# Facilitating the Development of Social Structure in Evolutionary Domains


Bruce Edmonds

http://bruce.edmonds.name

Centre for Policy Modelling

http://cfpm.org

# Key Issues

- How can social structures/systems that allow complex forms of coordination develop (e.g. cooperation or competition)
- …out of a collection of individuals which include some which are non-cooperative, deceptive, selfish etc.
- …without requiring heavy administration.
- i.e. how *might* such structures have arisen?
- Here, I will focus on *groups*

# The Explored Mechanism

- There might be a disparity of skills/abilities among the individuals due to one of:
  - Time/resources takes to develop skills (e.g. different trades in humans)
  - Necessary trade-offs between different abilities (e.g. heat retention due to size vs. speed)
  - Sheer evolutionary happenstance
- So that it is advantageous for groups of individuals with complementary skills to form where group members share
- I.e. *symbiotic* relationships

# Proposed Group Member Recognition Mechanism: tags

- Tags are socially observable cues…

…that can be used as a (fallible) guide as to group membership/whether to cooperate …

…depending on how "close" they are to one's own (set of) tags.

I.e. the rule is: *cooperate with those with similar tags*

- Can be: single- or multi-dimensional; continuous or discrete
- Are not necessarily unique to an individual – they can be "forged" by others
- Are not necessarily associated with any other characteristics of the individuals who have them

# A Brief History of Tags

- Idea proposed by John Holland in 1993
- Developed by (among others): Rick Riolo (1997, 2001, etc.); and David Hales (2000, 2001, etc.)
- Nature paper in 2001 by Riolo, Cohen and Axelrod exposes tags to wider audience
- But this model is flawed (Roberts & Sherrat 2002, Edmonds and Hales 2003)
- Further work fixes these flaws, explores conditions where tags work and works towards applications
- This paper is part of this development

# How tags work

- By some process (e.g. chance) a small cooperative group with similar tags occurs
- Due to benefits of cooperation those in the group reproduce more than others
- Eventually a parasite appears in the group
- The parasite (and its progeny) do even better than the cooperators in the group
- Thus parasites reproduce more and come to dominate the group and cooperation ceases
- Thus the benefit of the group (compared to others) disappears and the group dwindles away
- But in the meantime other cooperative groups may have formed based round other tags etc.

# So…

- For the tag mechanism to promote cooperation it is necessary that:
  - There is benefit to individuals to cooperate with similar others (this is easy to arrange)
  - When defectors arise they are self-defeating (e.g. they "kill" their own group)
  - New "seed" groups are always arising, so that when a dominant group dies others can grow
- Thus there is a continual dynamic process of "tag groups" arising and falling allowing cooperation to flourish in new groups

# **Part 1: Some just-published work**

*group formation via specialisation and tags* (Edmonds 2006 JASSS)

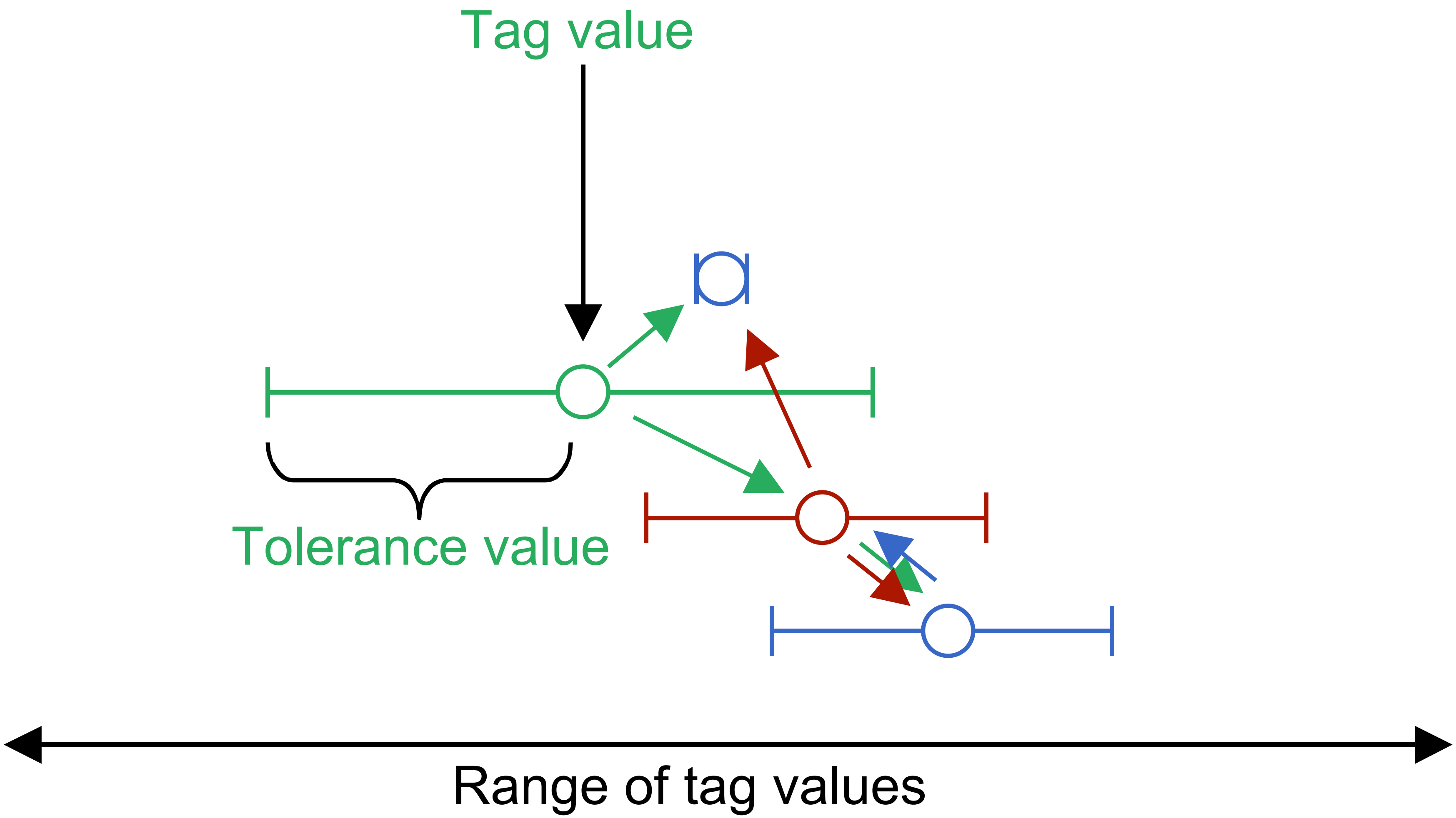
# Basic Design Ideas – static structure

- Discrete time simulation
- There are a variable number of individuals
- There are *n* (necessary) food types
- Each individual has:
  - A limited *store* for each food type (1 when new)
  - One *skill*, it can gather only one type of food
  - A *tag* value in [0, 1]
  - A *tolerance* value in [0, 1]
- The tag and tolerance may be mutated during reproduction

