

An understanding of food-web persistence from local to global scales

Daniel B. Stouffer

Integrative Ecology Group
Estación Biológica de Doñana - CSIC
Sevilla, Spain
stouffer@ebd.csic.es

CABDyN Seminar Series



Invasive species in the Great Lakes

Invasive species in the Great Lakes

- Zebra mussel




Invasive species in the Great Lakes

- Zebra mussel



Invasive species in the Great Lakes

- Northern snakehead



MSNBC Home » U.S. News

'Frankenfish' rears its ugly head in Lake Michigan

Voracious non-native fish strikes fear in hearts of marine biologists

By Jack Chesnutt
Producer
NBC News
Updated: 10:13 a.m. CT Oct 15, 2004

CHICAGO - It looks like a pike on steroids. But, the northern snakehead, a non-native fish with a voracious appetite, is one fish no one wants in the neighborhood.


This week, fish biologists were alarmed to learn that a Chicago-area fisherman caught a snakehead in his net while fishing in Lake Michigan's Burnham Harbor.

"I hope this is the only one they find in Lake Michigan," Walter Courtney, of the U.S. Geological Survey told the Chicago Tribune. "If there is a male and female out there, anything can happen."

Major threat to habitat

The snakehead is a potential threat to inland lakes and rivers because it feeds on native fish and can wipe out some species of sport fish. In the Great Lakes, they would compete with popular sport fish like bass and walleye.

Story continues below ↓



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Leslie E. Kossoff / AP file

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Invasive species in the Great Lakes

- Asian carp

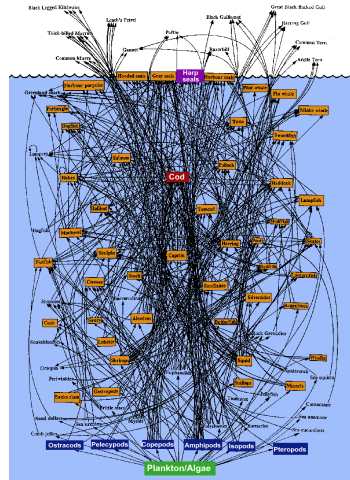


Invasive species in the Great Lakes

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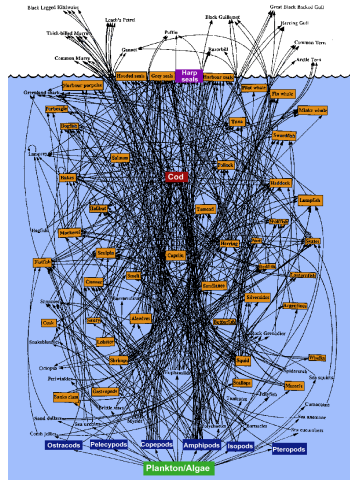


Challenge of solving these problems



Challenge of solving these problems

- A true complex system
- Experimentation is impossible (or impractical)



What makes a food web stable?

Allesina and Pascual, *Theor. Ecol.* (2007) and Otto *et al.*, *Nature* (2007)

What makes a food web stable?

- “Complexity-stability” debate
- Stability of small sub-webs

What makes a food web stable?

- “Complexity-stability” debate
 - More diversity and more connections = *Greater* stability
 - More diversity and more connections = *Lower* stability
 - Greater empirical realism increases stability
- Stability of small sub-webs

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 - Omnivory is a stabilizing force
 - Weak interactions confer stability
 - Predator-prey body size ratios

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- What is meant by stability?
 - Return to equilibrium after perturbation
 - Stabilization of dynamics
 - Greater species persistence

Food-web structure and persistence

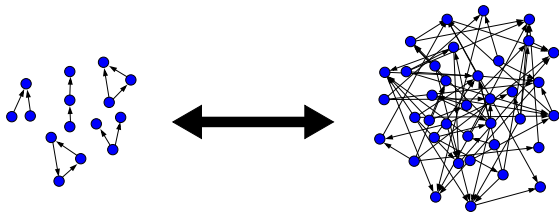
- What is the role of food-web structure on persistence?

