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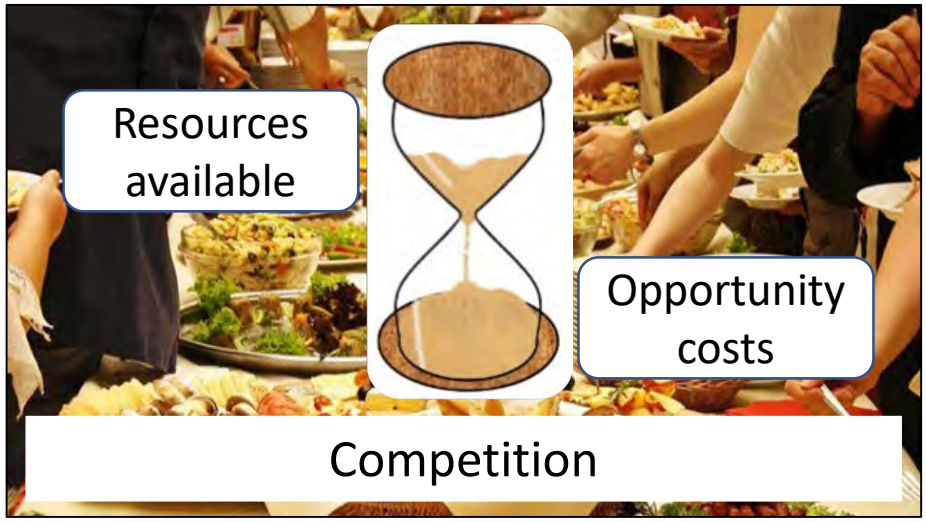
Effet des interactions inter- et intraspécifique et de la variabilité intraspécifique sur le comportement alimentaire de coléoptères carabiques

Alice Charalabidis

Making a choice

Making a choice

No competition



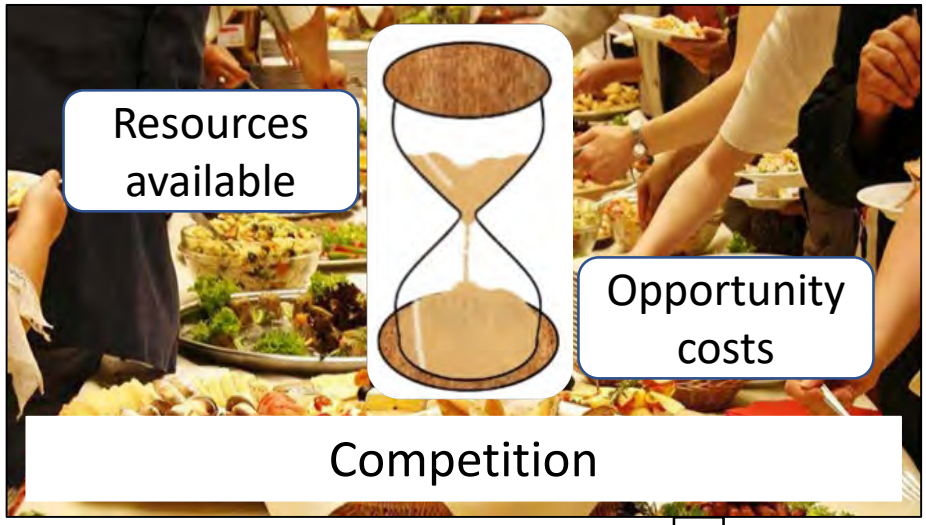
Competition

Making a choice

No competition

Accurate choice

Choice is preference



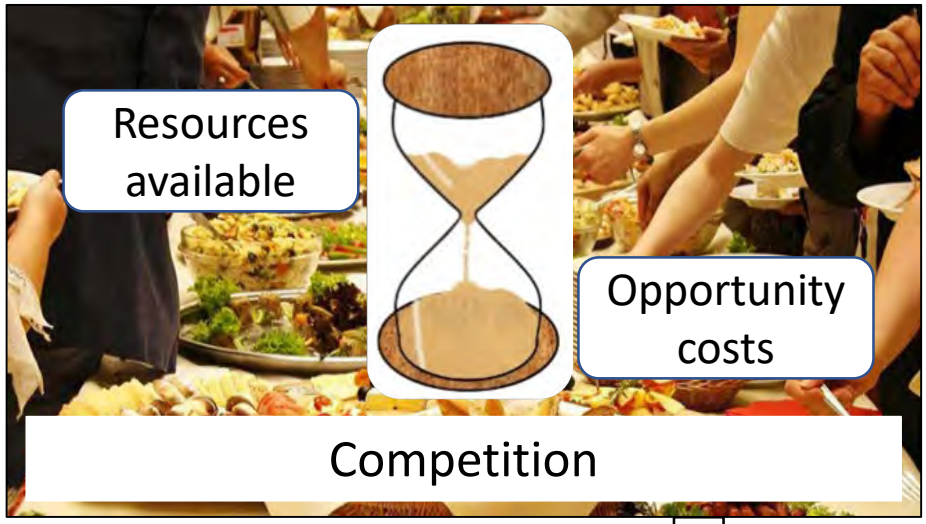
Competition

Fast choice

Choice is good enough

Choice is context dependent

No competition



Competition

Accurate choice

Choice is preference

Fast choice

Choice is good enough

Choice depends on the context

Effect of individuals variability on choice

Are all individuals similar in their choices?

Effect of individuals variability on choice

Differ in temperament

Shy Bold

Differ in metabolic and physiological traits

Higher or lower energy requirements

Differ in feeding preference

- Choice depends on the context
- Individual choice might differ

Knowledge of an individual's decision making process (choice) could help improve biological control

Biological control: Regulation of pests (such as animals or weeds) by other organisms. Biocontrol agents are either predator, parasites, pathogens or competitors of the pest.

Ladybirds and aphids

Parasitic wasps and caterpillars

Carabids and seeds of weeds

Objective of biological control: A reliable and effective ecosystem service to reduce use of chemical inputs, such as pesticides

Knowledge of an individual's decision making process (choice) could help improve biological control

The carabid beetle : A candidate for the regulation of weeds in arable fields:

A credible candidate for the biological control of weeds in arable fields

- Estimated predation of 1150 seeds/m²/day

  (Honek et al. 2003)

- Effect on the seed bank turnover

  (Bohan et al., 2011)

- Attack the seeds on the ground

  (Martinkova et al. 2006)

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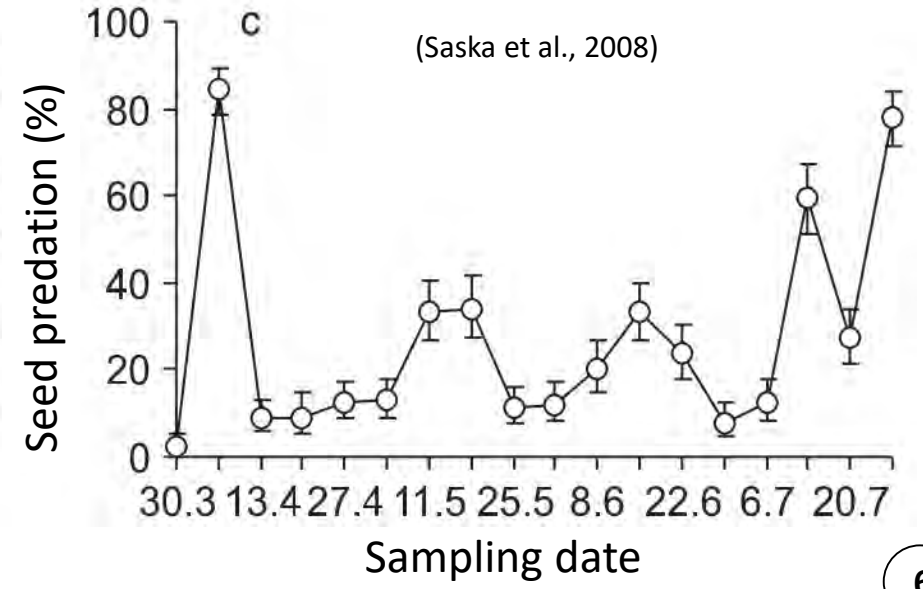

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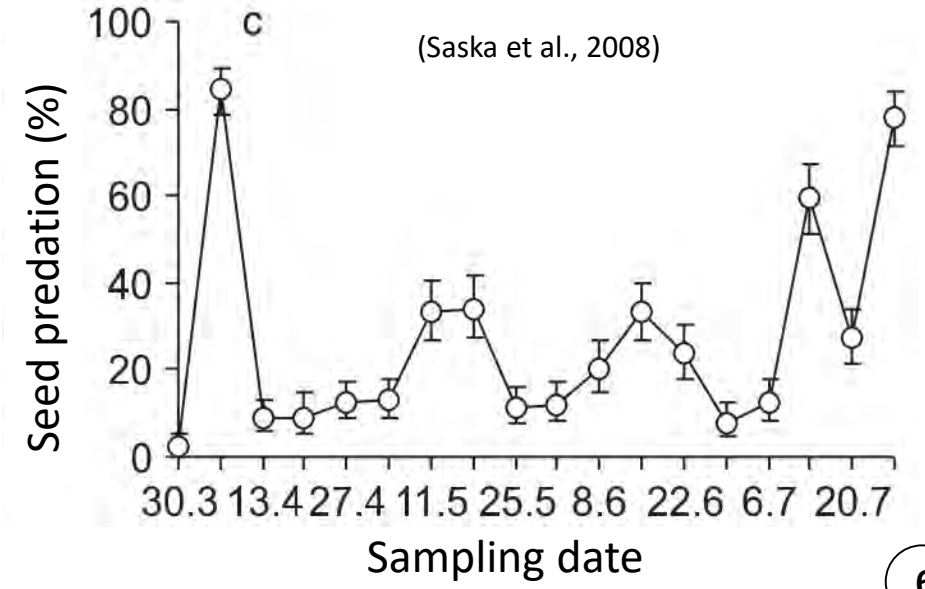
Yet, in-field predation rates are highly variable in time and space

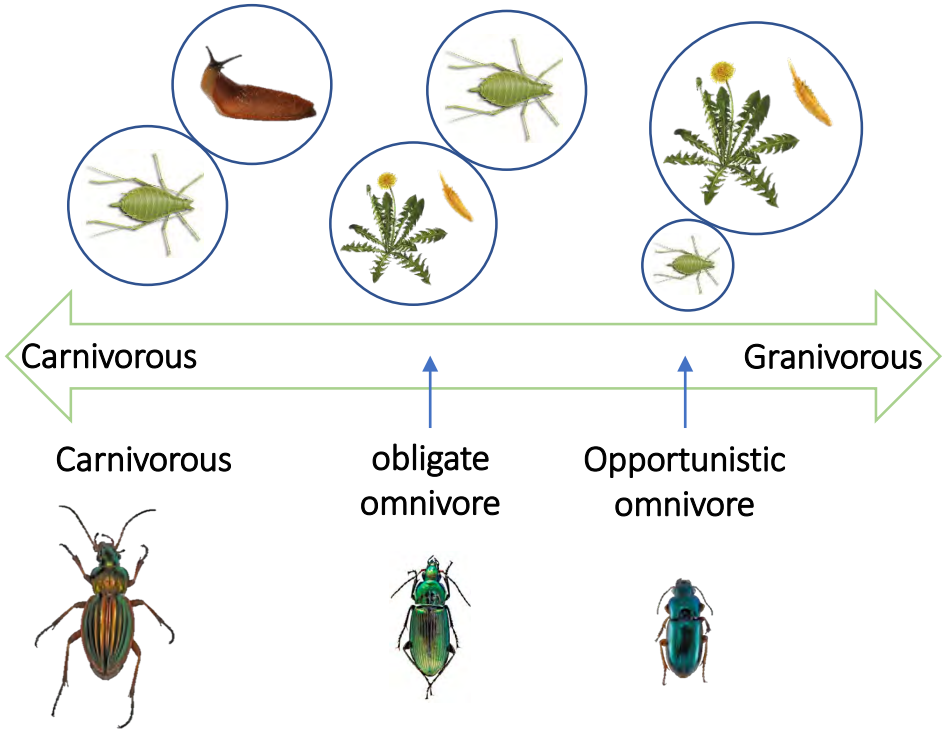
Not yet a predictable ecosystem service

(Saska et al., 2008)



Current knowledge of carabid feeding behaviour could explain variation in predation rates

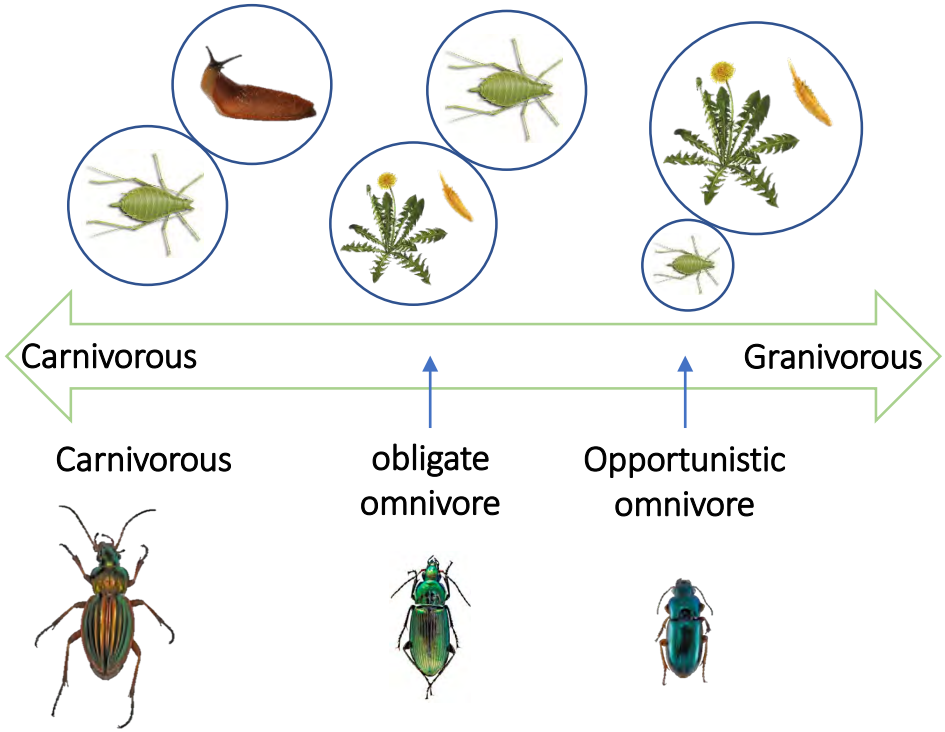
Carabid beetles can differ in their diet



Different potential roles in the biocontrol of weeds

Current knowledge of carabid feeding behaviour could explain variation in predation rates

Carabid beetles can differ in their diet



Different potential roles in the biocontrol of weeds

Carabid beetles have feeding preferences

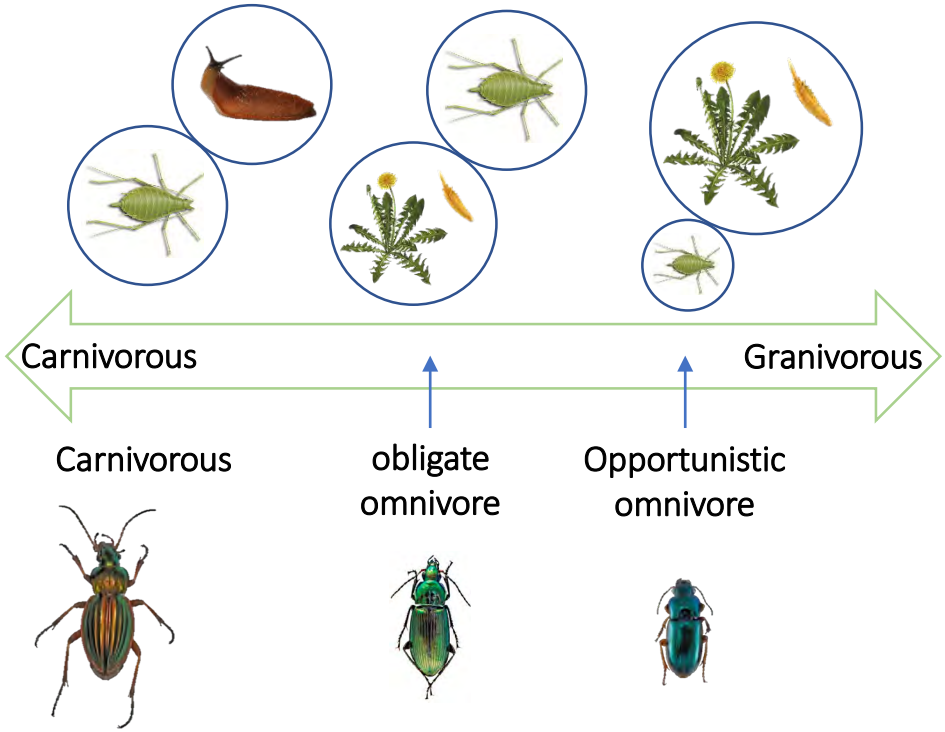
Multiple choice

knowledge on **relative preference**

Specific trophic link between some carabid species and some weed species

Current knowledge of carabid feeding behaviour that could explain variation in predation rates

