A prototype integrated SES for long-term analysis

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A Socio-Ecological Test Bed

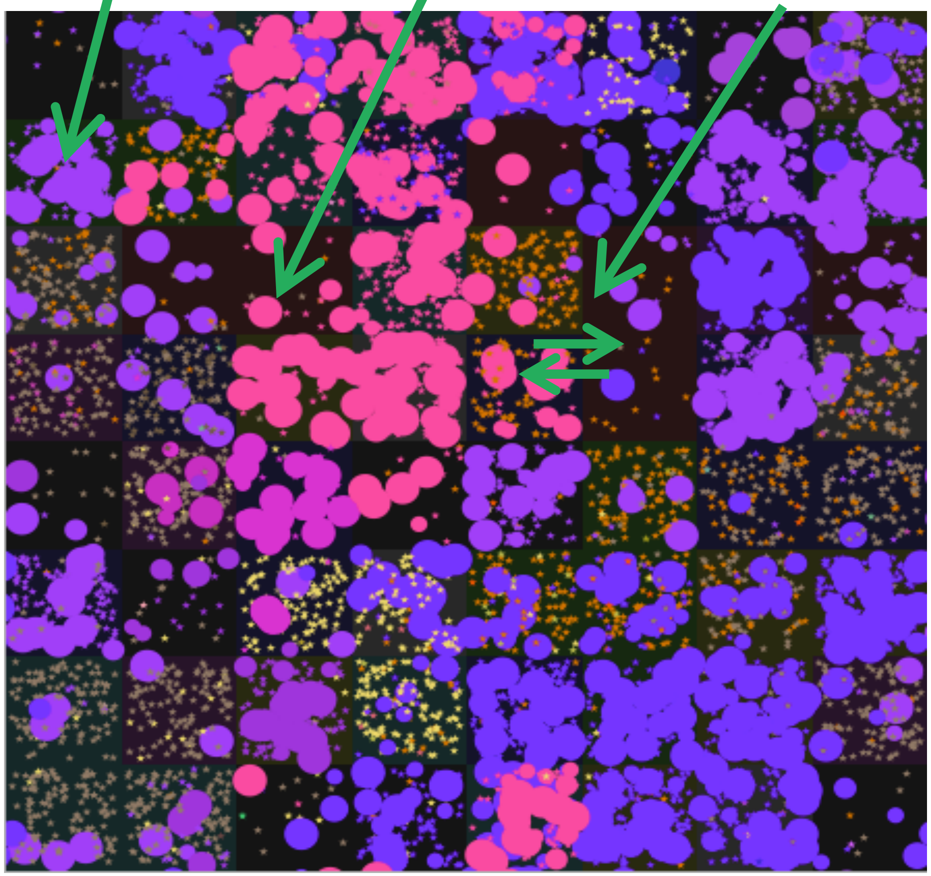
- Here I present a dynamic, spatial, individual-based ecological model that displays some of the complexity, adaptability and fragility of observed ecological systems with emergent outcomes
- It evolves complex, local food webs, endogenous shocks from invasive species, is adaptive but unpredictable as to the eventual outcomes
- Into this agents representing humans can be "injected" with different societal structures/ characteristics and the outcomes observed/analysed
- The humans and their knowledge co-evolve with the ecology they are part of
- The outcomes can be then analysed at a variety of levels over long time scales

The Model

A well-mixed patch

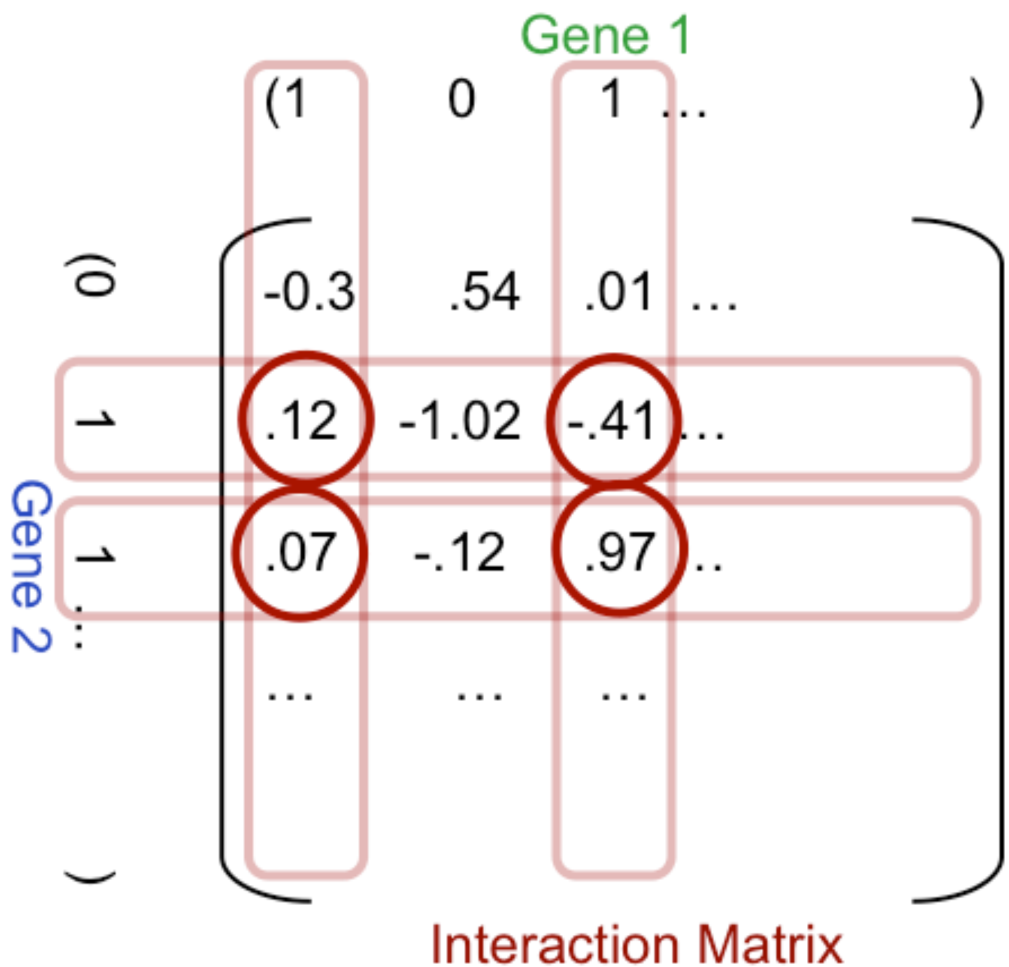
Each individual represented separately

Slow random rate of migration between patches



- A wrapped 2D grid of well-mixed patches with:
  - energy (transient)
  - bit string of characteristics
- Organisms represented individually with its own characteristics, including:
  - bit string of characteristics
  - energy
  - position
  - stats recorders