Food-web structure and persistence

- What is the role of food-web modules?

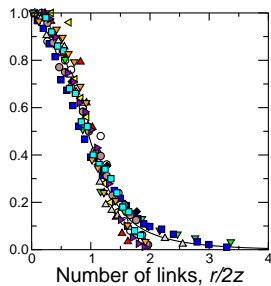
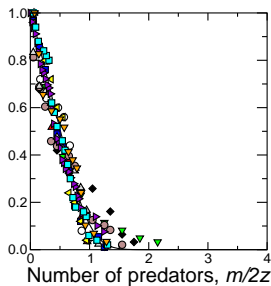
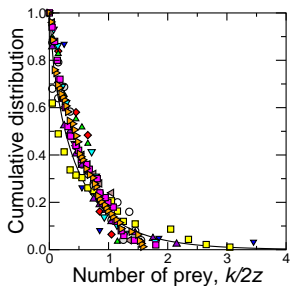
Food-web structure and persistence

- What is the role of food-web modules?
- How does persistence of food-web modules in isolation relate to their influence within community food webs?



Universal function forms for distributions of numbers of prey, predators, and links

- A key to the success of leading static food-web models



Ingredients for successful food-web model

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- Species can be ordered in one dimension



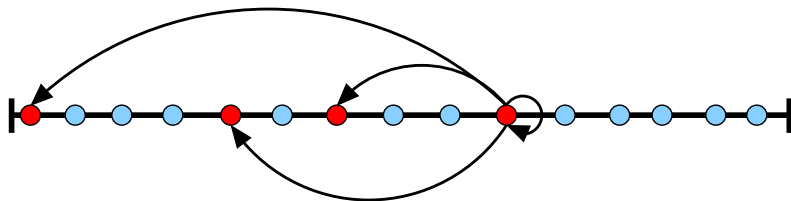
Ingredients for successful food-web model

- Species can be ordered in one dimension
- Prey selection



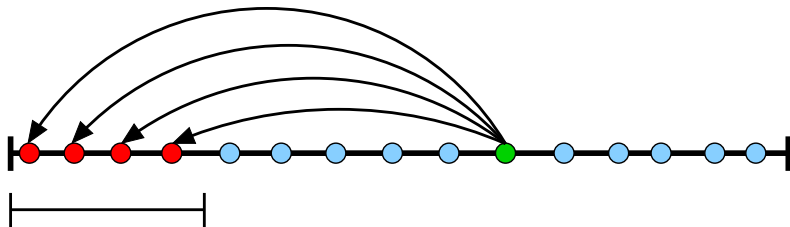
Ingredients for successful food-web model

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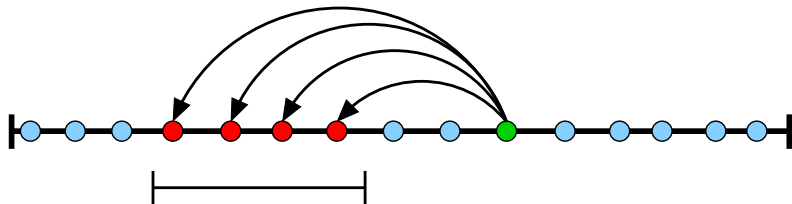
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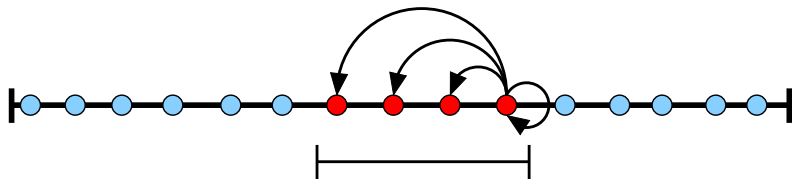
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Prey selection mechanism

- Random predation
- Contiguous predation

Prey selection mechanism

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 - Predators are indifferent to the identity of their prey
- Contiguous predation

