Forward-time Individual-based Simulations in Ecology and Evolution

Module 7: Species interactions

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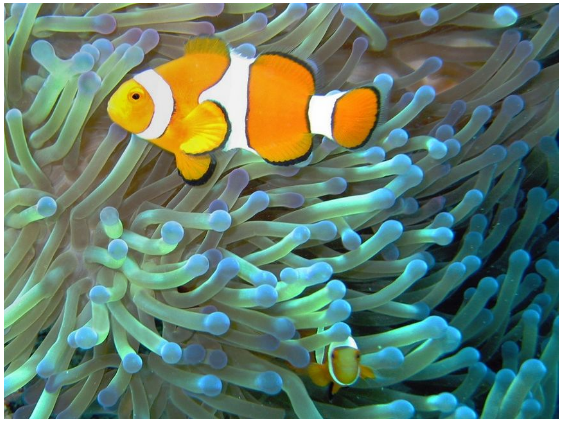
Ecological interactions

- predation
- parasitism
- facilitation
- competition
- …

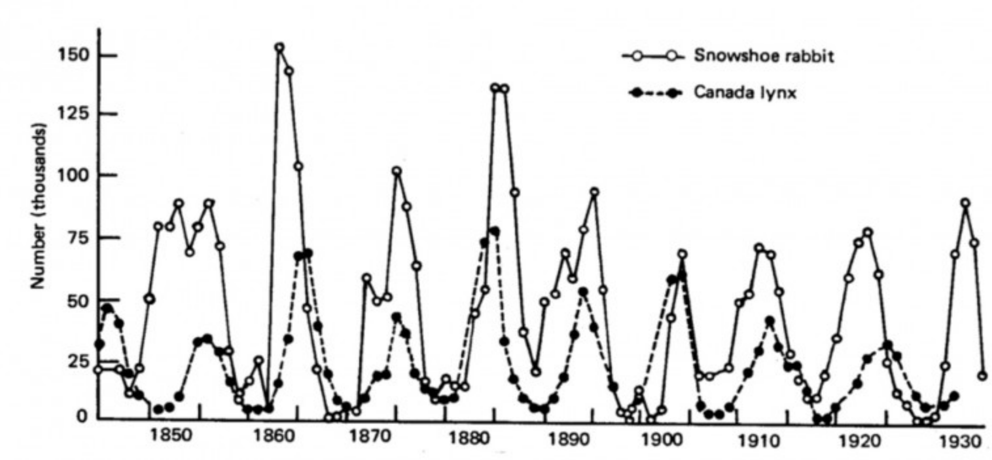


Ecological interactions

major consequences for reproduction, survival, and population dynamics

Ash dieback
(a chronic fungal disease of ash trees)

coupled population dynamics of Predator and Prey



Ecological interactions

… could shape the distribution of species,

and lead to the difference between *fundamental* and *realized* niche

For instance, the presence or absence of bark beetles
has major consequences for
the distribution of Norway spruce

Ecological interactions

… could drive evolution of

defense traits
(camouflage, spines in fish and plants, secondary metabolites, …)

attack traits
(mouth morphologies, “tools” like spider webs, etc)

co-evolution between species
(arms race, symbiotic traits)

Ecological interactions

→ In this lecture and the following exercise, we will deep-dive into the example of *competition for resources*

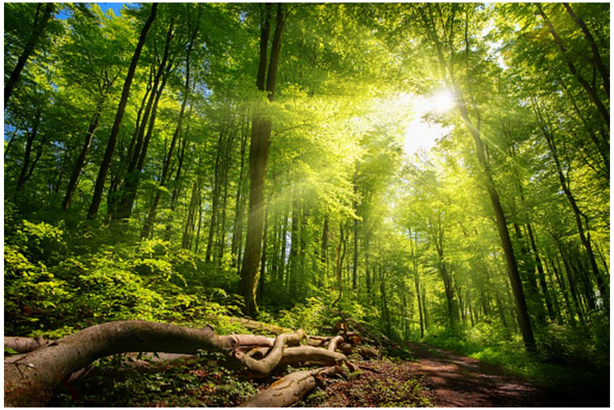
→ more precisely, we explore ***exploitation competition*** :

„when some quantity of resource (e.g., food, water,a nutrient) is consumed by an individual, thereby depriving other individuals of it"

→ instead we do not focus on *interference competition* :