How Dominance is Decided



Resulting value:

.12+-.41+.07+.97
= 0.75 (which is > 0)

So an individual with Gene 1 would be able to eat one with Gene 2

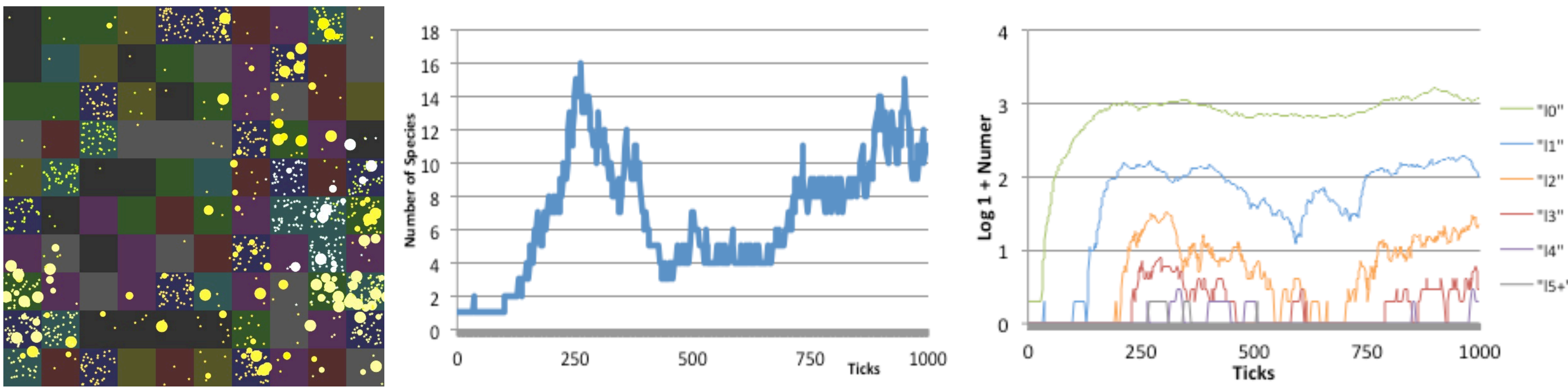
(Caldarelli, Higgs, and McKane 1998)

Model sequence each simulation tick

1. **Input energy** equally divided between patches.
2. **Death**. A life tax is subtracted, some die, age incremented
3. **Initial seeding**. until a viable is established, random new individual
4. **Energy extraction from patch**. energy divided among the individuals there with positive score when its bit-string is evaluated against patch
5. **Predation**. each individual is randomly paired with a number of others on the patch, if dominate them, get a % of their energy, other removed
6. **Maximum Store**. energy above a maximum level is discarded.
7. **Birth**. Those with energy > “reproduce-level” gives birth to a new entity with the same bit-string as itself, with a probability of mutation, Child has an energy of 1, taken from the parent.
8. **Migration**. randomly individuals move to one of 4 neighbours
9. **Statistics**. Various statistics are calculated.

