Structural dynamics and robustness of food webs

Phillip Staniczenko
Department of Physics and Saïd Business School
Oxford University

In collaboration with:

Owen Lewis	**Department of Zoology, Oxford University**
Nick Jones	**Systems Biology, Oxford University**
Felix Reed-Tsochas	**Cabdyn Complexity Centre, Oxford**

8th June 2010, Saïd Business School, Oxford University

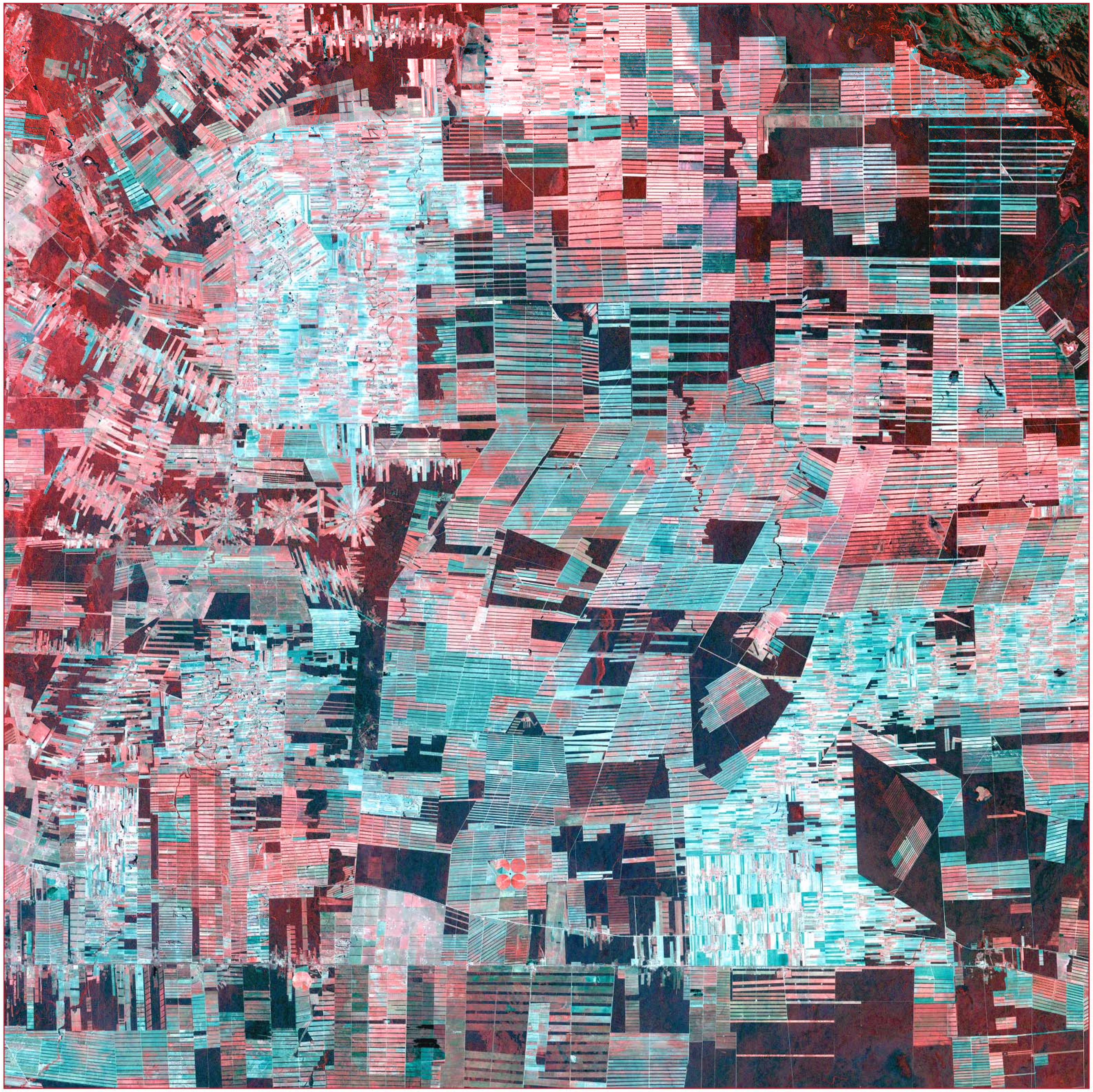
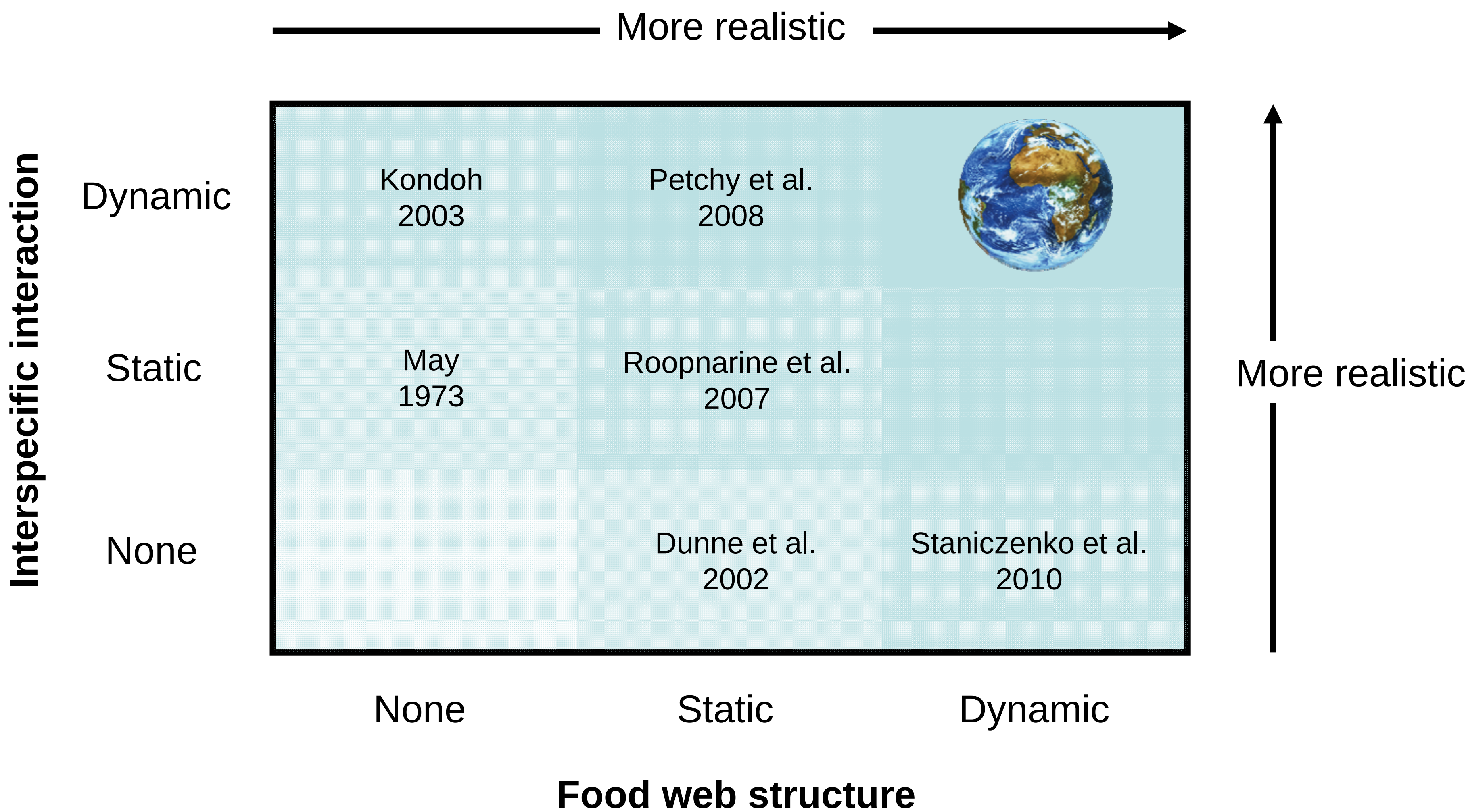


Image:
NASA
(2000)

