Empirical and theoretical opportunities in host-symbiont community ecology

Maxwell B. Joseph

University of Colorado, Boulder, Ecology and Evolutionary Biology

github.com/mbjoseph/esa2015

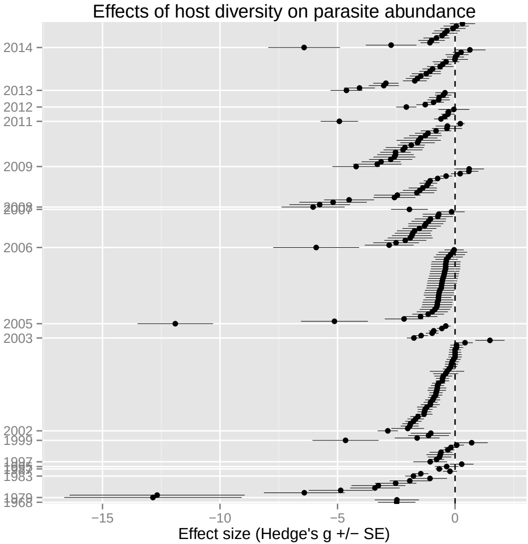
Dilution effect: biodiversity reduces disease risk

Amplification effect: biodiversity increases disease risk

A simple enough question

How general are these phenomena?

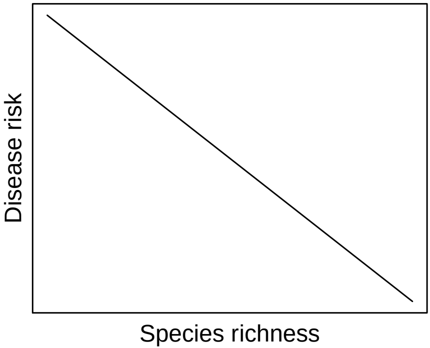
Civitello et al. 2015



Thought experiment

Assume that we know $\mu_{\beta_{diversity}} < 0$

i.e. biodiversity reduces disease risk on average



Thought experiment

Assume that we know $\mu_{\beta_{diversity}} < 0$

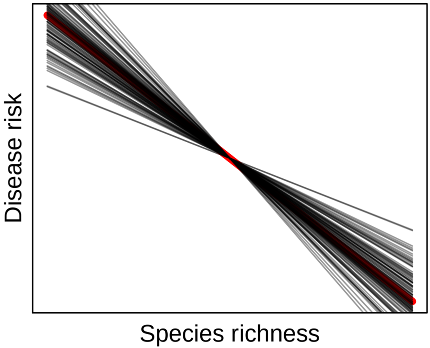
- effects vary across systems

$$\beta_i \sim N(\mu_{\beta_{diversity}}, \sigma)$$

Variance matters

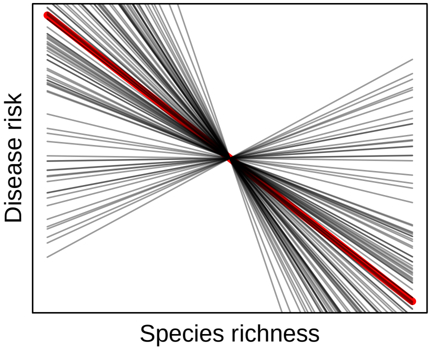
$\beta \sim N(\mu_\beta, \sigma)$

$\mu_\beta < 0, \sigma$ low



$\beta \sim N(\mu_\beta, \sigma)$

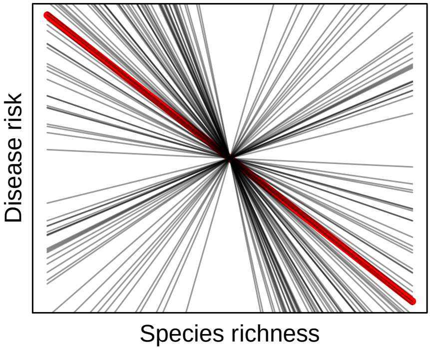
$\mu_\beta < 0, \sigma$ medium



Variance matters

$\beta \sim N(\mu_\beta, \sigma)$

$\mu_\beta < 0, \sigma$ high



Regardless of the mean effect

1. We all care about variation

Regardless of the mean effect

1. We all care about variation
2. Explaining the variation should be a common goal

1. **Thinking beyond the mean effect**

- What explains the variance?