Carabid beetles can differ in their diet

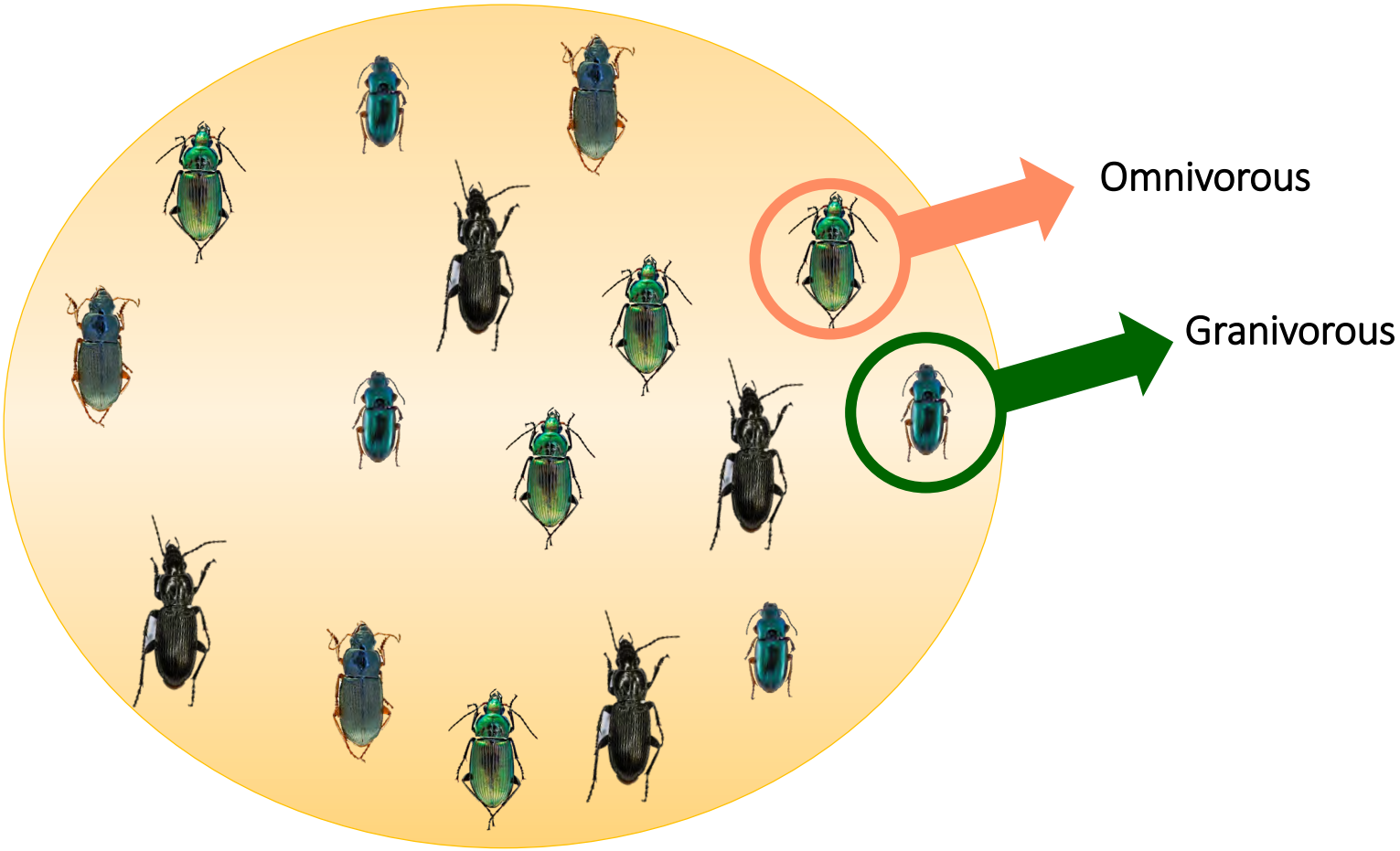


Carabid beetles have feeding preferences

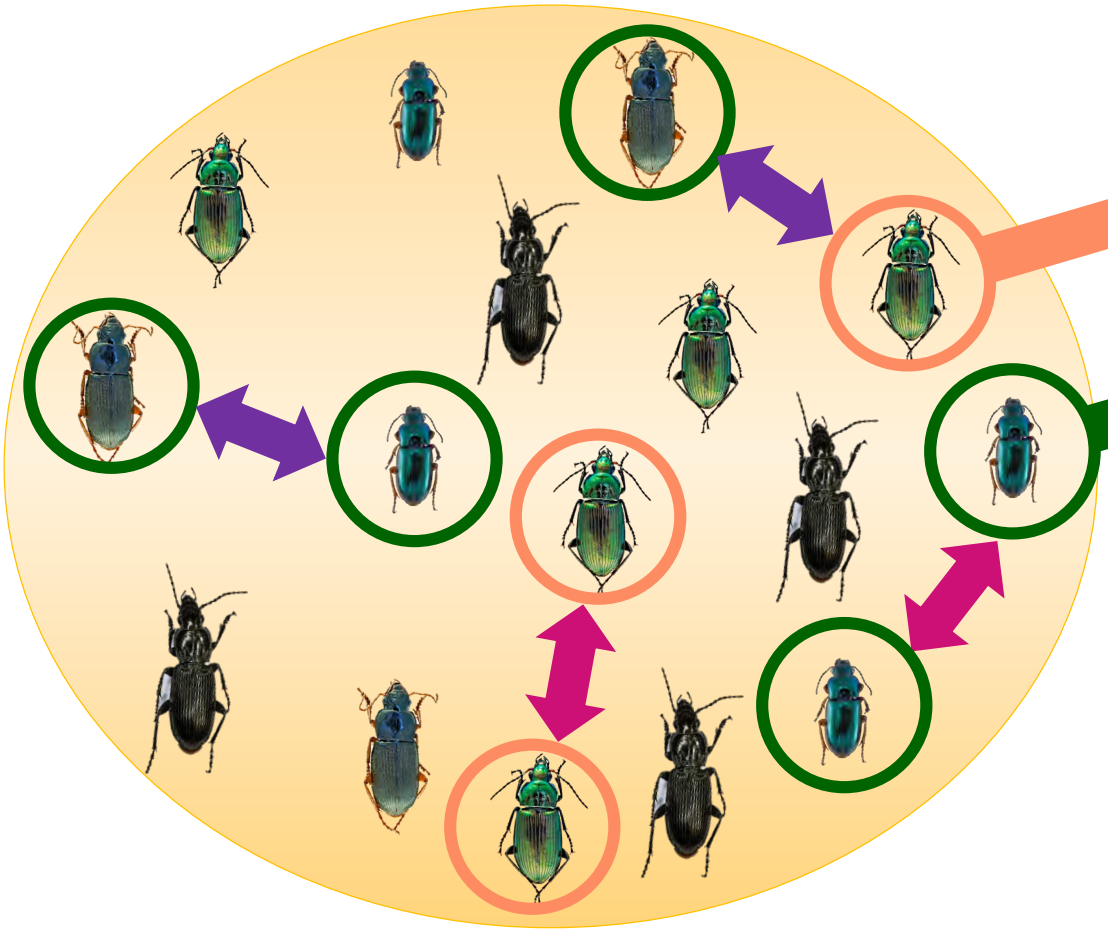
Multiple choice

Not much on a carabid individual's decision making process

Carabids communities are composed of several different seed-eating species



Carabid individuals may face competition for food items when foraging



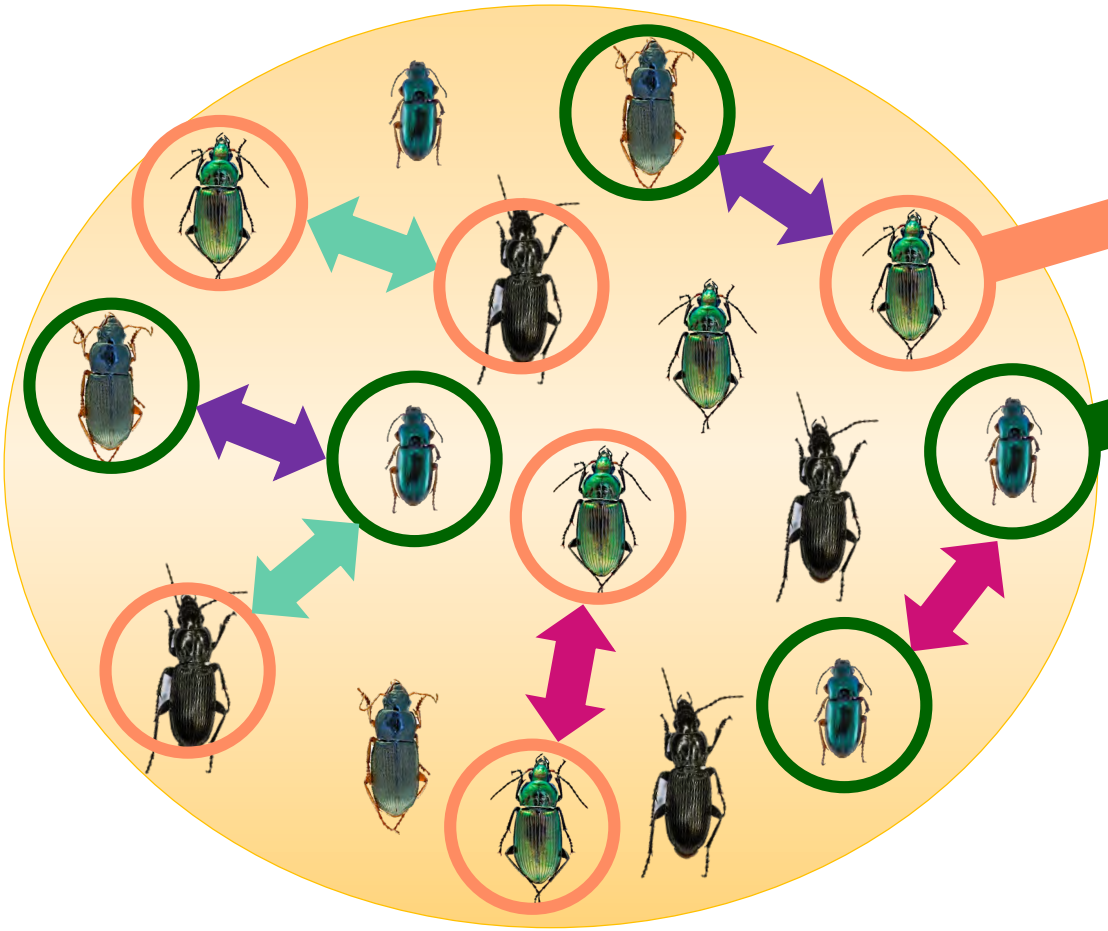
Omnivorous

Granivorous

Interspecific **competition**

Intraspecific **competition**

Carabid individuals may also face predation interference when foraging



Omnivorous

Granivorous

Interspecific **competition**

Intraspecific **competition**

Predatory interference

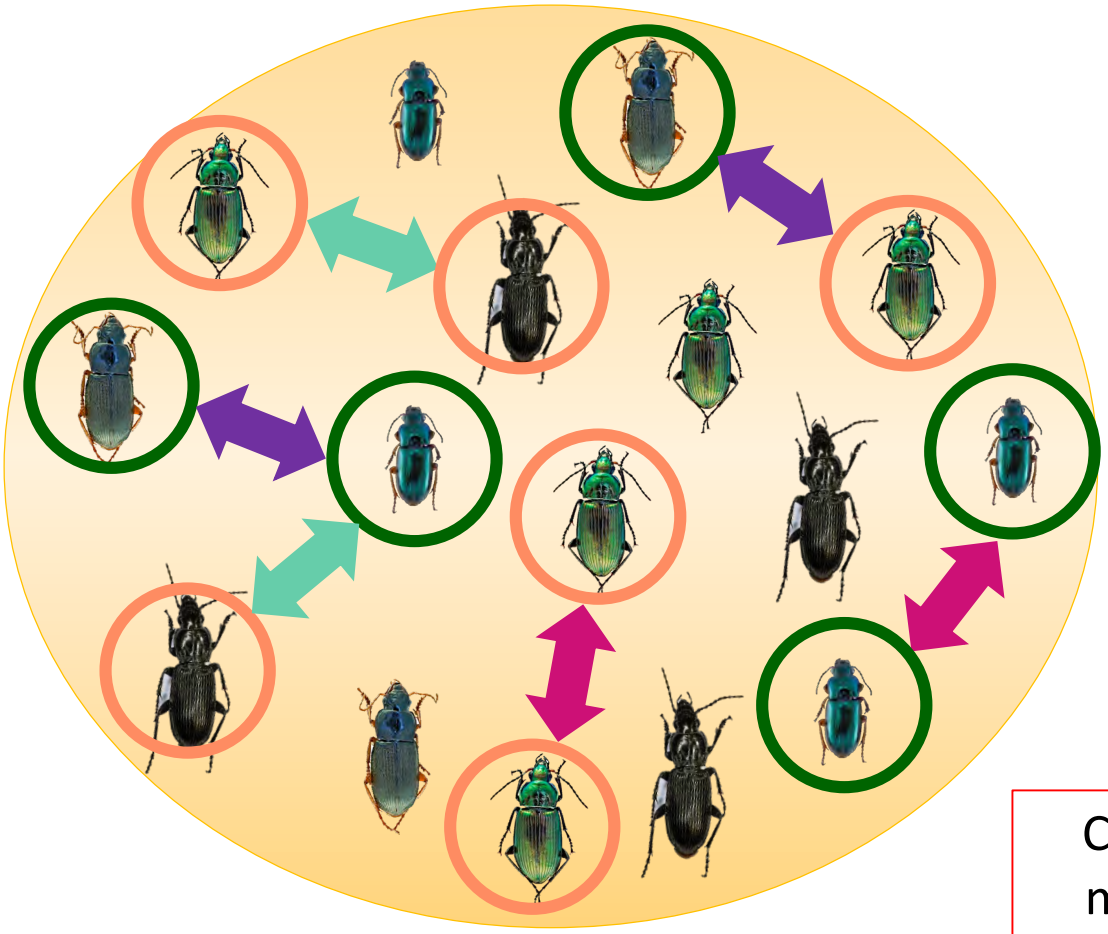
Predatory interactions can impact individual choices for food items

Making an accurate choice is time consuming

Foraging – Vigilance

Conflicting time-consuming tasks

Between individuals interactions could impact carabid individual feeding choices



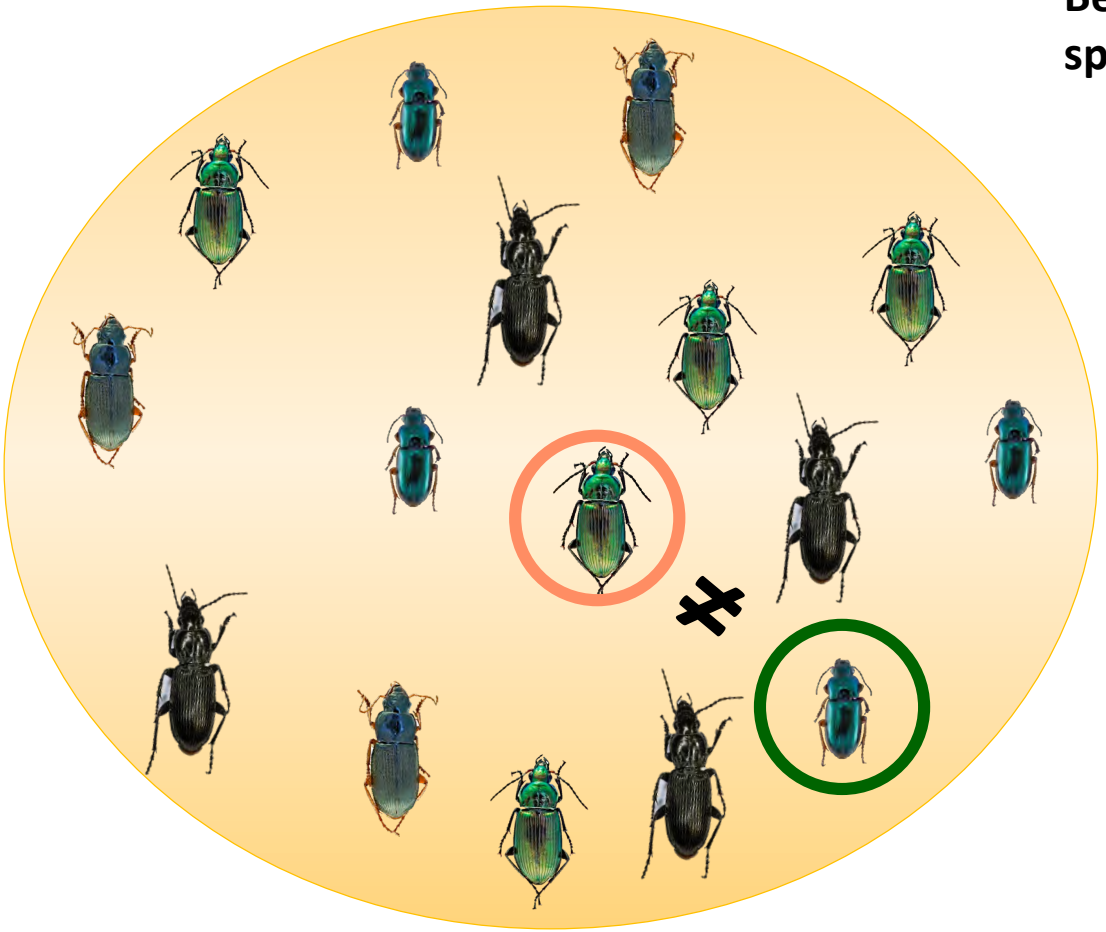
Interspecific competition

Intraspecific competition

Predatory interference

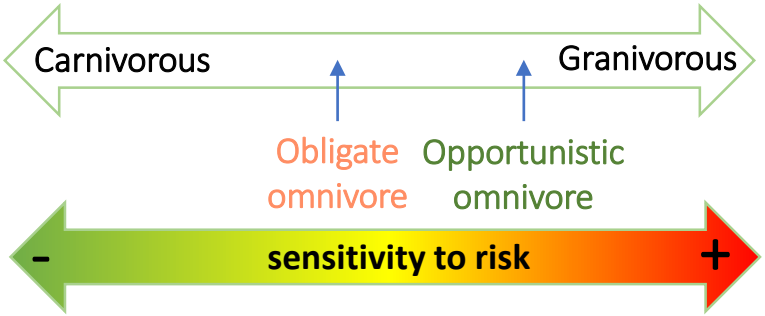
Carabids community composition might impact foraging individuals choices

Carabid species might differ in their feeding choices and sensitivity to competition and predation interference, depending on the relative importance of seeds in their diet

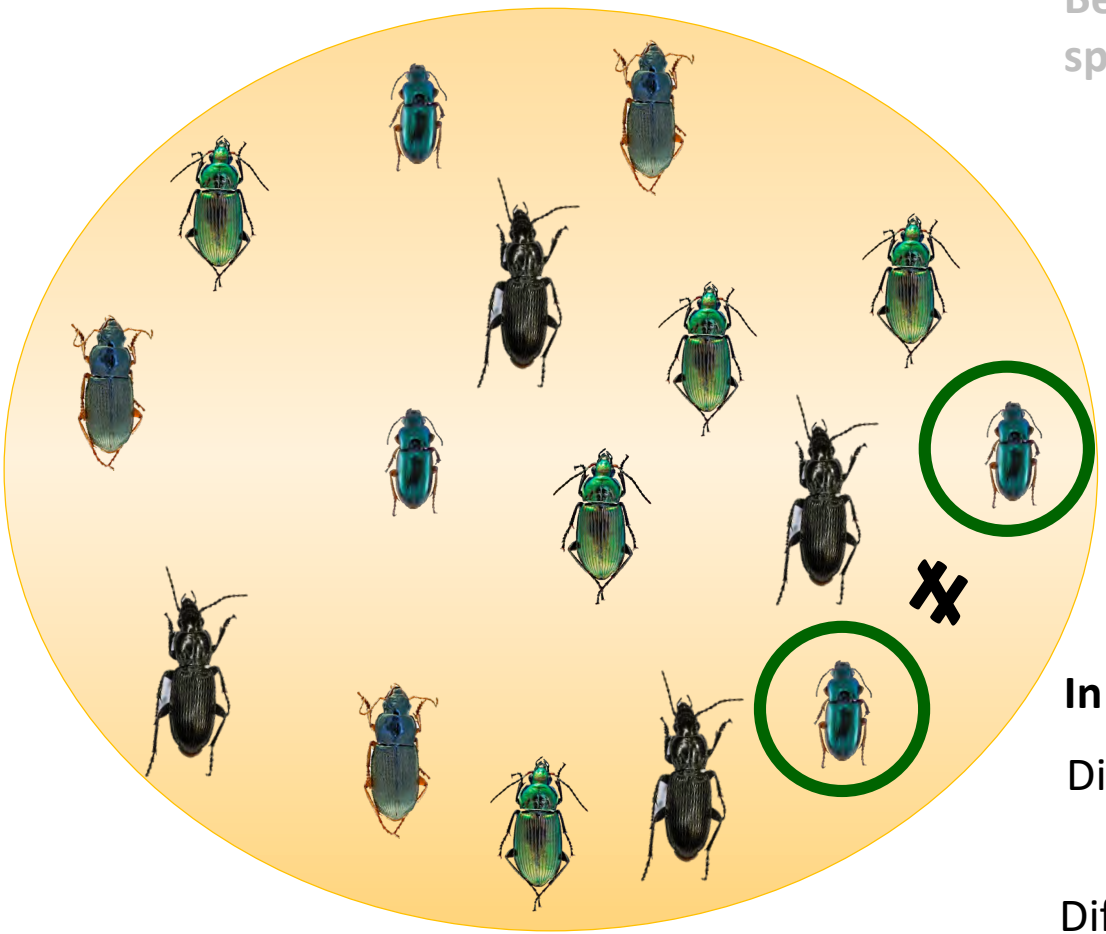


Between individuals of two different species:

The relative importance of seeds in the diet of a species can also impact individual feeding choices



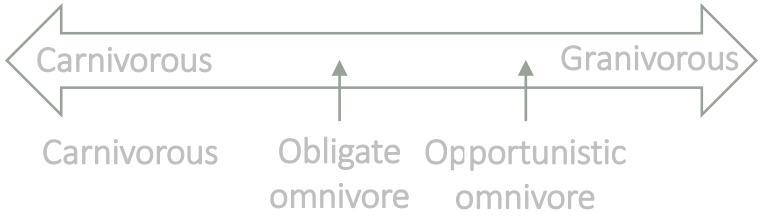
Individuals of a given species might also differ in their feeding choices and sensitivity to competition and predation interference



Inter-individual variability can impact carabid feeding choices

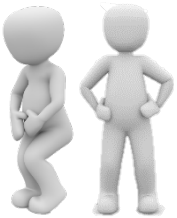
Between individuals of two different species:

The relative importance of seeds in the diet of a species can also impact individual feeding choices



In a given species:

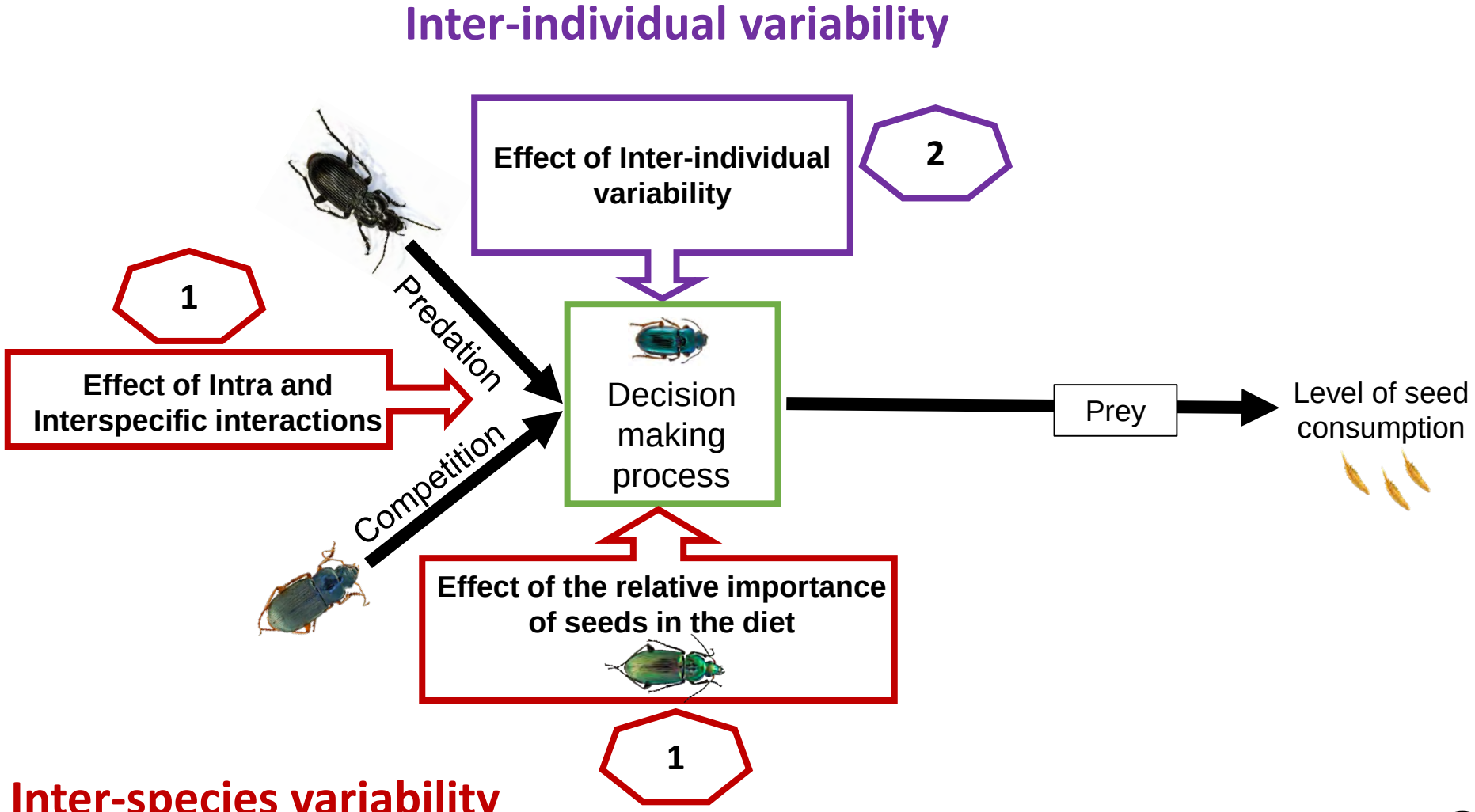
Differ in temperament?



Differ in energetic requirement

Sex effect?

Schematic diagram of the interference interactions (inter and intraspecific) and individual effects impacting carabid decision making



Choice of a metric to assess change in carabid decision making processes

Choosiness = Effort or energy invested in resource assessment

(Jennions & Petrie 1997)

Gives insight into an **individuals overall interest** in a given resource

Being choosy is time consuming 

Change in individual level of choosiness is a good metric to assess individuals change in decision making processes

Choosiness = Effort or energy invested in resource assessment

(Jennions & Petrie 1997)

Gives insight into an **individuals overall interest** in a given resource

Being choosy is time consuming 

Effort or energy invested should change according to the encountered intra and/or interspecific interactions

Perceived competition ➡ opportunity costs = change in level of choosiness?

Perceived predation risk ➡ tasks tradeoff = change in level of choosiness?

How to measure change in the level of choosiness?

Use of choice paradigm:

Gives insight into an **individual's preference** for a given resource over another one

I take one over two edible items

I have a feeding preference

How to measure change in the level of choosiness?

Use of choice paradigm:

Gives insight into an **individual's preference** for a given resource over another one

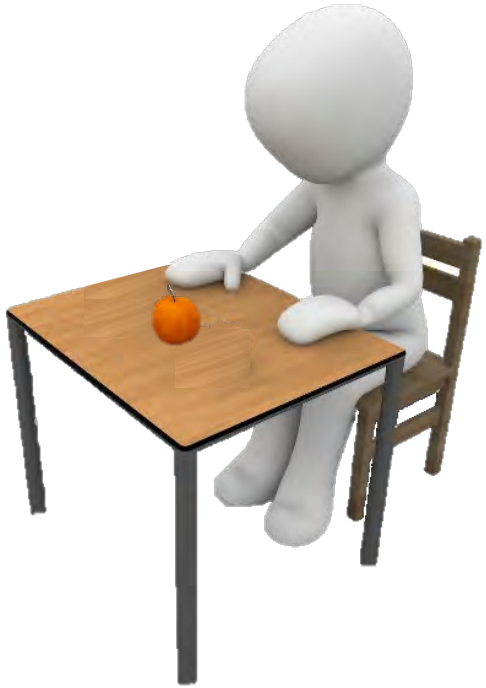
I take one over two edible items

I have feeding preference

Use of no-choice paradigm:

Gives insight into an **individual's interest** in a given resource

I invest time prior to accepting the only edible item available



I am choosy

Use of a no-choice paradigm helps assess an individual's levels of choosiness

- Can **vary according to the context** in which individuals forage
- Can **vary between individuals**

- **Easy to measure:**
  - Latency to first acceptance
  - Number of items consumed or rejected in a given time span
- **Easy to analyze:**
  - Independent variables

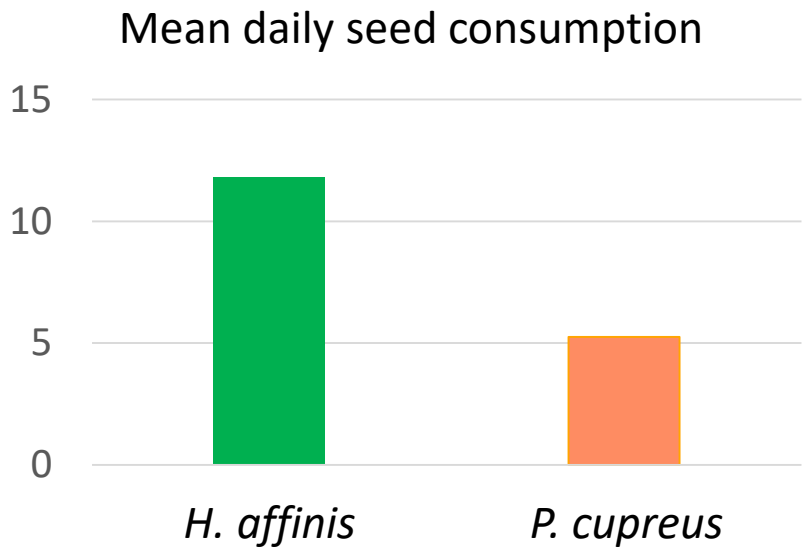
Which species of carabids to use in test?