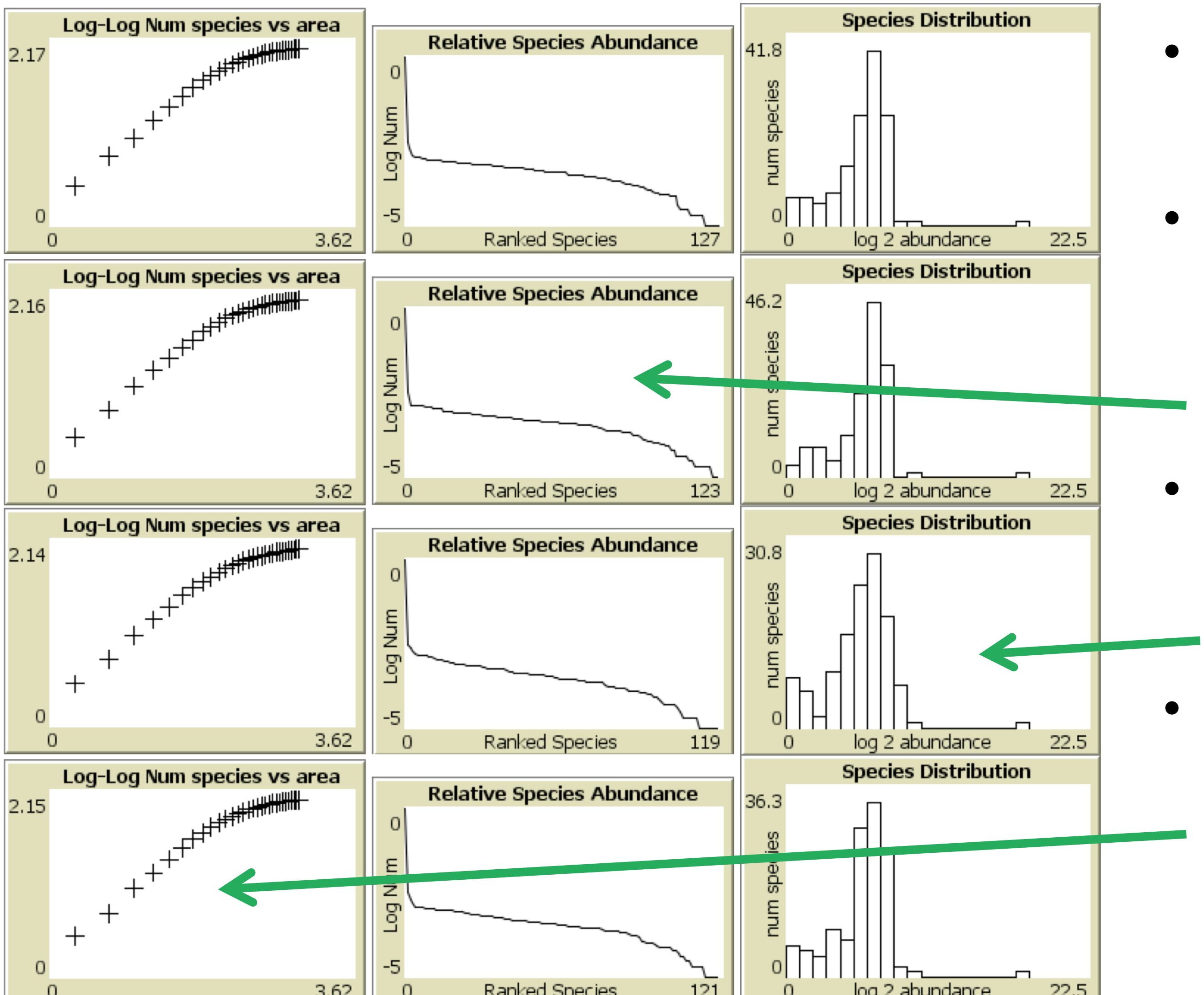
a Mixed Ecology Development

- Here new species are continually developing and spread out in waves, but a mix of trophic levels are maintained (but this varies over time)



Typical *Mixed Ecology* the world state (left) Number of Species (centre) Log, 1 + Number of Individuals at each trophic level (right)

Signatures of Outcomes: Neutral patches, random migration, plants only

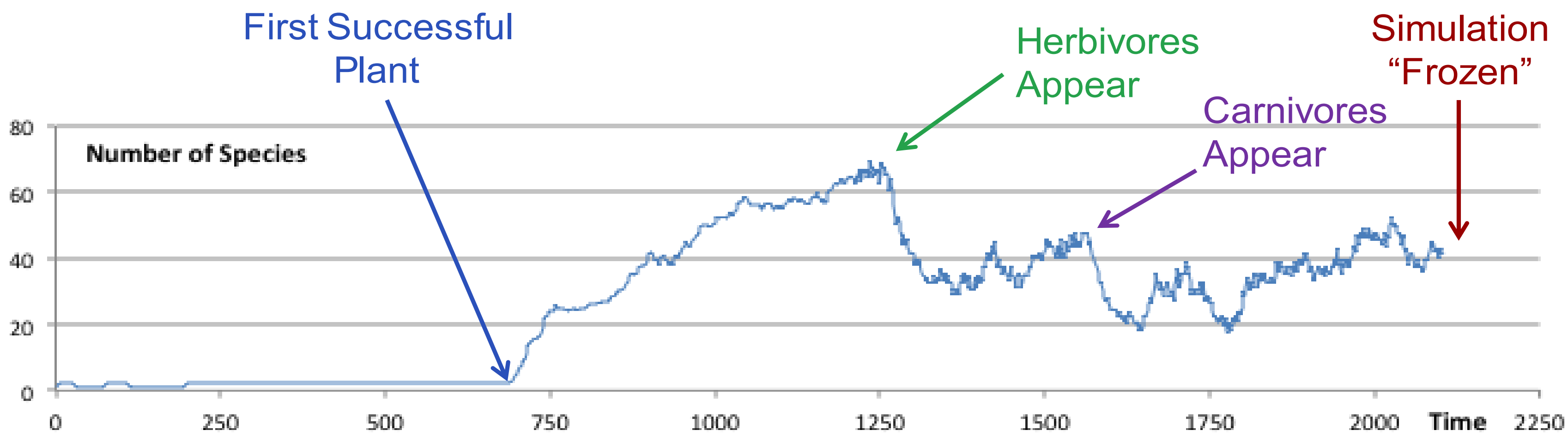


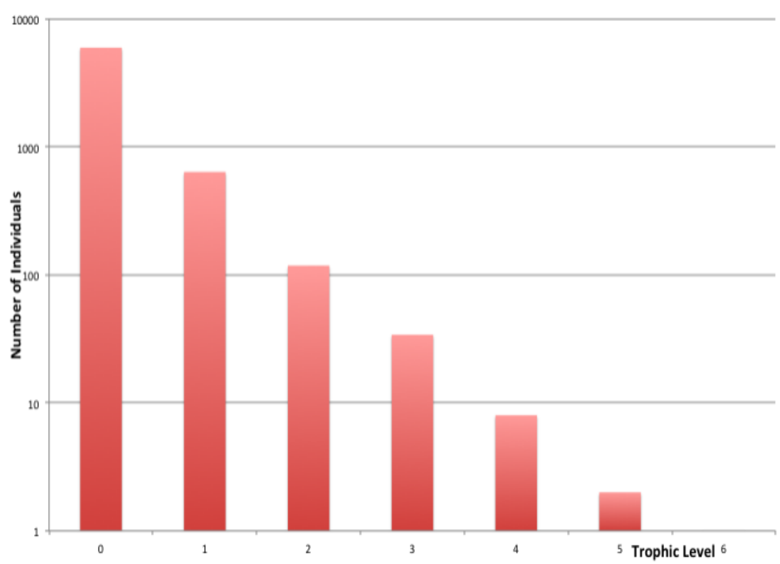
- As predicted by Hubble's "Neutral Theory"
- "skewed s-shaped" relative species abundance curve
- "Multinomial distribution" of log2 species distribution
- Except, species-area scatter chart might only reflect small scales

An Example of Adding Pretty Simple "Human" Agents

- The agents representing humans are "injected" (as a group) into the simulation once an ecology of other species has had time to evolve
- The state of the ecology is then evaluated some time later or over a period of time
- These agents are the same as other individuals in most respects, including predation but "humans":
  - can change their bit-string of skills by imitating others on the same patch (who are doing better than them)
  - might have a higher "innovation" rate than mutation
  - might share excess food with others around
  - might have different migration rates etc.
- Could have many other learning, reasoning abilities