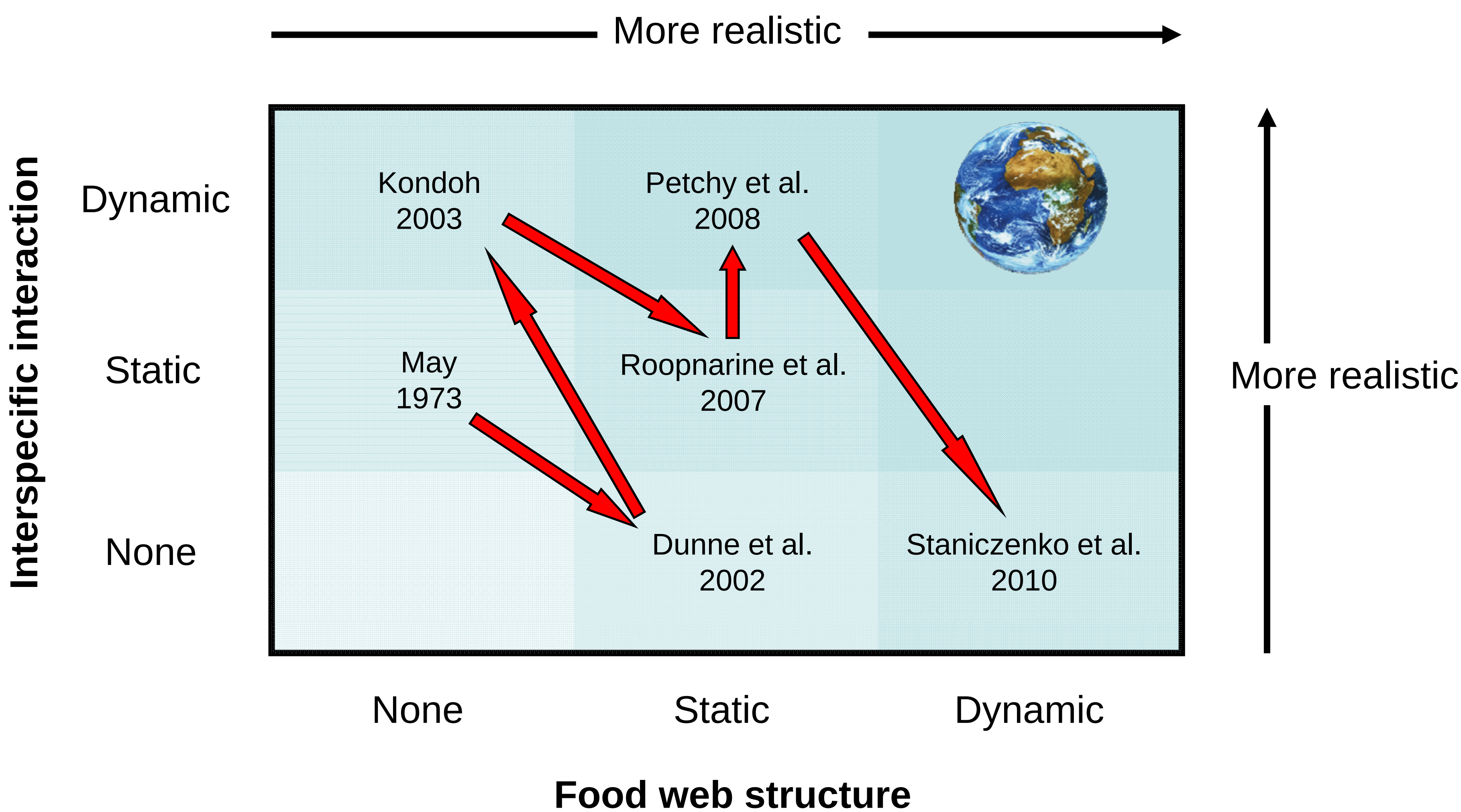
Overview

- Modelling community ecology
- Structural dynamics and robustness of food webs
- Other projects

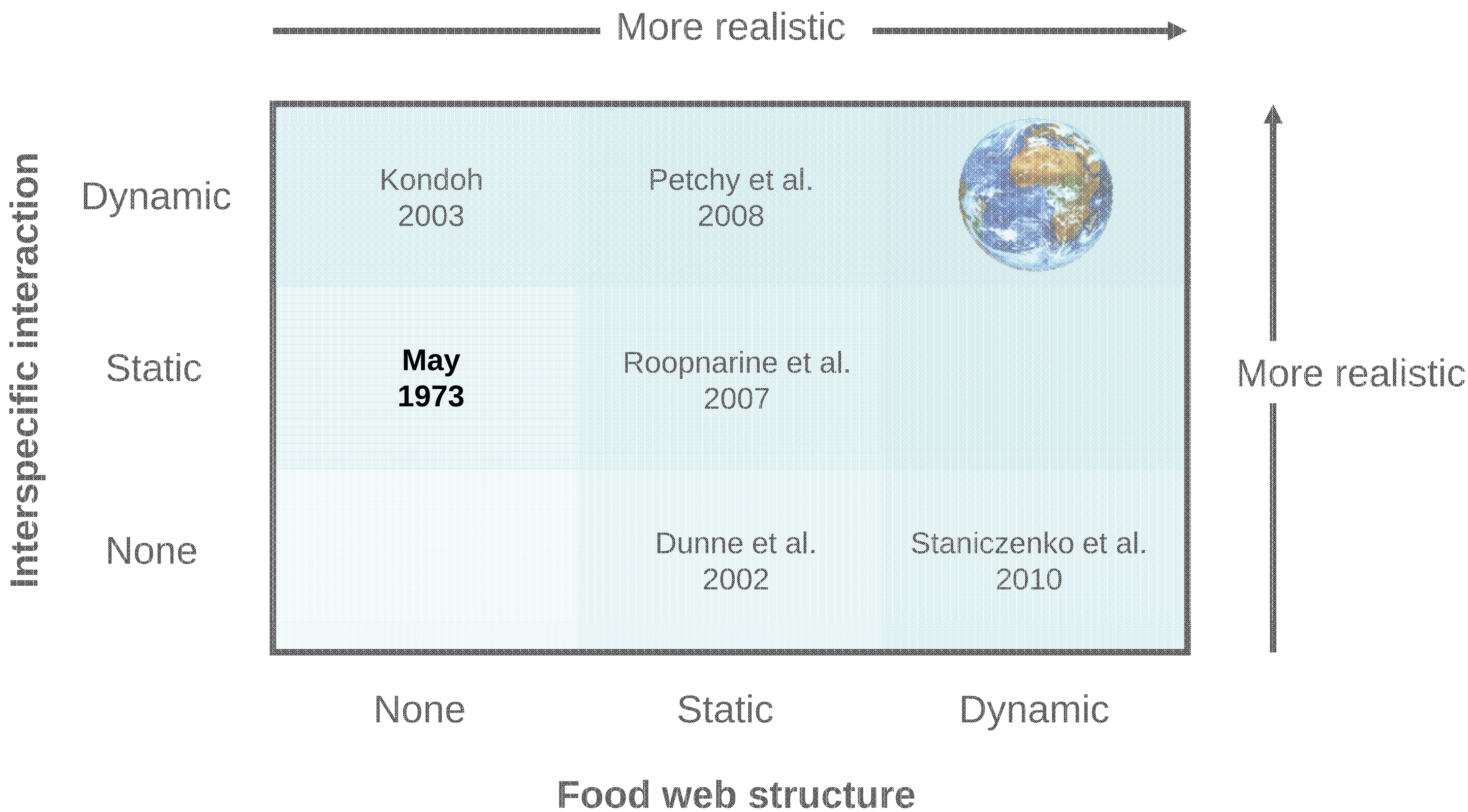
Modelling community ecology



Modelling community ecology



Modelling community ecology



Stability and complexity in model ecosystems

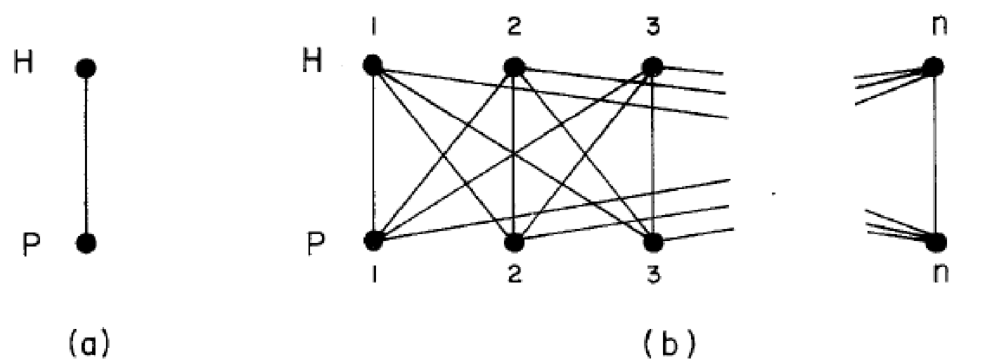
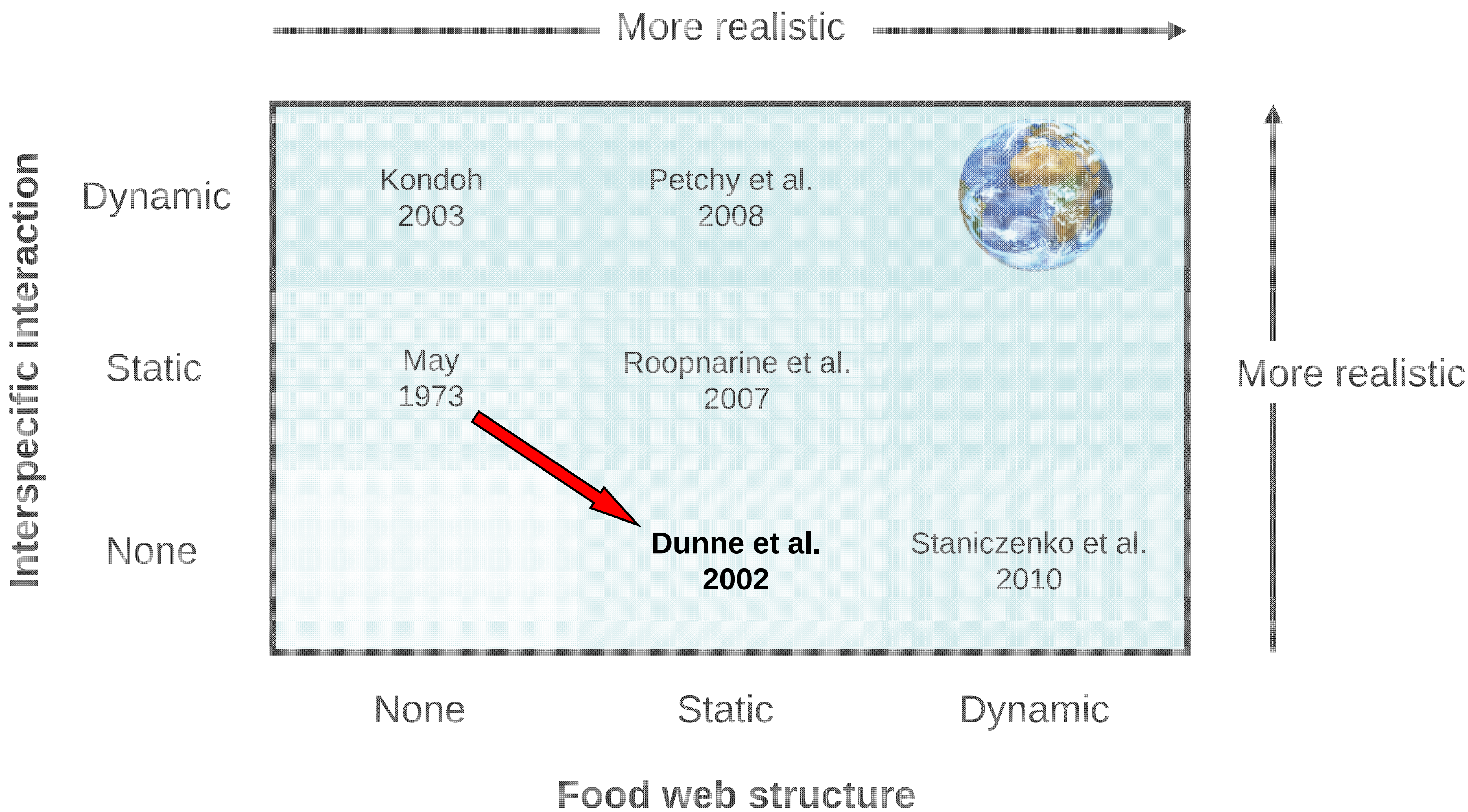