1)  *Harpalus affinis*

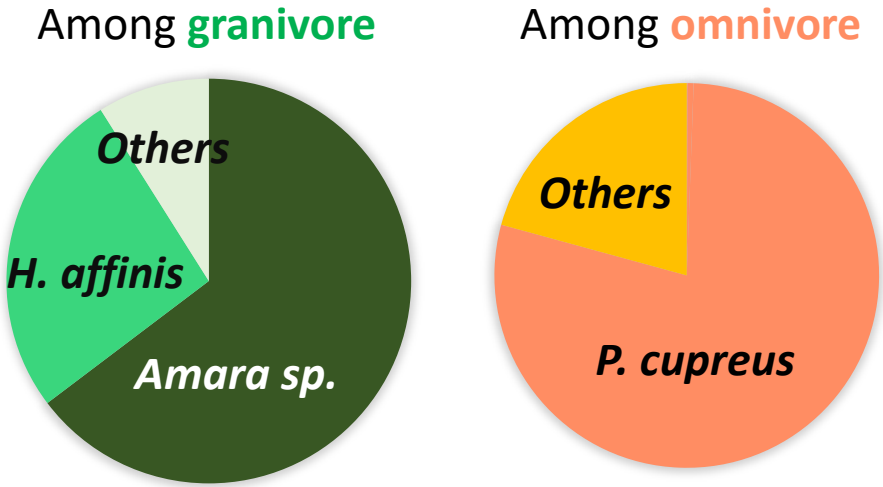
*Common **granivorous** species*
Abundant in fields

2)  *Poecilus cupreus*

*Common **omnivorous** species*
Abundant in fields

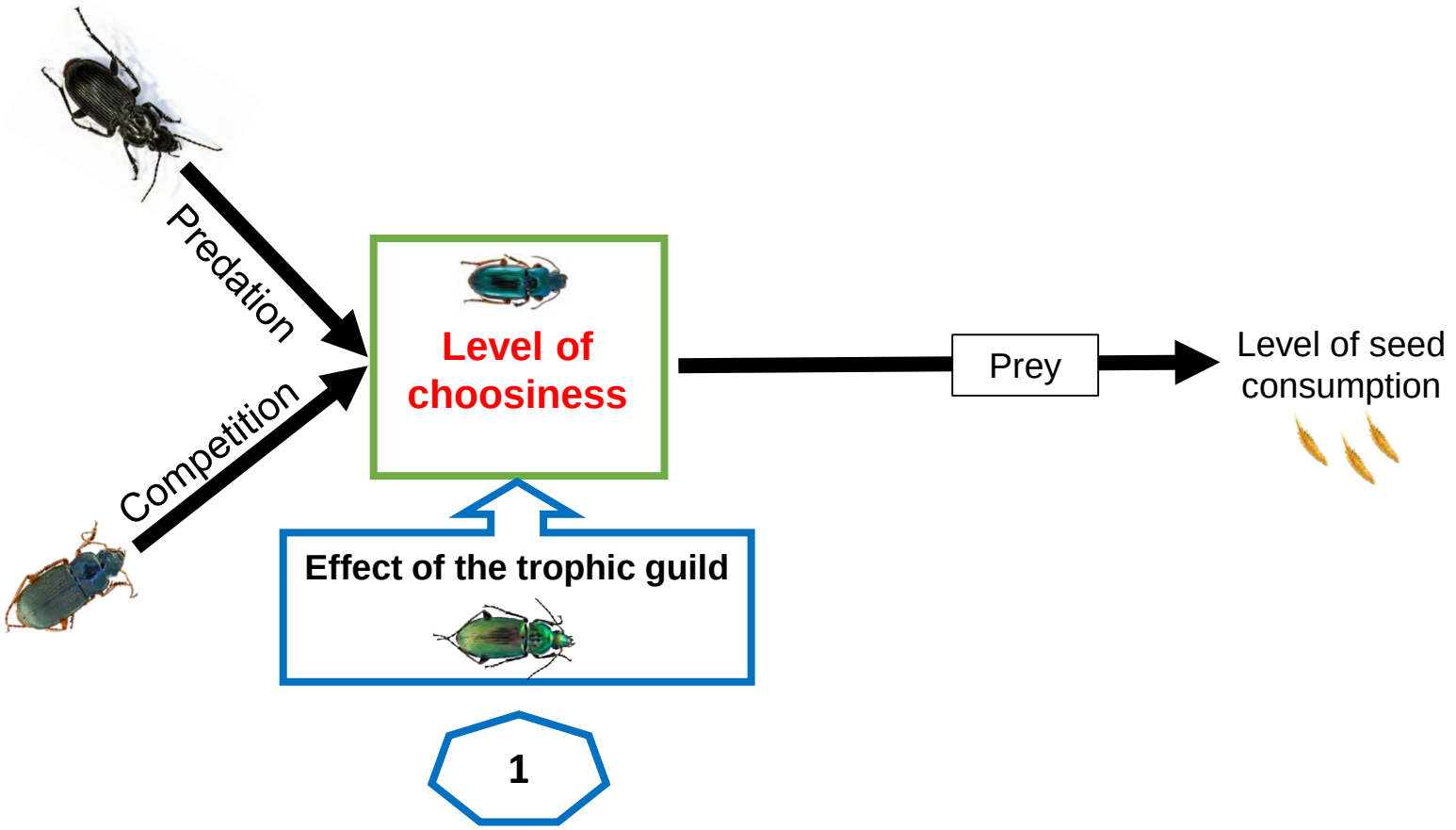


(Petit et al., 2014)



Common in arable fields

Will two carabid species differ in their level of choosiness for different species of seeds of weeds?



H: A carabid granivorous species will have a lower choosiness for seed of weeds in comparison to an omnivorous one

Interest for seeds of two abundant carabid species

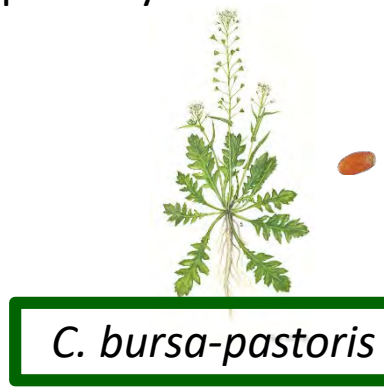
The **granivorous**
Harpalus affinis

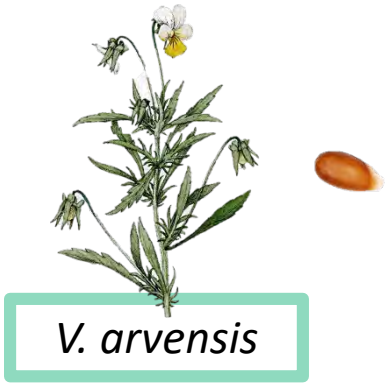
The **omnivorous**
Poecilus Cupreus

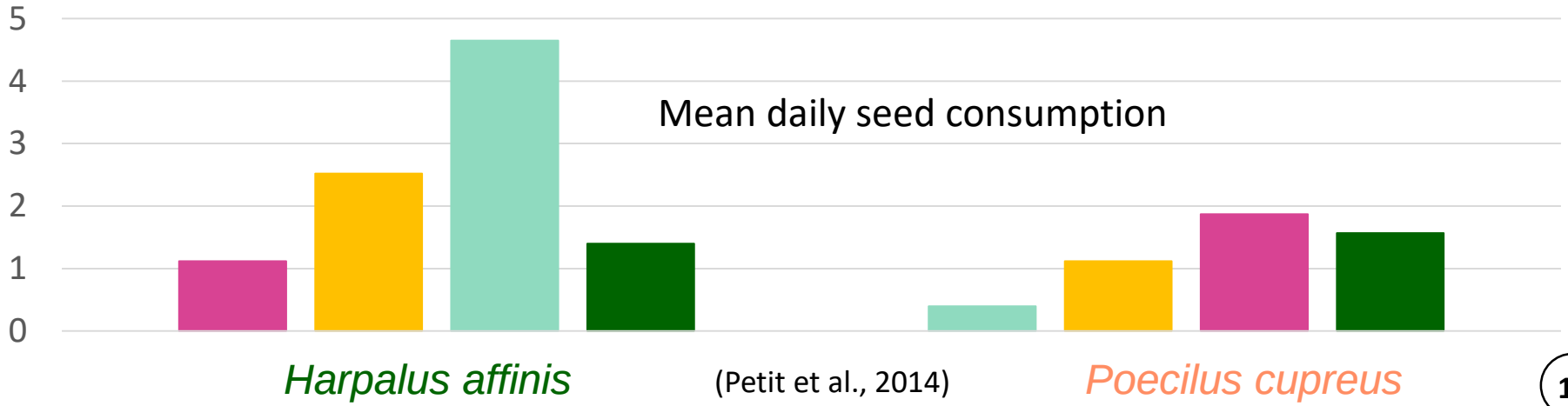
Mean consumption obtained from a choice – test paradigm

Relative preference

Carabid species tested separately







Interest for seeds of two main carabid species

The **granivorous**
Harpalus affinis

The **omnivorous**
Poecilus Cupreus

Carabid species tested separately

No-choice test

Level of choosiness

Latency to first seed acceptance

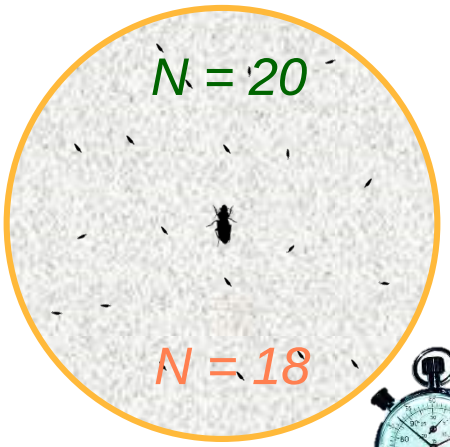
Total number of seed eaten

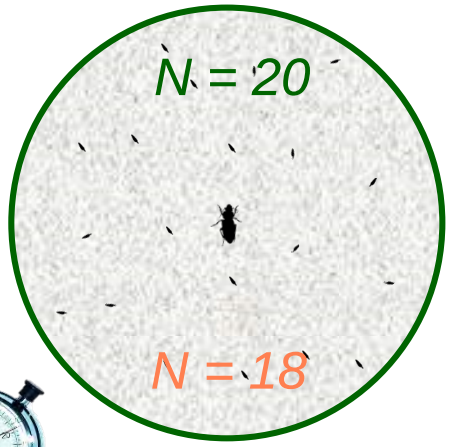
Taraxacum officinale

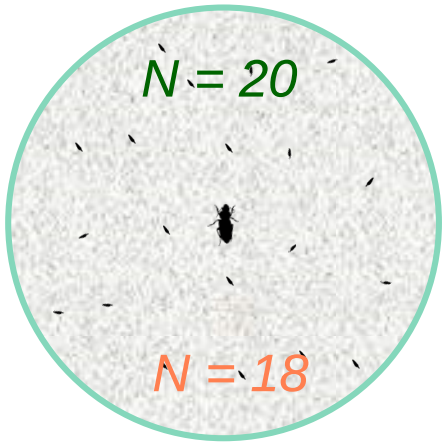
Capsella bursa-pastoris

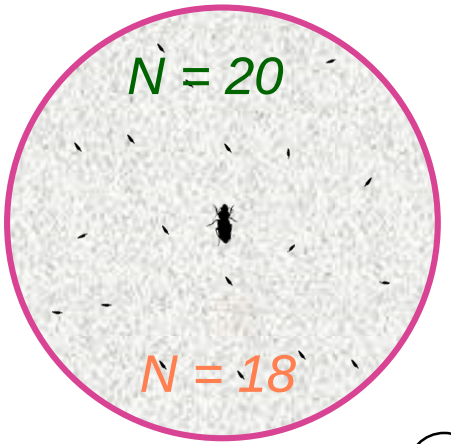
Viola arvensis

Senecio vulgaris





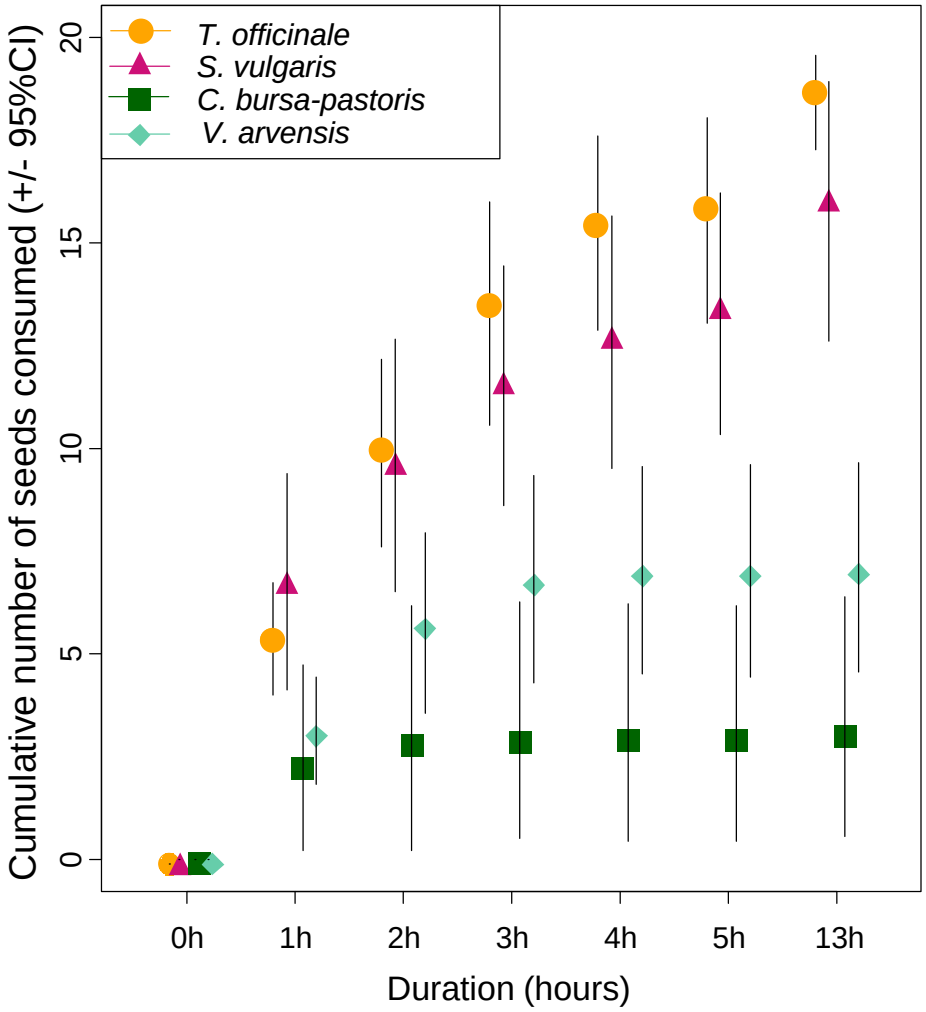




6 sample dates: 1h, 2h, 3h, 4h, 5h, 13h

The amount of seeds consumed by *P. cupreus* differed between weed species

P. cupreus (omnivorous)



(Charalabidis et al., 2019)

Consumption differed between weed species ($P < 0.05$)

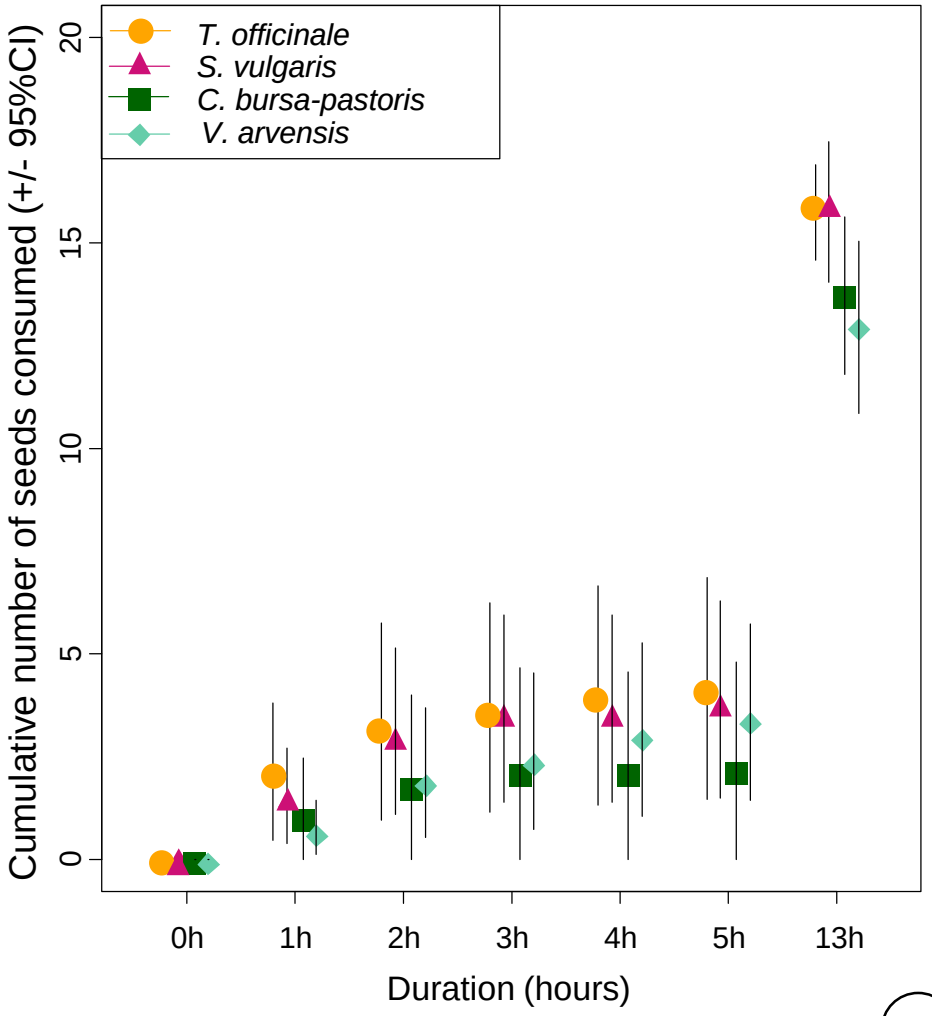
T. officinale and ***S. vulgaris*** were eaten more eagerly than ***C. bursa-pastoris*** and ***V. arvensis seeds*** ($P < 0.05$)

Seeds of ***V. arvensis*** and ***C. bursa-pastoris*** are in overall overlooked

The amount of seeds consumed by *H. affinis* did not differed between weed species

Consumption did not significantly differ between weed species (P = 0.88)

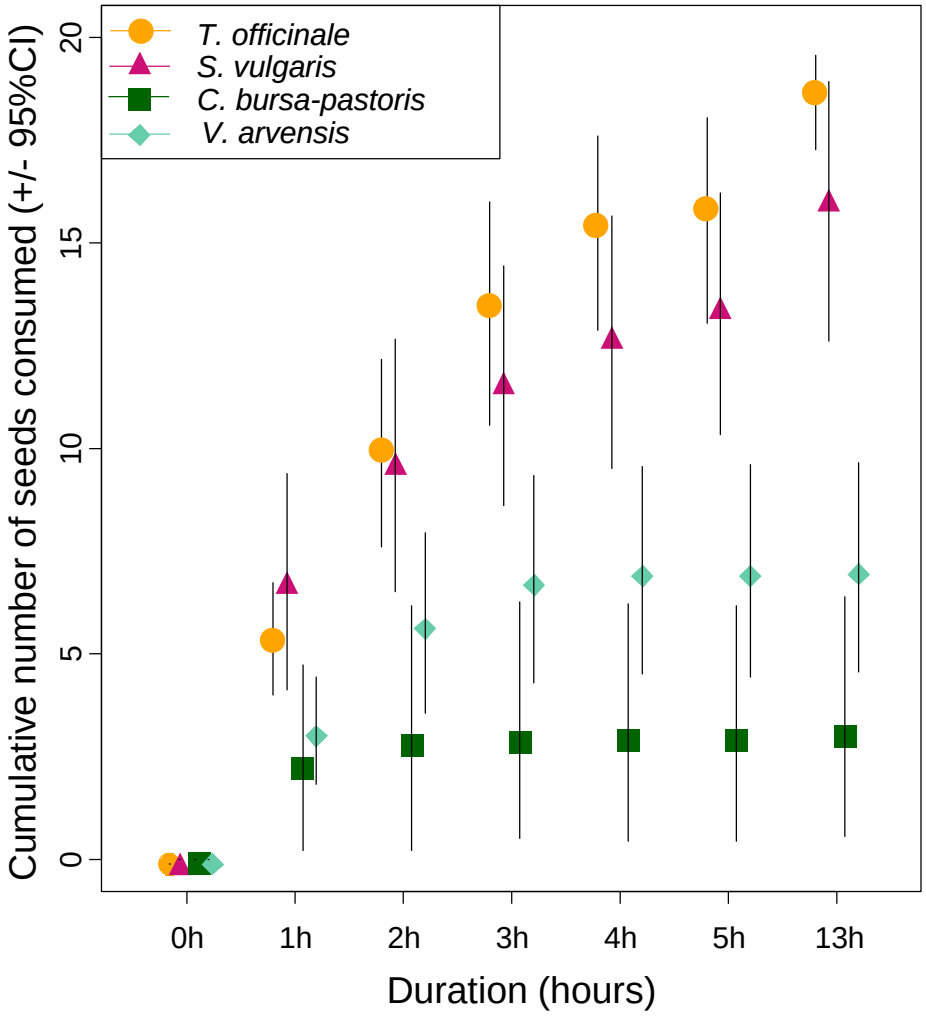
H. affinis (granivorous)



