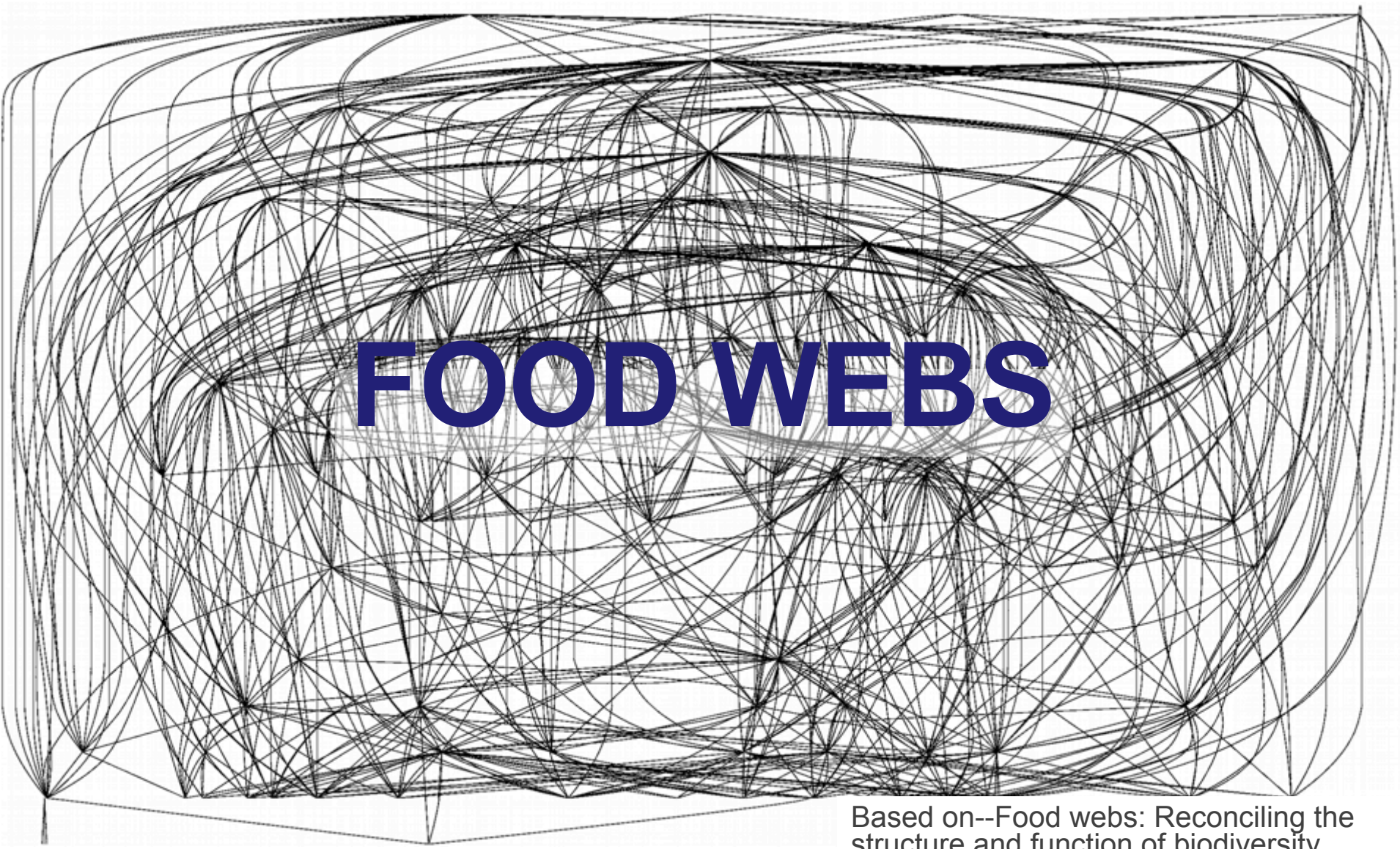


FOOD WEBS

Based on--Food webs: Reconciling the structure and function of biodiversity (Thompson et al., 2012).