# *Each iteration* **individuals:**

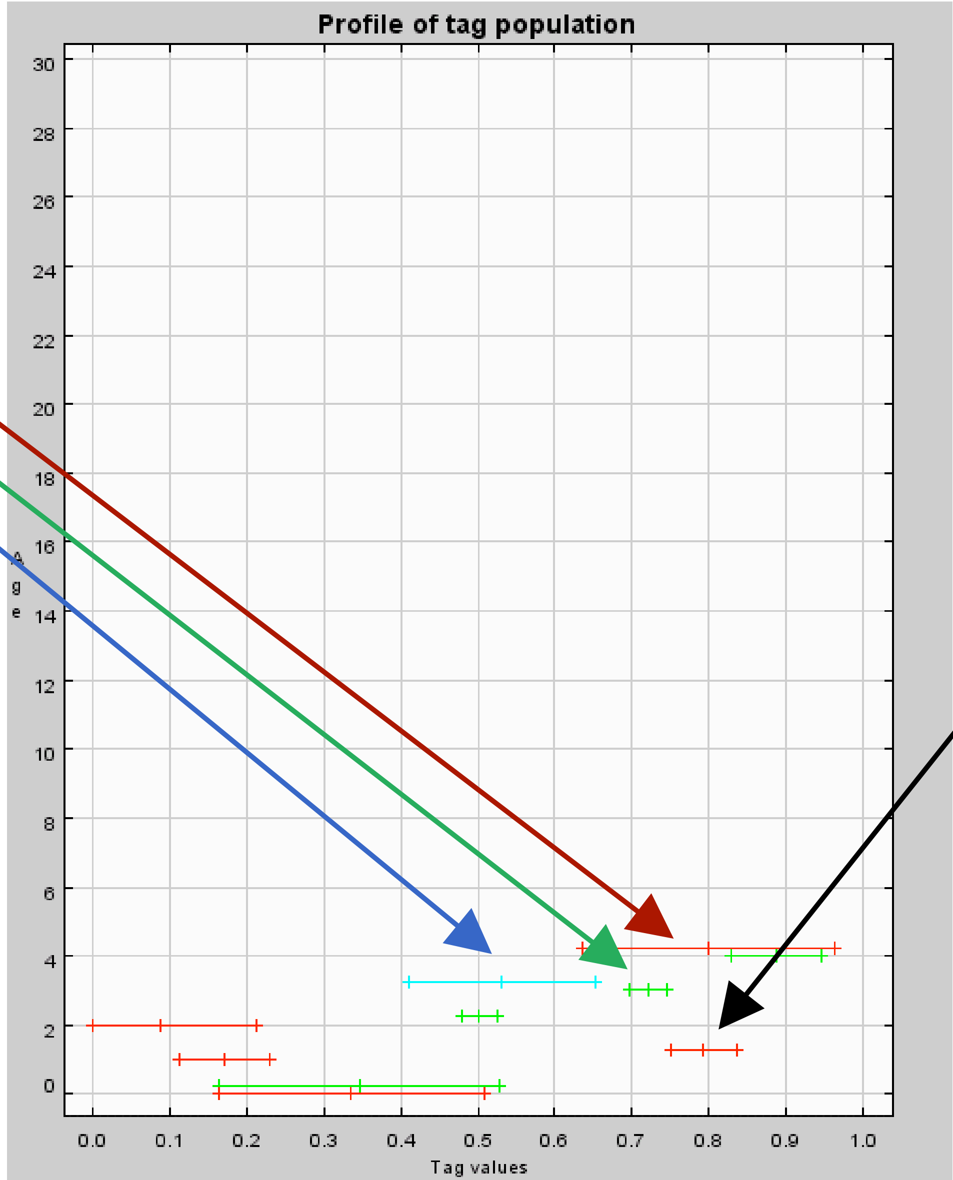
1. a few new random individuals enter from outside
2. get some randomly distributed food depending on their skill
3. are randomly paired *p* times
4. will donate share of some of any excess to those paired with if other's tag is within its tolerance to its own tag (get 95% of value)
5. all stores taxed 0.25; die if any ≤ 0, reproduce if all > 4

# When donations occur between individuals



# Animation of example run

The 3 colours indicate the 3 skills




Individual with tag 0.79 and tolerance 0.4

etc.

Age 3

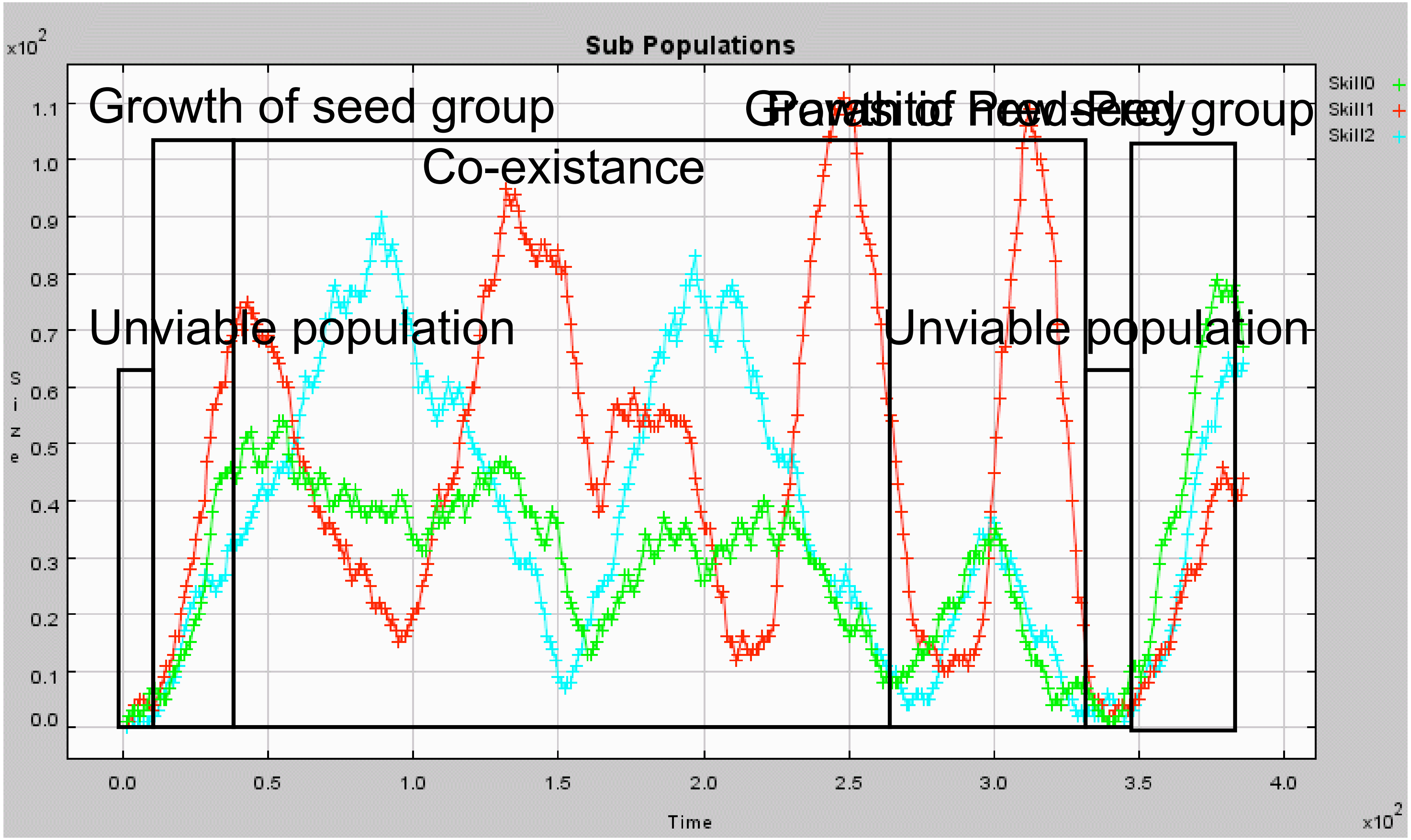
Age 2

Age 1

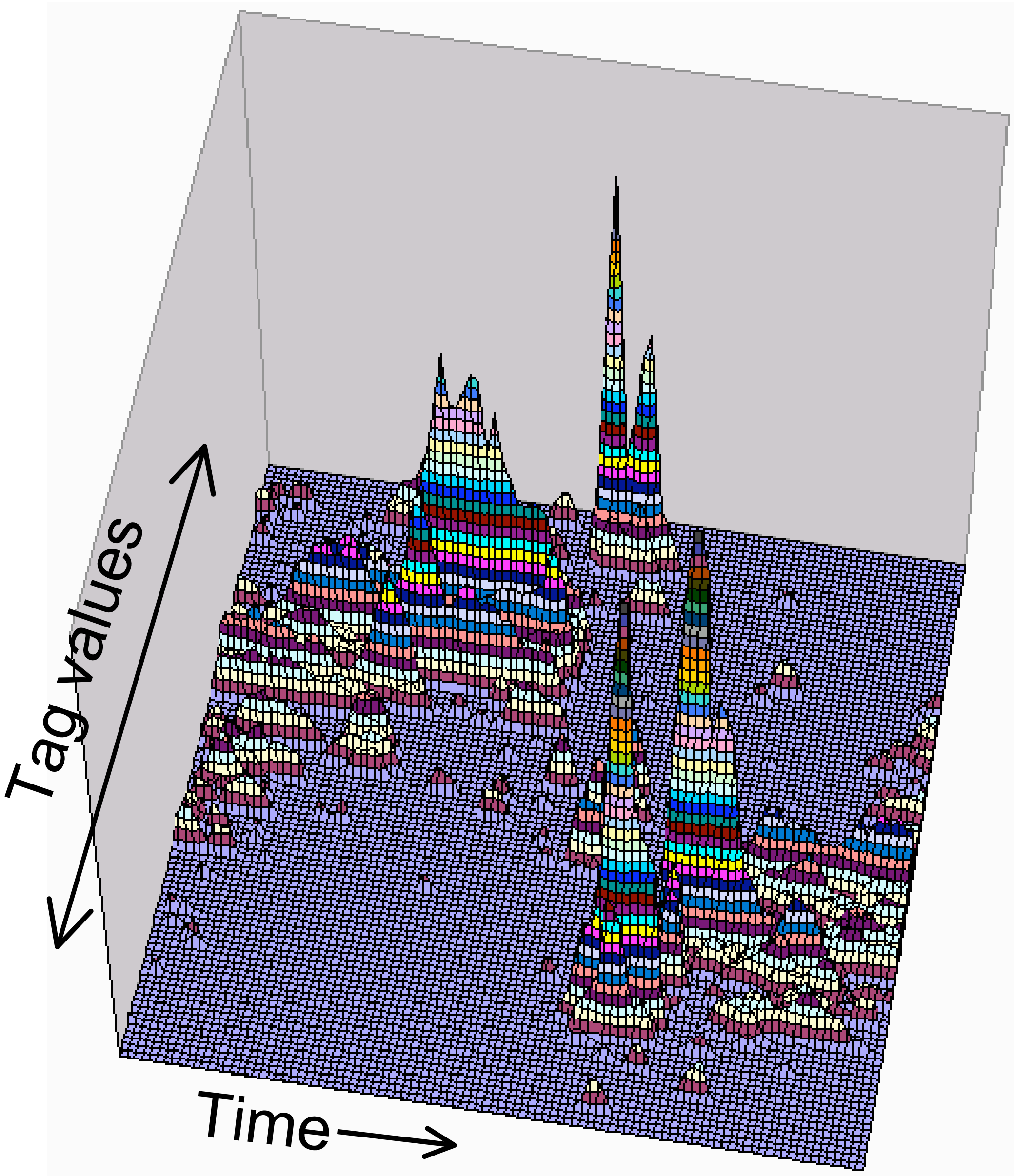
# Apparent phases in the dynamics of this model