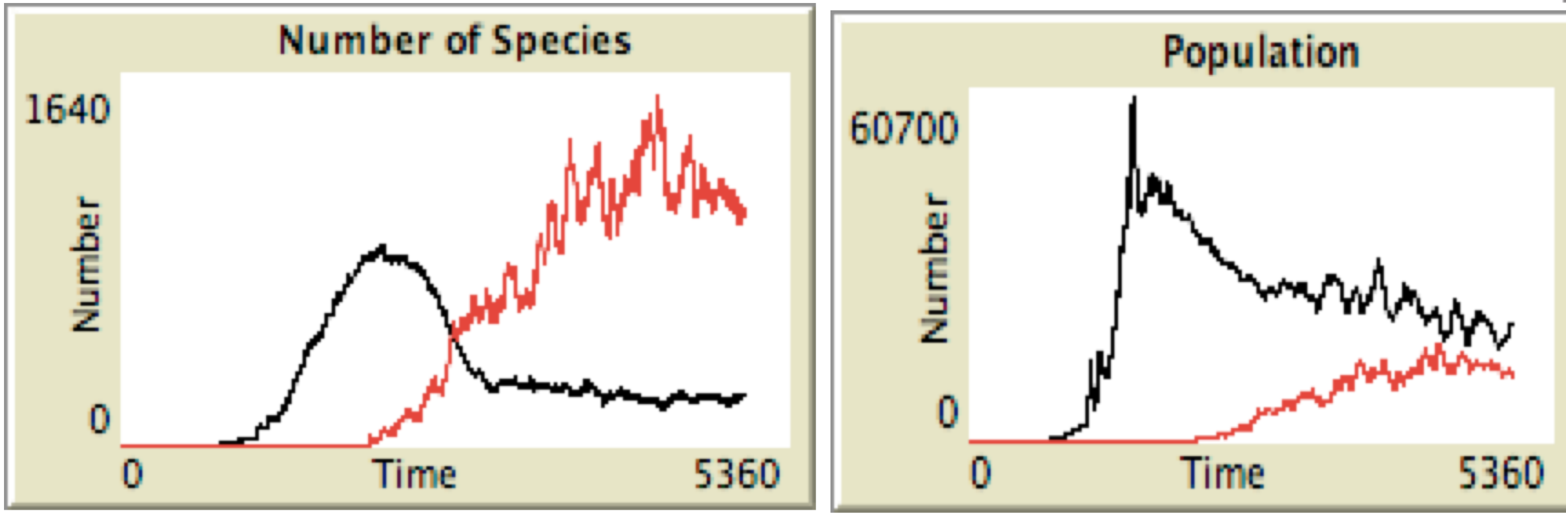
First, evolve a rich mixed ecology





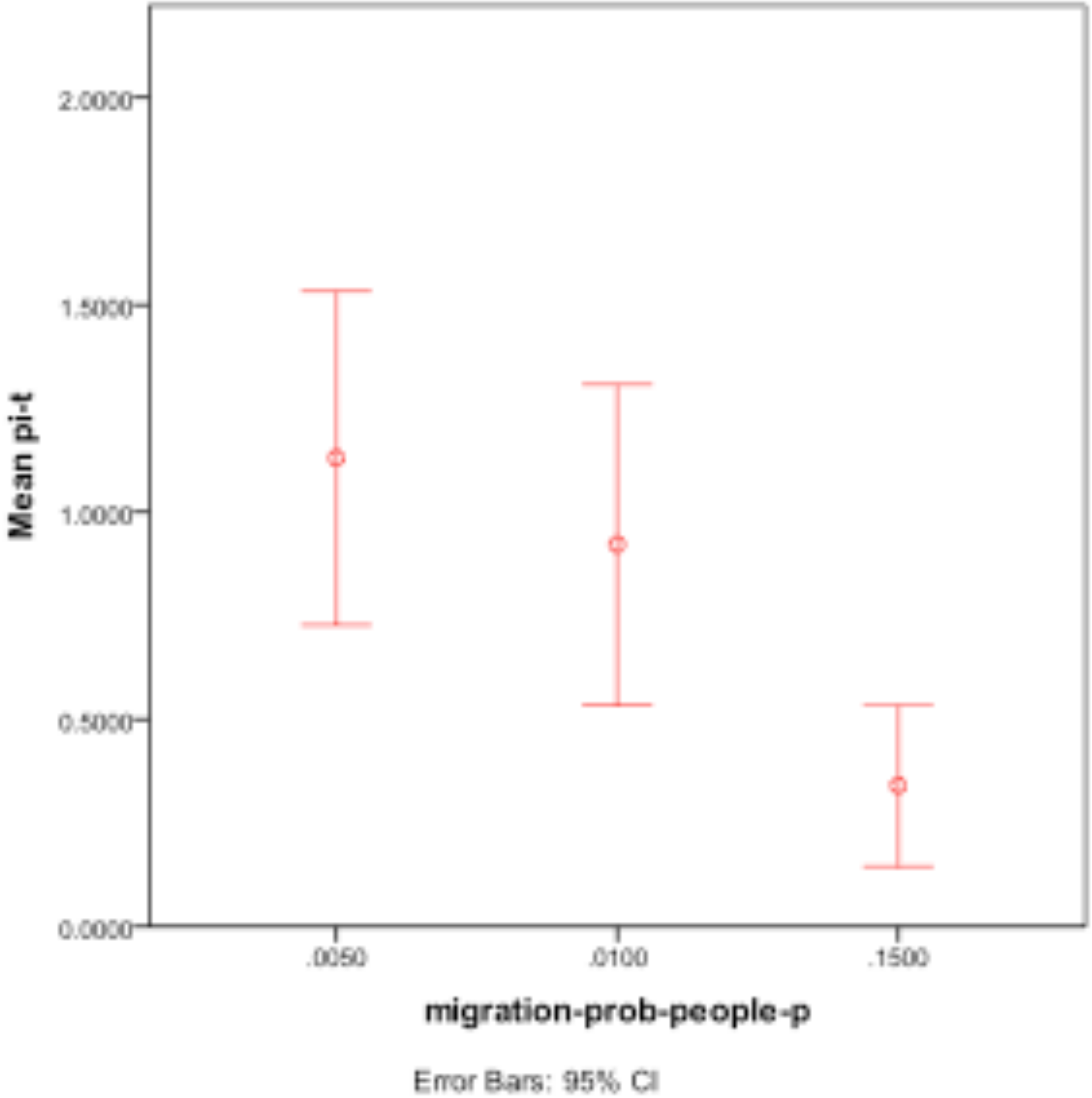
Evolve and save a suitable complex ecology with a balance of tropic layers (left with log population)

