Under which conditions can altruistic behaviour be an Evolutionary Stable Strategy?

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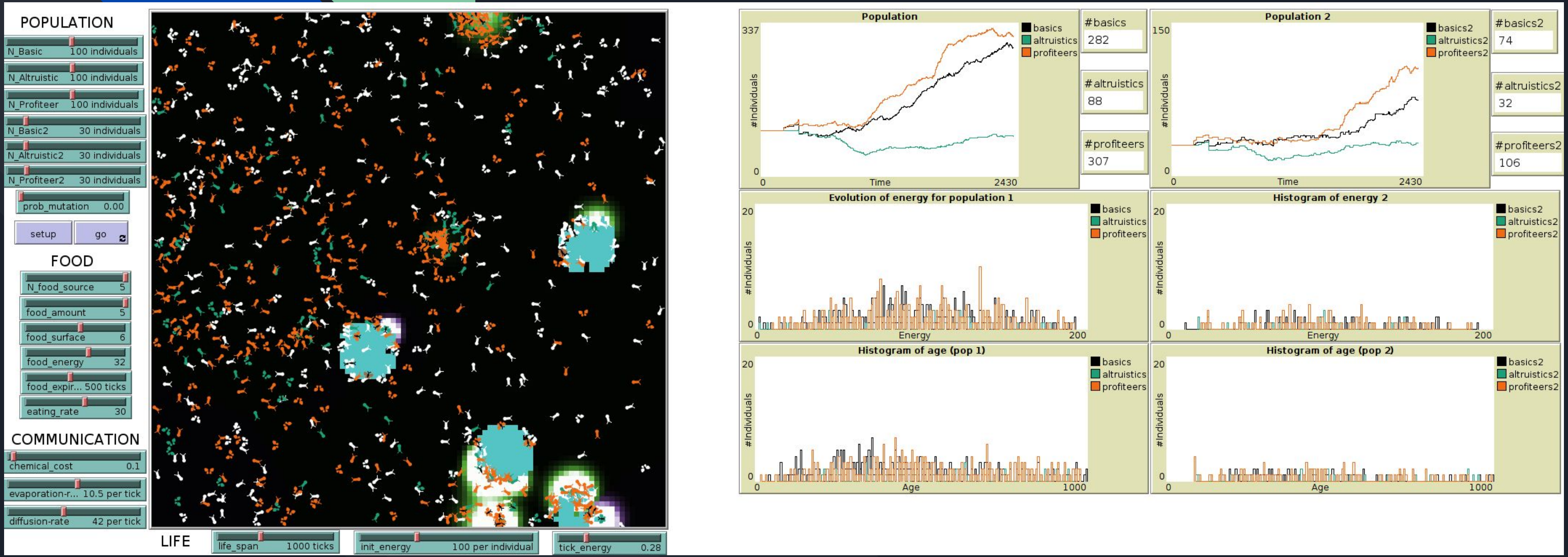


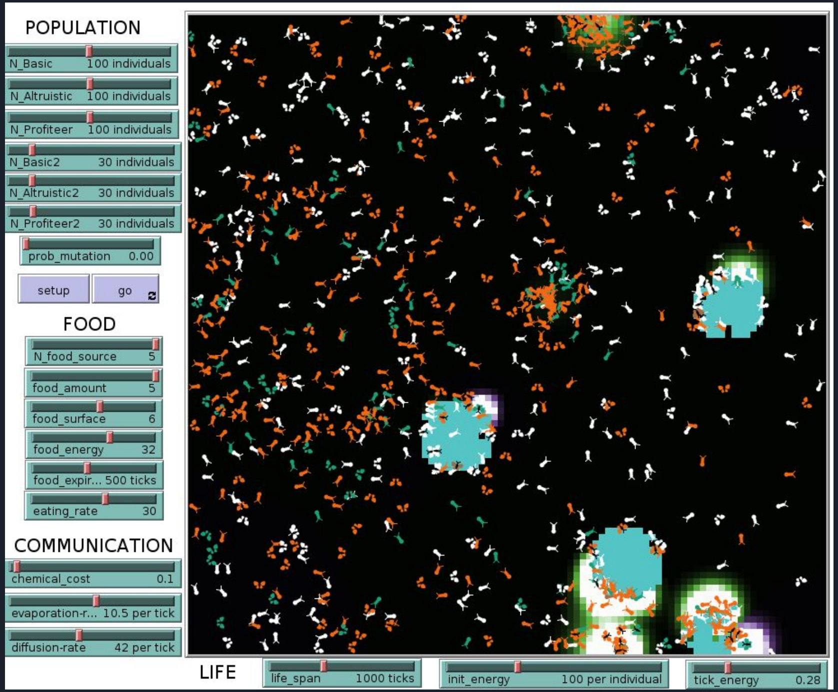
Can nice bugs not finish last?