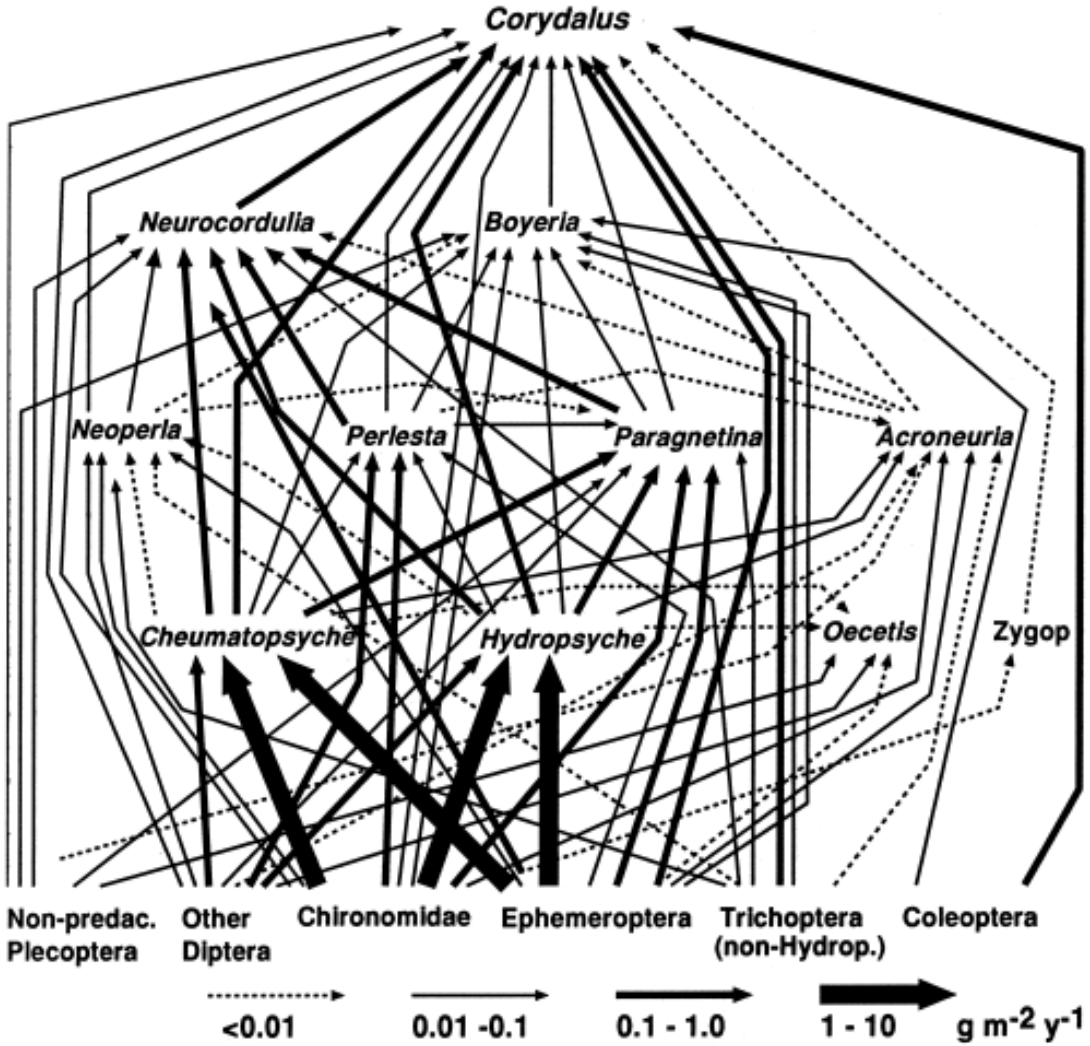
By Jessica and Marina

Outline

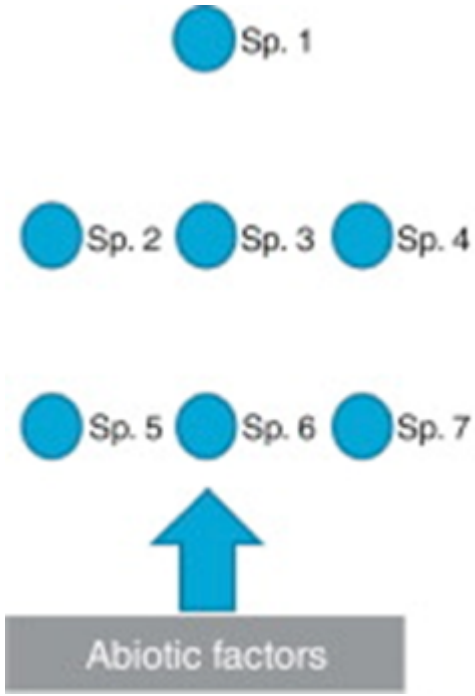
1. Food Web Attributes
2. Food Web Ecology
3. Characteristics of Food Web Studies
4. Case Study 1: Effects of overfishing on trophic cascades
5. Case Study 2: Applying food web ecology to resource management
6. Challenges in Food Web Studies

Food Web Attributes

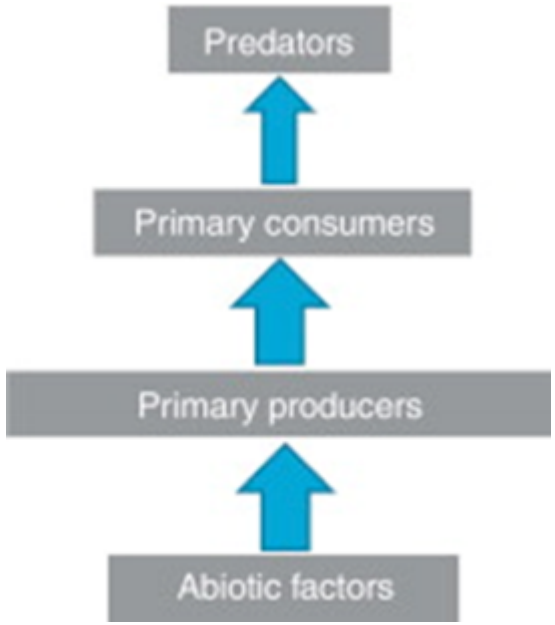
- Taxa Richness (S)
- Number of trophic links (L)
- Interaction strength (IS)
- Linkage density (=L/S)
- Connectance (=L/S^2)