Some of The Dynamics In An Example Run

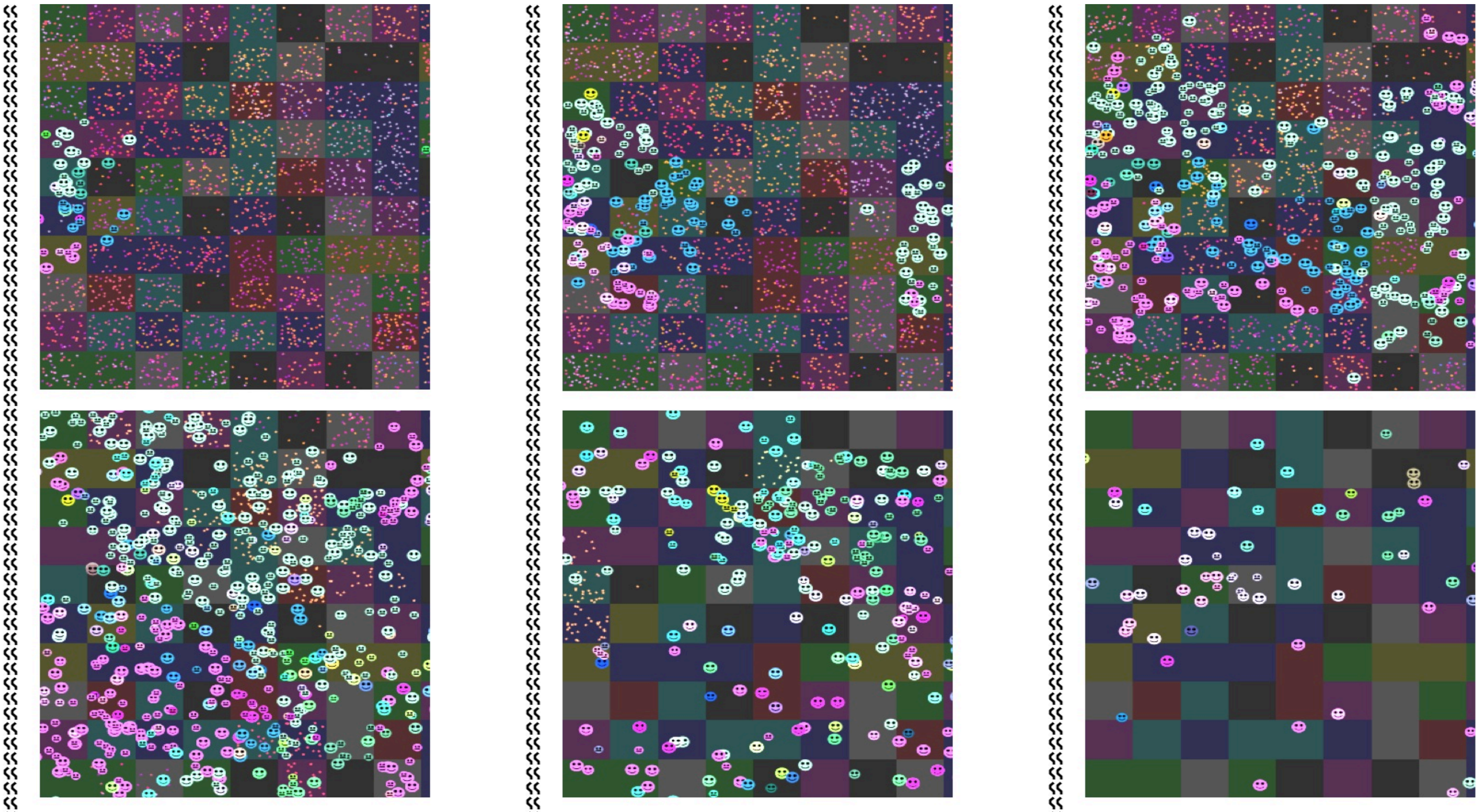


- The arrival of humans (when they don't die out) has an immediate impact on the ecosystem, in terms of both population and species diversity
- Typically they become the top predator and wipe out other higher predators
- But also the diversity of human variety can "displace" species variety by inhabiting many niches

