Predator-Prey Interactions

Today's Agenda:

- Quiz
- Predator-Prey Interactions

Predation

We’re going to start by focusing on one-predator, one-prey

(note this is relatively rare in nature)

Predation

One way of quantifying predation is with the feedinging rate

Feeding rate = # prey eaten per unit time

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Feeding rate = # prey eaten per unit time

We might imagine this as something like:

Feeding rate = aN

a = attack rate

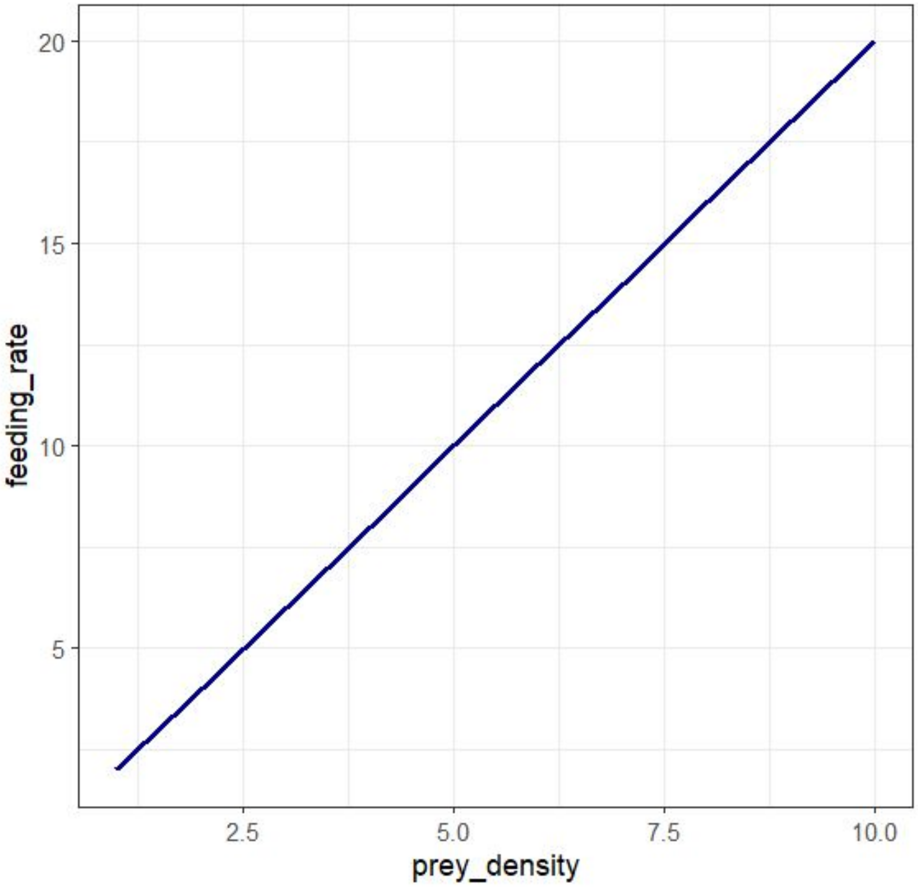
N= # prey

Type I functional response

Feeding rate = aN

a = attack rate

N= # prey



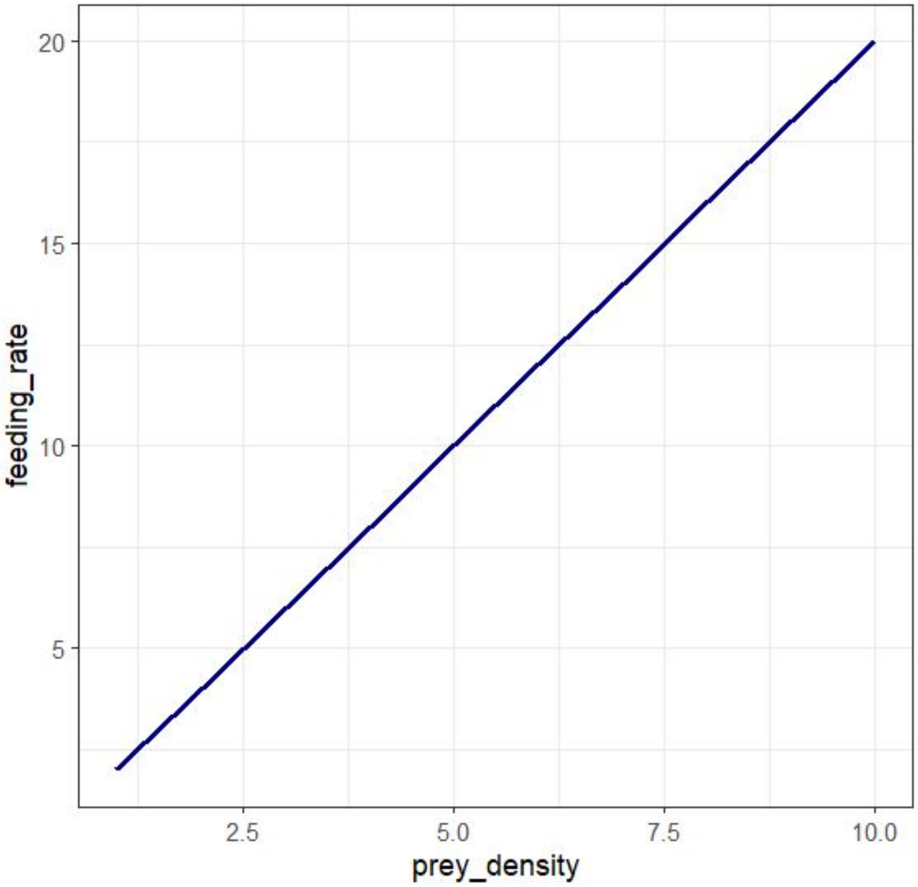
Type I functional response

Feeding rate = aN

a = attack rate

N= # prey

Not realistic in most scenarios!



Type II Functional Response

Predators can only eat so quickly!

aN

Feeding rate =

a = attack rate

N = # prey

Type II Functional Response

Predators can only eat so quickly!

