Recasting spatial food web ecology as an ecosystem science

François Massol

with Dominique Gravel, Nicolas Mouquet, Marc W. Cadotte,
Tadashi Fukami and Mathew A. Leibold

What is "spatial food web" ecology?

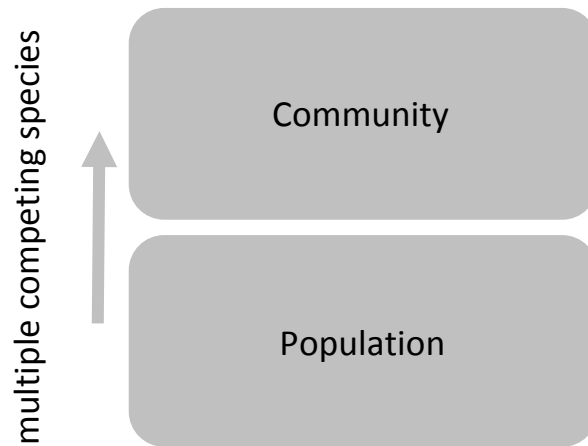**getting to grips:** from the basic ecological unit to complex systems

What is "spatial food web" ecology?

Population

the initial unit: single species, single location

What is "spatial food web" ecology?

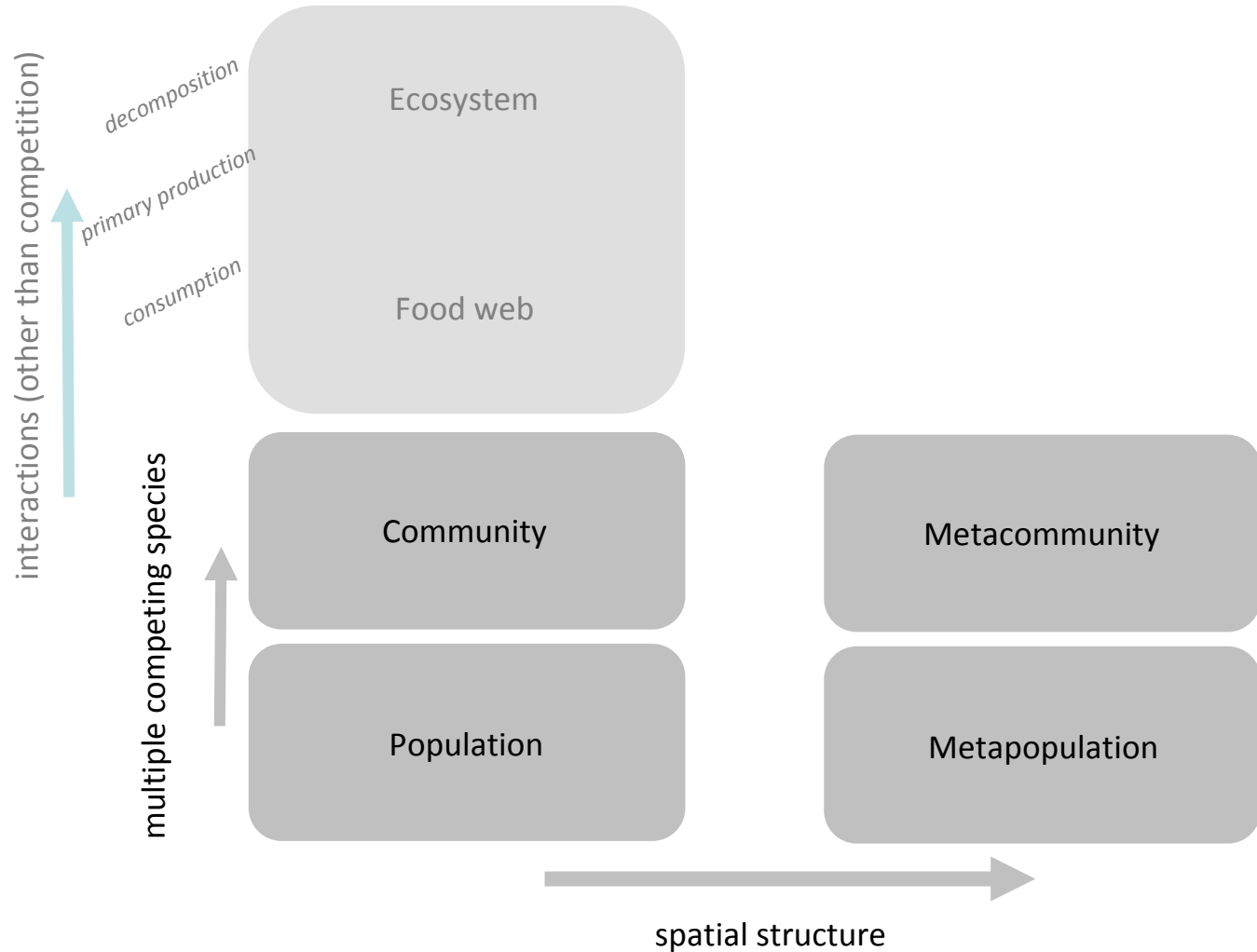multiple competing species

Community

Population

community complication: multiple species in competition at a single location
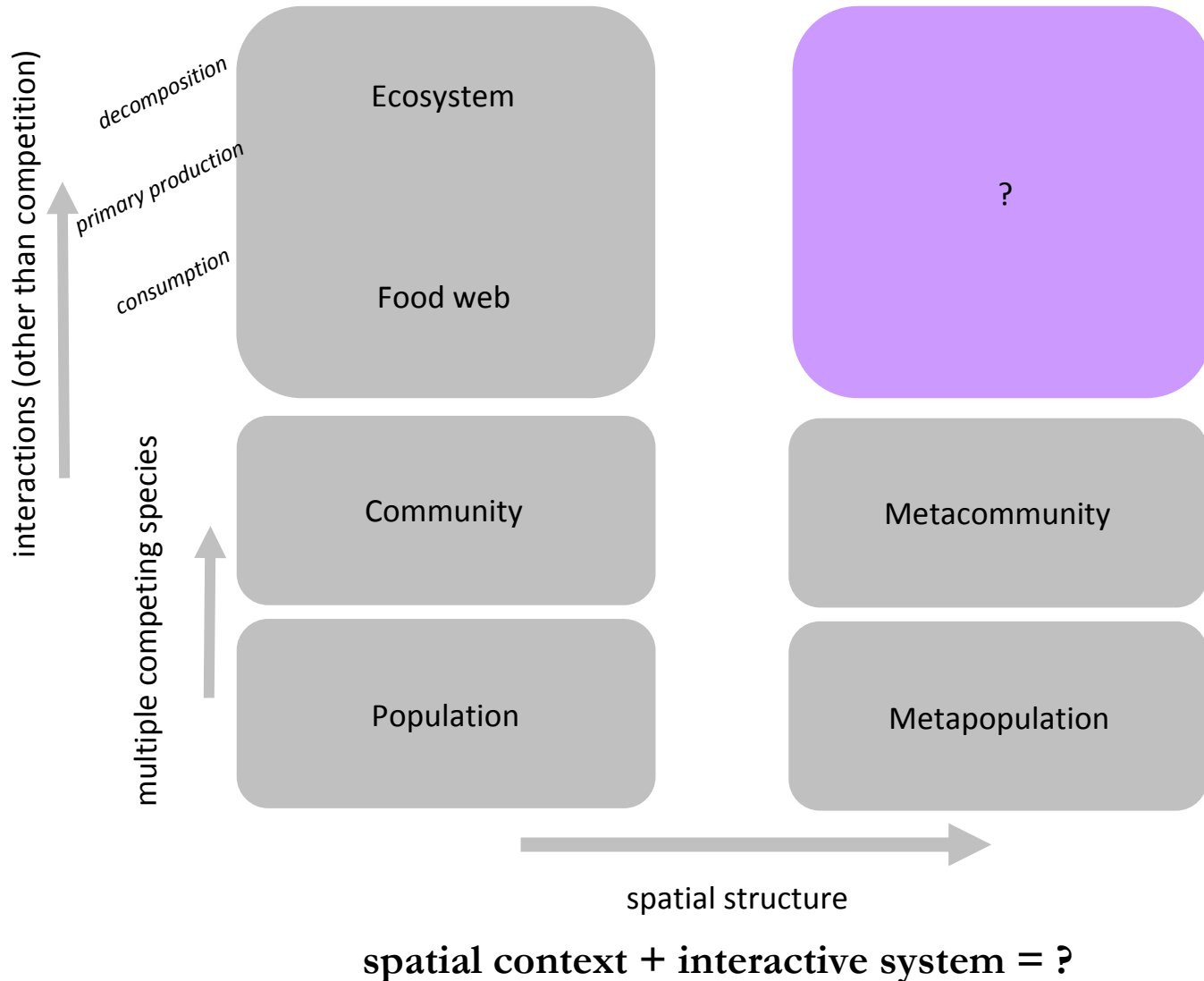
What is "spatial food web" ecology?
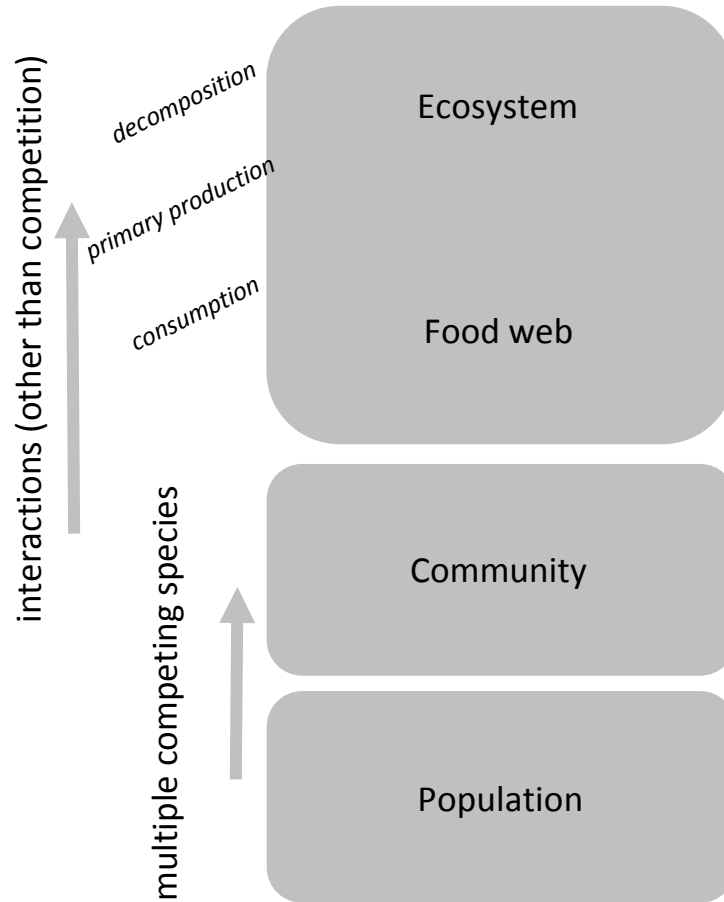
