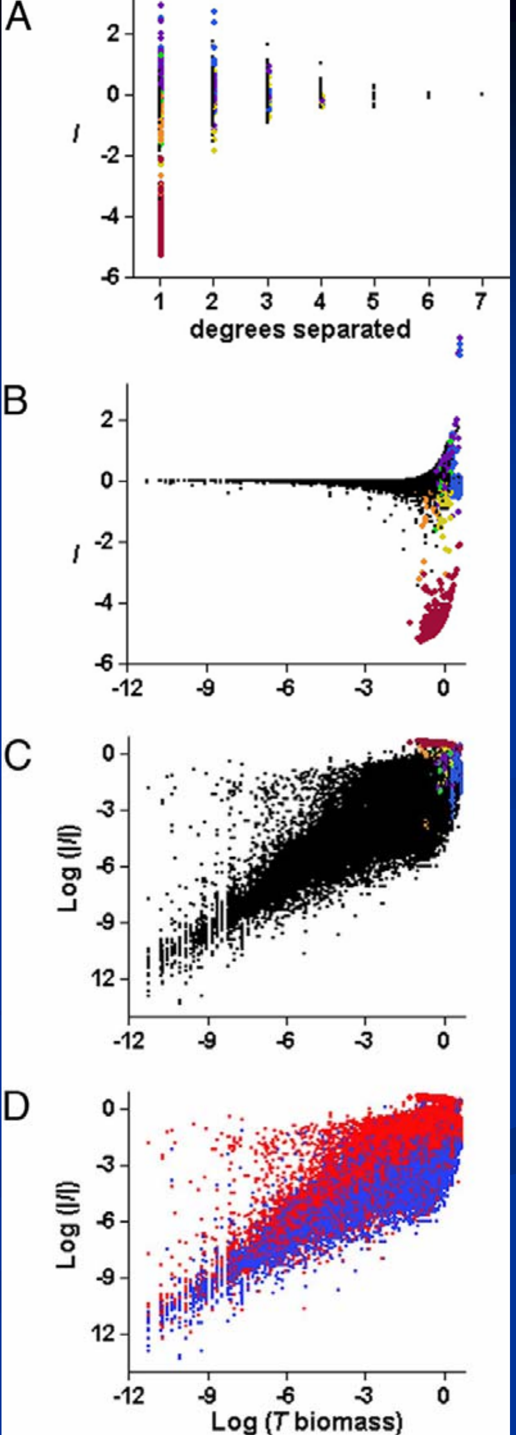
Applications

- Effects of species loss
  - Dunne, Williams and Martinez 2002 *Ecology Letters*
  - Brose, Berlow & Martinez 2005 *Ecology Letters*
  - Berlow et al. 2009 *PNAS**
- Effects of species invasions
  - Romanuk et al. 2009, in review, in prep….*

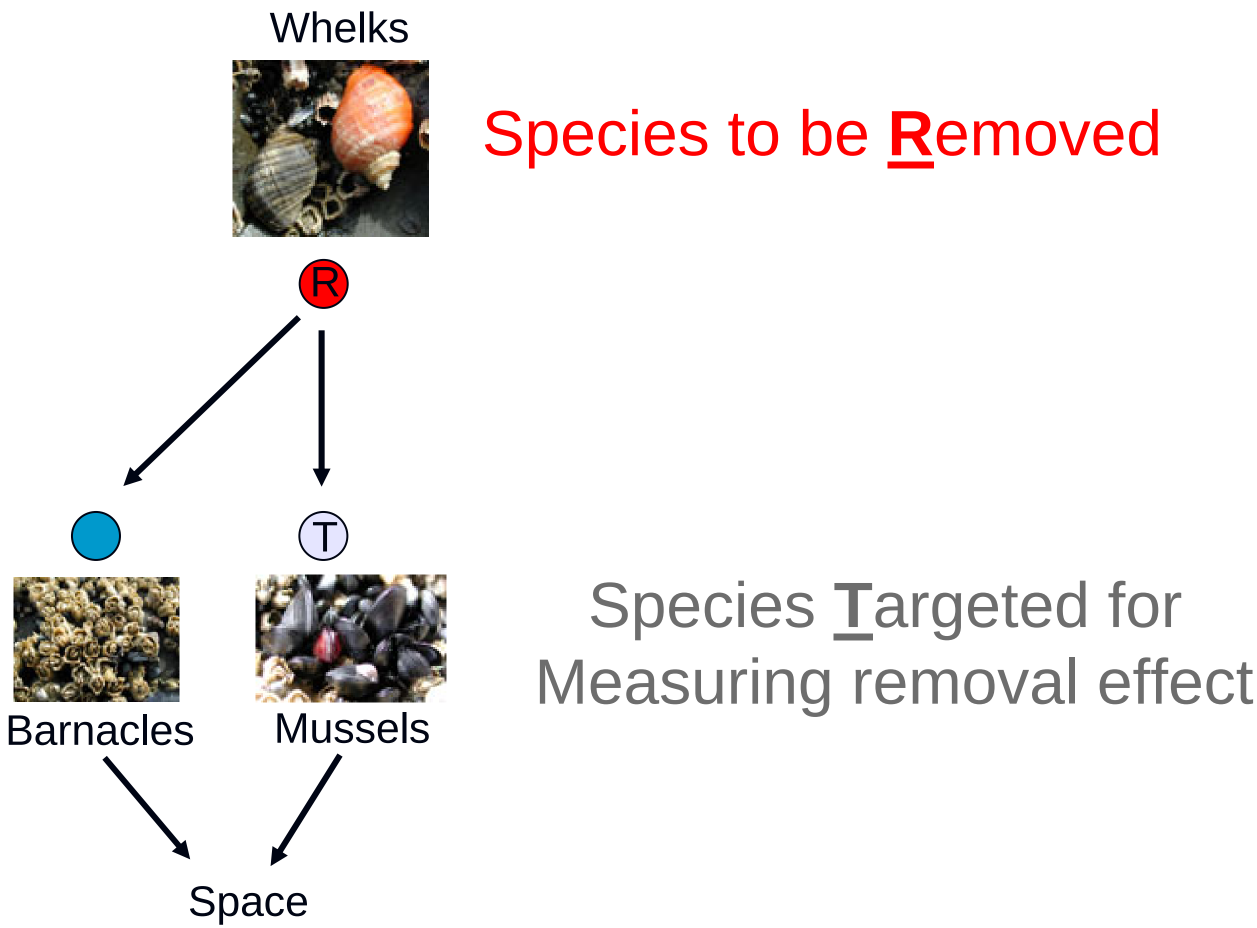
In Silico Removals

- 600 food webs with 10 to 30 species
- Randomly variation within observed:
  - complexity, body size, func. resp., etc.
- 254,032 interactions measured
- Between 12,116 species
- Interaction strength =
  - (biomass of T with R present) –
  - (biomass of T with R absent)



