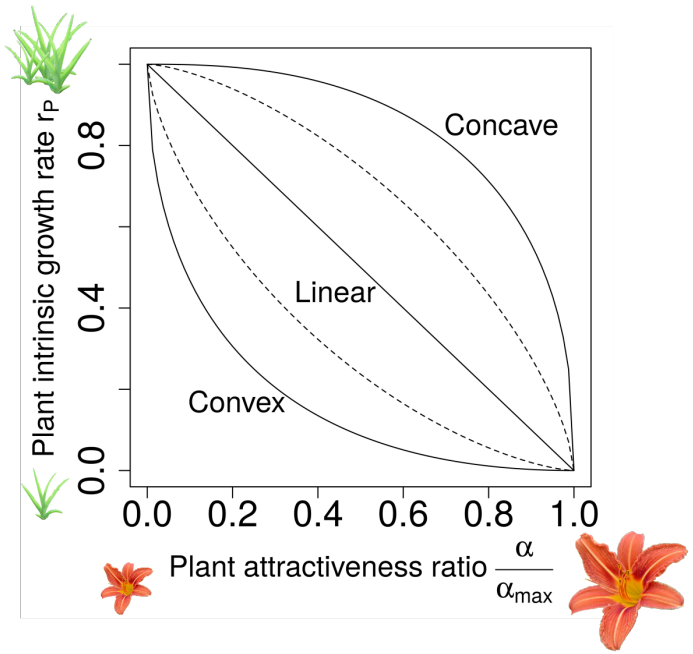
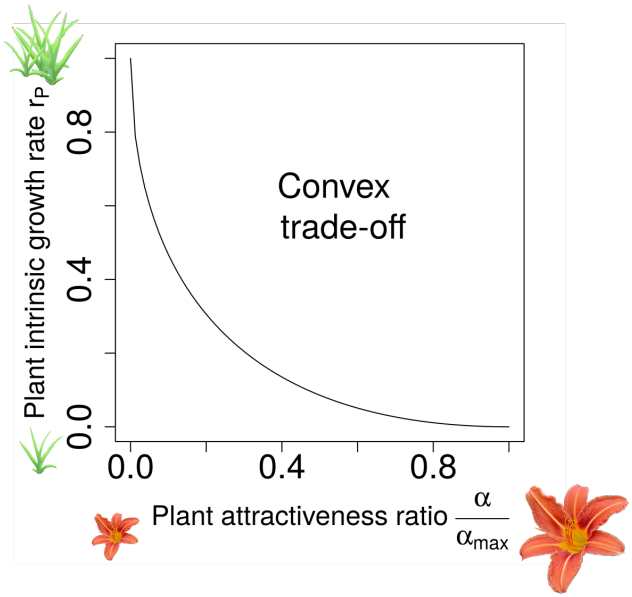
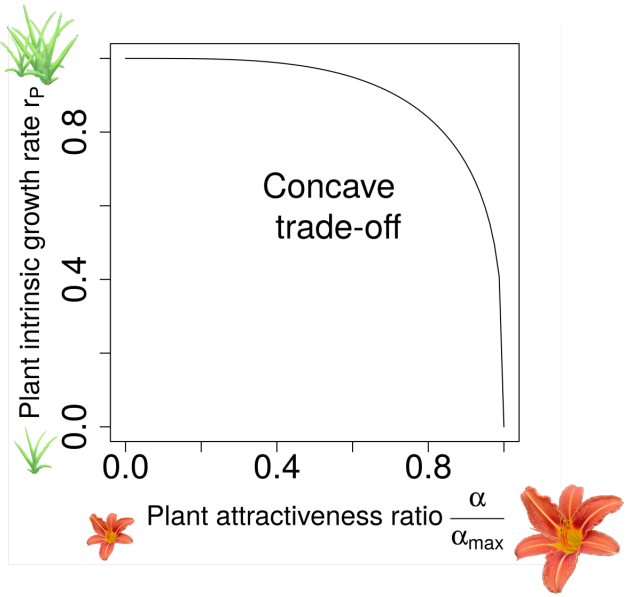



Plant intrinsic growth rate r_P
0.0
0.4
0.8
Convex
trade-off
0.0
0.4
0.8
Plant attractiveness ratio $\frac{\alpha}{\alpha_{max}}$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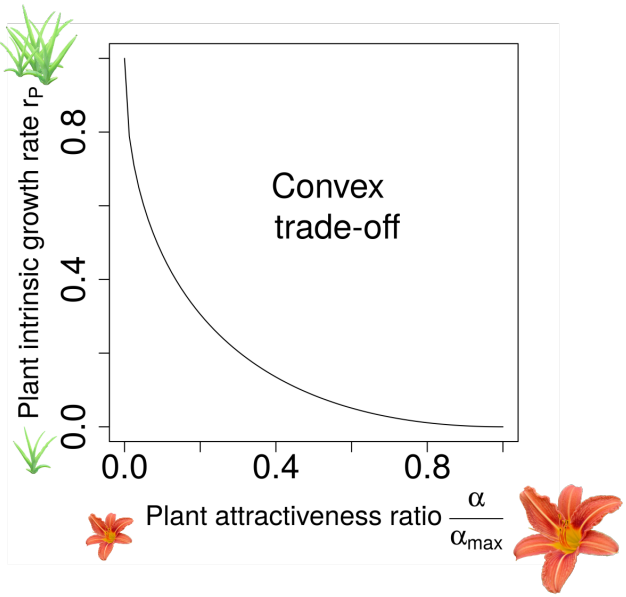
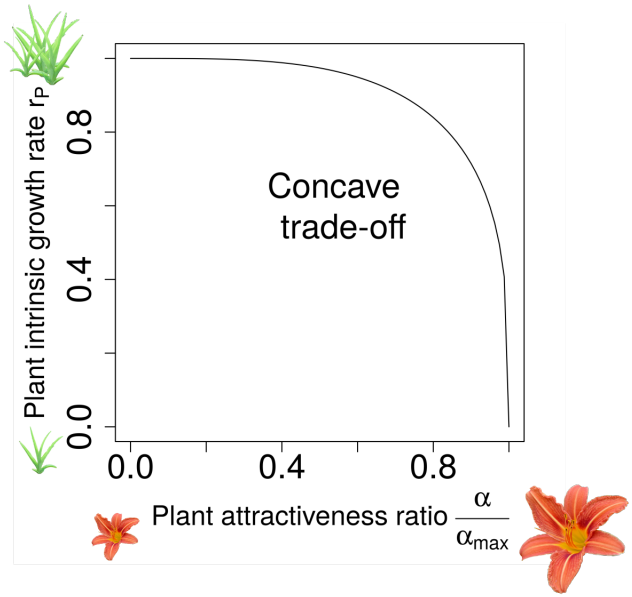
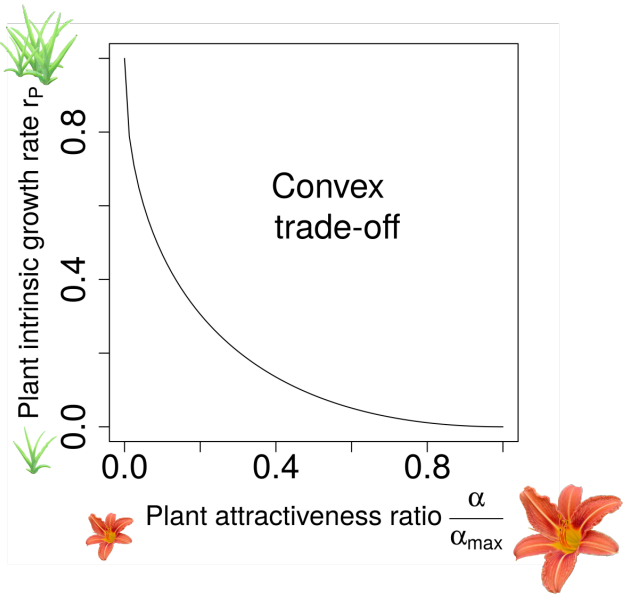
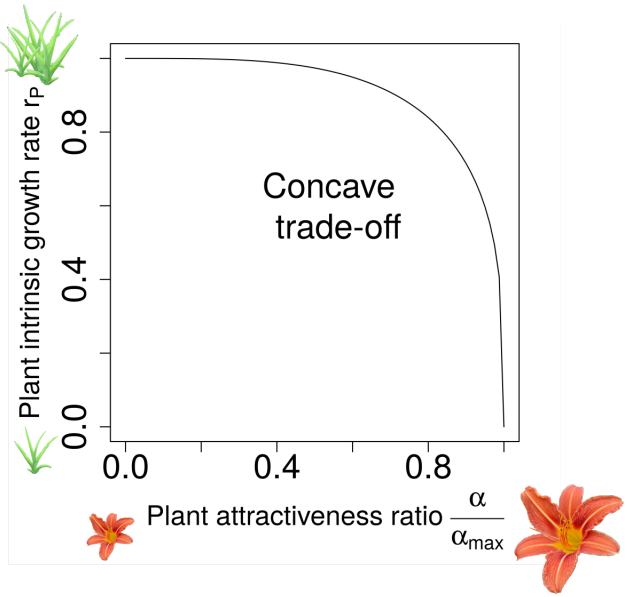


