Structural dynamics and robustness of food webs

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Overview

• Modelling community ecology

• Structural dynamics and robustness of food webs

• Other projects
Modelling community ecology

Food web structure

Interspecific interaction

None

Static

Dynamic

Kondoh 2003

Petchy et al. 2008

May 1973

Roopnarine et al. 2007

Dunne et al. 2002

Staniczenko et al. 2010

More realistic
Modelling community ecology

Food web structure

- None
- Static
- Dynamic

Interspecific interaction

- None
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Kondoh 2003
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Staniczenko et al. 2010

May 1973
Stability and complexity in model ecosystems

Figure 8.1. 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.
Modelling community ecology

<table>
<thead>
<tr>
<th>Interspecific interaction</th>
<th>Food web structure</th>
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<tbody>
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- More realistic

- None
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- Kondoh 2003
- Roopnarine et al. 2007
- Petchy et al. 2008
- Dunne et al. 2002
- Staniczenko et al. 2010
Network structure and biodiversity loss in food webs

Modelling community ecology

Food web structure

None | Static | Dynamic
--- | --- | ---
None | Static | Dynamic

Kondoh 2003
Roopnarine et al. 2007
Dunne et al. 2002
Staniczenko et al. 2010

May 1973
Petchy et al. 2008

More realistic

Interspecific interaction

Dynamic
Static
None
Foraging adaptation and the relationship between food-web complexity and stability

Modelling community ecology

Food web structure

None Static Dynamic

Interspecific interaction

None Static Dynamic

More realistic

Kondoh 2003 Petchy et al. 2008

Roopnarine et al. 2007

Dunne et al. 2002 Staniczenko et al. 2010

May 1973

None Static Dynamic

More realistic
Trophic network models explain instability of Early Triassic terrestrial communities

Modelling community ecology

- Dynamic
  - More realistic

- Static
  - May 1973
  - Roopnarine et al. 2007

- None
  - Dunne et al. 2002
  - Staniczenko et al. 2010

Food web structure
Size, foraging, and food web structure

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

Food web structure

- None
- Static
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Interspecific interaction

- None
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More realistic

Kondoh 2003
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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?

Predator-prey rewiring model

Food web

Overlap graph

Rewiring graph

Food web before species removal

Food web after species removal

Rewiring graph after removal
Structural robustness

Structural robustness

Extinction sequence forms

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

Structural robustness

Proportional increase in robustness

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

Expected range \([0,1]\)

Structural robustness in empirical food webs
Structural robustness in empirical food webs

Diagram showing relationships between various ecosystems and their structural robustness (Shelf, St. Marks Seagrass, Bridge Brook Lake, Reef, St. Martin Island, Benguela, Coachella Valley, Little Rock Lake, Ythan Estuary '91, Ythan Estuary '96, Chesapeake Bay, Skipwith Pond) and 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
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
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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

Chesapeake Bay rewiring graph
Overlap species and the proportional increase in robustness

$r = 0.94$
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. 

• **Structural dynamics and robustness of food webs.** 

• Spatial contagion of fluctuations in social systems. 

• Reallocation and switching dynamics in quantitative host-parasitoid food webs. 

• 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

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.

WORKING WITH MATHEMATICIANS AND COMPUTERS TO BUILD MATHEMATICAL MODELS OF THE COMPLEX INTERACTIONS INCLUDING, OF COURSE, THE EFFECTS OF MAN.

BIOLGIST'S "BIOME TECHNIQUE" STUDIES EVERYTHING IN INTER-RELATION TO THE TOTAL, AND INVOLVES TEAMS OF SCIENTISTS — SPECIALISTS IN LAND, AIR AND WATER LIFE, PLANTS AND TREES...

These models as they develop will not only increase understanding, but also when we build a highway, dam, city or pipeline — predict the consequences!

By Athelstan Spilhaus
OUR NEW AGE

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.

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