$$\textbf{Feeding rate} = \frac{aN}{1 + ahN}$$

a = attack rate

N = # prey

h = handling time

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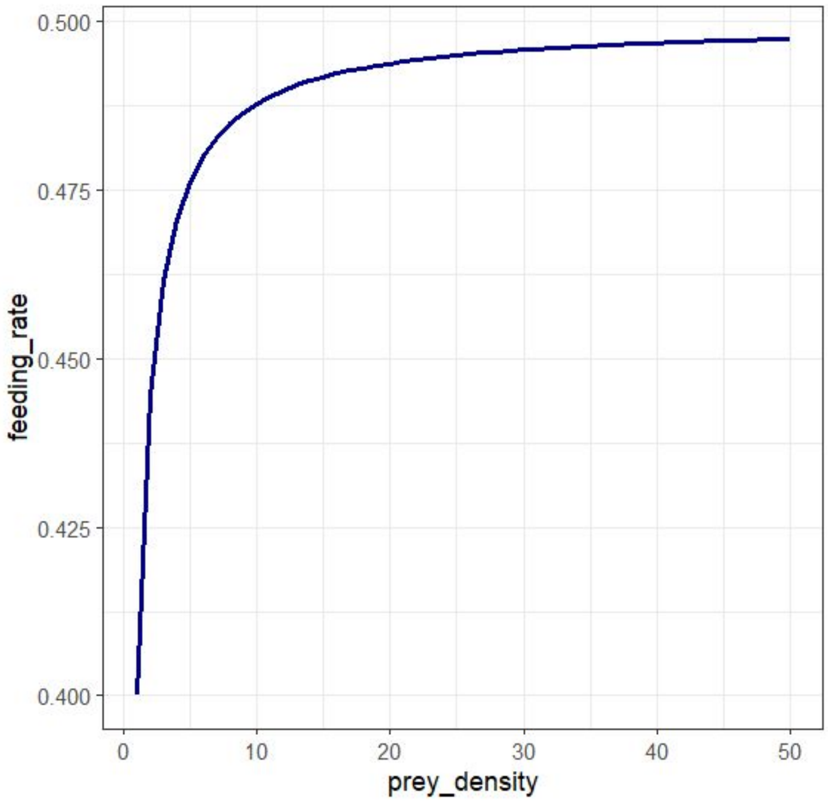

Type II Functional Response

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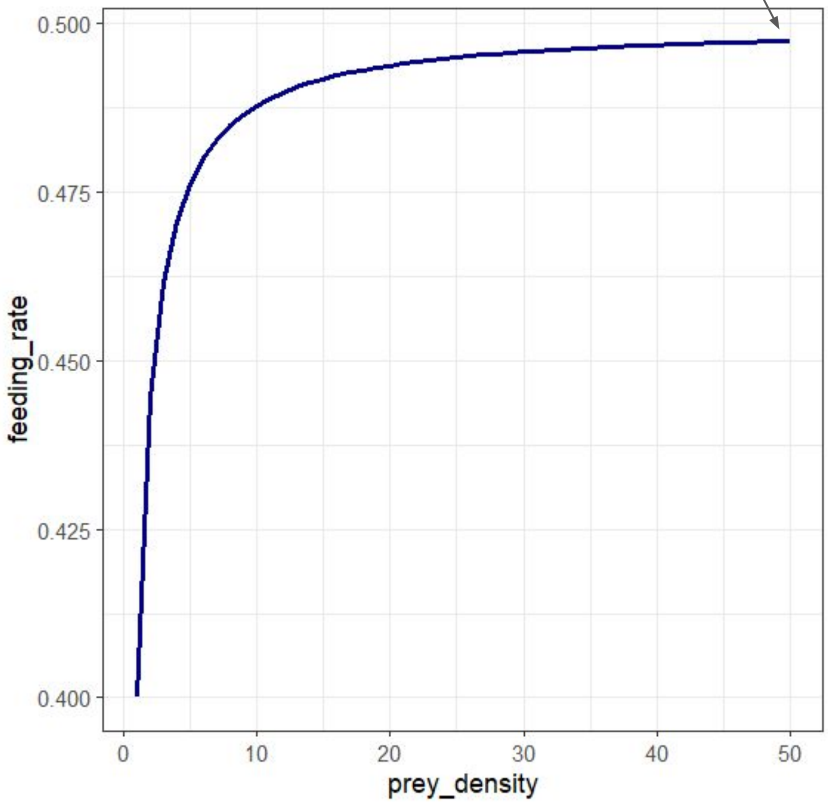
a = attack rate

N = # prey

h = handling time

Maximum feeding rate is 1/h



Type III Functional Response

… but what if predators ignore prey at low densities?

$$\textbf{Feeding rate} = \frac{cN^2}{d^2 + N^2}$$

N = # prey

c = 1/handling time = max. feeding rate

d = 1/attack rate * handling time

Type III Functional Response

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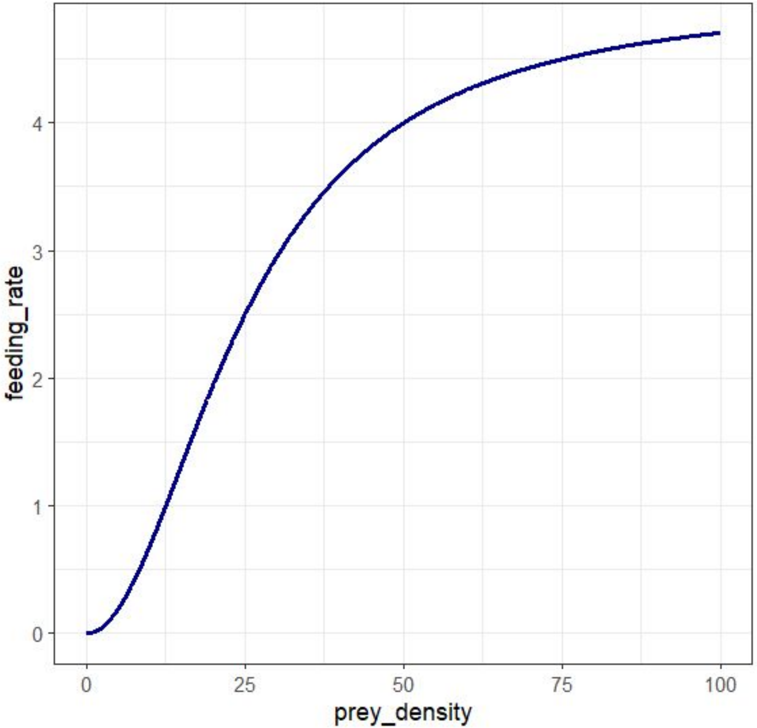

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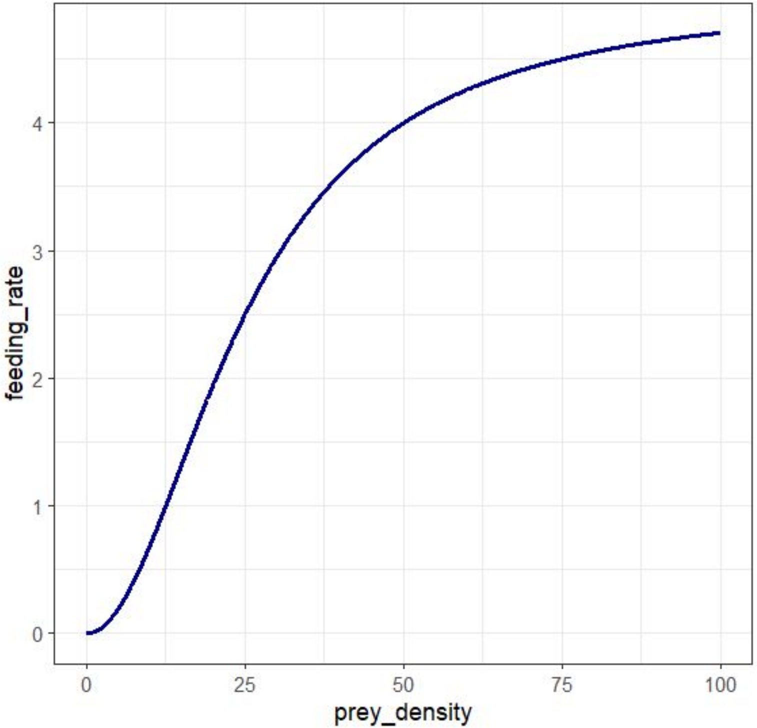