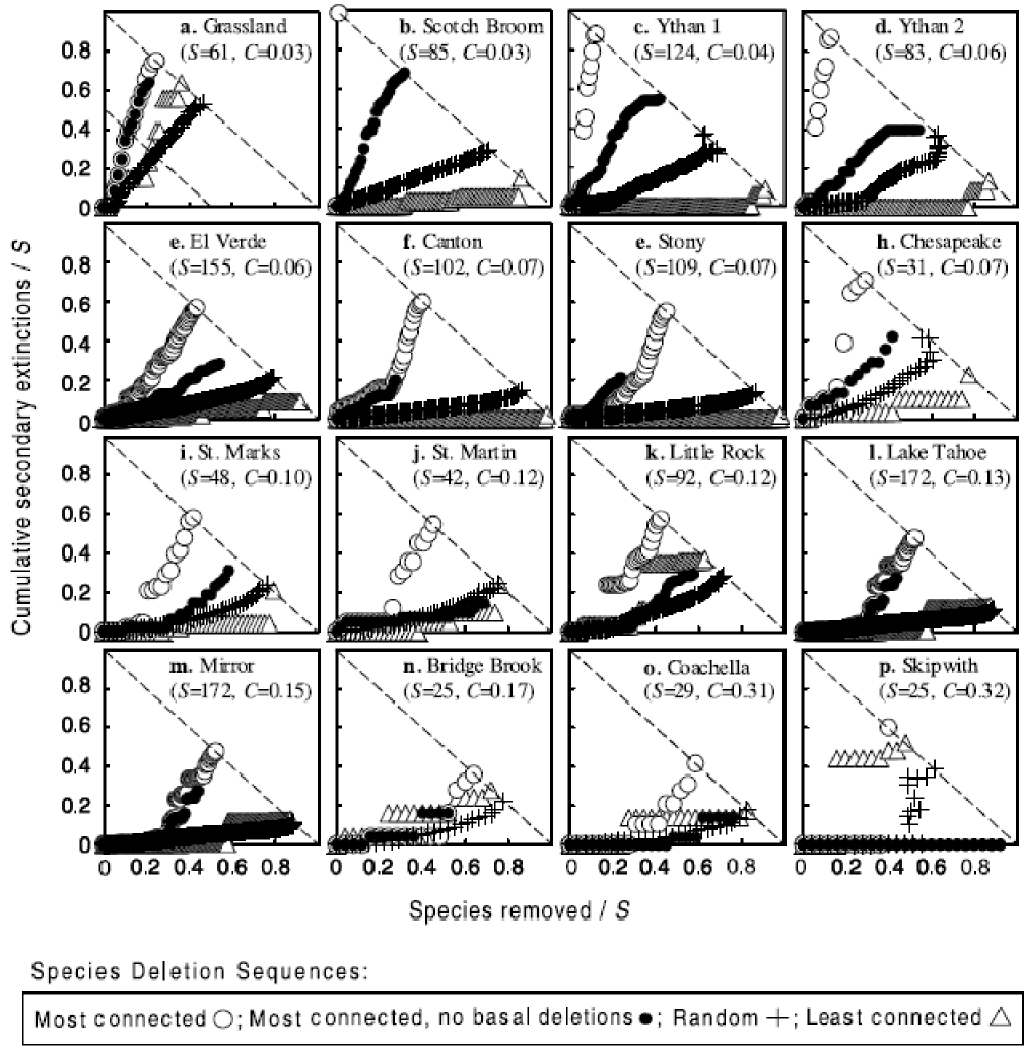
FIGURE 3.1. Schematic representation of a two-level trophic web with (a) one species at each level, and (b) n species at each level. H and P stand for host and parasite, or alternatively for herbivore and predator.