Prey selection mechanism

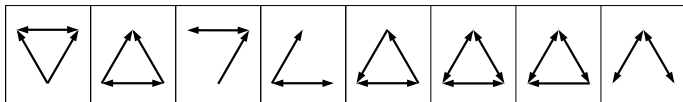
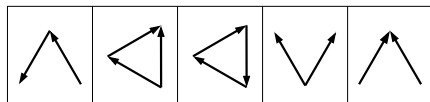
- Random predation
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- Contiguous predation
 - Predators specialize on species which have some characteristic features

Prey selection mechanism

- Random predation
 - Predators are indifferent to the identity of their prey
- Contiguous predation
 - Predators specialize on species which have some characteristic features
- Is there a signature in the data indicating the empirically observed mechanism?

Network motifs

- Complete set of unique connected triplets of species



Significance of network motifs

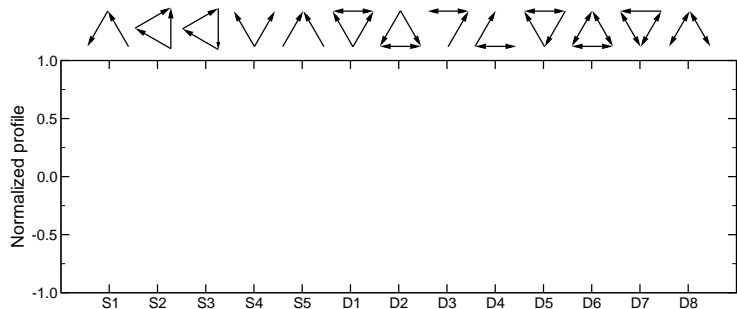
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- Compare to null hypothesis of a randomized network

Significance of network motifs

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- Compare to null hypothesis of a randomized network
- Could the observed motif pattern occur at random?

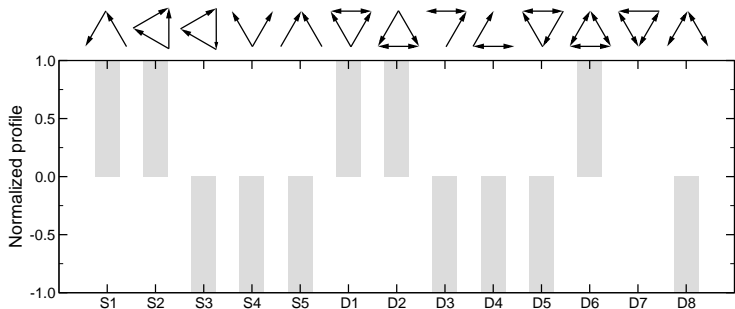
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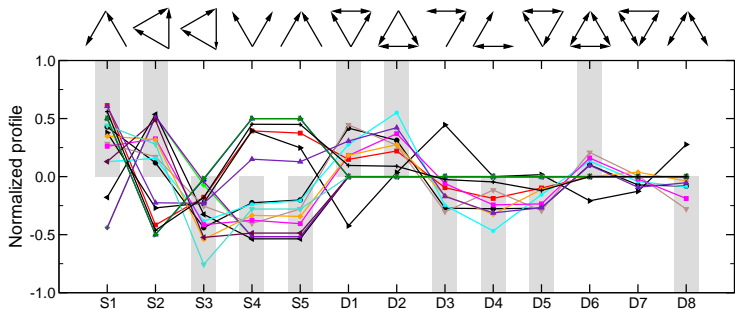
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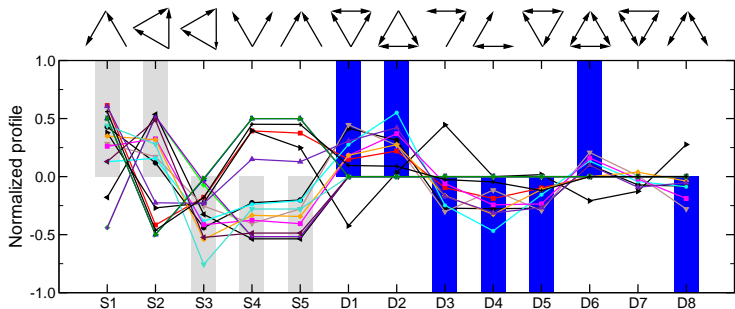
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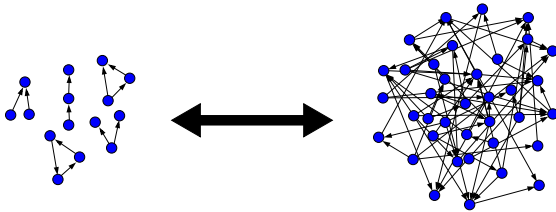


