Space and Migration in an Eco-evolutionary Food Web Model

Dr Gavin M Abernethy

Sheffield Hallam University, UK

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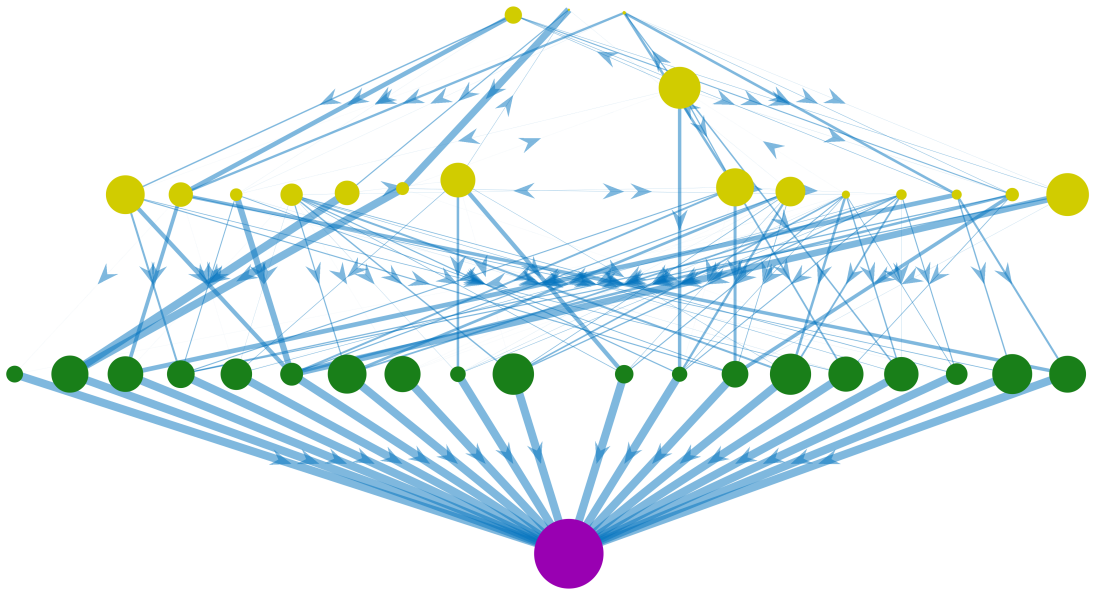
Introduction

Eco-evolutionary food web models combine population dynamics (*eco*) and network assembly (*evo*) to simulate food web assembly and maintenance.



Typical food web constructed by the Webworld model from a single initial species

Outline

1. Introduce the Webworld model.
2. Extend to a spatially-explicit model.
3. Assemble a large meta-community on a 6×6 space.
4. Study the effects of sequential habitat destruction.

The Webworld model [DHM01, AMG19a]

Standard population dynamics

$$\frac{\mathrm{d}N_i}{\mathrm{d}t} = -N_i + \lambda \sum_{j=0}^{n} N_i g_{i,j}(t) - \sum_{k=1}^{n} N_k g_{k,i}(t)$$

Mortality Intake Predation

- Species defined by 10 discrete traits they possess.
- Traits determine feeding and competition relationships.
- Periodic mutations create new species with 9 of parents' traits.

Extending to a spatial model [AMG19b]

Migration dynamics

$$N_i^{x,y} \mapsto N_i^{x,y} + \sum_{j=1}^{x_{max}} \sum_{k=1}^{y_{max}} \delta_{j,k,x,y} \mu_{i,j,k,x,y} - \sum_{j=1}^{x_{max}} \sum_{k=1}^{y_{max}} \delta_{x,y,j,k} \mu_{i,x,y,j,k}$$

- $\mu_{i,j,k,x,y}$ is amount of N_i in (j,k) that migrates to (x,y).
- What rules could we use to govern migration?
- CHOICE: local populations emigrate in proportion to decline in their habitat ("adaptive migration").

  This is computationally faster, and constant migration may result in synchronisation [AMG19b].