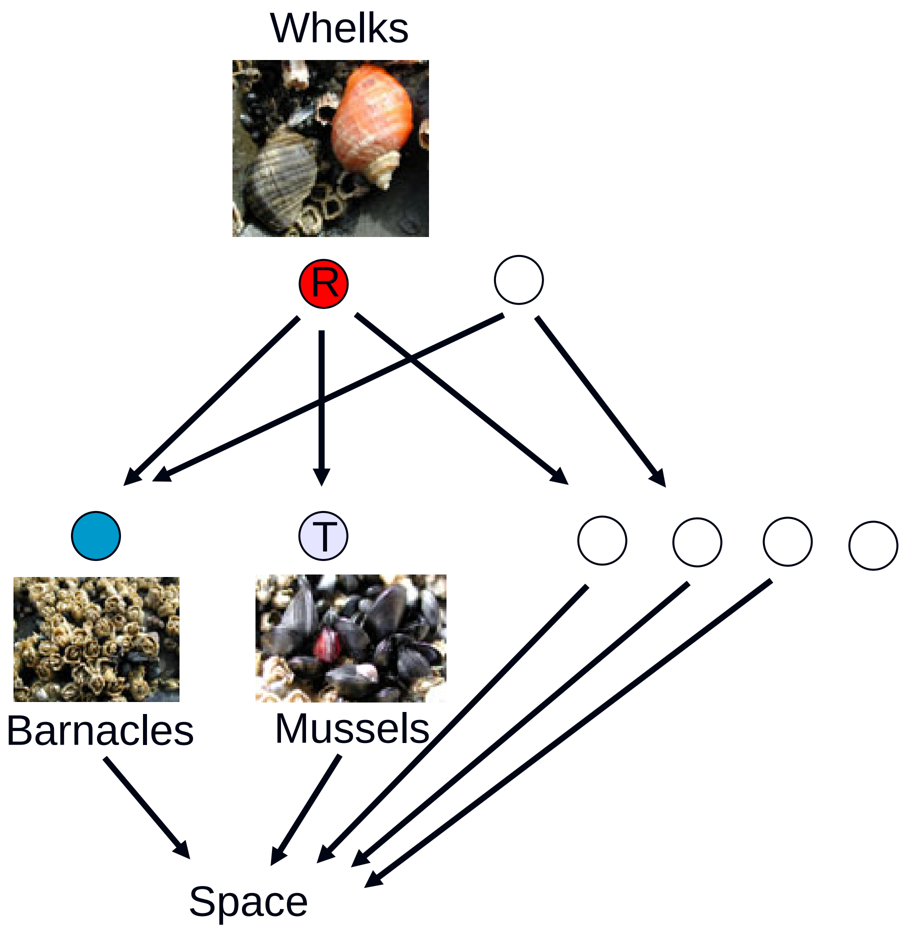
Berlow, Dunne, Martinez, Stark, Williams & Brose 2009 *PNAS*