Challenges and opportunities

1. **Thinking beyond the mean effect**
2. **Transmission dynamics**

Density-dependent:

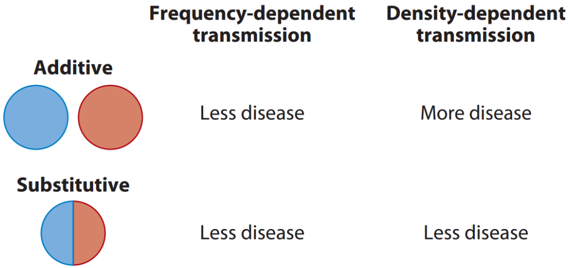
$$\beta S I$$

Frequency-dependent:

$$\beta SI/N$$

Contact rate independent from N

Tranmission dynamics, diversity, and disease



Ostfeld and Keesing 2012

Rudolf and Antonovics 2005

Dobson 2004

Joseph et al. 2013

Mihaljevic et al. 2013

Other transmission functions

Constant risk:

βS

Power law:

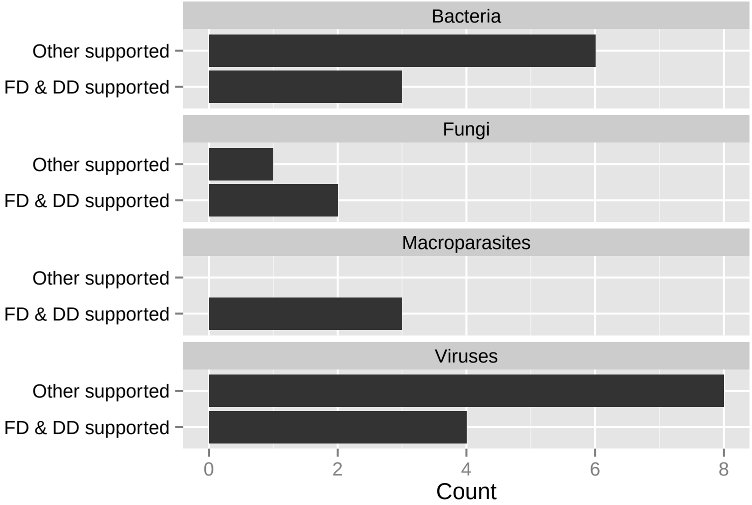
$\beta S^p I^q$

Negative binomial:

$kSlog(1 + \frac{\beta I}{k})$

Support for other transmission functions

(Orlofske, Joseph, et al. *in prep*)