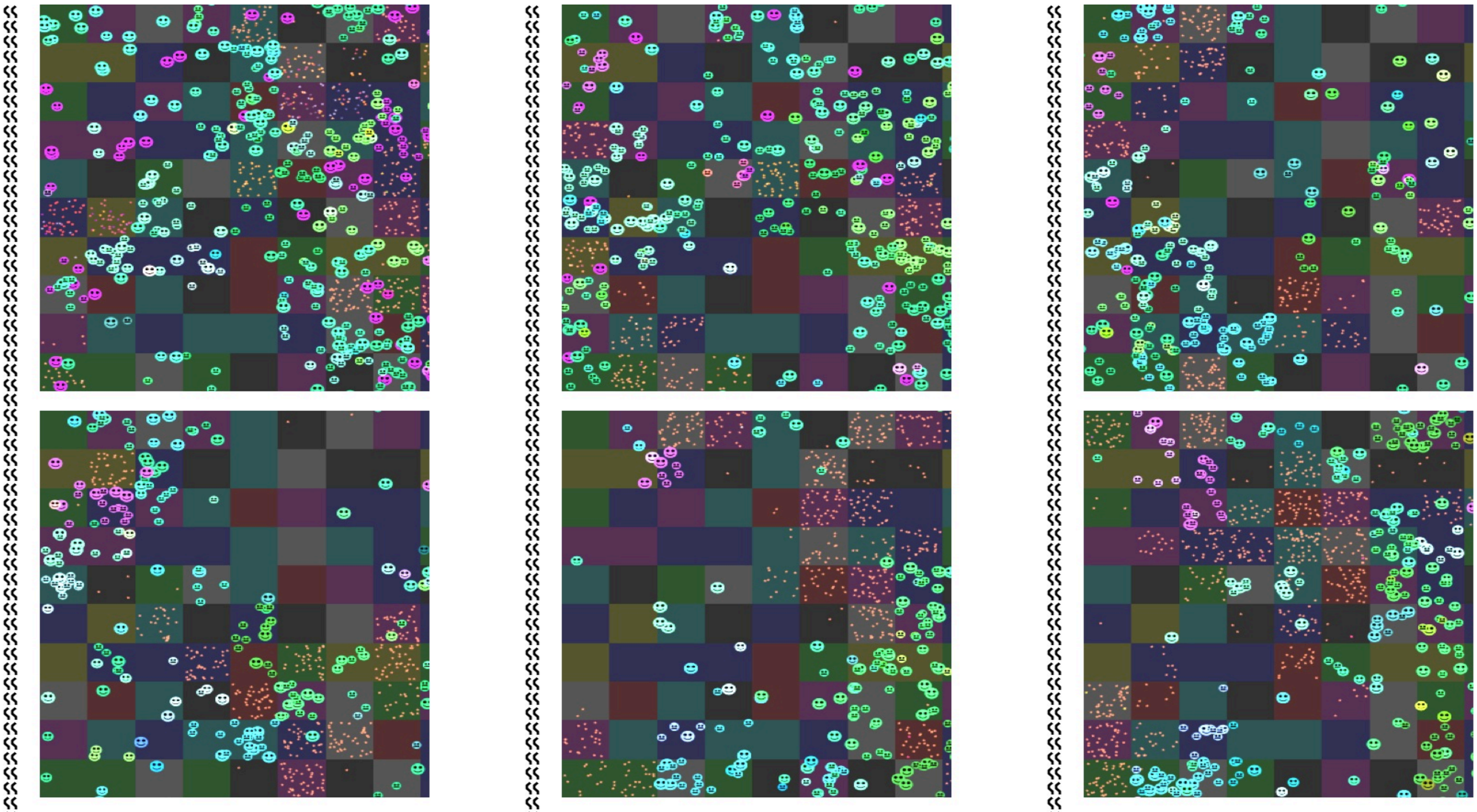
Human migr. rate vs. diversity (all with humans, other entities having 0.1 migration rate)