Lotka-Volterra

We’ve covered different ways that prey density impacts consumption rate

BUT we haven’t yet talked about how the populations are impacted by this

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Lotka-Volterra model is a simple model of predation

- Good starting point

Lotka-Volterra

$dN/dt = rN - aNP$

N = number prey

P = number of predator

r = prey per-capita growth rate

a= predator per-capita attack rate

Lotka-Volterra

dN/dt = rN − aNP

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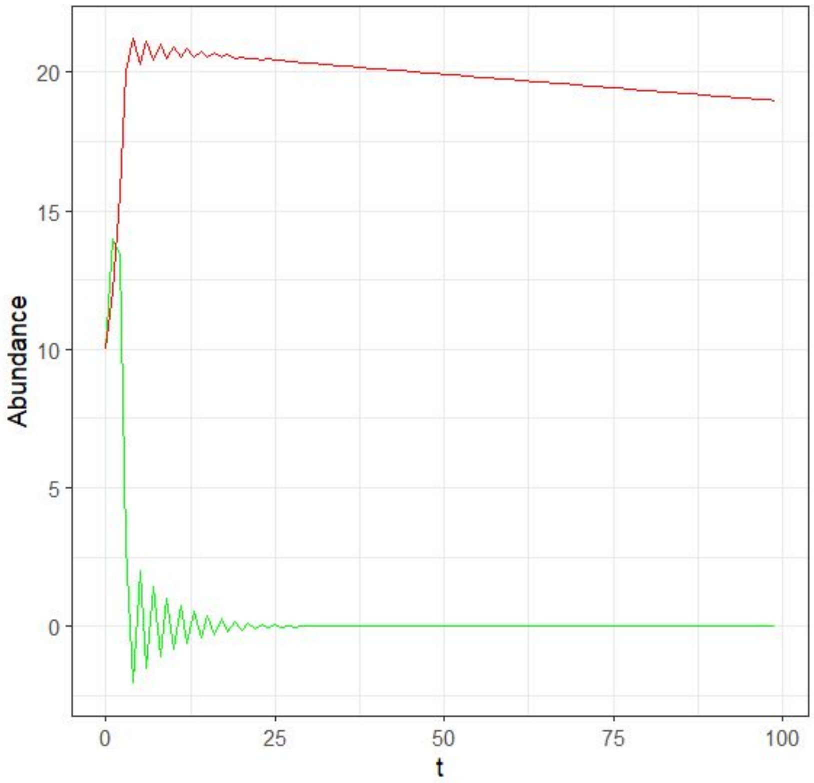
dP/dt = faNP - qP

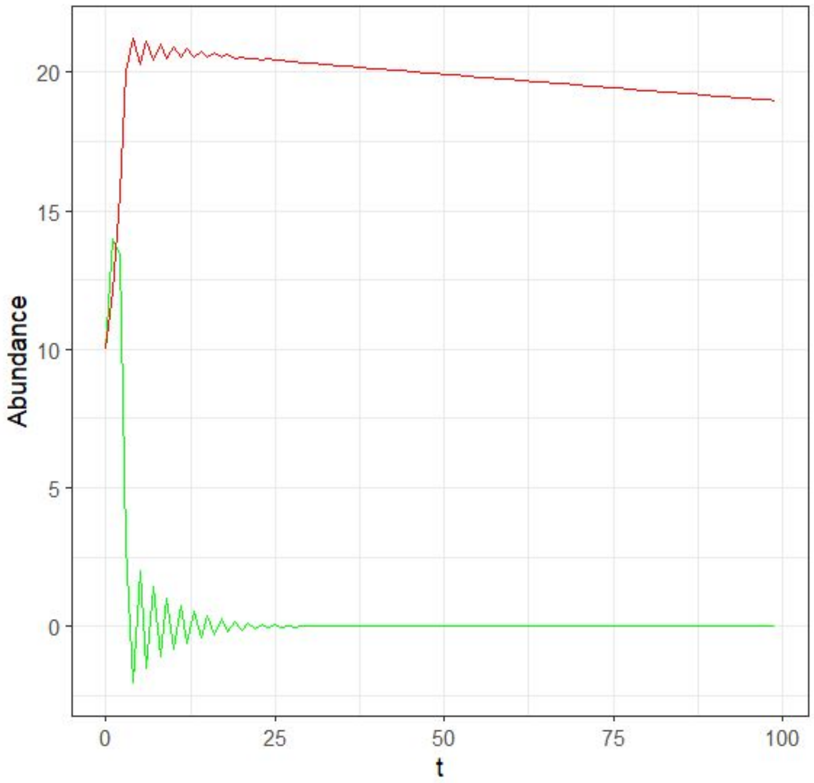
f = predator efficiency of converting prey to more predators

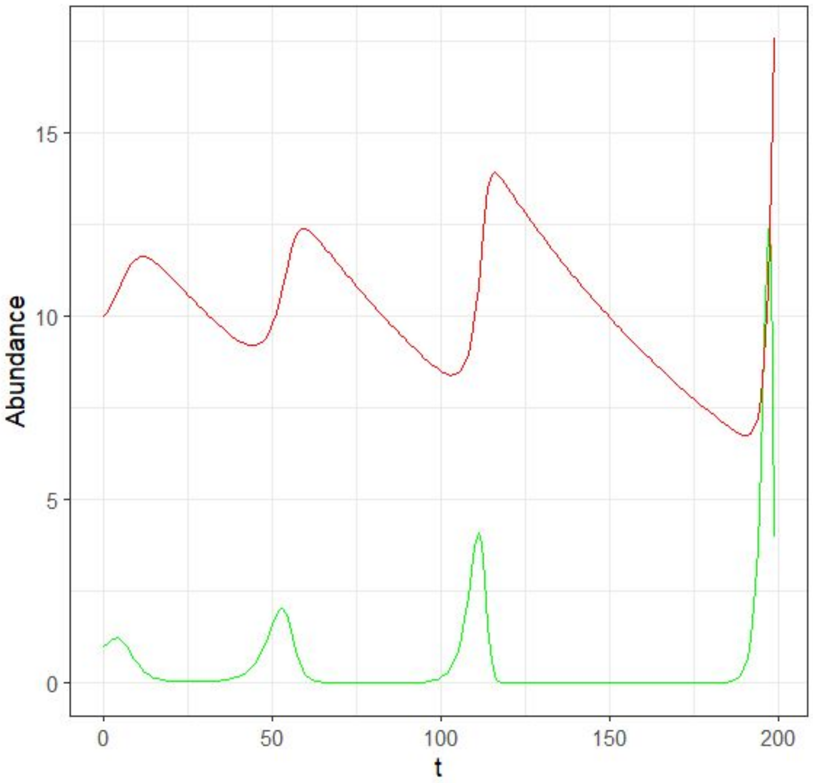
q = predator per-capita mortality

Lotka-Volterra



Lotka-Volterra





Lotka-Volterra

Oscillations of predator and prey

- Oscillations can increase or decrease over time
- Can also have stable oscillations
- Can easily get one species going to (or below) zero