"an individual aggressively defends, [...], a unit of space against other individuals"

Schoener (1983). AmNat 122: 240-285

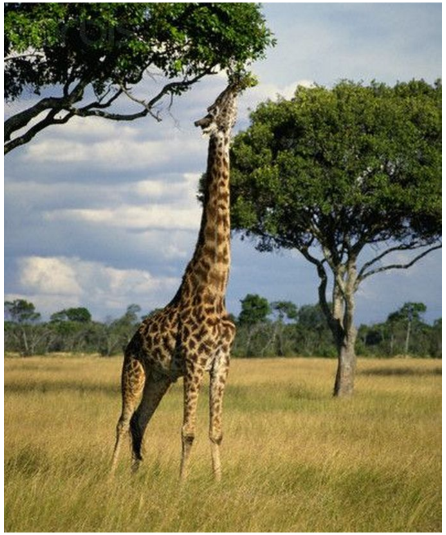


Resource competition

Resource consumption is *key* for all living organisms.

Resource competition

consumption varies with so called *consumer traits*



Resource competition

properties of resources drive consumer trait evolution

Darwin's orchid
(*Angraecum sesquipedale*)

→ the spur of the flower is 20–35 cm

Darwin wrote in a letter:

„*Good Heavens what insect can suck it?*"

Resource competition

properties of resources drive consumer trait evolution

Darwin's orchid
(*Angraecum sesquipedale*)

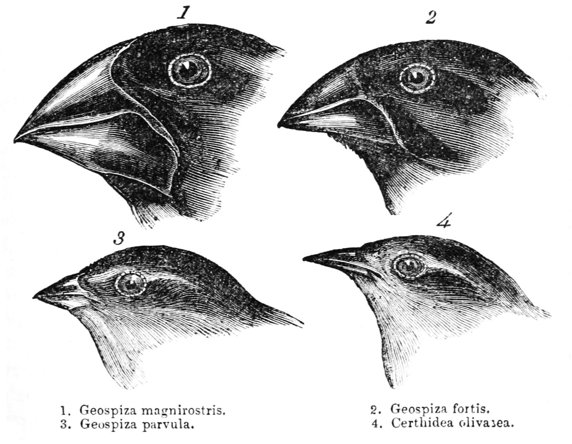
→ the spur of the flower
is 20–35 cm

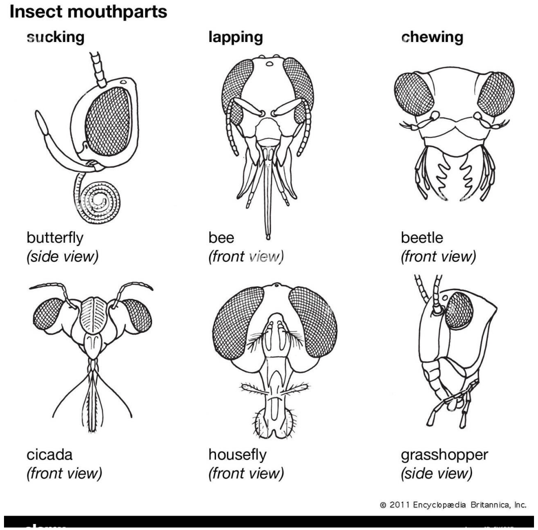
Morgan's sphinx moth
(*Macrosila morganii*)