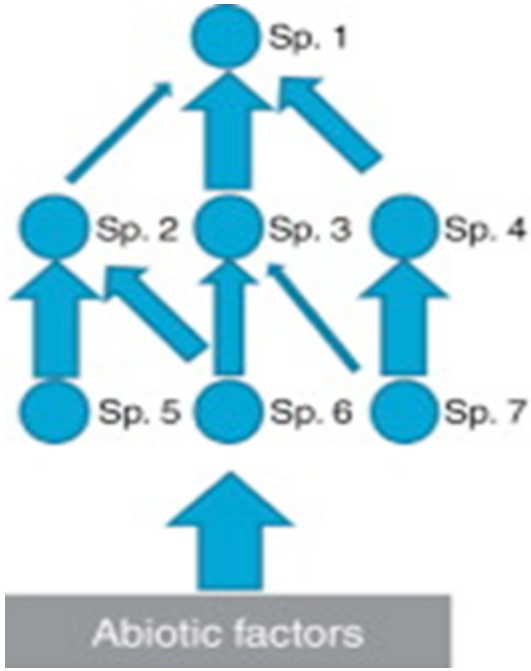
Benke, A. C., Wallace, J. B., Harrison, J. W. and Koebel, J. W. (2001), Food web quantification using secondary production analysis: predaceous invertebrates of the snag habitat in a subtropical river. Freshwater Biology, 46: 329–346. doi: 10.1046/j.



Community Ecology



Ecosystem Ecology



Food Web Ecology

Food Web Studies

What characterizes a good food web study when examining biodiversity and ecosystem function?

1. Measuring diversity within functional groups
2. Incorporating of fluxes of energy and materials
3. Incorporating individual species traits
4. Using a landscape approach
5. Using well-understood food-web attributes to explore structure and function
6. Using dynamic models based on species removal experiments to explore biodiversity and function

Interaction strength combinations and the overfishing of a marine food web

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*Integrative Ecology Group, Estación Biológica de Doñana, Consejo Superior de Investigaciones Científicas, Apartado Postal 1056, E-41080 Seville, Spain; and ‡Center for Marine Biodiversity and Conservation, Scripps Institution of Oceanography, University of California at San Diego, 9500 Gilman Drive, La Jolla, CA 92093

Communicated by Robert T. Paine, University of Washington, Seattle, WA, February 25, 2005 (received for review October 15, 2004)

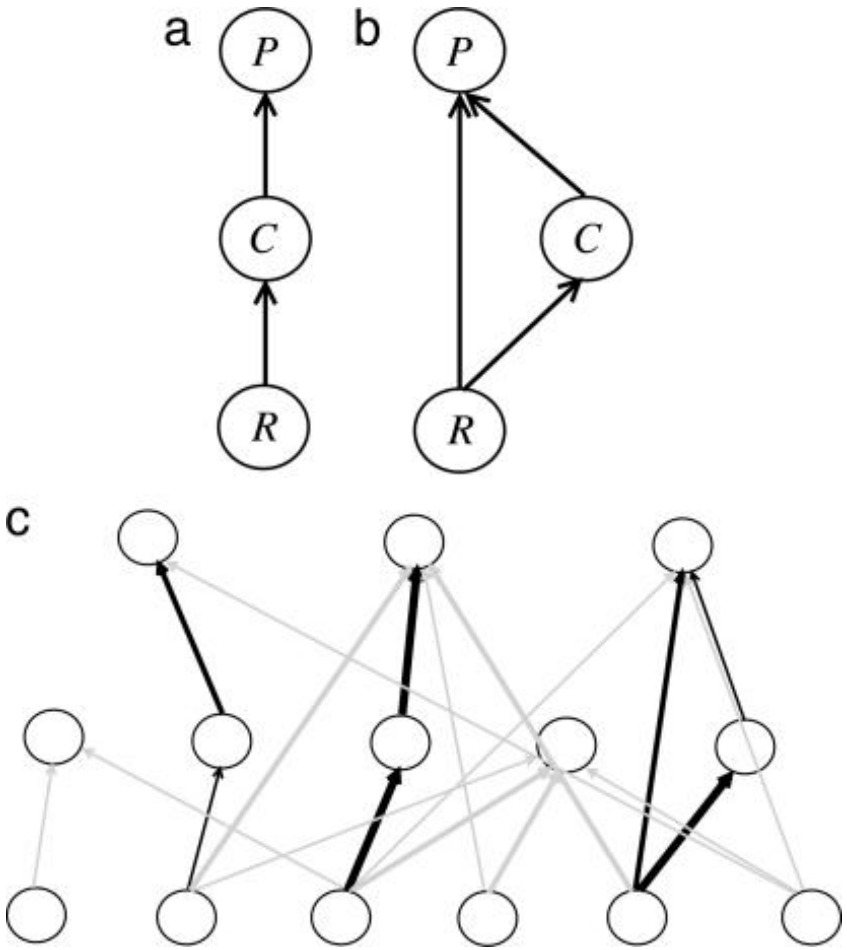
The stability of ecological communities largely depends on the strength of interactions between predators and their prey. Here we show that these interaction strengths are structured nonrandomly in a large Caribbean marine food web. Specifically, the cooccurrence of strong interactions on two consecutive levels of food chains occurs less frequently than expected by chance. Even when they occur, these strongly interacting chains are accompanied by strong omnivory more often than expected by chance. By using a food web model, we show that these interaction strength combinations reduce the likelihood of trophic cascades after the overfishing of top predators. However, fishing selectively removes predators that are overrepresented in strongly interacting chains. Hence, the potential for strong community-wide effects remains a threat.

