Biological Control of Slugs in North America

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Slug research in North America

Web of Science Search:

Slug* AND (biocontrol OR biological control) = 131

Within the USA = 31

Actually dealing with slug biological control = very few

Slug research in North America

<u>The problem of qualitative and anecdotal research</u>

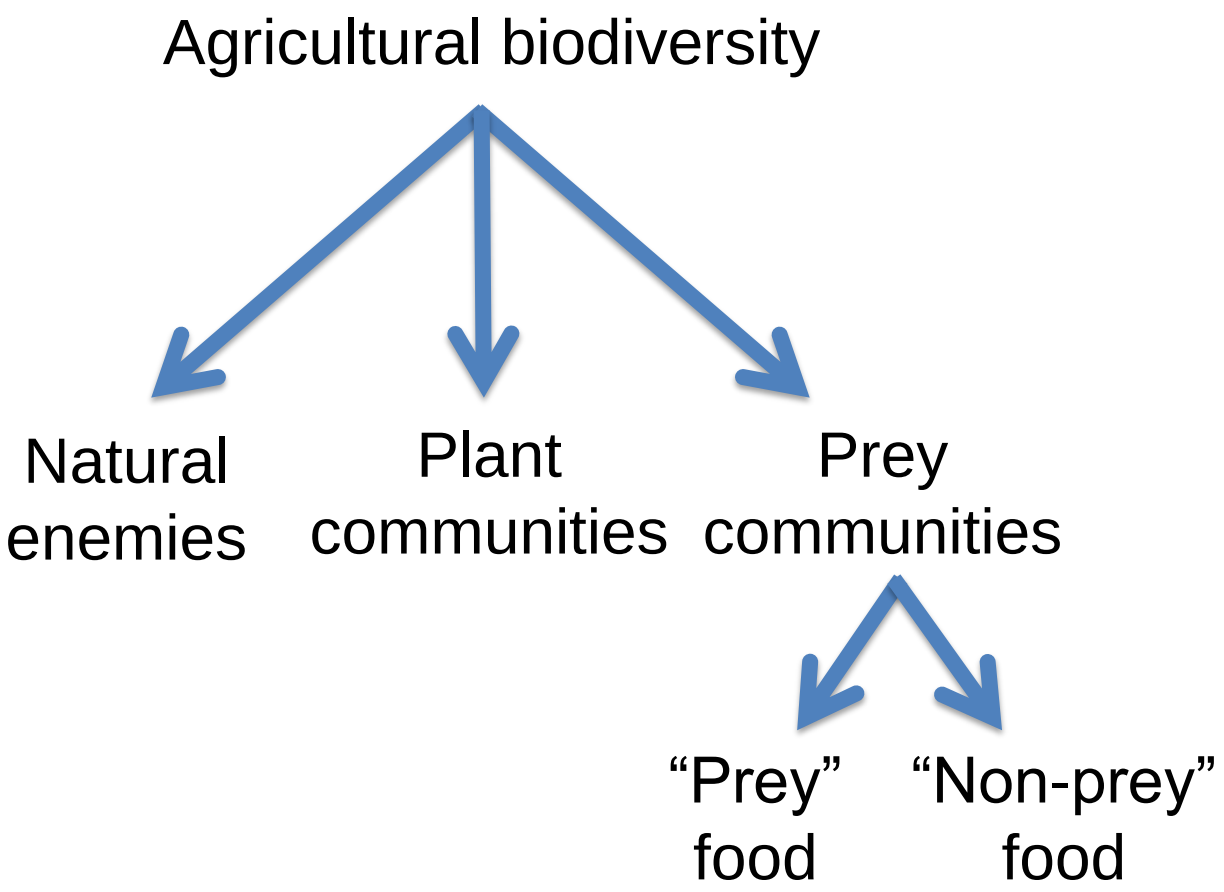
"…Araneid spiders were observed to be feeding on *Deroceras* slugs…."

"…coleopteran beetles were frequently found to feed on slug eggs in the field…"

"…firefly larvae are major predators of slugs…"

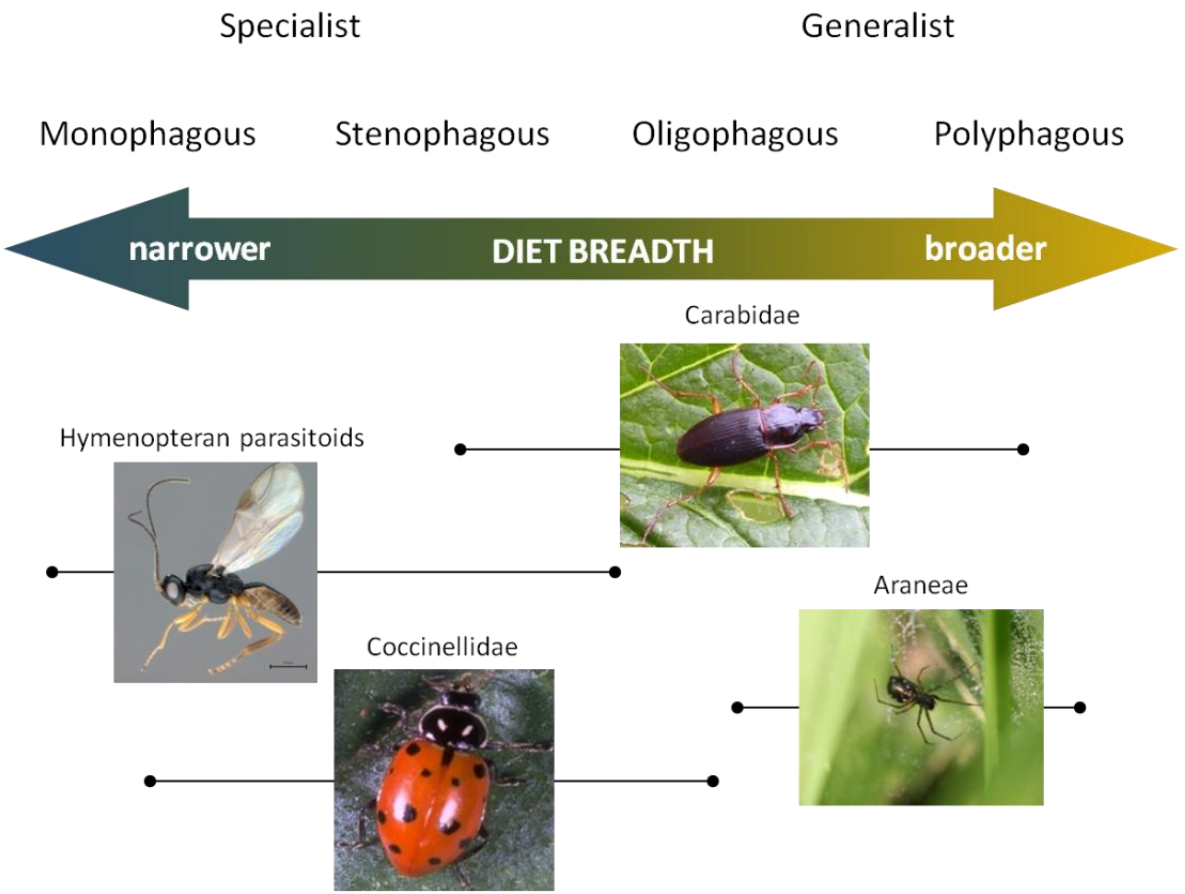
>>> THE NEED FOR QUANTITATIVE STUDIES

The importance of biodiversity?



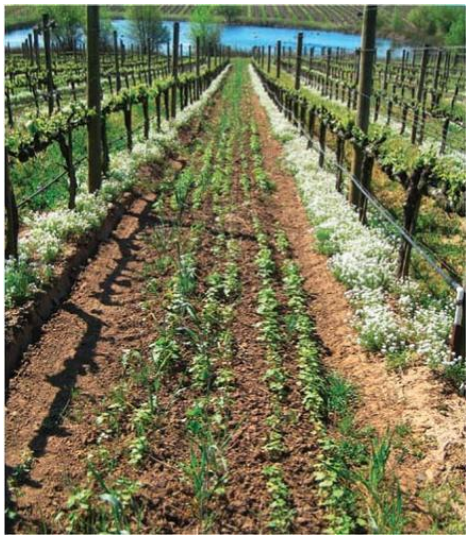
What is biodiversity?

Dietary diversity (breadth) of natural enemies



What is biodiversity?