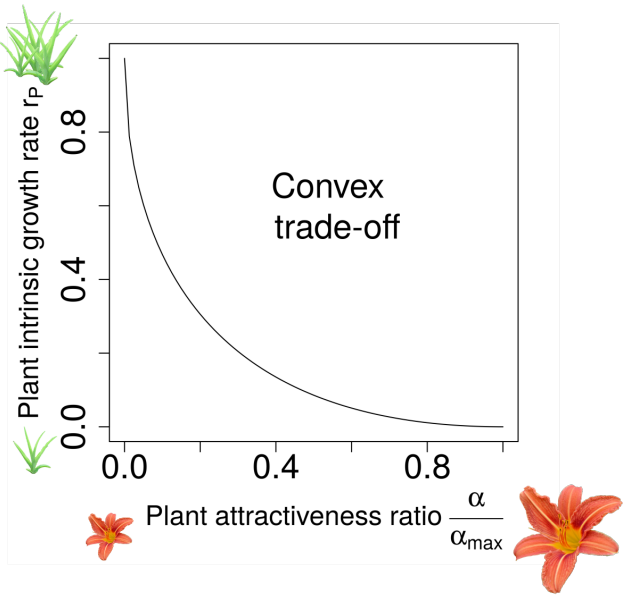


- Plant evolve toward 100% attractiveness
  $\rightarrow$ no intrinsic growth.





- Plant evolve toward 100% attractiveness
  $\rightarrow$ no intrinsic growth.
- Plant evolve toward 0% attractiveness
  $\rightarrow$ no interaction with pollinator.



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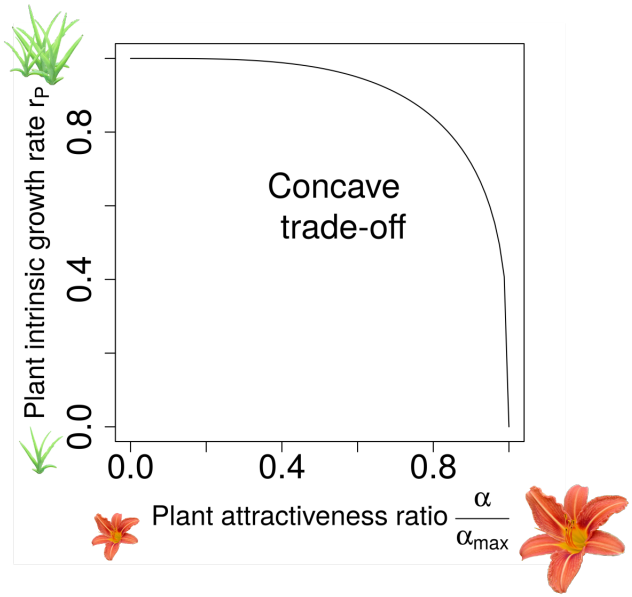
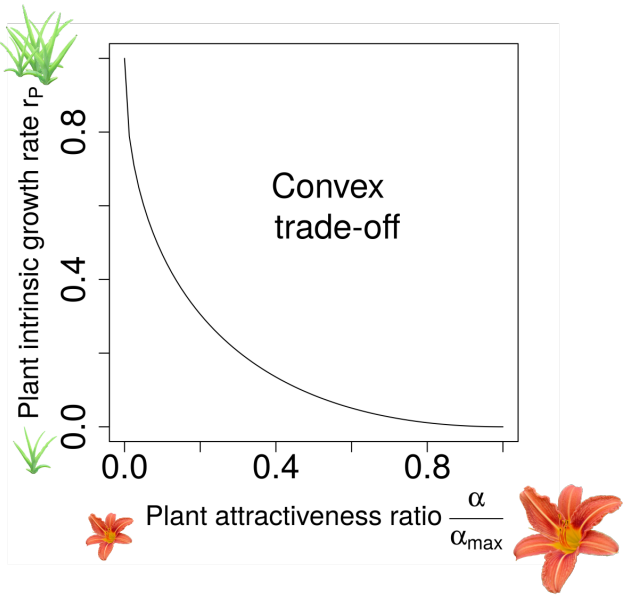


- Plant evolve toward intermediate attractiveness
  $\rightarrow$ stable coexistence of the two species.



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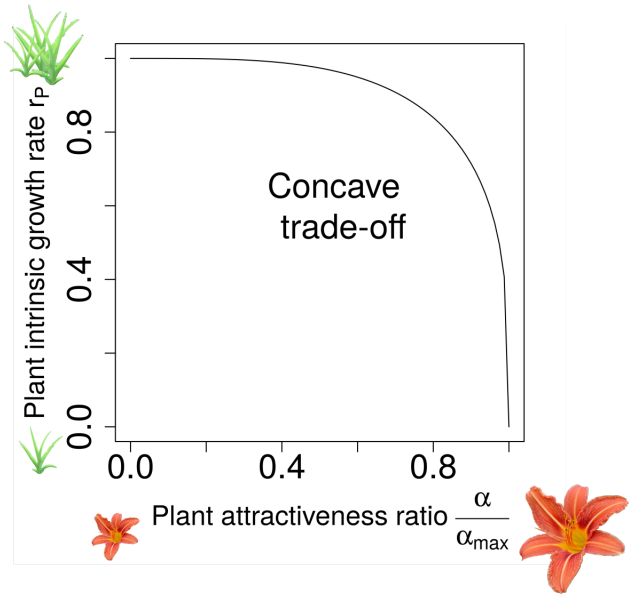

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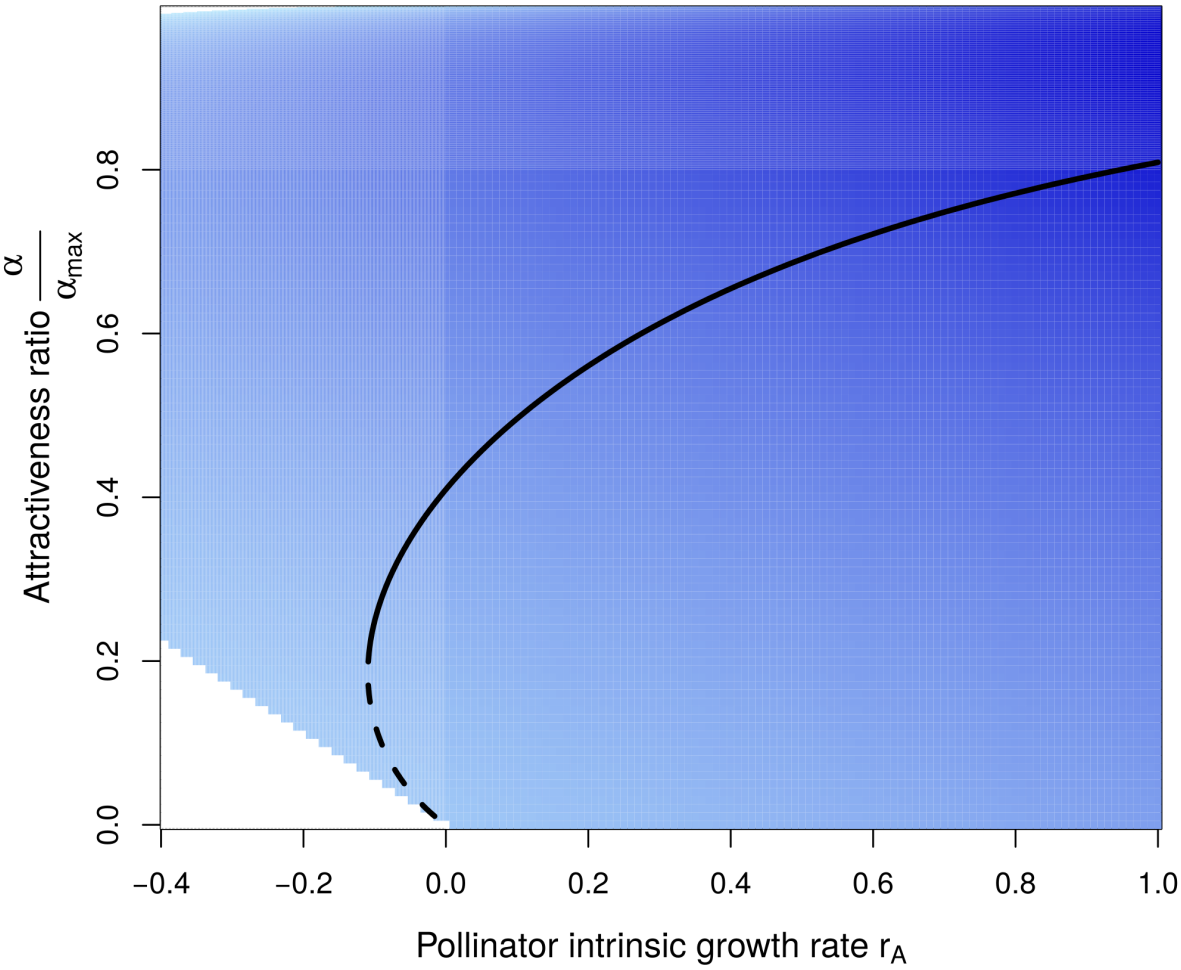
Concave trade-off:



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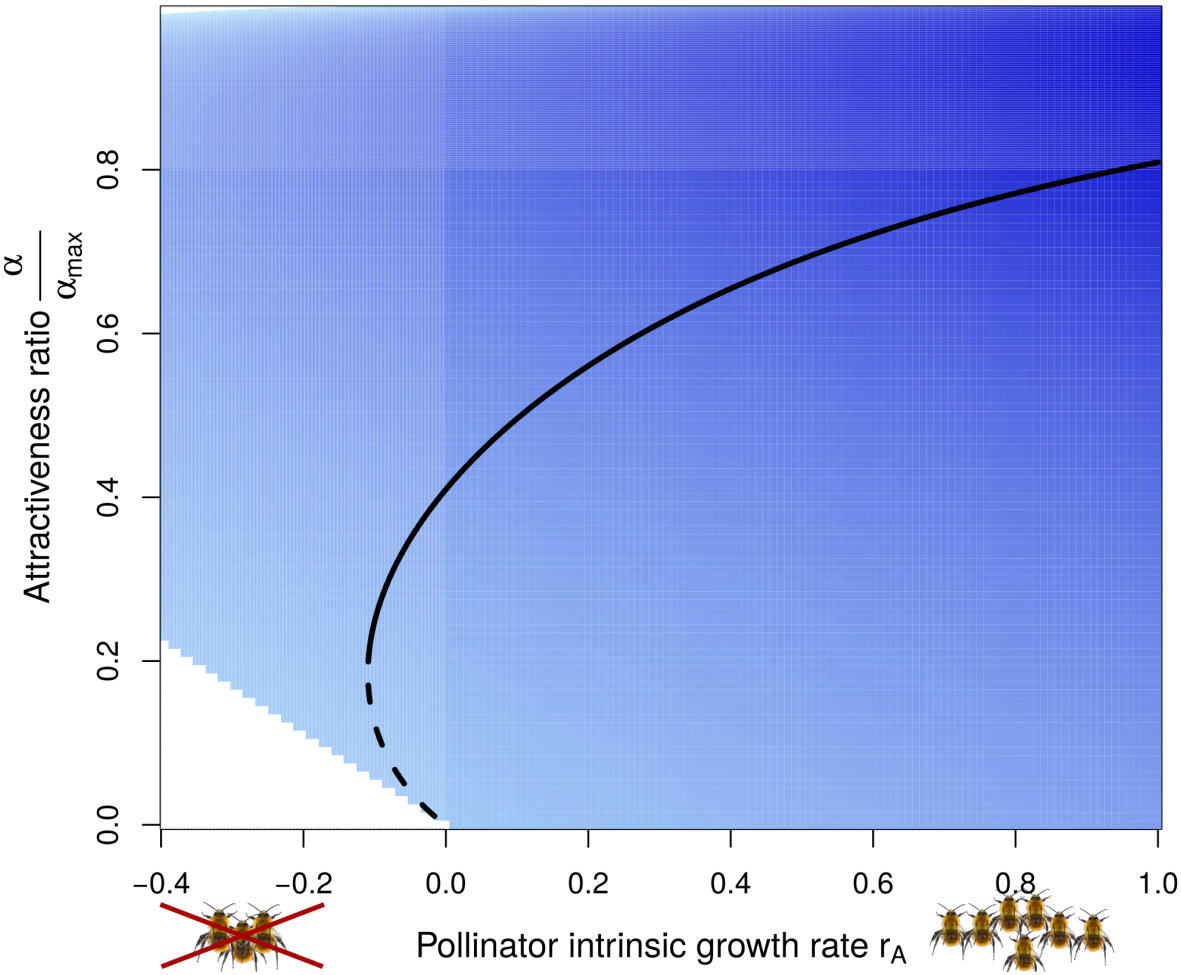

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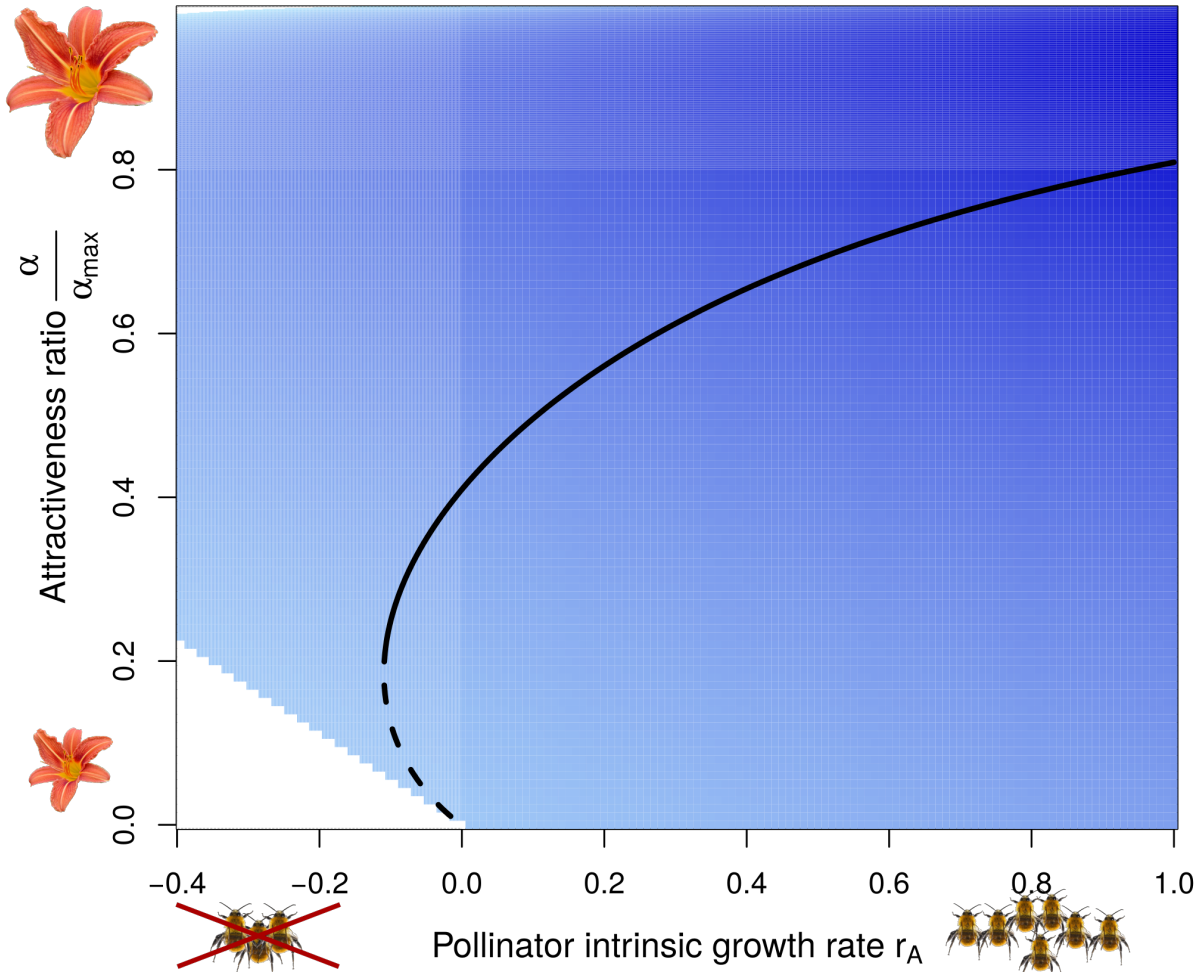