Lotka-Volterra

Very basic model

- Ignores self-limitation by prey or predator
- Type I functional response

Lotka-Volterra

Very basic model

- Ignores self-limitation by prey or predator
- Type I functional response

Can modify by

- adding in prey density dependence
- Using a Type II predator response

Rosenzweig-MacArthur

$dN/dt = rN(1 - (N/k)) - aNP$

N = number prey

P = number of predator

r = prey per-capita growth rate

a= predator per-capita attack rate

k= carrying capacity

$$dP/dt = \frac{faNP}{1 + ahN} - qP$$

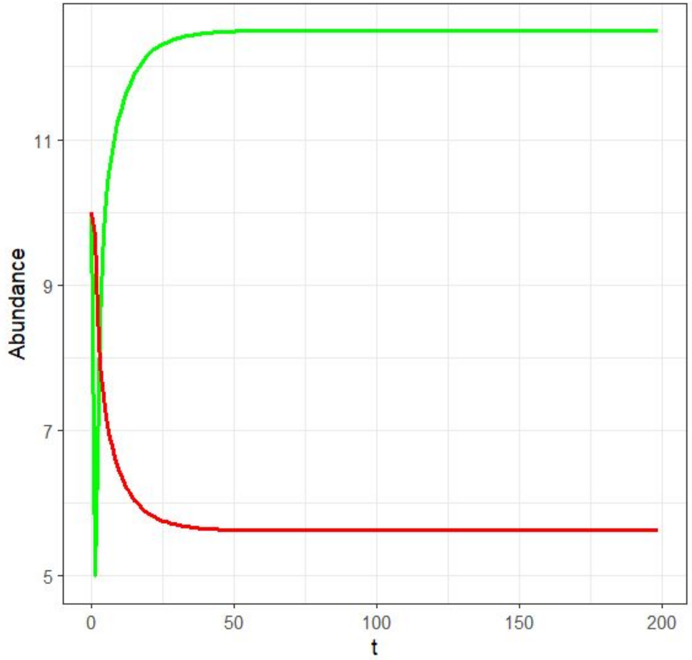
f = predator efficiency of converting prey to more predators

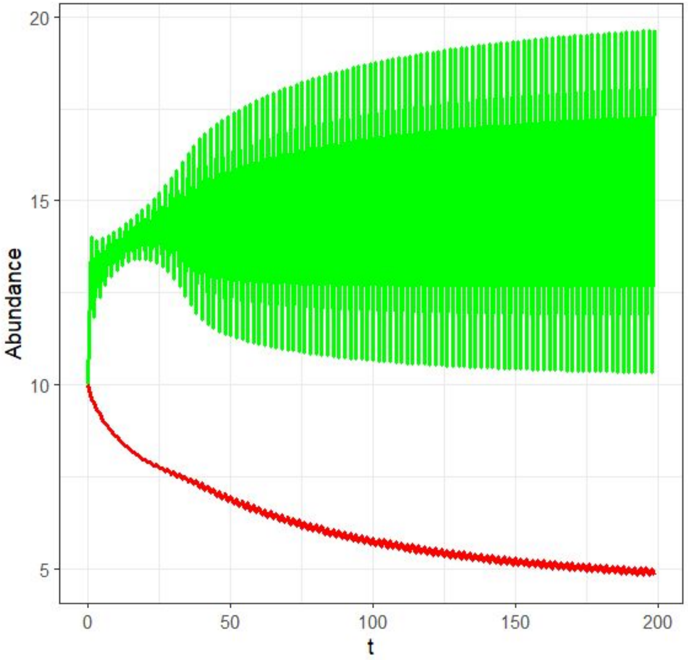
q = predator per-capita mortality

h = handling time

Rosenzweig-MacArthur

$$dN/dt = rN(1 - (N/k)) - aNP \qquad dP/dt = \frac{faNP}{1 + ahN} - qP$$





Rosenzweig-MacArthur

$$dN/dt = rN(1 - (N/k)) - aNP \qquad dP/dt = \frac{faNP}{1 + ahN} - qP$$

By adding in a bit more realism, coexistence is easier

Other modifications to Lotka-Volterra

LV is based on predator-prey interactions, but can be modified!

Herbivory

- Whole individuals aren’t eaten
- Model is re-framed in terms of biomass rather than individuals

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Disease

- Model can likewise be modified to focus on disease
- Alternatively, it can handle disease AND e.g., predation, herbivory

Multiple Prey

We’ve been assuming 1 predator, 1 prey systems.

What happens when you have multiple prey?

Optimal Foraging Theory

Predators often have options!

What are some of the reasons why predators might select different prey?

Optimal Foraging Theory

Predators often have options!

What are some of the reasons why predators might select different prey?

- Availability
- Energy content
- Safety
- Time (to catch, eat, etc.)

Optimal Diet Model

$$\frac{E}{T} = \frac{\Sigma_i^k \lambda_i E_i p_i}{1 + \Sigma_i^k \lambda_i h_i p_i}$$

E/T = energy gained per unit time

λ_i = # prey species *i* encountered per unit time

E_i = energy gain from prey species *i*

p_i = probability of pursuit, capture of species *i*

h_i = handling time of prey species *i*

Optimal Diet Model

$$\frac{E}{T} = \frac{\Sigma_i^k \lambda_i E_i p_i}{1 + \Sigma_i^k \lambda_i h_i p_i}$$

Handling time slows things down, so prey with high h values should only be eaten in they have a high E value

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Optimal Diet Model

$$\frac{E}{T} = \frac{\Sigma_i^k \lambda_i E_i p_i}{1 + \Sigma_i^k \lambda_i h_i p_i}$$

Can increase E/T by improving capture rates

- But only if the E_i:h_i ratio is profitable

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Optimal Diet Model

Reducing handling time improves E/T

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Optimal Diet Model

Overall, a relatively simple model
BUT it makes testable predictions!

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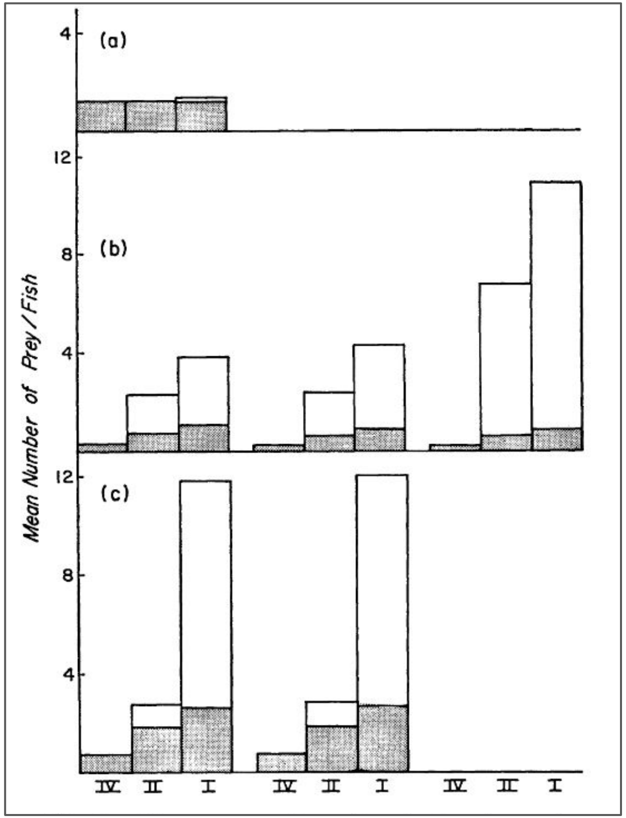
Testing the Optimal Diet Model