Berlow 1999 *Nature* 398:330

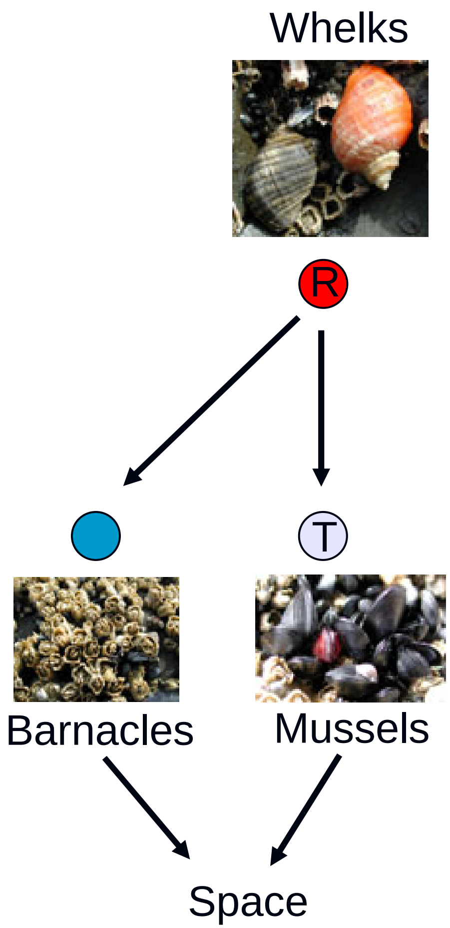


Berlow, Dunne, Martinez, Stark, Williams & Brose 2009 *PNAS*

Field Experiment Conditions

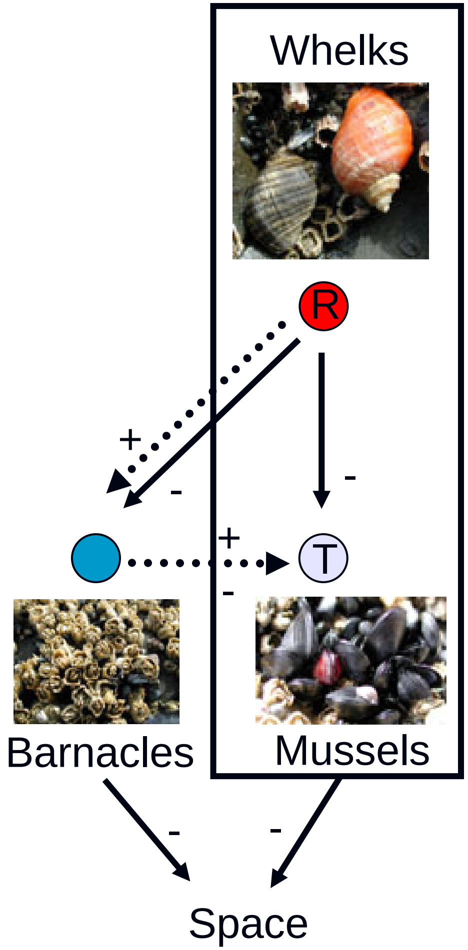


Berlow et al. 2009 *PNAS*



Berlow et al. 2009 *PNAS*

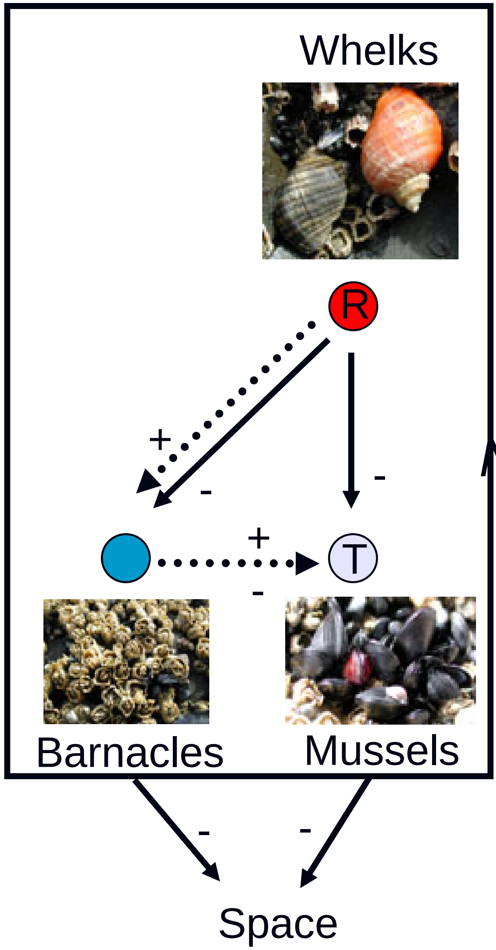
Experiment 1
Barnacles absent



Metabolic

Berlow et al. 2009 *PNAS*

Experiment 2
Barnacles present



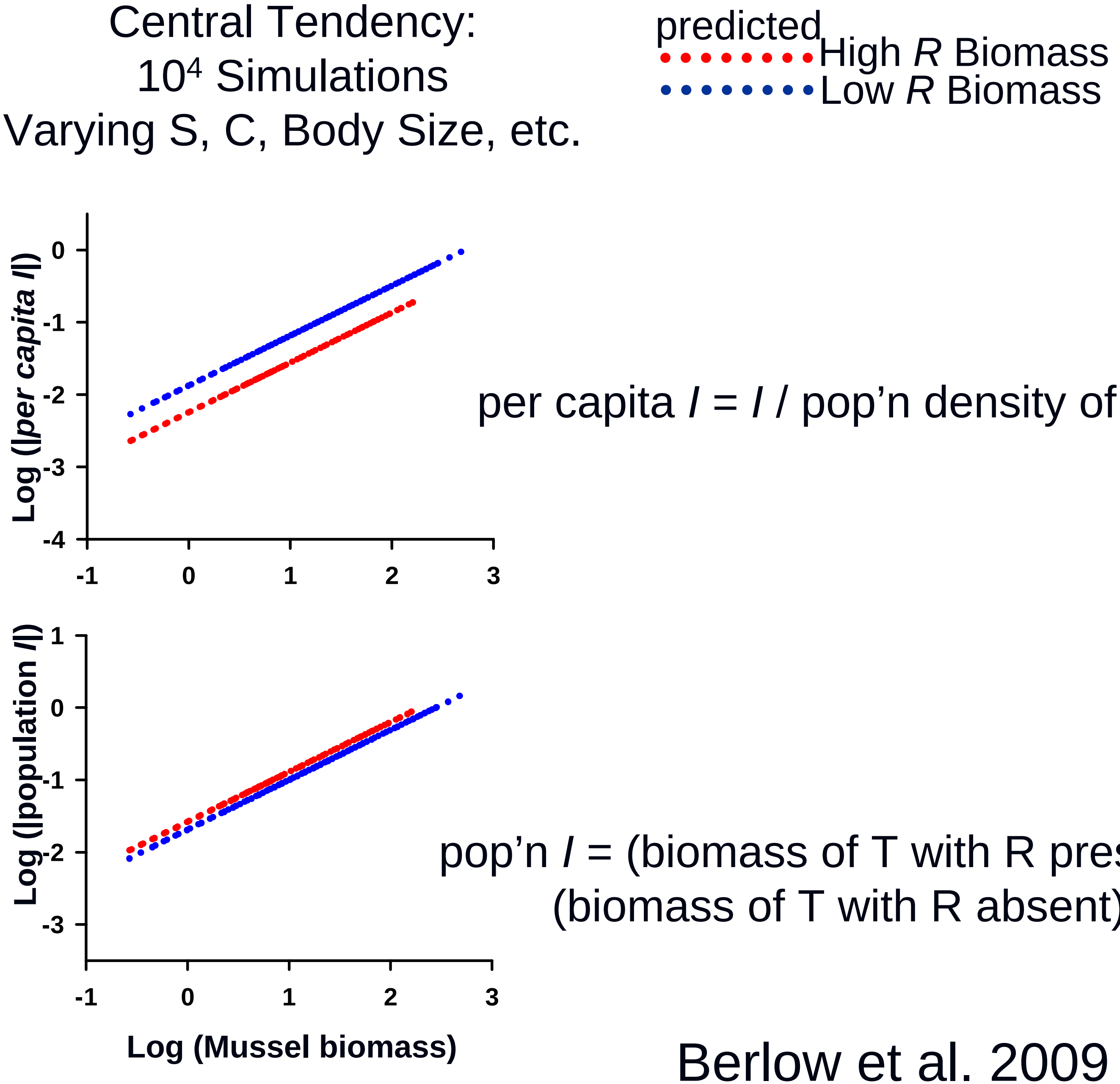
Metabolic

\+

Non-Metabolic

Berlow et al. 2009 *PNAS*

Central Tendency:
10^4 Simulations
Varying S, C, Body Size, etc.

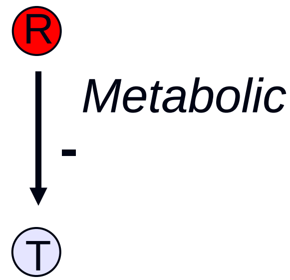


per capita *I* = *I* / pop'n density of R

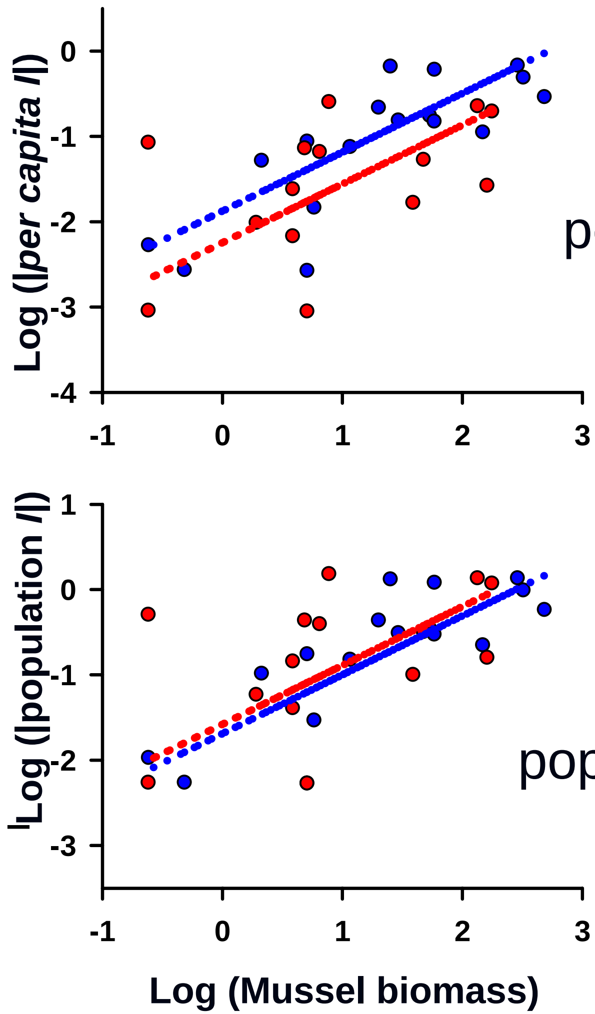
pop'n *I* = (biomass of T with R present) – (biomass of T with R absent)