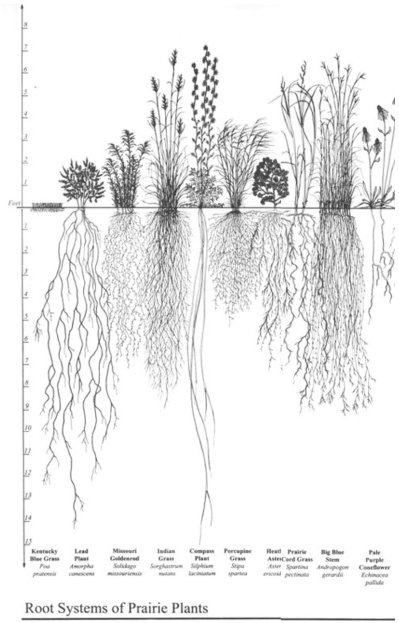
Diversity in resources

Diversity in resources

→ can lead to diversity in consumers



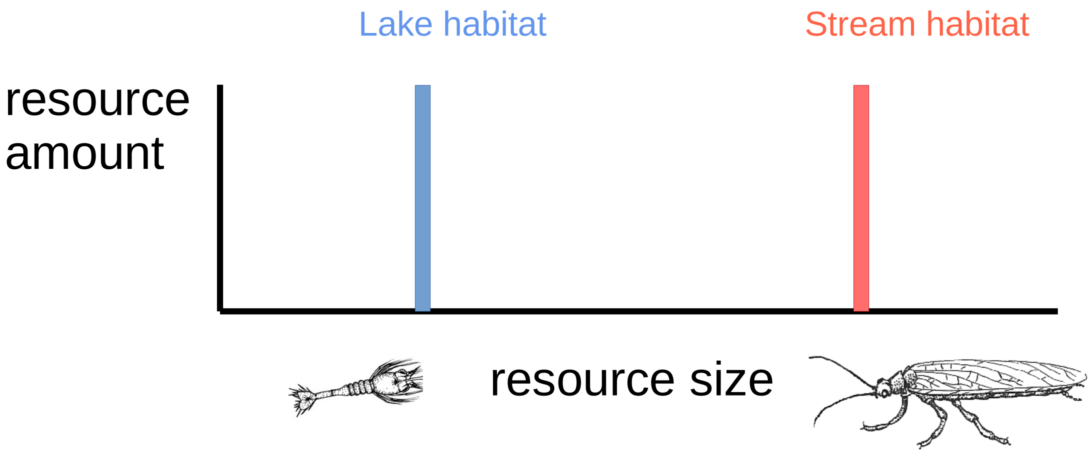




Skúlason & Smith (1995). TREE
Skúlason et al. (2019). Biological Reviews