On-farm plant diversity



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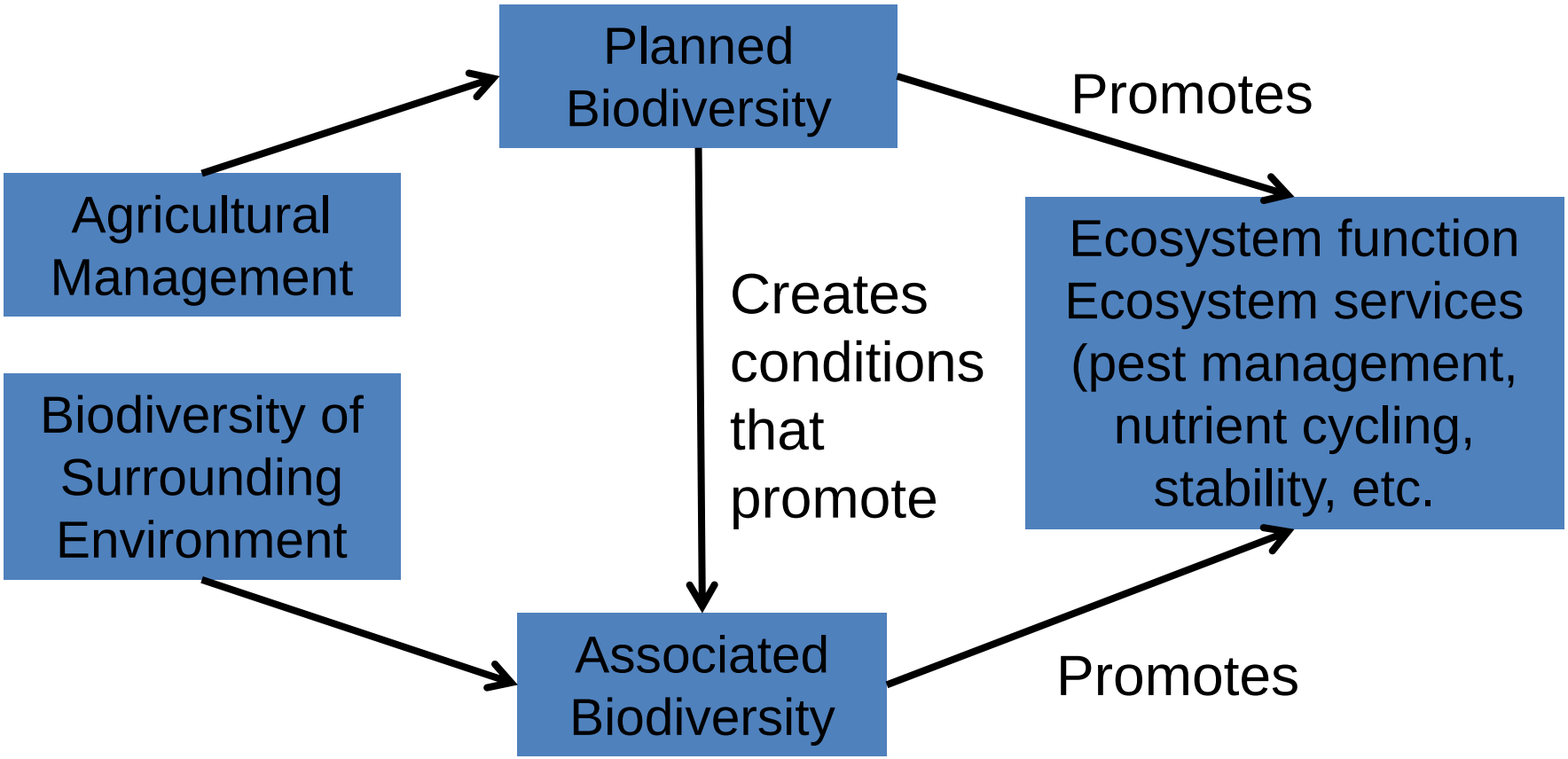
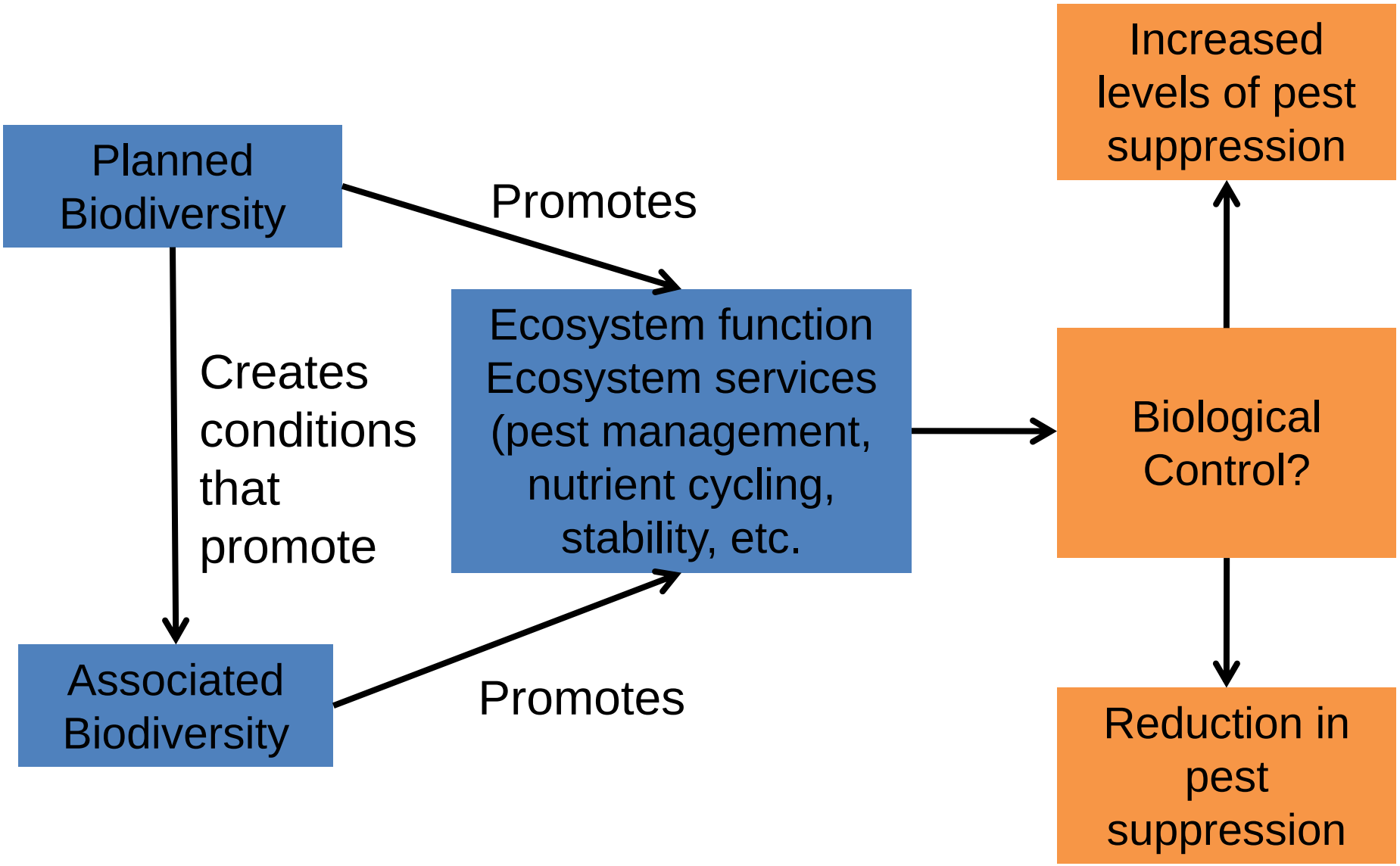
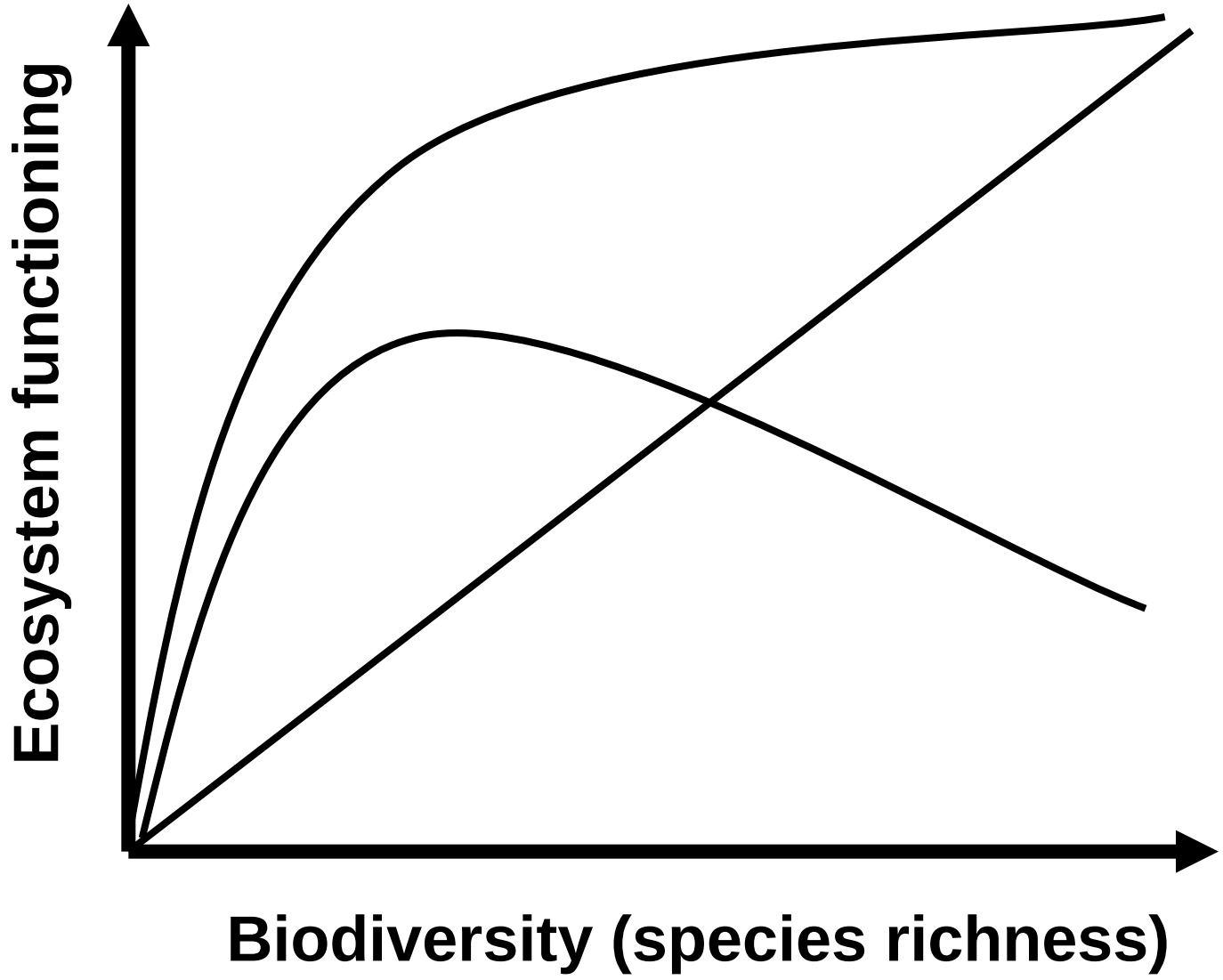


