Space and Migration in an Eco-evolutionary Food Web Model

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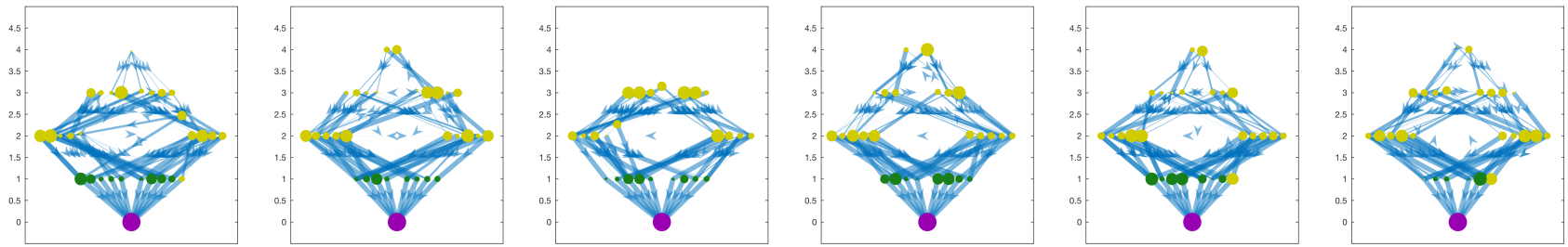
Outline

1. Eco-evolutionary models combine species interaction (*eco*) and network assembly (*evo*) to simulate food webs.
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]

After feeding and reproduction, movement occurs:

Migration dynamics

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

- $\delta_{j,k,x,y} = 1$ if cells (j, k) and (x, y) are adjacent and distinct.
- $\mu_{i,j,k,x,y}$ is amount of N_i in cell (j, k) that migrates to (x, y).
- Scaled by body-size $\implies$ larger species move faster.
- Populations emigrate in proportion to decline in their habitat.

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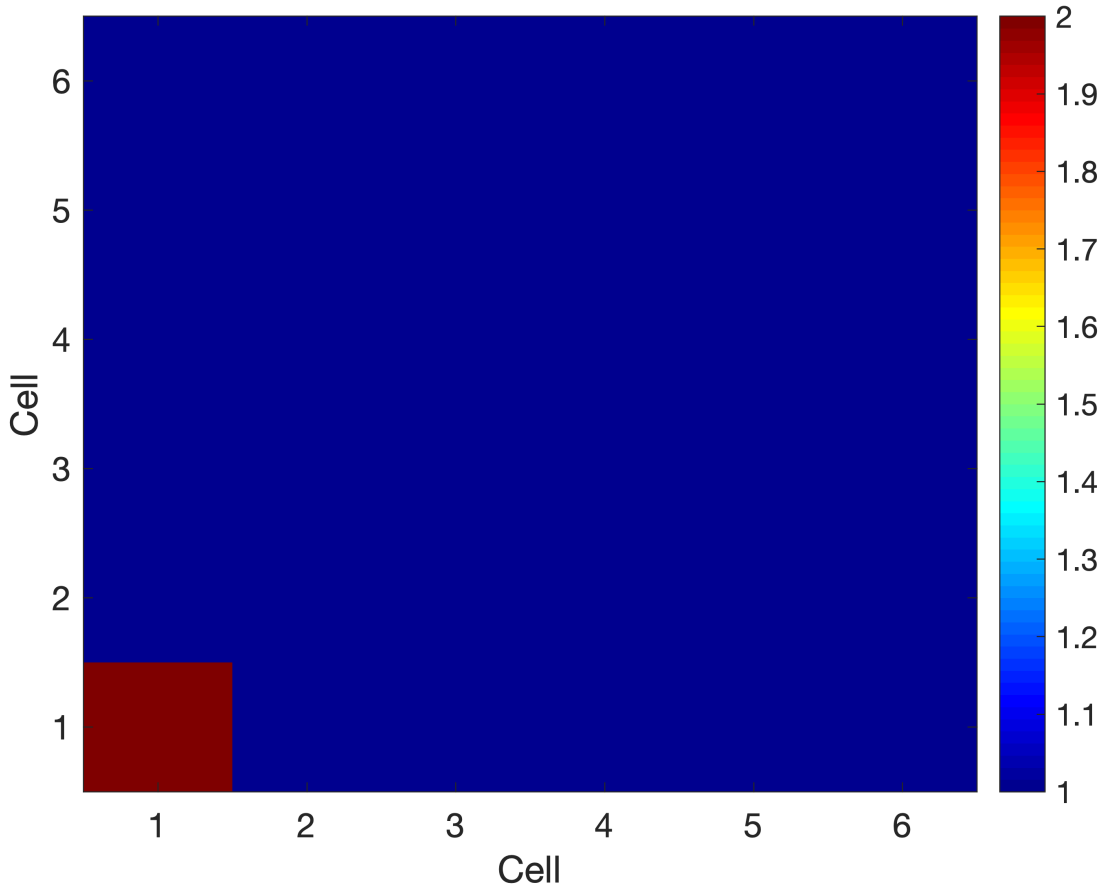
Experiment: Sequential habitat destructions

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?