Berlow et al. 2009 *PNAS*

Experiment 1
Barnacles absent



predicted
High *R* Biomass
Low *R* Biomass



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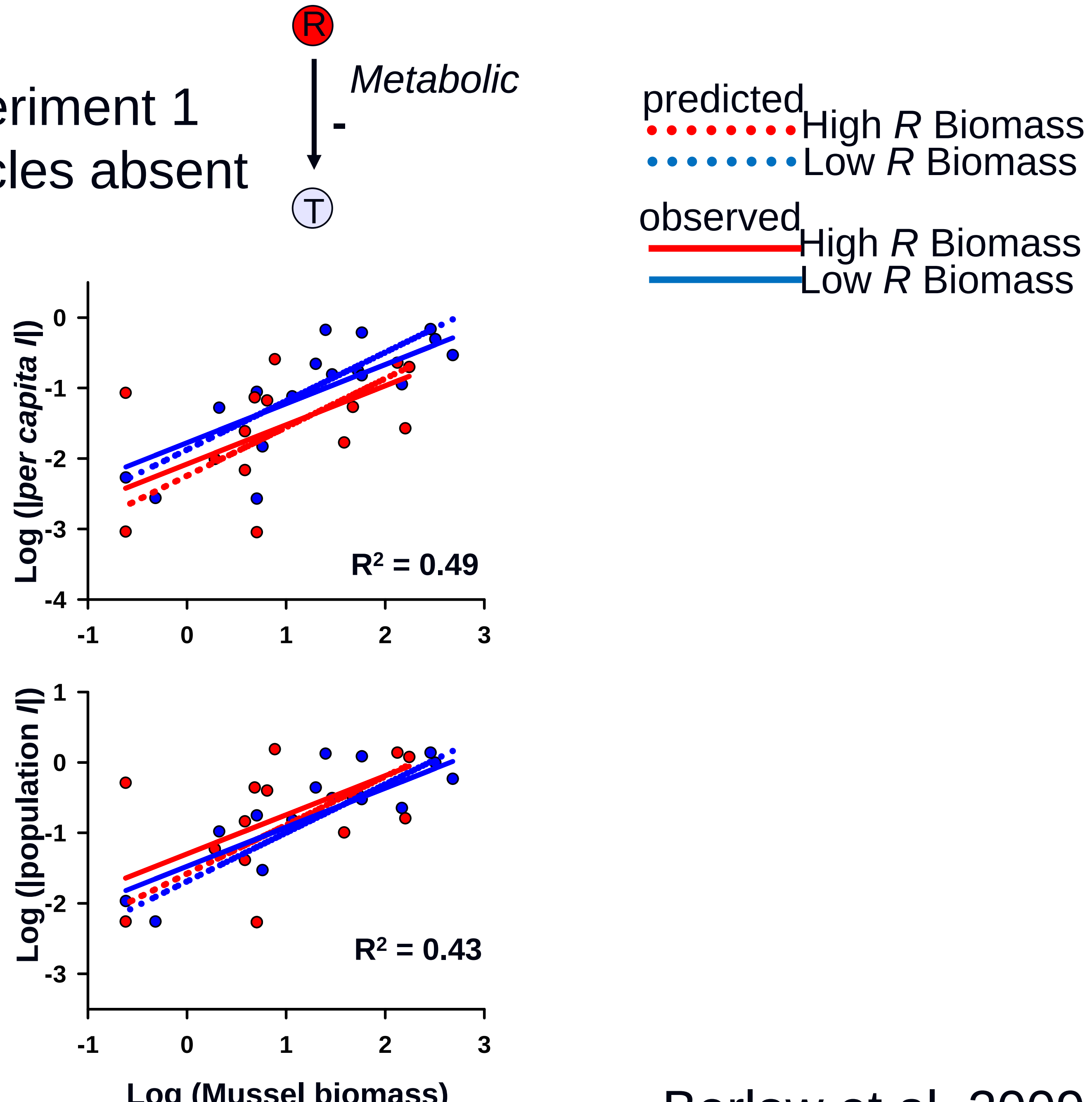
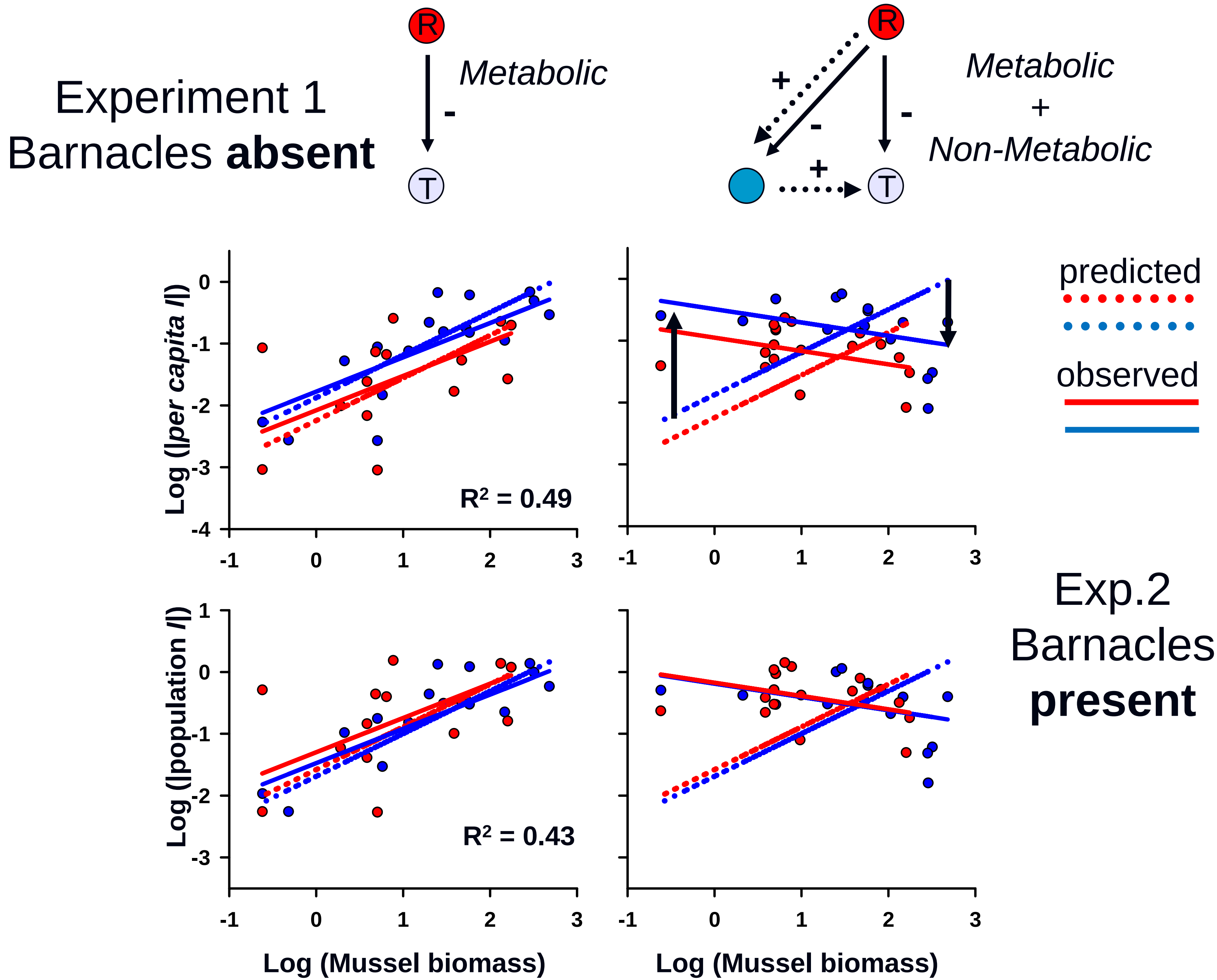
Berlow et al. 2009 *PNAS*

Experiment 1
Barnacles absent



Berlow et al. 2009 *PNAS*



Experiment 1
Barnacles absent
R
T
Metabolic
-
R
T
+
-
-
+
Metabolic
+
Non-Metabolic
predicted
observed
Log (|per capita I|)
Log (|population I|)
R² = 0.49
R² = 0.43
Log (Mussel biomass)
Log (Mussel biomass)
Exp.2
Barnacles
present

Invasions

In Silico explorations of the success and effects of species invasions

Tradeoffs between Resistance & Resilience

“the maintenance of functioning in the face of disturbance” (Levin & Lubchenco 2008)
Disturbance: single successful invasion
Functioning: the number of species dynamically supported