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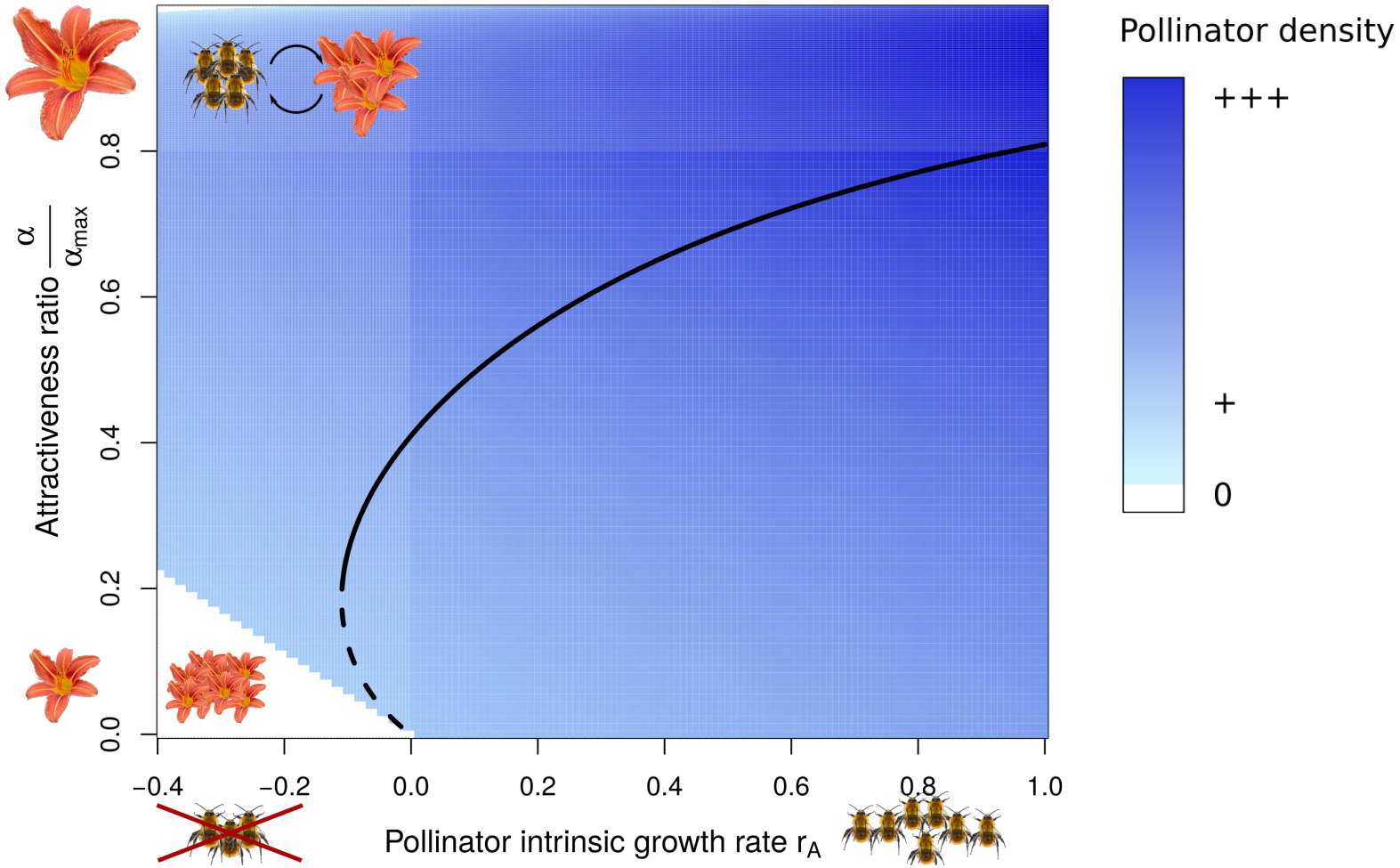

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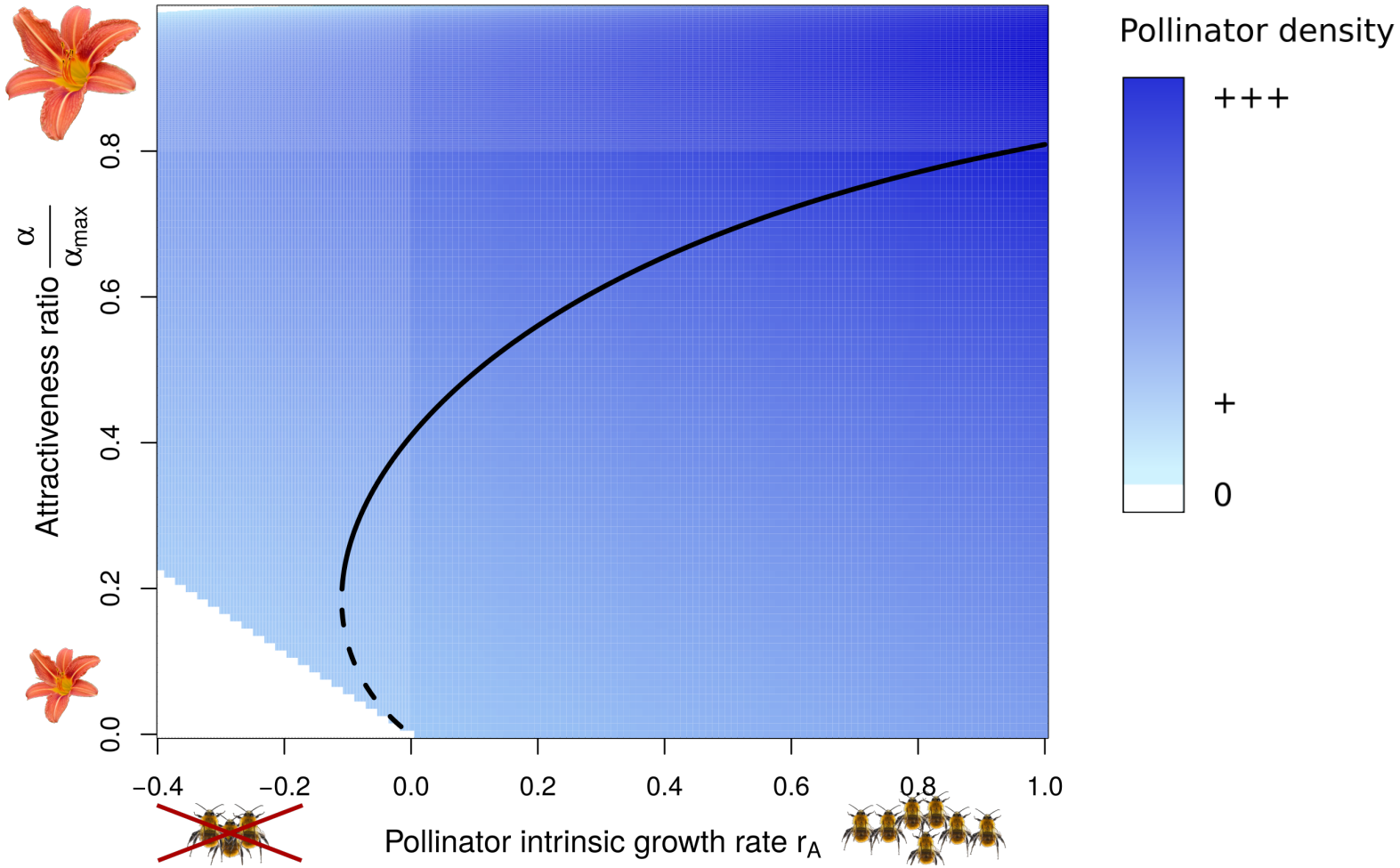