2 species (mostly focus on one)

3 types of individuals:
- **Basics: none**
- **Profiteers: pick-up signal**
- **Altruists: emit signal + pick-up signal**

1 communication media: chemical ~gradient

5 actions: search for food, eat, reproduce, ***emit signal, pick-up signal,***



Overview

1. Introduction
2. Theoretical background
3. Implementation
4. Experimental setup
5. Experiment analysis and discussion

Theoretical background

*An ESS or **evolutionarily stable strategy** is a strategy such that, if all the members of a population adopt it, no mutant strategy can invade. -- Maynard Smith (1982)*

Nash Equilibrium

*A **Nash equilibrium** is a strategy in a game such that if all players adopt it, no player will benefit by switching to play any alternative strategy.*

$\forall i \in [|1, N|], \forall ti \in Si , gi(si , s-i) \geq gi(ti , s-i).$

*A population is said to be in an **evolutionarily stable state** if its genetic composition is restored by selection after a disturbance, provided the disturbance is not too large. Such a population can be genetically monomorphic or polymorphic. -- Maynard Smith (1982)*

Implementation: adaptation of the Ants model

Population

- 6 different breeds:
  - 2 different populations
  - 3 behaviors: Basics, Altruistics, Profiteers.
- Initial state:
  - Random position.
  - Initial energy
  - Random age

Life

- Reproduction
  - Pregnancy
  - Mutation
- Death
  - Starvation.
  - Old age

Food

- Patch variable.
- Variable number of food sources.
  - Circle around random centroids.
  - Expiration date.
  - Eating cooldown

Communication

- 2 types of chemicals (for populations 1 and 2).
- Diffused by altruistics.
- Detected by altruistics and profiteers.
- Evaporates with time.

Experiments

Experimental protocol

- Excel with parameter values (fixed and tweaked) per experiment
  - 30k+ ticks per experiment if smooth/regular oscillations, 50k+ otherwise
  - Model validation experiments were run until we hit the simplest parameters possible at it worked *at least twice in a row.*
  - Analysis experiments
- Model, experimental results and doc are available on git repo : https://github.com/Narmondil/altruism_versus_greed

Categories of experiments

- Model validation, empirical parameter finding (4xps, red)
- Energy supply/consumption (3xps, green)
- Ecological dynamics (a.k.a. population) (3xps, blue)

param / experiment	#xp00 What is the simplest environment S survive in?	#xp01 What is the simplest environment G survive in?	#xp02 What is the simplest environment A survive in?	#xp03 What is the simplest environment in which a mixed population is stable?	#xp04 How the number/size/amount of energy of food sources impact pop?	#xp05 How the dynamics of food availibility/eating affect pop?	#xp06 How the cost of signalling impacts survival of A?	#xp07 How initial pop ratios/numbers within one same specie affect long-term stability?	#xp08 How mutation probabilities affect pop stability/survival?	#xp09 How 2 populations interact/coexist (or not)
standard pop1	10/100	NA	NA	100	100	100	100			
altruistic pop1	NA	NA	10/100	100	100	100	100			
greedy pop1	NA	10/100	NA	100	100	100	100			
standard pop2	NA	NA	NA	NA	NA	NA	NA	NA	NA	
altruistic pop2	NA	NA	NA	NA	NA	NA	NA	NA	NA	
greedy pop2	NA	NA	NA	NA	NA	NA	NA	NA	NA	
prob mutation	NA	NA	NA	NA	NA	NA	NA	NA	NA	
nb food sources	?	?	?	?	1/3/2005					
food amount	?	?	?	?	2/3/2005					
food surface	?	?	?	?	5/7/10					
food energy	?	?	?	?	10/30/50					
food expiration	?	?	?	?	200/500/1000					
eating rate	?	?	?	?		3/5				
chem cost	NA	NA	0.5							
evaporation rate	NA	NA	5							
diffusion rate	NA	NA	50							
life span	1000*k	1000*k	1000*k	1000*k	1000*k	1000*k	1000*k	1000*k	1000*k	1000*k
initial energy	100	100	100	100	100	100	100	100	100	100
tick energy loss	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Model validation & empirical parameter finding