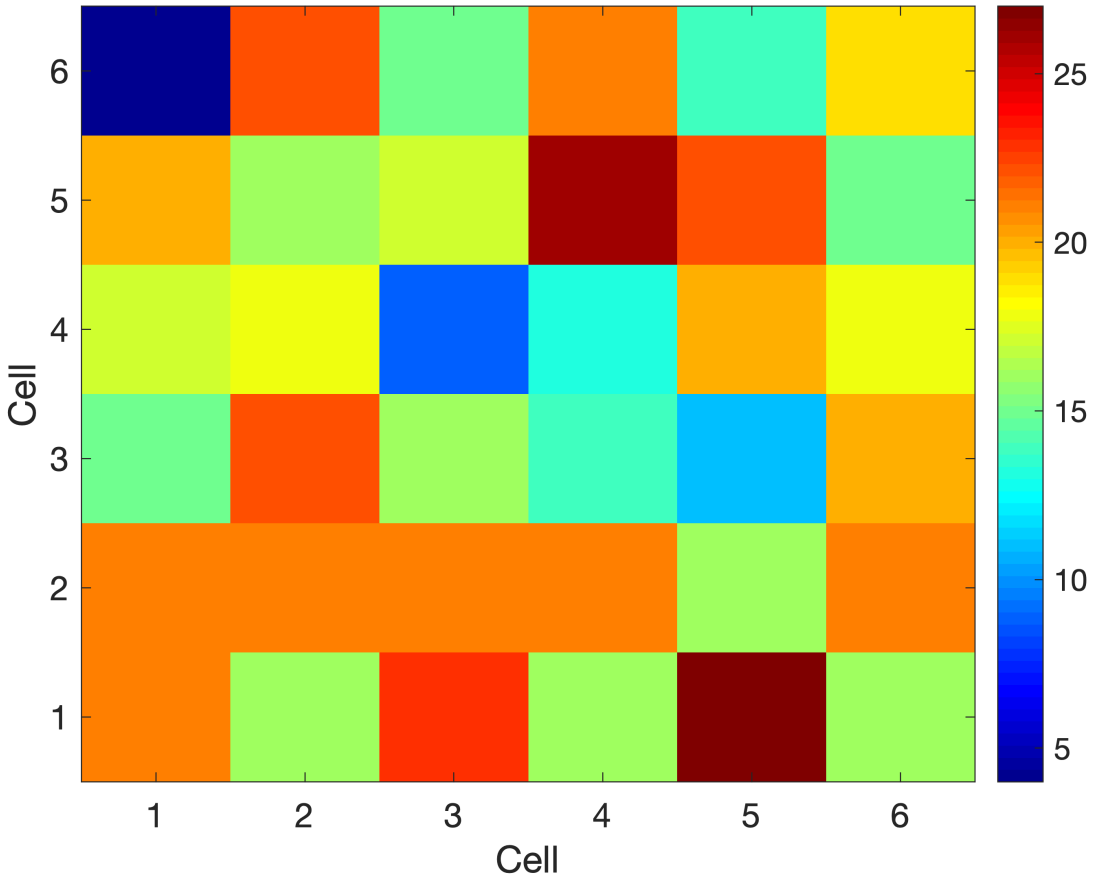
Assembling the test meta-community: Initial conditions

Global diversity: 37 species (inc. 36 resources)