1. No viable population
2. Growth phase of new seed symbiotic group
3. Resource competition between those within a group of symbiots
4. Predator-prey type dynamics between a parasite and collection of symbiots
5. Destruction of viable population

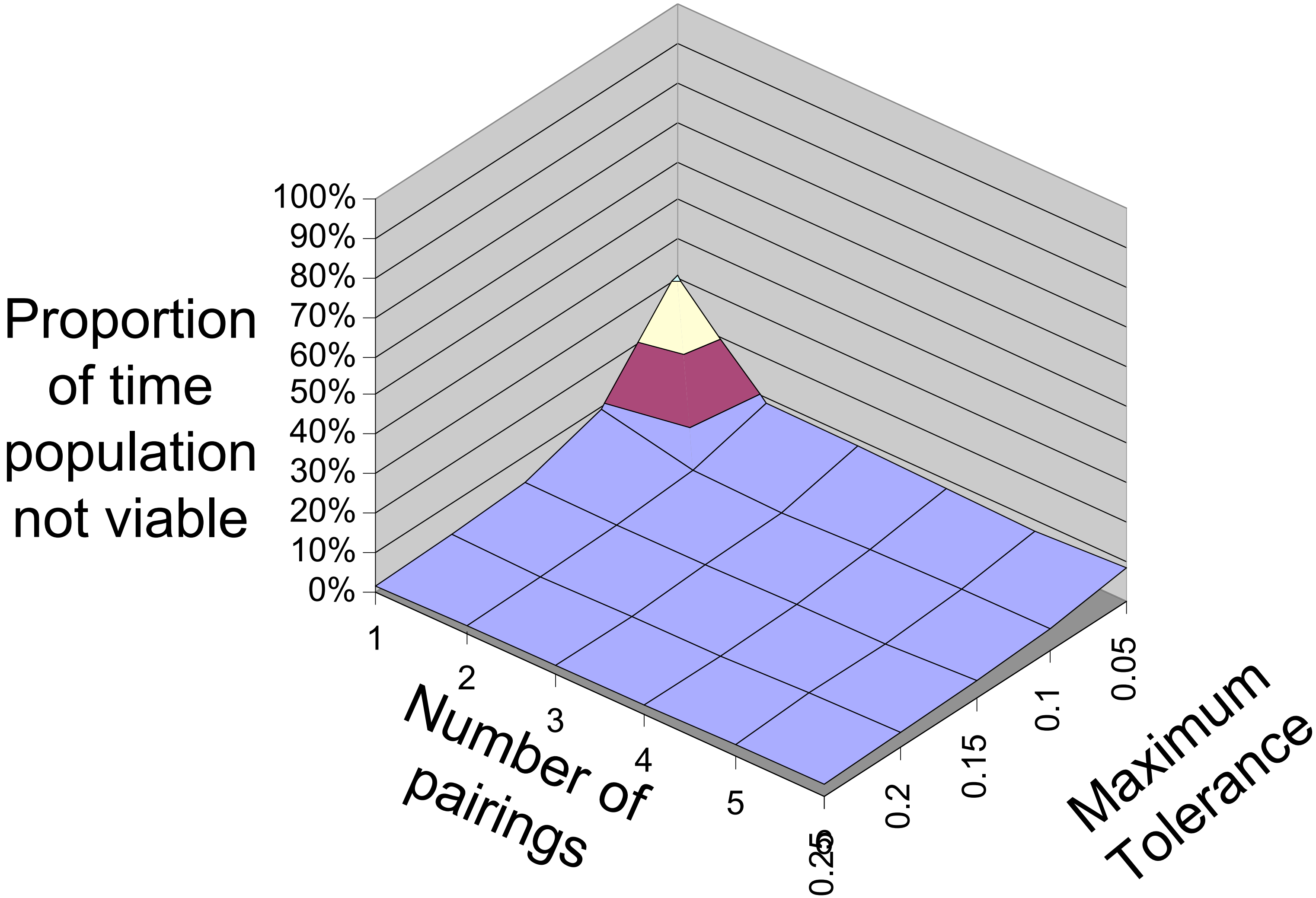
# Example run – subpopulations



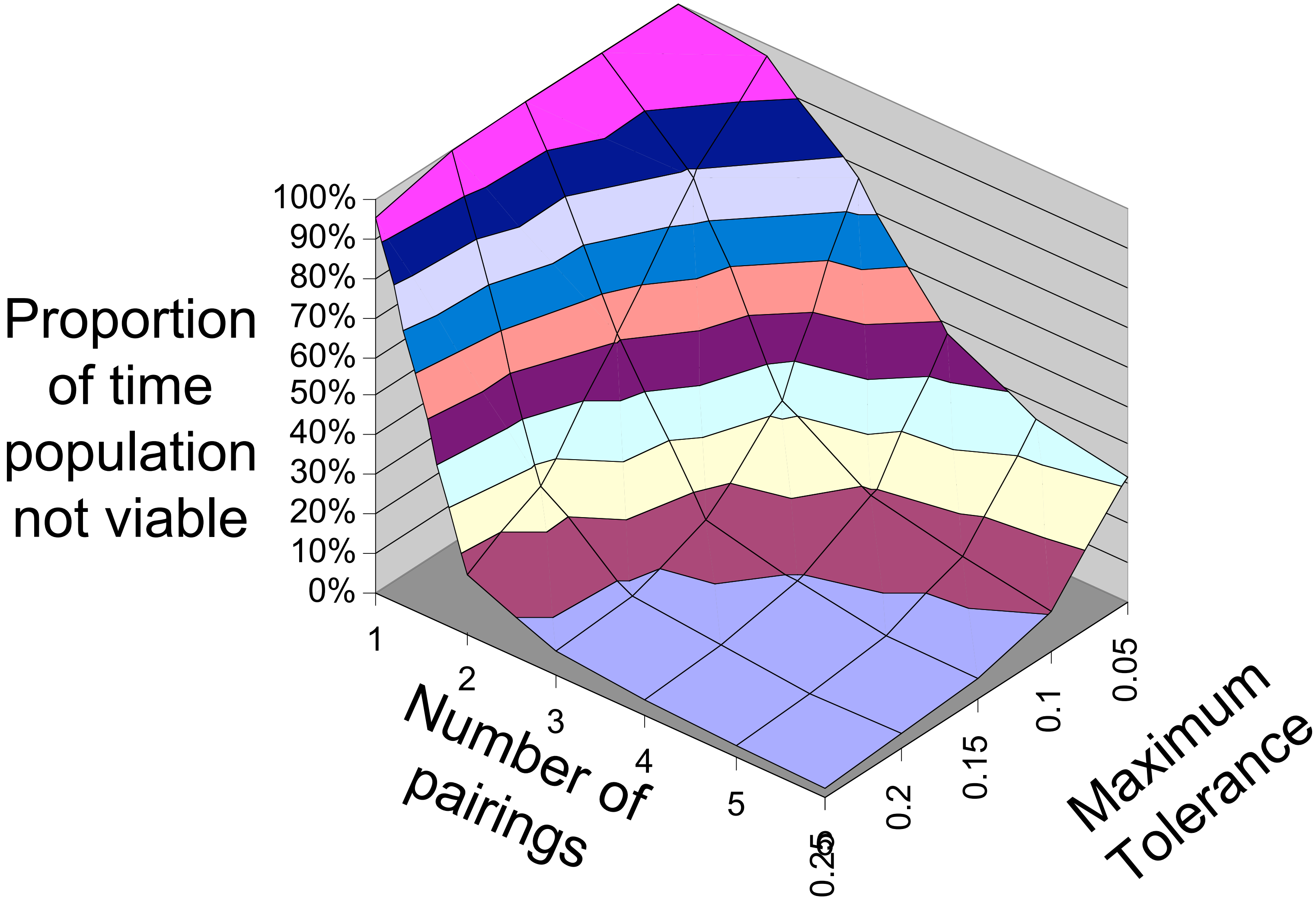