What is biodiversity?



Biodiversity-ecosystem functioning



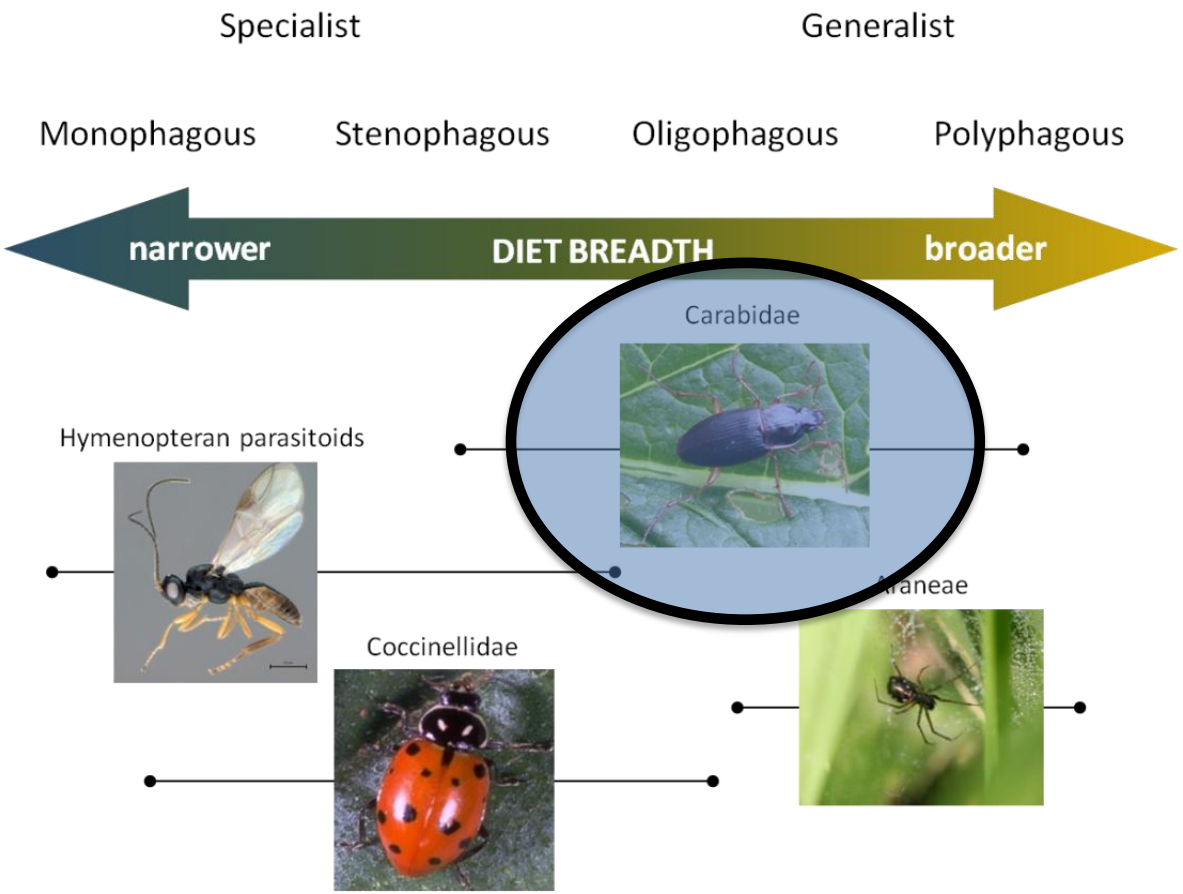
Biodiversity and slugs?

Diverse, low-input, minimum (zero) tillage crops typically increase slug populations

Does increased predation pressure from natural enemies mitigate this effect?

What is biodiversity?

Dietary diversity (breadth) of natural enemies



Outline

Slug consumption by carabids

Mesocosm studies on slug population dynamics

Molecular delineation of trophic connectedness between natural enemies and slugs under open-field and unmanipulated conditions

Slug consumption and diversity

“Prey biodiversity promotes growth and development”

Carabid beetles subjected to different feeding regimes

Growth, development, egg production, egg hatching success, etc., all measured

Analyzed using a series of mixed models examining predicted and actual hatching success

Slug consumption and diversity

Methods

Controlled laboratory mesocosms (n=10 ♀:♂ pairs per treatment)

8 feeding regimes

8 weeks

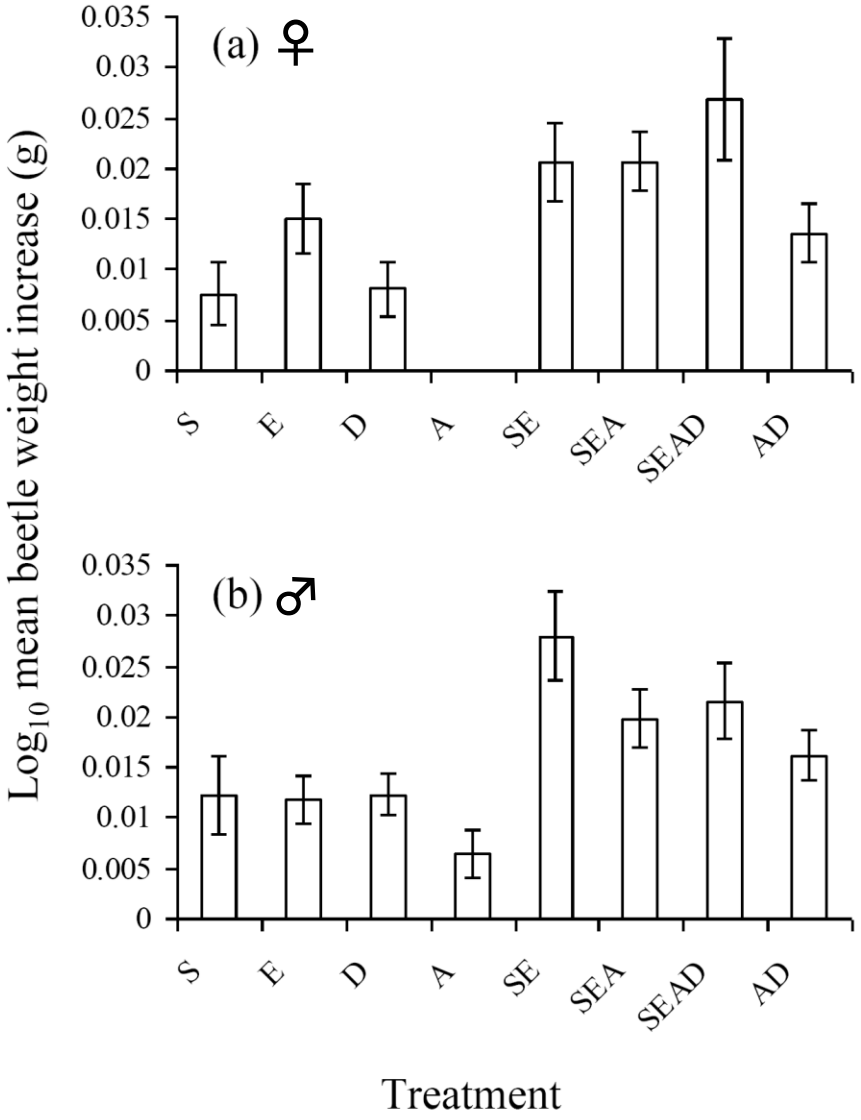
Egg production
hatching success
weight change
hatching time