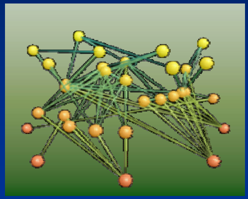
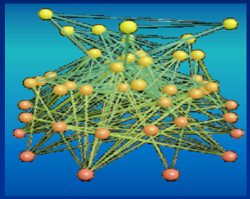
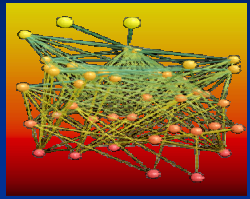
Romanuk, Zhou, Brose, Berlow, Williams & Martinez 2009
Phil. Trans. of the Royal Society B, Romanuk et al. *in review*

Simulation Methods

- STEP ONE:

Parameterizing niche 150 webs (*t*=0)

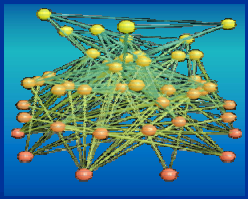
  - 30 species, initial *C*=0.05, 0.15, 0.30

- STEP TWO:

Parameterizing 100 niche invaders (*t*=0)

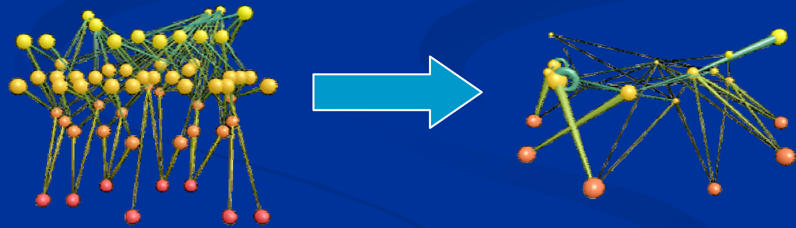
  - 30 species, initial *C*=0.15



- STEP THREE:

Generating persistent webs (*t*=0 to *t*=2000)

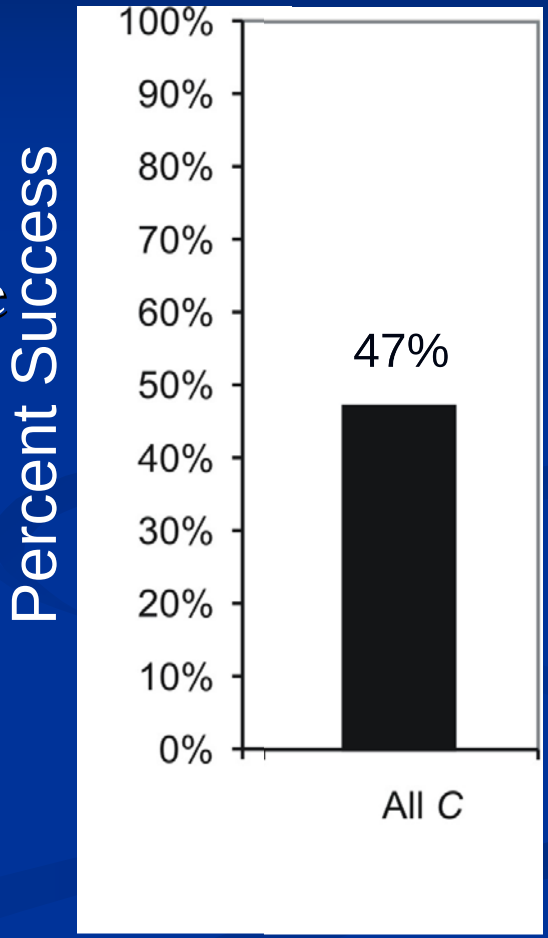
  - S and C range



- STEP FOUR:
  - Introducing invaders in the webs (*t*=2000 to *t*=4000)
  - Running the simulations without invasions (*t*=2000 to *t*=4000)

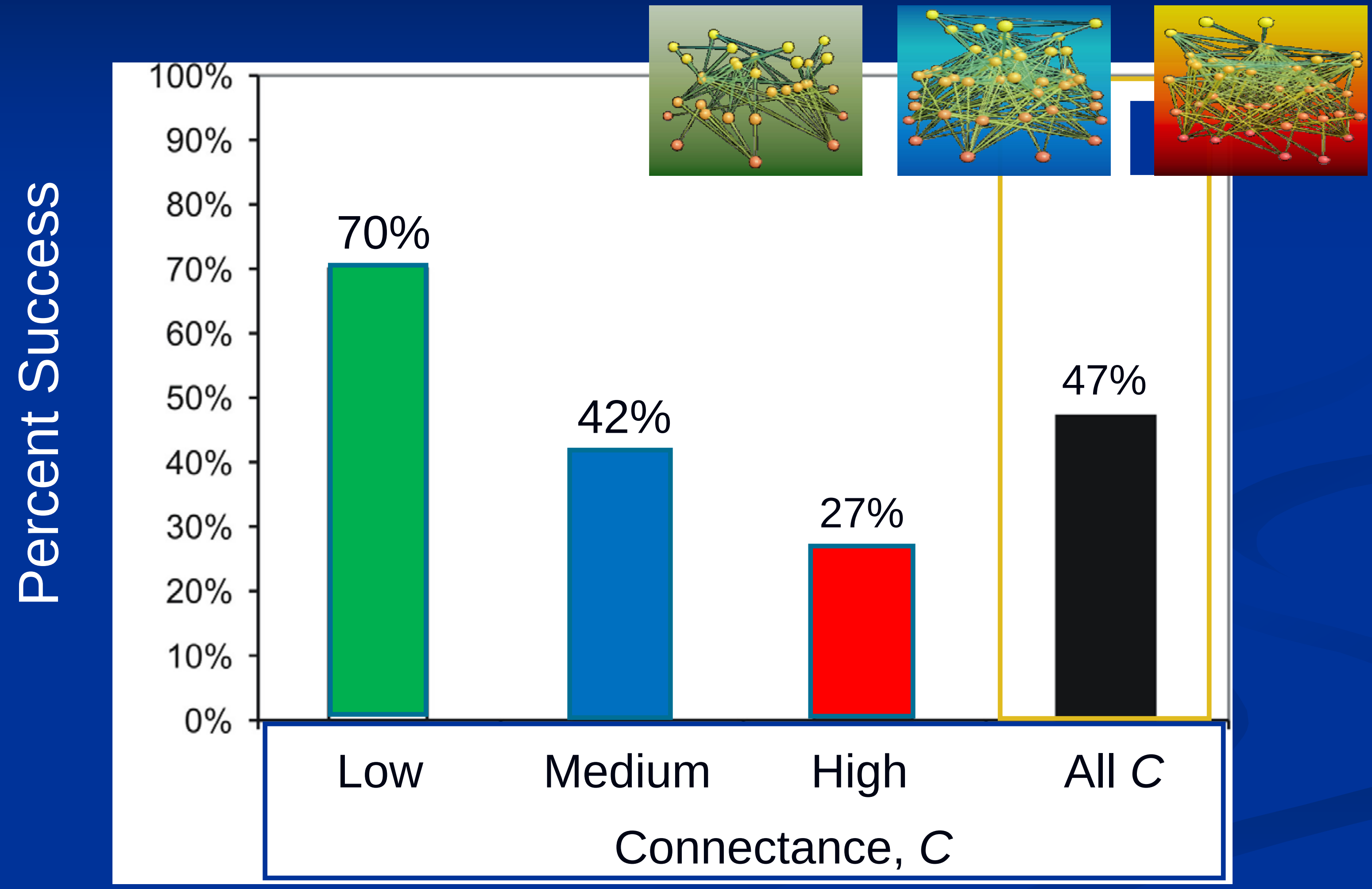
Resistance is not Futile

- 11,438 invasion attempts by non-basal species
- Basal species are eliminated
- 47% of these introductions were successful with the invader persisting till *t*=4000