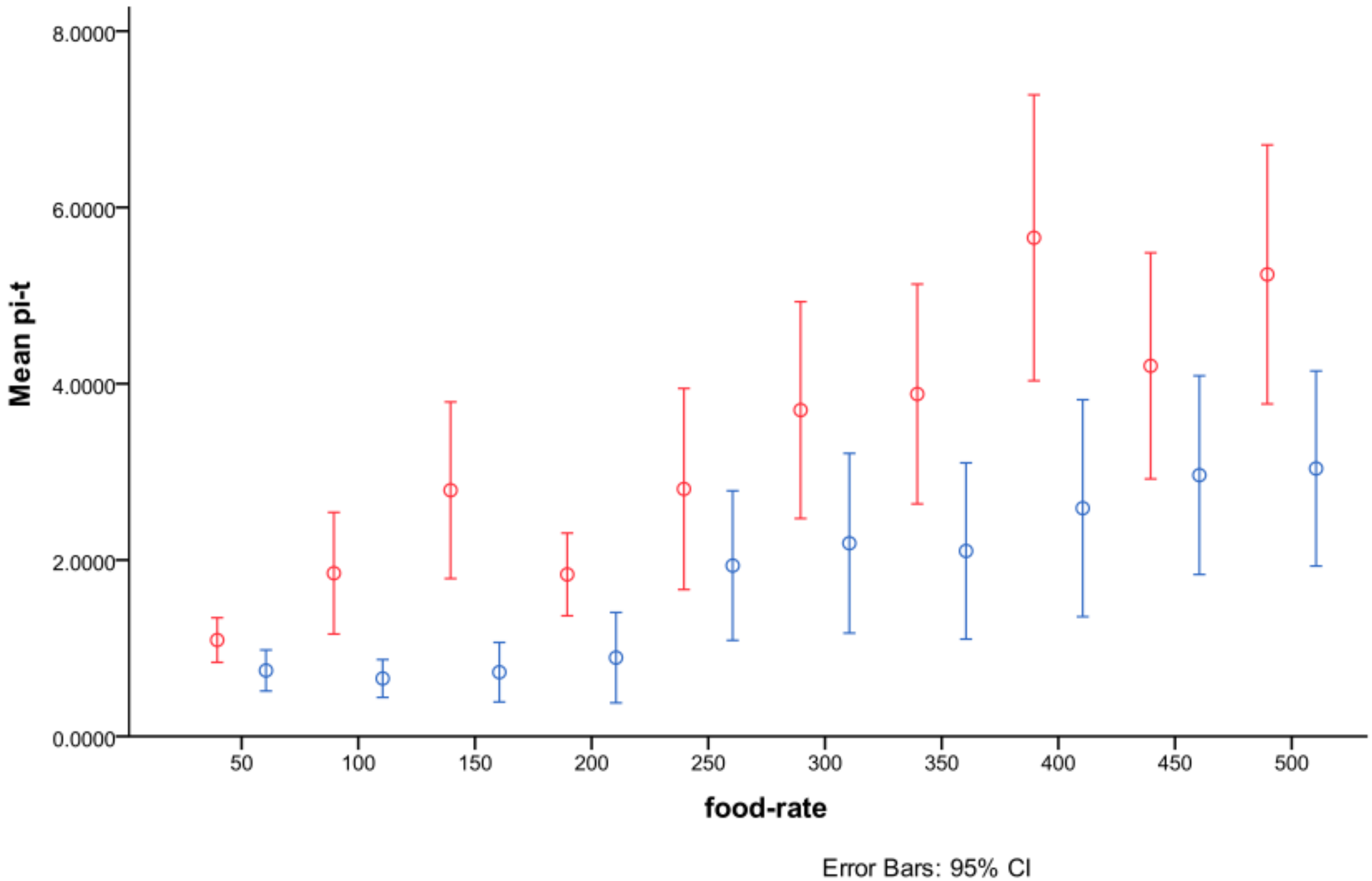
Extinction due to Consuming all Others



Waves of (Human) Predator-Prey Patterns

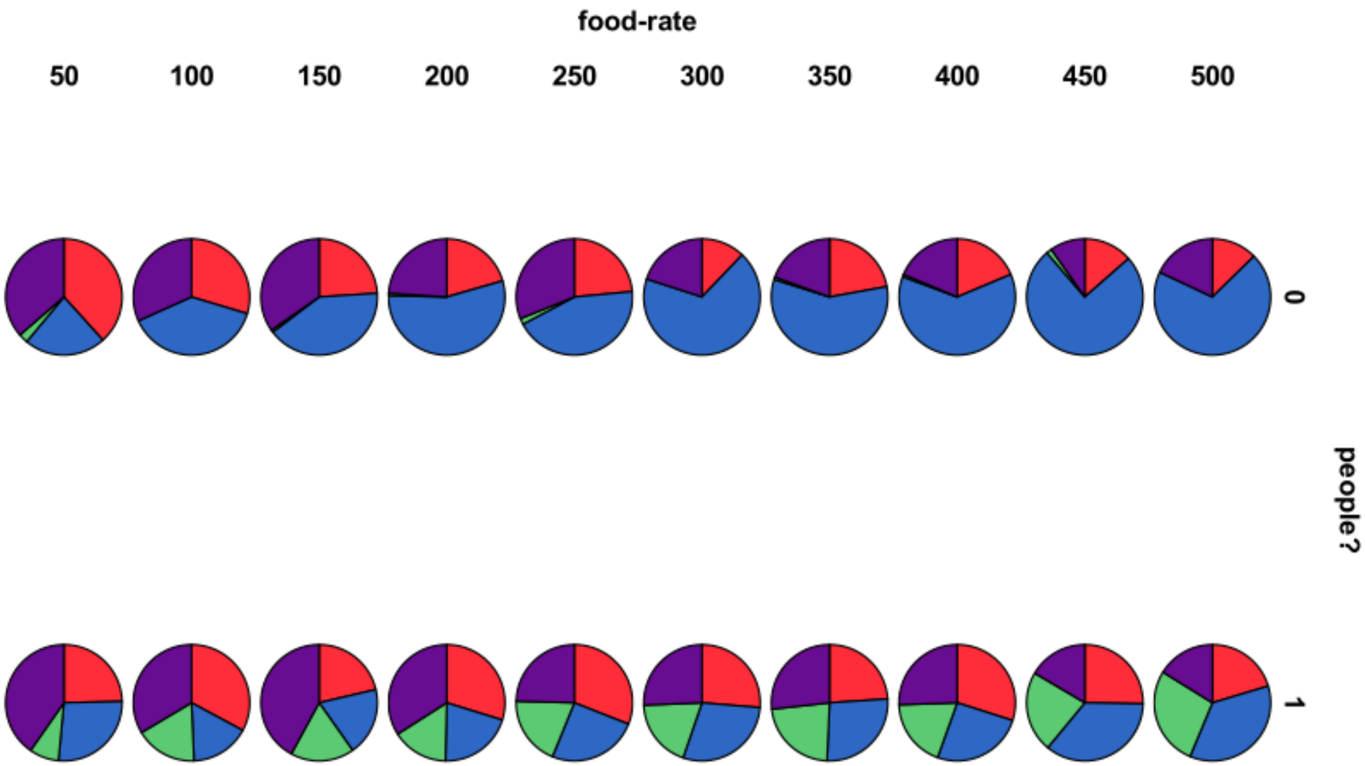


Effect of humans vs. food input to world



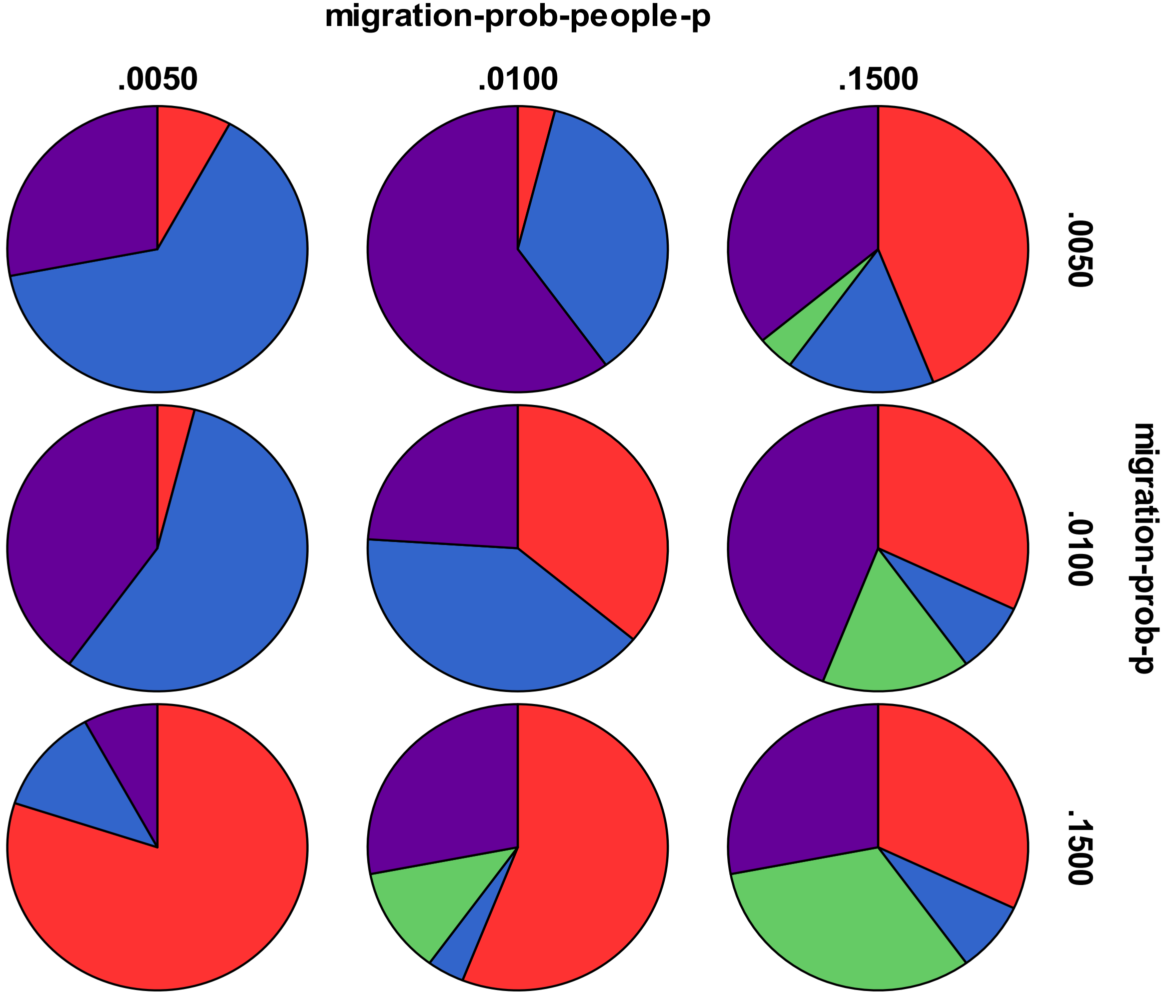
diversity of ecology, blue=with humans, red=without