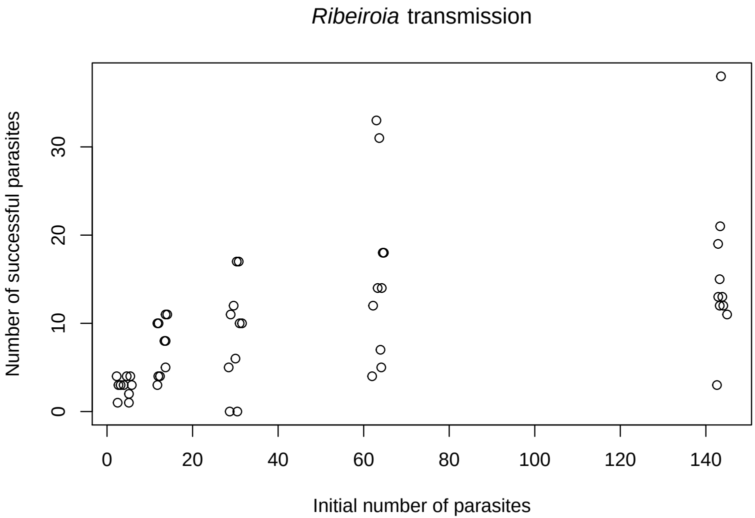
Evaluating support for different models

1. Build set of transmission functions (DD, FD, etc.)
2. Design experiments varying:

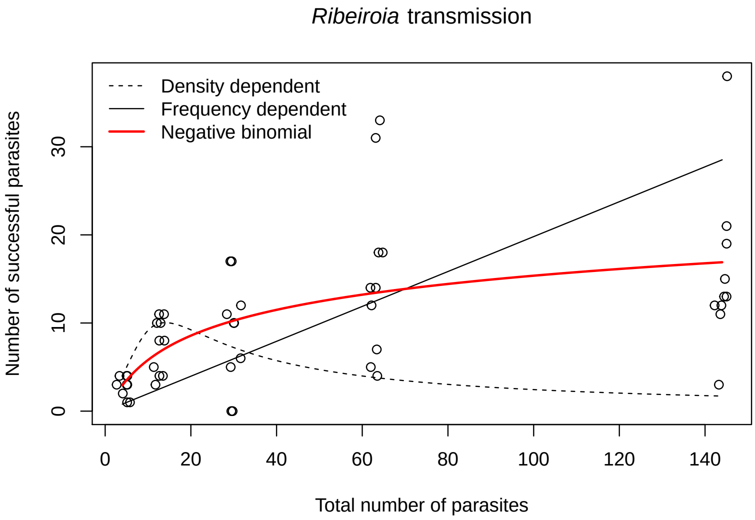
   - P: number of parasites
   - H: number of hosts
   - t: exposure time
   - $\frac{P}{v}$: parasite density

3. Fit models, evaluate support with information theoretics

Evaluating support for different models



Evaluating support for different models



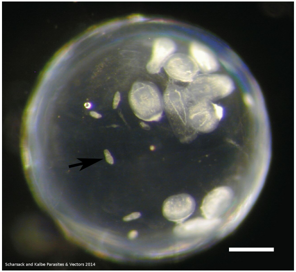
Ribeiroia:

- P: neg. binom.
- H: power law
- t: power law
- $\frac{P}{v}$: uninformative

Summary of support

Diplostomum spathaceum (Karvonen et al. 2003):

- $\frac{P}{v}$: neg. binom. and power law
- P: power law



Centrocestus armatus experiments (Paller et al. 2007):

- $\frac{P}{v}$: neg. binom.
- P: neg. binom.

What transmission functions are supported empirically?

What else might we expect theoretically?

1. **Thinking beyond the mean effect**
2. **Transmission dynamics**

- What models have empirical support?
- How to theoretical expectations change?

1. Thinking beyond the mean effect
2. Transmission dynamics
3. Biodiversity and symbionts

Questions:

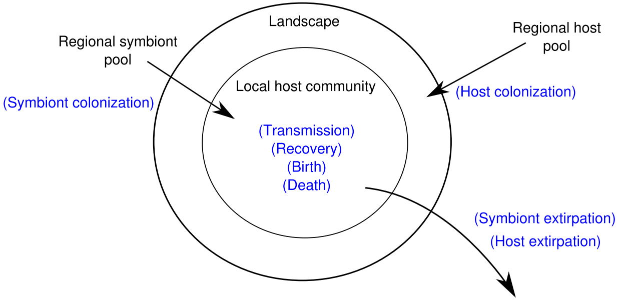
1. What is effect of host diversity on:

- symbiont diversity
- symbiont transmission

Questions:

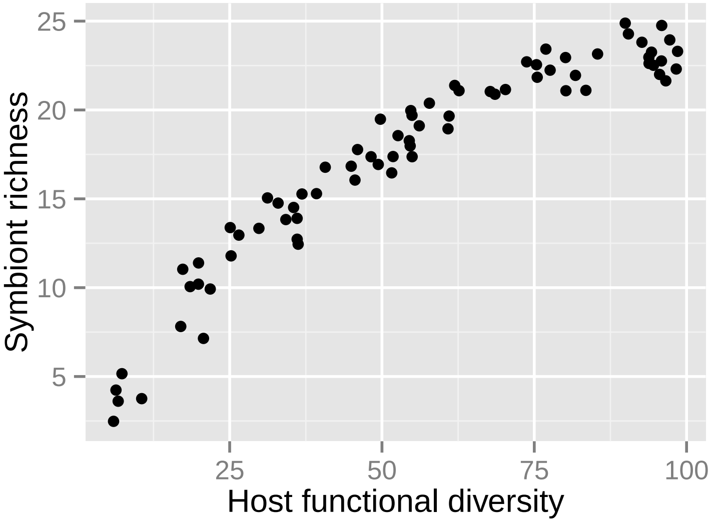
1. What is effect of host diversity on:
   - symbiont diversity
   - symbiont transmission
2. What role does parasitism play?