Low Prey Density

High Prey Density

Predators:
Class I = biggest
Class IV = smallest

White: prey eaten
Grey: null expectation

Ecology (1974) **55**: pp. 1042–1052

OPTIMAL FORAGING AND THE SIZE SELECTION OF PREY BY THE BLUEGILL SUNFISH (*LEPOMIS MACROCHIRUS*)[1]

EARL E. WERNER[2] AND DONALD J. HALL
Zoology Department, Michigan State University, East Lansing 48824

Optimal Foraging Theory

Predators also often have an option of WHERE they forage

Optimal Foraging Theory

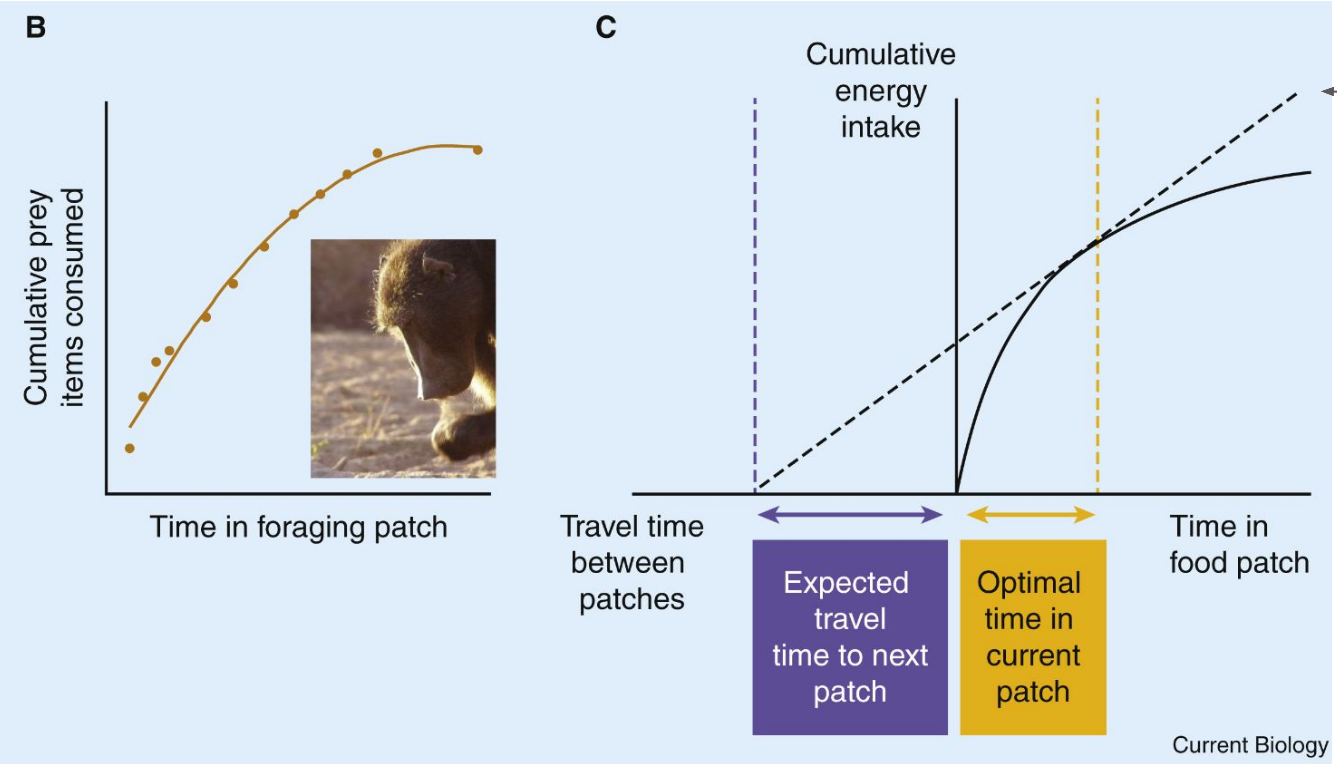
Predators also often have an option of WHERE they forage

Marginal Value Theorem

Choice to stay or leave depends on:

- Rate of gain of resources
- Average resource amount per patch
- Travel time between patches

Marginal Value



Rate of energy gain E/T

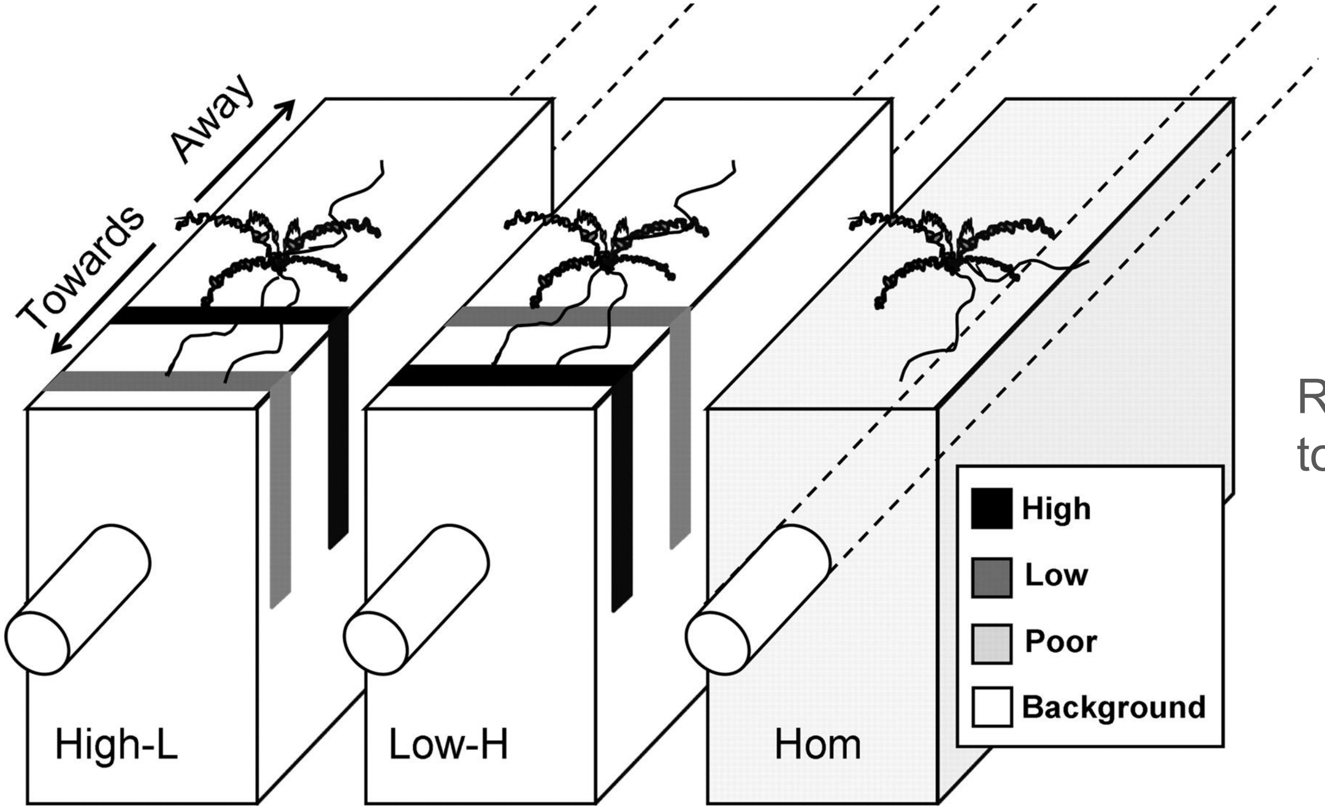
King, Andrew J. et al. Current Biology, Volume 32, Issue 12, R680 - R683