Study

1. Created a food web structure with interaction strengths

2. Examined how interaction strengths are combined
   - Co-occurance of strong interactions
   - Influence of omnivory

3. Used a bioenergetic food web model to see how interaction strengths affect trophic cascades



Structural Food Web

Food Web

- Used data from published studies to create a food web: 249 species, 3 313 interactions in the Caribbean

Predator-Prey Interaction Strengths

- Per capita strength of a predator's interactions on its prey

$$\frac{(Q/B)_j \times DC_{ij}}{B_i},$$

- Classified interactions based on strength
  - Strong: > 10^{-3}

Co-occuring interaction strengths

- Compared results against a randomized food web to see how often they occur by chance

Food Web Model

- Created a bioenergetic model of a simple TFC and a food chain with omnivory
- Independent trophic modules were embedded into the food web
- Simulated removal of top predators to examine the effects on the resource

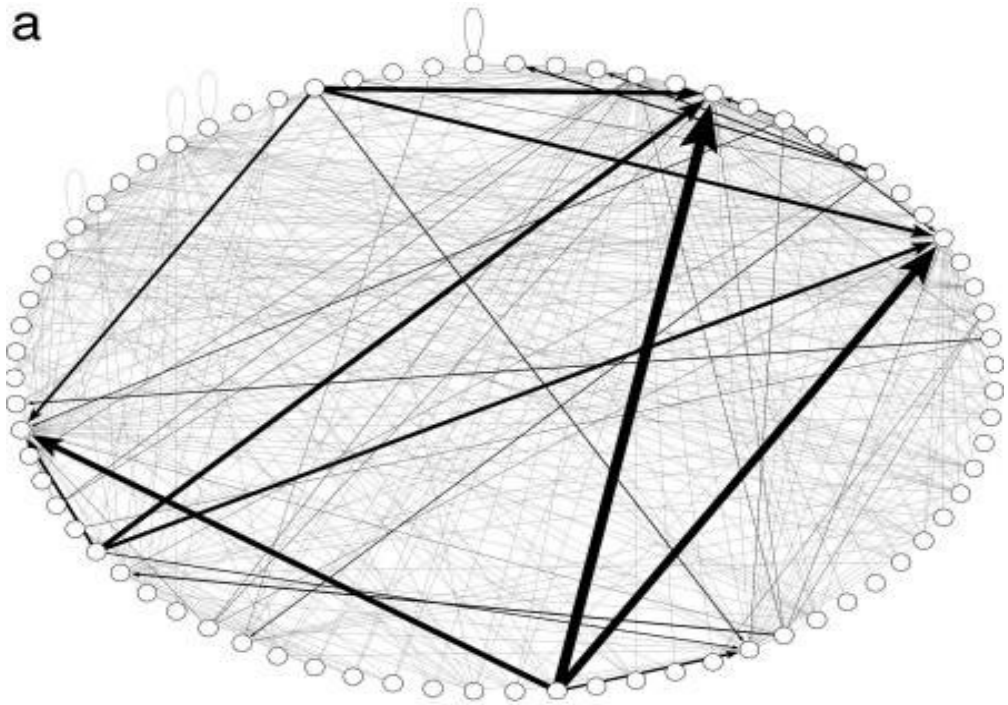
$$\frac{dR}{dt} = rR\left(1 - \frac{R}{K}\right) - \frac{(1-\Omega_{Ac})X_{RC}Y_C R^n C}{(1-\Omega_{Ac})R^n + \Omega_{Ac}A_c^n + (1+c_C C)R_0^n} - \frac{\Omega_{RP}X_{RP}Y_P R^n P}{\Omega_{RP}R^n + \Omega_{Ap}A_p^n + \Omega_{CP}C^n + (1+c_P P)R_{02}^n};$$

$$\frac{dC}{dt} = -X_C C + \frac{(1-\Omega_{Ac})X_{RC}Y_C R^n C}{(1-\Omega_{Ac})R^n + \Omega_{Ac}A_c^n + (1+c_C C)R_0^n} + \frac{\Omega_{Ac}X_{AC}Y_C A_c^n C}{(1-\Omega_{Ac})R^n + \Omega_{Ac}A_c^n} - \frac{\Omega_{CP}X_{CP}Y_P C^n P}{\Omega_{RP}R^n + \Omega_{Ap}A_p^n + \Omega_{CP}C^n + (1+c_P P)C_0^n};$$

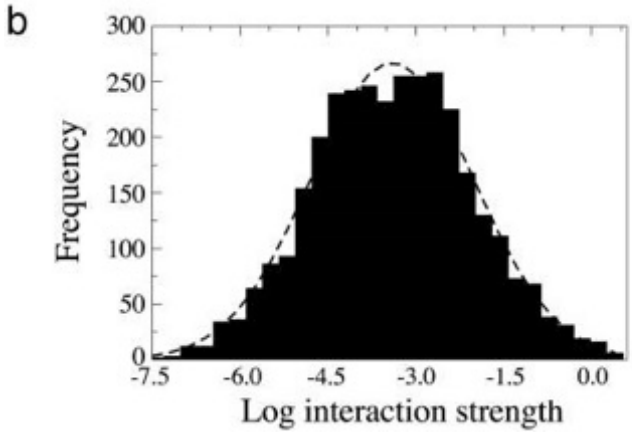
$$\frac{dP}{dt} = -X_P P - FP + \frac{\Omega_{RP}X_{RP}Y_P R^n P}{\Omega_{RP}R^n + \Omega_{Ap}A_p^n + \Omega_{CP}C^n + (1+c_P P)R_{02}^n} + \frac{\Omega_{CP}X_P Y_P C^n P}{\Omega_{RP}R^n + \Omega_{Ap}A_p^n + \Omega_{CP}C^n + (1+c_P P)C_0^n} + \frac{\Omega_{Ap}X_{AP}Y_P A_p^n P}{\Omega_{RP}R^n + \Omega_{Ap}A_p^n + \Omega_{CP}C^n},$$