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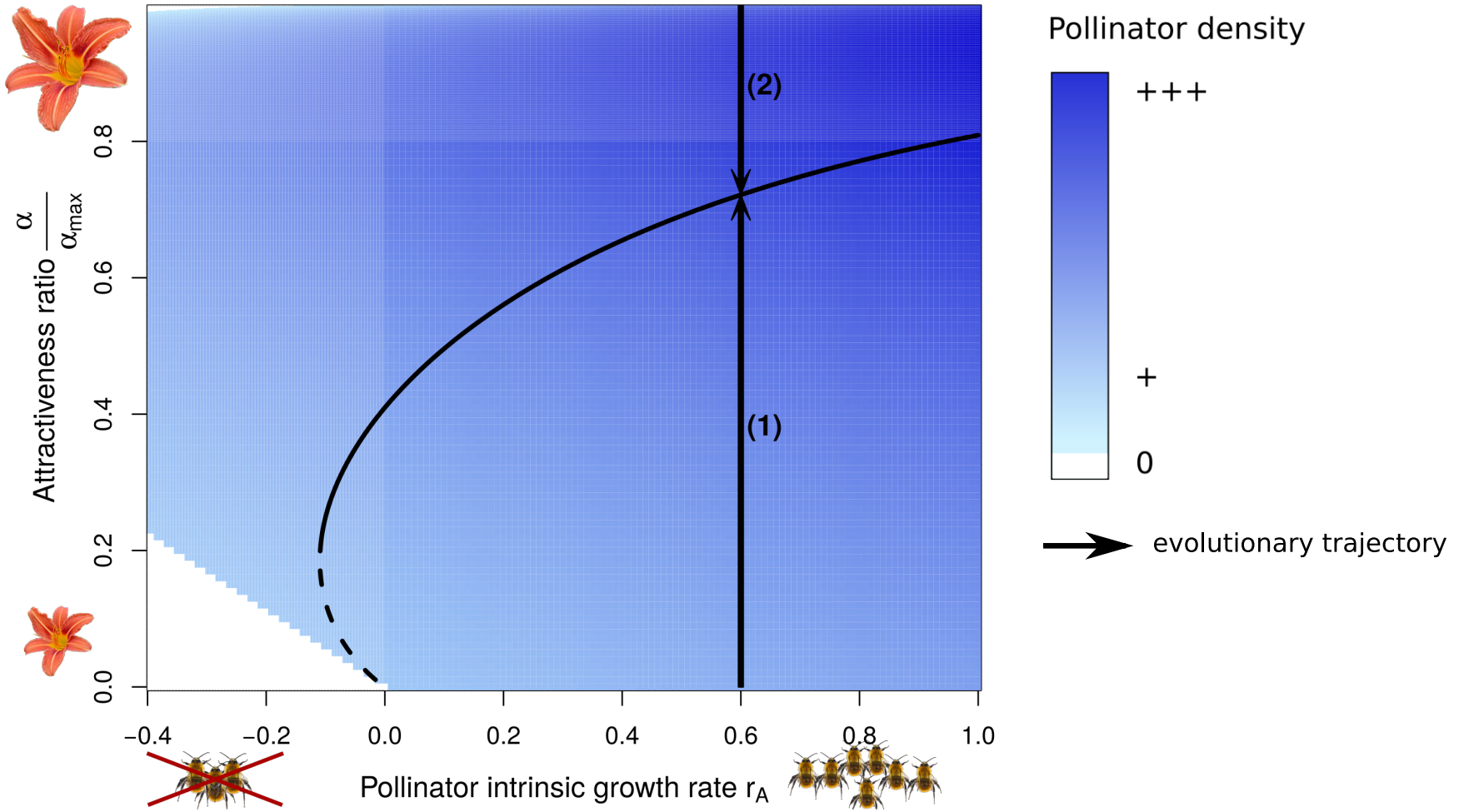

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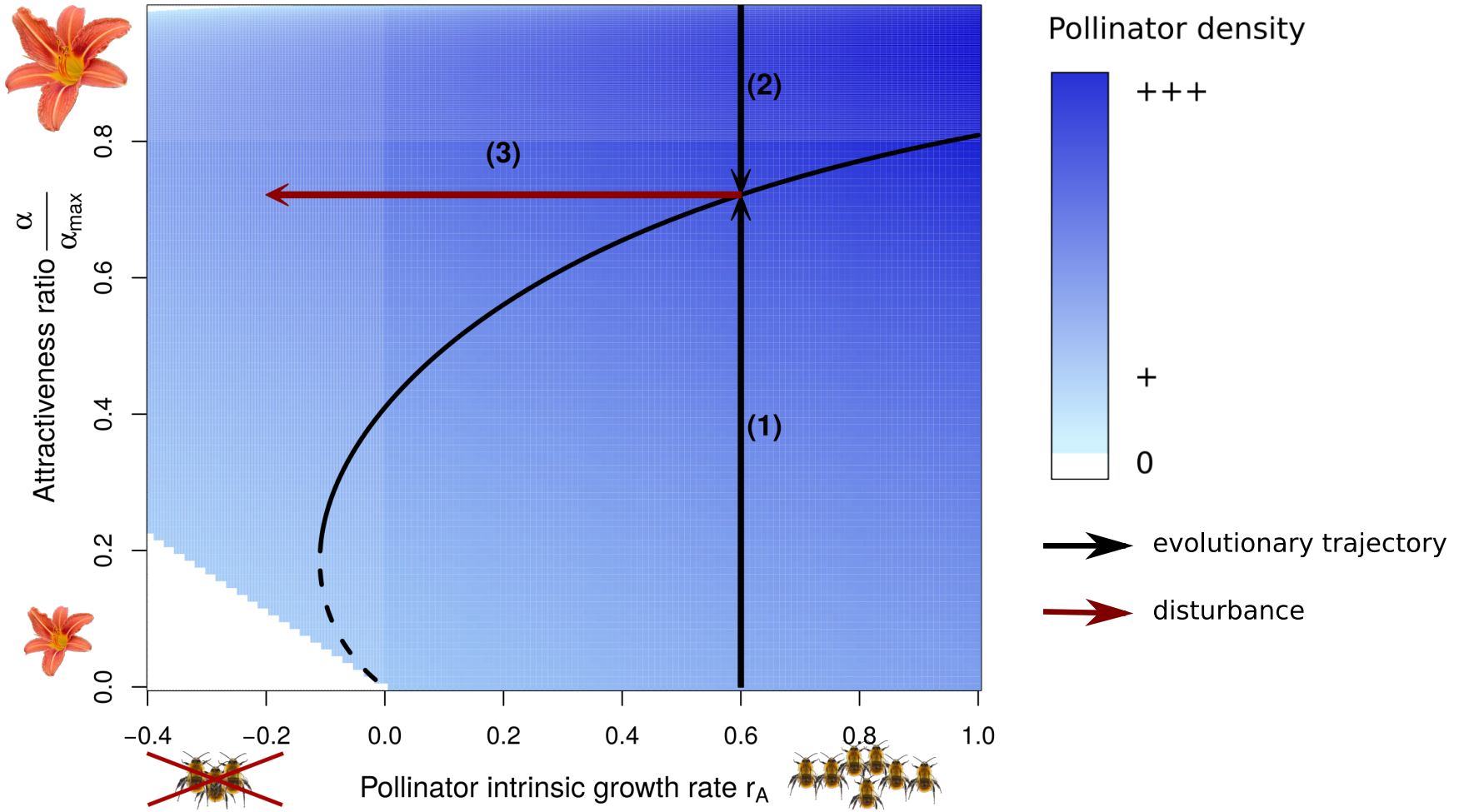

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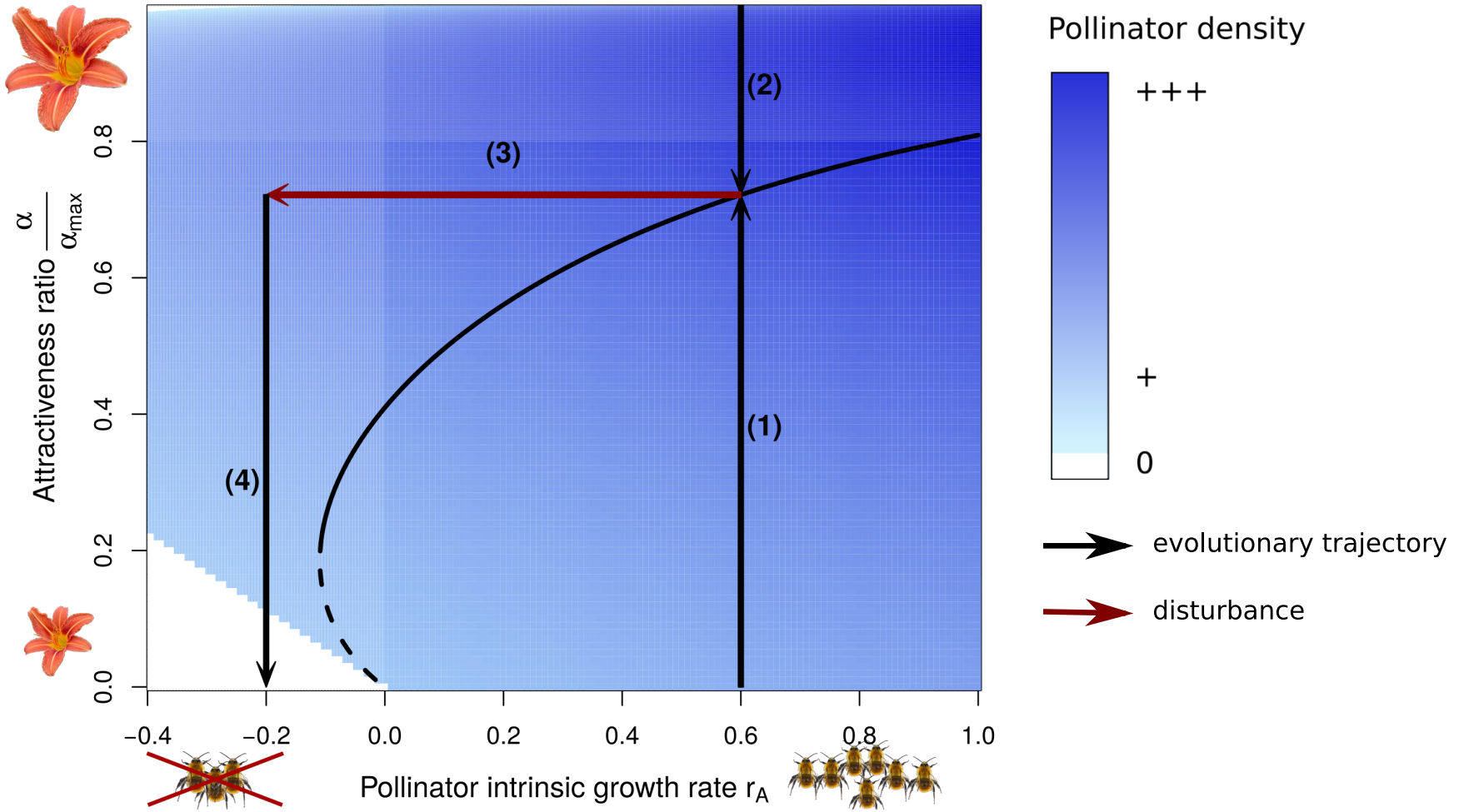