Table 1. Prey species provided in each of the ten diets offered to pairs of *Pterostichus melanarius*. All prey was provided *ad libitum*.

Treatment	Prey species
S	Slugs (*Deroceras reticulatum*)
E	Earthworms (*Lumbricus terrestris*)
D	Diptera (larvae of *Musca domestica*)
A	Aphids (*Sitobion avenae*)
SE	Slugs and earthworms
SEA	Slugs, earthworms and aphids
SEAD	Slugs, earthworms, aphids and Diptera
AD	Aphids and Diptera

Slug consumption and diversity

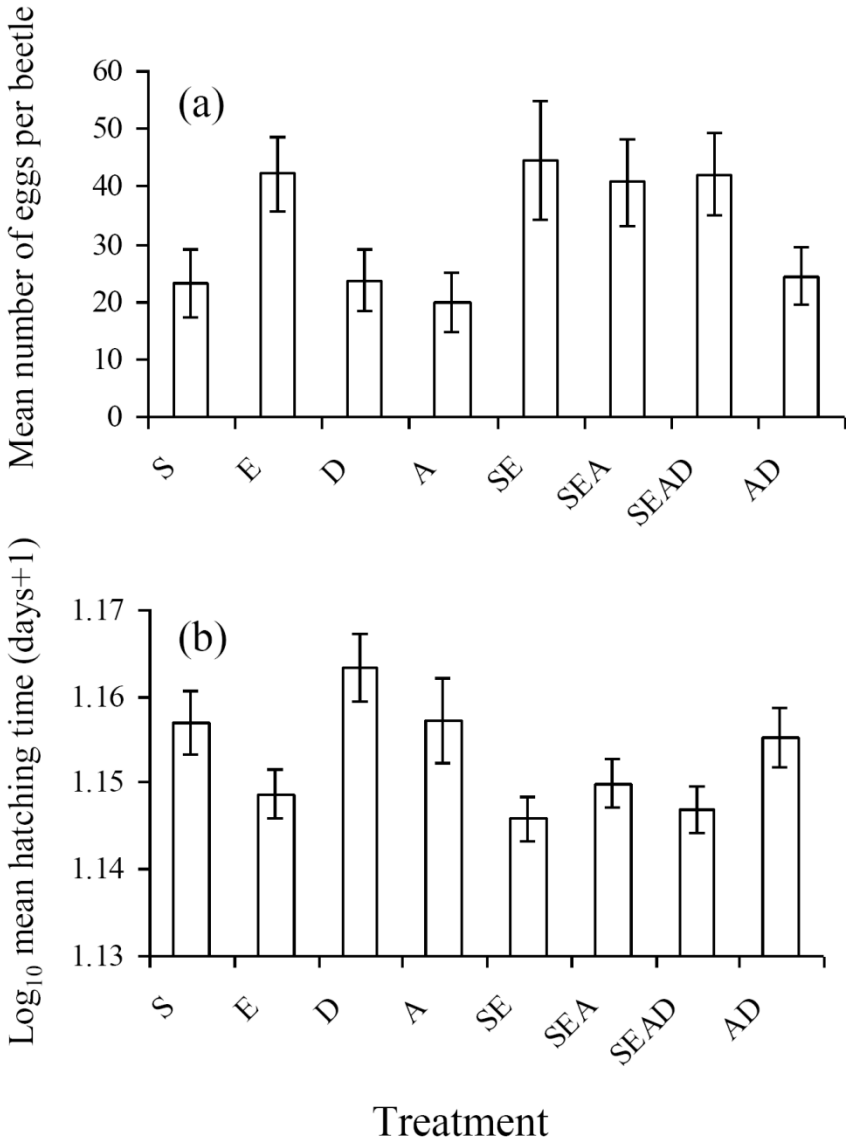
Weight gain



Slug consumption and diversity

Eggs produced

Hatching time

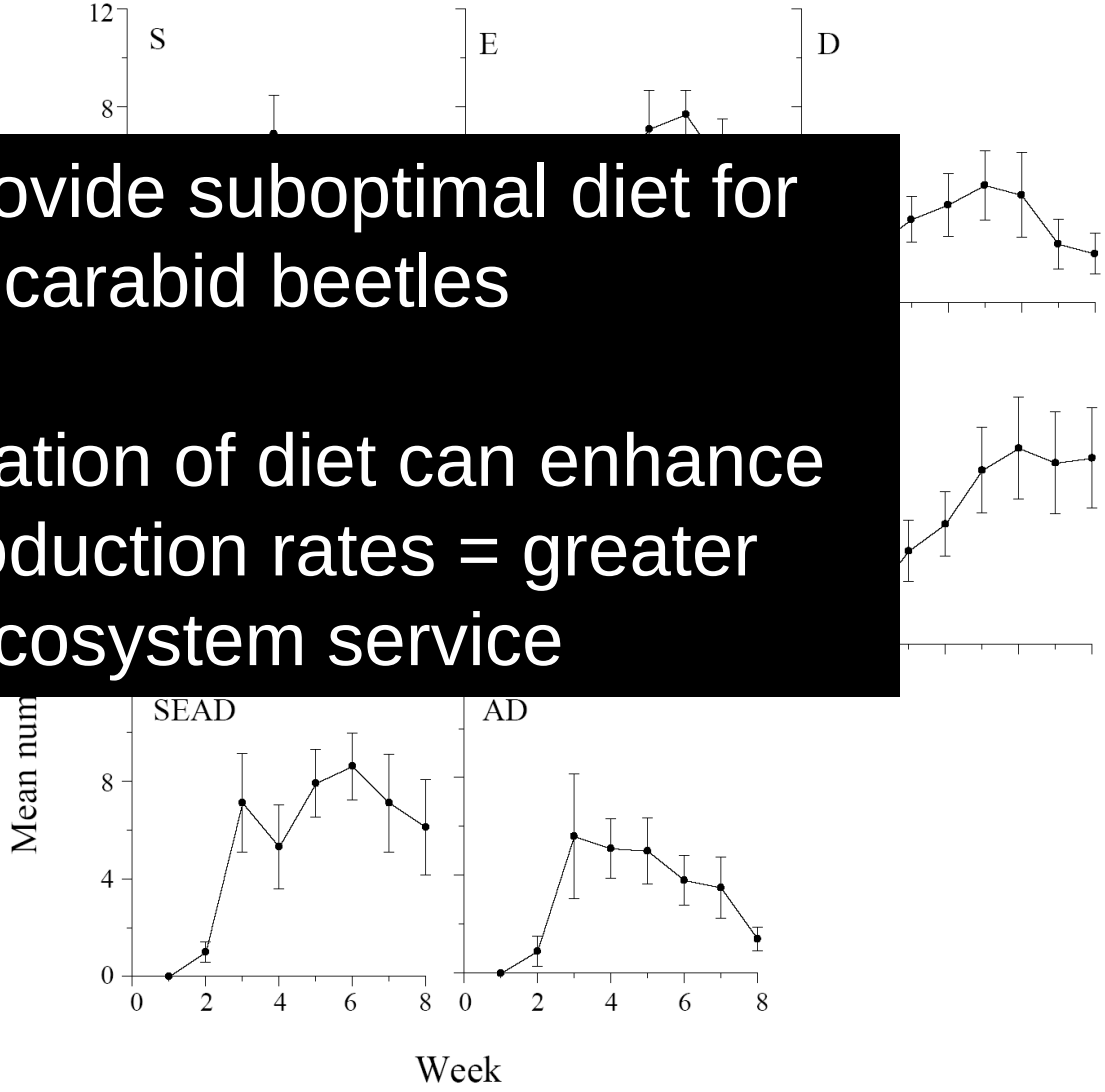


Slug consumption and diversity

Egg p
rates

Slugs provide suboptimal diet for carabid beetles

Diversification of diet can enhance egg production rates = greater ecosystem service