Model structure

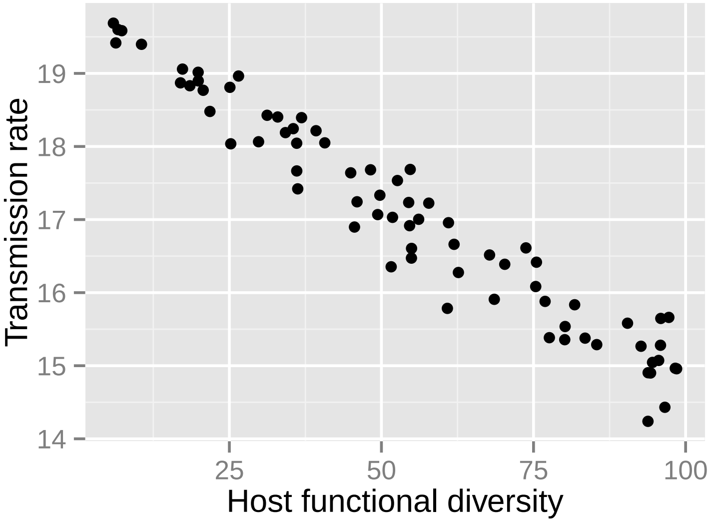


github.com/mbjoseph/abm

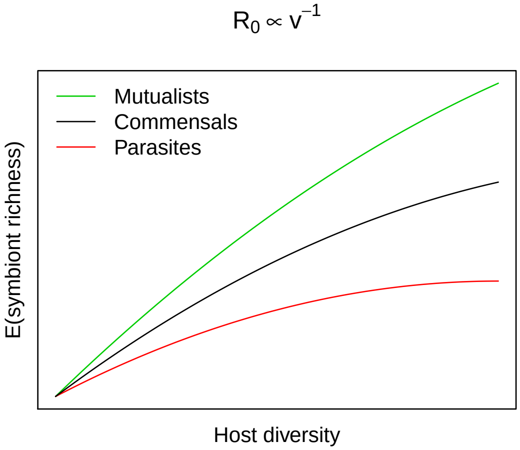
Model predictions: diversity begets diversity



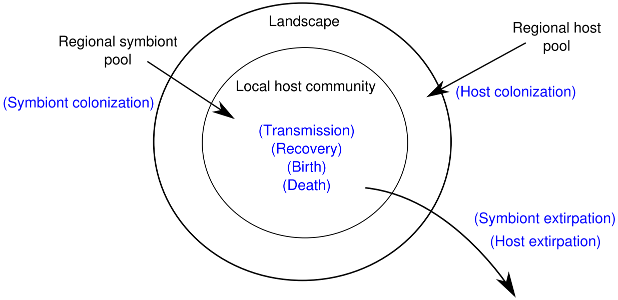
Model predictions: diversity reduces transmission



A priori expectations

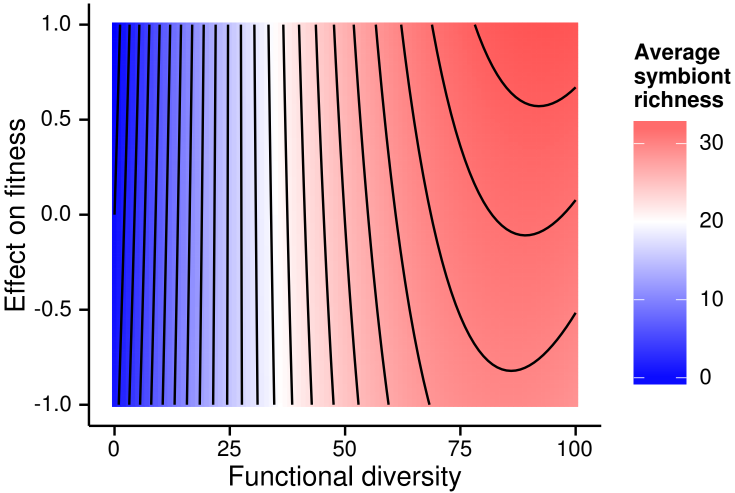


Model structure

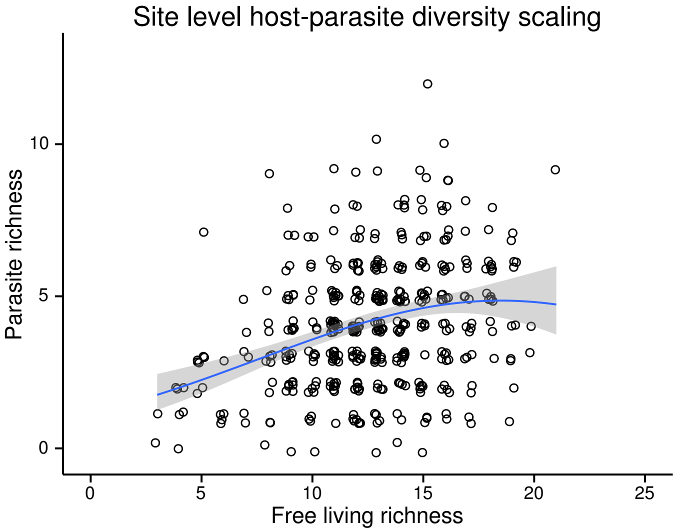


github.com/mbjoseph/abm

Model predictions



San Francisco Bay Area amphibian parasites



Why symbionts in general?