Results: Interaction Strength

- Random sample of 30% of species and 11% of interactions
- Majority of interaction strengths are weak

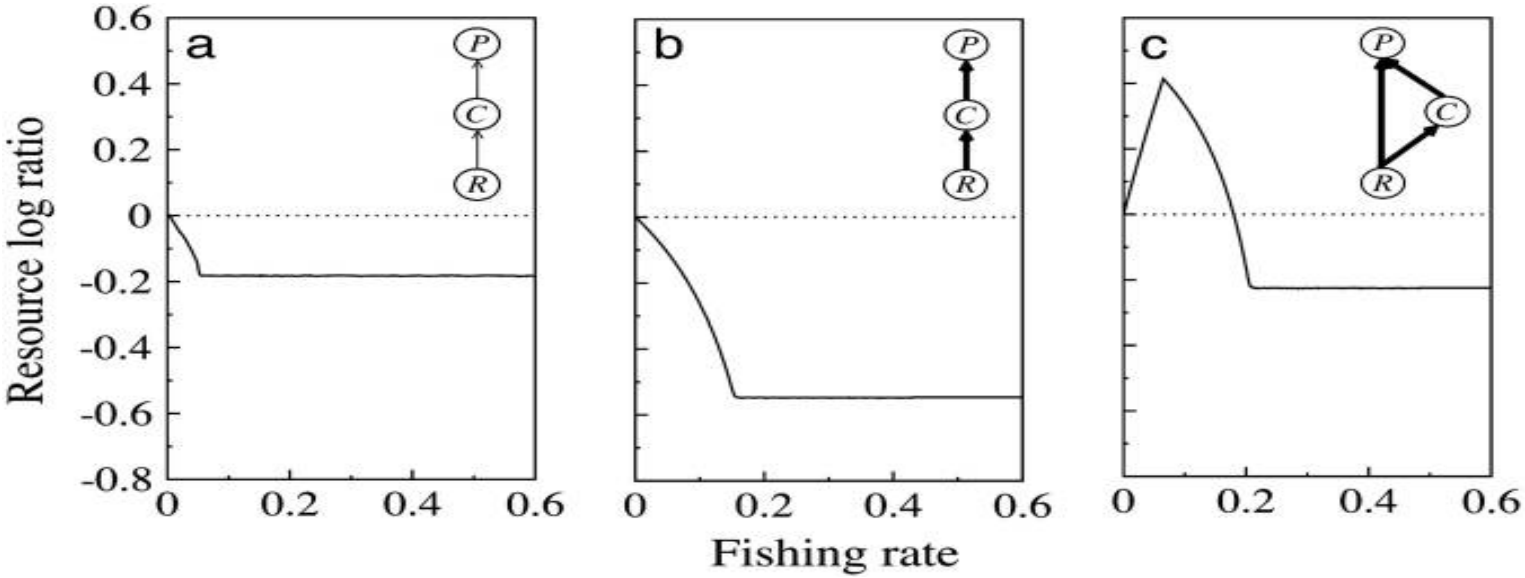


- Extreme variability in interaction strengths (7 orders of magnitude)



Results: Trophic Cascades

- Co-occurance of two strong interactions is less frequent than expected by chance
- When co-occurance does occur, omnivory is more frequent than expected by chance



Why?

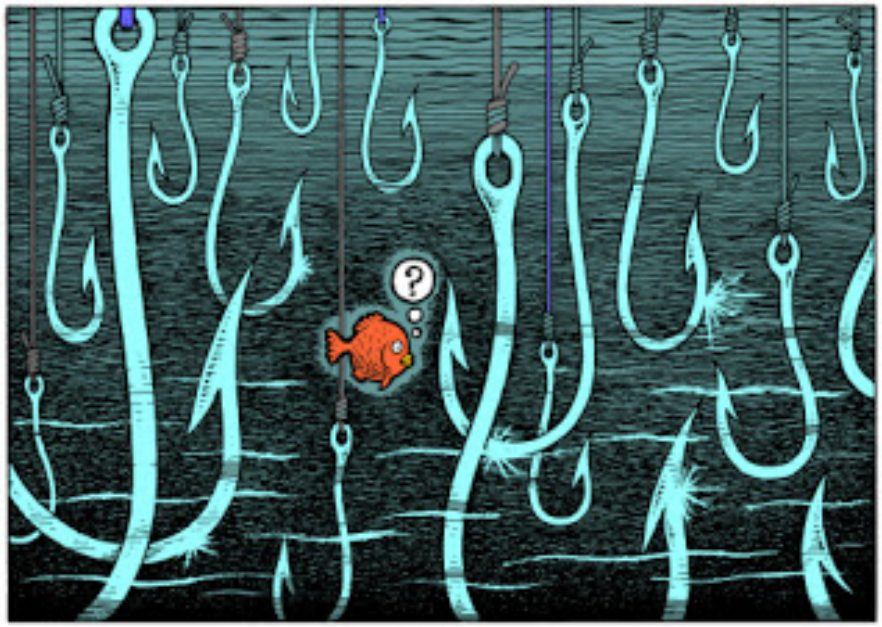
- Co-occurance of two strong interactions increases the magnitude of a trophic cascade
- Presence of omnivory reduces the magnitude of a trophic cascade