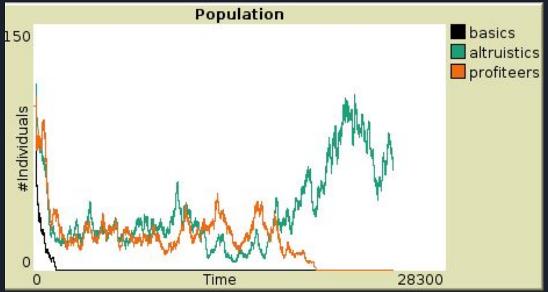
- What is the simplest environment for each population to stabilise on their own (no mixed pop here)?
- What is the simplest environment in which altruists can outlive a mixed population with P>0.5 ?

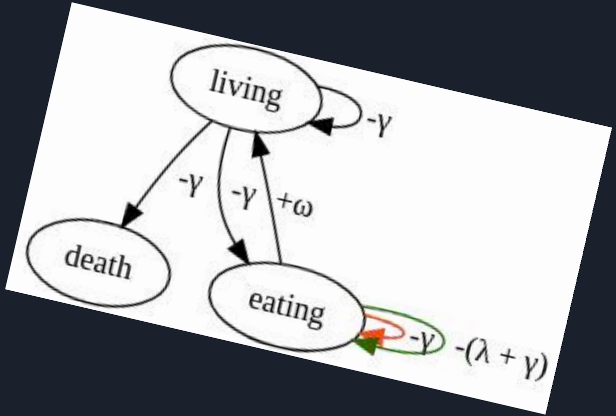
$$\mathcal{G}_a = (\omega - \gamma - \lambda)P_{ap}(F) - \gamma(1 - P_{ap}(F))$$

$$\mathcal{G}_p = \begin{cases} (\omega - \gamma)P_{ap}(F) - \gamma(1 - P_{ap}(F)), & \text{if} card(a) \geq 1 \\ (\omega - \gamma)P_b(F) - \gamma(1 - P_b(F)), & \text{else} \end{cases}$$

$$\mathcal{G}_b = (\omega - \gamma)P_b(F) - \gamma(1 - P_b(F))$$

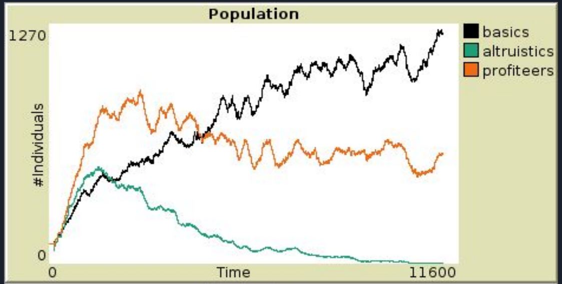
$$\forall \gamma \geq 0.65 \ \frac{\lambda}{\gamma} \geq \frac{1}{2} \rightarrow P(A) \geq \frac{1}{2}$$