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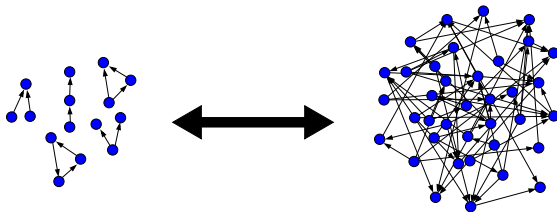
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Food-web modules and persistence

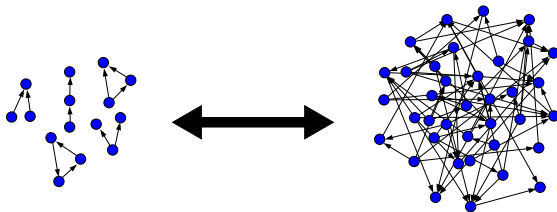


Food-web modules and persistence



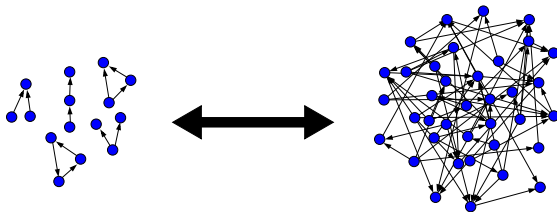
- What is the relationship between persistence of modules in isolation and their influence on community food-web persistence?

Food-web modules and persistence



- How does a module's influence on community food-web persistence relate to its presence in community food-webs?

Food-web modules and persistence



- We will model module and food-web dynamics and examine the consequences of structure

Modeling food-web dynamics

Modeling food-web dynamics

- Bioenergetic population dynamics model[†]
- Allometric scaling of metabolic parameters[×]

$$\frac{dB_i}{dt} = r_i G_i B_i - \sum_{k=\text{pred}} \frac{x_k y_k B_k F_{ki}}{e_{ki}}$$

$$\frac{dB_i}{dt} = -x_i B_i + x_i B_i \sum_{j=\text{prey}} y_j F_{ij} - \sum_{k=\text{pred}} \frac{x_k y_k B_k F_{ki}}{e_{ki}}$$

[†]Yodzis and Innes, *Am. Nat.* (1992)

[×]Brose *et al.*, *Ecol. Lett.* (2006)

Modeling food-web dynamics

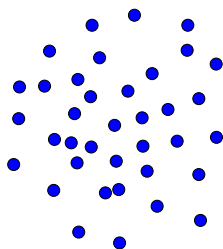
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- Required inputs:

Modeling food-web dynamics

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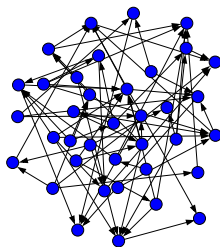
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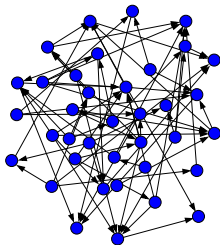
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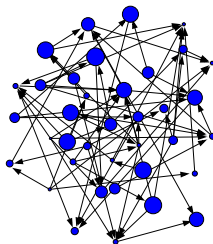
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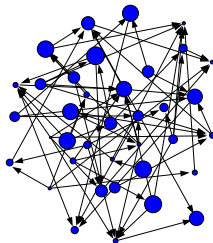
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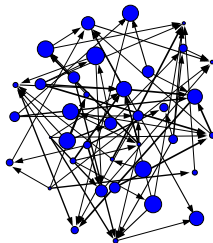
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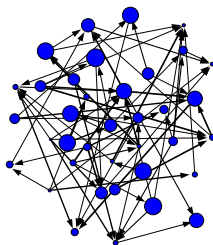
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Modeling food-web dynamics

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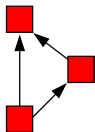
- What is the persistence after t timesteps?

