Effect of Parasites on the Structure and Dynamics of Food Webs

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Motivation

Structural Fingreprint of Parasites

Goals

- Look for systematic difference between parasite and free liver communities

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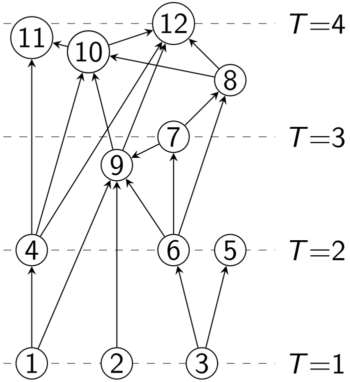
- Standardized data format

Properties Considered

Property	Name
g	Generality
v	Vulnerability
v_r	Mean. Vul. Resources
g_c	Mean. Gen. Consumers
T	Prey-Averaged
λ	Eigenvector based
C_B, C_{EB}	Betweenness
$\gamma^{\cdot}$	Four types of directed clustering

Example Food Web



West Coastal Tundra, Barrow, Alaska Food Web

ID	Species Description
1	Monocots
2	Dicots
3	Detritus
4	Lemmings
5	Microorganisms
6	Saprovores
7	Carnivorous Arthropods
8	Shorebirds
9	Longspurs
10	Weasels
11	Owls
12	Jaegers

Source: Cohen, J. E. (compiler) 2010 Ecologists' Co-Operative Web Bank. Version 1.1. Machine-readable data base of food webs. New York: The Rockefeller University.

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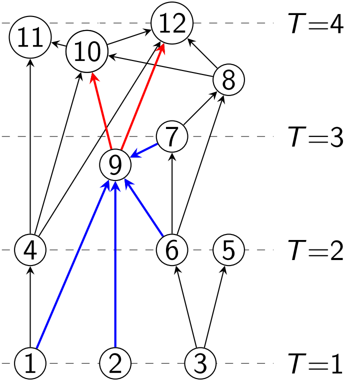

Longspurs:

$$v_9 = 2$$

$$g_9 = 2$$

$$T_9 = \frac{1+1+2+3}{4} + 1 = 2.75$$

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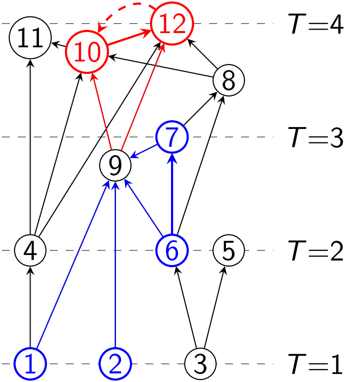


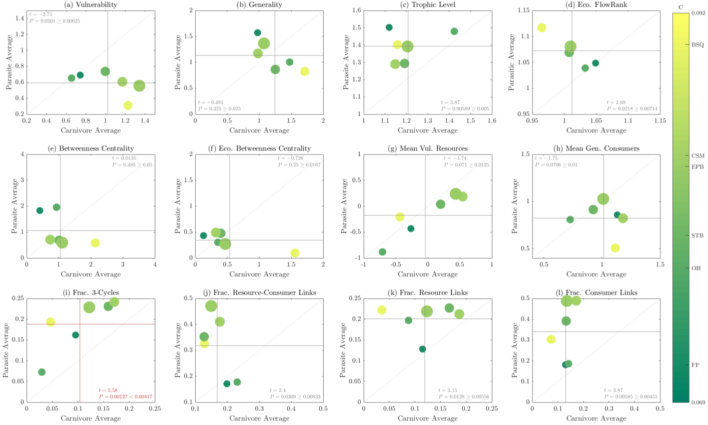
Longspurs:

$$\gamma_9^c = \frac{1}{2}$$

$$\gamma_9^r = \frac{1}{12}$$

$$\gamma_9^{rc} = \gamma^{cr} = 0$$

Observed Patterns



Patterns are there

- Network properties of individual nodes could differentiate parasite from free liver on about 85% of nodes