Slug population dynamics

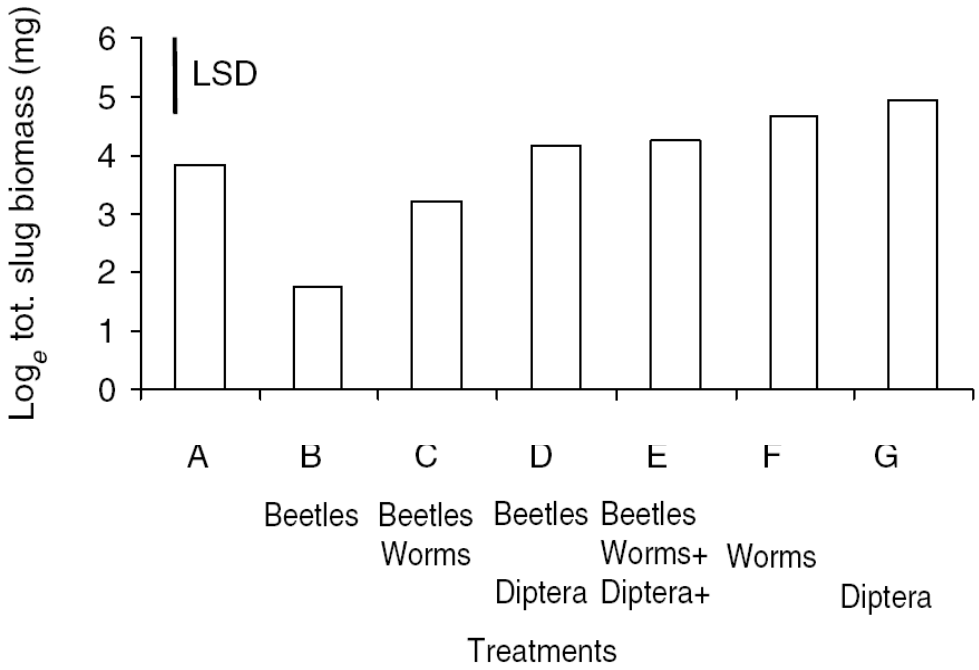
Methods

- Outdoor mesocosms (35cm diam, 18cm depth; n=10 per treatment)
- Prey added (slugs = 28/plot)
- Beetles (2/plot) added
- Changes in community composition evaluated

Slug population dynamics

- Results
  - Slug
  - Slug
  - Slug

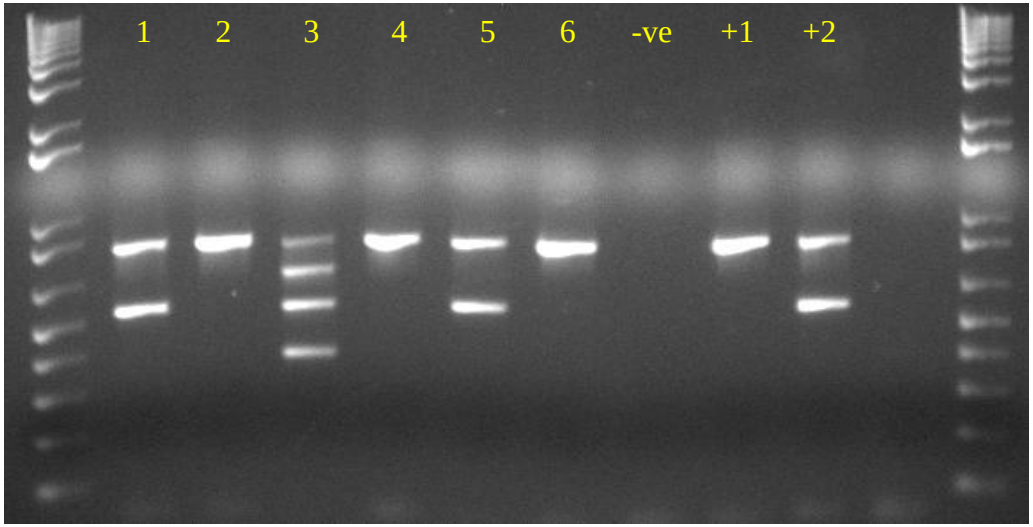
Diverse p
reduce p
on slug p



Molecular delineation of slug-carabid interactions

Identification of naturally occurring slug-carabid trophic interactions

- Field analysis of prey populations
- Parallel collection of predators
- Molecular analysis of predation
- Identify effect of predators on pest suppression



Molecular delineation of slug-carabid interactions

1. *Pterostichus melanarius* – prey interactions in winter wheat

2. Carabid – slug interactions in strawberries

1. Molecular delineation of slug-carabid interactions

The predator: *Pterostichus melanarius*

- Dominant carabid
- Generalist feeding habits
- Spatially correlated to prey
- Potentially restricts pest population densities

- What is the effect of prey biodiversity of pest predation dynamics?

1. Molecular delineation of slug-carabid interactions

6 species

>15 species

5 species

1 species

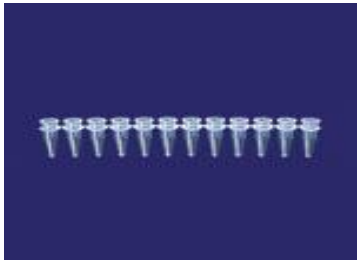
1 species

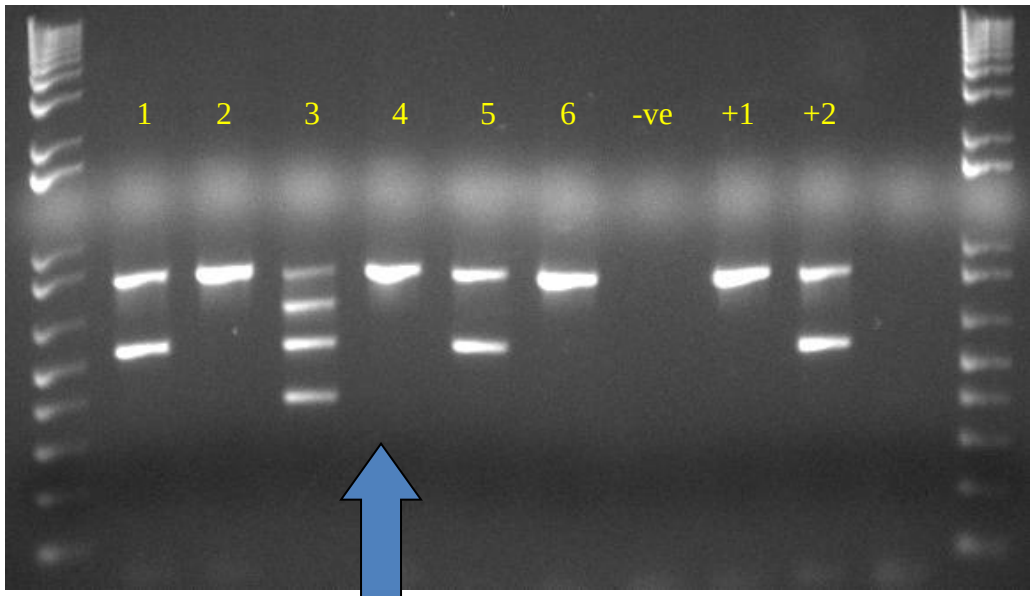
1. Molecular delineation of slug-carabid interactions

Primer development

- *COI* mitochondrial markers developed
  - 6 species-specific aphid primers 
  - 5 species-specific slug primers 
  - 1 Sitona specific primer 
  - 1 species-specific snail primer 