Experiment: Sequential habitat destructions

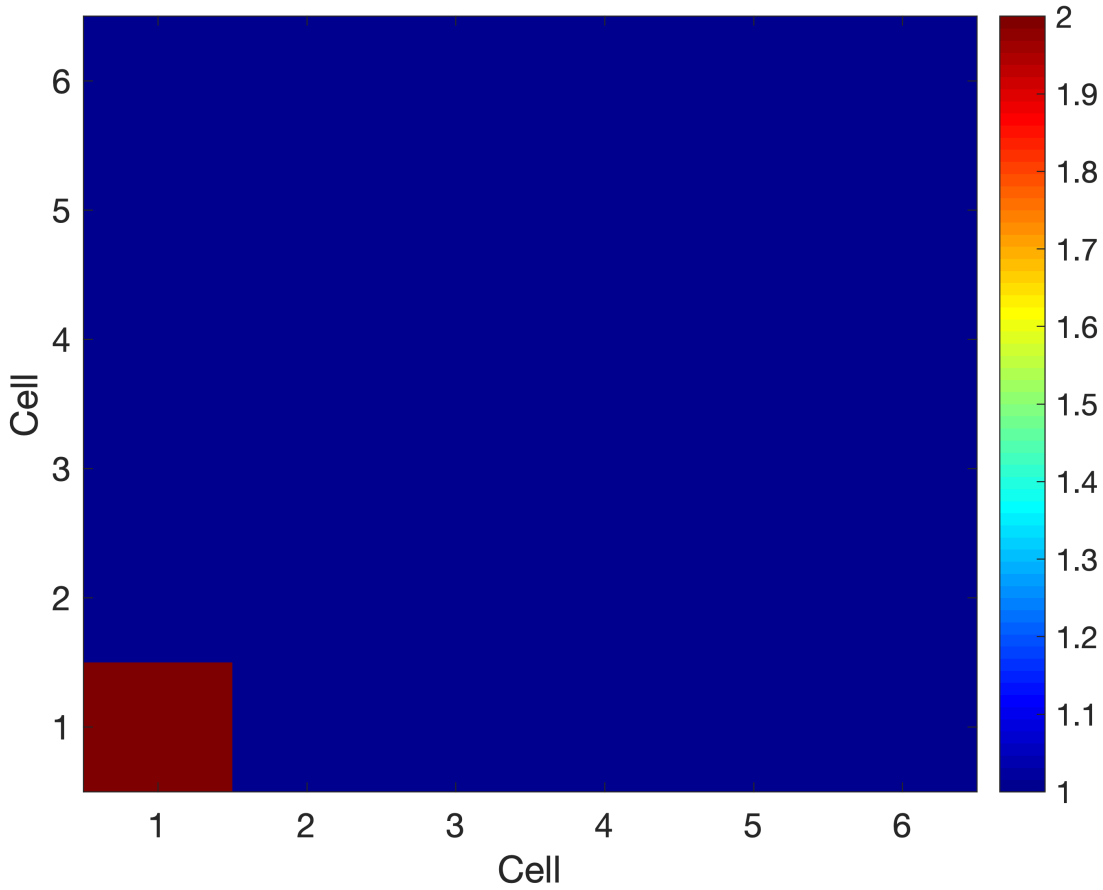
1. Conduct a single simulation from one initial species in a large spatial system (6x6).

2. After 10,000 mutation events, save the system and disable mutation. This will be the base data set for our experiments.