Persistence of isolated modules

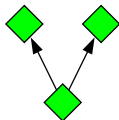
Tri-trophic
chain



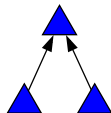
Omnivory



Exploitative
competition



Apparent
competition

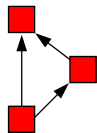


Persistence of isolated modules

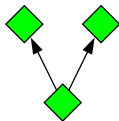
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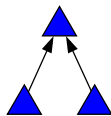
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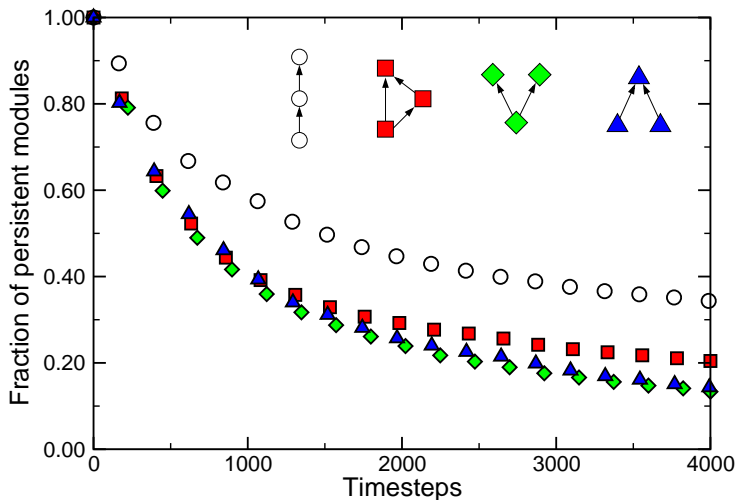


Apparent
competition



- Constitute 95% of empirically observed modules

Persistence of isolated modules

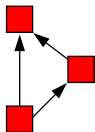


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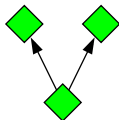
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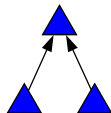
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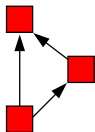


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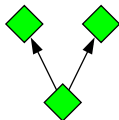
Tri-trophic chain



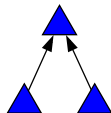
Omnivory



Exploitative competition



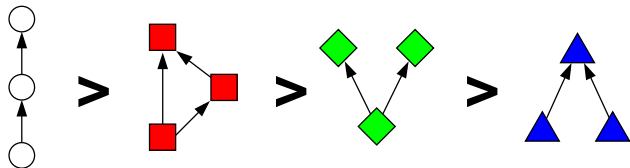
Apparent competition



- Expectation based upon isolated persistence

Persistence of isolated modules

Tri-trophic chain Omnivory Exploitative competition Apparent competition



- Expectation based upon isolated persistence

Community food-web persistence

- How does presence of modules relate to persistence?

Community food-web persistence

- How does presence of modules relate to persistence?
- Generate a food web, assign masses, assign interaction strengths. . .