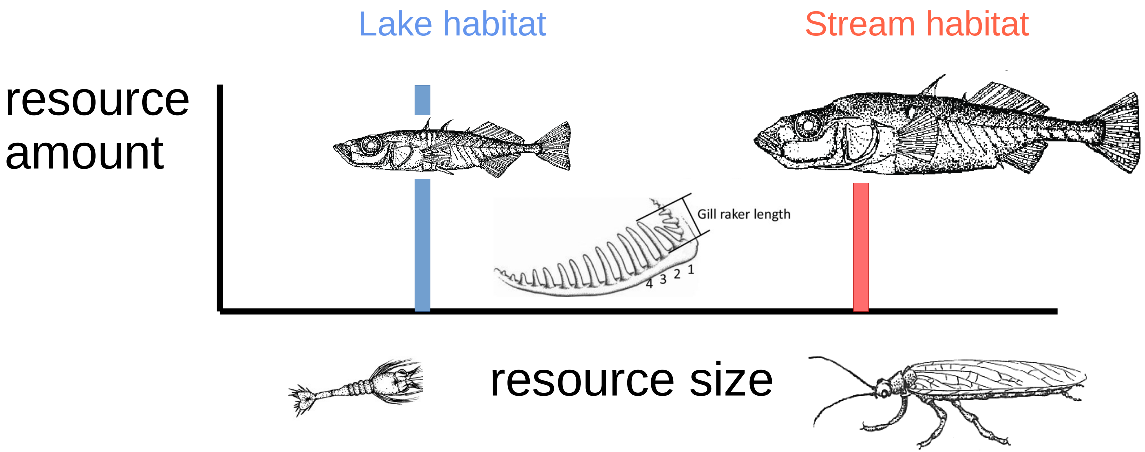
Diversity in resources

a) _spatial_ resource variation



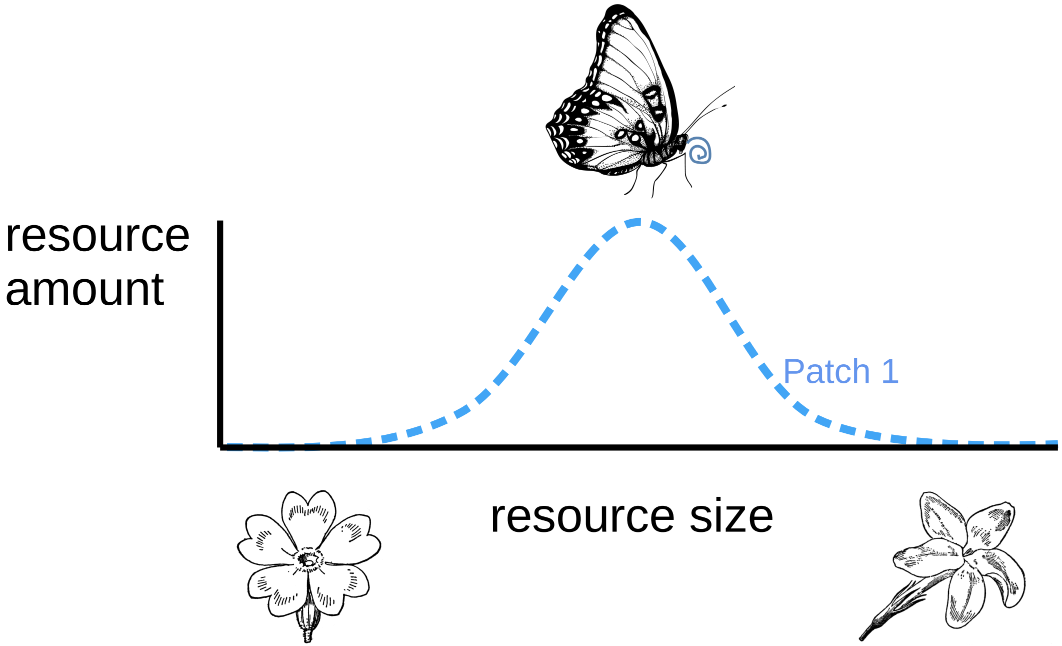
Diversity in resources

a) *spatial* resource variation → divergent selection
→ spatial consumer diversity (local adaptation)