3. Sequentially destroy the 36 individual habitats.
   What is the impact on species diversity?

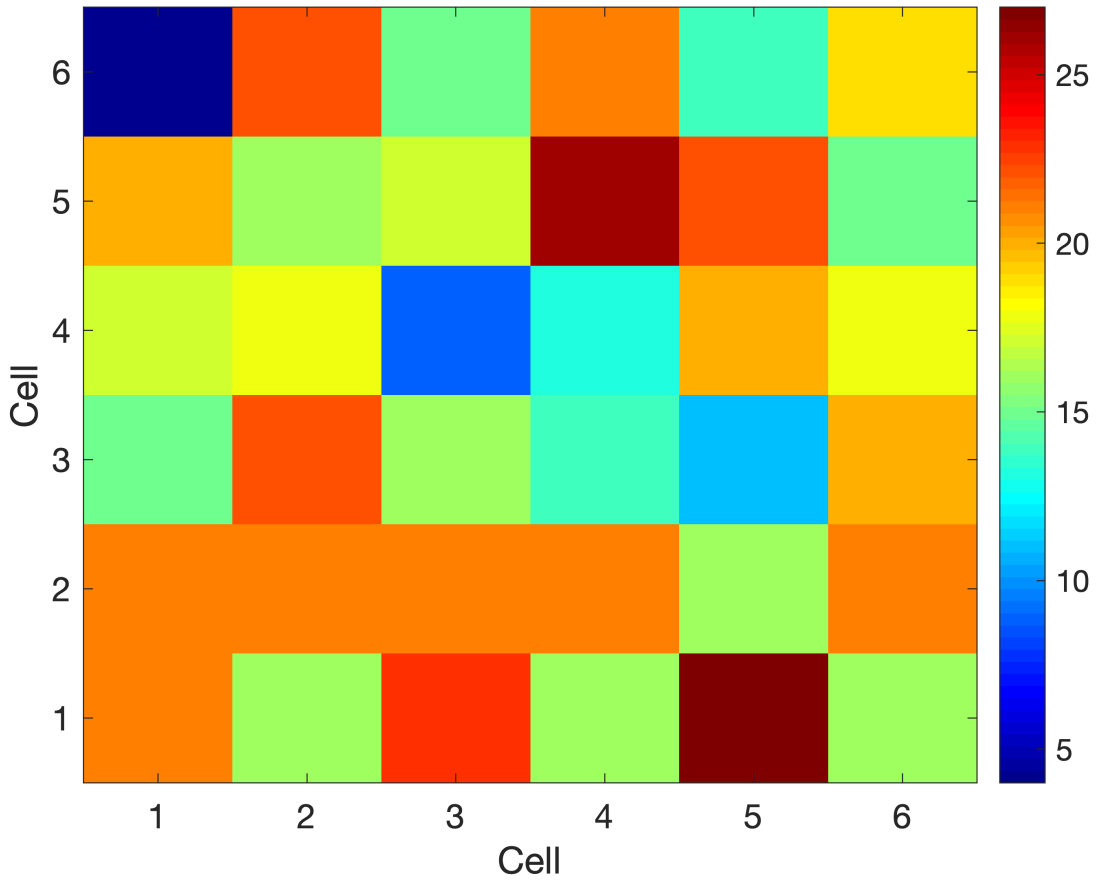
Assembling the test meta-community: Initial conditions

Global diversity: 37 species (inc. 36 resources)



Assembling the test meta-community: After 10,000 evolutionary events

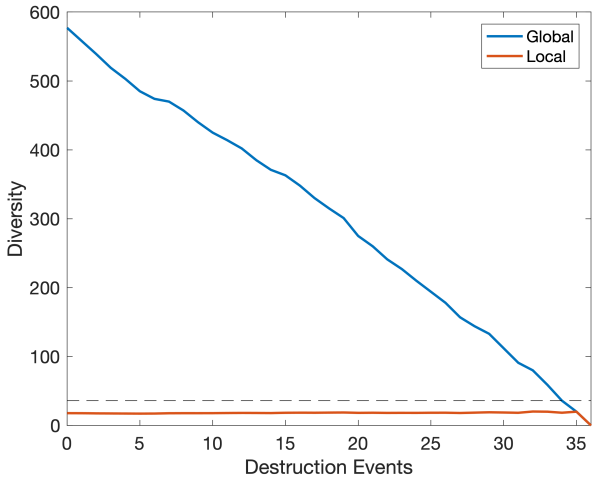
Global diversity: 577 species (inc. 36 resources)



