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

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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
Invasive species in the Great Lakes

- Asian carp
Invasive species in the Great Lakes

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Challenge of solving these problems
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- A true complex system
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- Experimentation is impossible (or impractical)
Challenge of solving these problems

- A true complex system
- Experimentation is impossible (or impractical)
- A modeling approach is imperative
What makes a food web stable?

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

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- “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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- Stability of small sub-webs
  - 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

Stouffer et al., Ecology (2005)
Ingredients for successful food-web model

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- Species can be ordered in one dimension

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- Prey selection

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- Prey selection: Random

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Stouffer et al., Ecology (2005)
Prey selection mechanism

- Random predation
- Contiguous predation

Stouffer et al., PRSB (2007)
Prey selection mechanism

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

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

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- Is there a signature in the data indicating the empirically observed mechanism?

Stouffer et al., PRSB (2007)
Network motifs

- Complete set of unique connected triplets of species

Milo et al., Science (2002)
Significance of network motifs

- Just the appearance of motifs is not significant
- Compare to null hypothesis of a randomized network

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- Could the observed motif pattern occur at random?

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Food-web modules and persistence
What is the relationship between persistence of modules in isolation and their influence on community food-web persistence?
How does a module’s influence on community food-web persistence relate to its presence in community food-webs?
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×

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

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

†Yodzis and Innes, Am. Nat. (1992)
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- Allometric scaling of metabolic parameters
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Modeling food-web dynamics

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- Required inputs:
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- Bioenergetic population dynamics model
- Allometric scaling of metabolic parameters
- Required inputs:
  - Network of interactions
  - Species’ body masses
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- Required inputs:
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  - Species’ body masses
  - Interaction strengths
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Required inputs:
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What is the persistence after $t$ timesteps?
Modeling food-web dynamics

- Bioenergetic population dynamics model
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**Required inputs:**

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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

- Tri-trophic chain
- Omnivory
- Exploitative competition
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- Constitute 95% of empirically observed modules
Persistence of isolated modules
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- 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?
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- Generate a food web, assign masses, assign interaction strengths...
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- Generate a food web, assign masses, assign interaction strengths... 
- The food web has some number of each module:
  - Tri-trophic food chain
  - Omnivory
  - Exploitative competition
  - Apparent competition
- How does the number of each module present influence the food web’s persistence?
Community food-web persistence

![Graph showing model residuals vs. N_module with a color gradient representing conditional probability density.](image)
Community food-web persistence

Conditional probability density

Model residuals

$N_{module}$
Community food-web persistence
Community food-web persistence

[Graph showing conditional probability density and model residuals related to $N_{module}$]
Community food-web persistence

Model residuals vs. $N_{\text{module}}$ with conditional probability density.
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
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- Caution must be taken when attempting to scale up from modules to community food webs
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- 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
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?
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