Implications

- Caribbean food web is “buffered” against overfishing if species are randomly fished

- However, impacts of fishing are stronger than expected due to selective fishing
  - Predators account for 48% of strong interactions
  - Only 31% of these interactions have omnivory

- A food web model can be used to show how interaction strength can influence trophic cascades



Ecological Applications, 21(6), 2011, pp. 2016–2033

Ecosystem ecology meets adaptive management: food web response to a controlled flood on the Colorado River, Glen Canyon

Wyatt F. Cross,[1,2,7] Colden V. Baxter,[3] Kevin C. Donner,[3] Emma J. Rosi-Marshall,[4] Theodore A. Kennedy,[5] Robert O. Hall, Jr.,[2] Holly A. Wellard Kelly,[4] and R. Scott Rogers[6]

- Dam construction impacts natural sediment delivery , river flow and temperature regimes
- Directly affects food webs in the river and ecosystem process.
- Use of controlled floods
- Resource management of rainbow trout (*Oncorhynchus mykiss*)

Glen Canyon Dam photo: http://damnationfilm.com/press

Cross et al. were the first to use flow based food webs for adaptive management in river ecosystems

Objective:

Use detailed food web analysis that combines information on interaction strengths and primary and secondary production to inform dam management

- Determine pathways of material flow
- Check for food limitations for the predatory rainbow trout (*Oncorhynchus mykiss*)
- Quantify consumer-resource interaction strengths

Methods:

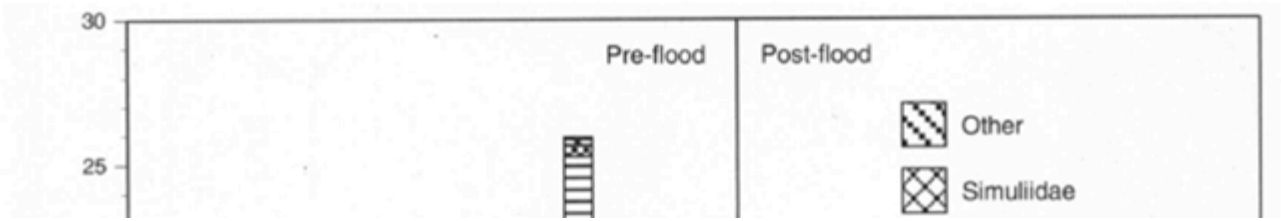
➢ 2006-2009: Flooding event February 2008

Measured:

- secondary production
- organic matter flows
- invertebrate biomass
- different habitat classes
- population and biomass of rainbow trout
- gut contents of rainbow trout
- rates of invertebrate drift

- **trophic basis of production method**
- **instantaneous growth rate method**
- **species impact values**

photo: George Andrejko
http://thefisheriesblog.com/2012/11/12/dam-trout-how-do-trout-populations-respond-to-altered-flow/