interactive system: multiple agents consuming/transforming each other at a single location
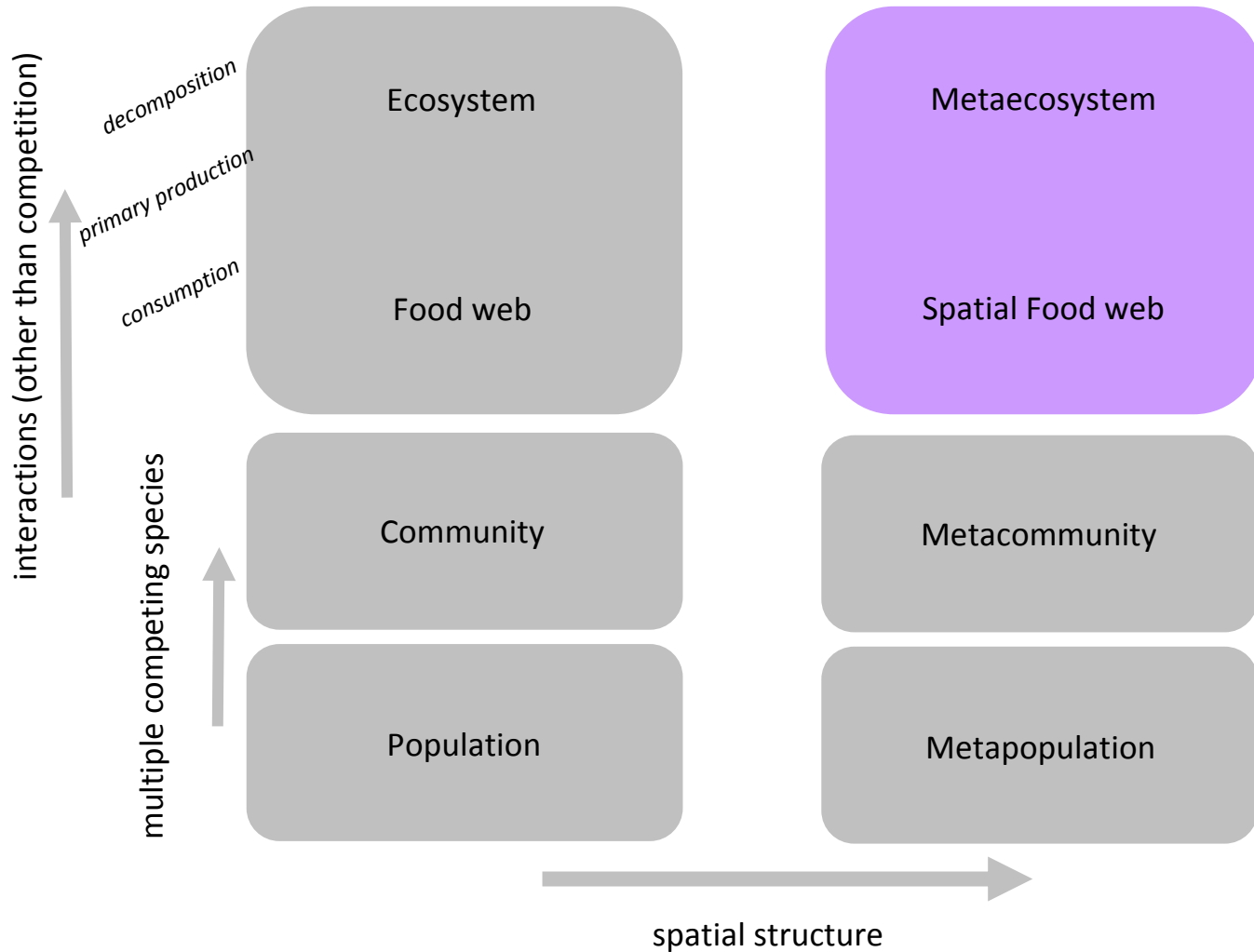
What is "spatial food web" ecology?

interactions (other than competition)

decomposition

primary production

consumption

Ecosystem

Food web

Community

Metacommunity

Population

Metapopulation

multiple competing species

spatial structure

spatial context: single/multiple species at multiple locations

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Ecosystem / Food web	?
Community	Metacommunity
Population	Metapopulation

spatial structure

spatial context + interactive system = ?

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Ecosystem Food web	Metaecosystem Spatial Food web
Community	Metacommunity
Population	Metapopulation