Marginal Value

As with Optimal Foraging, the marginal value theorem has received support

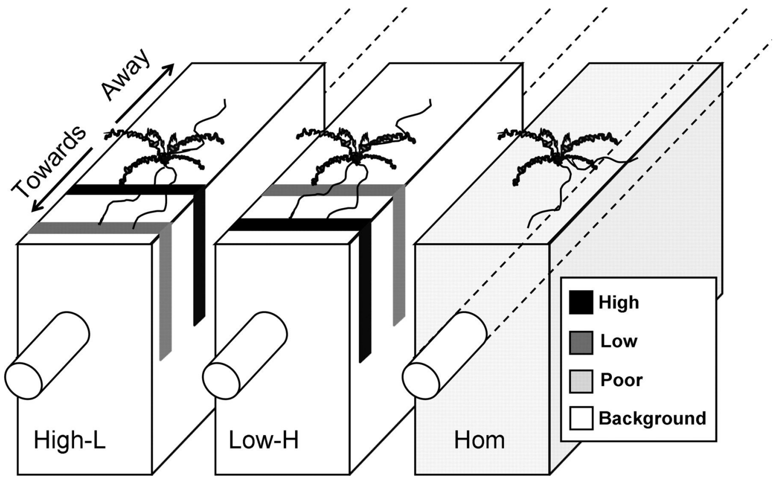
… and not just with animals!

Marginal Value in Plants



Root length is analogous to time foraging

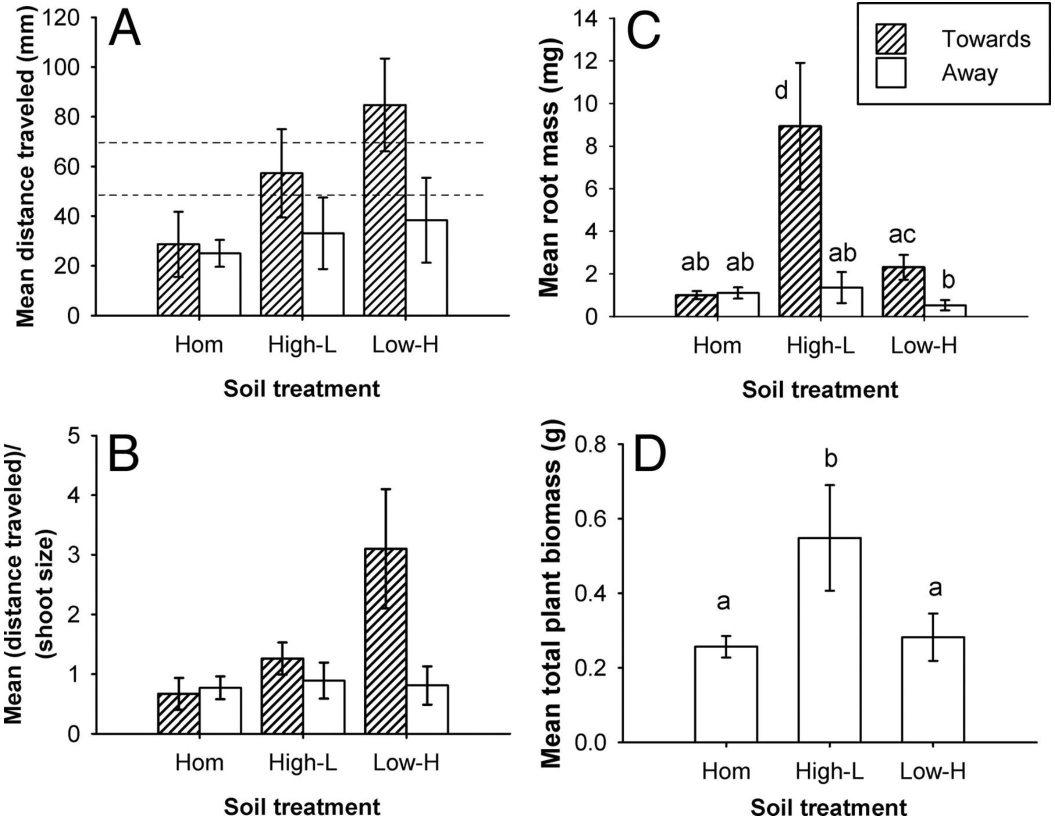
Marginal Value in Plants



Plant root growth and the marginal value theorem

Gordon G. McNickle[1] and James F. Cahill, Jr.

Department of Biological Sciences, University of Alberta, CW 405, Biological Sciences Centre, Edmonton, AB, Canada T6G 2E9



Non-consumptive Effects

Predators can also have impacts on prey other than eating them!

Can you think of examples?

Non-consumptive Effects

Predators can also have impacts on prey other than eating them!

Can you think of examples?

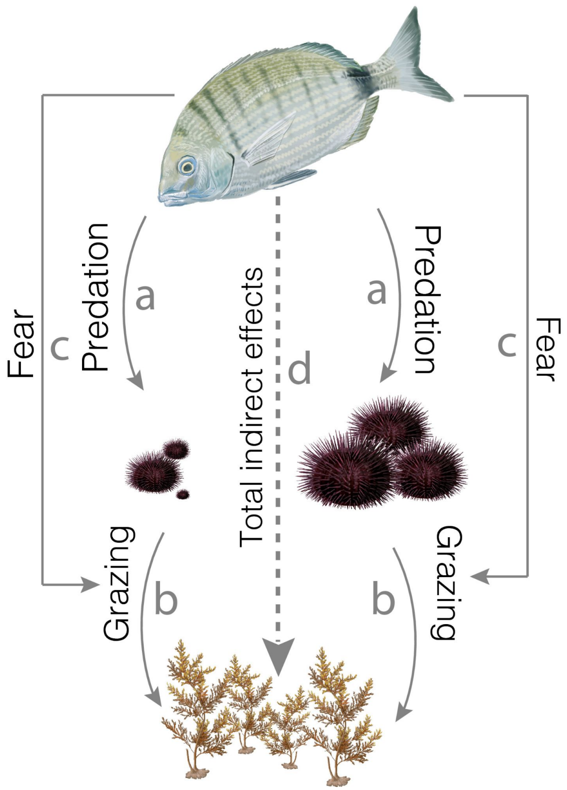
- Stress
- Life history changes
- Habitat usage
- Behavioral changes
- Morphology

Nonconsumptive Effects

Ecology, 100(5), 2019, e02649

Consumptive and non-consumptive effects of predators vary with the ontogeny of their prey