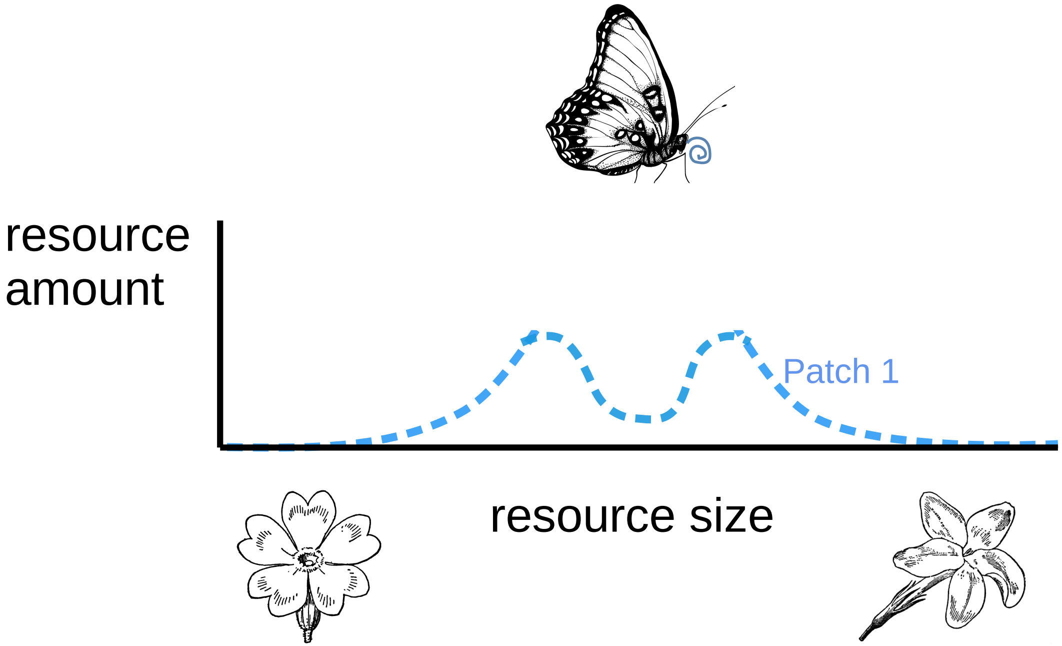
Diversity in resources

b) *local* resource variation



Diversity in resources

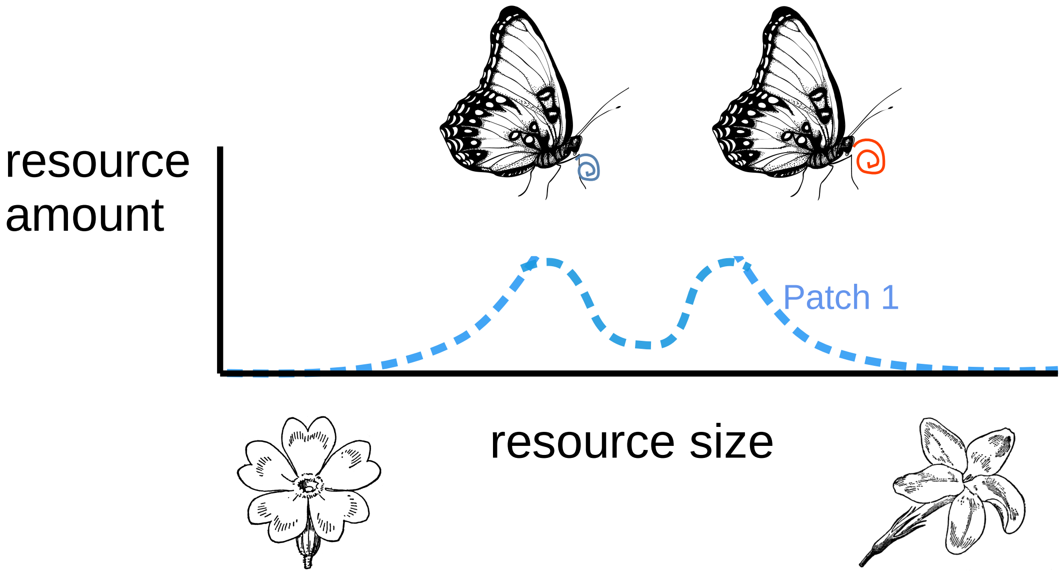
b) *<u>local</u>* resource variation & competition



Diversity in resources

b) *local* resource variation & competition → frequency-dependent selection

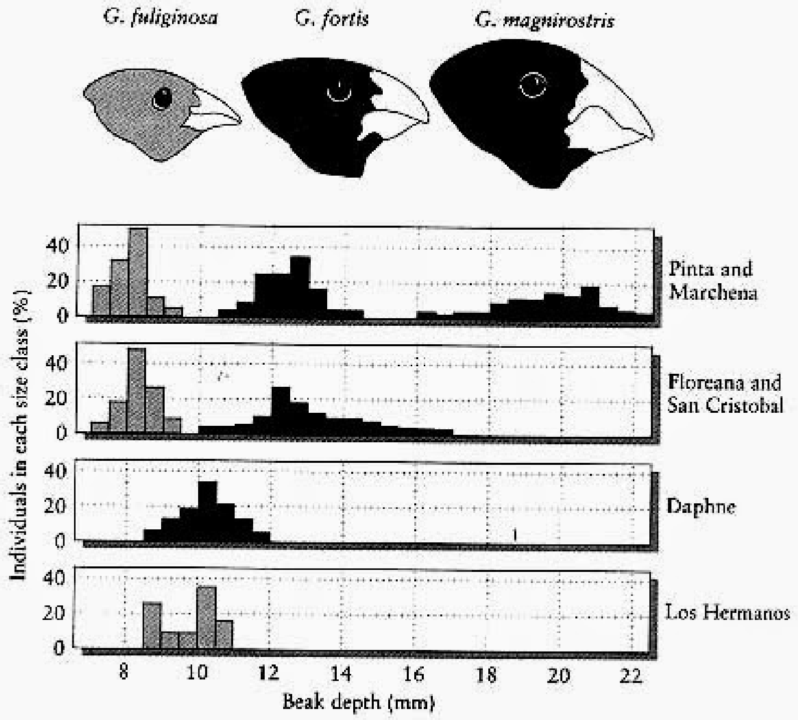
→ local polymorphism



Character displacement

„when two species of animals overlap geographically, their differences are accentuated in the zone of sympatry and weakened or lost entirely […] outside this zone“

(Brown & Wilson 1956 Syst. Zool. 5: 49–64)



Ricklefs' (1996) Economy of Nature.