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  - Detritus as basal node

Food Web Models

Background

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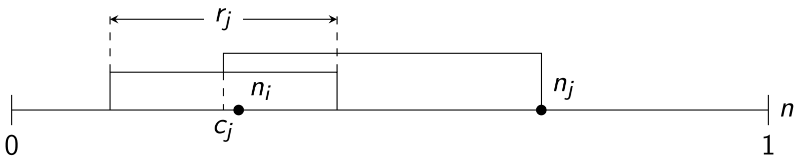
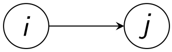
- Variants

The Niche and Inverse Niche Models





- $n_i \sim U(0, 1)$
- $y_i \sim \text{Beta}(1, \beta)$
- $r_i \sim n_i \cdot y_i$
- $c_i \sim U(\max(0, r_i/2), \min 1 - r_i/2, n_i)$

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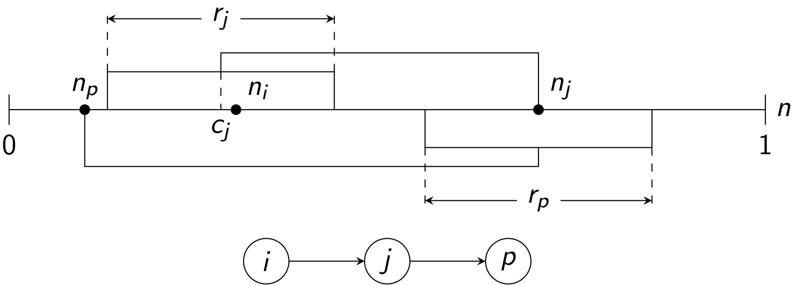

- $n_p \sim U(0, 1)$
- $y_p \sim \text{Beta}(1, \beta_p)$
- $r_p \sim (1 - n_p) \cdot y_p$
- $c_p \sim U(\{n_j | j \in \text{free livers}, n_j > n_p\})$

Models Tested

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  - e.g. free liver - parasite more common than parasite - parasite

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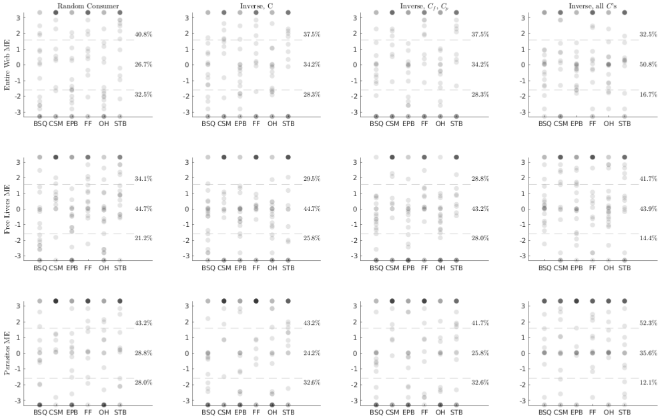
- Distribution of ensemble properties
- How many of the empirical properties are reasonable viz. ensemble properties?