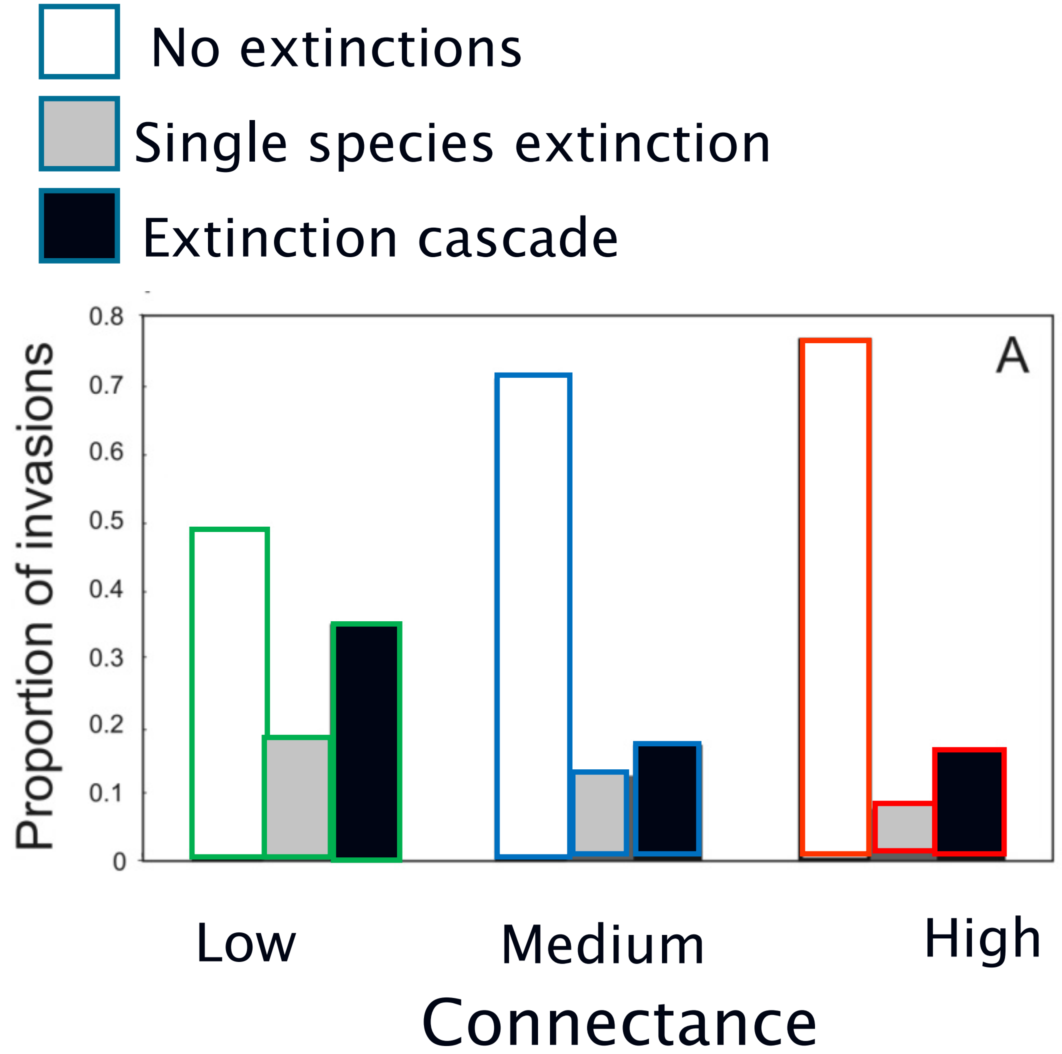
Theme Issue: '**Food-web assembly and collapse: mathematical models and implications for conservation**', Romanuk *et al*., Phil. Trans. R. Soc. B 2009