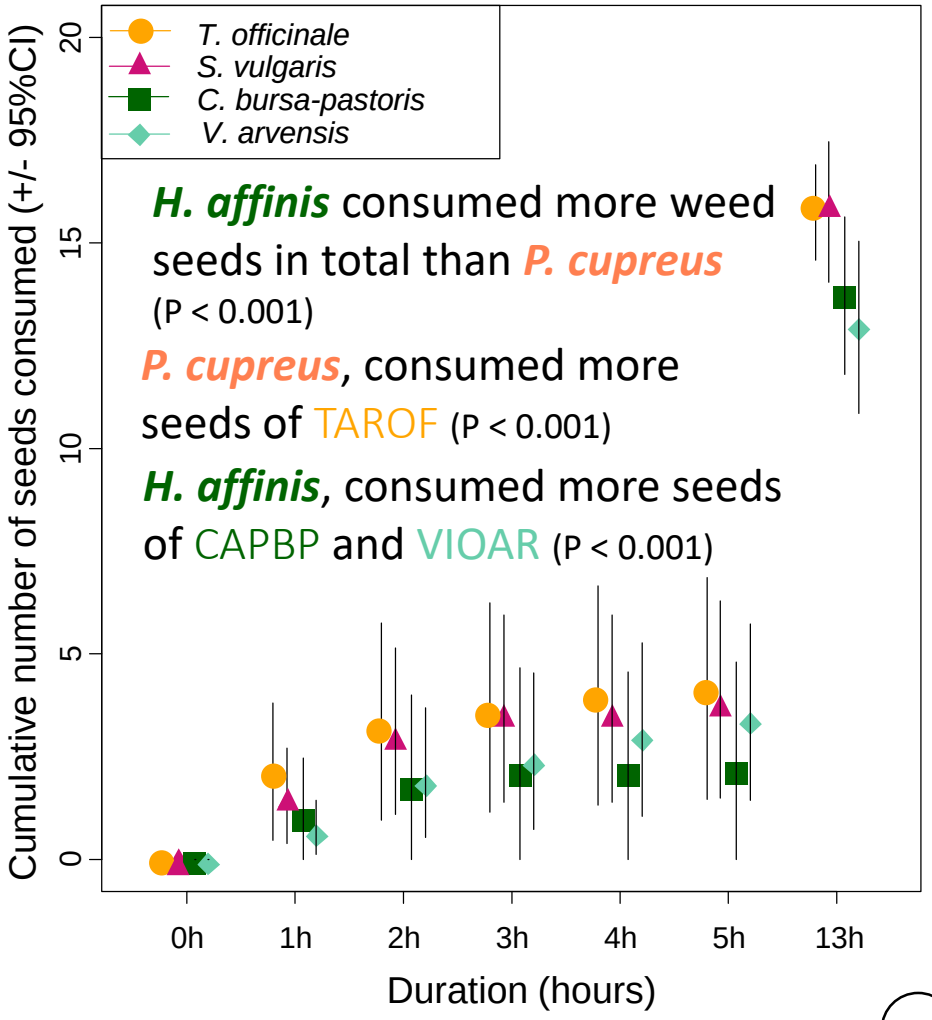
(Charalabidis et al., 2019)

Both tested carabid species differed in their foraging behaviour

P. cupreus (omnivorous)



H. affinis (granivorous)



H. affinis consumed more weed seeds in total than ***P. cupreus*** ($P < 0.001$)

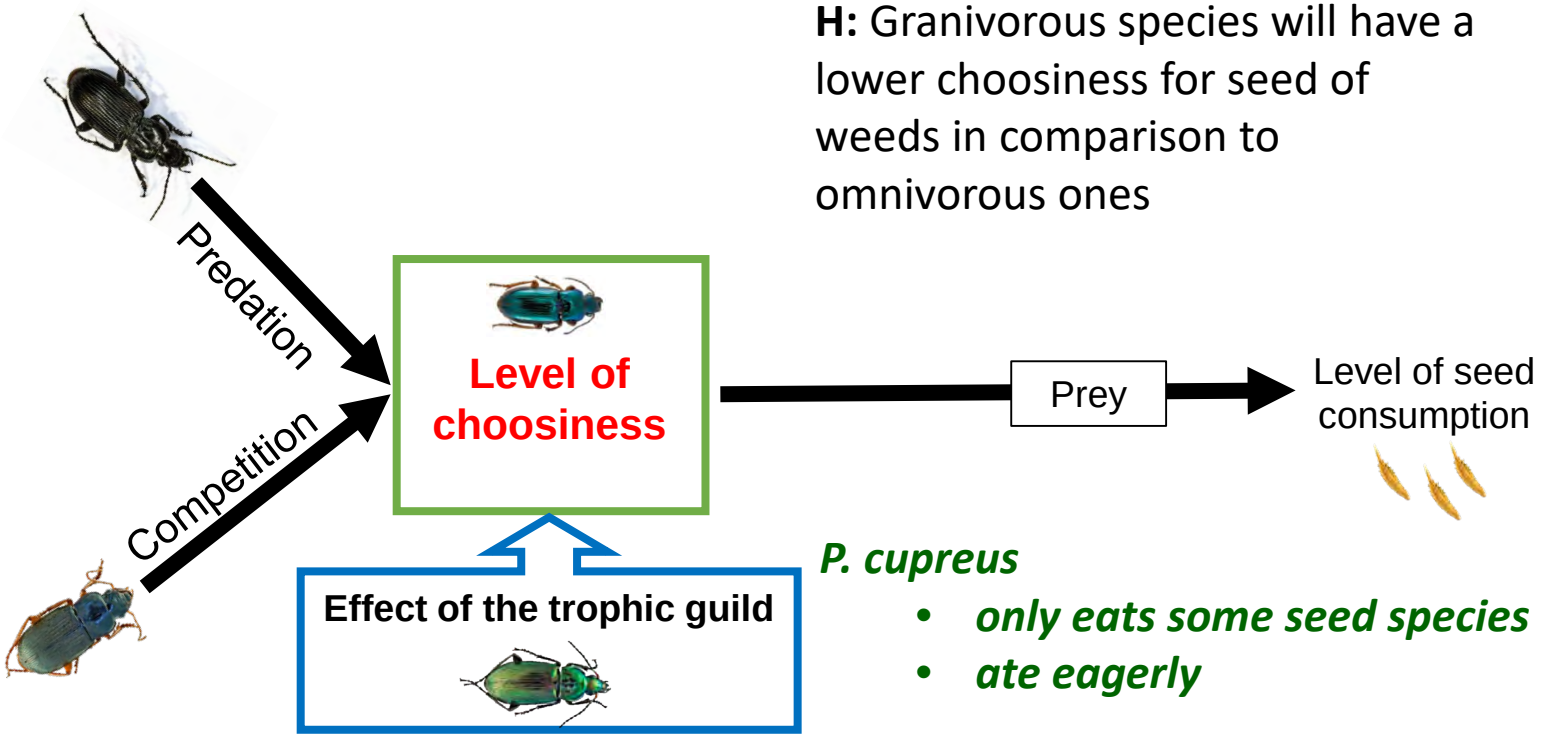
P. cupreus, consumed more seeds of TAROF ($P < 0.001$)

H. affinis, consumed more seeds of CAPBP and VIOAR ($P < 0.001$)

(Charalabidis et al., 2019)

Will two carabid species differ in their level of choosiness for different species of seeds of weeds?

H: Granivorous species will have a lower choosiness for seed of weeds in comparison to omnivorous ones



P. cupreus

- ***only eats some seed species***
- ***ate eagerly***

H. affinis

- ***Ate all species of seeds***
- ***Only start eating after 5hours***

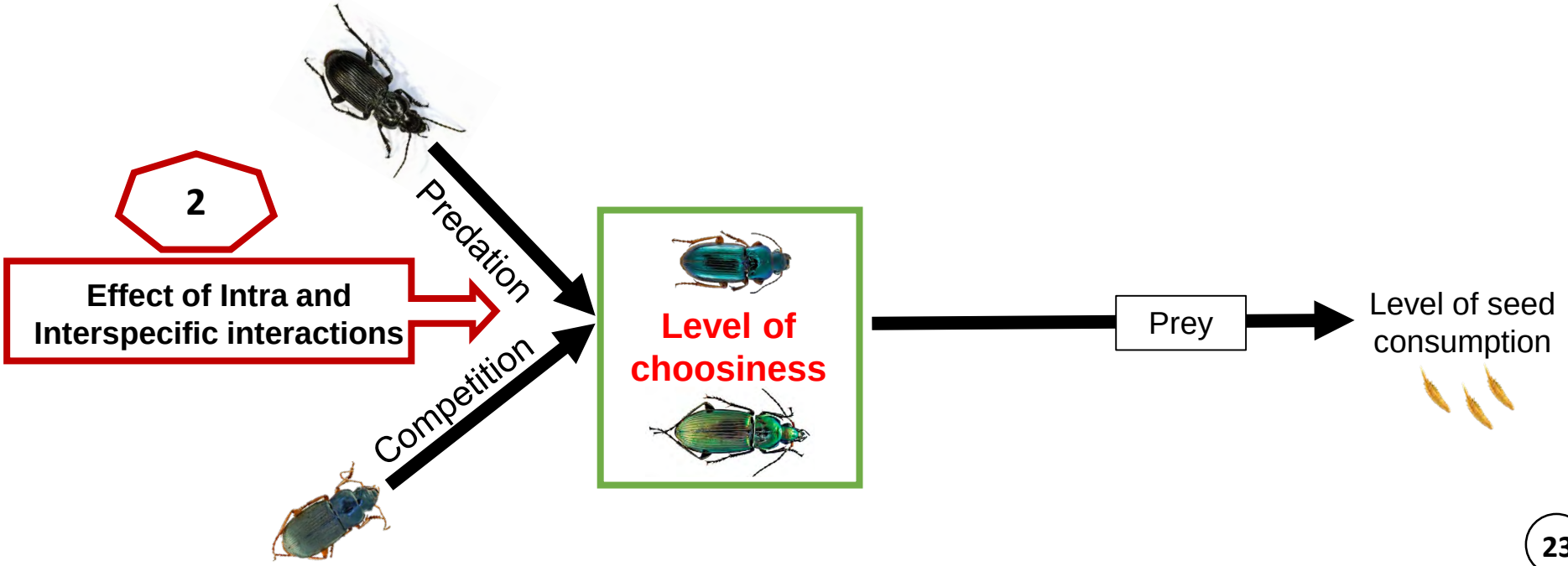
The two carabid species differed in their foraging behaviour

Do individuals adjust their level of choosiness according to the intra and interspecific interactions they encounter?

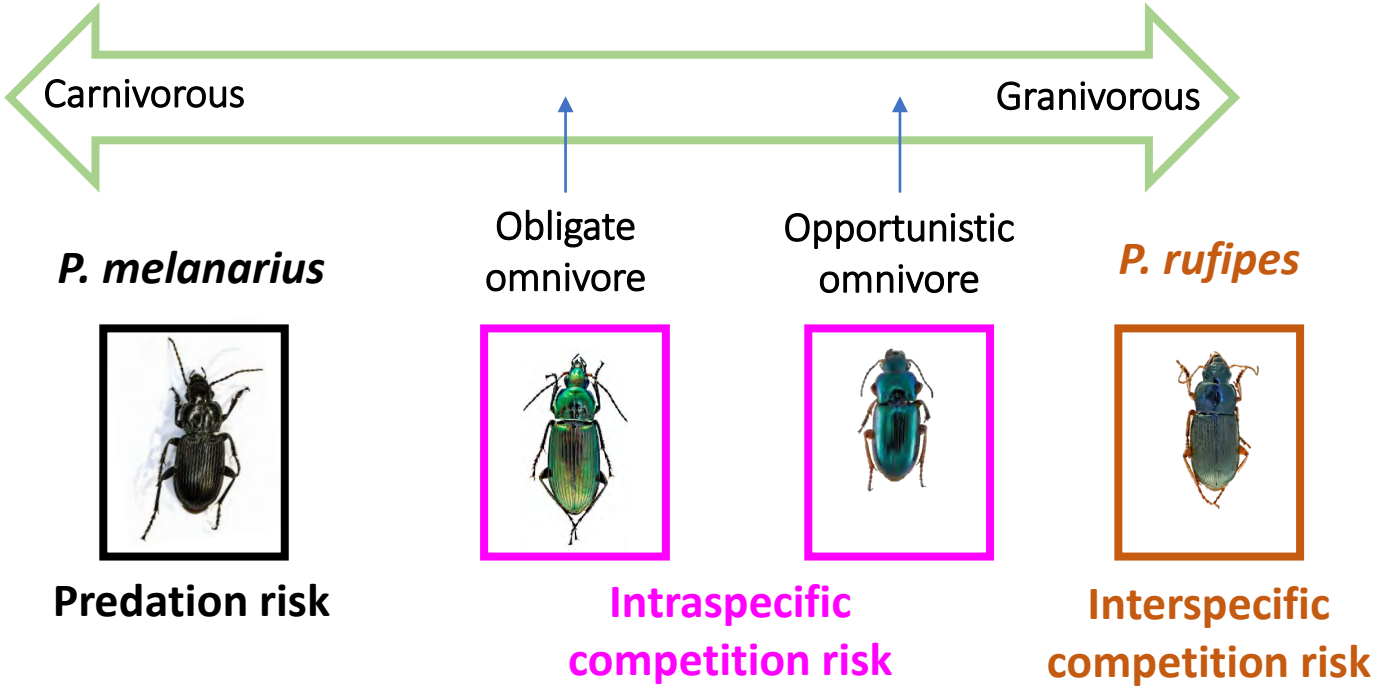
H: Both carabid species will adjust their level of choosiness according to the intra and interspecific interactions they encounter

H: Intensity of the behavioural adjustment to risk depends on:

- the relative importance of seeds in the carabid species diet
- the relative perception of the risk - danger



Used two other carabid species for testing interactions: one that eats a lot of seeds and one that is a invertebrate predator



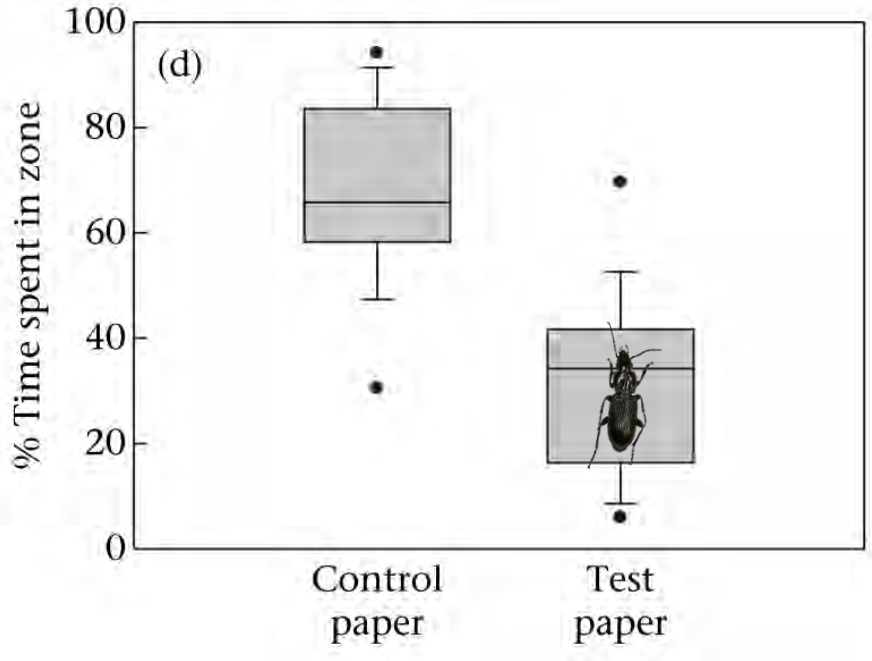
Preys on :

- **invertebrate predator** (Kromp, 1999)
- **other carabid species** (Currie et al. 1996)

Readily eats a large amounts of seeds in laboratory conditions
(Petit et al. 2014)

Use of olfactory cues instead of actual individuals to avoid confounding effects

(Guy et al. 2008)



A study showing perception and behavioural adjustment to olfactory cues by carabids

Papers saturated with **olfactory cues** instead of actual individuals

Avoid confounding effects of direct interaction between the focal individual under test, and the intraguild predators and competitors

Choice of a seed species that will allow change in individual levels of choosiness

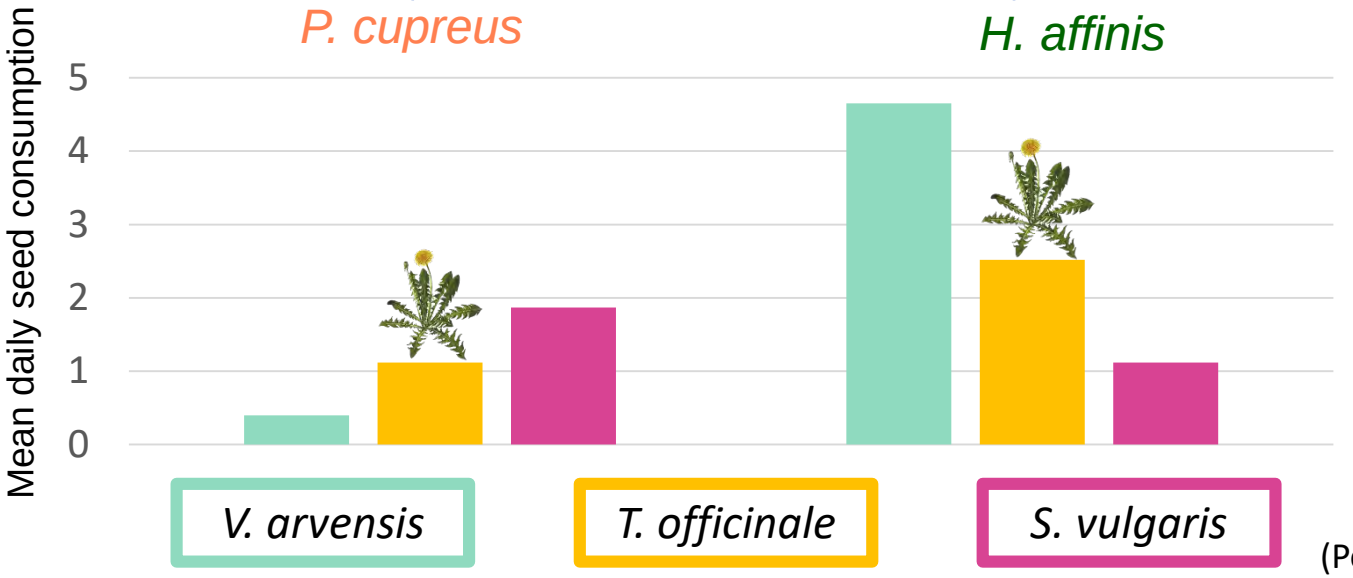
Taraxacum officinale

Multiple choice test

A moderatly but not highly preferred species

Carnivorous — Granivorous

P. cupreus — *H. affinis*



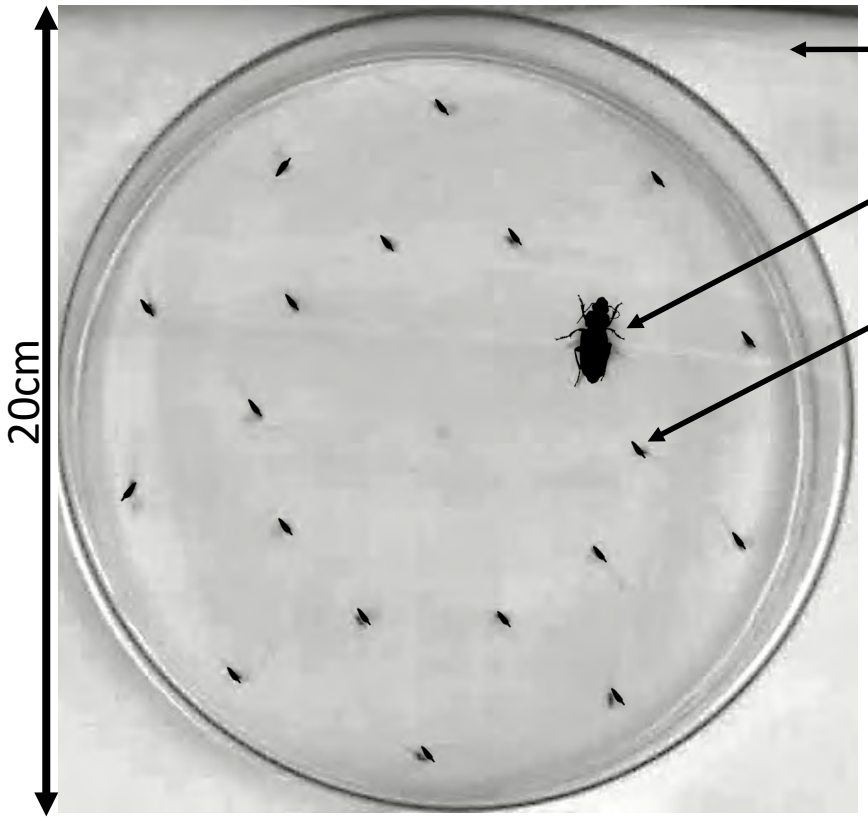
(Petit et al., 2014)

Set up for the assessment of changing in level of choosiness, under different interference interactions

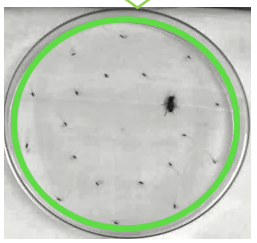
Harpalus affinis
N= 290

Poecilus cupreus
N= 288

Distributed in four treatments

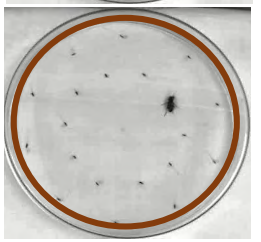


Control

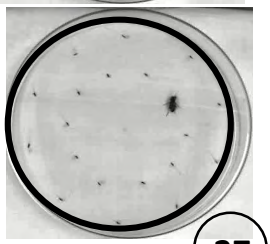


Intraspecific competition

Intraspecific competition



Predation

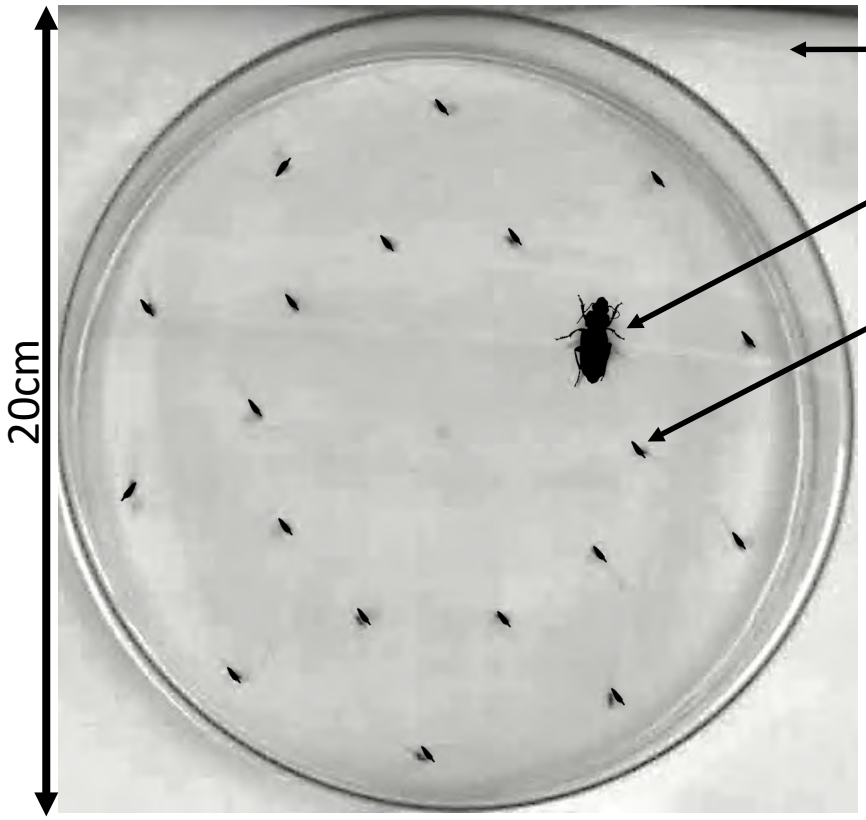


Set up for the assessment of changing in level of choosiness, under different interference interactions