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

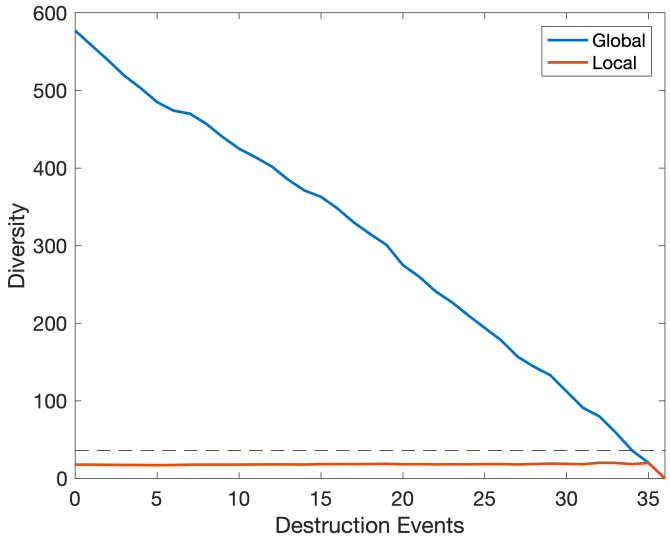
Global diversity: 577 species (inc. 36 resources)



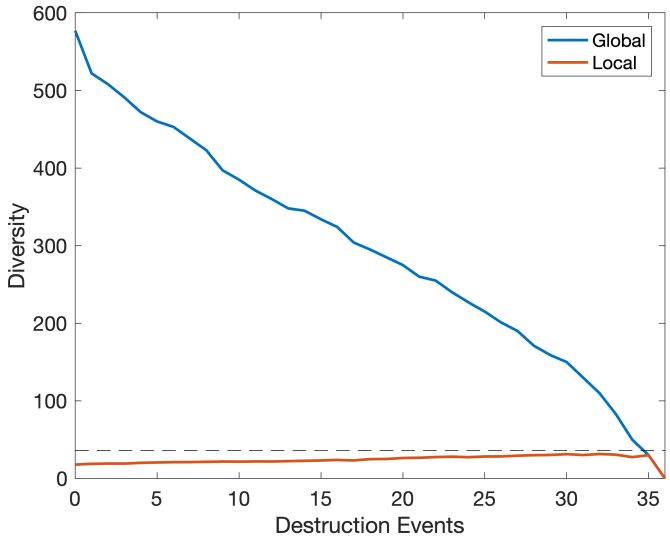
Variants of habitat destruction

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

Results: If habitat destruction is permanent. . .



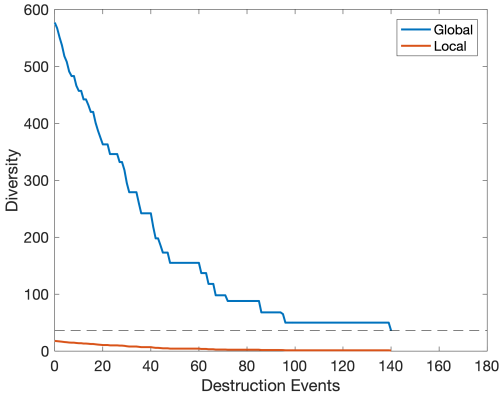
(a) Elimination



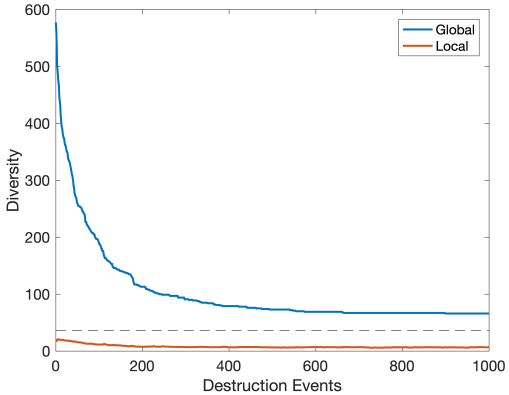
(b) Displacement

- Displacement of affected populations is *as severe* as eliminating them outright.
- Order of choosing habitats has little impact.

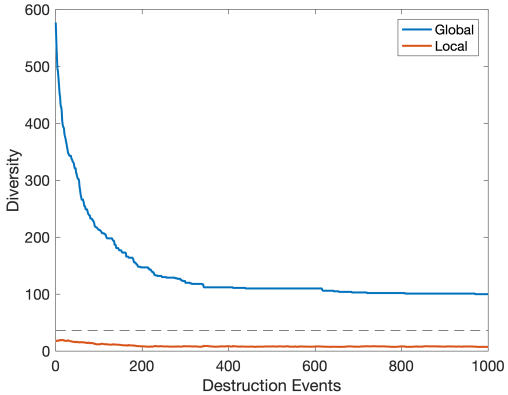
Results: If re-colonisation is permitted...



(c) Elimination



(d) Displacement



(e) Displacement with Reserves

- Eliminating local populations still leads to eventual collapse.
- Displacement can be survived indefinitely, but species diversity is *extremely* limited (from 577 to fewer than 80).
- Diversity can be increased by incorporating reserves that can't be selected.

References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