Resistance varies with *C*



Romanuk et al., Phil. Trans. Roy. Soc. B 2009

Among Successful Invasions: Connectance affects likelihood of extinction



Cascades are more likely than single species extinctions

High C webs are more resistant to extinctions

High Connectance Webs most Robust

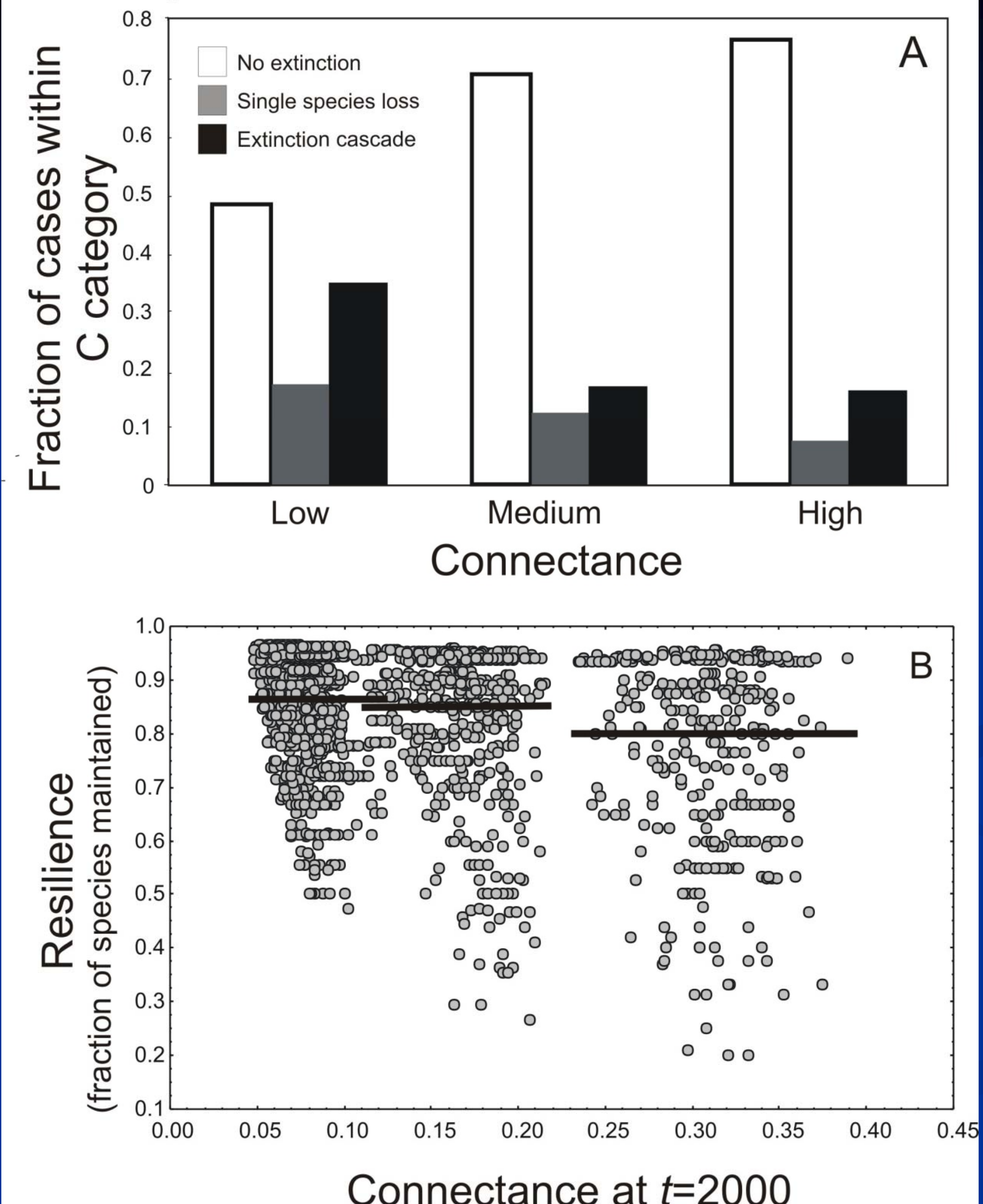


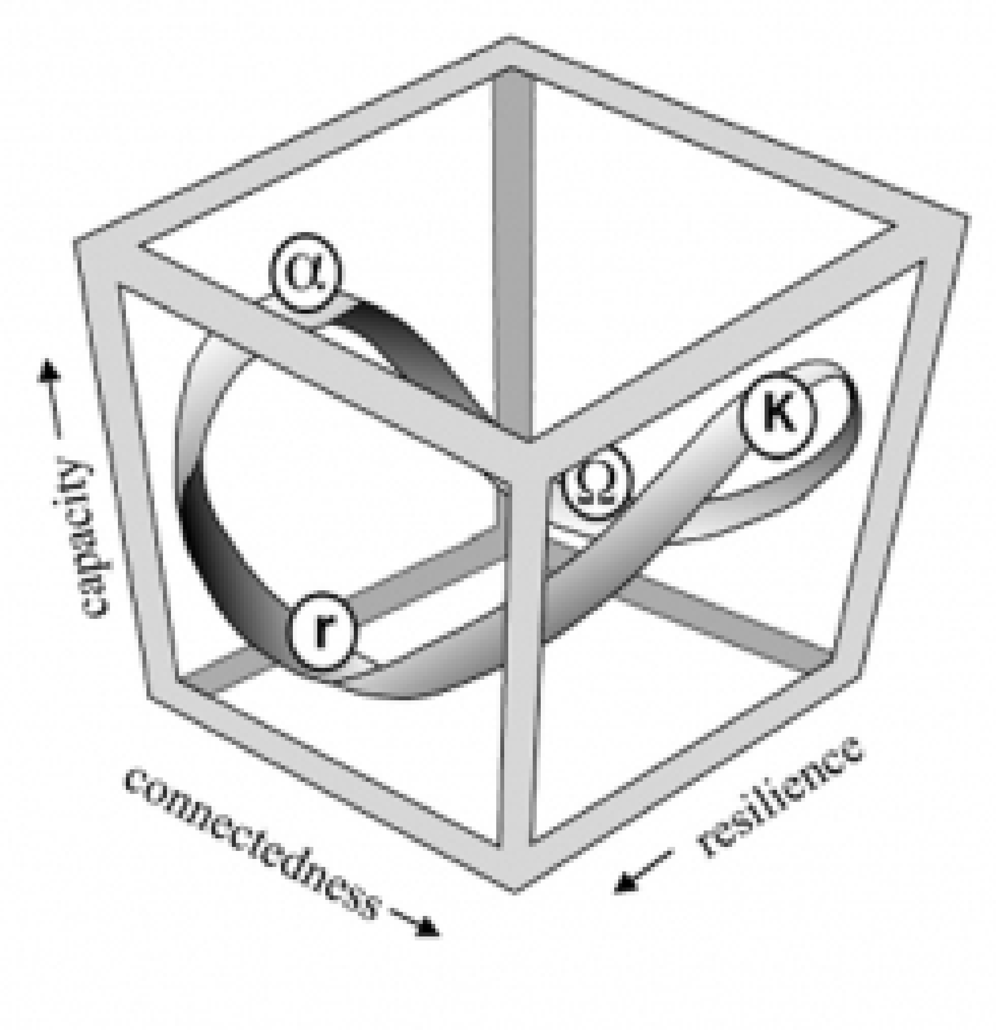
Figure 3a-b

C affects magnitude of secondary extinctions

- The magnitude of the extinctions was much greater in high *C* webs than in the low *C* webs.

Low Connectance Webs most Resilient

Resilience Alliance: Panarchy

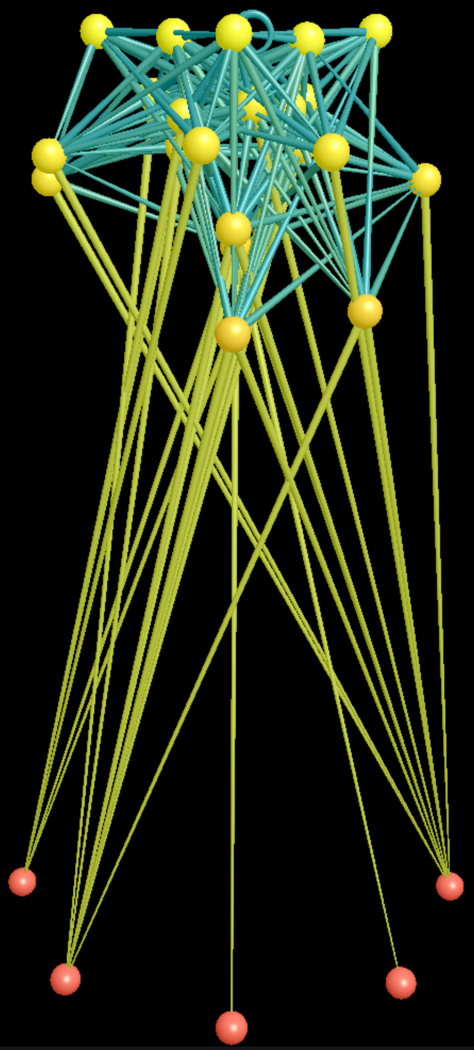


- A more rigorous framework for exploring fundamental concepts

Future Directions

- Include nontrophic interactions
  - Facilitation, plant-fungal, plant-pollinator
  - Sublethal effects of predators
  - Nutrients, remineralization, decomposition
- Evolution within networks
- Add economic nodes to ecological networks
  - Explore integrated ecological-economic models