spatial structure

spatial context + interactive system = SFW / metaecosystem

Spatial food webs as a study object: why?
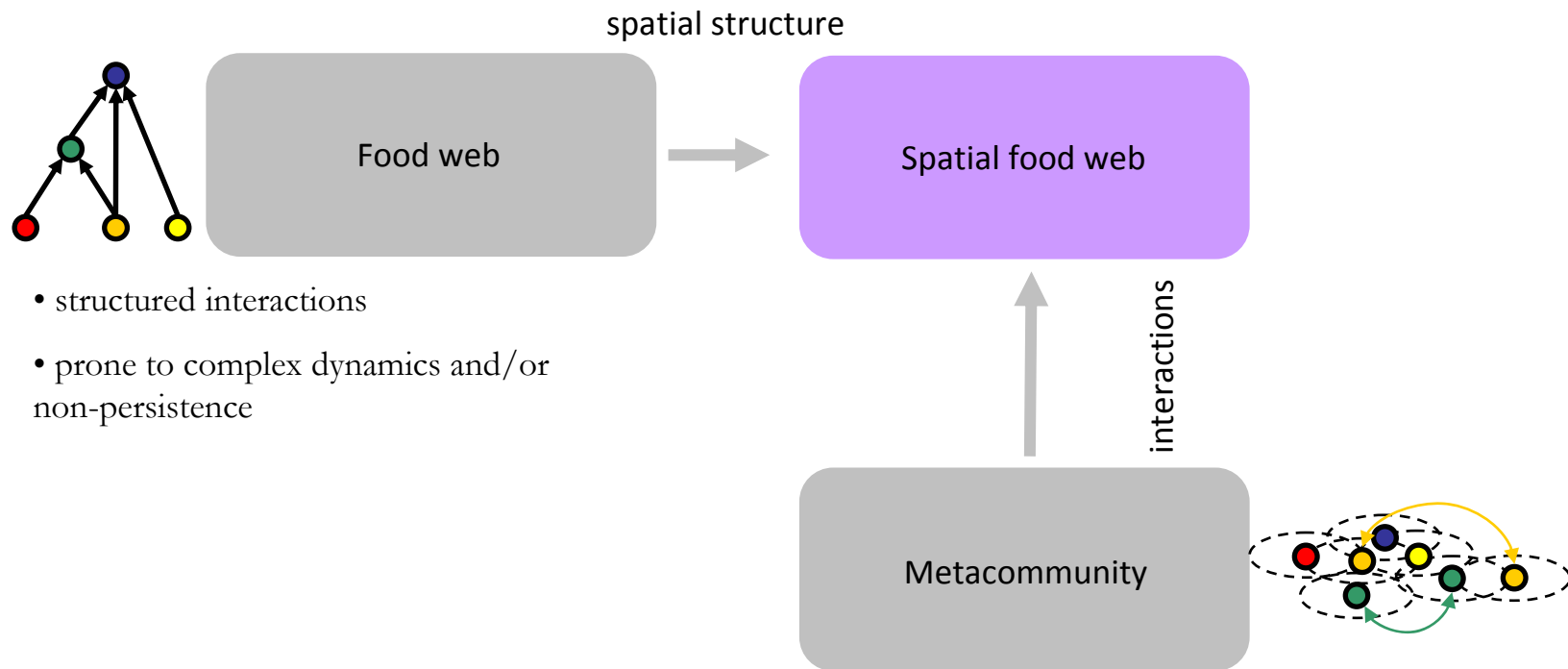
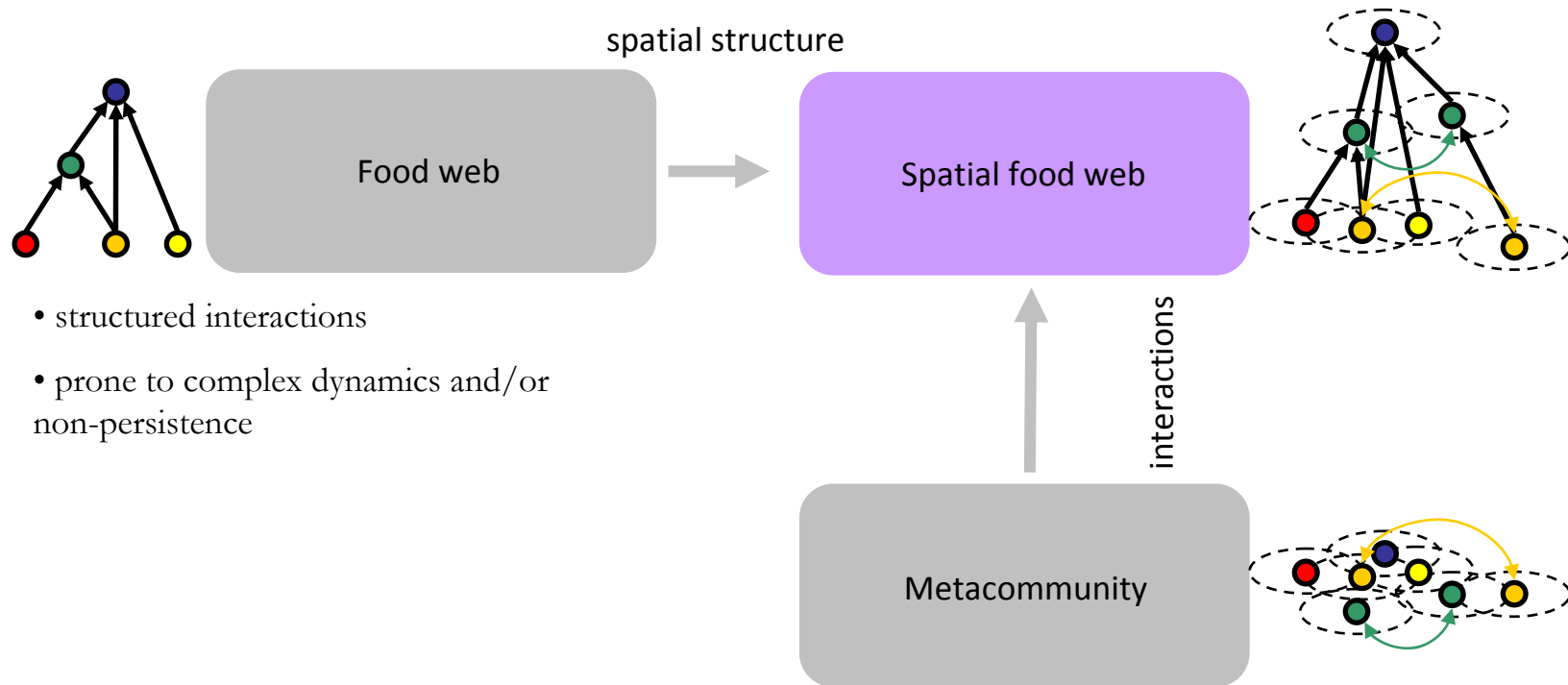spatial structure

Food web

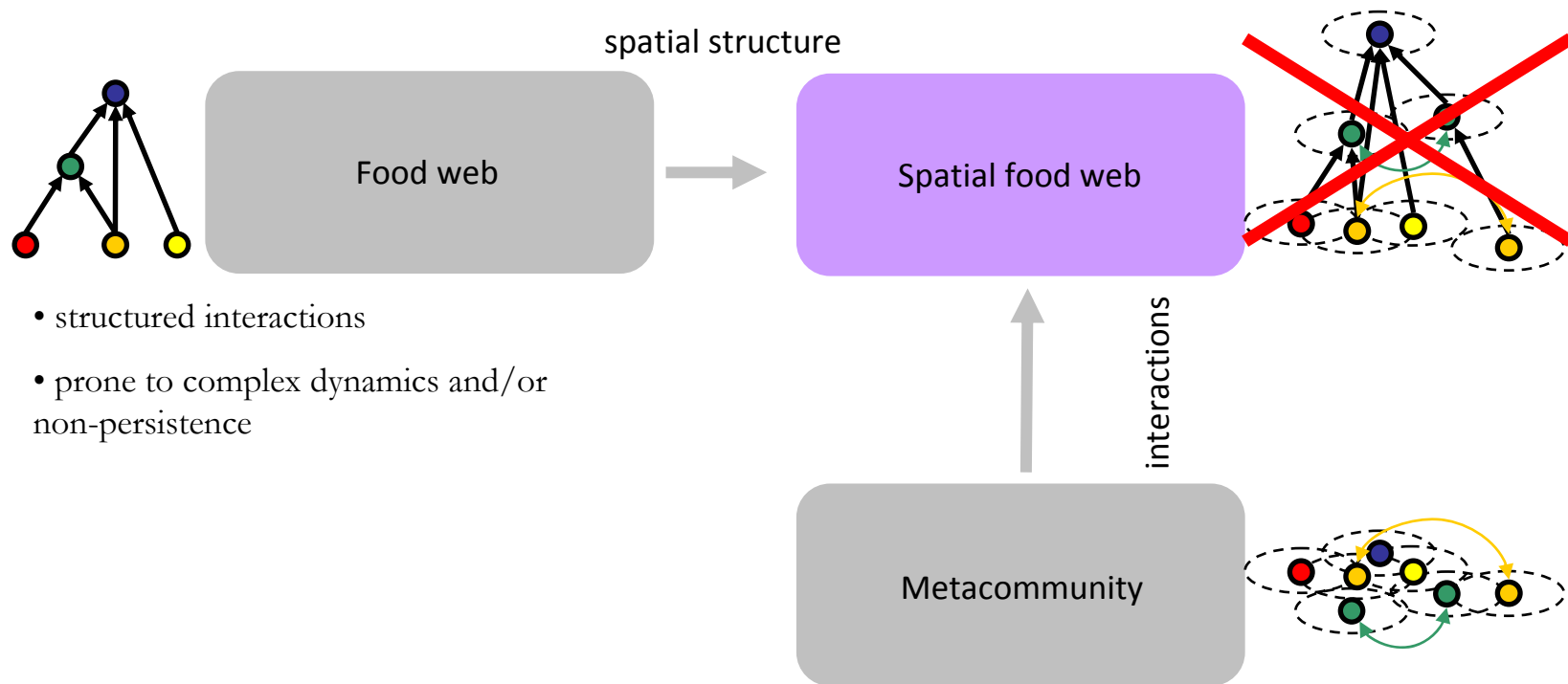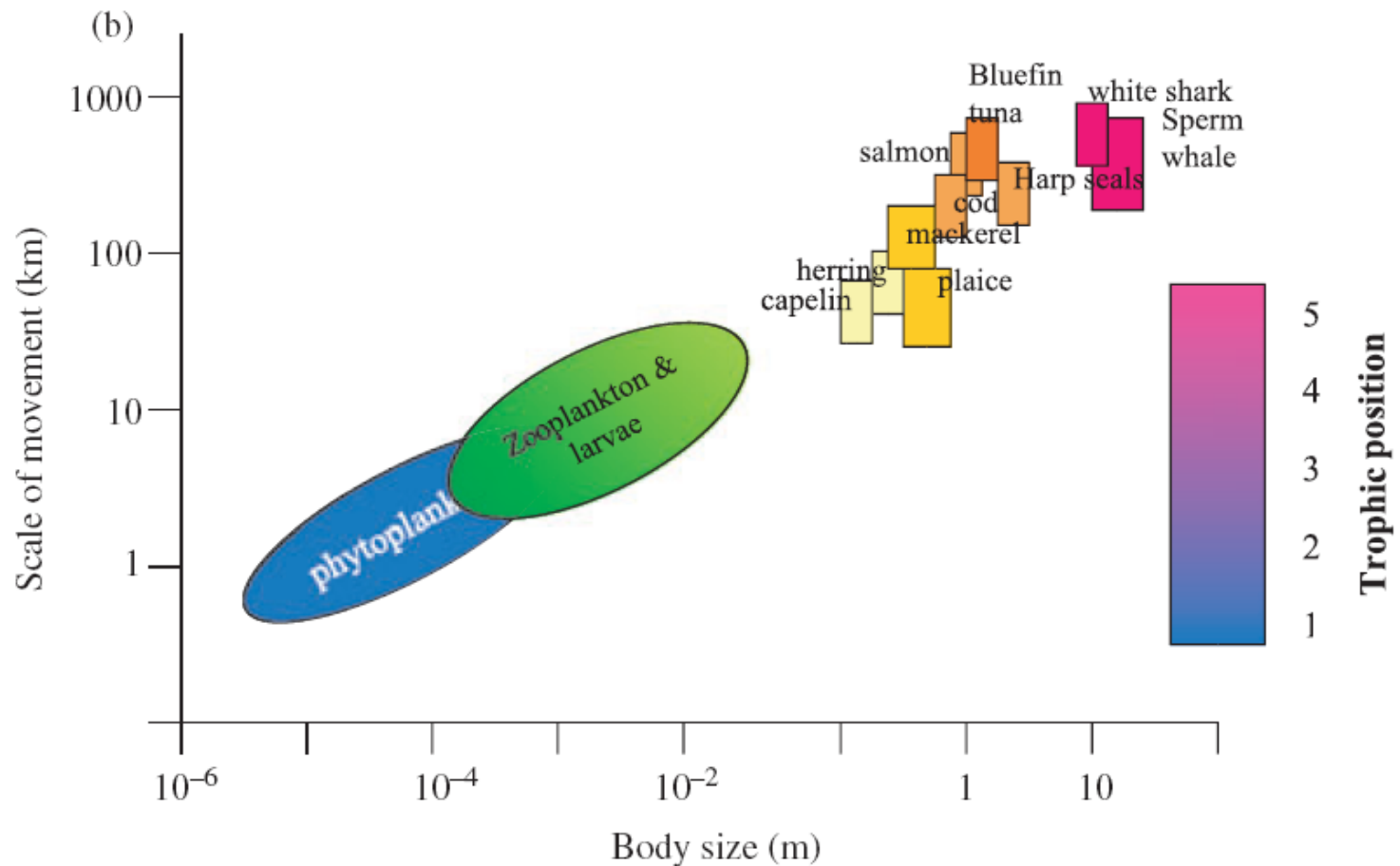Spatial food web