May (1973) Princeton University Press, Princeton NJ

Modelling community ecology

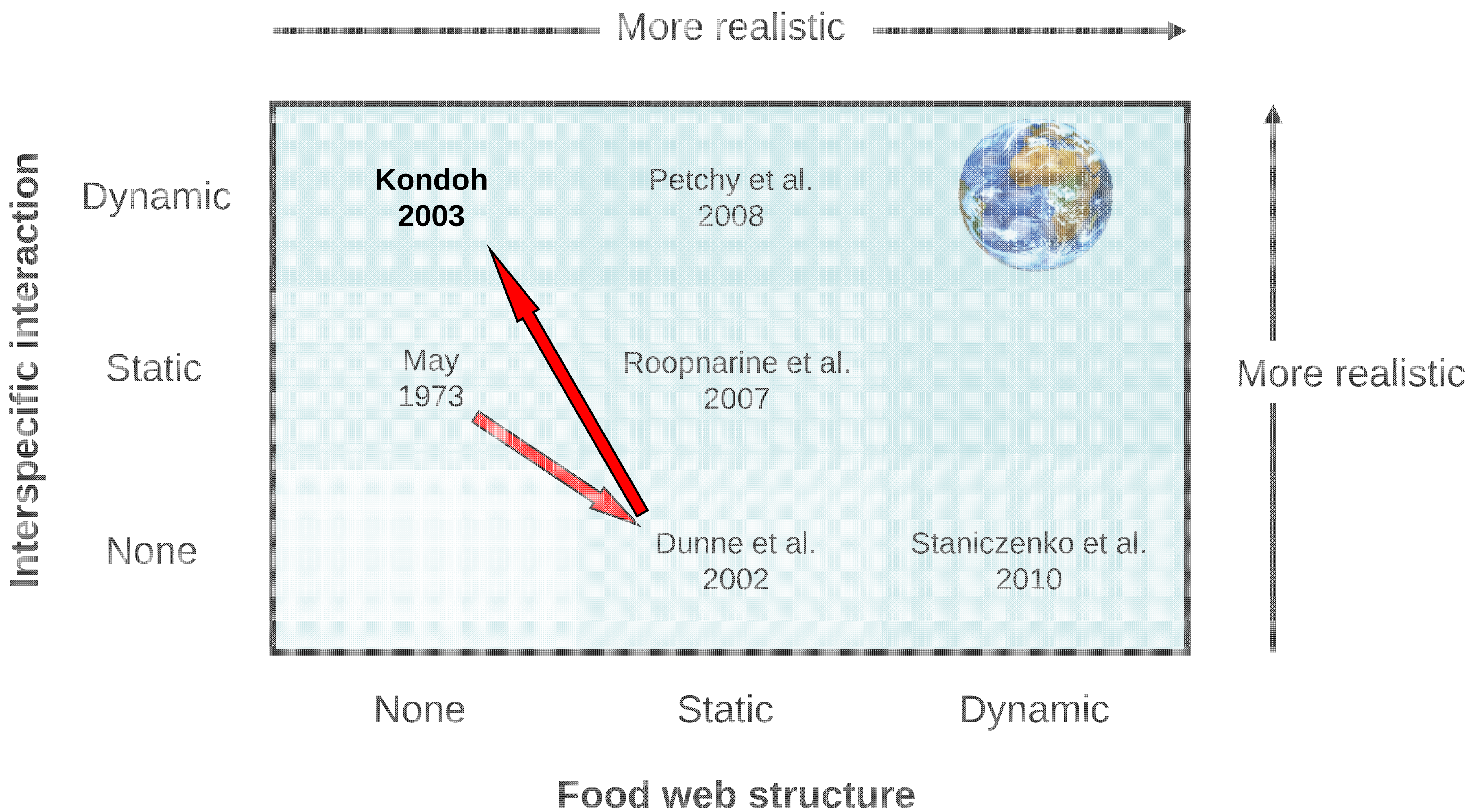


Network structure and biodiversity loss in food webs

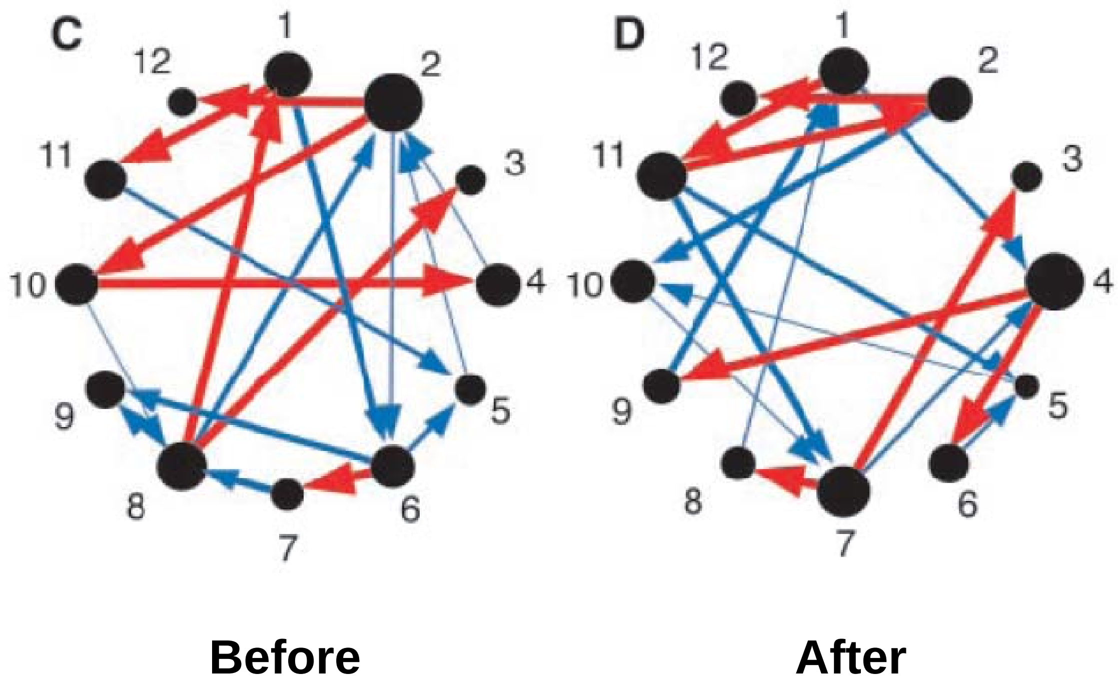


Dunne et al. (2002) Ecology Letters 5, 558-567

Modelling community ecology

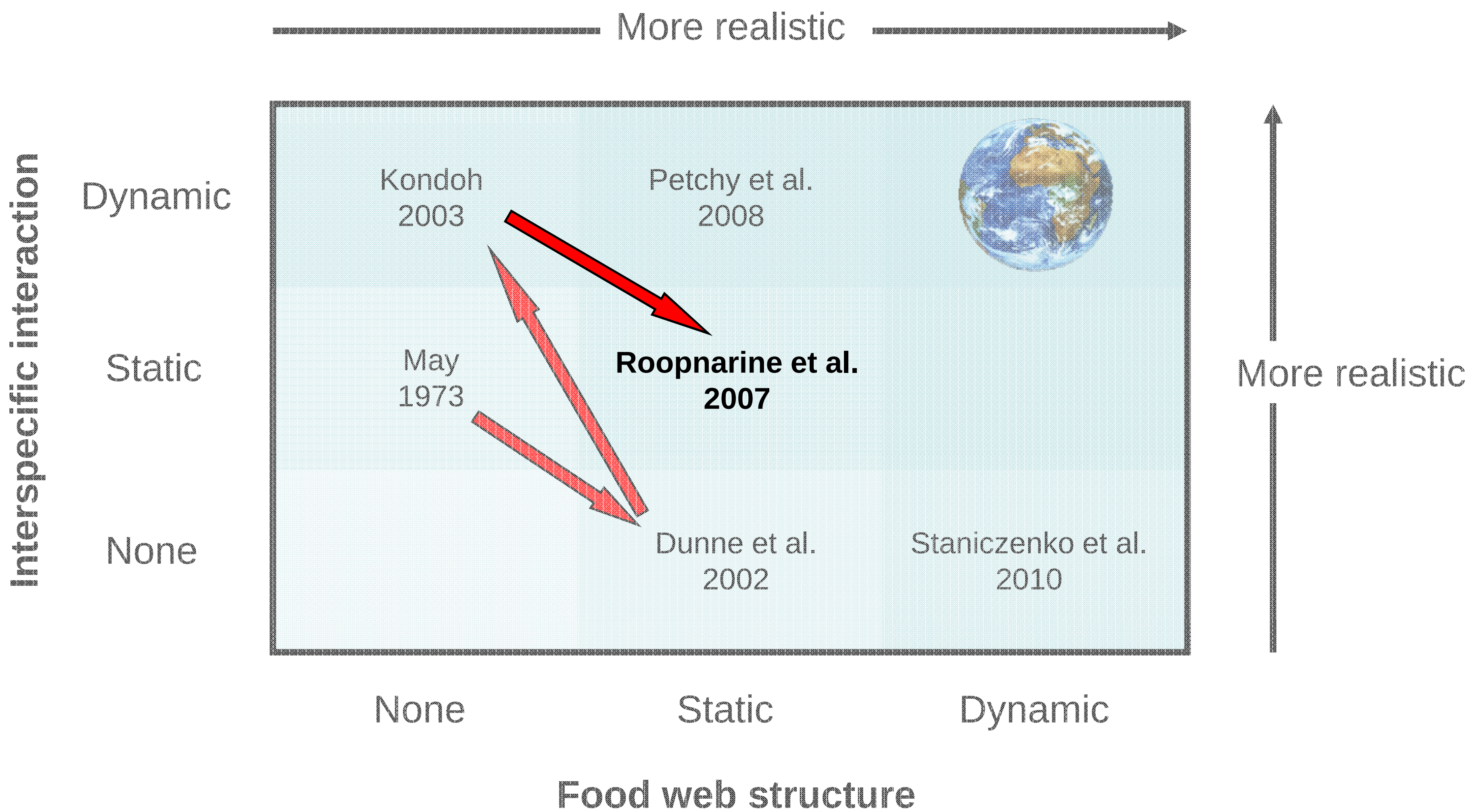


Foraging adaptation and the relationship between food-web complexity and stability

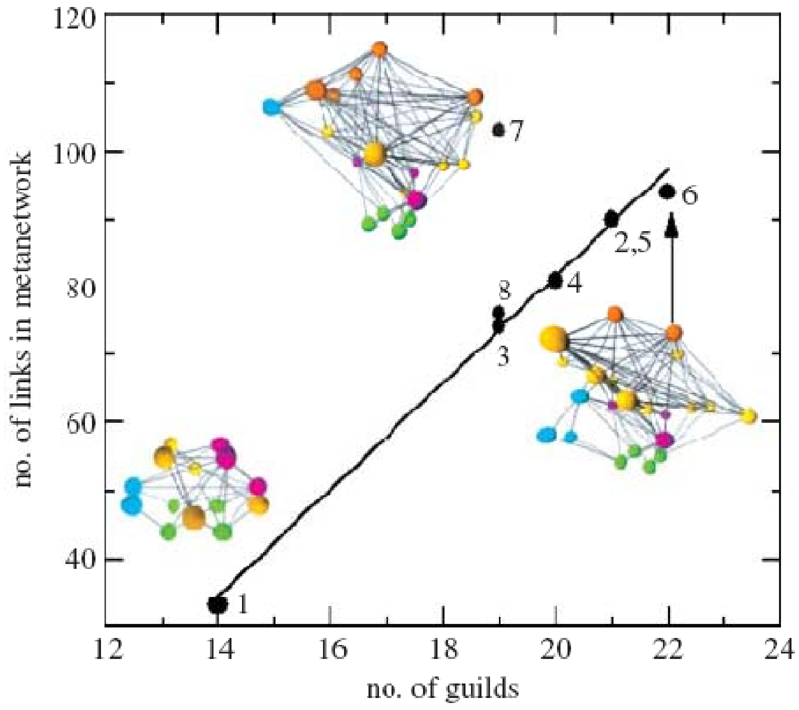


Kondoh (2003) Science 299, 1388-1391

Modelling community ecology

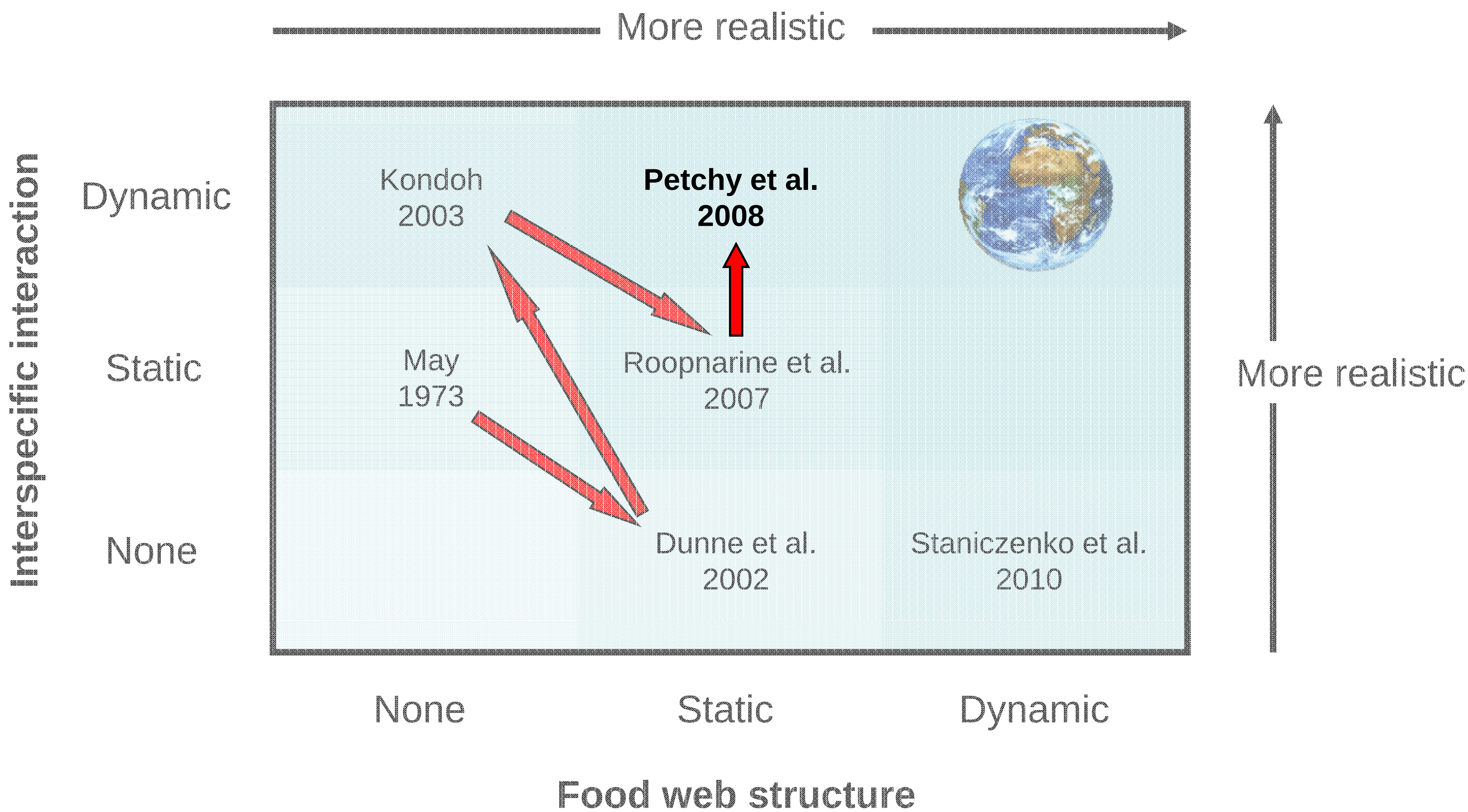


Trophic network models explain instability of Early Triassic terrestrial communities