Character displacement

„when two species of animals overlap geographically, their differences are accentuated in the zone of sympatry and weakened or lost entirely […] outside this zone"

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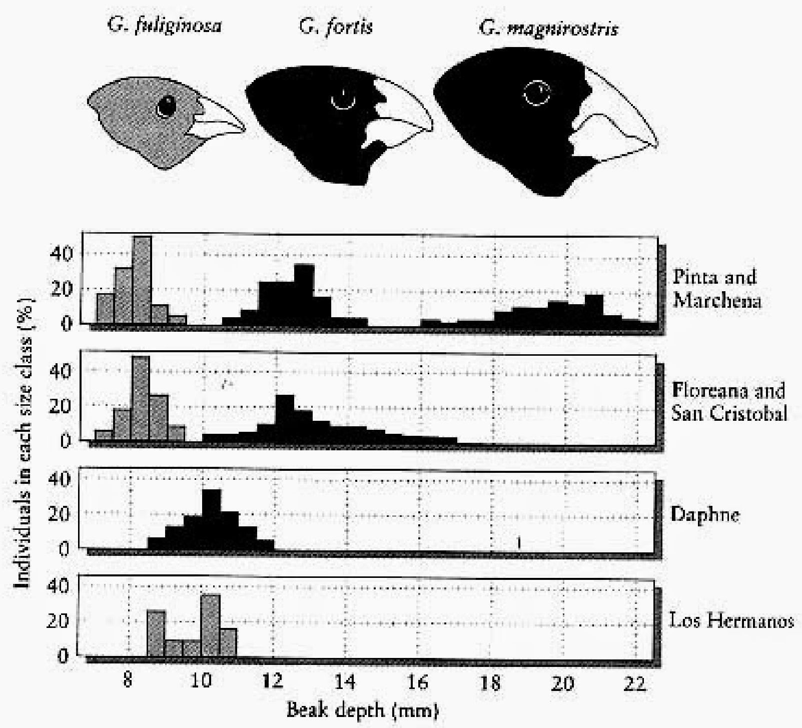
„at the heart of the debate regarding the role of competition in structuring ecological communities"

(Dayan & Simberloff 2005, Ecology Letters 8: 875-894)



Ricklefs' (1996) Economy of Nature.

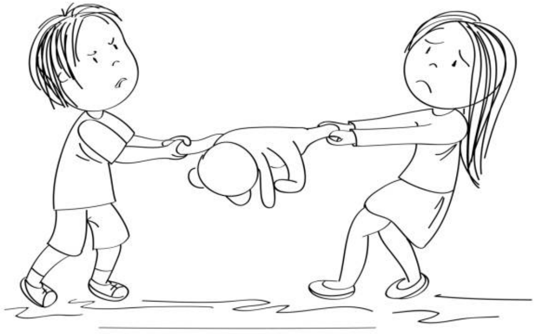
Kin competition

= competition between related individuals (kin)

It matters with whom you are competing !

because kin share:

- similar genotypes and consumer traits
- habitat *(at limited dispersal)*
- *the same resource preferences*



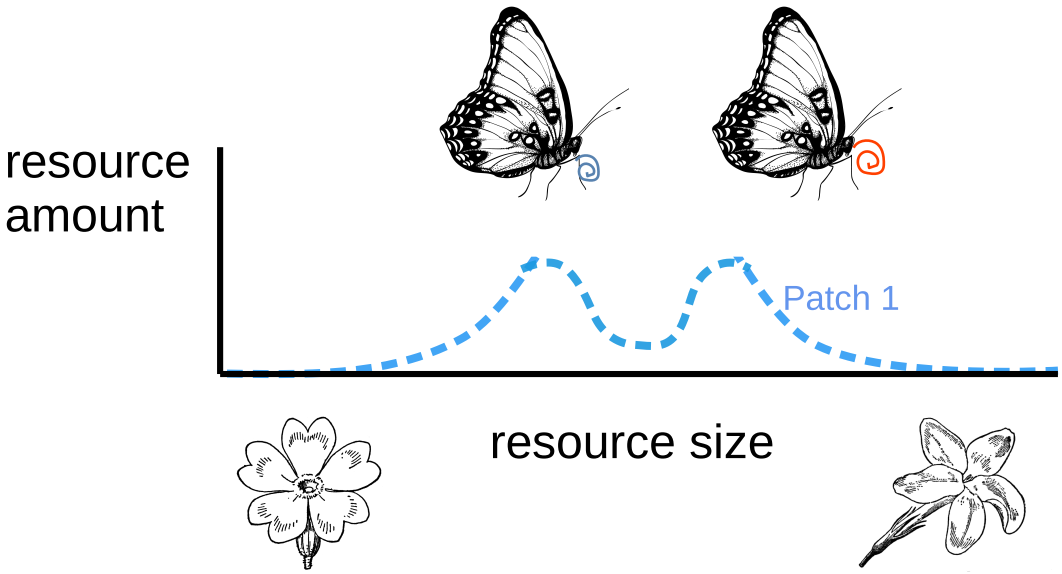
→ *Kin competition can* act against the evolution of diversity in consumers

Exercise

Exercise: When does diversity in consumers evolve ?