interactions

Metacommunity

- structured interactions

- prone to complex dynamics and/or non-persistence

- competition between (close) populations

- dispersal between populations of the same species

- simple dynamics and persistence of at least 1 species

Spatial food webs as a study object: why?

spatial structure

Food web

→

Spatial food web

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just add ingredients together?

Spatial food webs as a study object: why?

spatial structure

Food web → Spatial food web

Metacommunity

interactions

• structured interactions

• prone to complex dynamics and/or non-persistence

• competition between (close) populations

• dispersal between populations of the same species

just add ingredients together? no!   • simple dynamics and persistence of at least 1 species

Spatial food webs as a study object: why?

Reason 1: different spatial scales

McCann *et al.* 2005 *Ecology Letters*

Spatial food webs as a study object: why?

Reason 1: different spatial scales
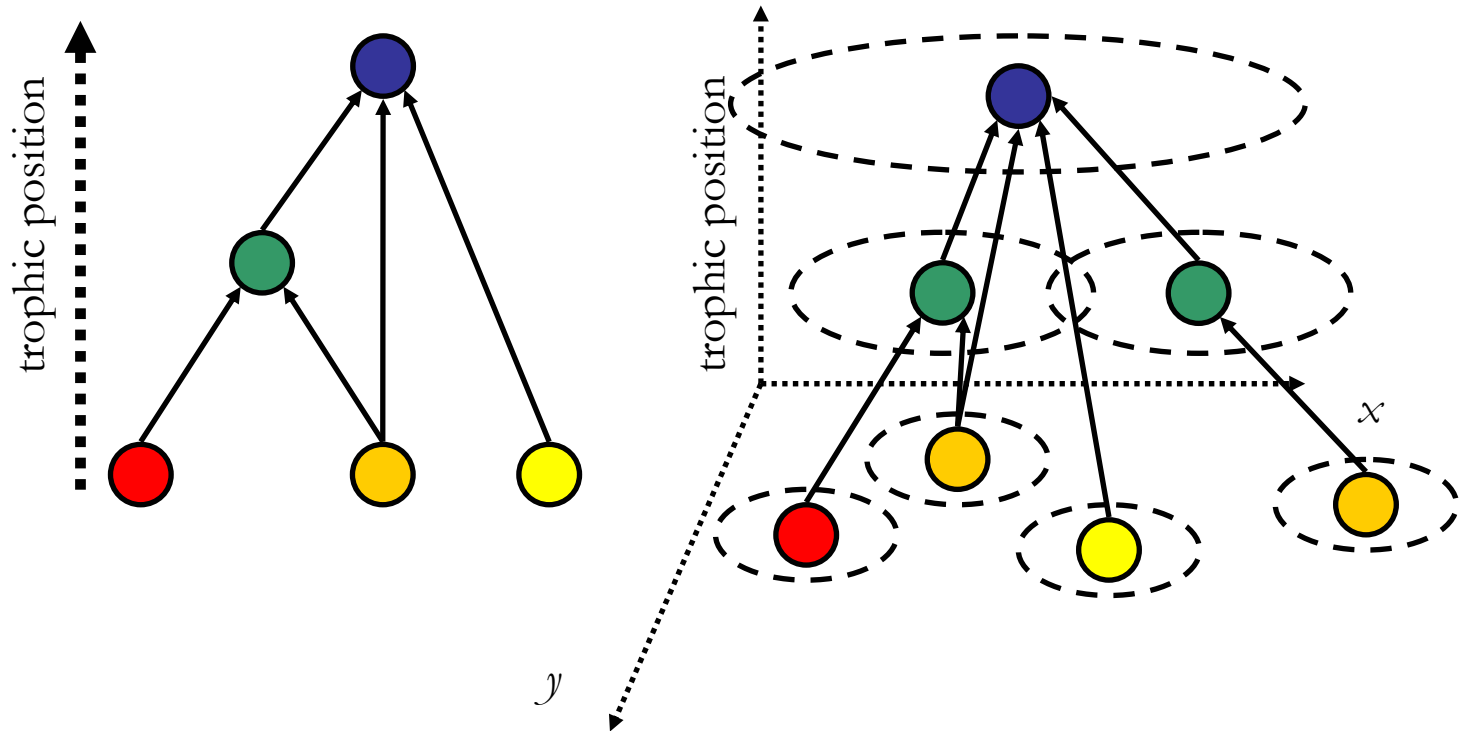
adapted from Holt *et al.* 2005 *Metacommunities: Spatial Dynamics and Ecological Communities*

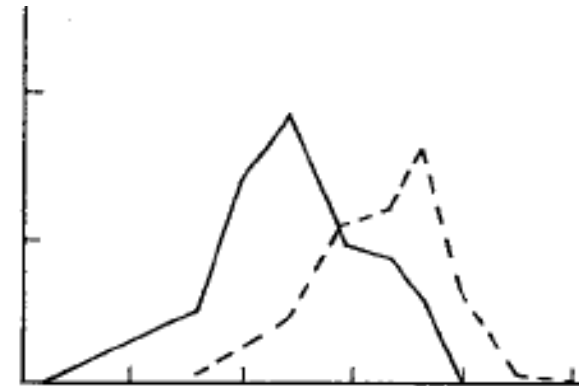# Spatial food webs as a study object: why?