1. Molecular delineation of slug-carabid interactions





1. Molecular delineation of slug-carabid interactions

7147 beetles collected

Number of prey per beetle 0 – 7

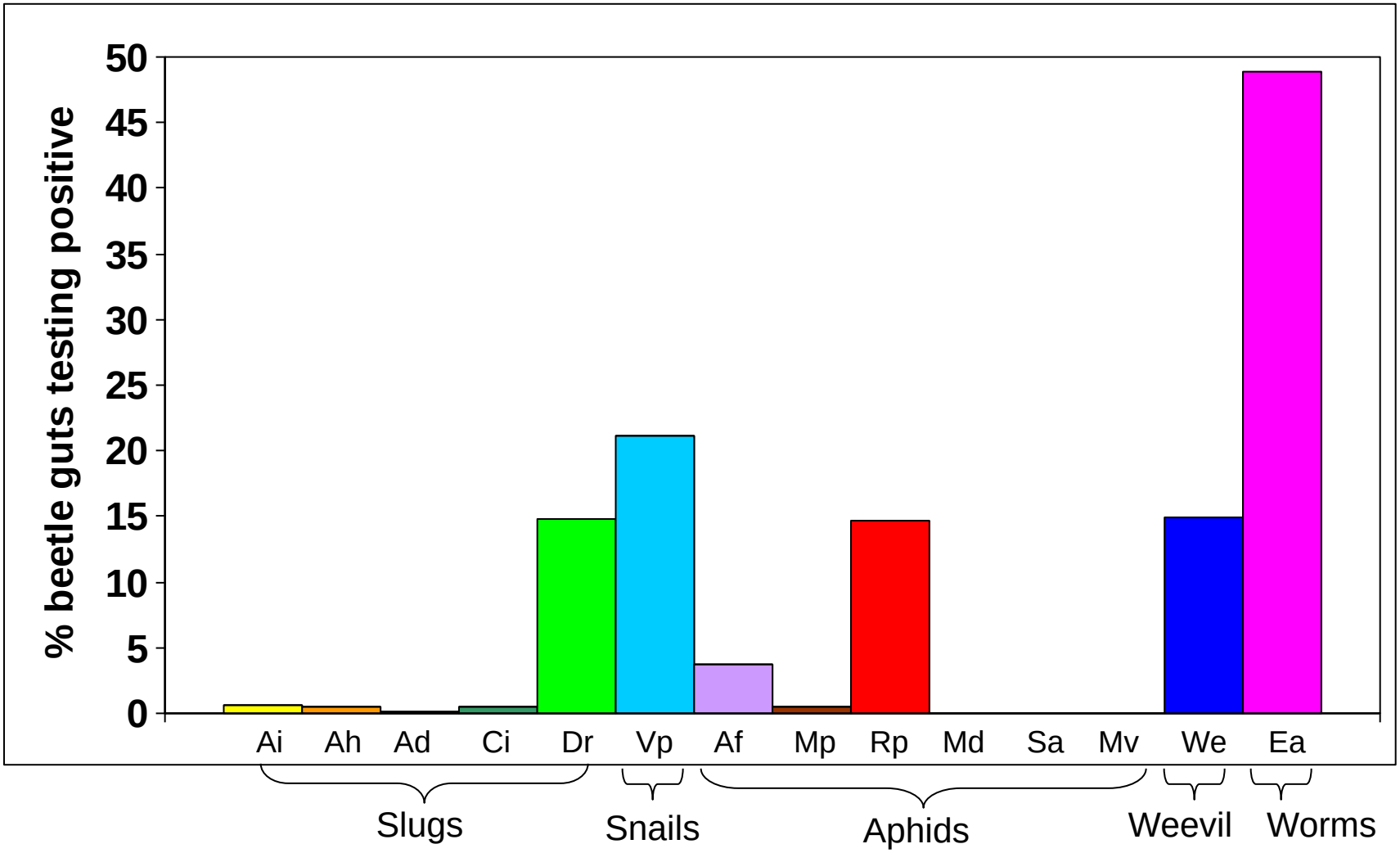
Percentage of beetles with zero prey in their guts was:

- 2001 - 34 %
- 2002 – 31 %

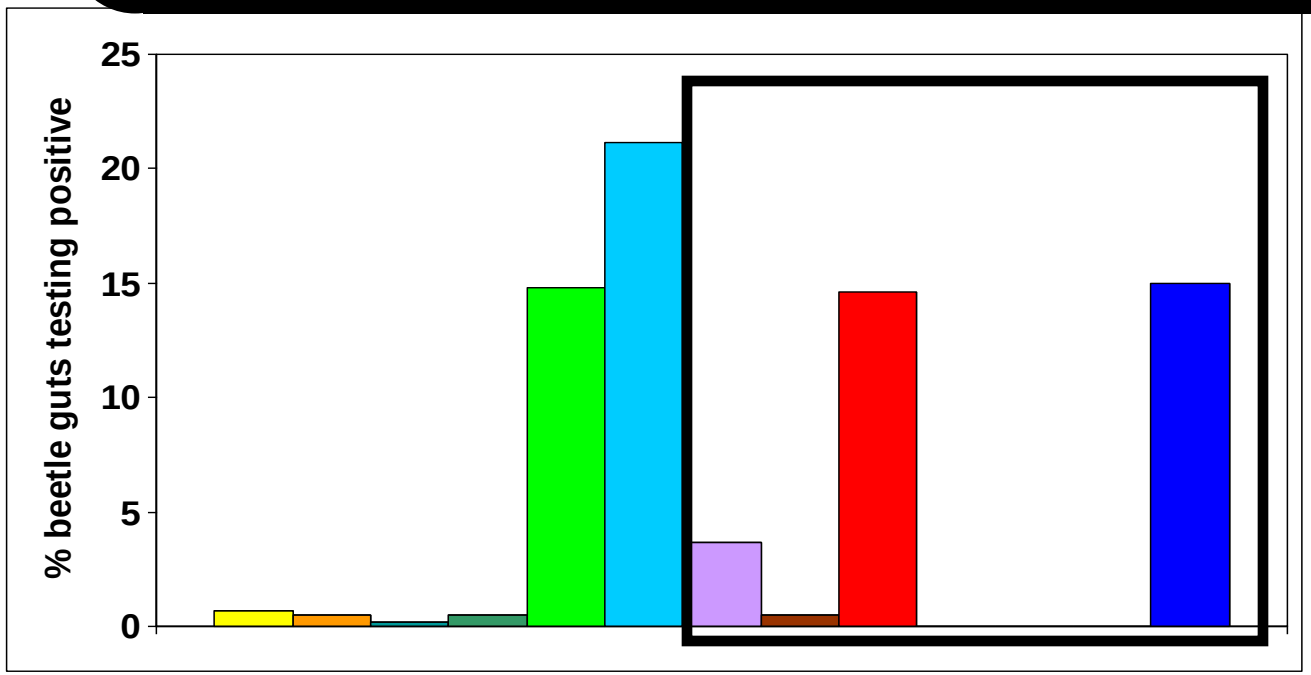
Mean number of prey per beetle in each year:

- 2001 - 1.205
- 2002 - 1.427

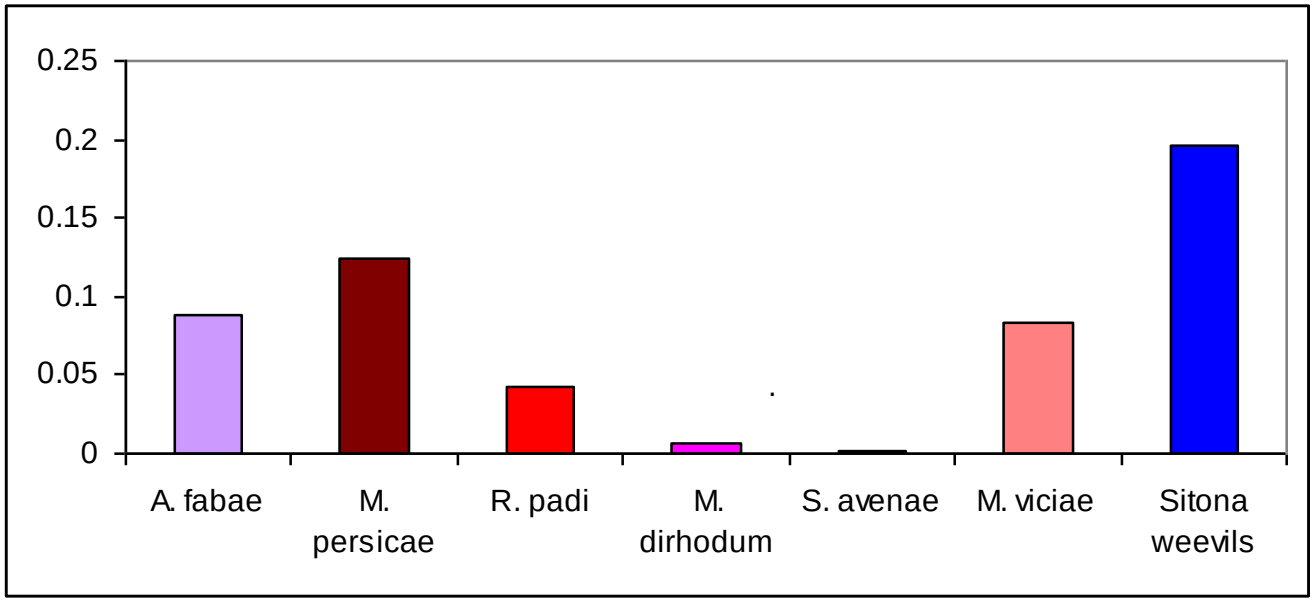
1. Molecular delineation of slug-carabid interactions