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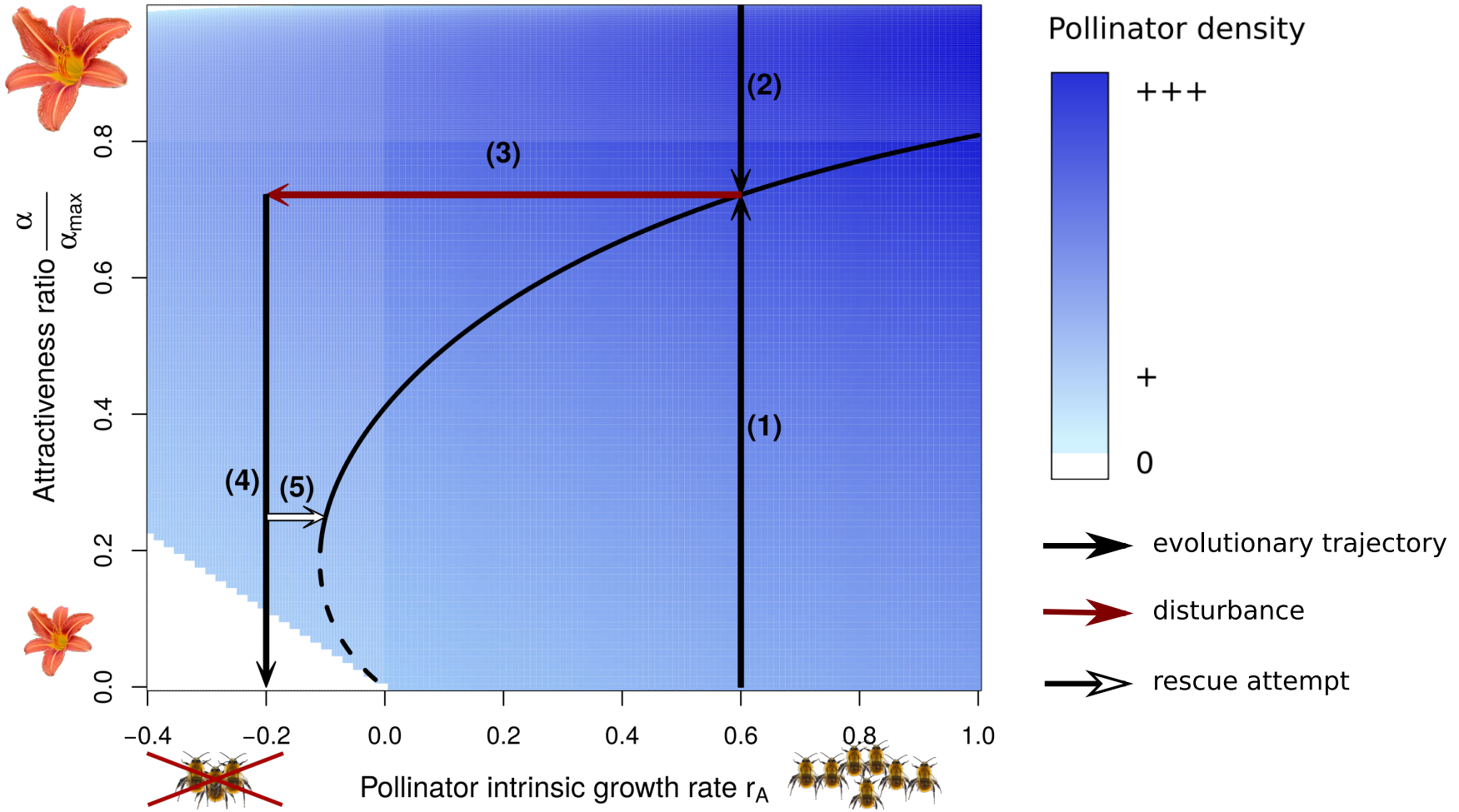

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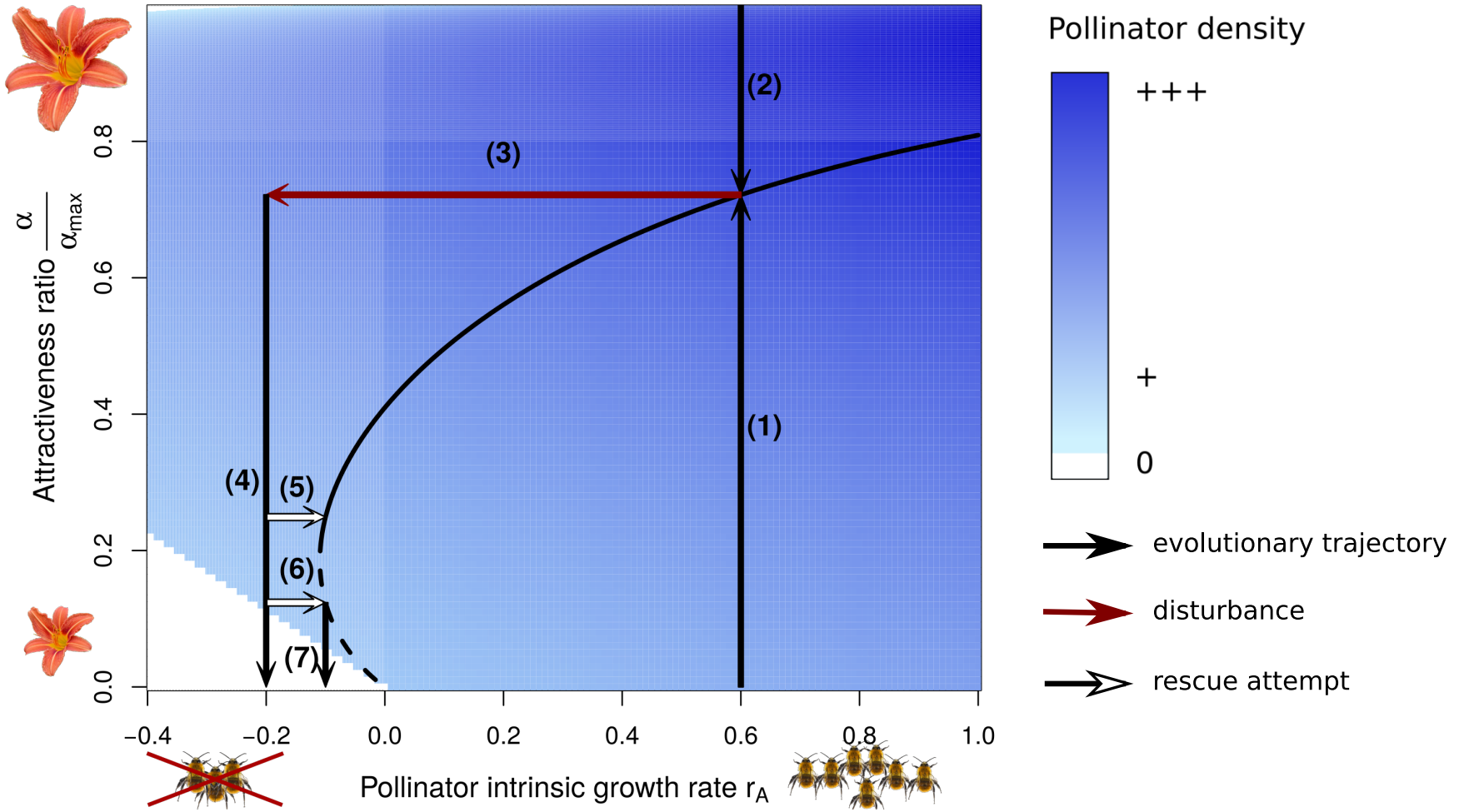
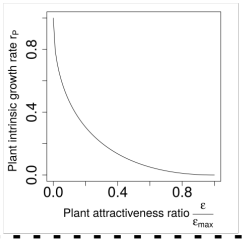
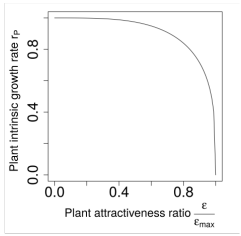