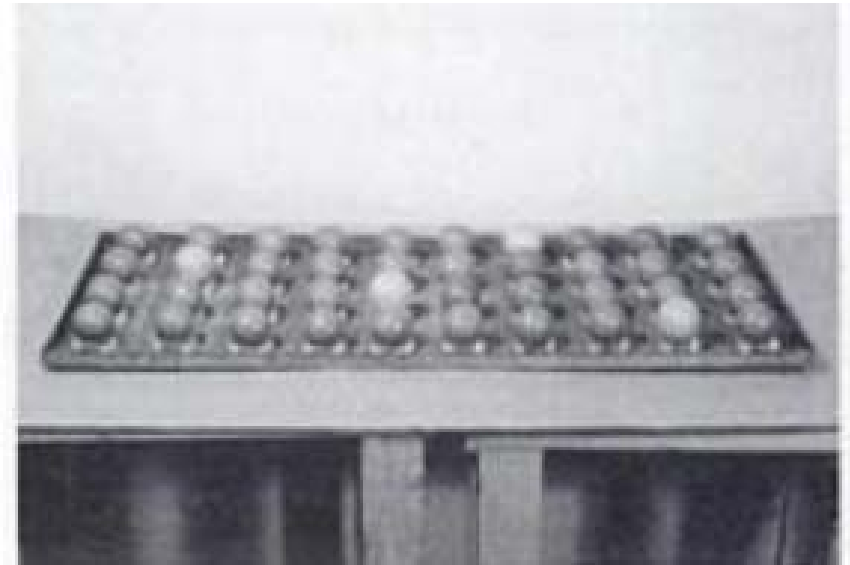**Reason 2:** trophic dynamics interact with spatial structure

Spatial food webs as a study object: why?

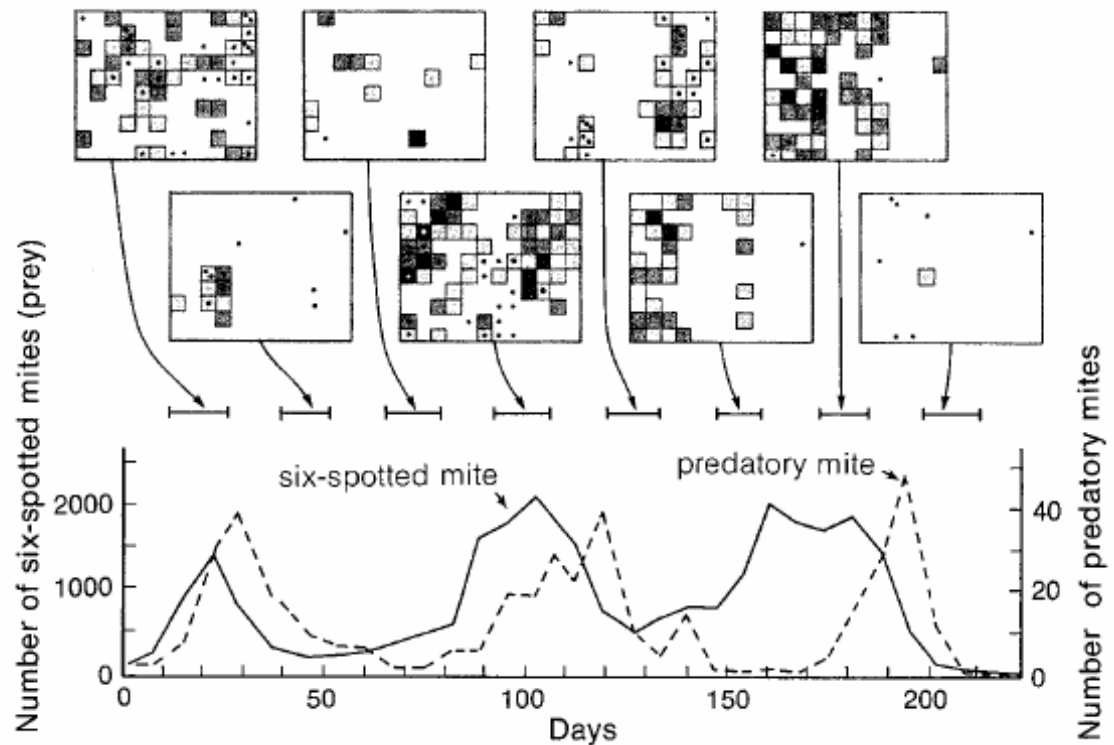**Reason 2:** trophic dynamics interact with spatial structure

Huffaker 1958; Huffaker *et al.* 1963 *Hilgardia*
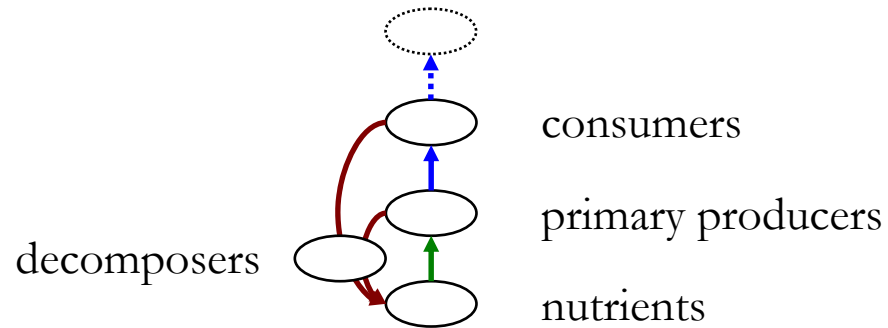
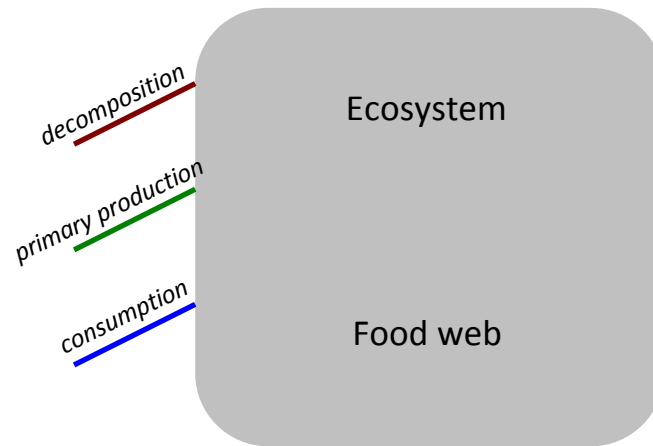# Spatial food webs as a study object: why?

Reason 2: trophic dynamics interact with spatial structure

"Preys escaping predators" insures persistence

Huffaker 1958; Huffaker *et al.* 1963 *Hilgardia*
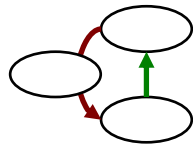
How SFWs have been tackled?

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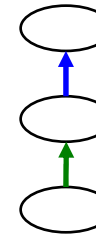
Ecosystem

Food web

decomposers

primary producers

nutrients

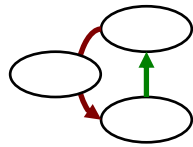consumers

primary producers

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How SFWs have been tackled?

Ecosystem

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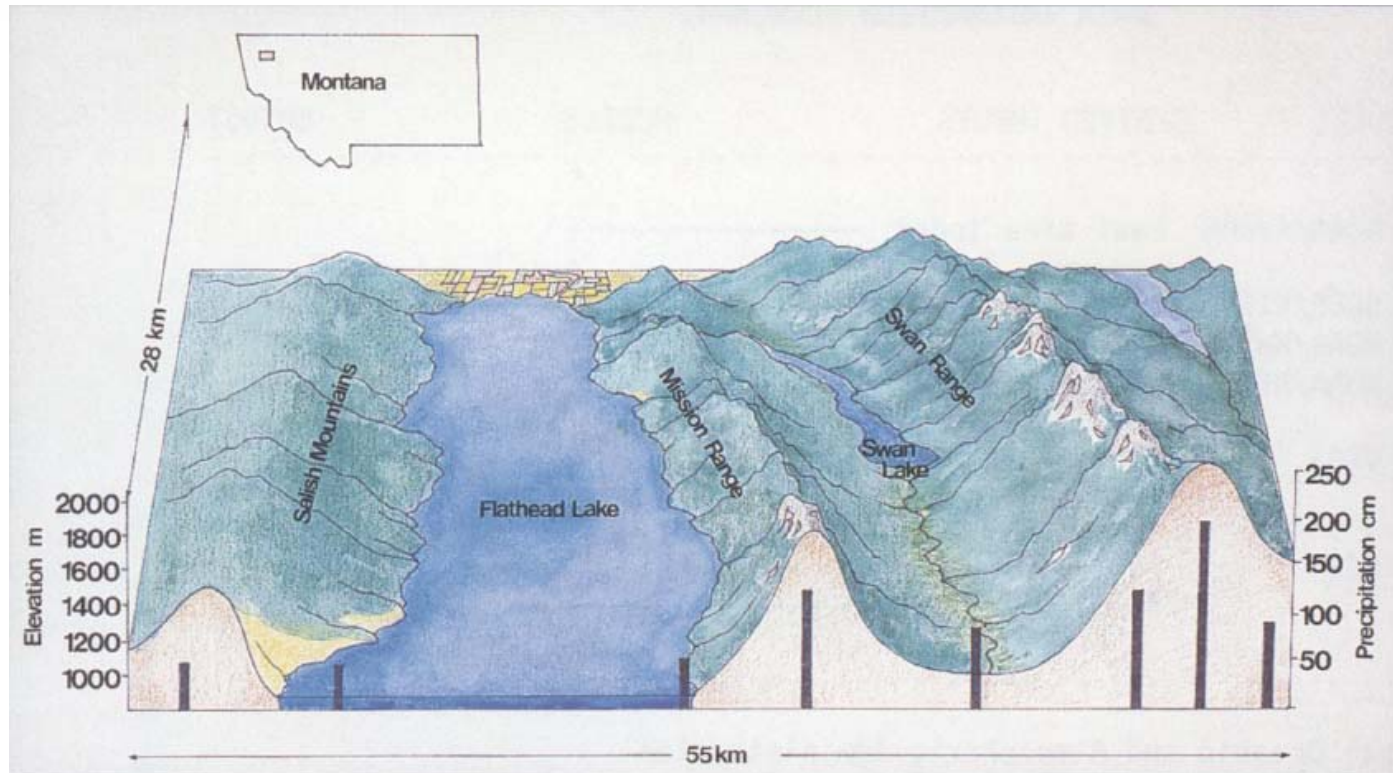
consumers

primary producers

nutrients

…with space

Landscape
Ecosystem
Ecology

Food web
metacommunity
Ecology

How SFWs have been tackled?