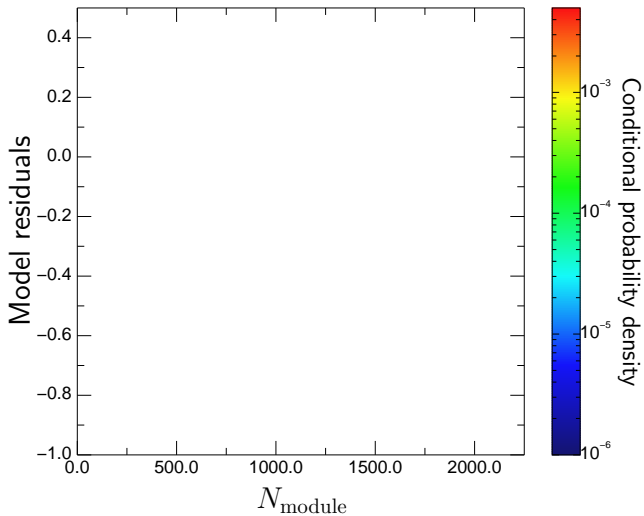
Community food-web persistence

- How does presence of modules relate to persistence?
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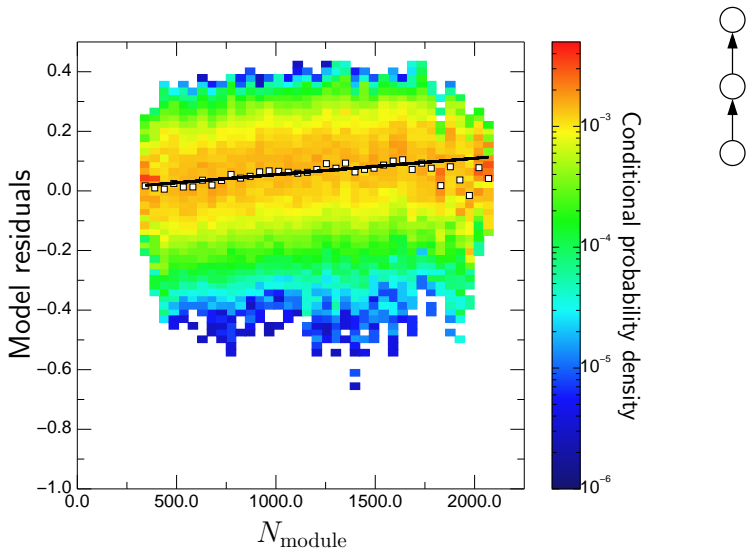
Community food-web persistence

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- The food web has some number of each module:
 - Tri-trophic food chain
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- How does the number of each module present influence the food web's persistence?