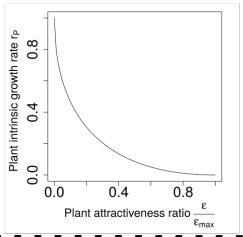


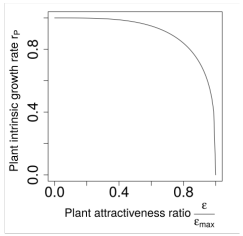


Attractiveness evolution

Eco-evolutionary dynamics

Impact of perturbations





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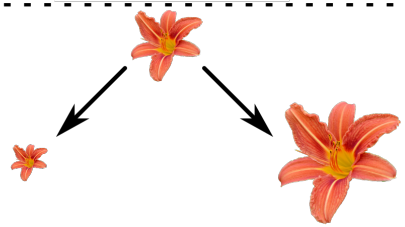

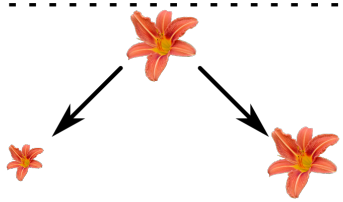

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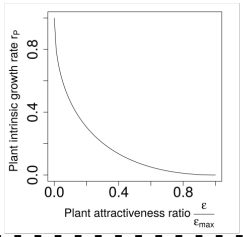

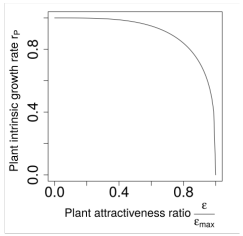

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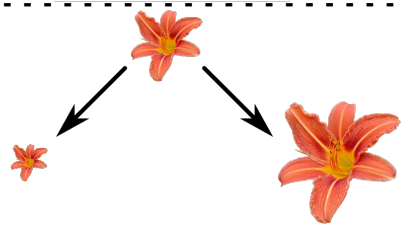
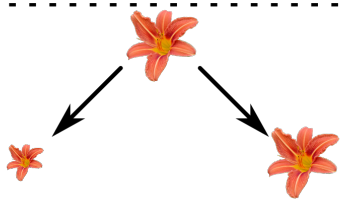
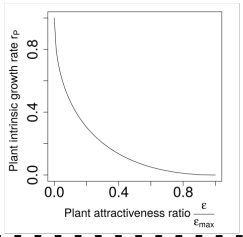


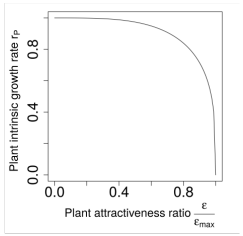


Eco-evolutionary dynamics

Evolutionary murder

Impact of perturbations





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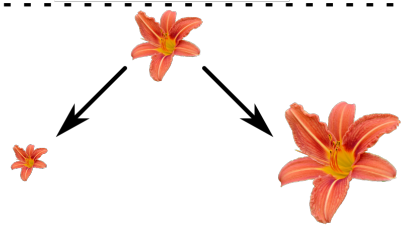

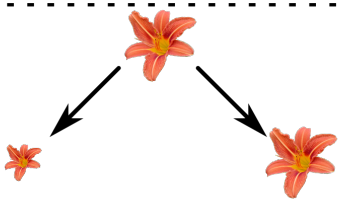

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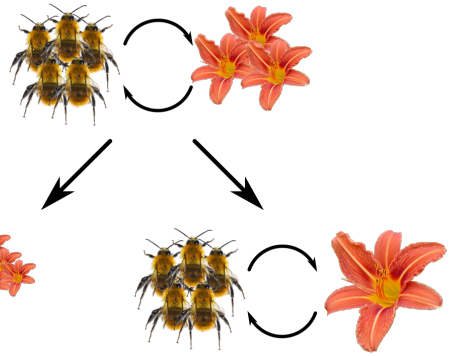
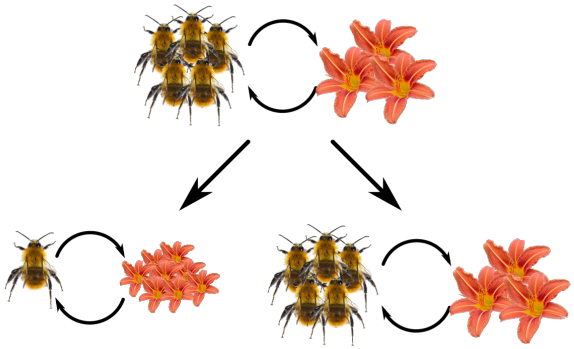
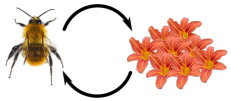




Evolutionary murder

Impact of perturbations



Restoration

Evolutionary murder

Early

Late

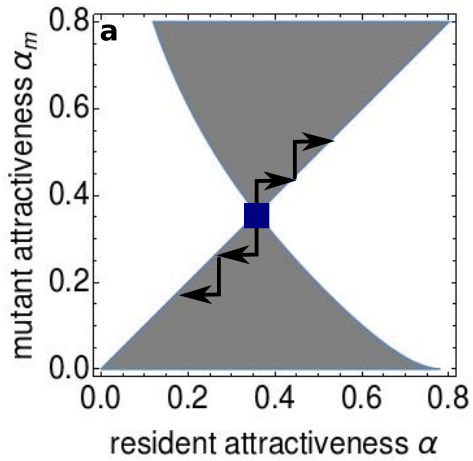
Evolutionary murder

Many thanks to:

R. Rohr and N. Loeuille for their guidance along this project,

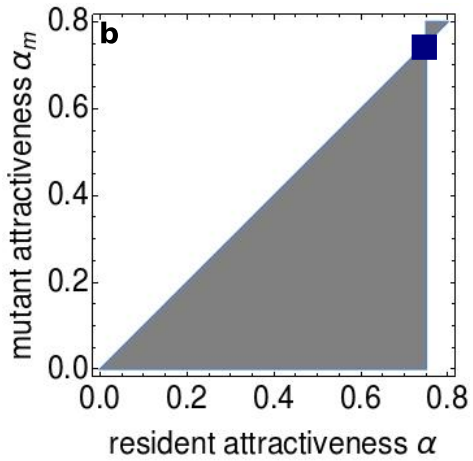
Everybody from the EERI team in Paris and the Ecology Department in Fribourg...

and you for your attention !



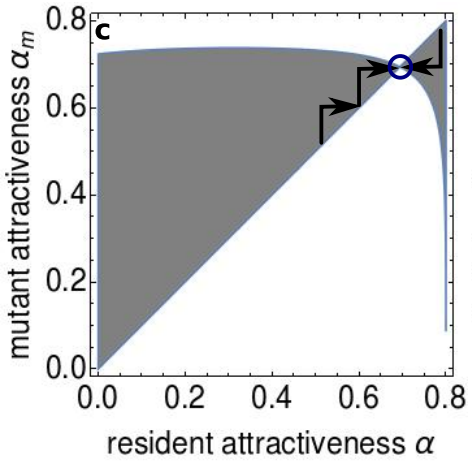
convexe trade-off (s = 0.5)

r_A = 0.5



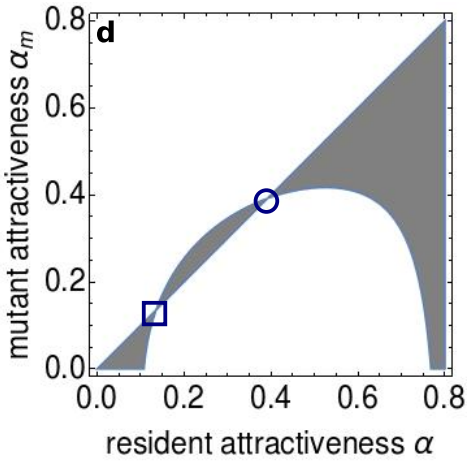
linear trade-off (s = 1)