Examples

Landscape Ecosystem Ecology

MAPPING REGIONAL FOREST EVAPOTRANSPIRATION AND PHOTOSYNTHESIS BY COUPLING SATELLITE DATA WITH ECOSYSTEM SIMULATION[1]

Running *et al.* 1989 *Ecology*

How SFWs have been tackled?

Landscape Ecosystem Ecology

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MAPPING REGIONAL FOREST EVAPOTRANSPIRATION AND PHOTOSYNTHESIS BY COUPLING SATELLITE DATA WITH ECOSYSTEM SIMULATION[1]

Running *et al.* 1989 *Ecology*

Food web metacommunity Ecology

Species coexistence and self-organizing spatial dynamics

Examples

1 host + 2 parasitoid species dynamics

$$N_{t+1} = \lambda N_t f(P_t + rQ_t)$$
$$P_{t+1} = cN_t[1 - f(P_t + rQ_t)][P_t/P_t + rQ_t)]$$
$$Q_{t+1} = dN_t[1 - f(P_t + rQ_t)[rQ_t/(P_t + rQ_t)]$$
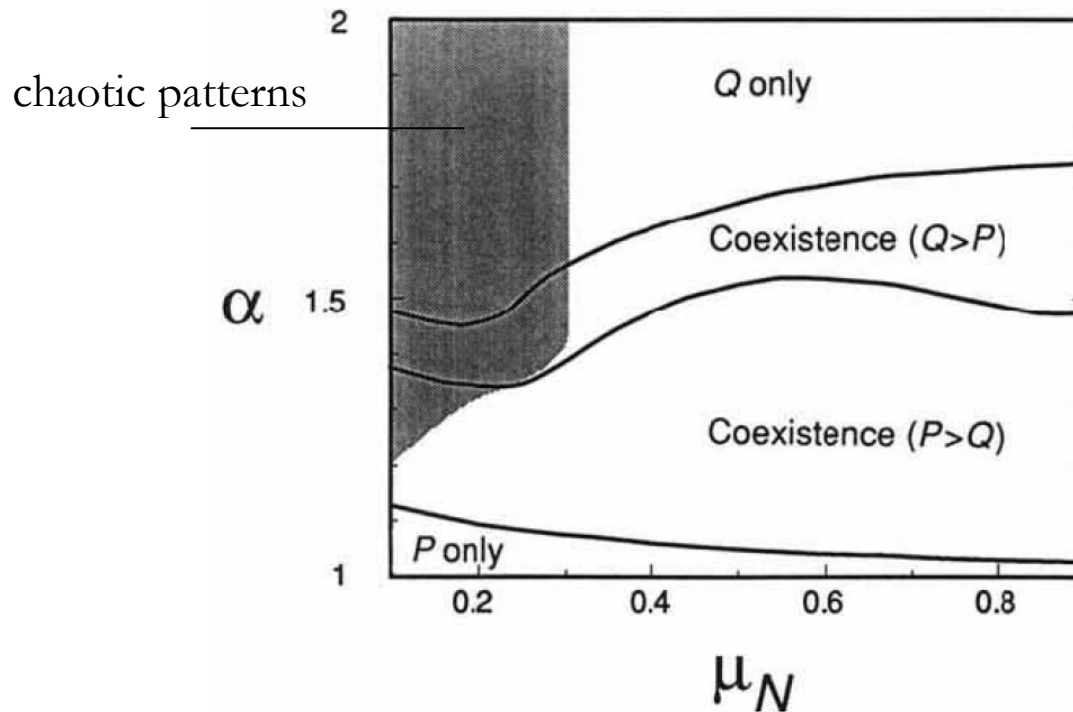
+ stepping-stone dispersal on a grid

Hassell *et al.* 1994 *Nature*

How SFWs have been tackled?

Food web metacommunity Ecology

Species coexistence and self-organizing spatial dynamics

Examples

chaotic patterns

Hassell *et al.* 1994 *Nature*

How SFWs have been tackled?

| *Landscape Ecosystem Ecology* | *Food web metacommunity Ecology* |

Effect categories

Functioning	**Dynamics**
Organization	Diversity
Dynamics	Organization
Diversity	Functioning

Coupling media

| **Material** | **Traits** |

Interacting agents

| **Nutrients + Primary producers + Decomposers** | **Consumers + Primary producers + Nutrients** |

How SFWs have been tackled?

Effect categories

Landscape Ecosystem Ecology
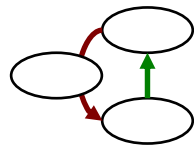
Food web metacommunity Ecology

Functioning

Dynamics

Organization

Diversity
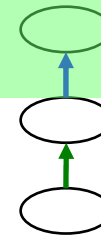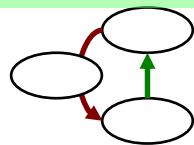
Dynamics

Organization

Different perspectives, different methods…

…with such well cleaved traditions, do we miss something?

Interacting agents

Nutrients + Primary producers + Decomposers

Consumers + Primary producers + Nutrients

Cross-tradition problems

Extraordinarily high spider densities on islands: Flow of energy from the marine to terrestrial food webs and the absence of predation

GARY A. POLIS AND STEPHEN D. HURD

Department of Biology, Vanderbilt University, Nashville, TN 37235

Polis and Hurd 1995 *PNAS*

Cross-tradition problems

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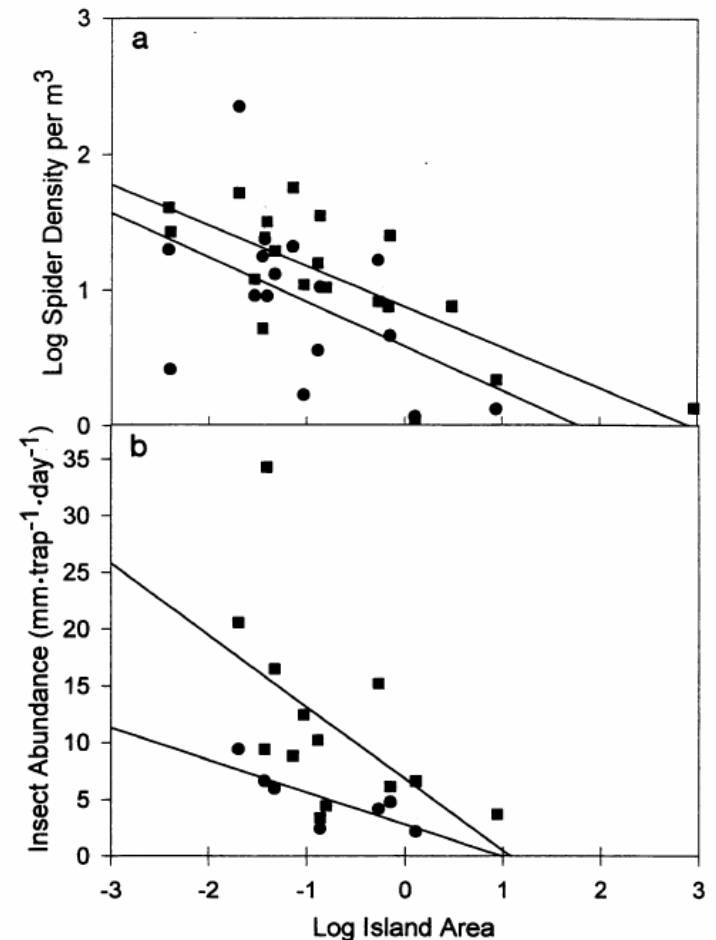
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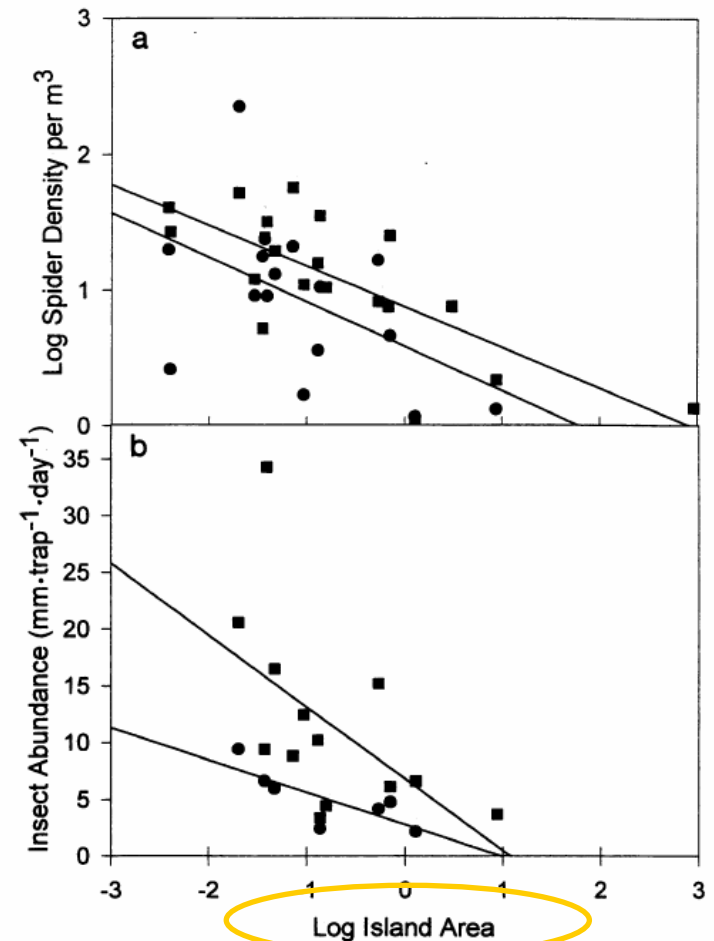
Cross-tradition problems