# Population profile for a typical run



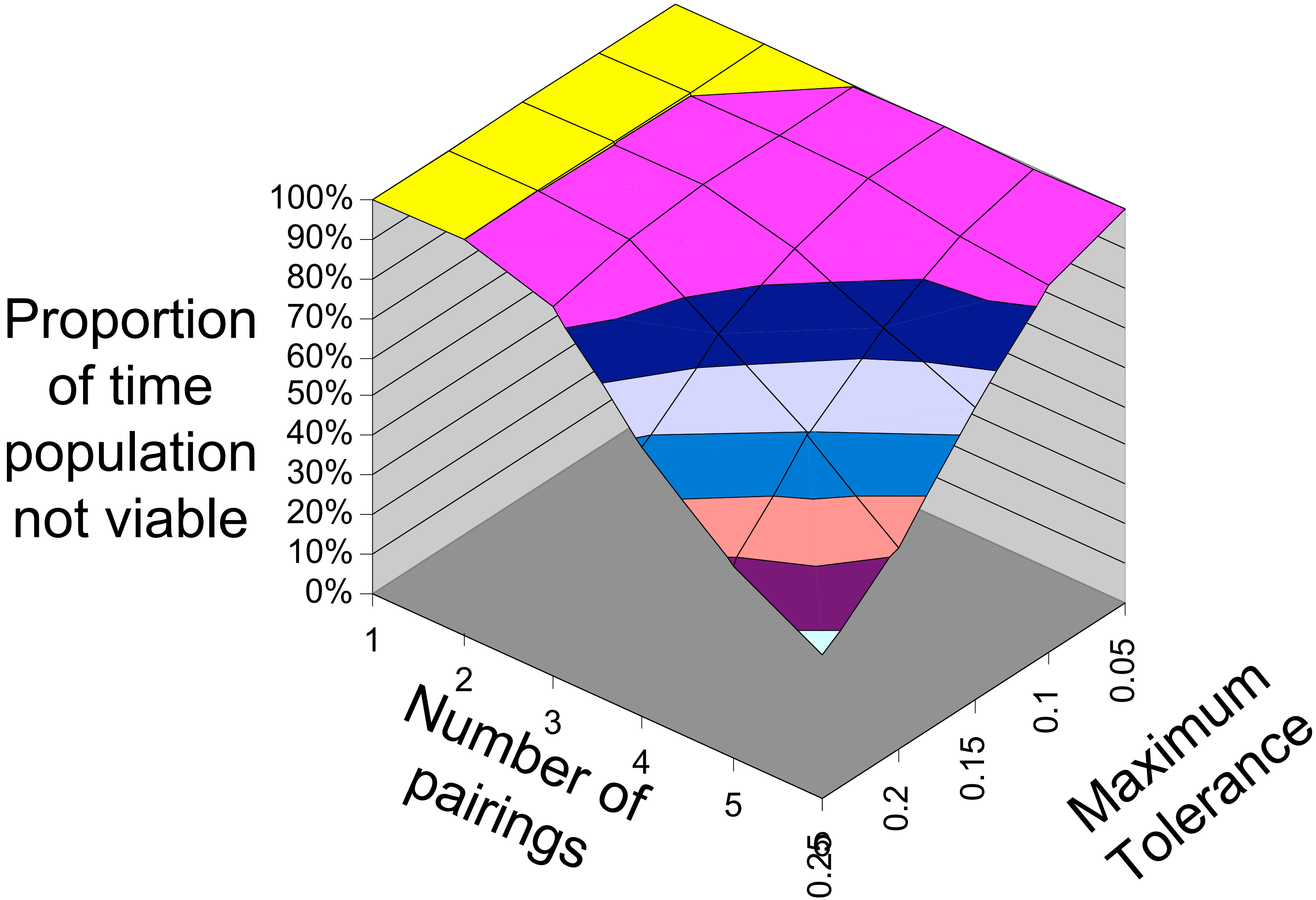
# **Av.** *proportion of time population not viable* **against** *maximum tolerance* **and** *number of pairings*: **2 Food types**



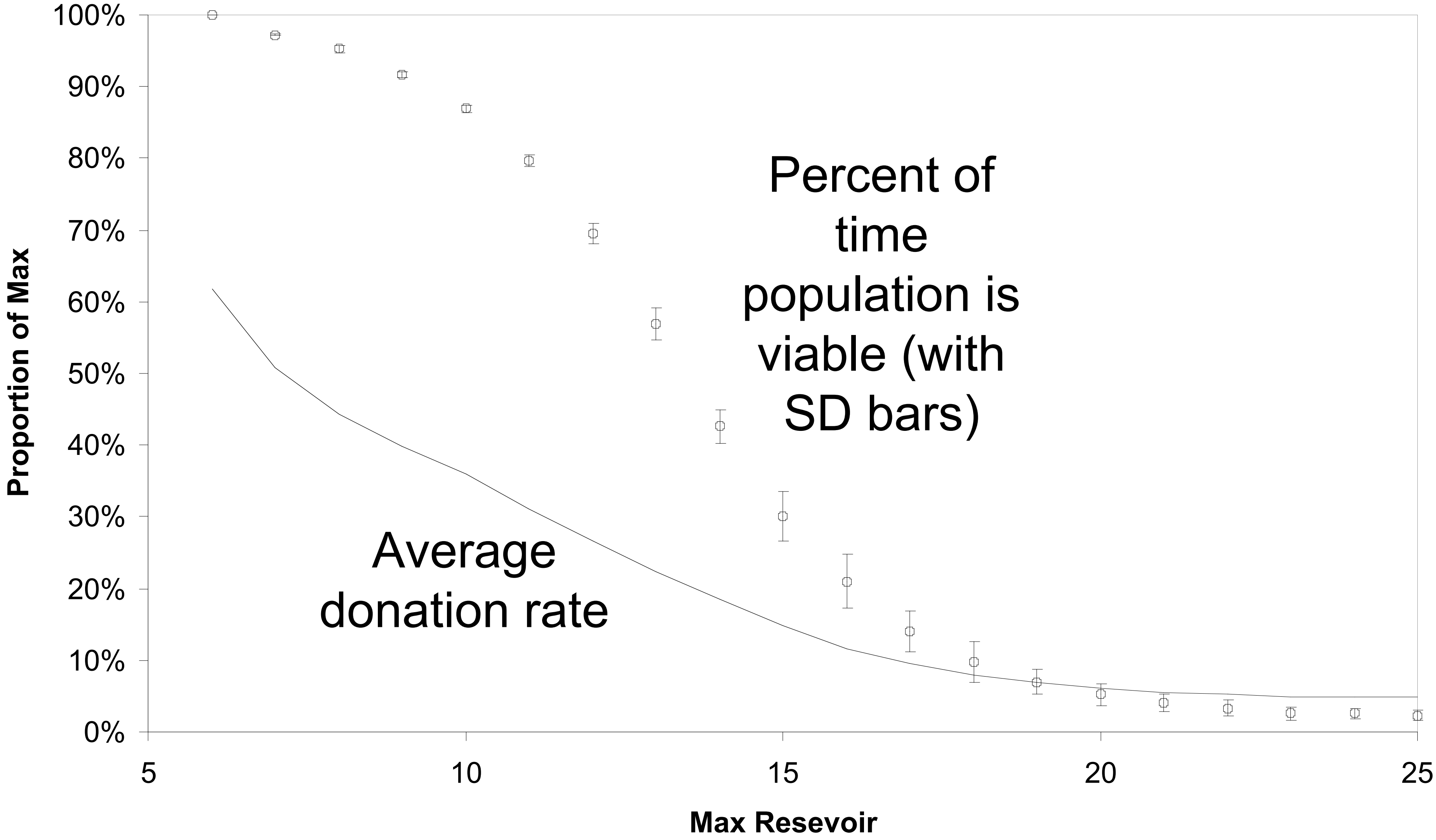
# **Av.** *proportion of time population not viable* **against** *maximum tolerance* **and** *number of pairings*: **3 Food types**