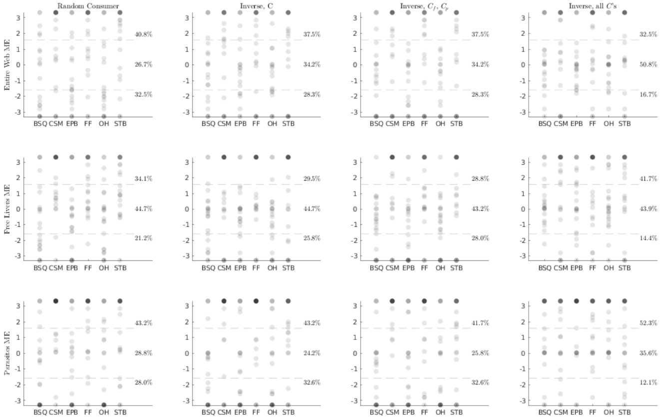
Laundry List of Properties

Property	Definition and Comments
Global and Comm. Props.	
Top,Int,Bas	The fraction of top, intermediate, and basal species in the web, respectively.
Herb,Carn	The fractions of herbivores and carnivores,respectively.
Omn	The fraction of species that consume both a basal and a non-basal species. The set {Top,Int,Bas,Herb,Carn,Omn} has only four degrees of freedom.
Cann	The fraction of cannibals in the food web.
ρ_{gv}	The correlation between generality and vulnerability.
σ_g	The standard deviation of generality.
σ_v	The standard deviation of vulnerability.
T	The mean prey-averaged trophic level.
FlowRankSD	The standard deviation of the FlowRank metric.
PATH	The average link distance of every species to every other.
Loop	The fraction of species involved in a loop.
EcoBtwn	The mean Ecological Betweenness over all species.
γ^c, γ^r, γ^{rc}, and γ^{cr}.	The clustering coefficients
MaxSim	The average of the maximum similarity of each species to all other species.
Community Properties	
$\overline{v}$,$\overline{g}$	Mean vulnerability and mean generality.
FlowRank	Based on eigenvalue of the augmented food web
C_{EB}	Ecological Betweenness
v_r and g_c	Mean vulnerability of resources and mean generality of consumers.

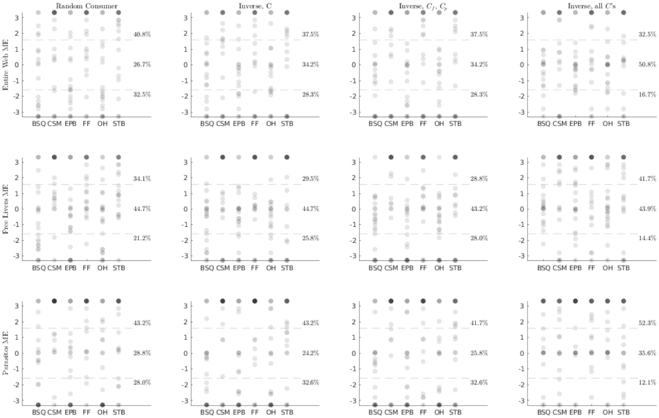
Entire Web Results



Free Liver Community Results



Parasite Community Results



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- Correlations in properties

ATN Model

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- $M_i = Z^{T-1}$

Equations

$$\frac{dB_b}{dt} = r_b B_b \left(1 - \frac{\sum_{k \in \text{basal}} B_k}{K}\right) - \sum_k x_k B_k \frac{y_{bk} F_{bk}}{e_{bk}} \qquad (1)$$

$$\frac{dB_c}{dt} = -x_c B_c + x_c B_c \sum_k y_{kc} F_{kc} - \sum_k x_k B_k \frac{y_{ck} F_{ck}}{e_{ck}} \qquad (2)$$

Functional Response

"Attack rate on population of species i by a unit of species j"

$$F_{ij} = \frac{\omega_{ij} B_i^{1+q}}{B_0^{1+q} + \sum_k \omega_{kj} B_k^{1+q}}$$