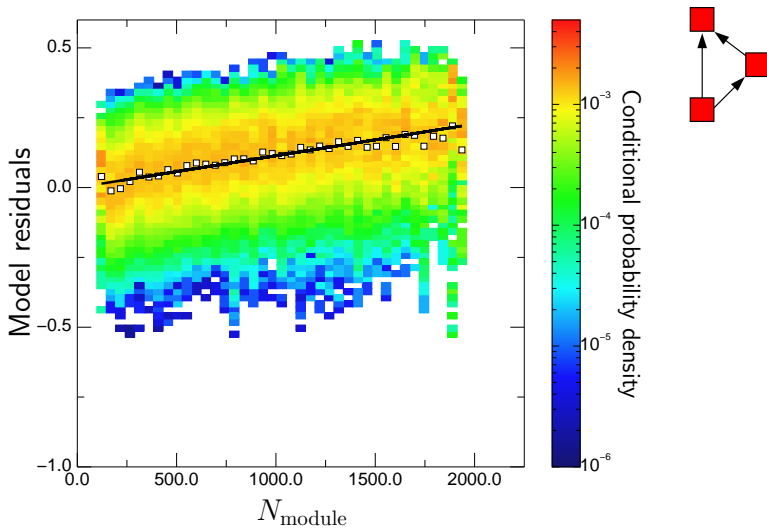
Community food-web persistence



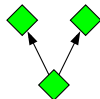
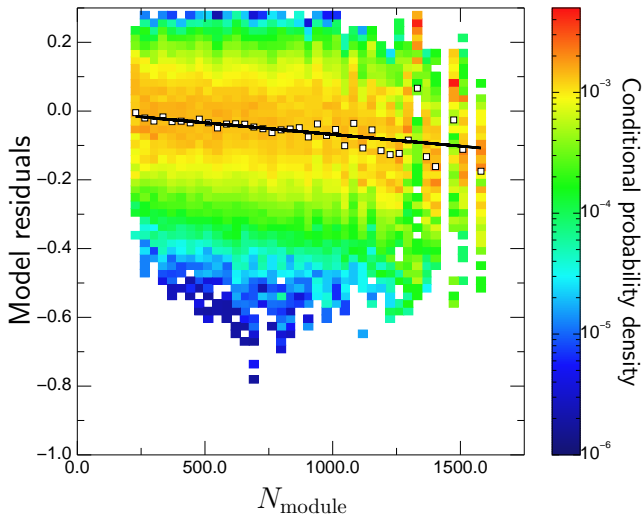
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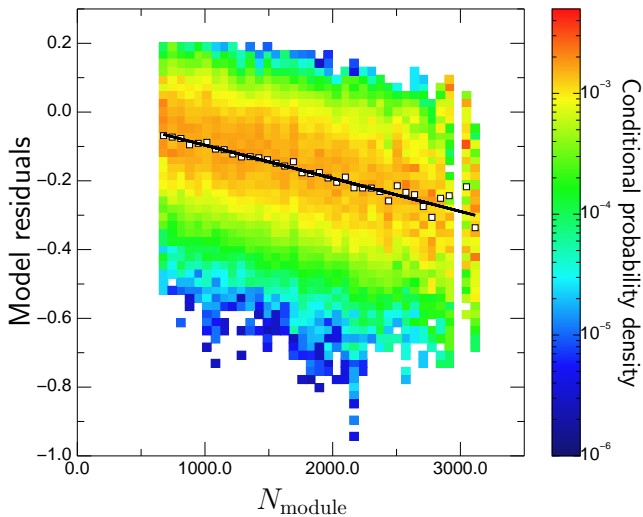
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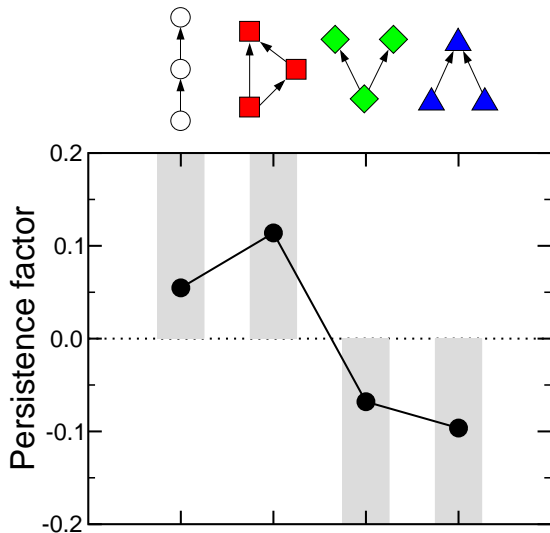
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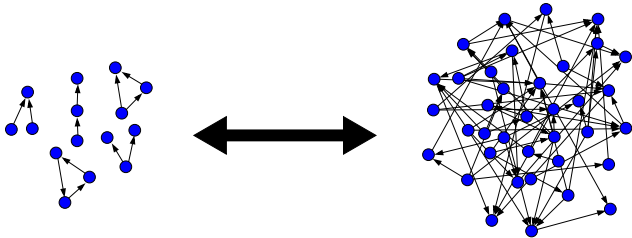
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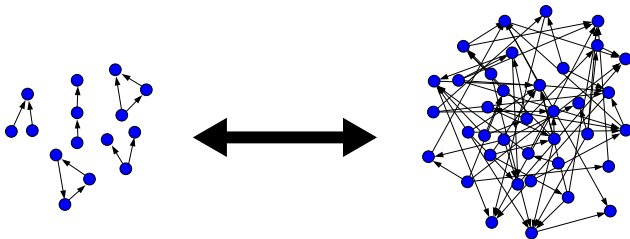
Persistence profile