# **Av.** *proportion of time population not viable* **against** *maximum tolerance* **and** *number of pairings*: **4 Food types**



# Viability and donation rate against size of reservoirs (averaged over 25 runs)



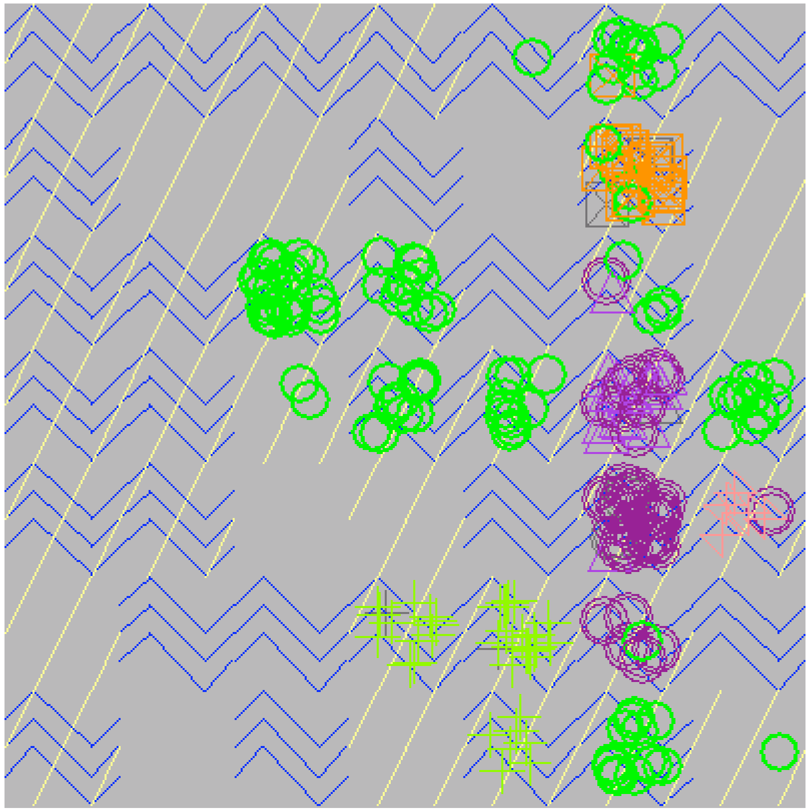
# What the model suggests to increase cooperation

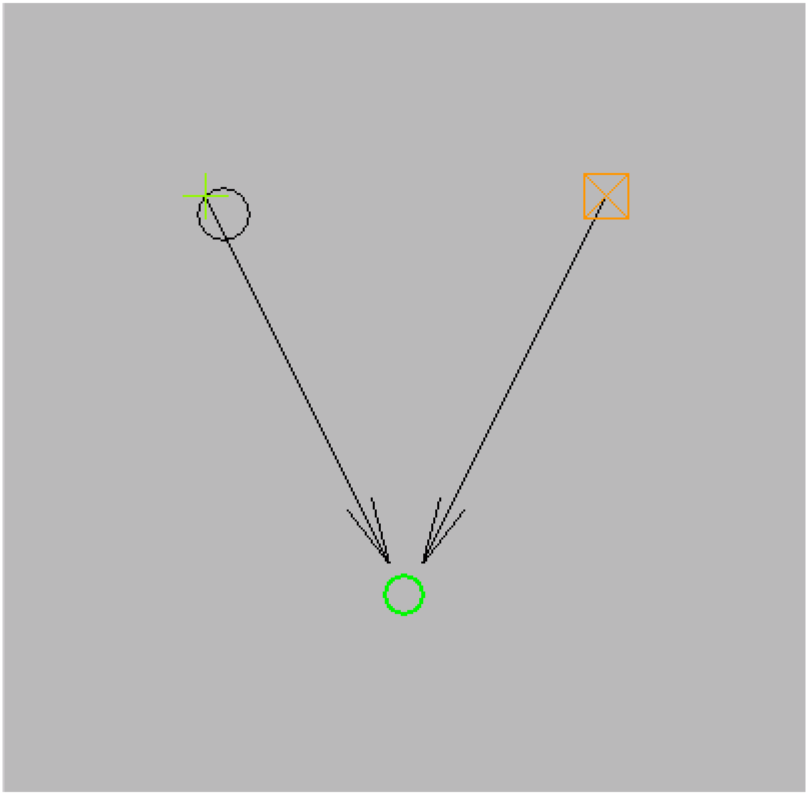
- A sufficient number of pairings (compared to population size)
- A sufficient but low size of reservoir (i.e. resource is difficult to store)
- A larger maximum tolerance (though this is a mixed effect)
- A smaller number of necessary food types
- Delay in deleterious effects of parasites are more likely to kill any symbiot groups
- Mechanisms that facilitate the continual formation of new seed groups

# Part 2: Some new speculative work

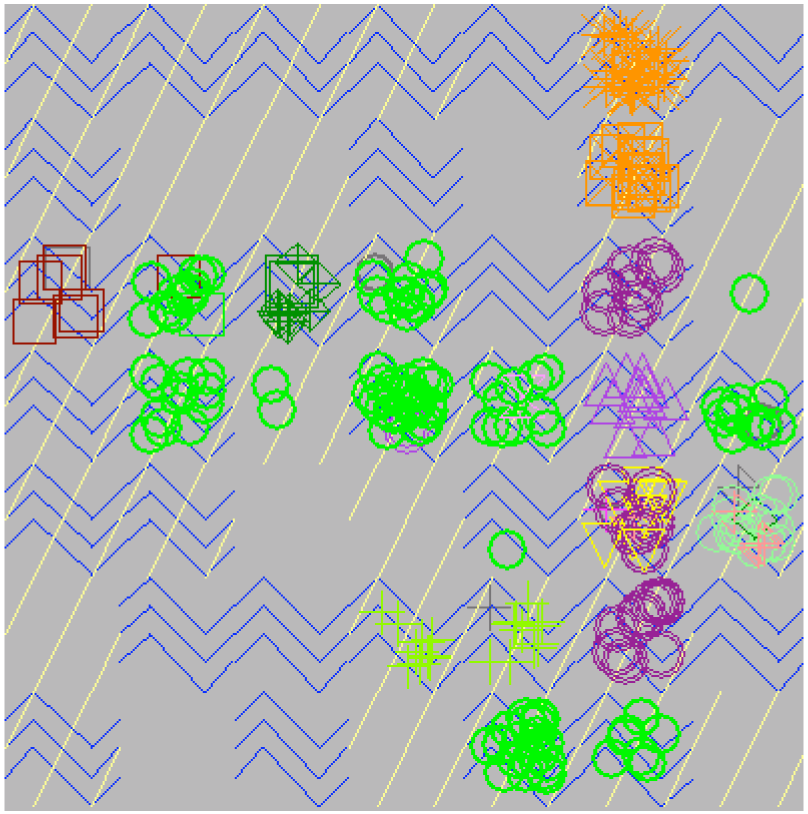
*the robustness of this variety of symbiosis within a more complex evolutionary model*