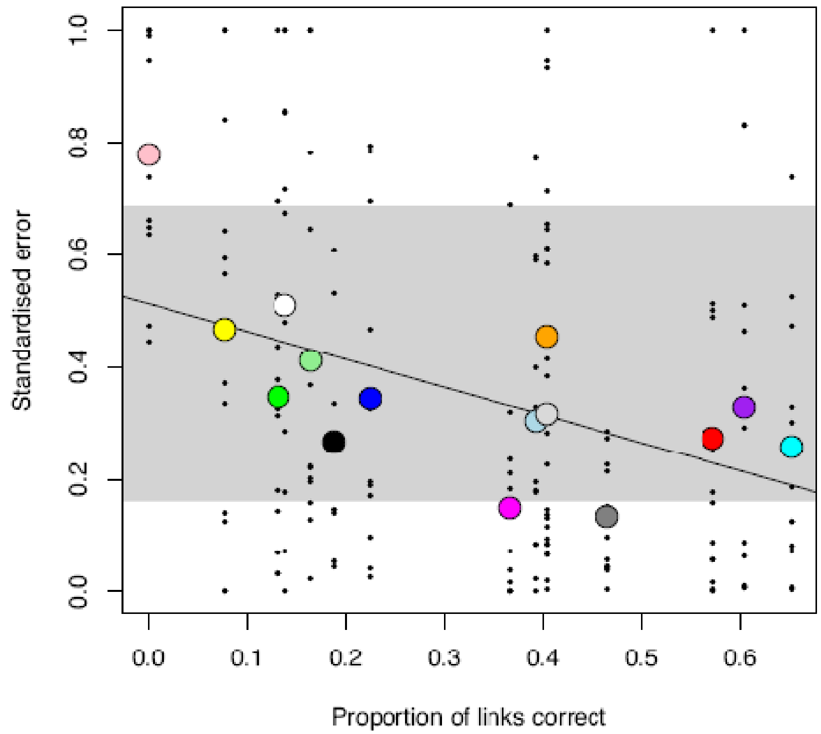


Roopnarine et al. (2007) Proc. R. Soc. B 271, 2077-2086

Modelling community ecology

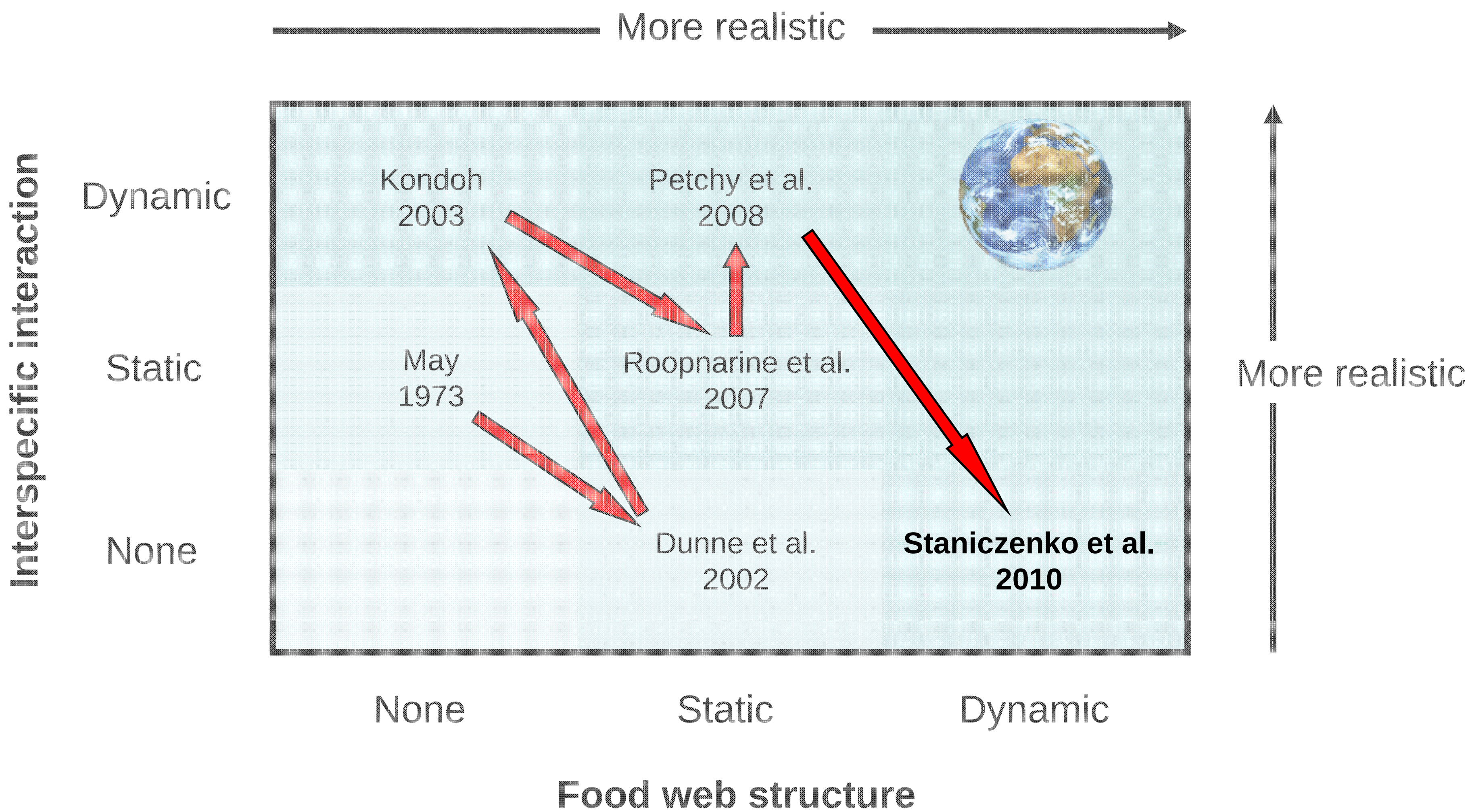


Size, foraging, and food web structure



Petchey et al. (2008) PNAS 105, 4191-4196

Modelling community ecology



Structural dynamics and robustness of food webs

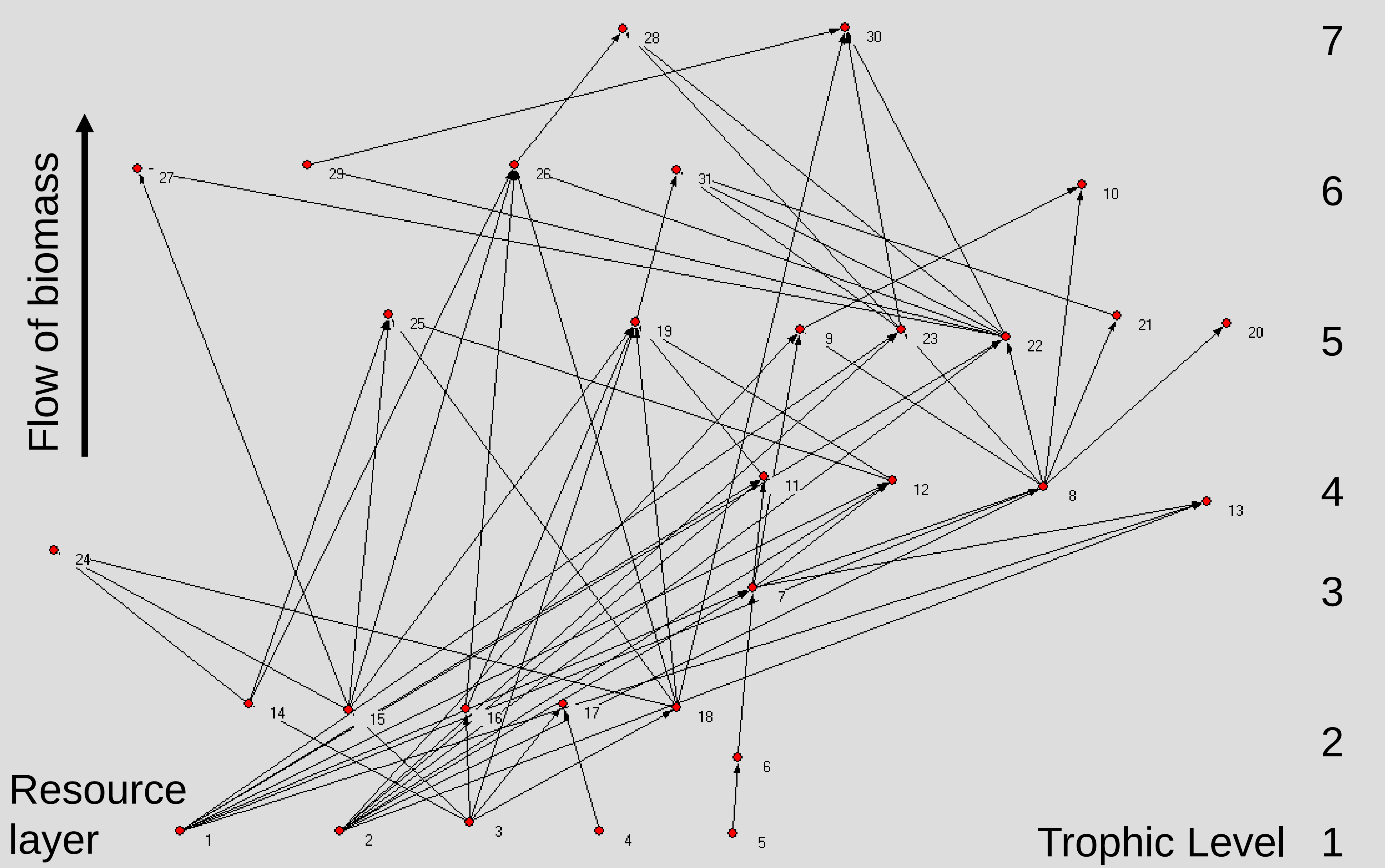
- Introduce a model with realistic, dynamic, food-web structure
- Identify a new category of species that promote adaptive robustness