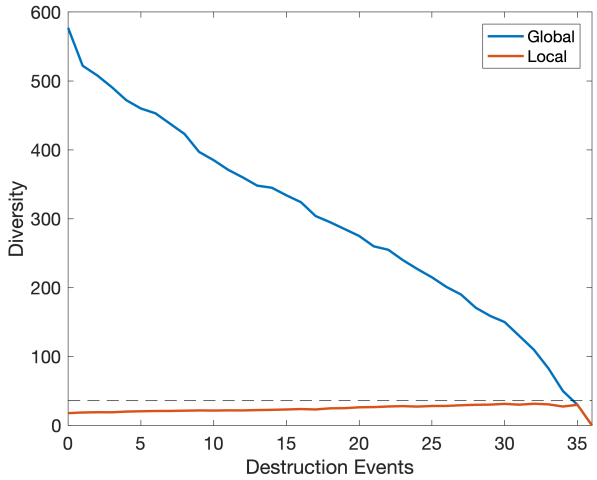
Variants of habitat destruction

Nature of event	**Effect on population**	**Reserves**
Permanent	Elimination	None
Temporary	Displacement	One large

Results: If habitat destruction is permanent. . .



(a) Elimination



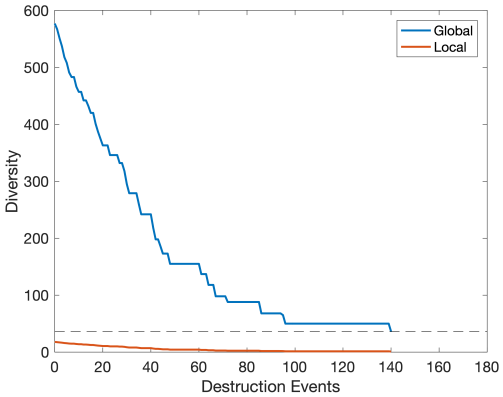
(b) Displacement

- Displacement of affected populations is *as severe* as eliminating them outright:

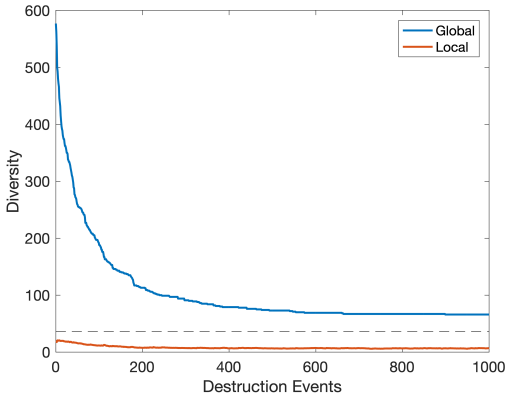
  Species adapted to distinct local webs can't survive elsewhere.

- Order of choosing habitats has little impact due to loose-connectedness of local webs.

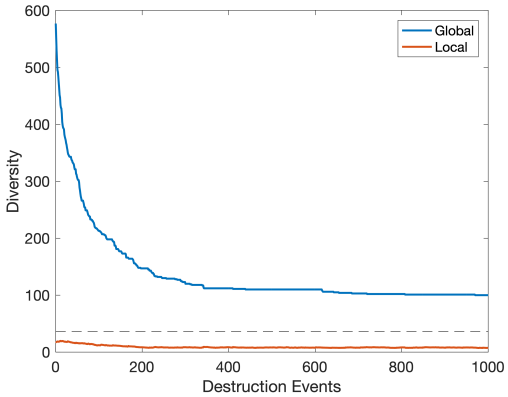
Results: If re-colonisation is permitted...



(c) Elimination



(d) Displacement



(e) Displacement with Reserves

- Eliminating local populations still leads to eventual collapse.
- Displacement can be survived indefinitely, but diversity limited from 577 to fewer than 80.
- This can be increased by incorporating nature reserves. No difference between one large or multiple small reserves.

Summary/Conclusions

- Habitat destruction in co-evolved meta-communities can be simulated on spatial eco-evolutionary models.
- Choice of model migration rules strongly impacts the resulting food webs, and thus the impact of habitat destruction.

In this variant with adaptive migration . . .

- Permanent displacement as harmful as permanent elimination.
- Temporary displacement can be survived indefinitely.
- Nature reserves increase persisting diversity.

References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