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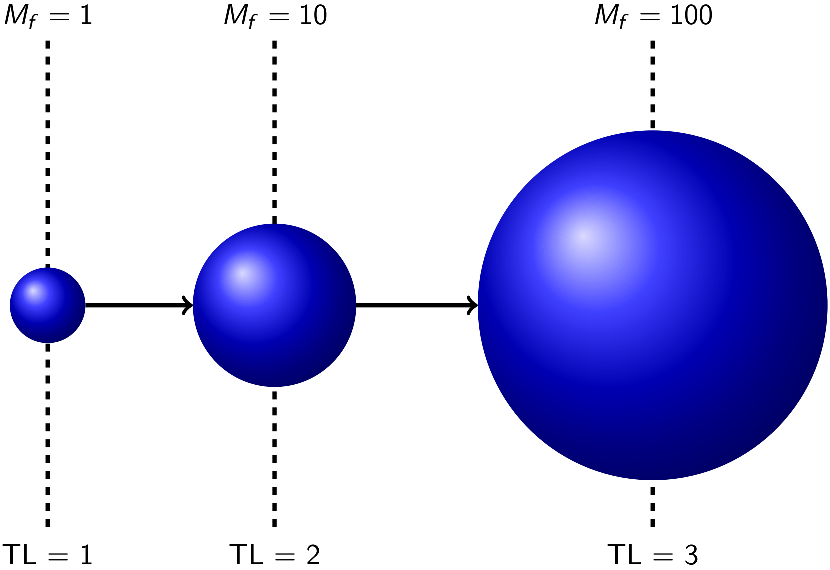
Wrong!
$$\cancel{M_p = Z_p^{TL-1}}$$

Body Size Hierarchy

$Z = 10$ (no parasites):



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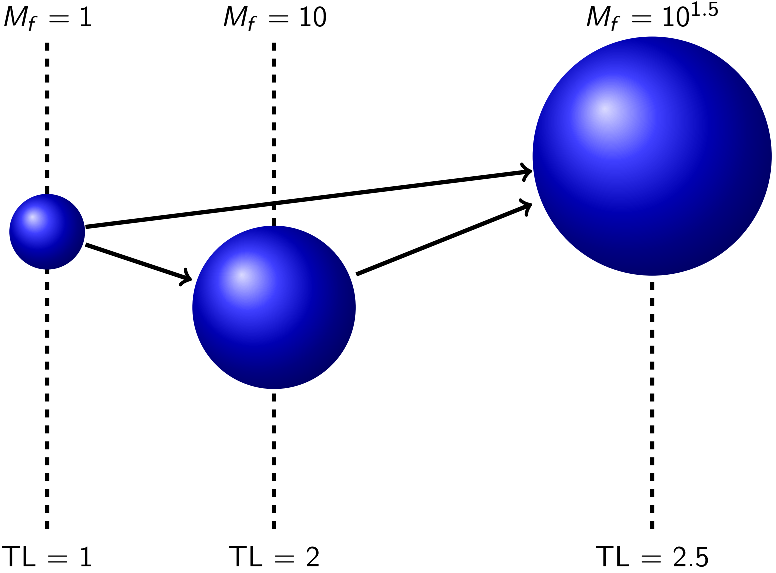
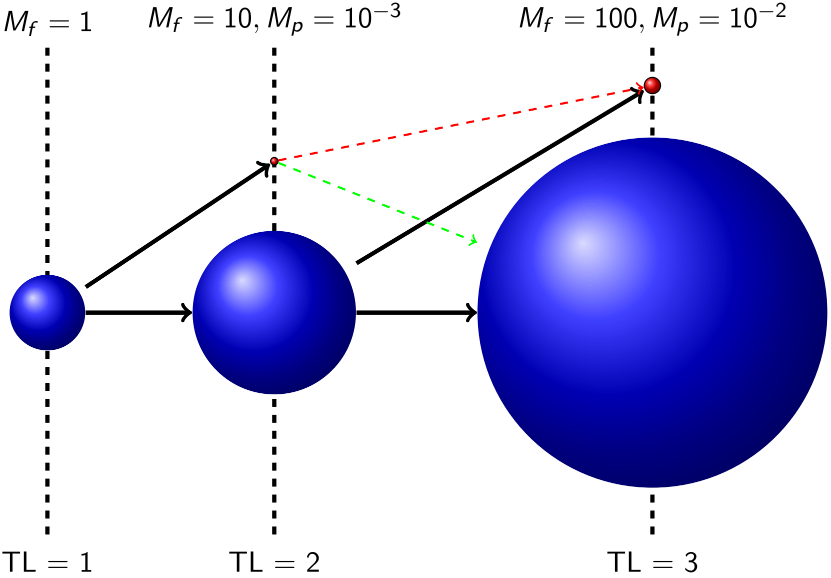