Implications for biodiversity conservation

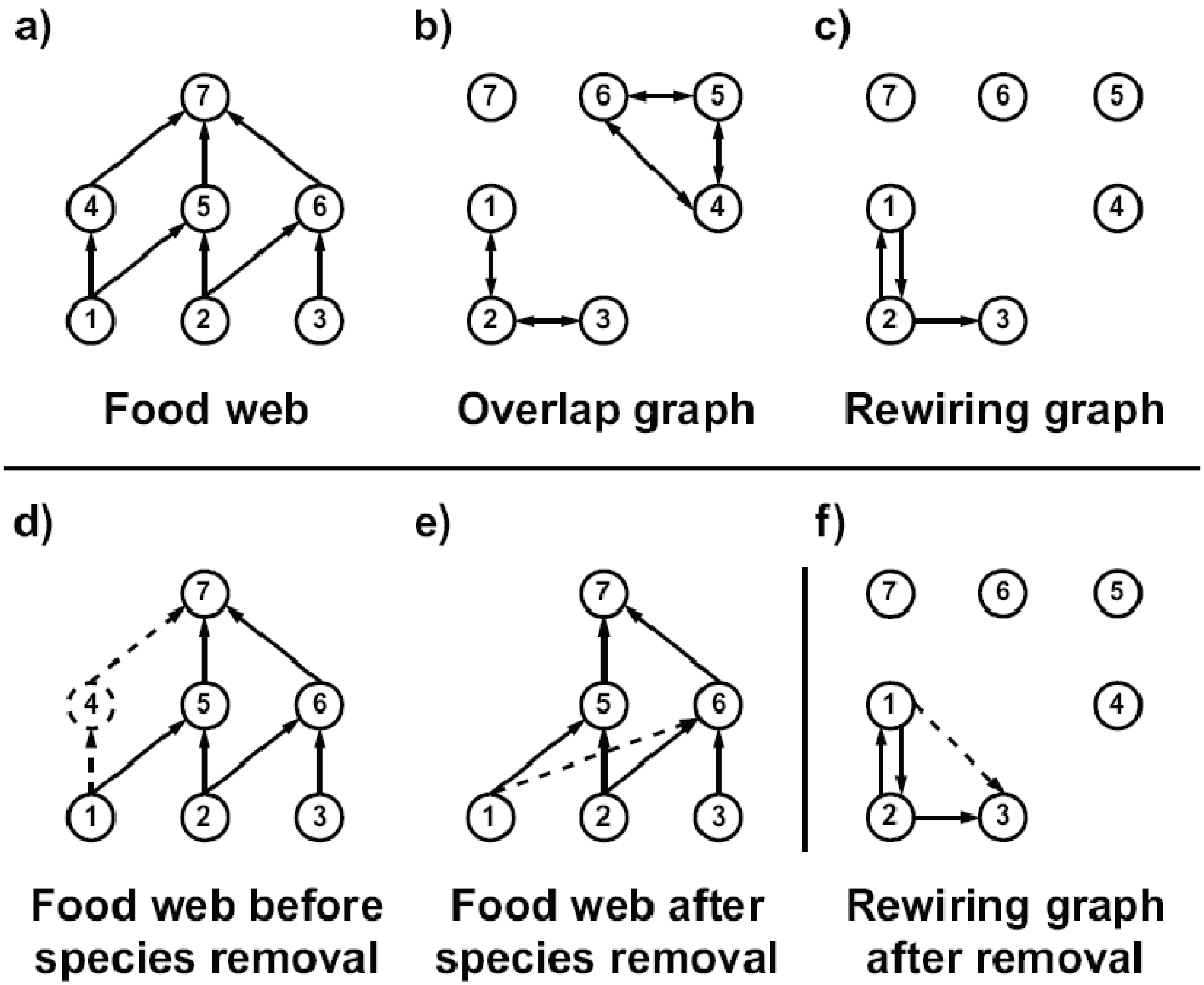
Which species removals cause the largest knock-on effect? → **Which species provide ecosystem stability in the first place?**

Staniczenko et al. (2010) Ecology Letters 13, 891-899

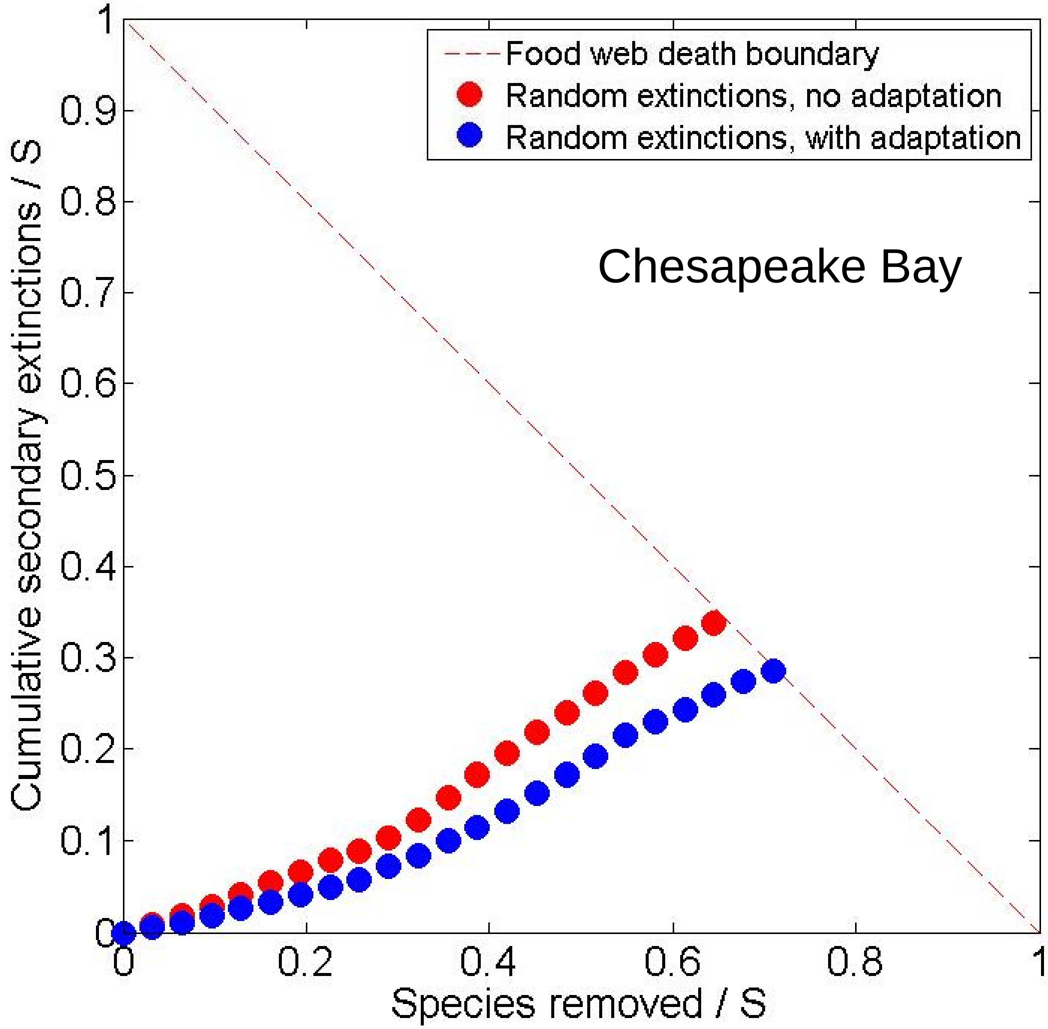
Chesapeake Bay food web



Predator-prey rewiring model



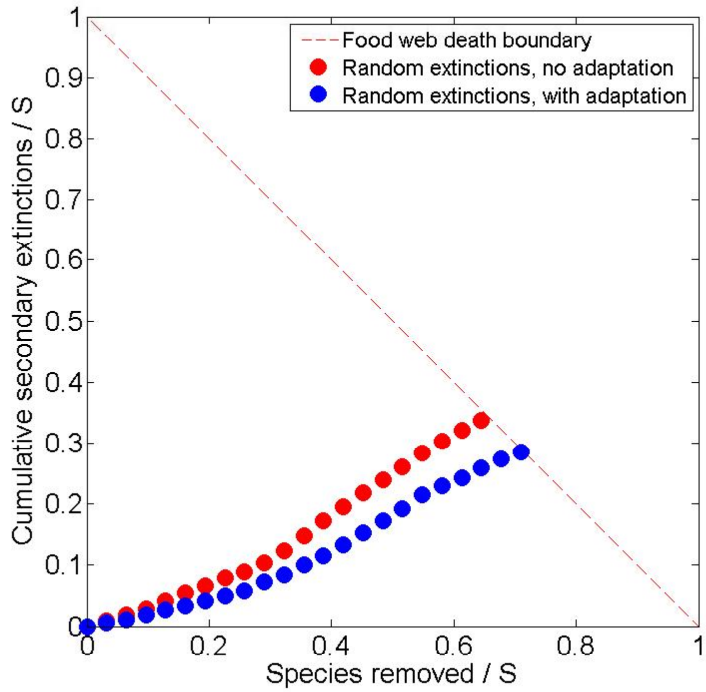
Structural robustness



Average of 1,000 simulations

Method based on J. A. Dunne et al., Ecology Letters 5, 558 (2002)

Structural robustness

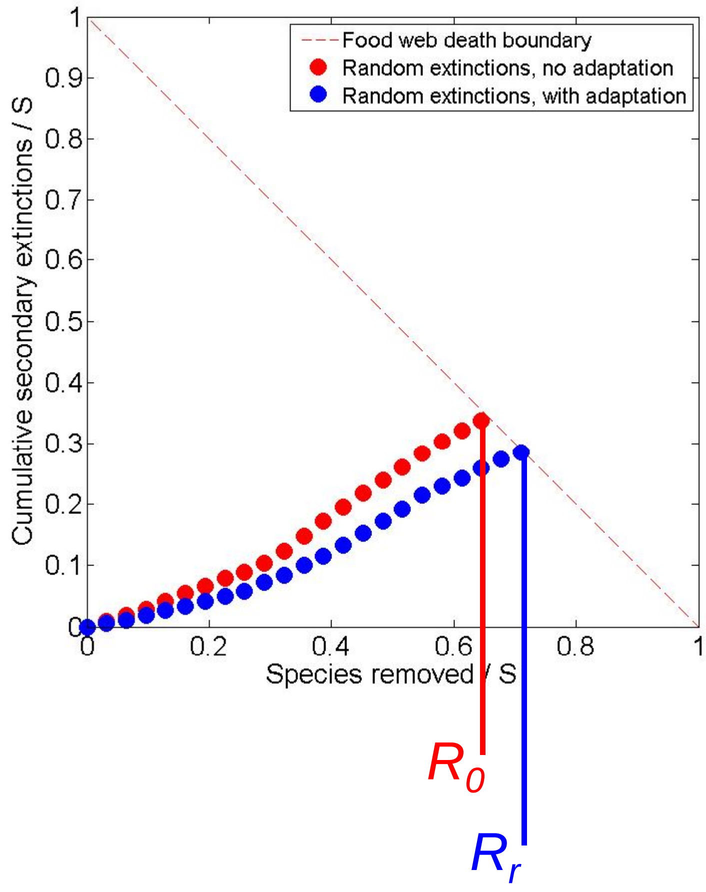


<u>Extinction sequence forms</u>

- Random
- Preferentially removing species with low degree
- Preferentially removing species at high trophic level

Method based on J. A. Dunne et al., Ecology Letters 5, 558 (2002)