Albert Pessarrodona,[1,5,6] Jordi Boada,[1,2] Jordi F. Pagès,[3] Rohan Arthur,[1,4] and Teresa Alcoverro[1,4]



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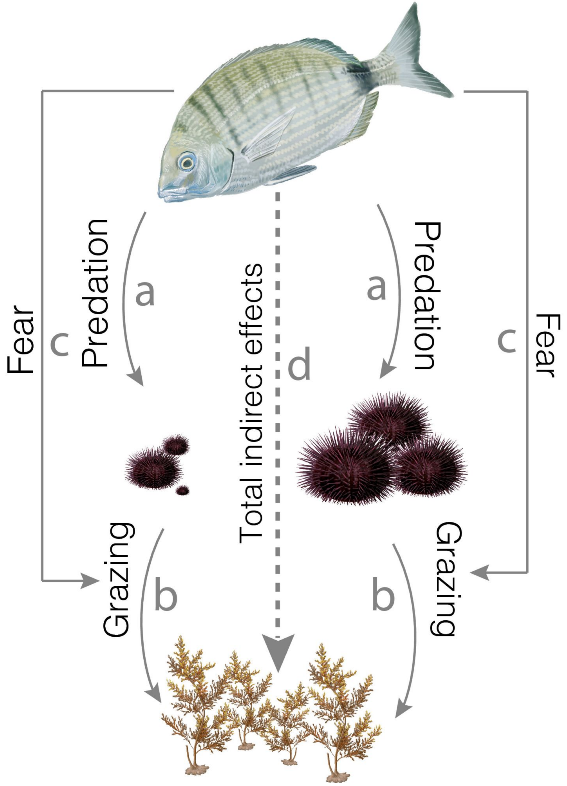

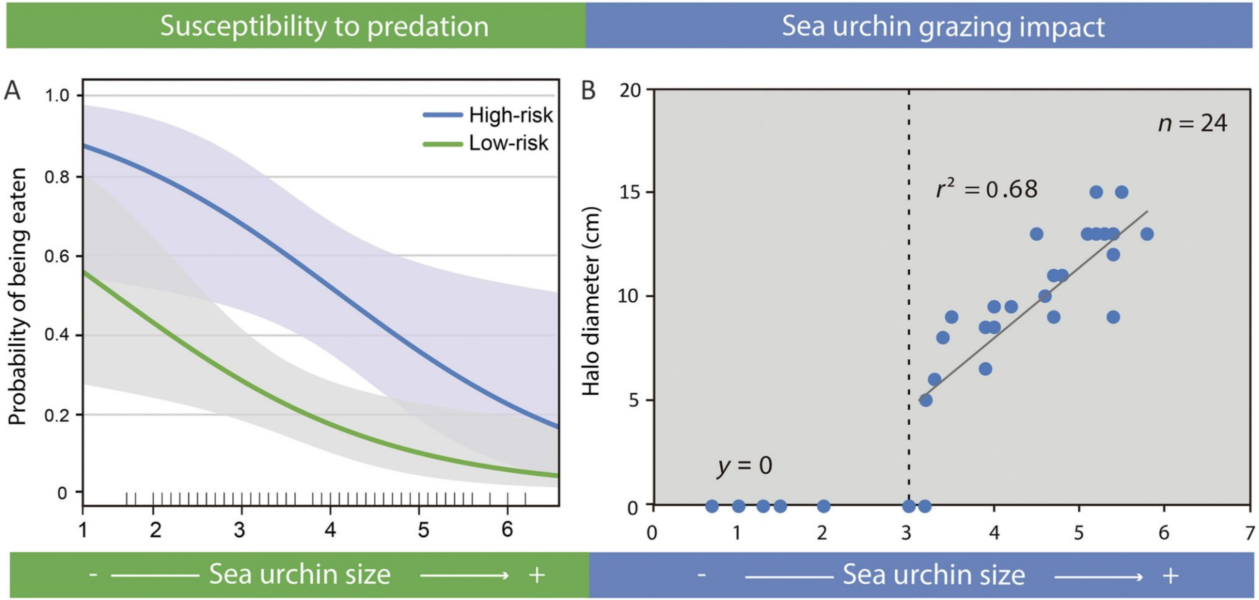

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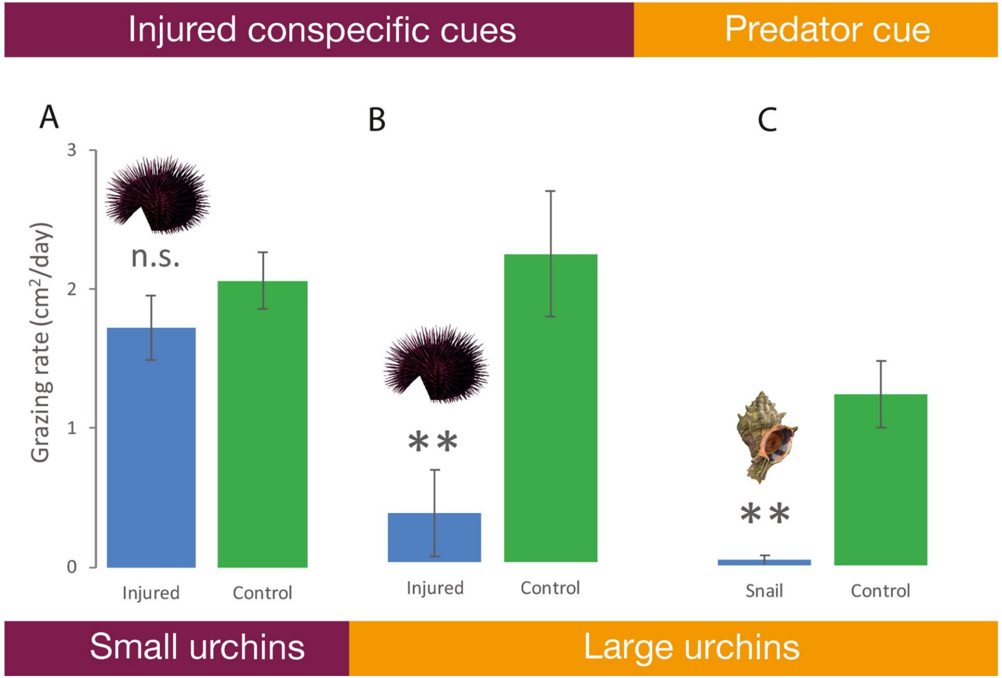

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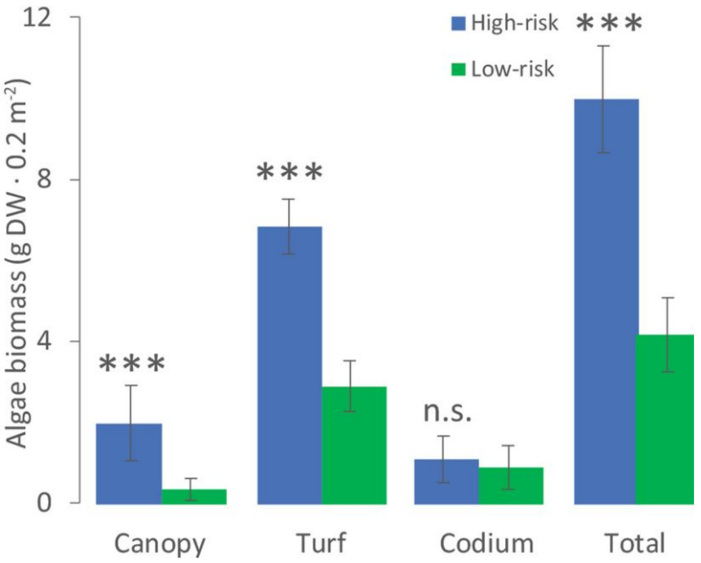