Aphids and weevils

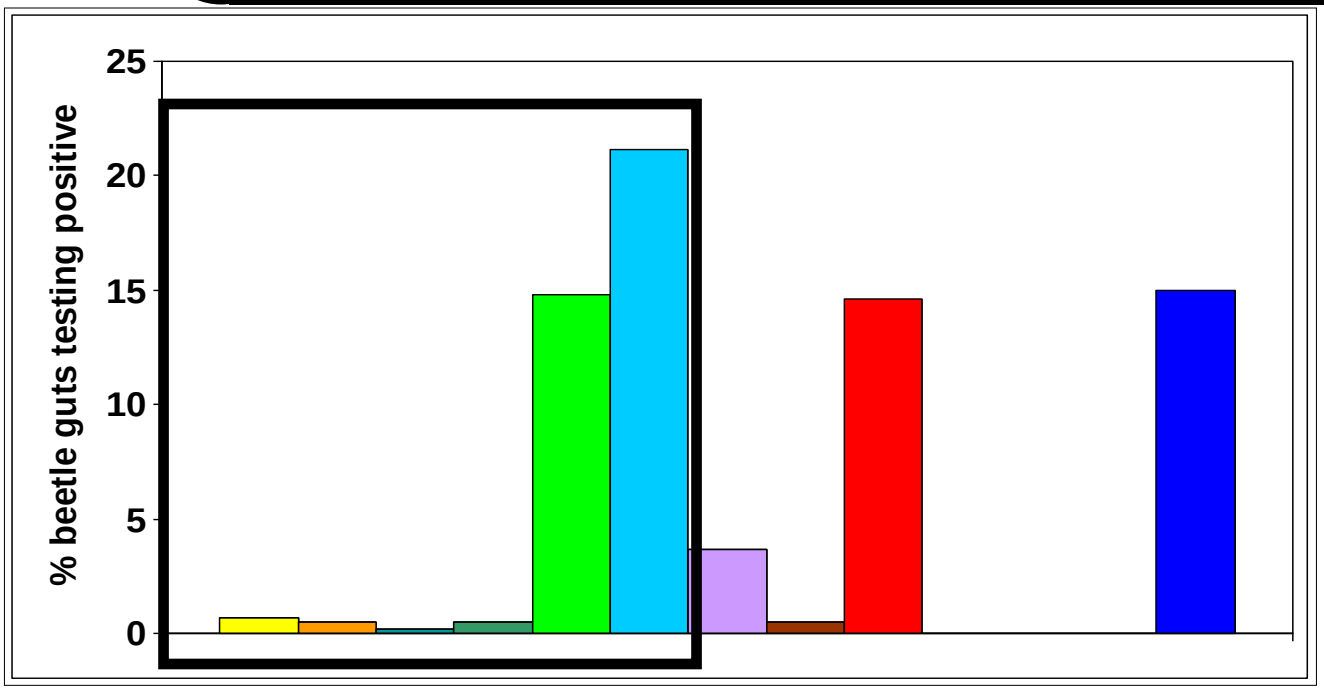


In beetle guts

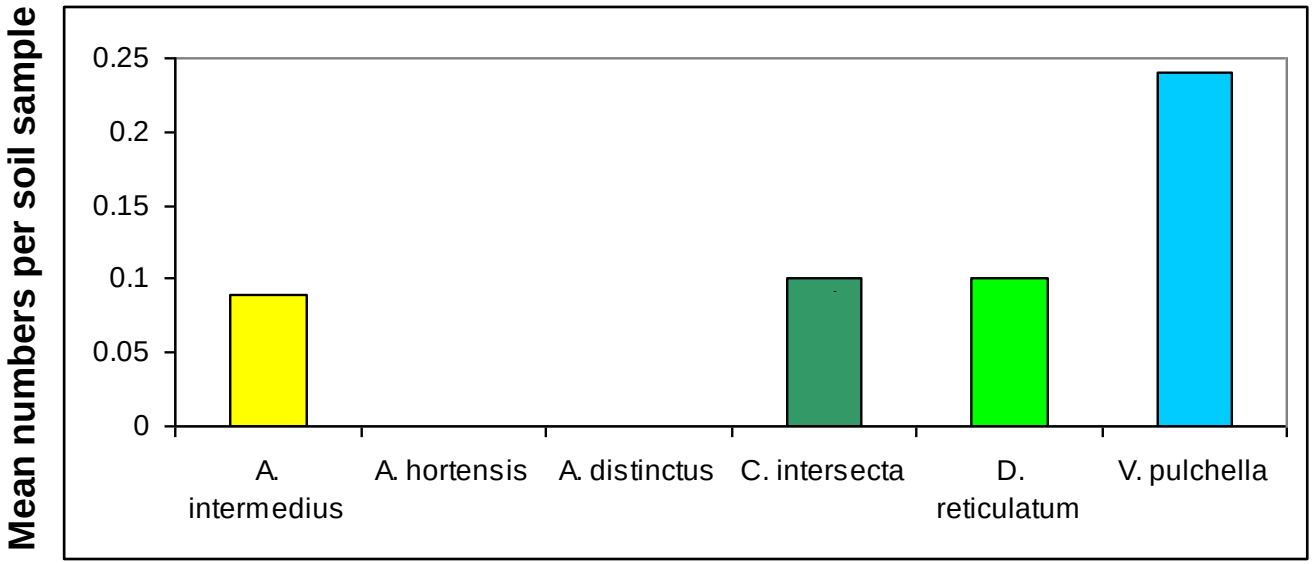


In the field

Slugs and snails



In beetle guts



In the field

1. Molecular delineation of slug-carabid interactions

Slugs constitute a major portion of carabid diets

Do not track all prey equally

Have high fidelity to some prey – counter to the argument that generalists do not track their prey closely enough to exert any level of control

Dietary diversification?

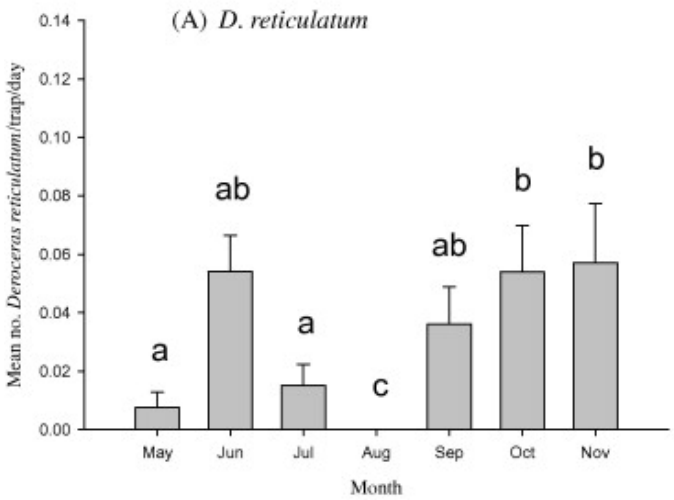
2. Molecular delineation of slug-carabid interactions

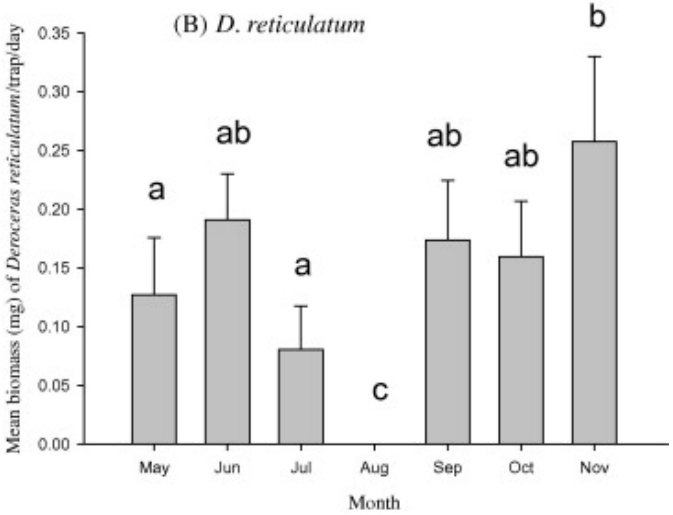
Slug primers (*Deroceras reticulatum* and *D. laeve*) developed to quantify the prevalence of slug-carabid interactions in the field