Structural robustness



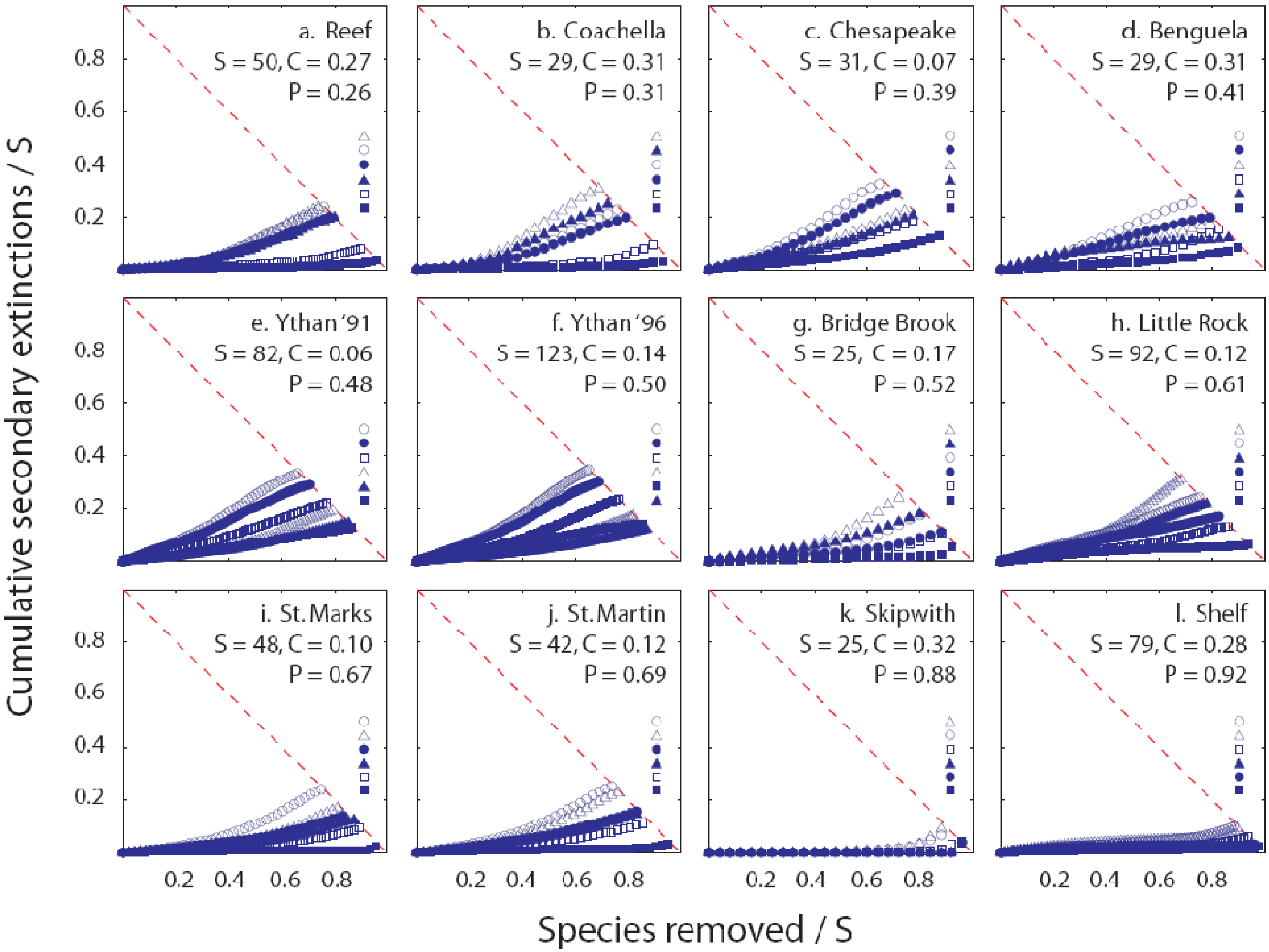
Proportional increase in robustness

$$R^{+} = \frac{R_r - R_0}{1 - R_0}$$

Expected range [0,1]

Method based on J. A. Dunne et al., Ecology Letters 5, 558 (2002)

Structural robustness in empirical food webs



Structural robustness in empirical food webs

Structural robustness in empirical food webs

Biodiversity?

Link density, Connectance?

Top, Intermediate, Bottom species?

Average trophic level?

Shelf
Skipwith Pond
St. Martin Island
St. Marks Seagrass
Little Rock Lake
Bridge Brook Lake
Benguela
Ythan Estuary '91
Chesapeake Bay
Reef
Ythan Estuary '96
Coachella Valley

Proportional increase in robustness, R^+

Structural robustness in empirical food webs

~~Biodiversity?~~

~~Link density, Connectance?~~

~~Top, Intermediate, Bottom species?~~

~~Average trophic level?~~

Shelf
Skipwith Pond
St. Martin Island
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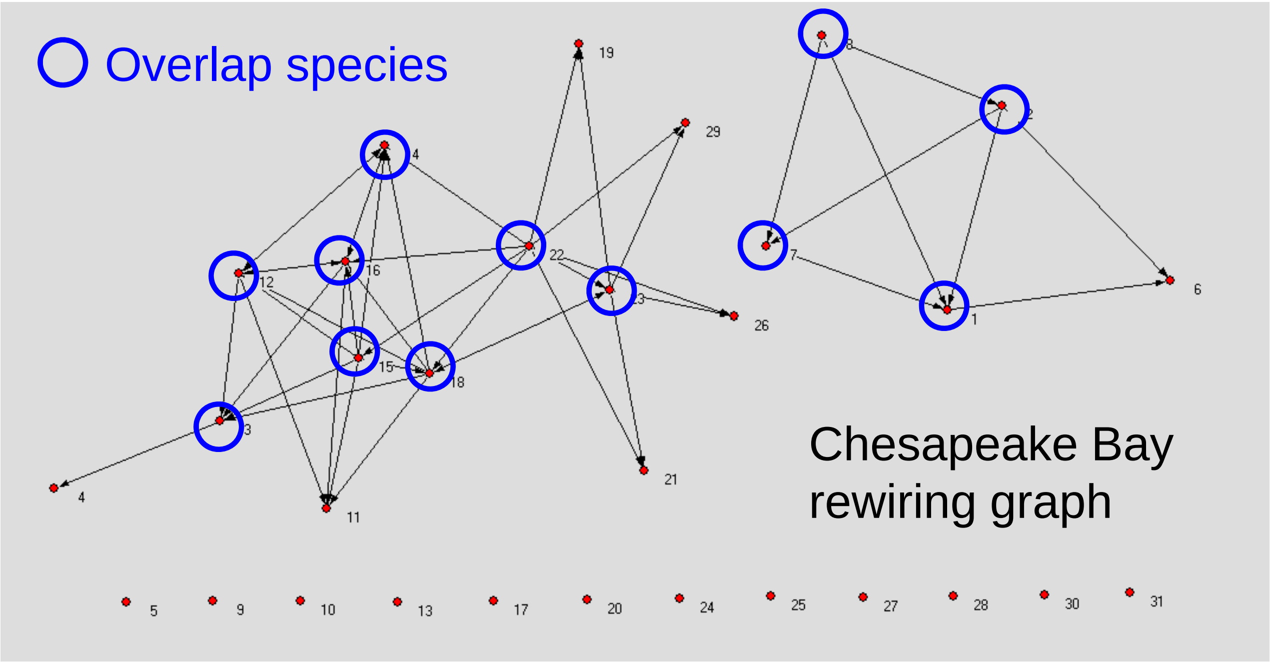
Coachella Valley

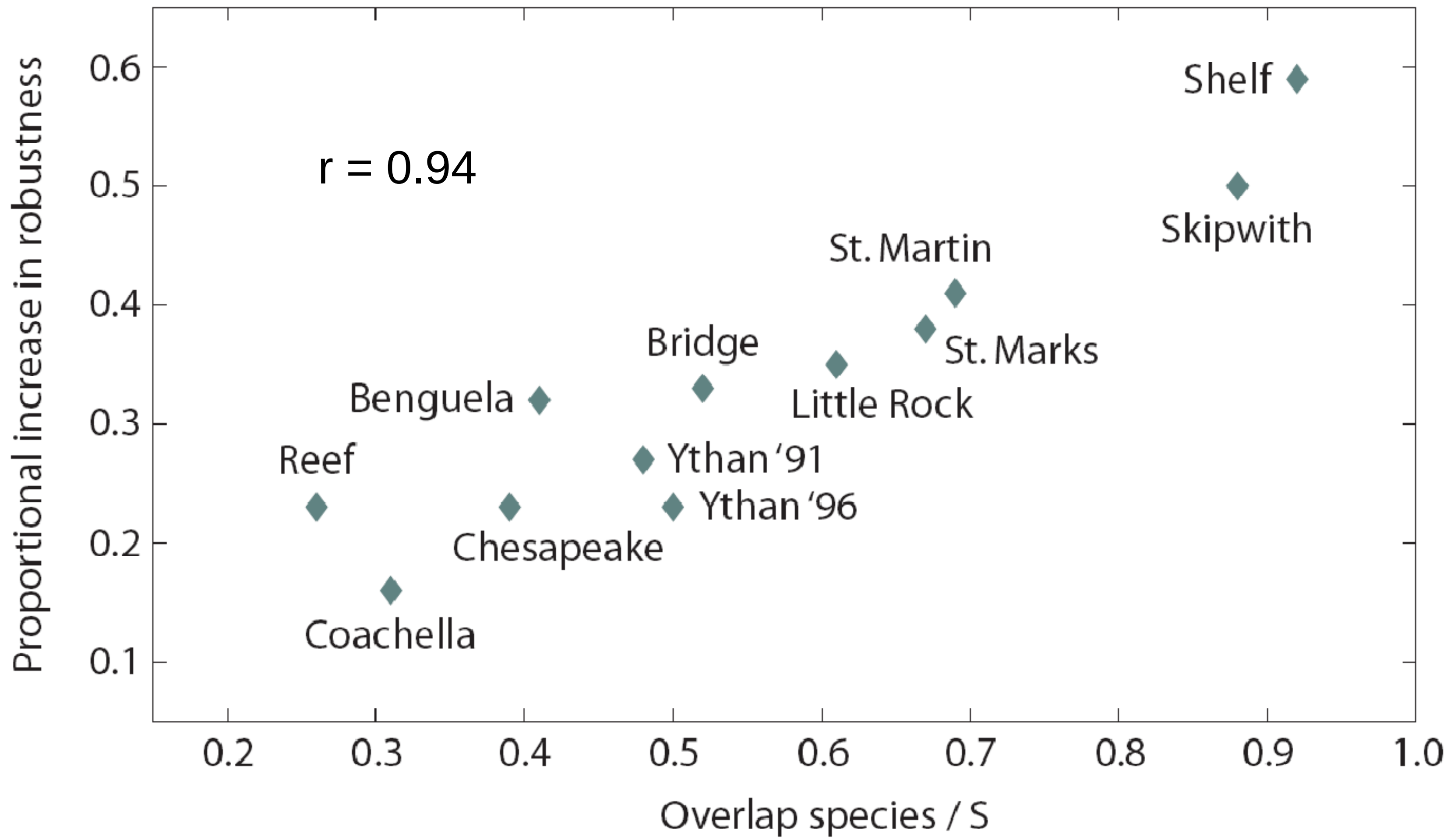
↑ Proportional increase in robustness, R^+