r_A = 0.5



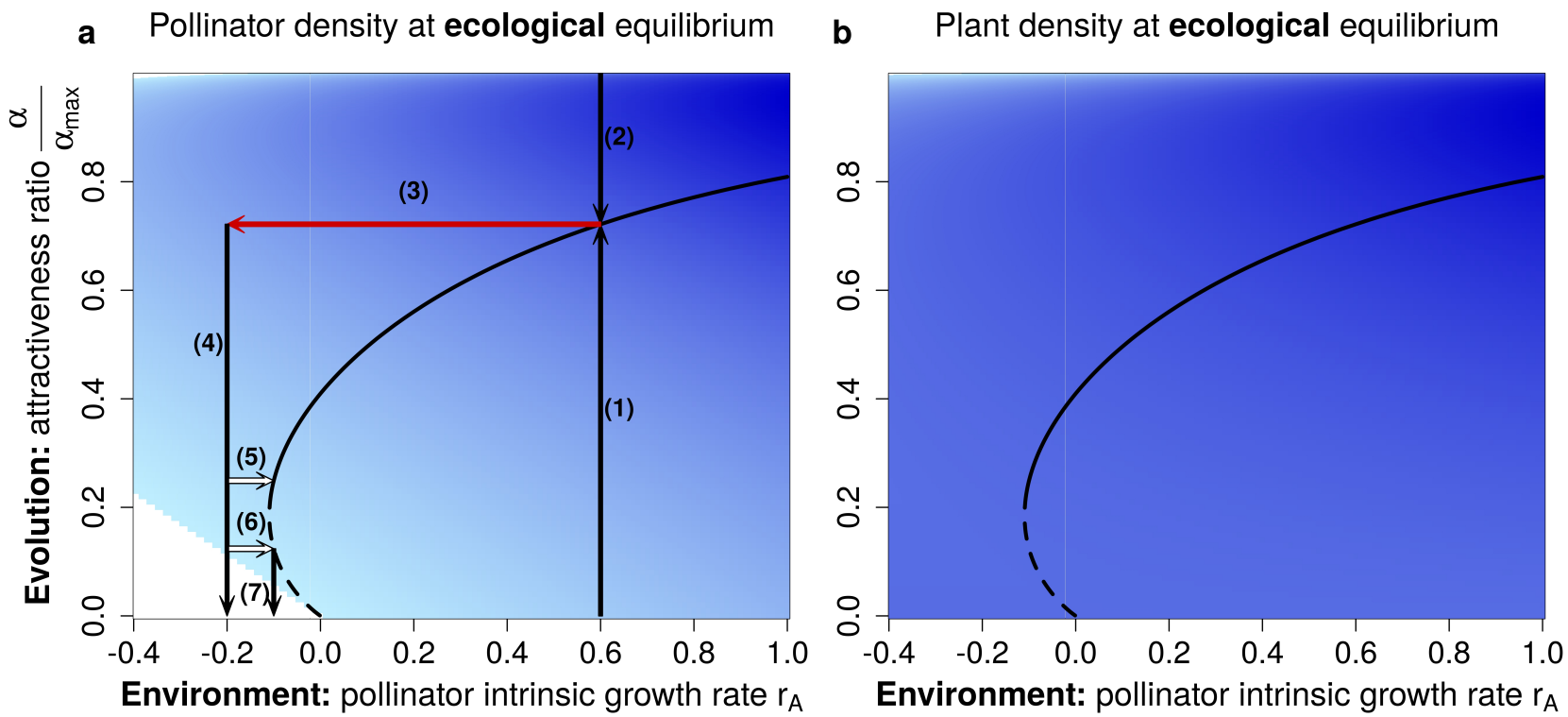
concave trade-off (s = 3)

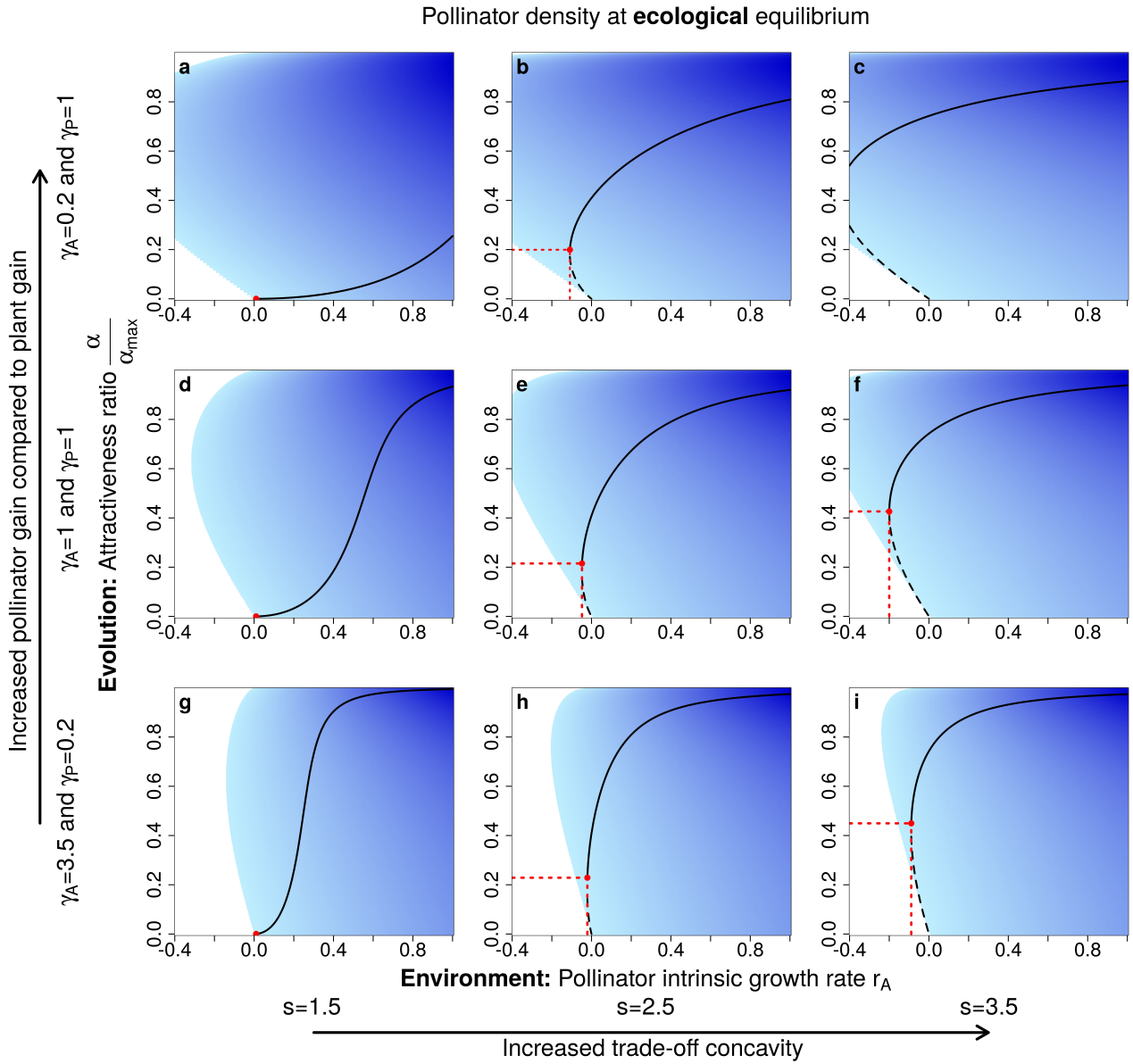
r_A = 0.5



concave trade-off (s = 3)

r_A = -0.1


a
Pollinator density at **ecological** equilibrium
b
Plant density at **ecological** equilibrium
Evolution: attractiveness ratio $\frac{\alpha}{\alpha_{max}}$
0.0
0.2
0.4
0.6
0.8
(1)
(2)
(3)
(4)
(5)
(6)
(7)
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Environment: pollinator intrinsic growth rate r_A


Pollinator density at **ecological** equilibrium
a
b
c
d
e
f
g
h
i
-0.4
0.0
0.4
0.8
0.0
0.2
0.4
0.6
0.8
Increased pollinator gain compared to plant gain
γA=0.2 and γP=1
γA=1 and γP=1
γA=3.5 and γP=0.2
Evolution: Attractiveness ratio α/αmax
Environment: Pollinator intrinsic growth rate rA
s=1.5
s=2.5
s=3.5
Increased trade-off concavity