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Area relates to…

- colonization/extinction ratios (MacArthur & Wilson)

- perimeter/area ratios (openness to ocean fluxes)

Polis and Hurd 1995 *PNAS*
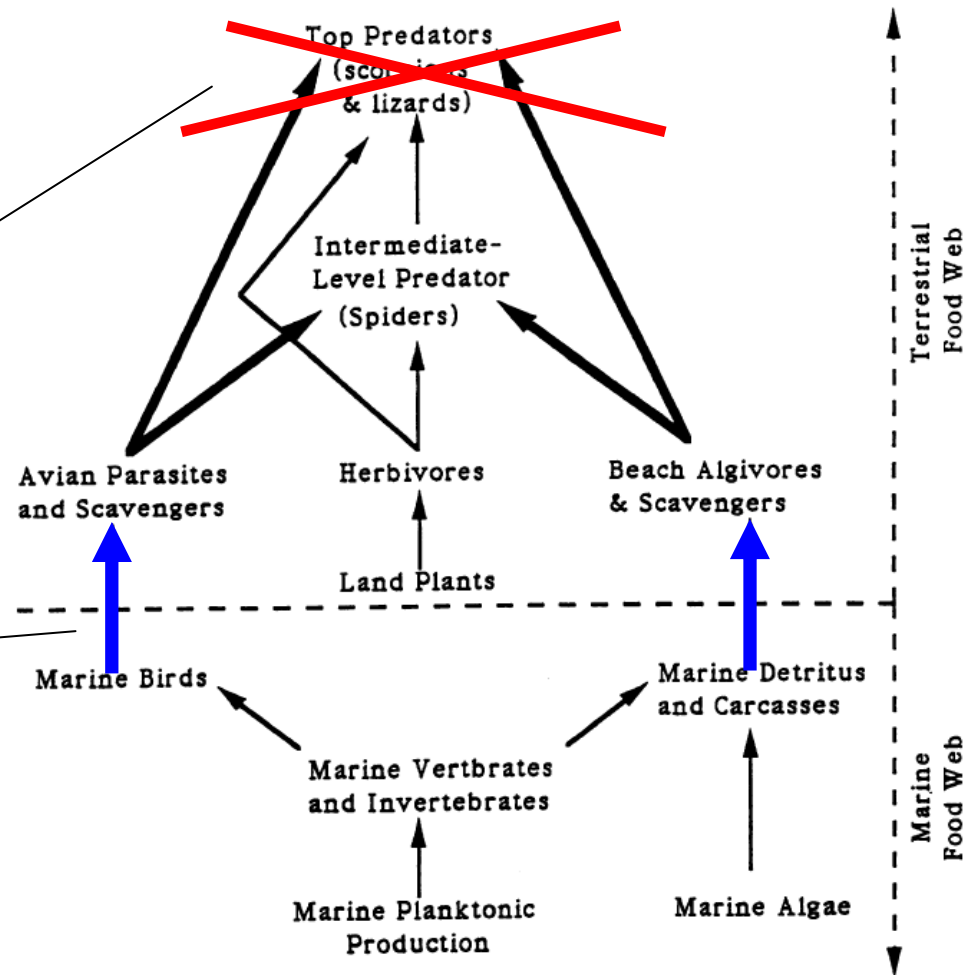
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biogeographical argument
(trait = c/e ratio)

nutrient flow argument
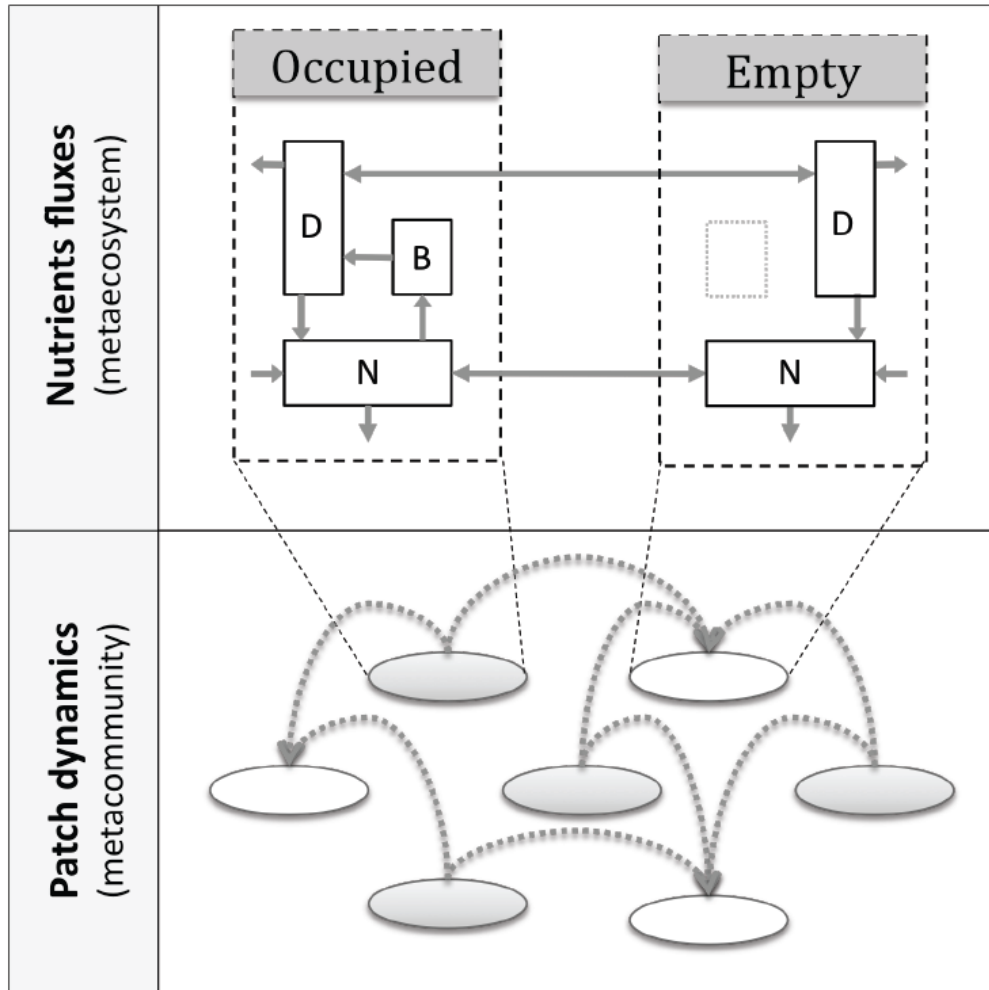(material)

Polis and Hurd 1995 *PNAS*

Meta-ecosystems: a theoretical framework for a spatial ecosystem ecology

- from metacommunities to metaecosystems

- how?:

  – put mass-balance and stoichiometry back in the picture

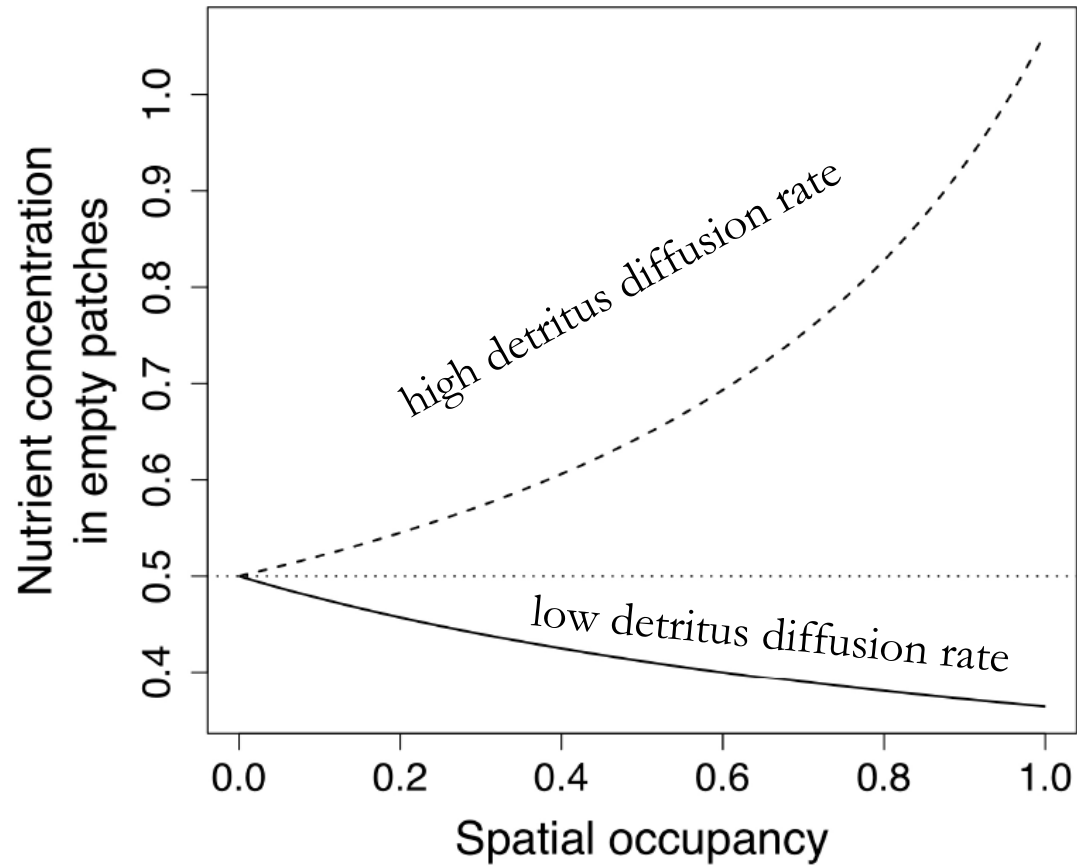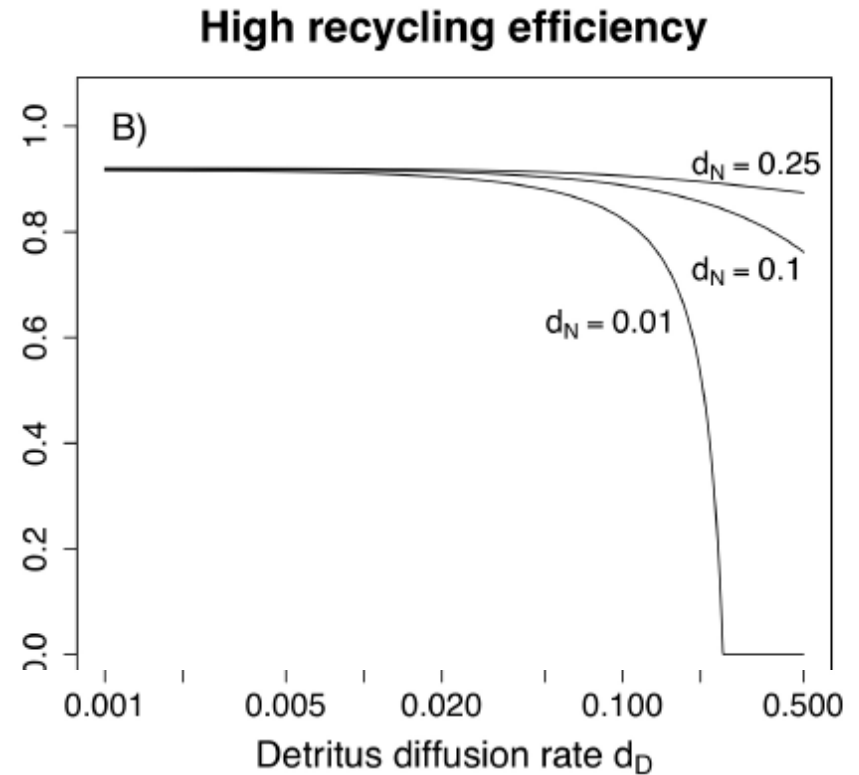 – extend the concepts of sources and sinks

Loreau *et al.* 2003 *Ecology Letters*

Merging traditions
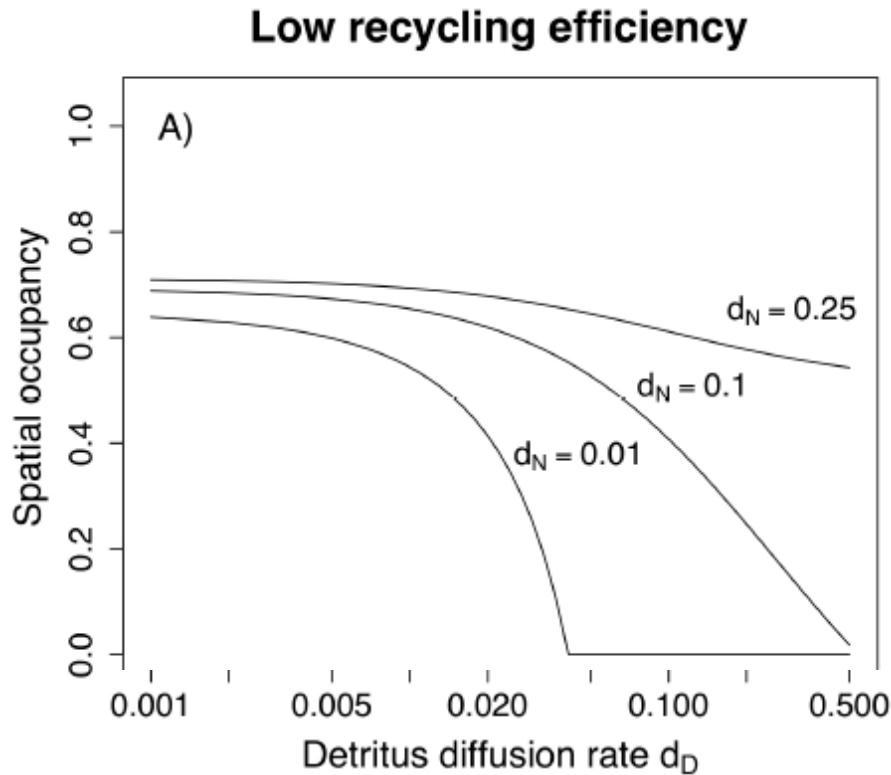
L-V-like ODEs for B, D, and N biomass

Levins' metapopulation model for plants (patch colonization & extinction)

Gravel *et al.* in press *Am. Nat*

Merging traditions

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Take-home messages

1. Ecosystem- and population biology-oriented ecologists have tackled SFWs in different ways

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3. Some situations require both perspectives to be fully understood

Take-home messages

1. Ecosystem- and population biology-oriented ecologists have tackled SFWs in different ways

2. Ecosystemists have emphasized the movement of <u>material</u>; population biologists, the movement of <u>traits</u>

3. Some situations require both perspectives to be fully understood

4. To merge these perspectives, we propose to put back ecosystem processes (recycling, stoichiometric and mass-balance constraints) in SFWs

Thank you!

Discussions/comments/inputs

V. Calcagno, E. Canard, J. Cox, T. Daufresne, A. Duputié, A. Gonzalez, F. Guichard, M. Johnston, S. Leroux, G. Livingston, N. Loeuille, M. Loreau, J. Malcolm, C. de Mazancourt, J. Pantel, C. Parent, R. Shaw, G. Smith

NIMBioS Working group: "Food Web Dynamics and Stoichiometric Constraints in Meta-ecosystems"

Institutes

CEMAGREF (Aix-en-Provence), University of Texas (Austin), ISEM (Montpellier), UQAR (Rimouski), University of Toronto-Scarborough, Stanford University