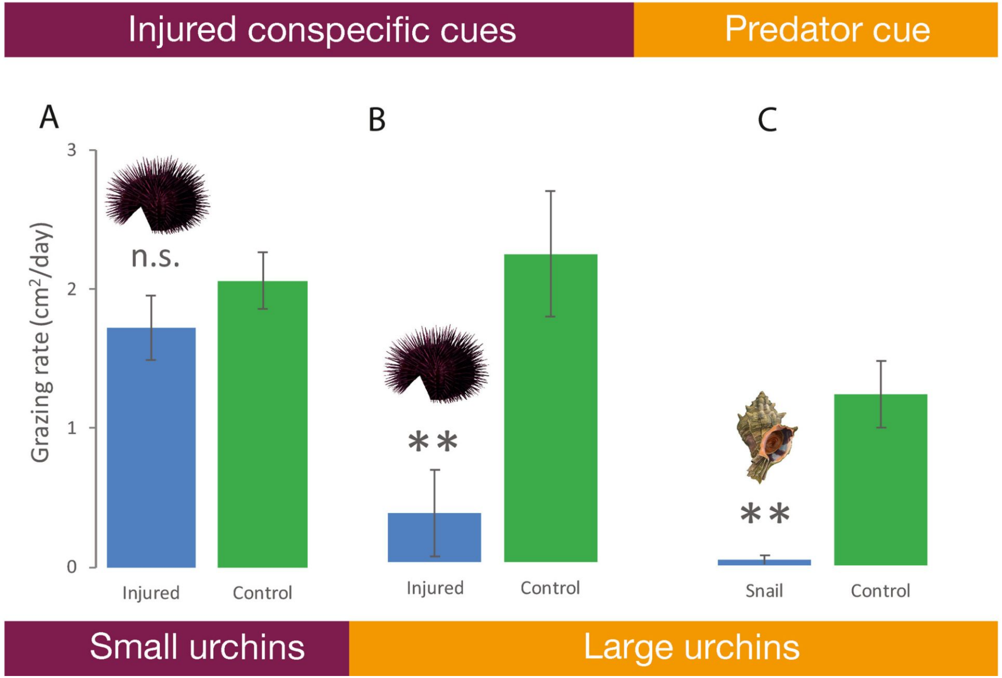

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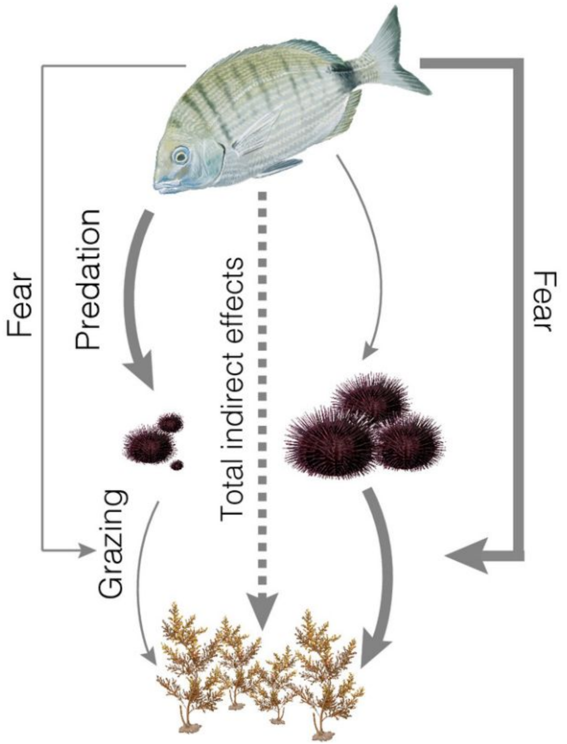

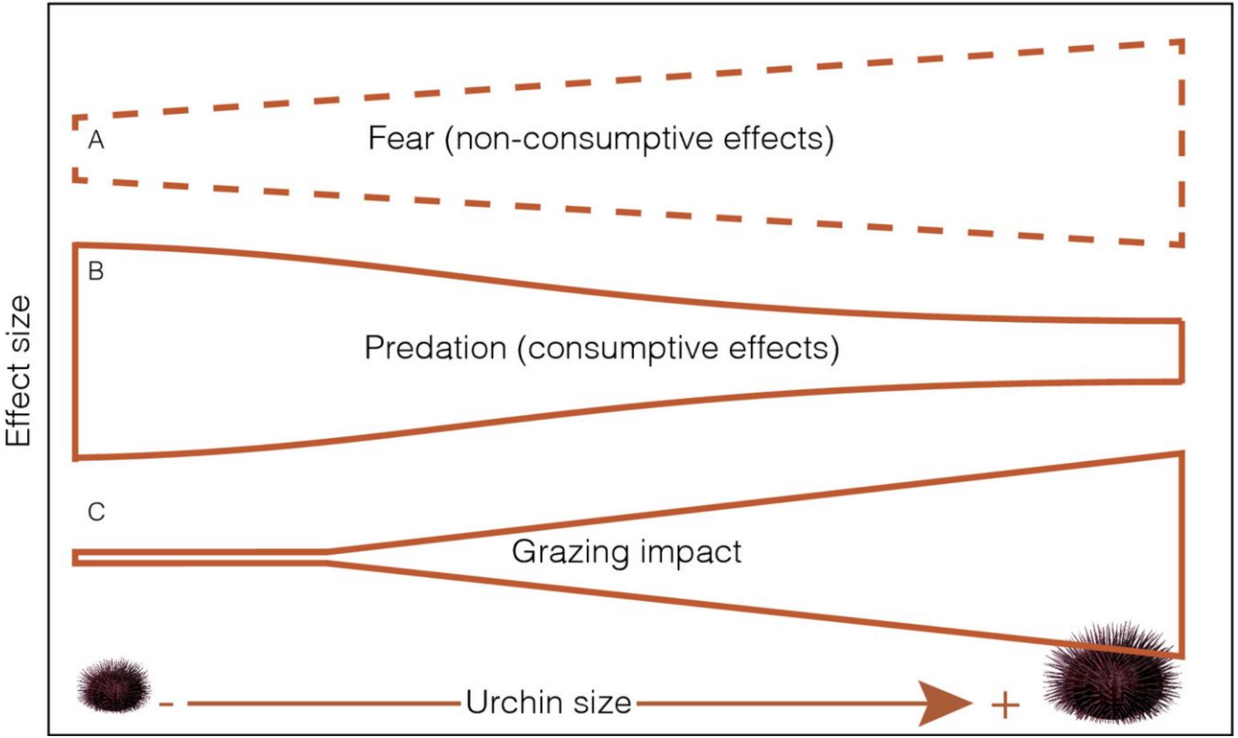

Next class: Competition