Rainbow trout production increased by 194%

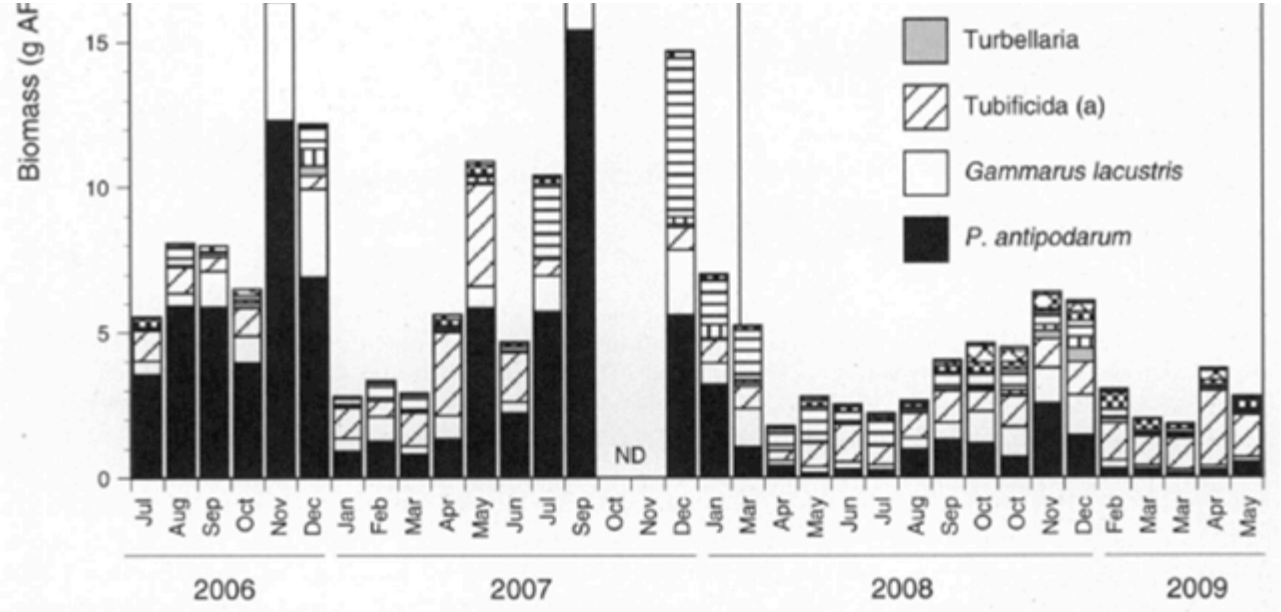
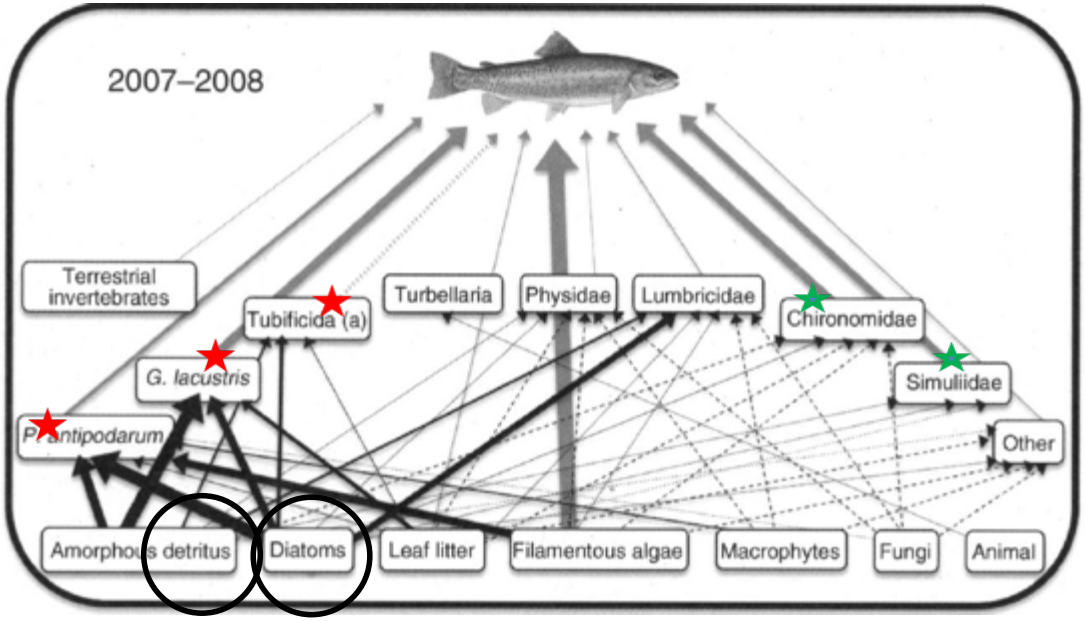
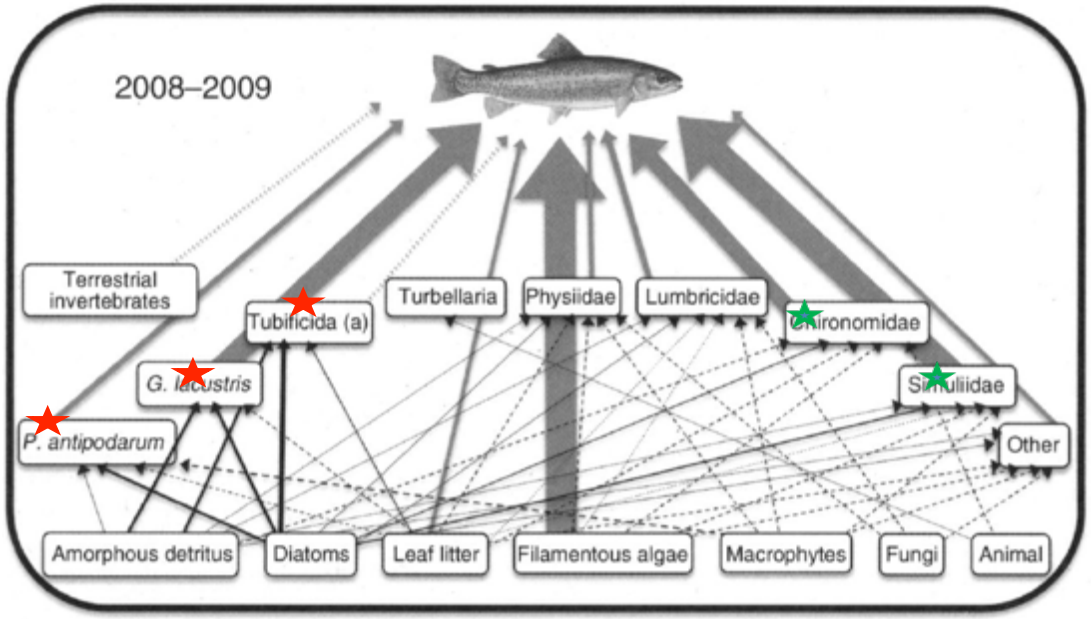