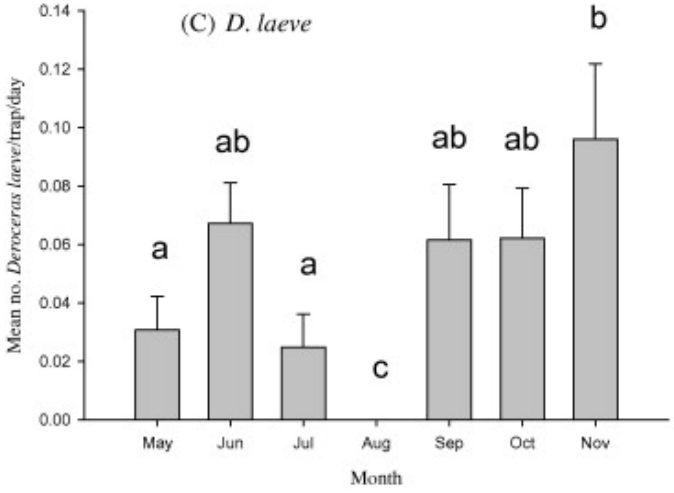
Slug and carabid populations monitored in strawberry plots subjected to traditional and detrital subsidy cultivation

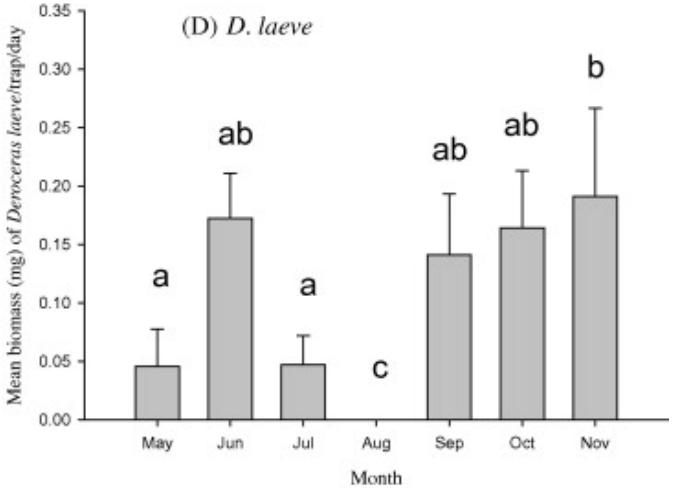
Carabids screened for presence of slug DNA

2. Molecular delineation of slug-carabid interactions









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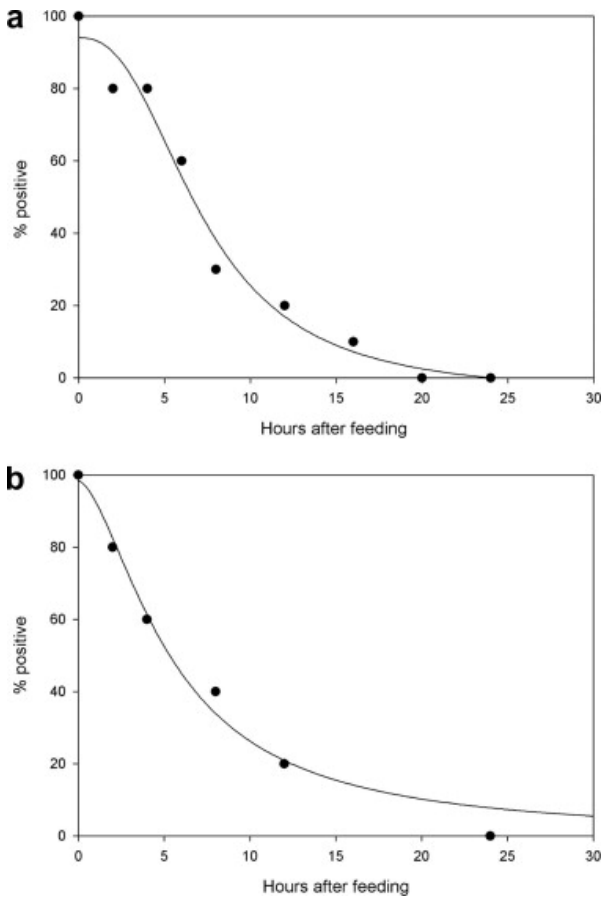
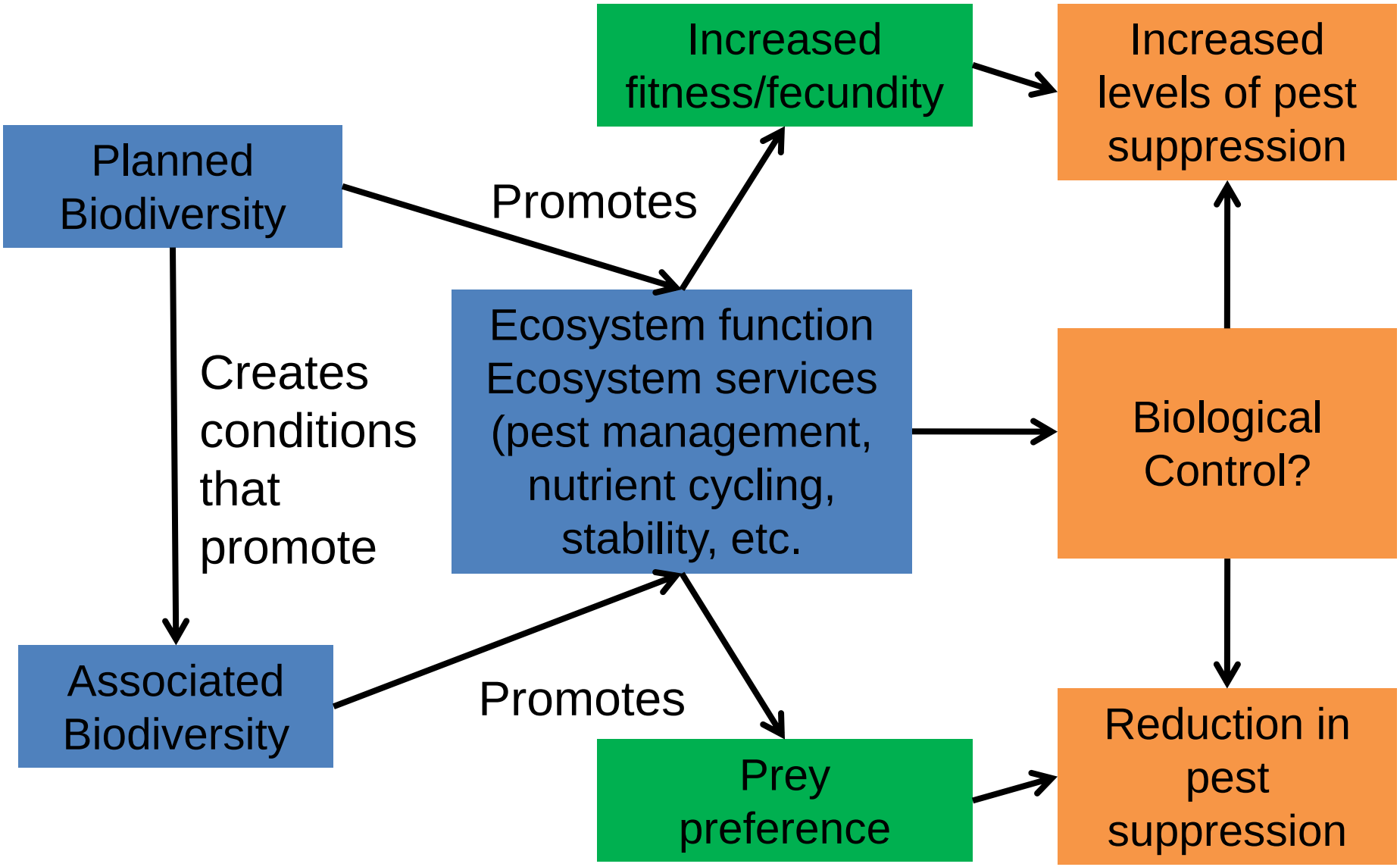


Short detection limits

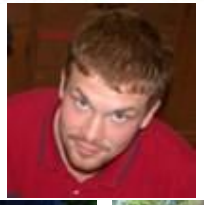
2. Molecular delineation of slug-carabid interactions

	% positive	
	D. reticulatum	*D. laeve*
Agonum sp.	0%	0%
Amara sp.	0%	0%
Anisodactylus santaecrusis	0%	0%
Chlaenius pusillus	0%	0%
Chlaenius tricolor	16%	16%
Cicindela punctata	0%	0%
Cratacanthus dubius	0%	0%
Harpalus caliginosus	0%	0%
Harpalus pensylvanicus	7%	0%
Poecilus chalcites	0%	0%
Poecilus lucublandus	0%	0%
Scarites subterraneus	0%	0%
Tetracha virginica	0%	0%

Biodiversity vs. biological control



Acknowledgements



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