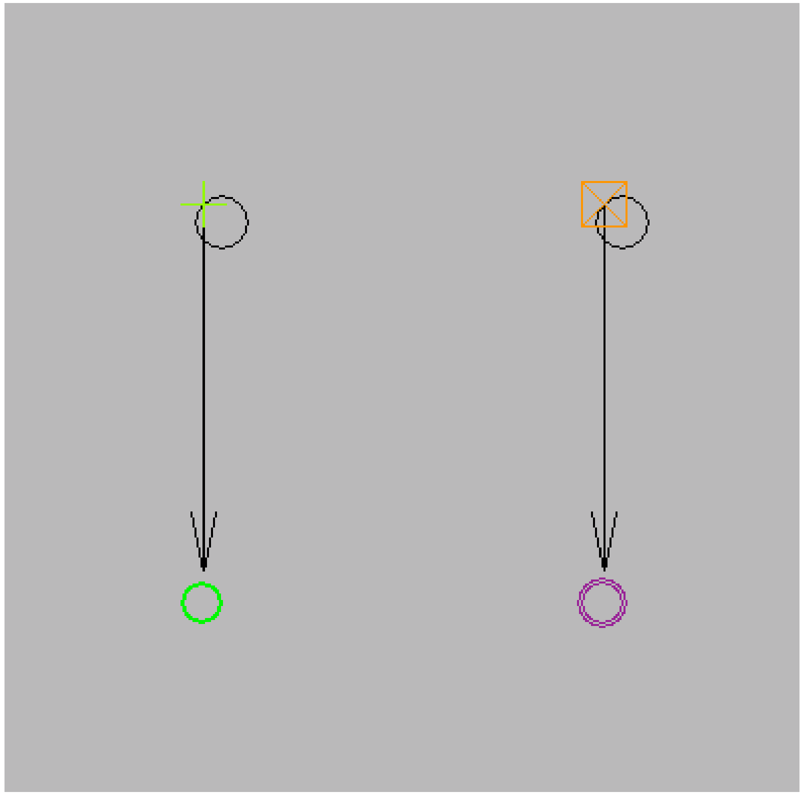
# Snapshots from the unsimplified model - 1



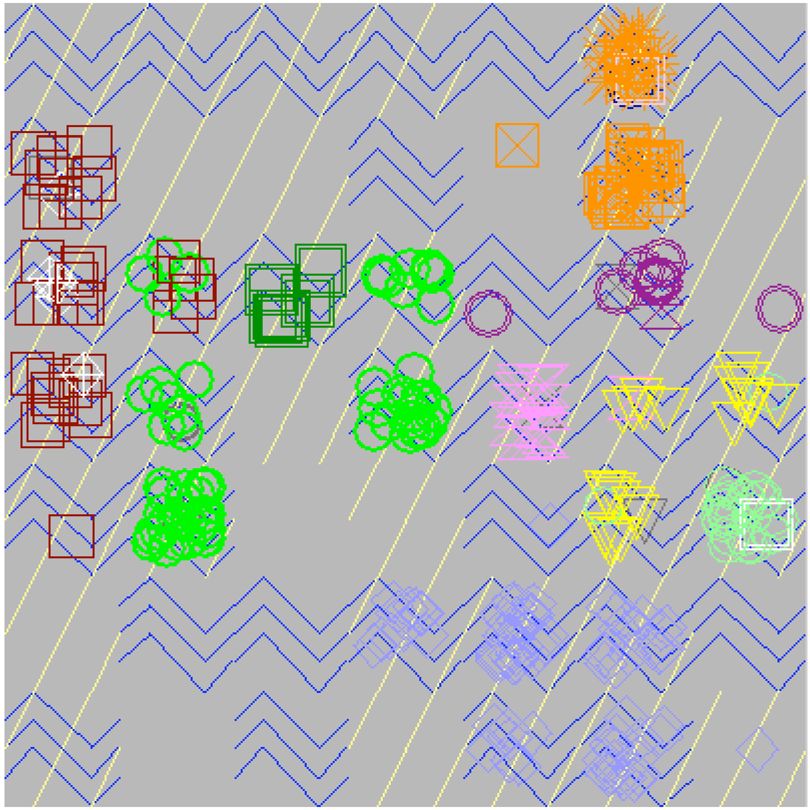


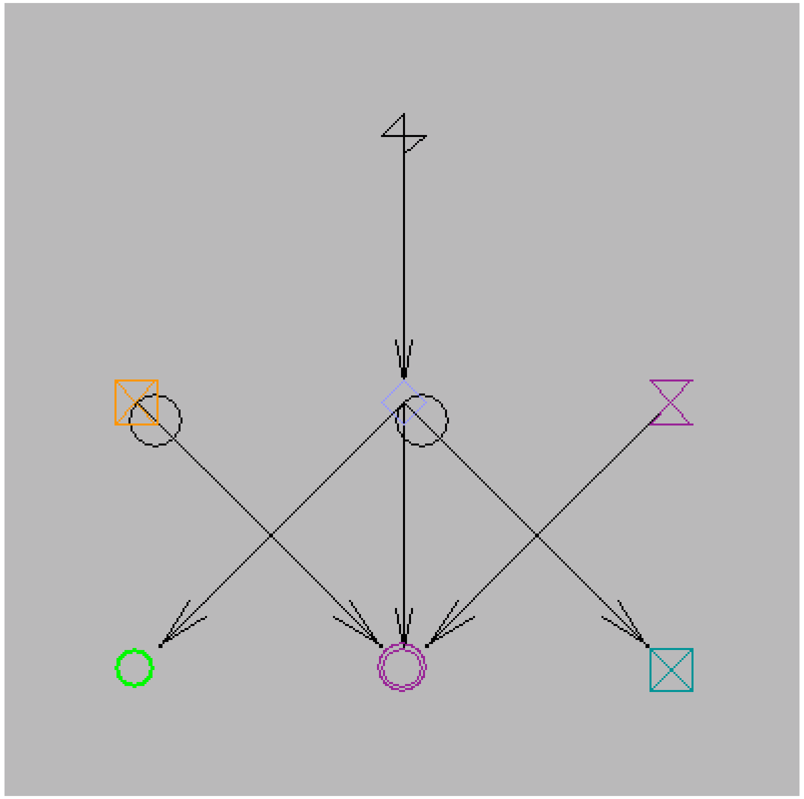
# Snapshots from the unsimplified model - 2