Touching some aspects of
Schmid, Rueffler, Lehmann, Mullon (2022), bioRxiv

Exercise: When does diversity in consumers evolve ?



How do we model exploitation competition ?

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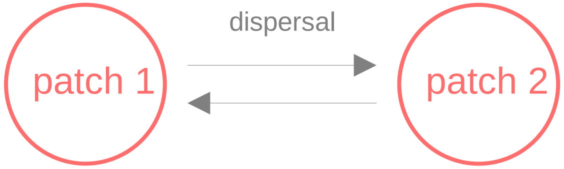


Resource distribution:

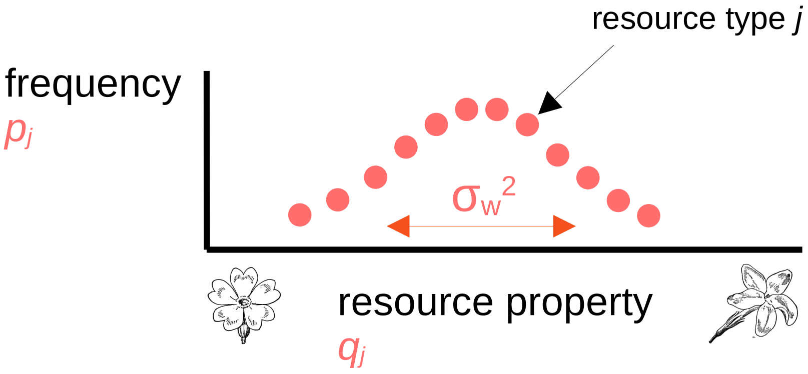
discrete resource types (e.g., different seed types).

Each resource type has
- certain property (q_j)
- specific frequency (p_j)

Each patch can harbor a range of resource types
- within-patch variation ($\sigma_w^2 = \sum p_i(q_j - avg(q))^2$)

→ resources fully re-grow at the beginning of each season

→ distribution is constant over the years



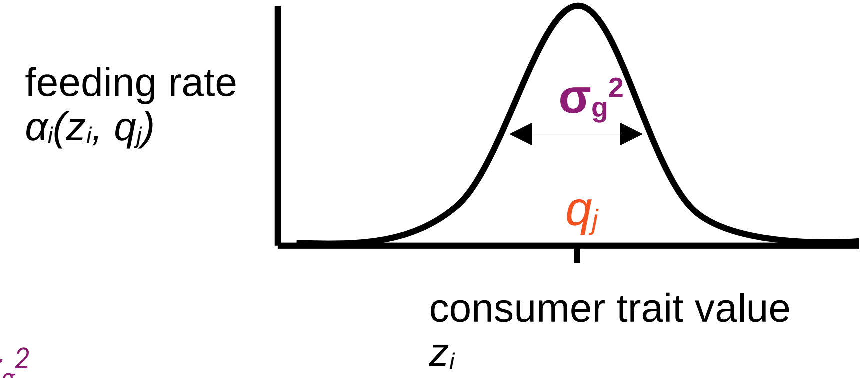
How do we model exploitation competition ?

Resource exploitation:

controlled by a single consumer trait (e.g., beak morphology)

feeding rate $\alpha_i(z_i, q_j)$ on each resource type j is

$$\alpha_i(z_i, q_j) \;=\; Exp\left(-\frac{(z_i - q_j)^2}{2\sigma_g^2}\right)$$



variance of Gaussian reflects resource generalism σ_g^2

How do we model exploitation competition ?