- More data
- Many parasites are facultative
- Broader class of species interactions

-/-	-/0	-/+
	0/0	0/+
		+/+

Challenges and opportunities

1. **Thinking beyond the mean effect**
2. **Transmission dynamics**
3. **Biodiversity and symbionts**

- Relationships between host and symbiont diversity
- Parasites, commensals, and mutualists
- Interplay b/t host diversity and symbiont transmission

Challenges and opportunities

1. **Thinking beyond the mean effect**
2. **Transmission dynamics**
3. **Biodiversity and symbionts**
4. **Scale transitions**

Local dynamics

Local dynamics $\rightarrow$ regional dynamics

Local dynamics $\neq$ regional dynamics if

- local dynamics are non-linear
- densities vary spatially
- conditions vary spatially

(Chesson et al. 2005)

1. **Thinking beyond the mean effect**
2. **Transmission dynamics**
3. **Biodiversity and symbionts**
4. **Scale transitions**

- is the existing theory useful?

Acknowledgements

Pieter Johnson

Joseph Mihaljevic

Chelsea Wood

Sarah Orlofske

Dan Preston

EBIO QDT

Support from: NSF GRFP, CU Research Computing

Thank you

slides: github.com/mbjoseph/esa2015

symbiont model: github.com/mbjoseph/abm

e-mail: `maxwell.b.joseph@colorado.edu`

Temporal scale discrepancies

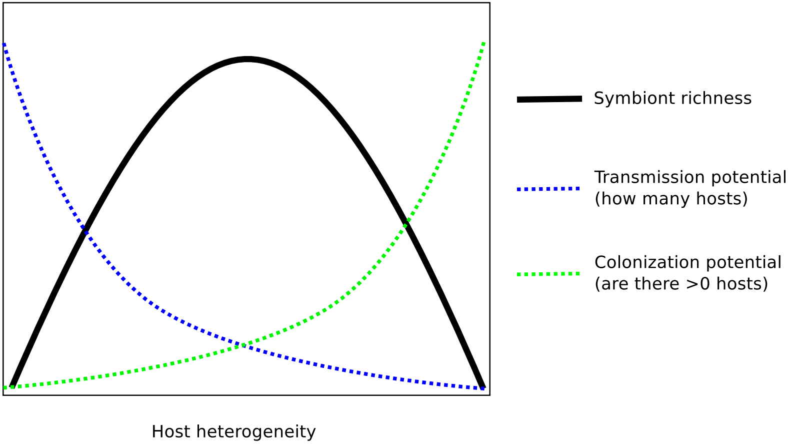
Lots of theory (but see Roche et al. 2012): instantaneous rates

- transmission
- R_0
- force of infection

Most data: integrated quantities

- prevalence
- seroprevalence
- density of infected hosts

Similar to habitat area-heterogeneity trade-off in free living species

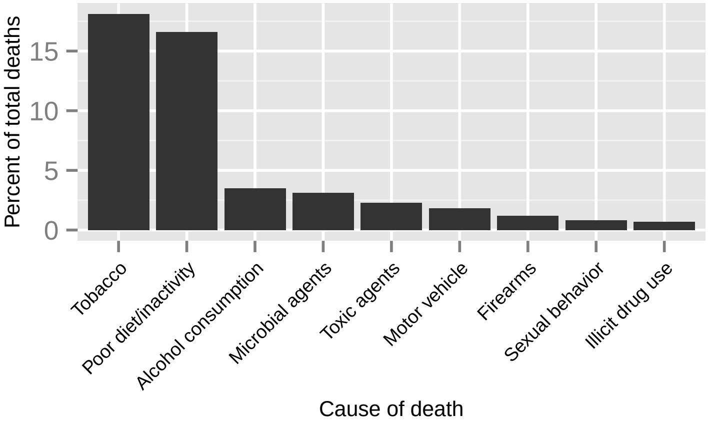


Points of contention

1. generality
2. justification for conservation

If we knew biodiversity was good for our health, would we conserve biodiversity?

Actual causes of death in the U.S.



Mokdad et al. 2004.