Overlap species

- Species in the rewiring graph with $k_{out} > 0$
- Offer biologically-plausible potential predators to other species
- Provide a compensatory mechanism that enables ecosystem adaptation



Overlap species and the proportional increase in robustness



Summary

- Introduced a model with realistic, dynamic, food-web structure
- Shown some results for empirical food webs
- Identified a new category of species that promote adaptive robustness

Further work

- Theoretical:
  - Consider synthetic food webs
  - Apply to mutualistic and antagonistic ecological networks
  - Incorporate with population dynamic models

- Empirical:
  - Overlap species in the field
  - Phylogenetic relationships
  - Implications for ecosystem conservation and management

Which species removals cause the largest knock-on effect?

Which species provide ecosystem stability in the first place?

Projects

- Rapidly detecting disorder in rhythmic biological signals.
  Staniczenko, Lee & Jones (2009) *Phys. Rev. E* 79:011915.

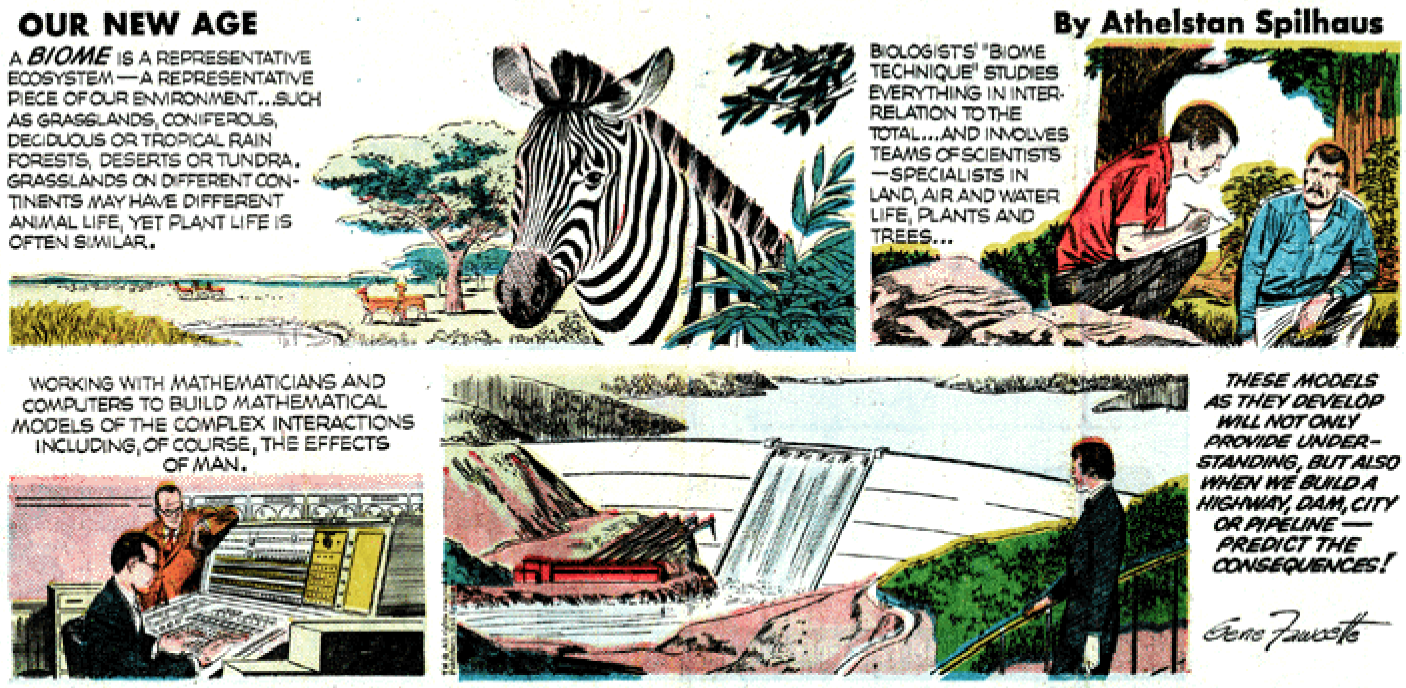
- **Structural dynamics and robustness of food webs.**
  Staniczenko, Lewis, Jones, Reed-Tsochas (2010) *Ecology Letters* 13, 891.

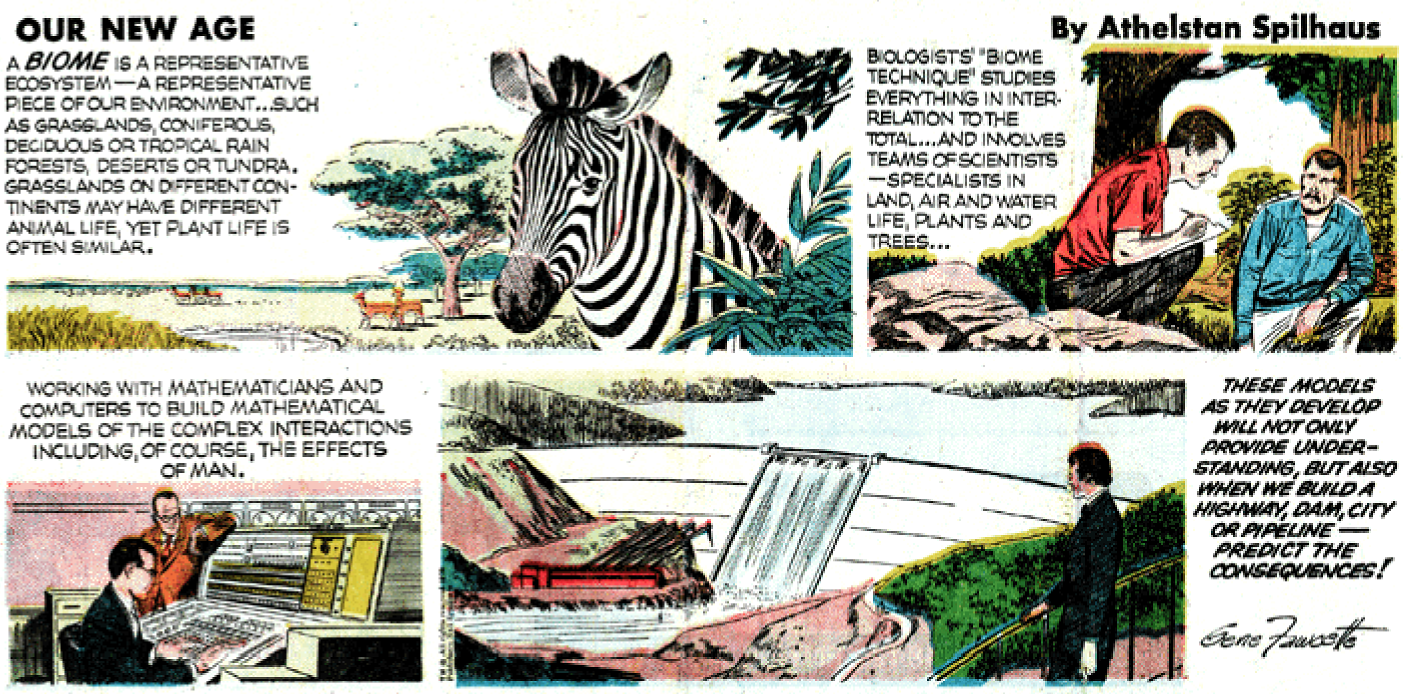
- Spatial contagion of fluctuations in social systems.
  Staniczenko, Reed-Tsochas, Plant & Johnson (2010) *in preparation*.

- Reallocation and switching dynamics in quantitative host-parasitoid food webs.
  Staniczenko, Lewis & Reed-Tsochas (2010) *in preparation*.

- Nestedness in quantitative antagonistic and cooperative ecological networks.
  Staniczenko, Lewis & Reed-Tsochas, *on going*.

- Biodiversity optimisation in multi-functional ecosystems.
  Bagchi, Garlaschelli & Staniczenko, *on going*.


OUR NEW AGE
By Athelstan Spilhaus
A *BIOME* IS A REPRESENTATIVE ECOSYSTEM — A REPRESENTATIVE PIECE OF OUR ENVIRONMENT...SUCH AS GRASSLANDS, CONIFEROUS, DECIDUOUS OR TROPICAL RAIN FORESTS, DESERTS OR TUNDRA. GRASSLANDS ON DIFFERENT CONTINENTS MAY HAVE DIFFERENT ANIMAL LIFE, YET PLANT LIFE IS OFTEN SIMILAR.
BIOLOGISTS' "BIOME TECHNIQUE" STUDIES EVERYTHING IN INTERRELATION TO THE TOTAL...AND INVOLVES TEAMS OF SCIENTISTS — SPECIALISTS IN LAND, AIR AND WATER LIFE, PLANTS AND TREES...
WORKING WITH MATHEMATICIANS AND COMPUTERS TO BUILD MATHEMATICAL MODELS OF THE COMPLEX INTERACTIONS INCLUDING, OF COURSE, THE EFFECTS OF MAN.
THESE MODELS AS THEY DEVELOP WILL NOT ONLY PROVIDE UNDERSTANDING, BUT ALSO WHEN WE BUILD A HIGHWAY, DAM, CITY OR PIPELINE — PREDICT THE CONSEQUENCES!
Gene Fawcette



Thank you for your attention.

phillip.staniczenko@physics.ox.ac.uk

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