Body Size Hierarchy

$Z_f = 10,\ Z_p = 10^{-3}$



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- i free liver:

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- i parasite:

$$M_i = 10^{p + k(T_i - 2)}$$

Modifications to ATN

- Concomittant predation

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- Concomittant predation
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- Cartoon of models

New Equations

$$\frac{dB_b}{dt} = r_b B_b \left(1 - \frac{\sum_{k \in \text{basal}} B_k}{K}\right) - \sum_k \phi_k B_k x_k \frac{y_{bk} F_{bk}^{(troph)}}{e_{bk}} - \sum_k (1-\phi_k) B_k x_k \frac{y_{bk} F_{bk}^{(para)}}{e_{bk}}$$

$$\frac{dB_c}{dt} = -x_c B_c + \phi_c x_c B_c \sum_k y_{kc} F_{kc}^{(troph)} + (1-\phi_c) x_c B_c \sum_k y_{kc} F_{kc}^{(para)} - \sum_k \phi_k x_k B_k \frac{y_{ck} F_{ck}^{(troph)}}{e_{ck}} - \sum_k (1-\phi_k) x_k B_k \frac{y_{ck} F_{ck}^{(para)}}{e_{ck}} - C_p$$

New Functional Response

$$F_{ij}^{(troph)} = \frac{\omega_{ij}^{(troph)}(\phi_i B_i)^{1+h}}{B_0^{1+h} + \sum_k \omega_{kj}^{(troph)}(\phi_k B_k)^{1+h}}$$

$$F_{ij}^{(para)} = \frac{\omega_{ij}^{(para)}(\phi_i B_i)^{1+h}}{B_0^{1+h} + \sum_k \omega_{kj}^{(para)}(\phi_k B_k)^{1+h}}$$

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- $$L_h = \sum_k x_k B_k \frac{y_{kh} F_{kh}^{(troph)}}{e_{kh}}$$

Summary of Experiments

- $Z_f = 10, 100$

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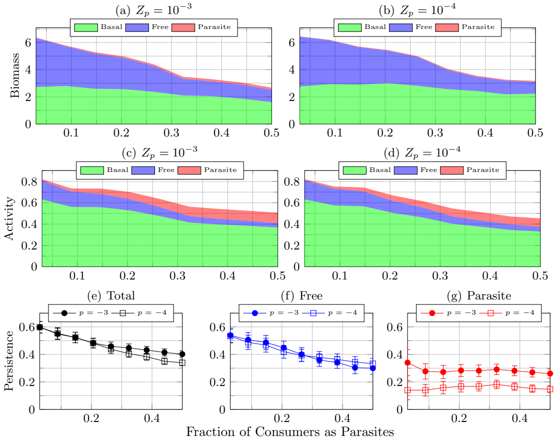
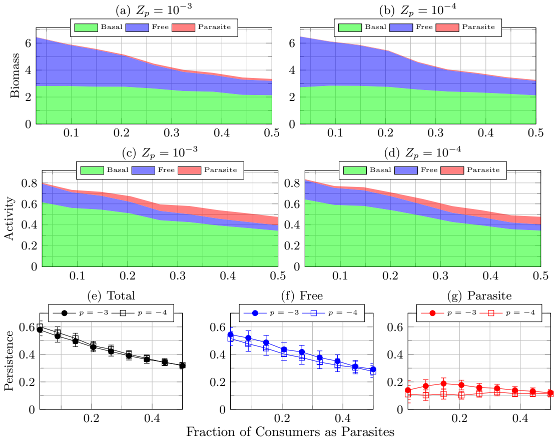
- Different fractions of parasites

Results of Simulations: Null Model



Results of Simulations: Full Model



Final Thoughts

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