Harpalus affinis
N= 290

Poecilus cupreus
N= 288

Observation: 1 hour



No-choice paradigm

Assessment of choosiness:

- Latency to first seed acceptance

- Total seed consumption

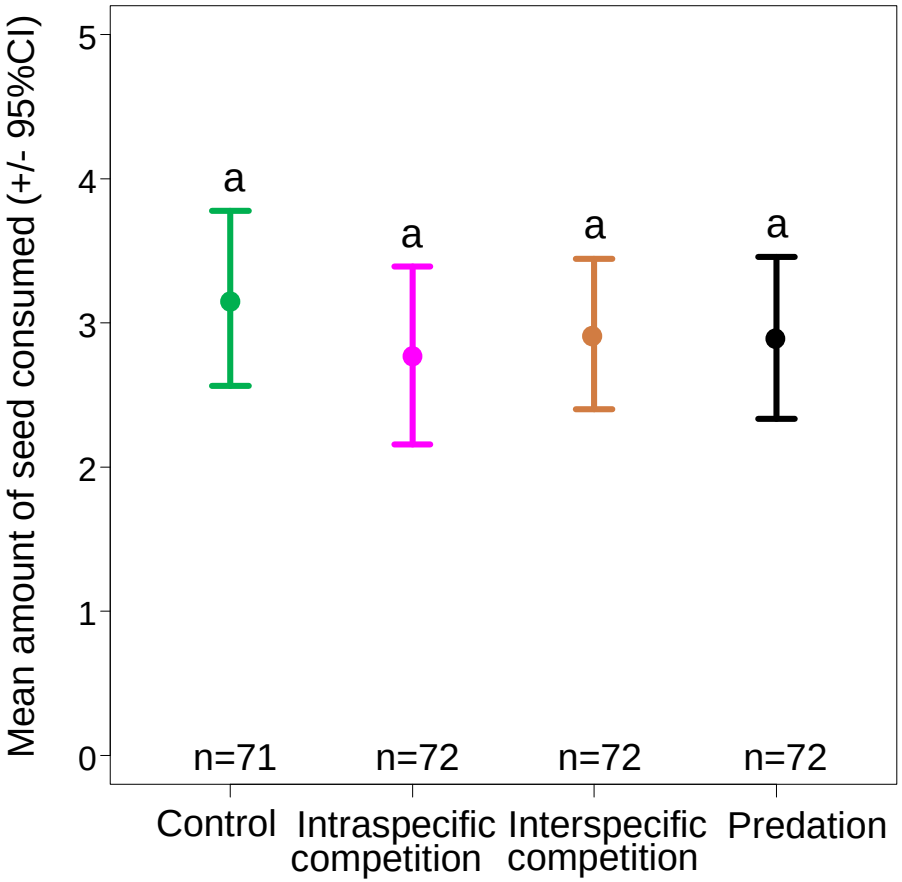
To control for change in seed encounter between treatments – confounding effect:

- Space use

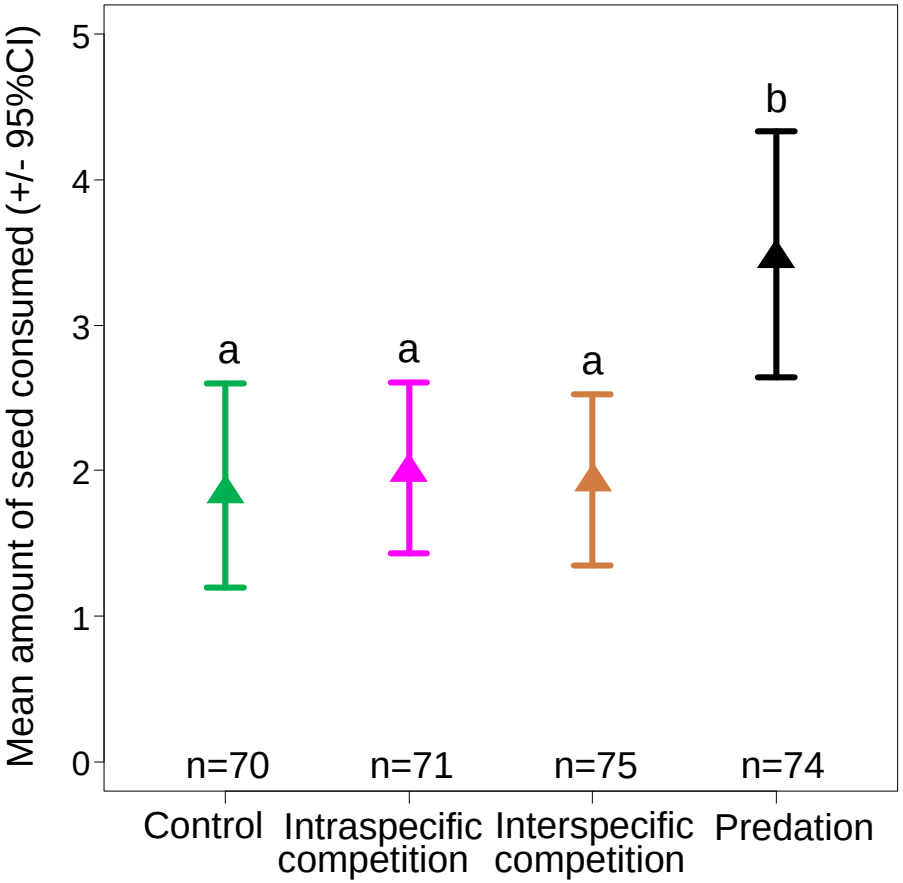
H. affinis increases seed consumption under predation risk

Observation: 1 hour

P. cupreus *(N=288)*



H. affinis *(N=290)*



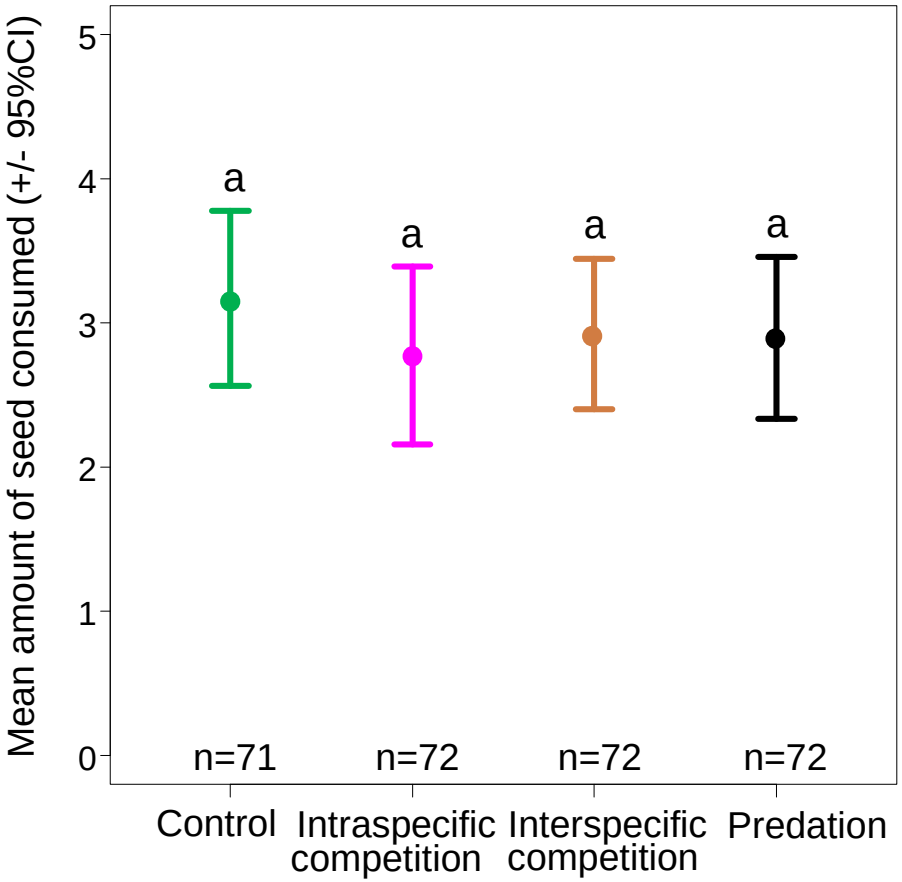
P. cupreus ate more seeds than *H. affinis* in the control treatment

(Charalabidis et al., 2017; Charalabidis et al., 2019)

H. affinis increases seed consumption under predation risk

Observation: 1 hour

P. cupreus *(N=288)*



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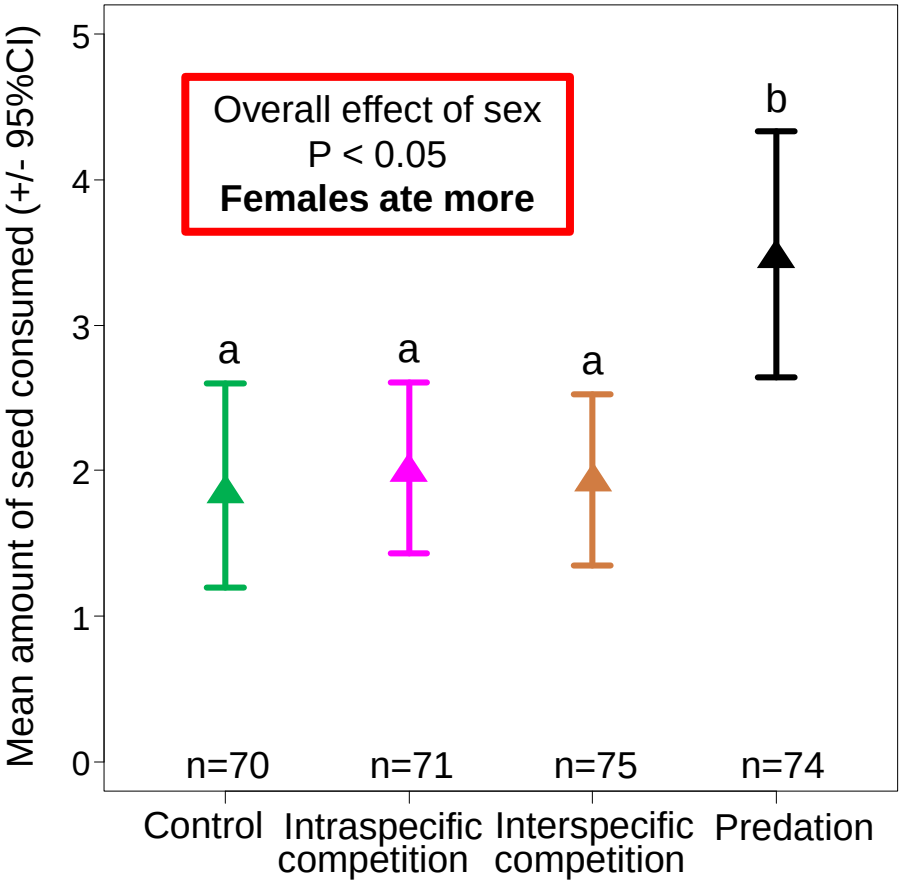


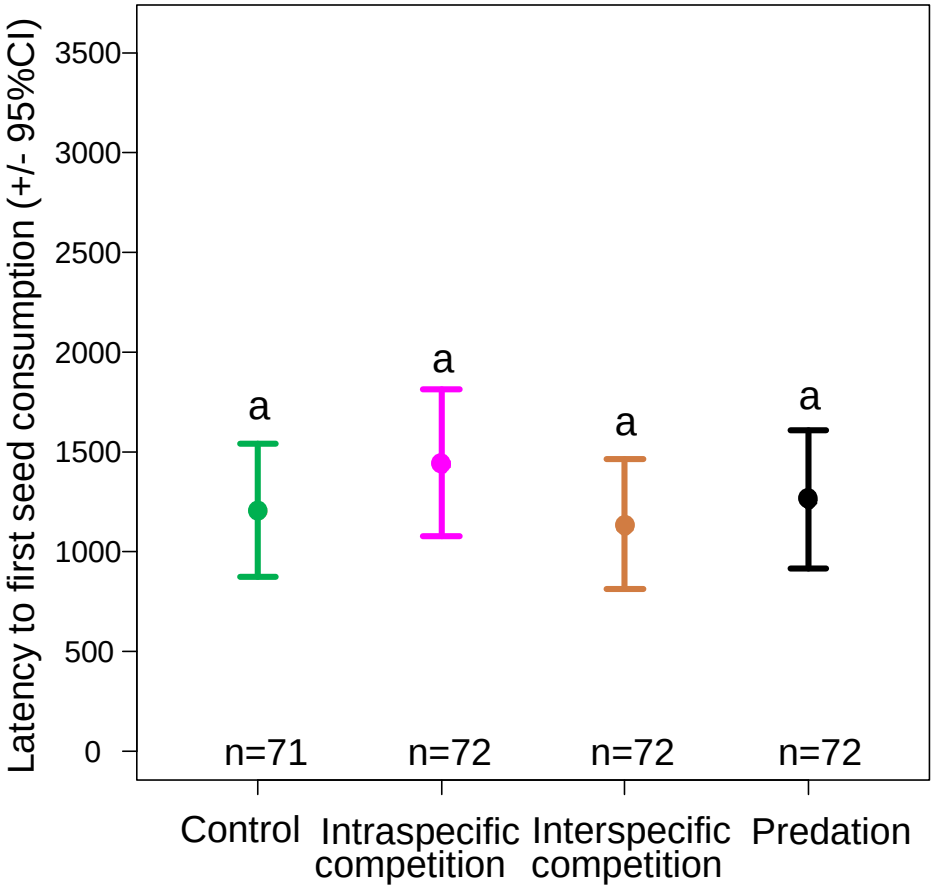
P. cupreus ate more seeds than *H. affinis* in the control treatment

(Charalabidis et al., 2017; Charalabidis et al., 2019)

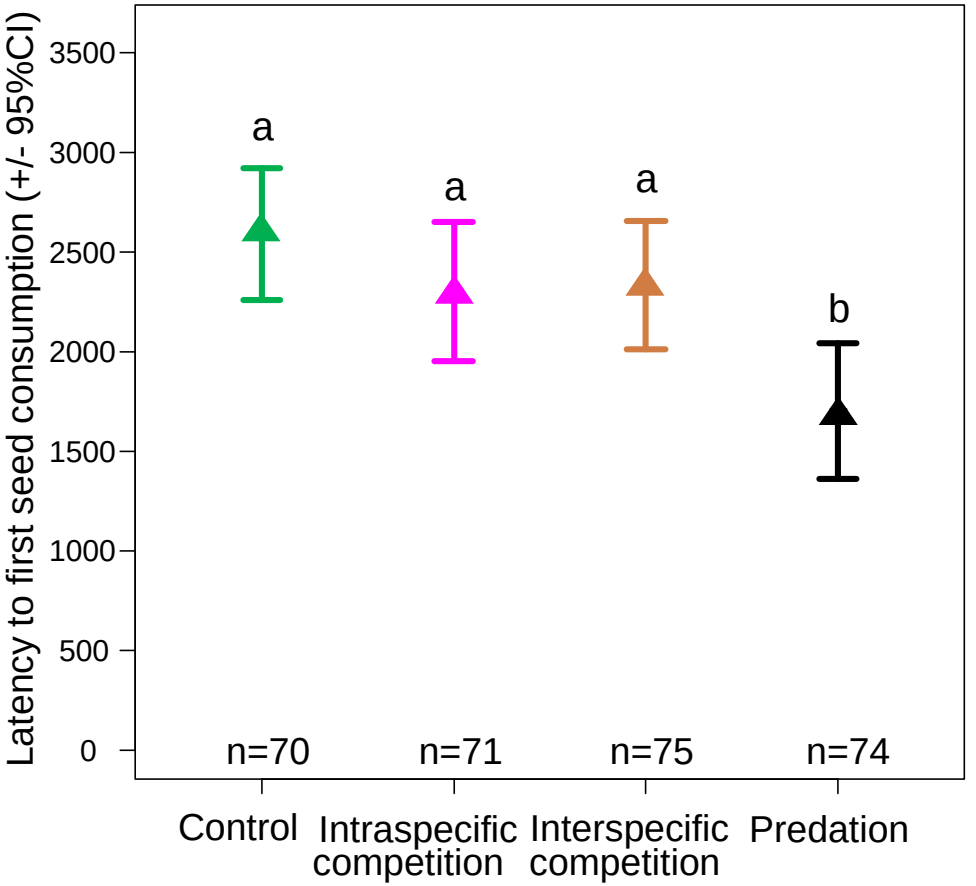
H. affinis accepts seeds earlier under predation risk

Observation: 1 hour

P. cupreus *(N=288)*



H. affinis *(N=290)*

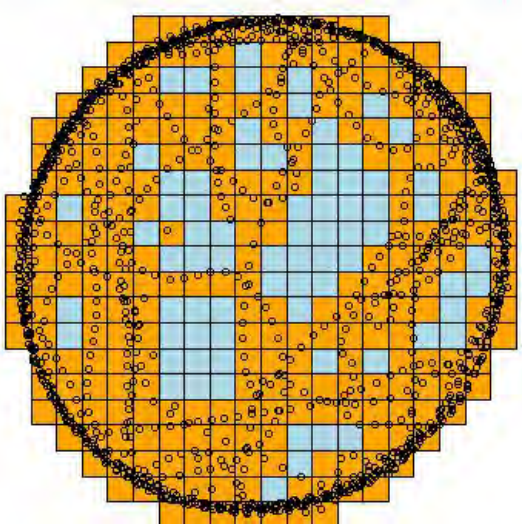


Overall, *P. cupreus* has lower choosiness for seeds of *T. officinale* than *H. affinis*

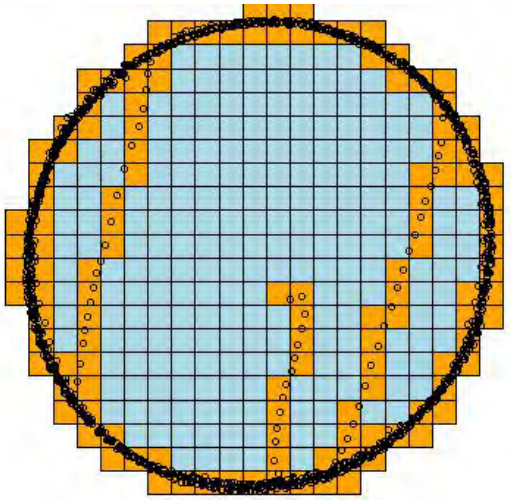
(Charalabidis et al., 2017; Charalabidis et al., 2019)

Space use did not differ between treatments for both carabid species

Two different potential scenario:



Higher space use = higher seed encounter



Lower space use = lower seed encounter

Space use:

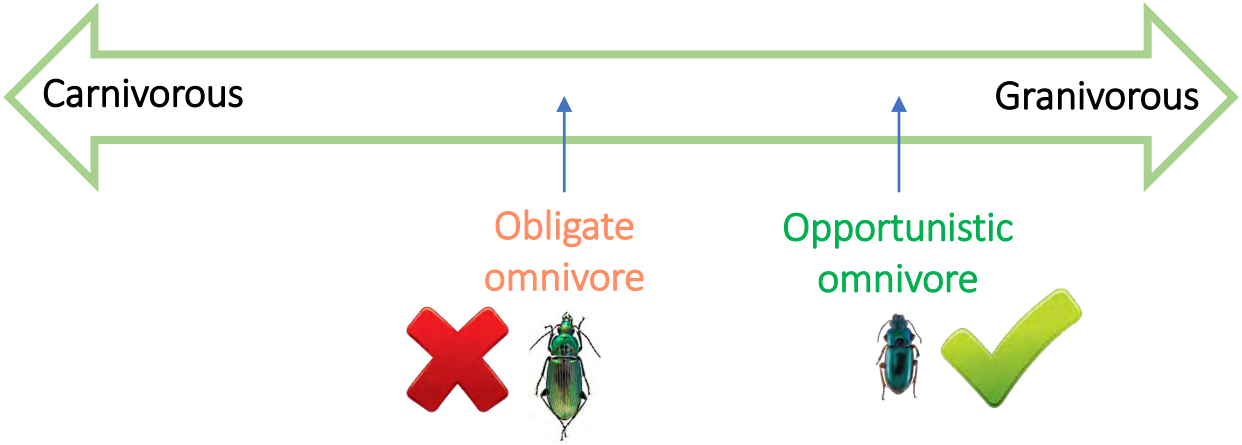
- Did not differ between treatments (~60%)
- was similar between the two carabid species

Higher seed consumption is due to a reduction in level in choosiness rather than higher seed encounter

(Charalabidis et al., 2017; Charalabidis et al., 2019)

Do individuals adjust their level of choosiness according to the intra and interspecific interactions they encounter?