Conclusions

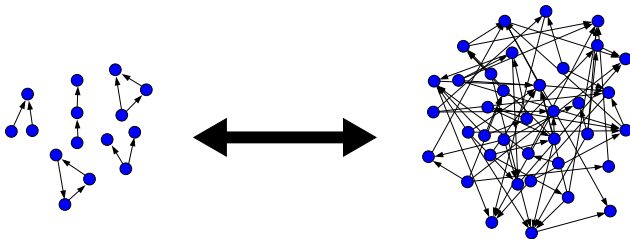


Conclusions



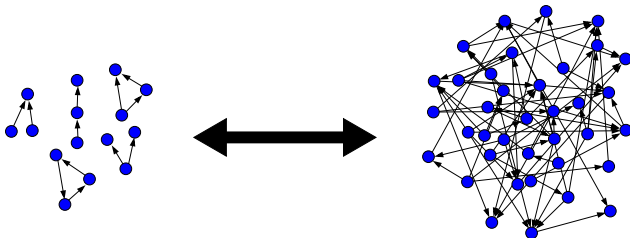
- Persistence of isolated modules is not the same as the effect within community food webs

Conclusions



- Presence of modules has clear influence on community food web persistence

Conclusions



- Presence of modules has clear influence on community food web persistence
- Strongly related to empirical observations

Implications

Implications

- There may be significant dynamic justifications for observed food-web structure

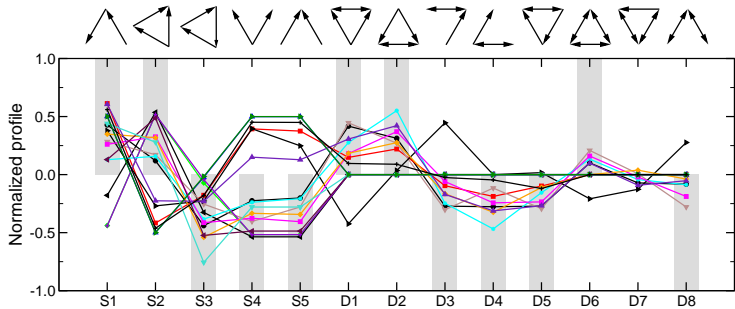
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- There may be significant dynamic justifications for observed food-web structure
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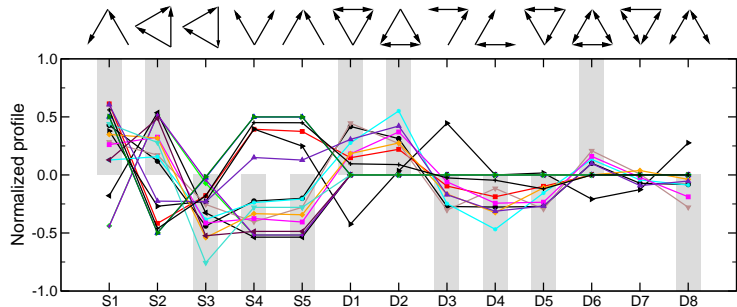
- There may be significant dynamic justifications for observed food-web structure
- Caution must be taken when attempting to scale up from modules to community food webs
- Species appear to participate in interactions which maximize community persistence and not necessarily their own persistence

Implications



- Some empirical food webs exhibit fewer instances of omnivory and greater instances of exploitative and apparent competition

Implications



- We hypothesize that these food webs are less persistent and more vulnerable to perturbation

Implications

- Management decisions
- Invasive species

Implications

- Management decisions
 - What motifs does a species participate in?
- Invasive species

Implications

- Management decisions
 - What motifs does a species participate in?
- Invasive species
 - What motifs is an invasive likely to participate in?

Acknowledgments

- Luís Amaral, Juan Camacho, Wenxin Jiang
- Jordi Bascompte
- Members of the Integrative Ecology Group and Amaral Lab
- NSF IGERT Graduate Research Fellowship
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- CSIC JAE Post-doctoral Fellowship
- Centro de Supercomputación de Galicia (CESGA)



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