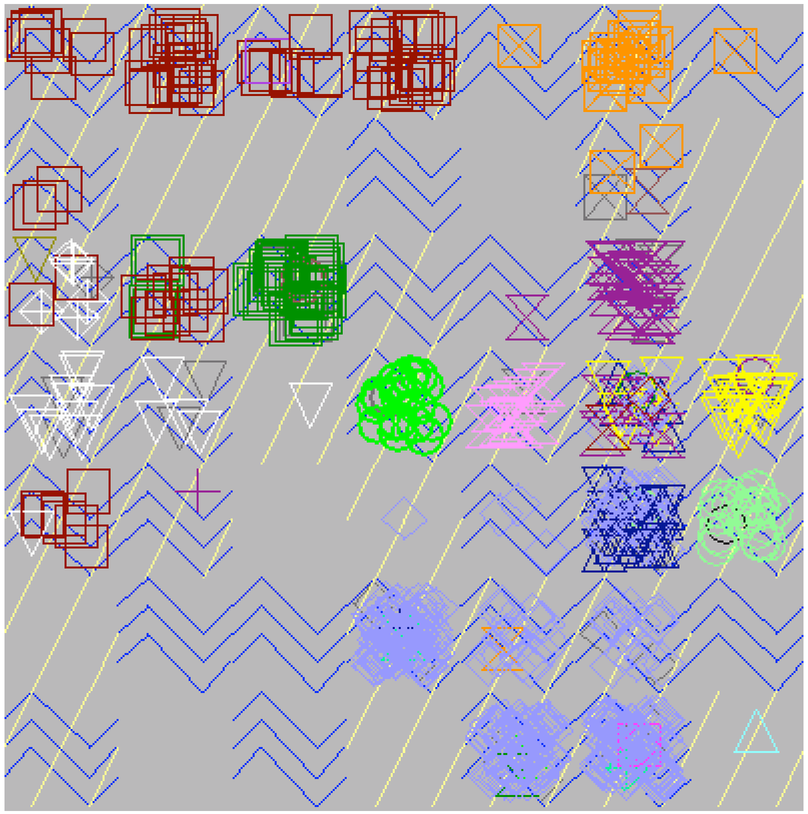


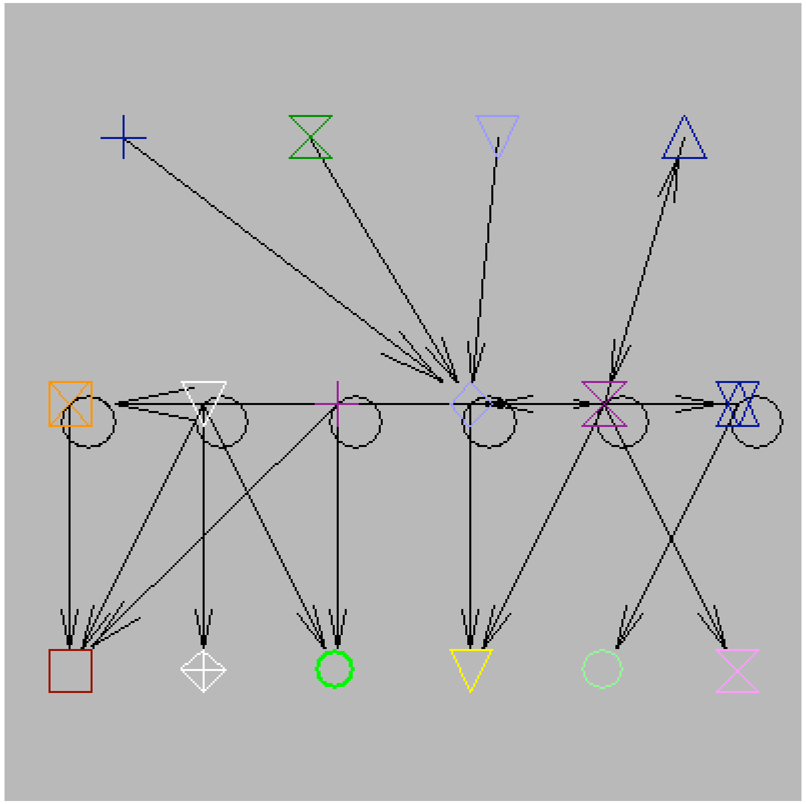
# Snapshots from the unsimplified model - 3





# Snapshots from the unsimplified model - 4





# About this Model

- To test the assumptions behind a more abstract model – the system-dynamics “Foodweb” model of Alan McKane and collaborators
- I have adapted and somewhat simplified it here to test the mechanisms just described

  Food types → Trace nutrients

  Tags → Locations

  Skill → gathering gene

  Donation → Excretion of excess to location

# The environment

- A 2D Grid with edges (not wrapped) for (relative) computational tractability
- Each location is a niche where many individuals can exist and act (i.e. mixed and accessible within each location)
- Finite conserved (but dissipated) resources
- Light, water and trace nutrients are distributed (in this case continually and evenly)
- Small probability of a random new species arriving from outside

# The individuals

- Are separately tracked
- Have individual properties: position, direction, nutrition, water, energy, temperature, stat and species
- Each species has its own genome which determines behaviour of individuals wrt. their individual circumstances
- Possible actions include: (asexual) reproduce, going forward, turning, photosynthesis, attack, defend, spread progeny, eat, adsorb water, eat dead, excrete excess nutrient, efficient gathering of nutrient
- In this version photosynthesis and water gathering is fixed and automatic for all species

# The Species' Genome

Have a genome with a fixed number of "slots" each of which is filled with a "characteristic", each of which is composed of 5 parts:

1. An action (attack, defend, eatDead…)
2. A when condition, which specifies when it occurs: (randomly, regularly, whenCold…)
3. A frequency which specifies how often (always, often, sometimes, rarely….)
4. An object kind which may be involved in the when condition (type1, type2 …)

Plus the nutrient kind that it specialises in

# Example Genome

[ [excrete 'type-1' whenNeedEnergy always]
[defend 'type-1' regularly rarely]
[eatDead 'type-2' randomly always]]

*Excrete any excess of nutrient of type 1 when I have above a critical level of energy; defend myself against a predator using strategy 1 regularly with period of 20; eat any dead individuals in this location.*

[gather 'tag-1' whenHaveLotsOfEnergy always]

*Gather Nutrients of type 1 when I have above a critical level of energy with probability 1*

# Reproduction

- New individuals are produced when an individual achieves certain conditions (minimum nutrition, water, energy, being alive)
- Initial resources of progeny are subtracted from parent (plus some simple loss)
- When this occurs there is a finite probability of a new species and genome being created by mutation from genome of parent

# Death etc.

Individuals die when:

- Their resources (nutrition, water, energy) run too low
- They are killed by another individual

- Killing occurs when another individual at the same location attacks (with a tag) and the individual does not defend (with that tag)
- They then persist as dead for a while with their nutrition and water content dissipating
- Any dead that are eaten provide some proportion of these resources to the eater
- Thus predation consists of killing then eating

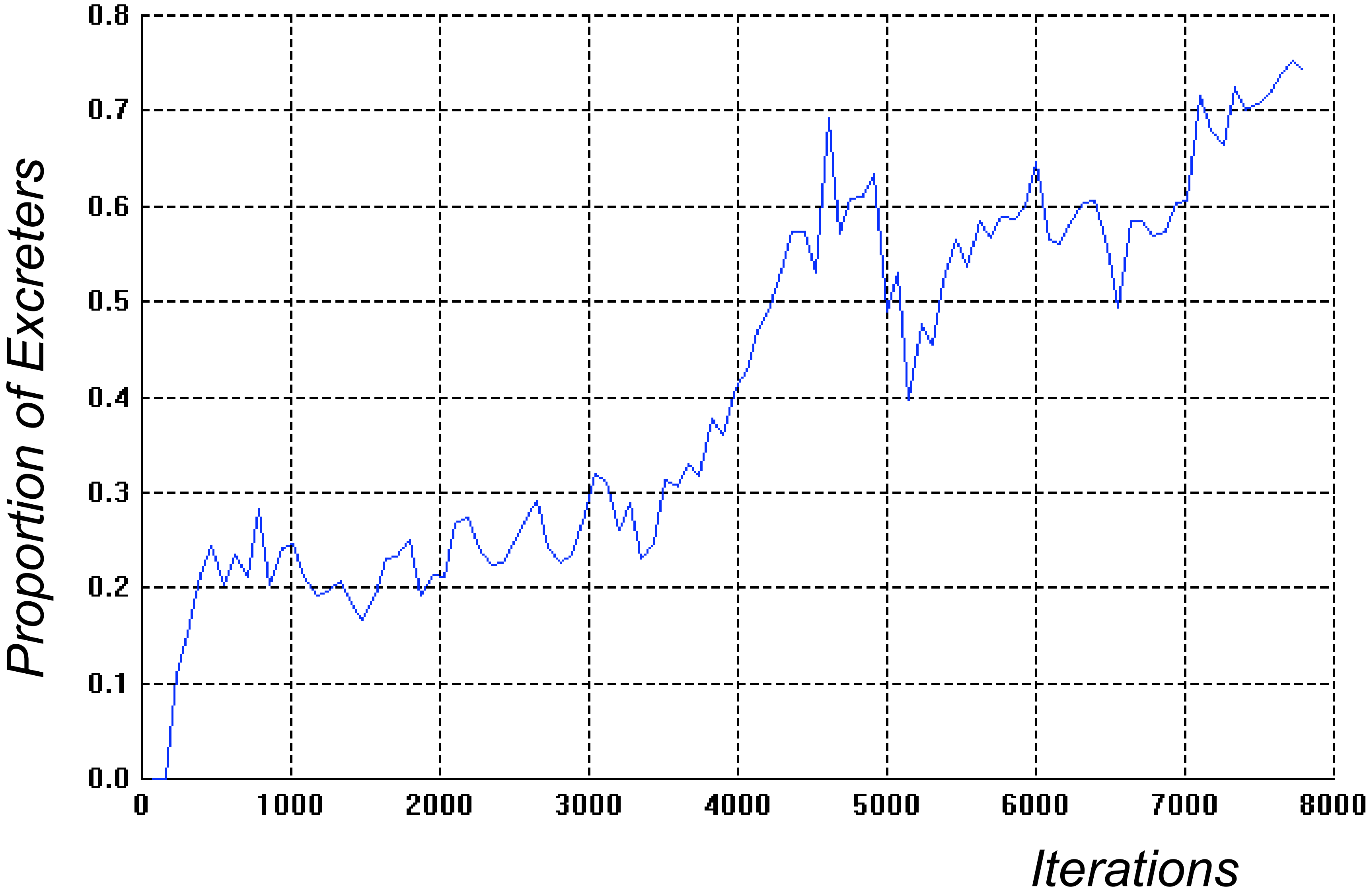
# Resources

- Sole ultimate source of energy is light via photosynthesis (apart from first individual)
- Resource input rate is thus limited
- Nutrition (inefficiently) passed down food chain by eating others
- Success at gaining resources determines rate of reproduction
- All actions require (different) amounts of energy/water
- Some energy, water, nutrition used simply to live