H: Both carabid species will adjust their level of choosiness according to the intra and interspecific interactions they encounter



P. cupreus = no effect of the tested intra and interspecific interactions

H. affinis = Behavioural adjustment to the tested intra and interspecific interactions

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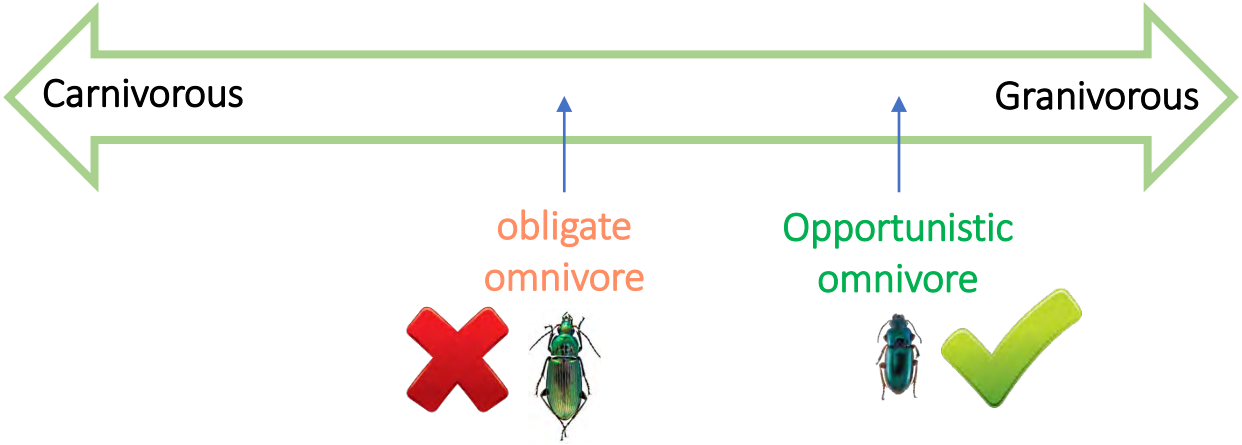


P. cupreus = no effect of the tested intra and interspecific interactions

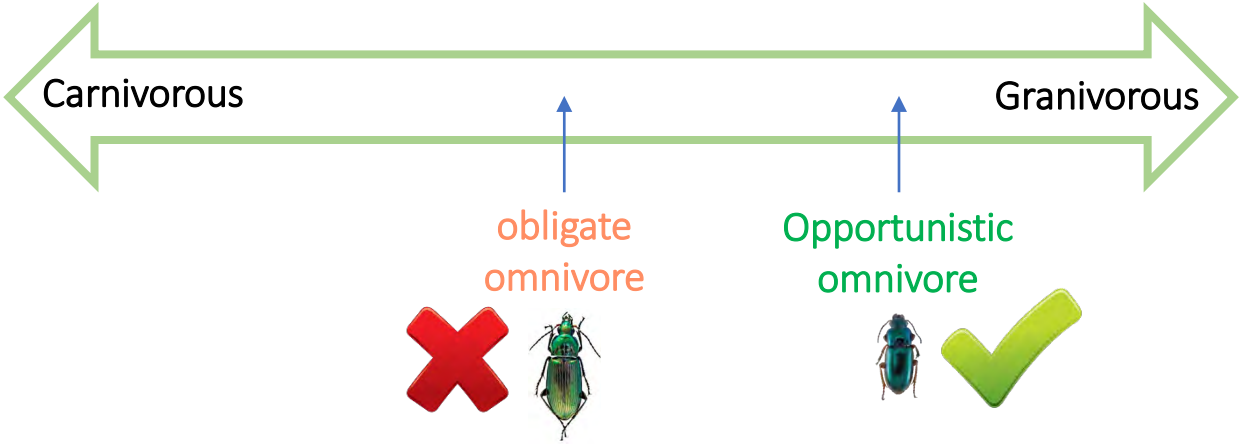
H. affinis = Behavioural adjustment to the tested intra and interspecific interactions

Olfactory cues are perceived

Intraguild interference can impact individual carabid levels of choosiness

Do individuals adjust their level of choosiness according to the intra and interspecific interactions they encounter?

H: Both carabid species will adjust their level of choosiness according to the intra and interspecific interactions they encounter



P. cupreus = no effect of the tested intra and interspecific interactions

H. affinis = Behavioural adjustment to the tested intra and interspecific interactions

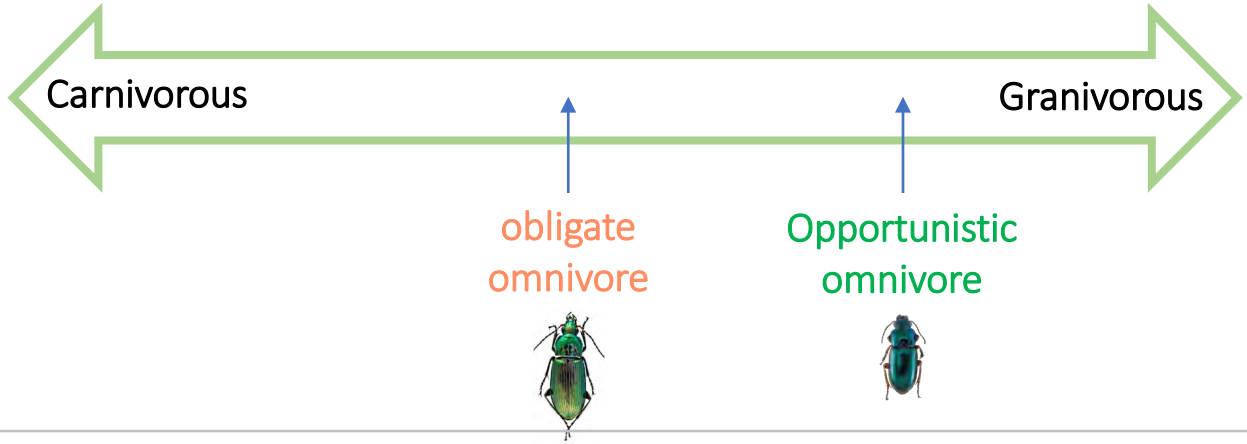
Relative importance of seeds in the diet may explain differences in behavioural adjustment

Olfactory cues are perceived

Intraguild interferences can impact individual carabid levels of choosiness

Do individuals adjust their level of choosiness according to the intra and interspecific interactions they encounter?

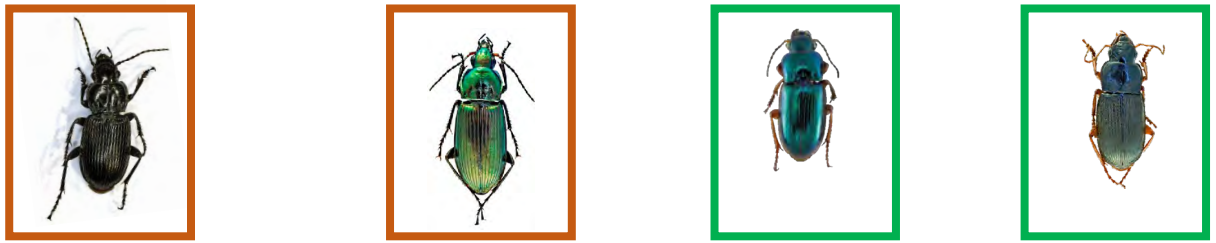
H: Both carabid species will adjust their level of choosiness according to the intra and interspecific interactions they encounter



P. cupreus = no effect of the tested intra and interspecific interactions

H. affinis = Behavioural adjustment to the tested intra and interspecific interactions

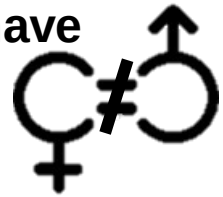
P. melanarius *P. cupreus* *H. affinis* *P. rufipes*



Tribu : Pterostichini Bonelli, 1810 *vs* **Tribu** : Harpalini Bonelli, 1810

Do individuals adjust their level of choosiness according to the intra and interspecific interactions they encounter?

H: Both carabid species will adjust their level of choosiness according to the intra and interspecific interactions they encounter

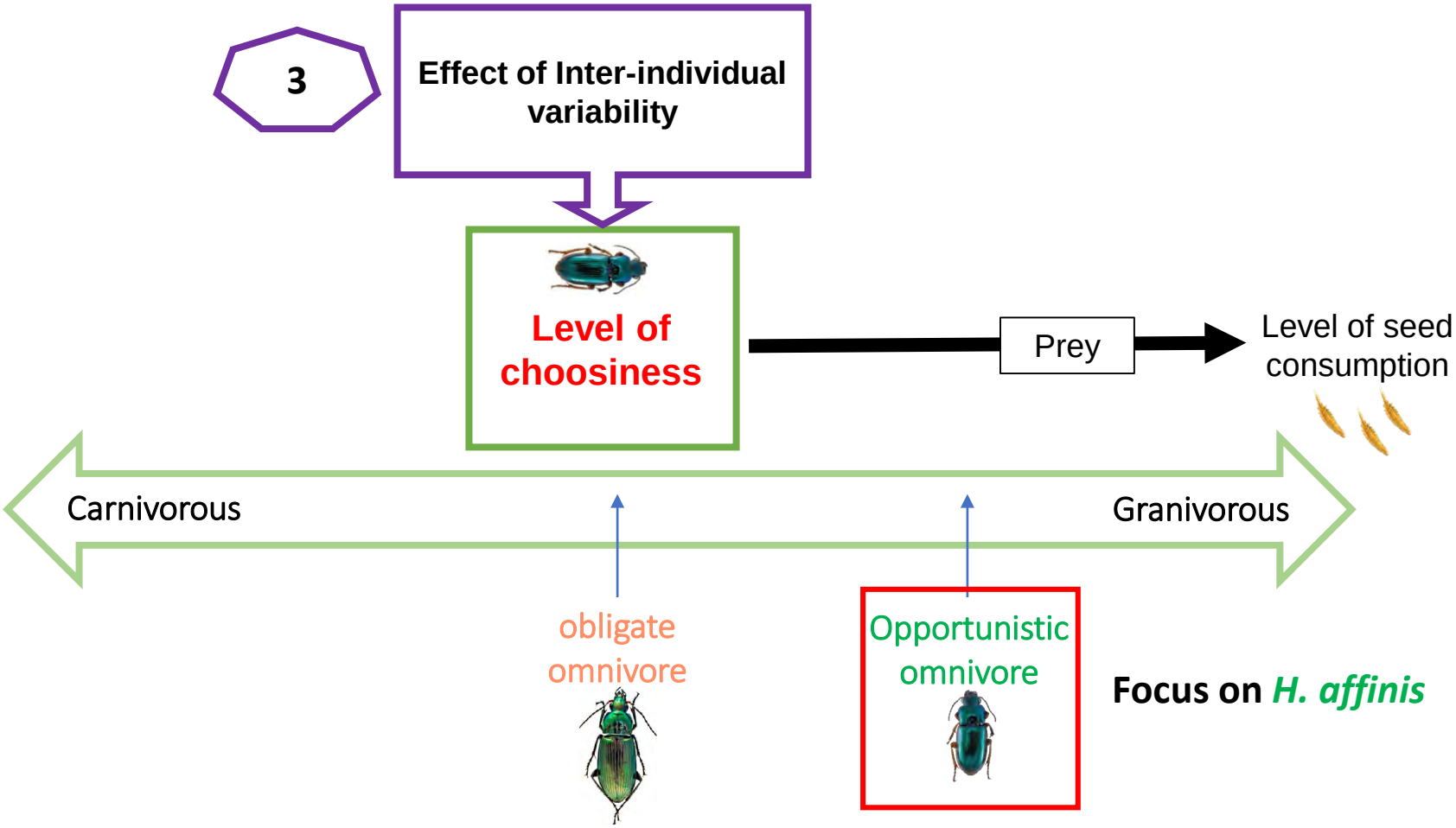
Sexes also behave differently  Females ate more than males

Sex differences in energetic requirement that could explain observed differences in total seed consumption in ***H. affinis***?

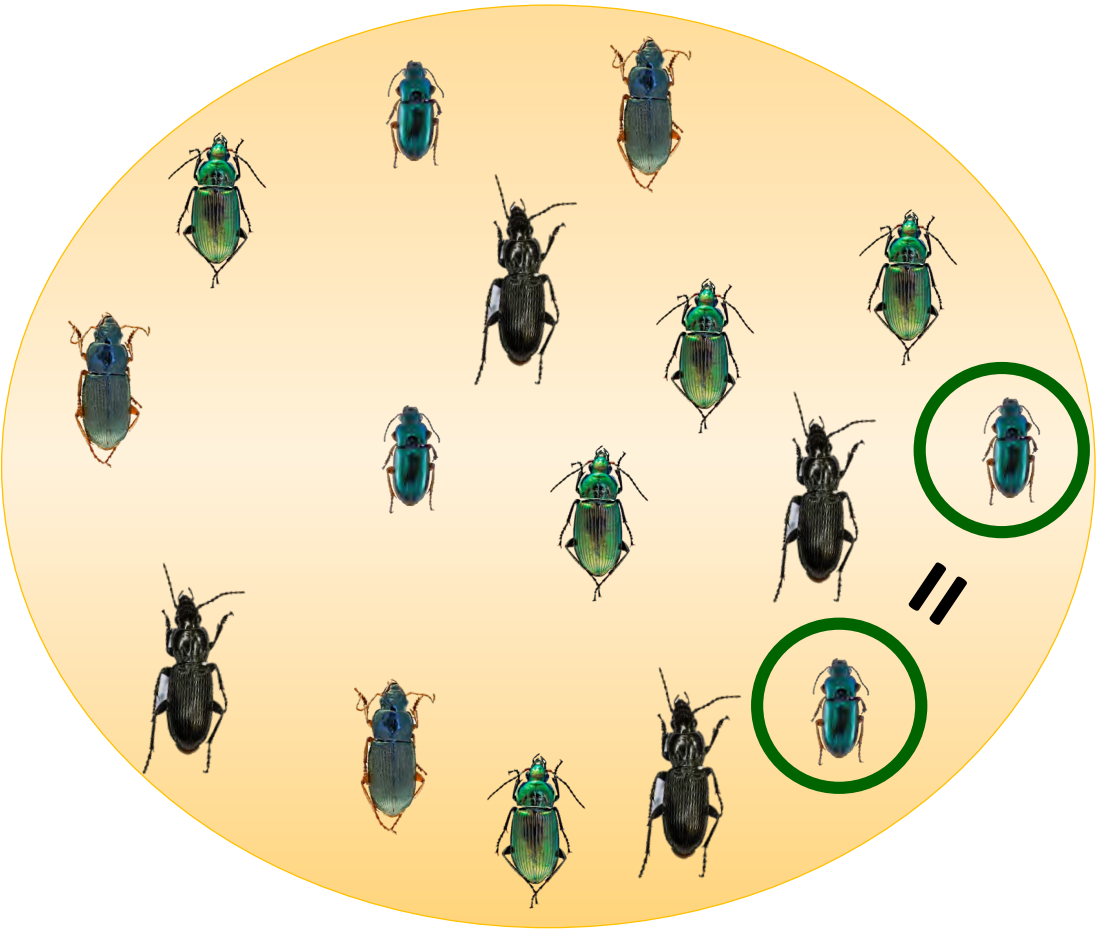
This result has also been observed in a different experiment + higher reduction in choosiness : Charalabidis et al. 2023

Do individuals differ in their level of choosiness for seeds

H: Level of choosiness will differ between carabids according to their **individual characteristics**

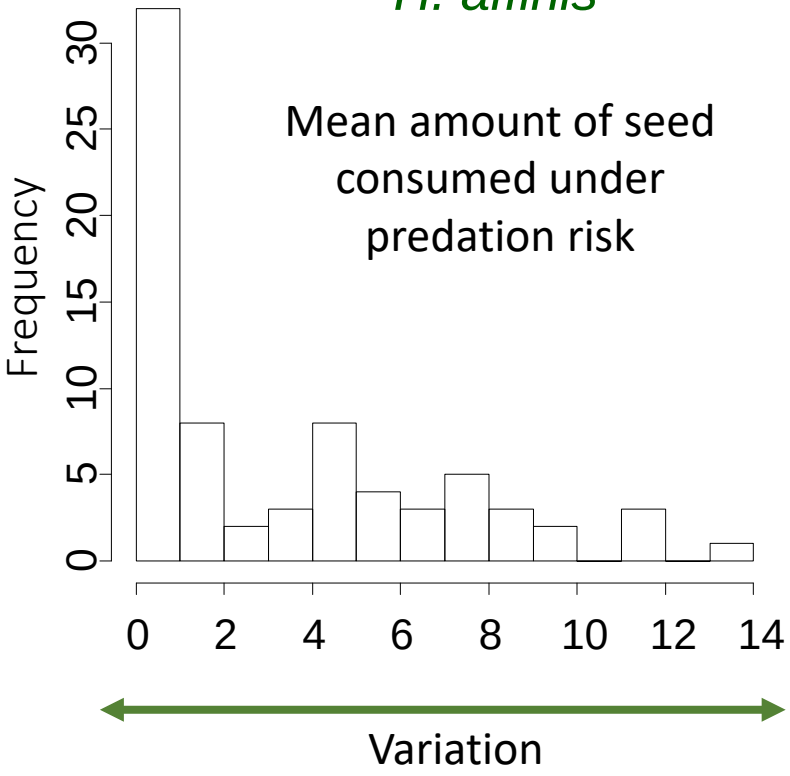


Results demonstrate inter-individual variability



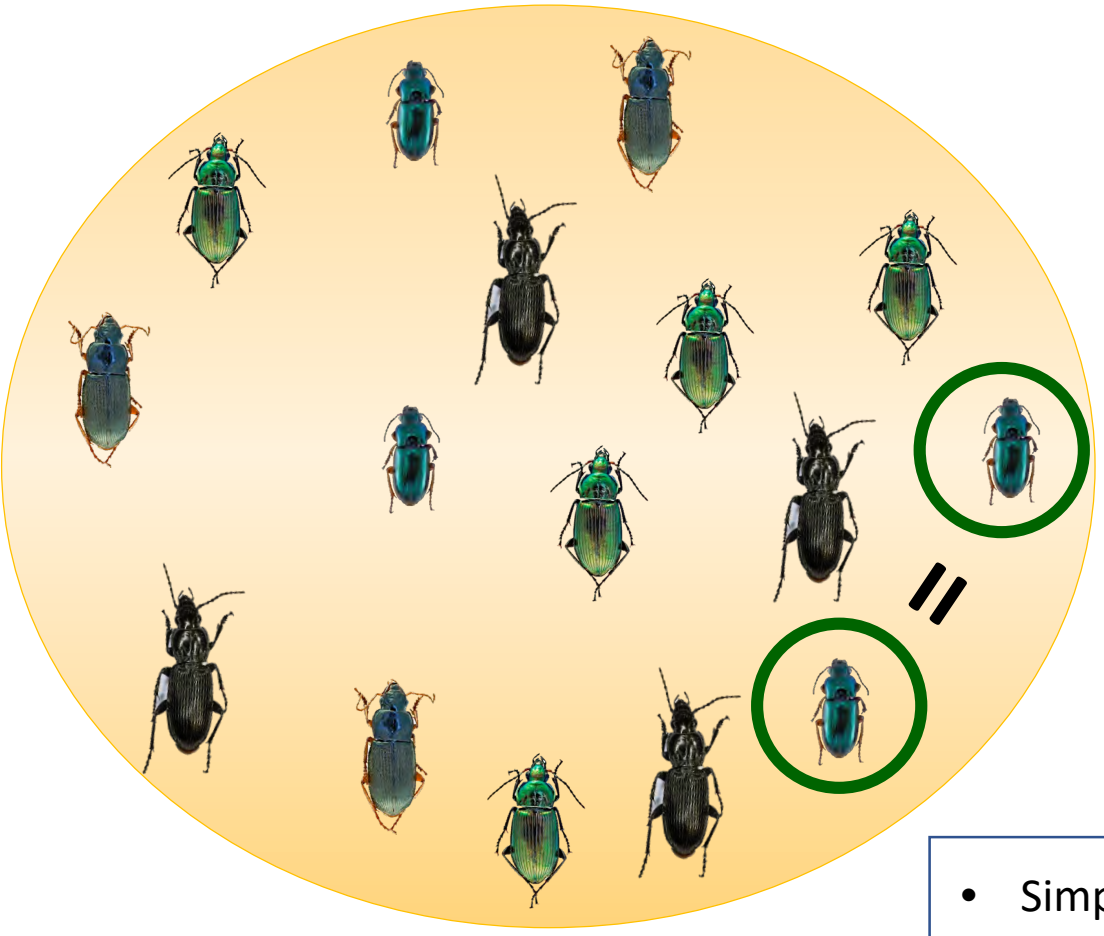
H. affinis

Mean amount of seed consumed under predation risk



Adapted from Charalabidis et al. 2017

Results demonstrate inter-individual variability



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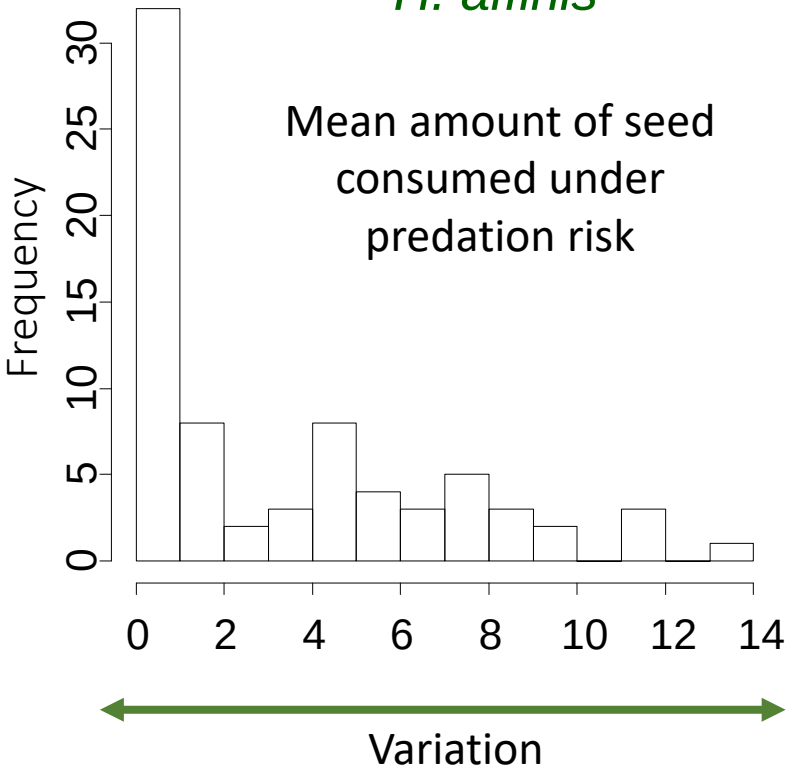
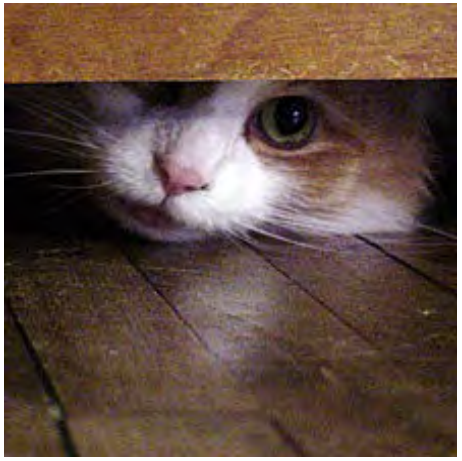


- Simple variation around an adaptive mean?
- Inter-individual variation in behaviour?

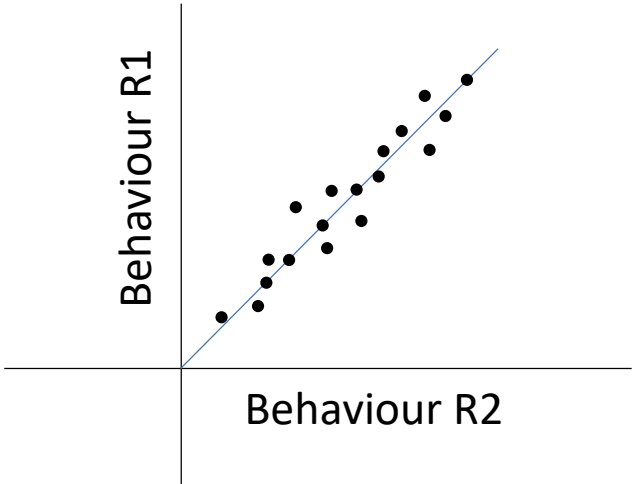
Do all individuals of a species follow a similar decision making process ?

Do personality traits exist in carabids and can they explain the observed variability in the level of choosiness?