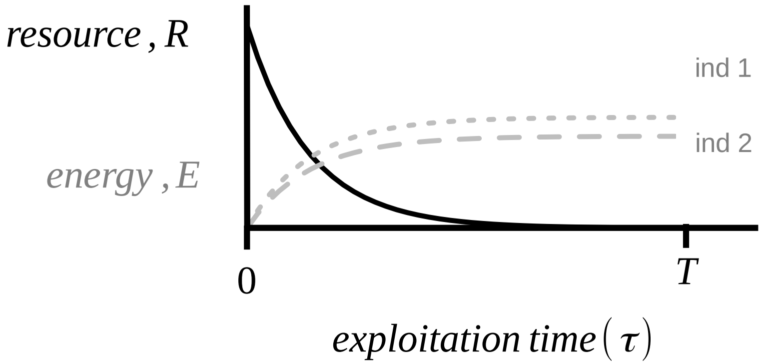
Consumer-Resource dynamics within season:

1) decline in resource amount within growing season

$$\frac{dR_j}{dT} \;=\; -\,R_j(\tau)\left(\sum_{k=1}^{n}\alpha(z_k, q_j)\right) \qquad (1)$$

2) energy uptake by each consumer individual *i*

$$\frac{dE_{j,i}}{dT} \;=\; R_j(\tau)\alpha(z_i, q_j) \qquad (2)$$



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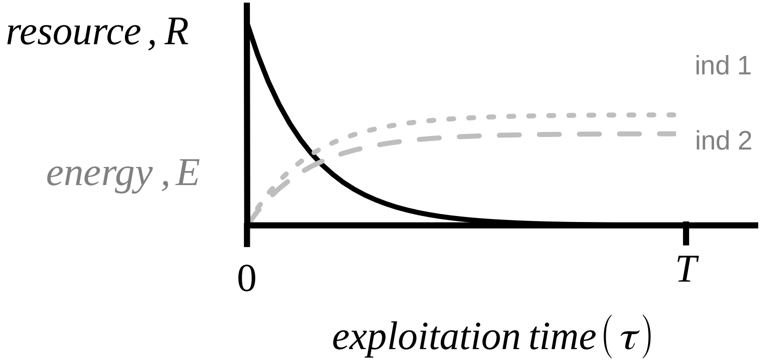

the more resources → the more energy → the larger ***fecundity***

How do we model exploitation competition ?

After solving eq. (1) and (2), we get individual fecundity

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1) at long exploitation time (T → ∞):

$$f_i = f_{max} \sum_j p_j \frac{\alpha_i(z_i, q_j)}{\sum_{k=1}^{n} \alpha_k(z_k, q_j)}$$

→ exploitation of all resources
→ *intense* exploitation competition

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→ exploitation of all resources
→ *intense* exploitation competition

2) at short exploitation time (T → 0):

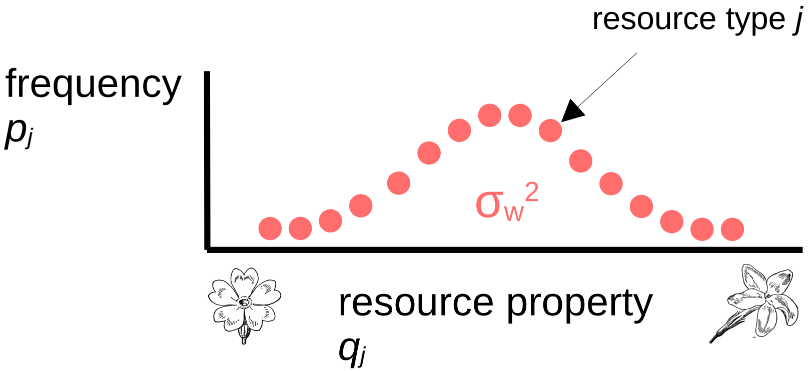
$$f_i = f_{max} \sum_j p_j \alpha_i(z_i, q_j)$$

→ resources never get scarce
→ *no* exploitation competition

When does diversity in consumers evolve ?

1) resource variation

→ σ_w^2



2) competition scenario

a) exploitation competition

$$f_i = f_{max} \sum_j p_j \frac{\alpha_i(z_i, q_j)}{\sum_{k=1}^{n} \alpha_k(z_k, q_j)}$$

b) <u>no</u> exploitation competition

$$f_i = f_{max} \sum_j p_j \alpha_i(z_i, q_j)$$

3) resource generalism

→ σ_g^2

When does diversity in consumers evolve ?

1. Read exercise file (*Exercise_Resource_competition.pdf*)
2. copy new nemo-age version into your bin-folder (*nemoage0.32.1*)
3. run the ini-file with new nemo-age (*Exercise_Resource_competition.ini*)
4. use the R script to plot (*Exercise_Resource_competition.R*)
5. explore the exercises