Evolved Web
From co-evolution to poly-evolution



Evolved Web
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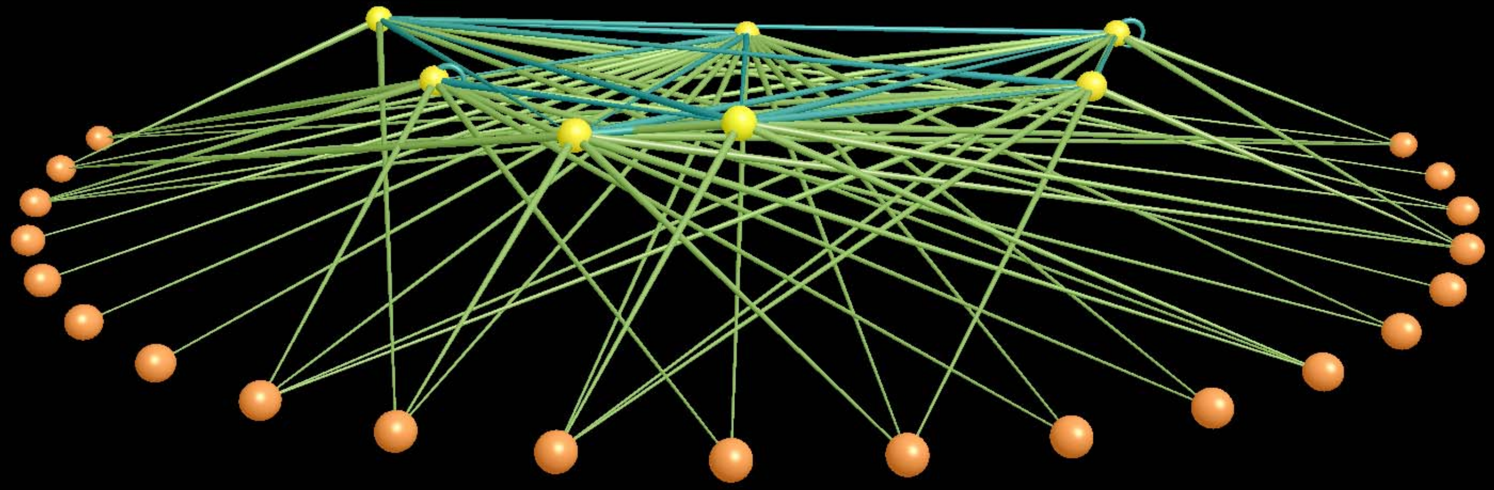


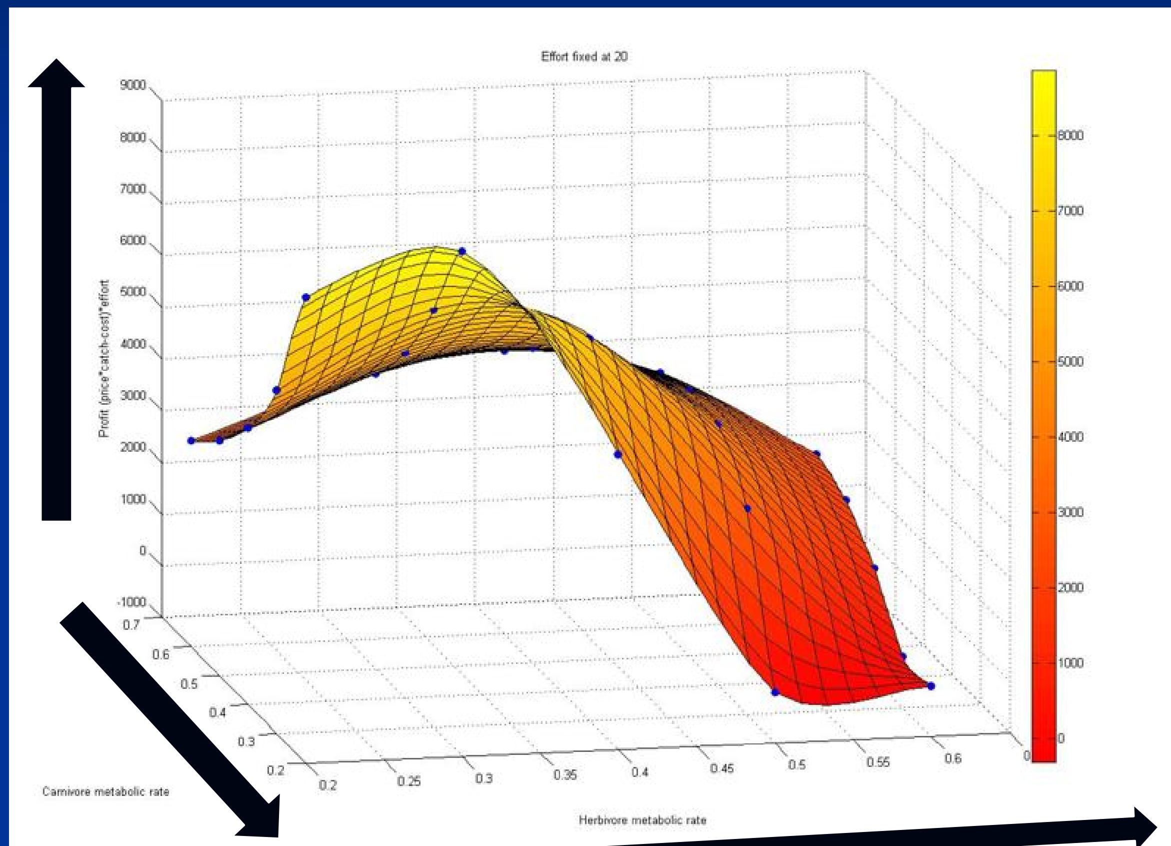
Economics and Ecology

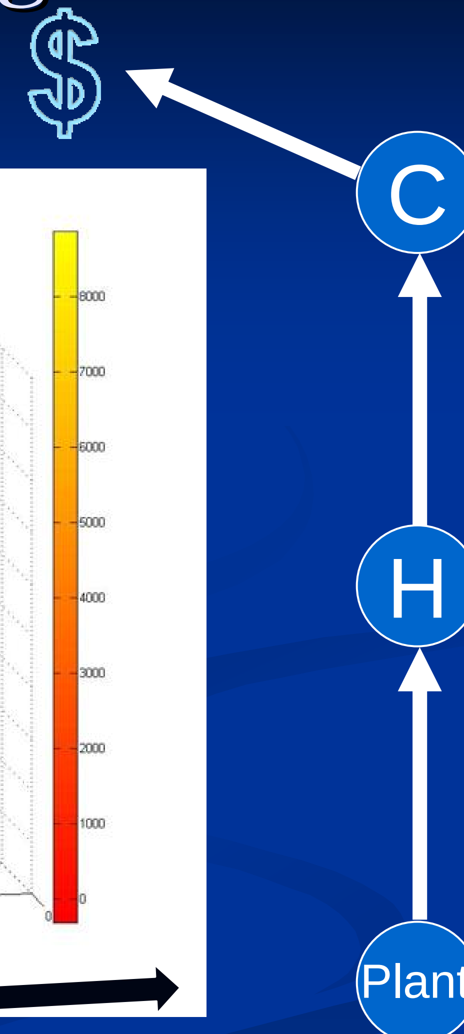
- Add economic nodes to ecological networks
- $E_k' = n(pqB_i - c)E_k$ (Conrad 1999)
  - E = exploitation effort
  - p = price per unit biomass
  - q = catchability
  - c = cost per unit effort
  - n = economic "openess"
- Explore dynamics of Eco^3
  - ecosystem models of economic-ecological networks

Effects of Body Size on Fishing Profits

Increasing Fishing Profit

Increasing Carnivore Size





Increasing Herbivore Size

Summary

1. Search for devious strategies led us to discover law-like behaviour in evolved and evolving biological systems.

2. Methods include simple models enabled via ecoinformatics computational ecology.

3. Successful Applications have been demonstrated

4. Increases the credibility of ecology to society

5. Progress towards an Systems Biology of Ecology

   Or and "Ecological Theory of Everything"?

6. Network Science Case History: Structure to Dynamics

To hell with Victorian notions of the struggle for existence

- Here comes the Californian notion of
  - ***THE PARTY FOR EXISTANCE!***
  - To survive and evolve, organisms have to hook up!
    - Eurkaryotes, sex, mutualisms, facilitation
      - Co-Evolution, reproduction, pollination, farming

- Cooperation more important than Competition?