Animal personalities = Individual temperament



Proactive ⟷ Reactive

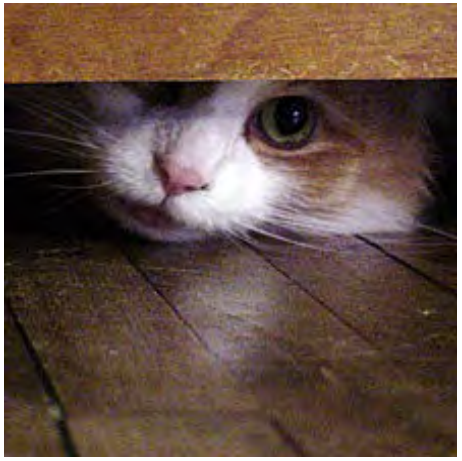


Repeatable patterns of individual behaviours that are consistent over time and across context

Exist across a wide variety of taxa (Réale 2007)

Do personality traits exist in carabids and can they explain the observed variability in the level of choosiness?

Animal personalities = Individual temperament



Proactive
Explorer
Not neophobic
Fast

Reactive
Low explorer
Neophobic
Slow

Difference in personality traits may explain difference in level of choosiness

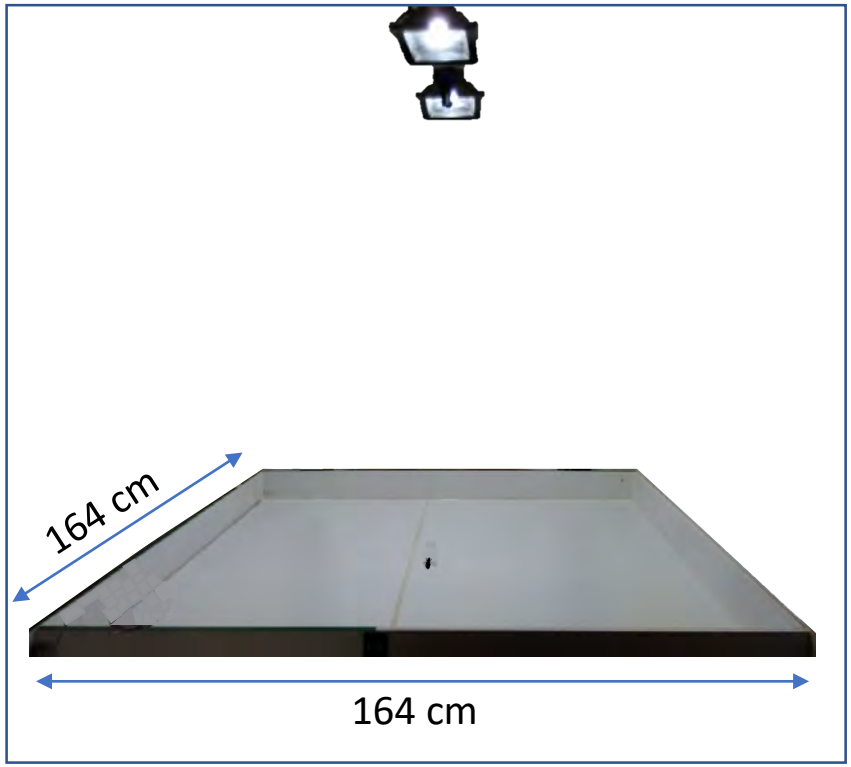
High risk tolerance
Higher consumption under predation risk

Low risk tolerance
Lower consumption under predation risk

(Koolhaas et al., 1999)

Proactive individuals show higher exploration behaviours than reactive ones

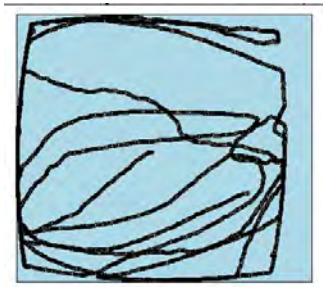
10 minutes video - recording



Harpalus affinis
N= 110

- **Total distance moved**:

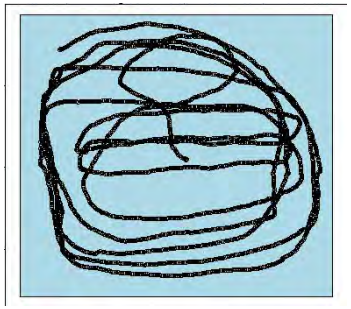
Proactive



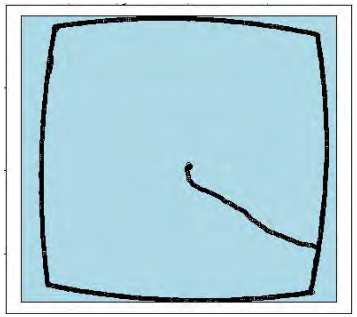
Reactive

- **Space use:**

Proactive



Reactive



Same total distance moved but lower space use

Could morphological characteristics or sex differences explain variation in levels of choosiness?

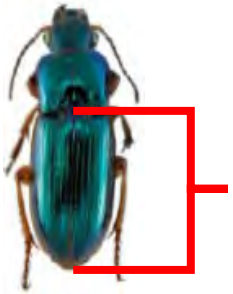
Larger individuals have higher energetic requirements?

Females have higher energetic requirements?

Differ in risk tolerance?

Could morphological characteristics or sex differences explain variation in levels of choosiness?

Larger individuals have higher energetic requirements?



elytra size measurement

♂ ♀

Females have higher energetic requirements?

Individual sex

Immunity traits could differ between wild individuals and between sex and impact individual levels of choosiness

Having high immune defense is costly

Immune activity has been shown to increase the overall energetic requirements of individuals

(Hess et al. 2015)

To maintain immunity, individuals may differ in their level of choosiness for food items

Higher level of choosiness to avoid investing time in bad quality items

Lower level of choosiness to ensure resource acquisition

Risk tolerance might also differ between individuals based on their immune traits

Sex differences and higher pathogen encounter rates and pesticide exposure could induce variation in individual immune defenses

Wild caught individuals used in test

Differ in pesticides exposure and encounter with pathogens

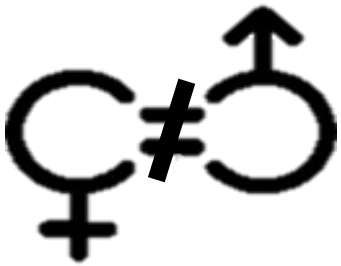
=

May differ in their immune defenses

(James & Xu, 2012)

Sex differences in immune traits were already shown in carabids

(Giglio et al., 2016,2017)



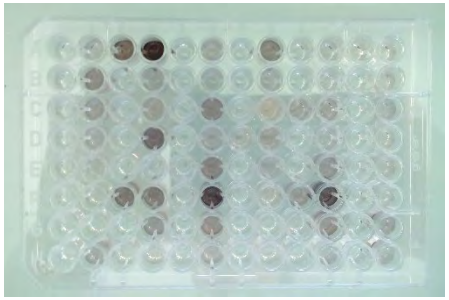
High variability in immune defenses could exist in our tested individuals

How to measure immunity traits in carabids: use of three key insect immune parameters

Harpalus affinis
N= 101
9 individuals died

Hemolymph samples

1) Phenyloxidase (PO) activity and 2) total PO activity



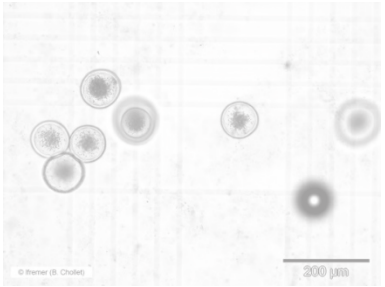
\+ **Enzymatic activity** -

High total PO activity = High immune defenses

Innate immune defense
against intruding pathogens
-Enzymatic cascade-

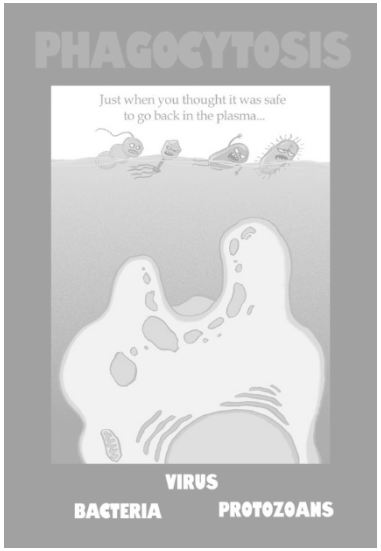
Spectral absorbance

3) Concentration of circulating hemocytes



Invertebrate immune system cells

Cellular defenses like phagocytosis and encapsulation



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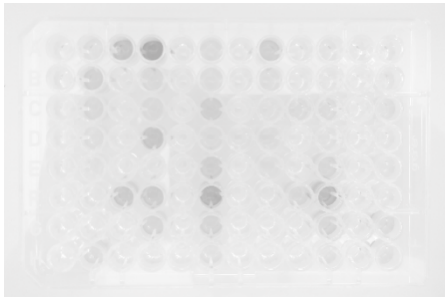

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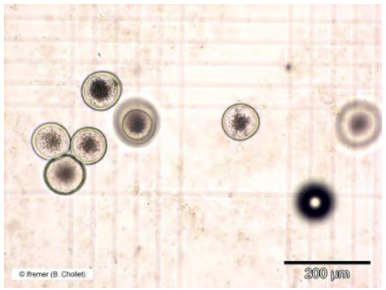

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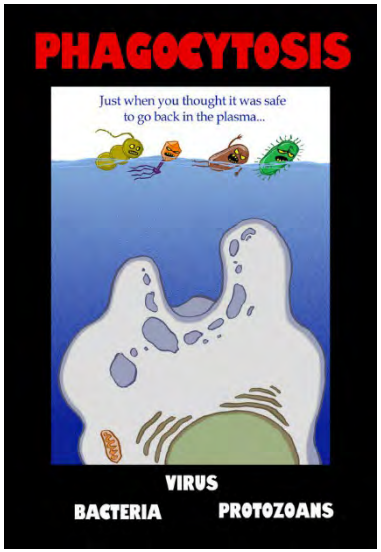

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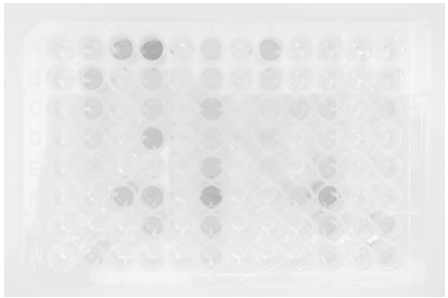

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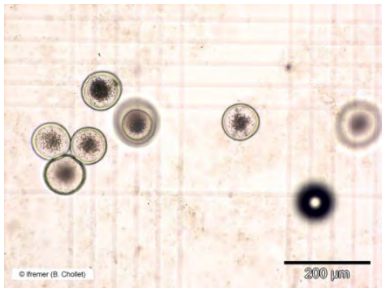

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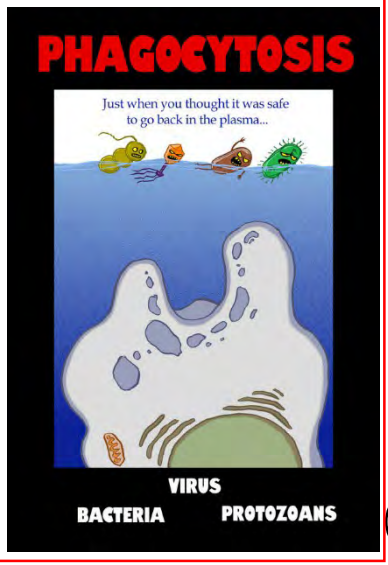
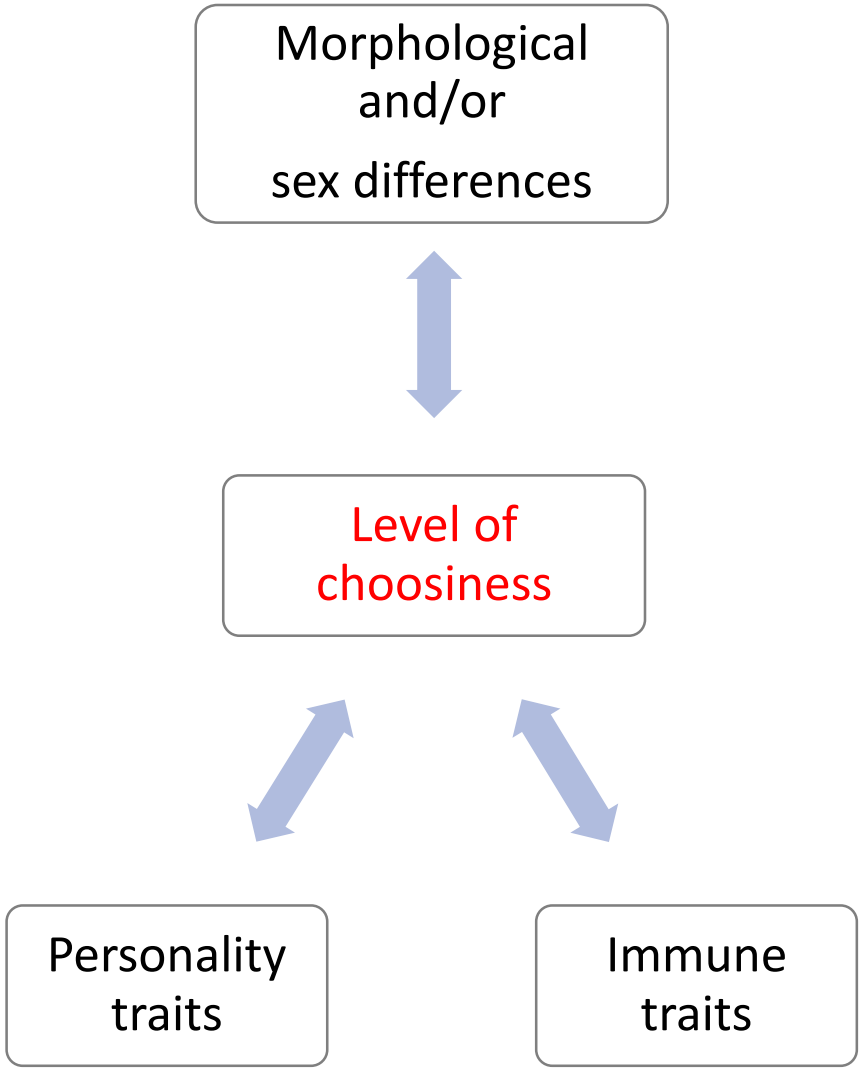


Which combination of personality traits, morphological differences, sex differences and immunity traits best explain individuals variability in the level of choosiness?



Measure of tested individual's level of choosiness

One hour recording

Only predation treatment

Assessment of individual levels of choosiness:

Latency to first seed acceptance

Proportion of individuals eating (feeding motivation)

Harpalus affinis

N= 101

Measure of tested individual's level of choosiness

One hour recording

Only predation treatment

Assessment of individuals levels of choosiness:

Latency to first seed acceptance

Proportion of individuals eating (feeding motivation)

- Ate or not during the test

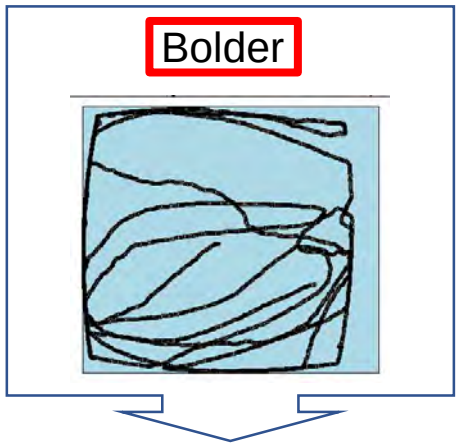
Harpalus affinis

N= 101

Personality could be linked to higher immune defenses and thus higher energetic requirements

(Real et al., 2010)

Pace-of-Life Syndrome hypothesis



Higher parasite-encounter rates

Higher immune system

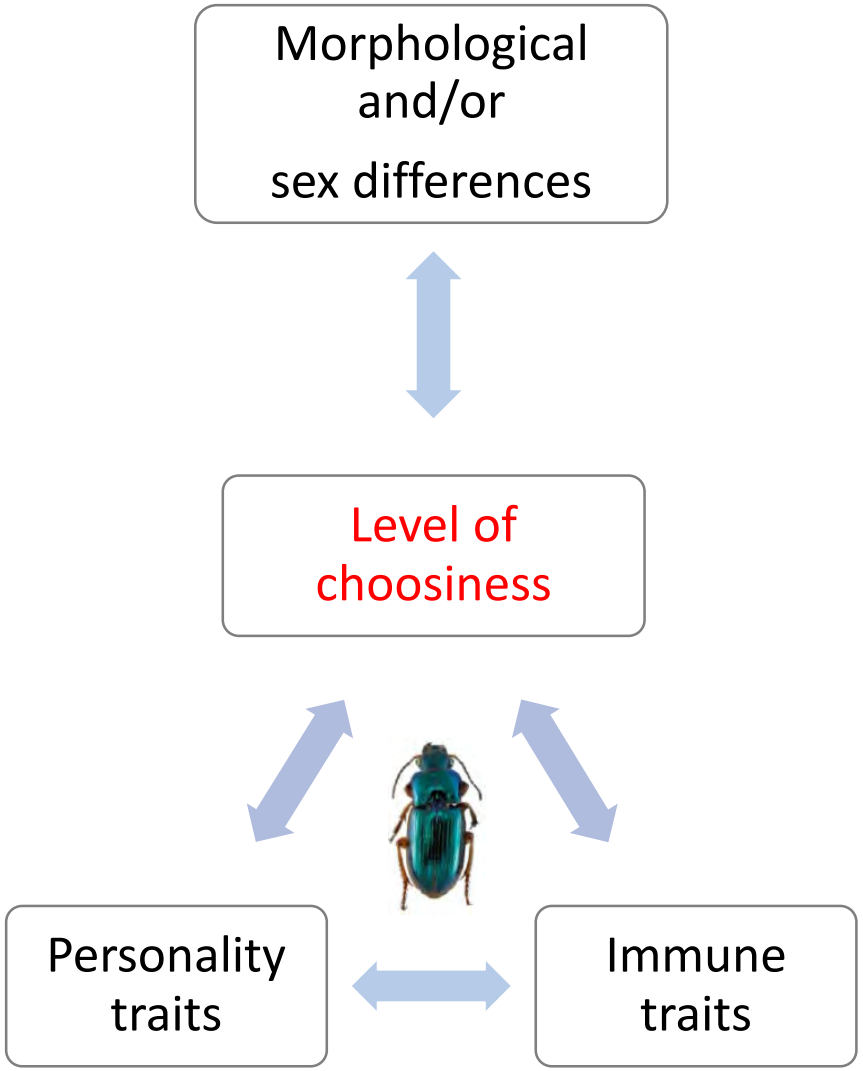
Morphological and/or sex differences

Level of choosiness

Personality traits

Immune traits

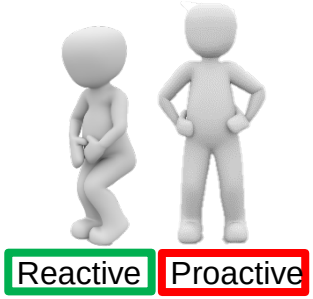
Which combination of personality traits, morphological differences, sex differences and immunity traits best explain individuals variability in the level of choosiness?

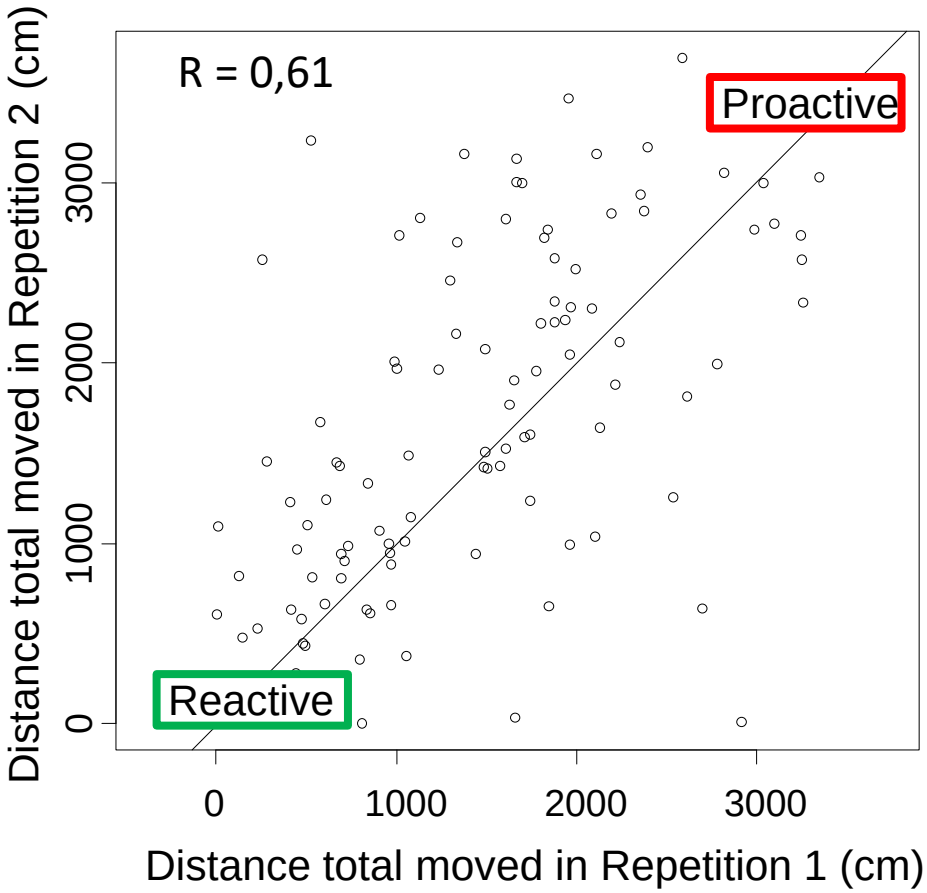


H. affinis individuals differ in personality

Harpalus affinis
N= 110

10 minutes video - recording





Highly **repeatable traits**
High variability between individuals

H. affinis individuals differ in personality

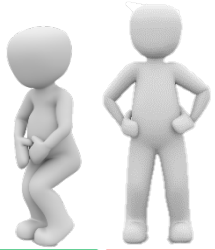
No sex effect – No effect of size

Intraclass correlation coefficient of Nakagawa and Schielzeth (2010)

Differences in levels of choosiness are not explained by personality traits in *H. affinis*