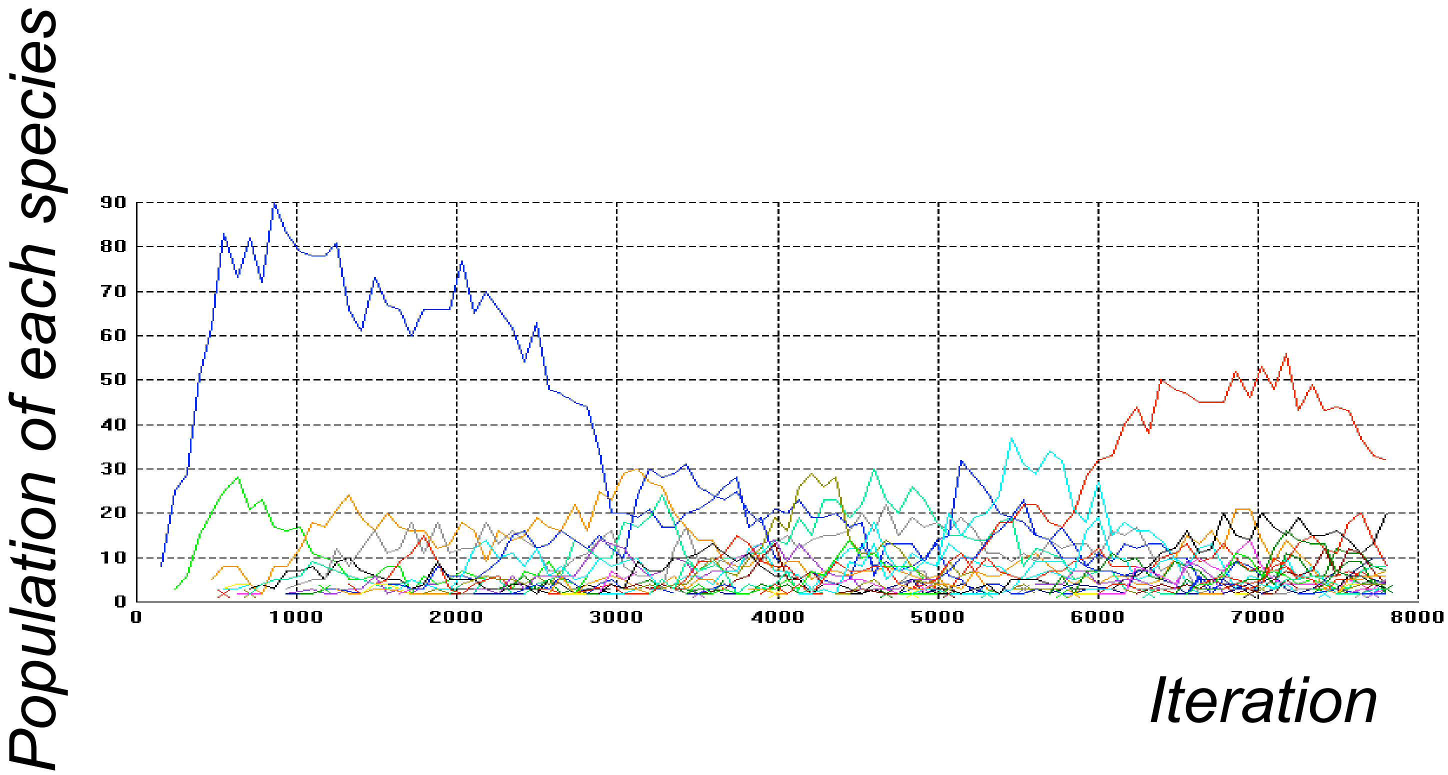
# A Case Where Cooperation Thrived

- Where individuals die if any of nutrients fall below critical level
- Starting from 1 species
- Enough resources for sizable population
- With EatDead genome but where predators are not allowed to photosynthesise

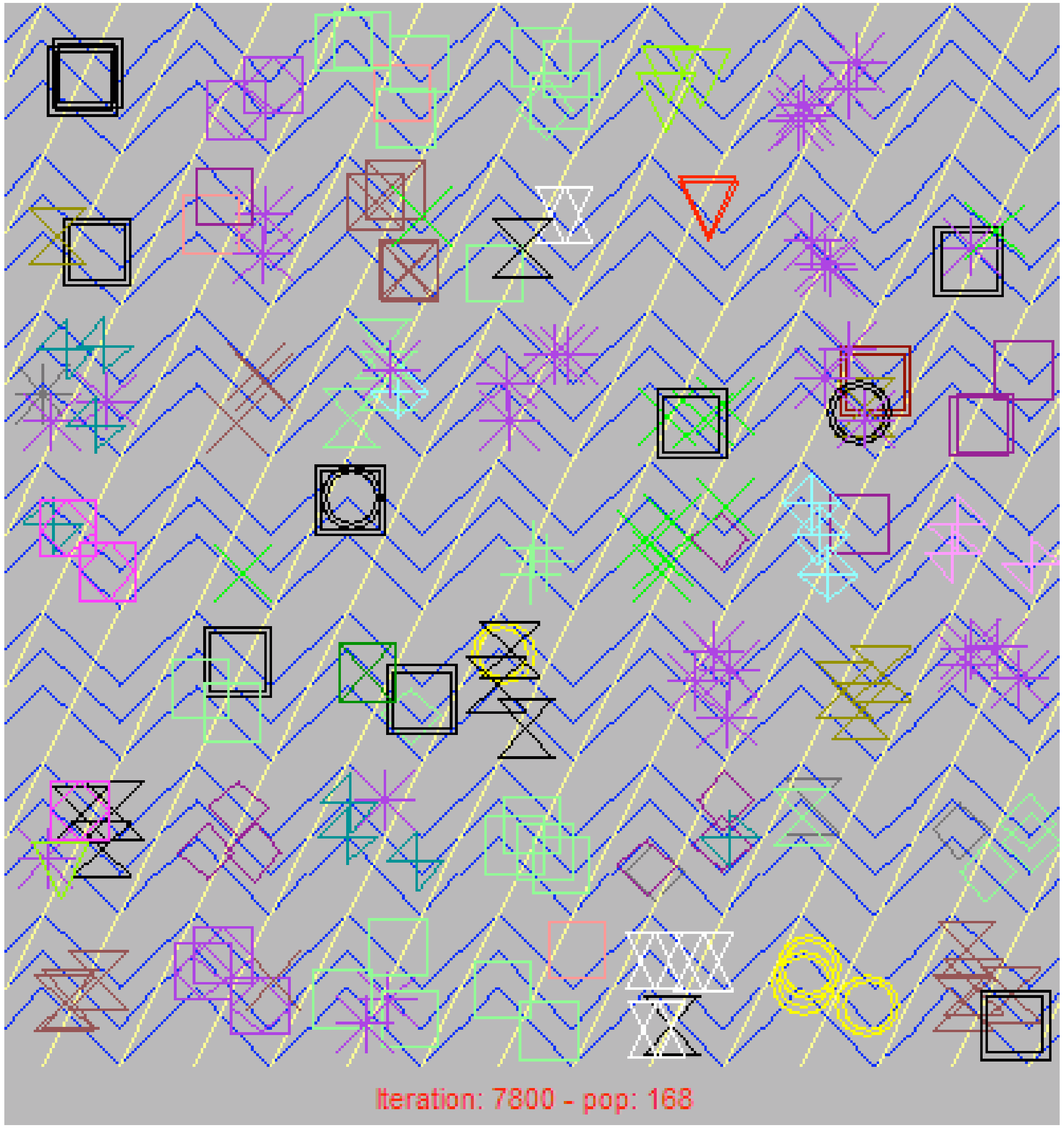
# Harsh Environment – *level of cooperation*



# **Harsh Environment** – *number in different species*



# Harsh Environment – *Final grid*



# Summary of investigation so far

- It was difficult to get tag-facilitated group formation with specialised skills in this model, possible reasons why include:
  - Ability of defectors to exist at low levels everywhere ready to stymy the establishment of cooperative groups?
  - Predators can gain nutrients via prey, they don't need to cooperate?
  - Environment was not tuned to make symbiosis 'worth it'?
  - Model needs to be much bigger with many individuals in a landscape large enough for there to be empty locations?
- I was not convinced it was as result of symbiotic tag-groups, but it seemed to be a similar process

# Part 3: Concluding Discussion

*questions, speculations and issues*

# Issues and questions

- How robust is symbiot-style grouping within an evolutionary setting?
- Can more general structures than simple groups be evolved/developed?
- Once groups exist can this be used as a base for more sophisticated structures to develop from?
- Can group formation be made more robust and inevitable in feasible ways?
- What other mechanisms might we add in to the mix?