Effect of humans vs. food input to world



proportion of ecology types, red=plant, blue=mixed, purple=single species, green=non-viable

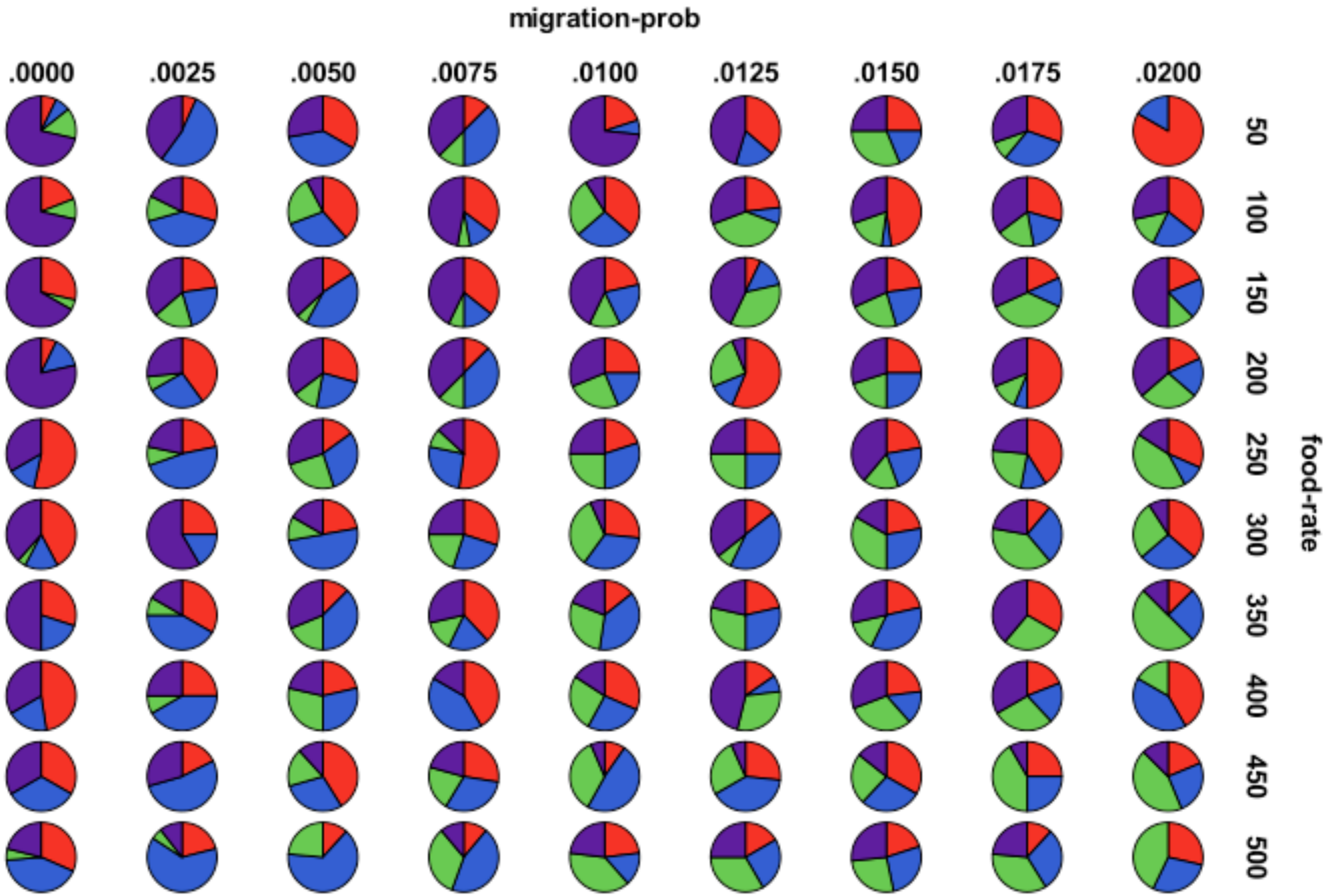
Migration rate people
vs **migration rate others**



proportion of ecology types 25 simulations each treatment

red=plant, blue=mixed, purple=single species, green=non-viable

Migration (all) vs. food rate (all with humans)



Some observations

- It does not ever get to a ‘steady state’ but is constantly changing and co-adapting
- So approaches to assessing resilience that assume such are not easily applicable
- But we can compare with and without “humans” after a long period of time
- In this model, the way “humans” adapt seems to be more significant that which particular adaption is adopted
- This is only a hunter-gatherer kind of society
- Competition among human groups and their general social evolution is also significant here

The End!

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The basic model (without "humans") is available at:
http://openabm.org/model/4204