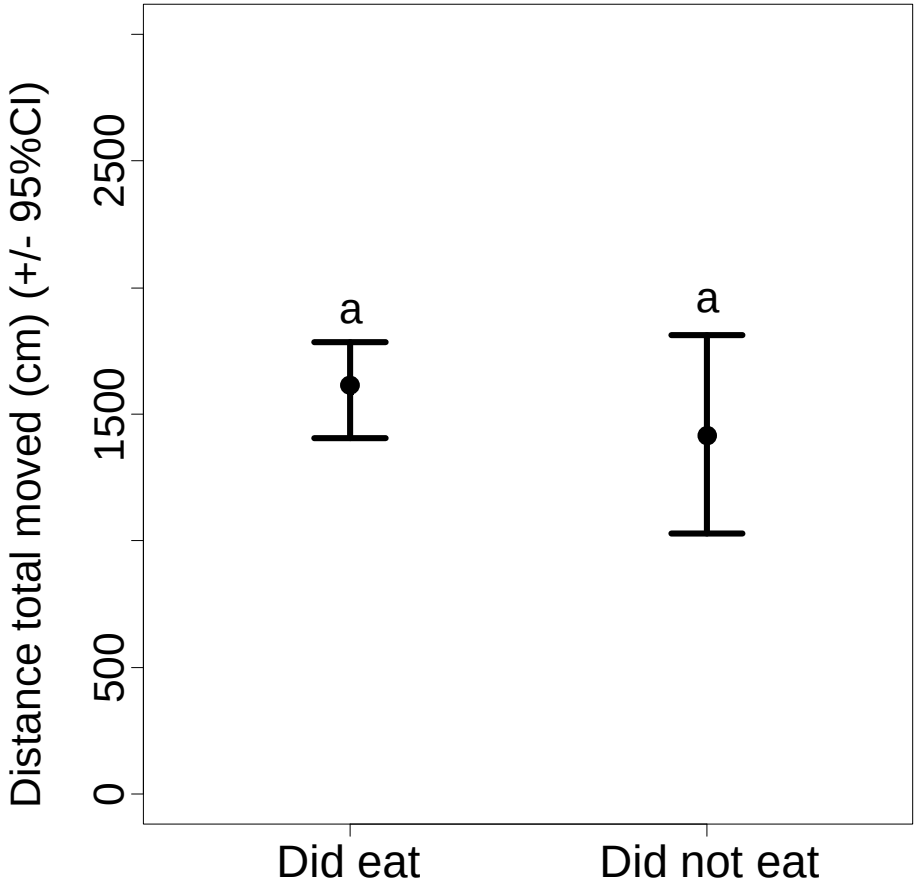
One hour recording

Harpalus affinis
N= 101



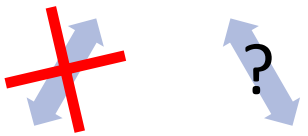
Proactive

Reactive



Personality did not impact individual level of choosiness

Level of choosiness

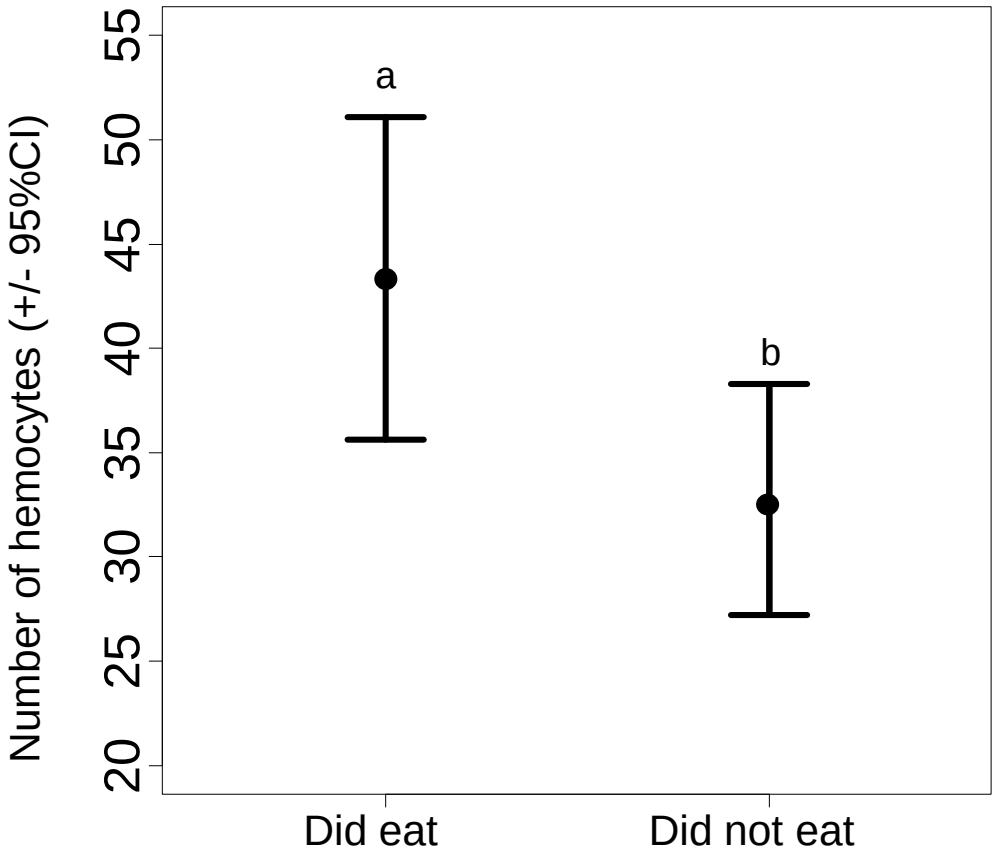


Personality traits ? Immune traits

Number of hemocytes was related to individual levels of choosiness

Harpalus affinis

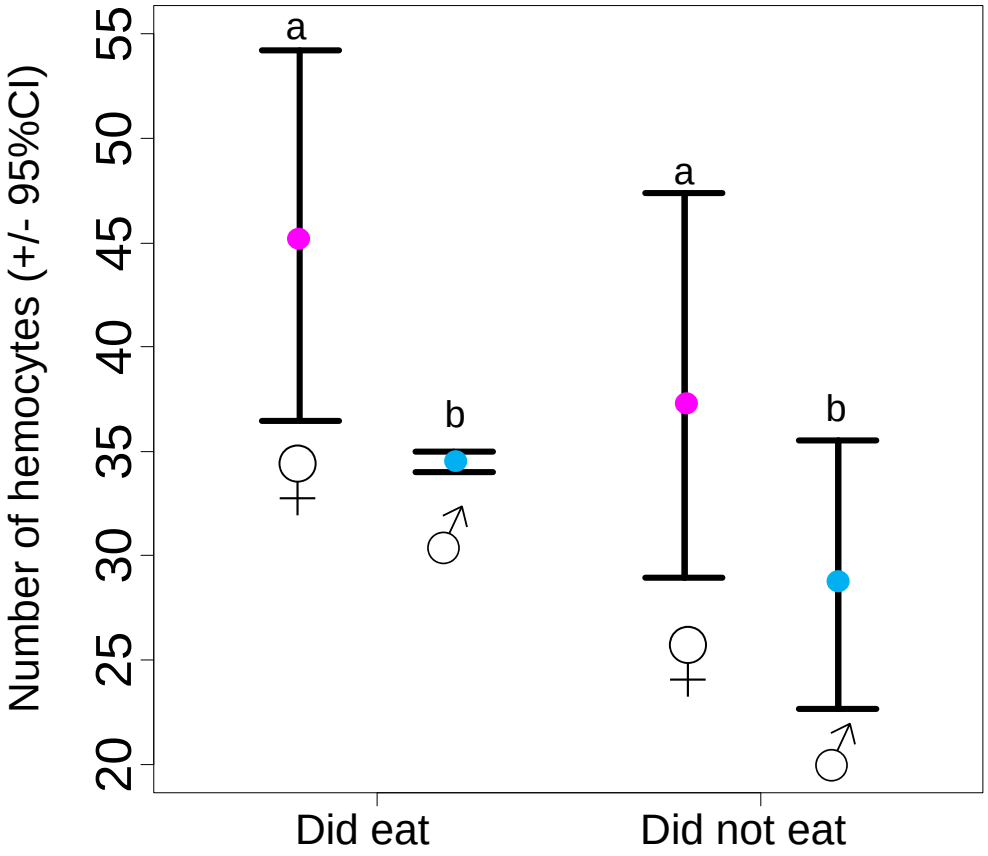
N= 101



Link between number of hemocytes and level of choosiness was a sex effect

Harpalus affinis
N= 101

♀ n= 47
♂ n= 54



Number of hemocytes (immune traits) did not impact carabid level of choosiness

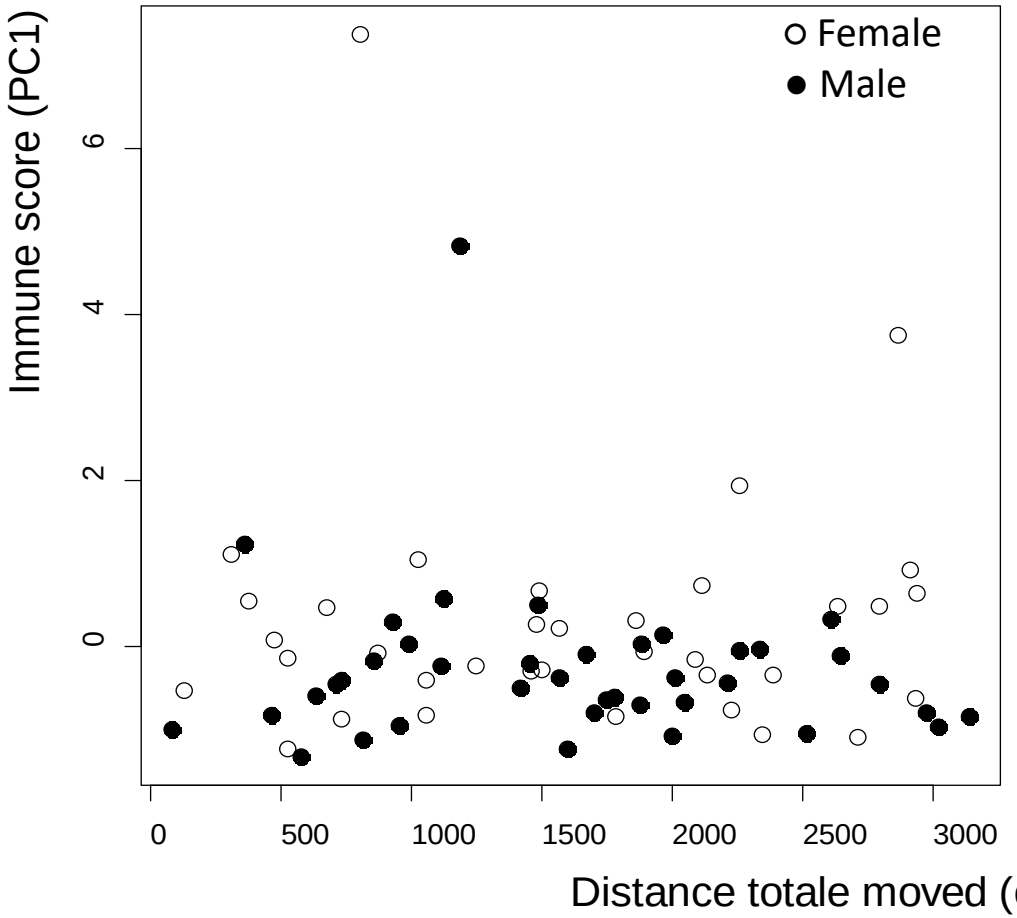
Level of choosiness

Personality traits ? Immune traits

No link between carabid immune scores and personality

Harpalus affinis

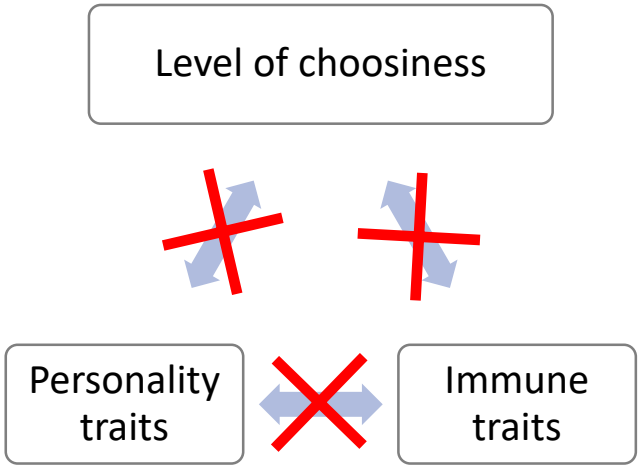
N= 101



Reactive ⟷ Proactive

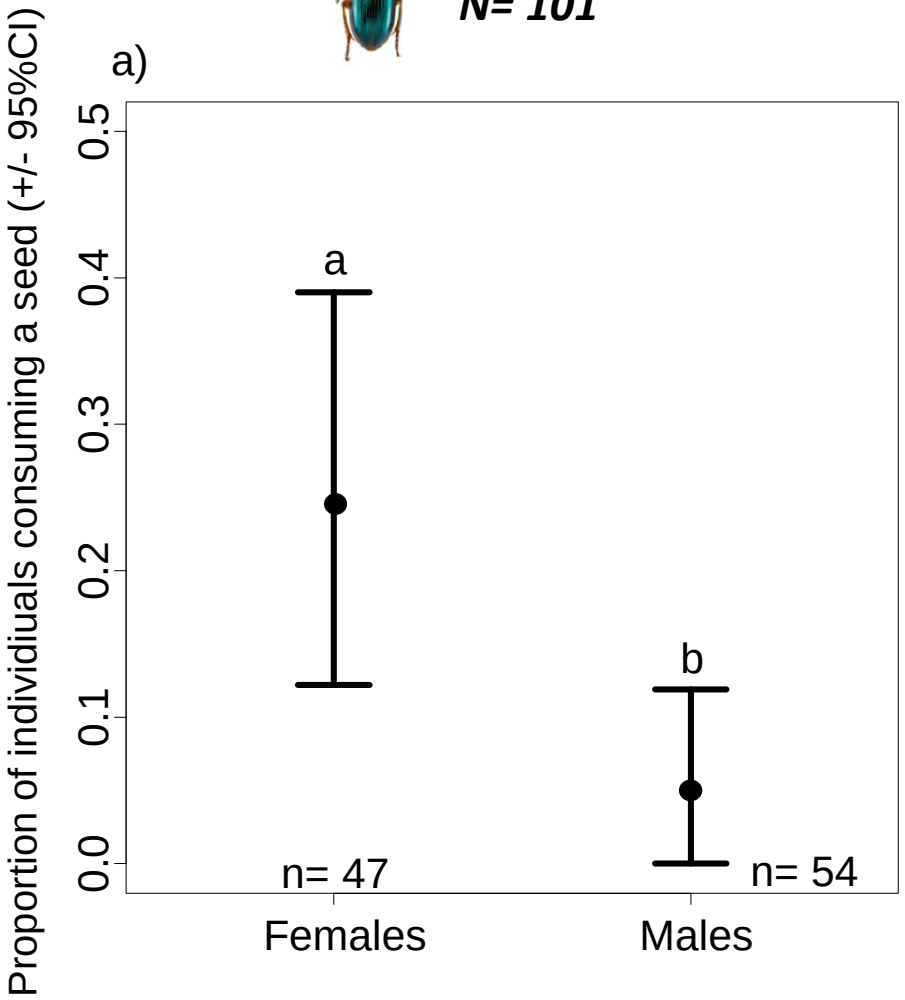
Individual immune score is not linked to personality trait

Our results contradict the Pace-of-Life Syndrome hypothesis:



Levels of choosiness differed between the sexes

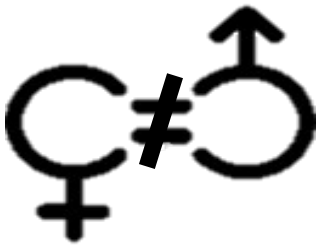
Harpalus affinis
N= 101



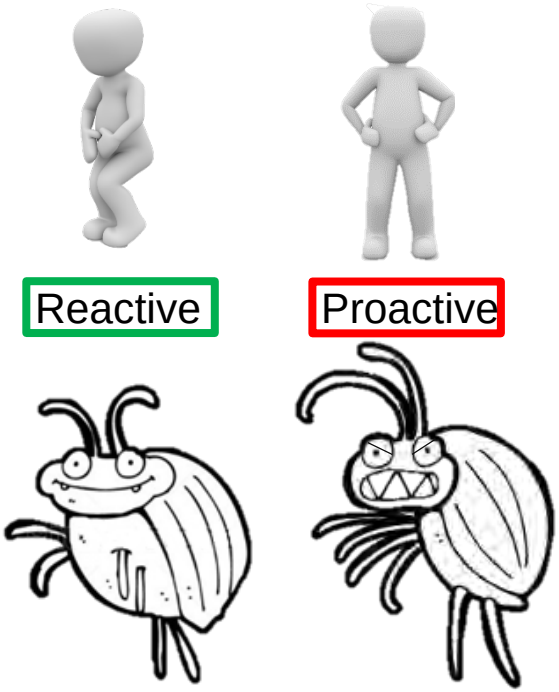
Females ate earlier and ate more in comparison to males

No effect of size in level of choosiness

Bigger females did not eat more than smaller ones

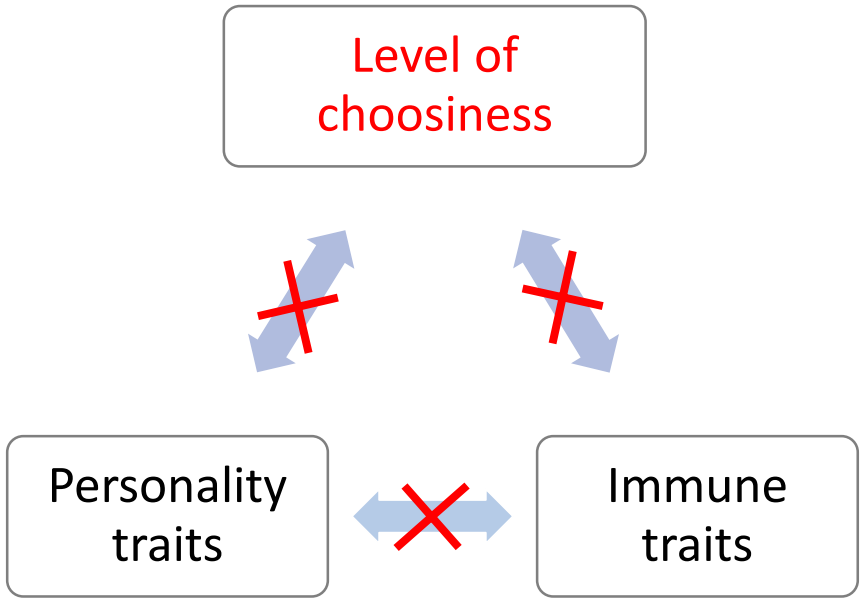


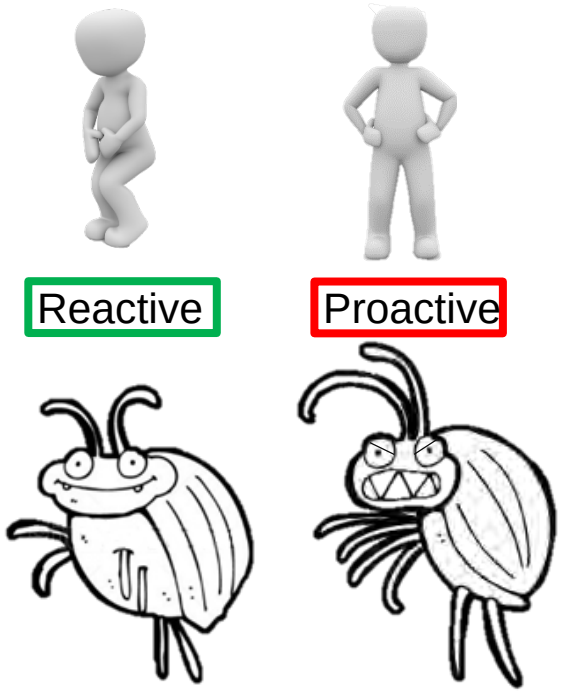
Which combination of personality traits, morphological differences, sex differences and immunity traits best explain individuals variability in the level of choosiness?



Personality traits exist in carabids

Which combination of personality traits, morphological differences, sex differences and immunity traits best explain individuals variability in the level of choosiness?

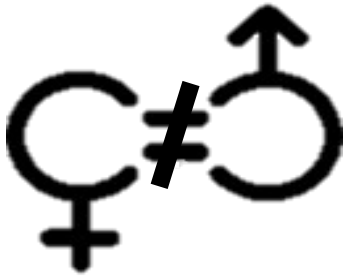




Personality traits exist in carabids

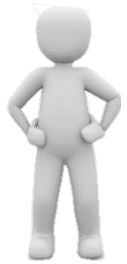
Which combination of personality traits, morphological differences, sex differences and immunity traits best explain individuals variability in the level of choosiness?

~~Morphological and/or~~ sex differences



Females eat more than males

Reactive



Proactive

Personality traits exist in carabids

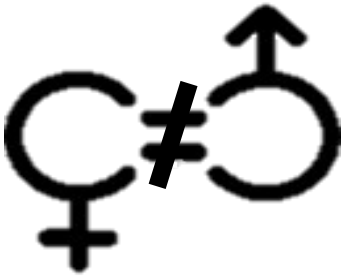
Level of choosiness

Personality traits

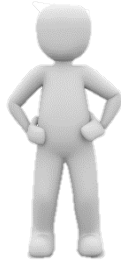
Immune traits

Which of personality traits, morphological differences, sex or immunity traits best explain individuals variability in level of choosiness?

~~Morphological and/or~~ sex differences



Females eat more than males



Reactive

Proactive

Level of choosiness

- Wrong metric to assess choosiness?
- Effect of the season?

Personality traits exist in carabids

Personality traits

Immune traits

Improve our understanding of carabid feeding choices

1

Do carabid seed-eating species differ in their decision making process?

- Carabid species appear to have different foraging strategies

  e. g. High *vs* Low sensitivity to competitive or predatory interactions

Complementarity in seed-eating species for their contribution to weed seed predation?

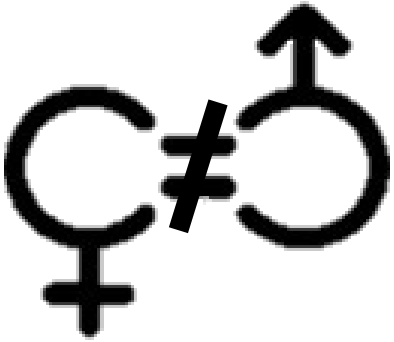
Eat some seeds readily

Do not eat seeds

But can impact other species level of choosiness

Major effect of sex and perspectives

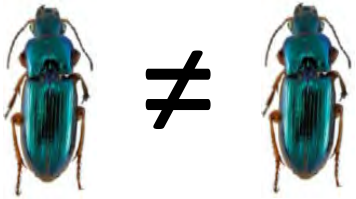
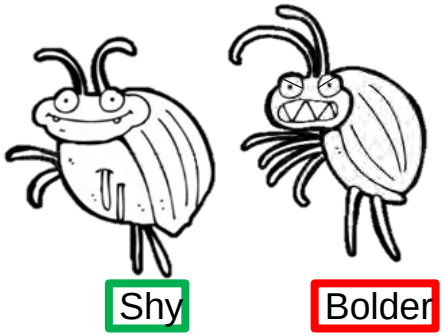
Eggs could be more costly than sperm explaining the differences observed between sex (Hayward & Gillooly, 2011)



Effect of the season on change of choosiness?

Temporal monitoring of change in level of choosiness in carabids

Perspectives and personality traits in carabids

Personality exists in carabids  

Is linked to exploration behaviour –> might be linked to dispersal

Effect of environmental quality on carabids personality? (Tremmel & Muller, 2013)

Exploration behaviour, and thus dispersal tendency, could be linked to individuals status

Use of behavioural data on biocontrol

Objective of Biological control: A reliable and effective ecosystem service to reduce use of chemical inputs, such as pesticides

Carabids and seeds of weeds

Individual scale

Behavioural flexibility

Species interactions

Choosiness

Knowledge of an individual behaviour could help to improve biological control

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INRA
SCIENCE & IMPACT

Thanks for your attention!!

Agroécologie
Dijon
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BIOGÉOSCIENCES

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