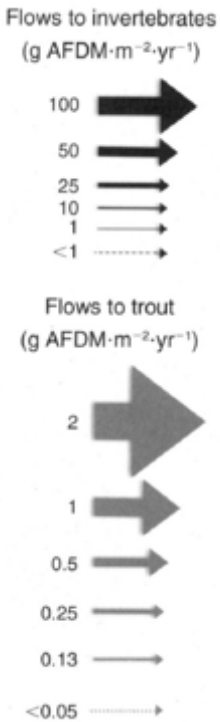
FIG. 3. Mean monthly habitat-weighted invertebrate biomass (g AFDM/m^2) was dominated by *P. antipodarum* and *G. lacustris*, declined following the controlled flood, and was generally highest during autumn months. ND indicates no habitat-weighted data due to missing depositional samples in October and November 2007. The "Other" category includes Cladocera, Copepoda, Tubificida (b), Ceratopogonidae, Acari, Ostracoda, and Nematoda. The vertical line represents the timing of the controlled flood. Missing months indicate that no samples were taken; duplicate months indicate that samples were taken twice during that month (usually the beginning and end).

Pre-Flood

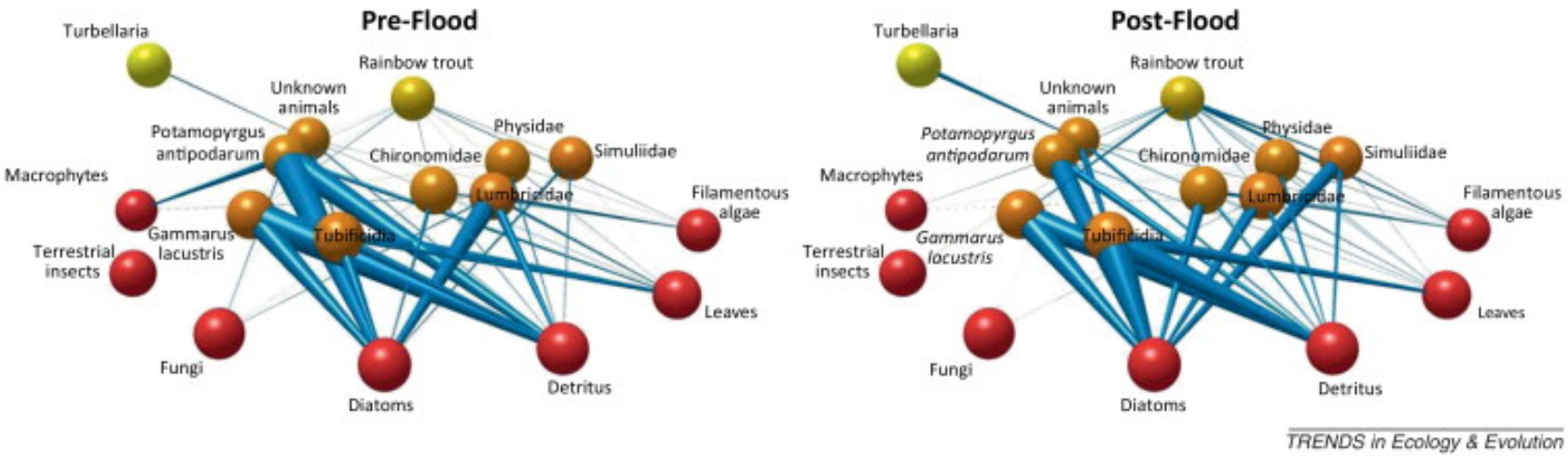


Post-Flood





Determined there was a food limitation on trout production.



Thompson et al. Food webs from the Colorado River pre- and post-flood, produced using Network3D

- Increased interaction strengths
- Dominant organic matter flows

Information on taxa production and interaction strengths between species in can help guide future management decisions.

5 Challenges in Food Web Ecology

1. Relating food web structure to ecosystem function

2. Combining food web and ecosystem models

3. Relating individual traits to ecosystem function

4. Incorporating space and time into BEF studies

5. Biodiversity loss and effects on ecosystem function

1 Relating food web structure to ecosystem function

- Which specific aspects of food web structure (# species, # links, link density) can we connect to which specific ecosystem function?

Possible approaches:

- Weighted Networks
- Food web motifs

2 Combining food web and ecosystem models

- How can we incorporate interacting species and fluxes of material to fully understand biodiversity and ecosystem function?

Possible approaches:

- Model biodiversity ecosystem function relationships by superimposing
    - A base food web structure model
    - A complex bioenergetic model

3 From individual traits to ecosystem function

- How can we connect individual variation of organisms (physiological or behavioral) to ecosystem functions?

Possible approaches:

- Include adaptive behavior and physiological variation within a population in the study to help predict relationships between diversity and ecosystem functioning

4 Incorporating space and time into BEF studies

- How can we include spatial and temporal variability to increase accuracy of food web models?

Possible Approaches:

- Landscape scale approach that includes animal movement, spatial segregation of taxa and coupling across food webs (Ex. Meta food web model)
- Extend food models to include awareness of temporal scale and potential for evolution

5 Biodiversity loss and effects on ecosystem function

- How can we apply food web models to predict biodiversity and the effect of extinctions on ecosystem function?

Possible Approaches:

- Use dynamic models to predict vulnerability of species to primary and secondary extinctions by removing the node
- Look at one species and assess its vulnerability to extinction and dynamic importance

Discussion ☺

5 Challenges in Food Web Ecology

1. Relating food web structure to ecosystem function

2. Combining food web and ecosystem models

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5. Biodiversity loss and effects on ecosystem function