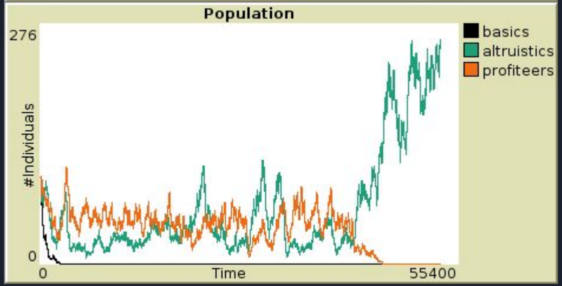


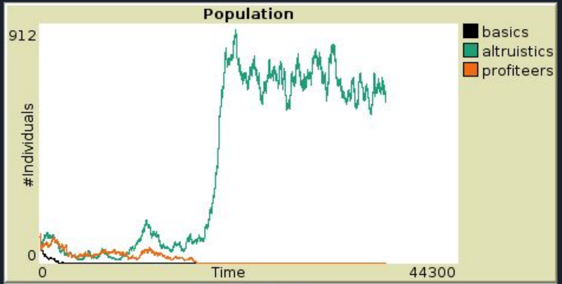


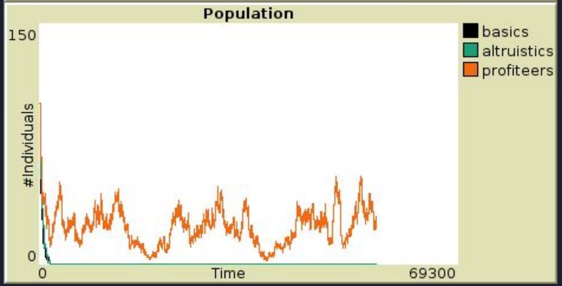
Impact of energy supply and consumption on population stability

- How does the number, size and amount of food of food sources impact the population?
- How does the eating pace impact the population?



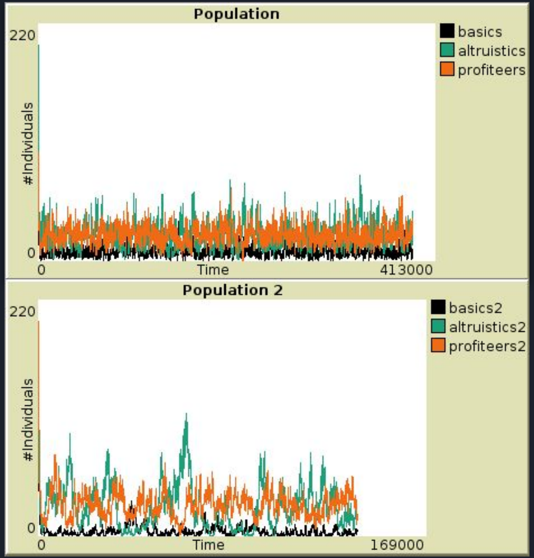


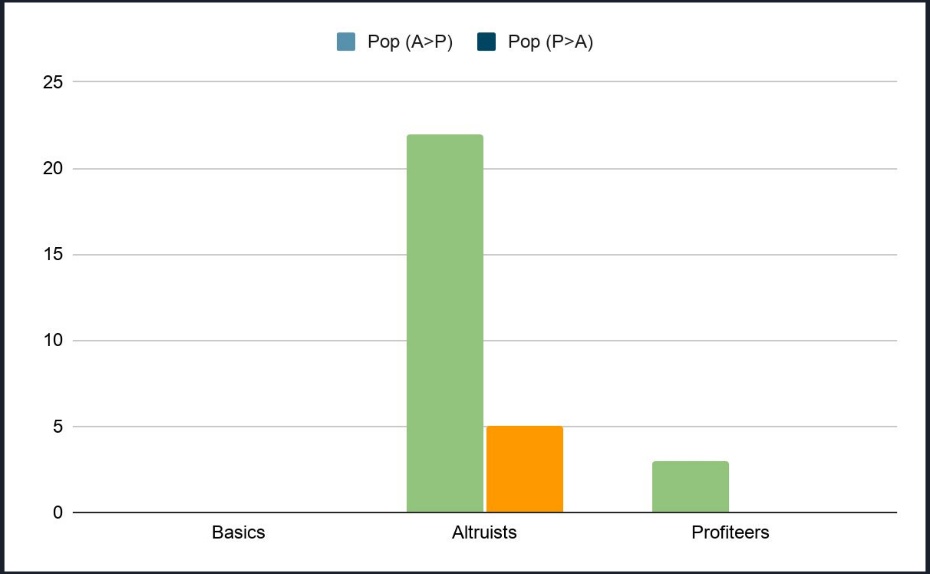




Impact of initial ratios, mutations and exogenous species on altruist survival rates

- How does the initial population size and ratio between different strategies of the same specie affect long-term population composition?
- How mutation probabilities affect population stability and survival?
- When competing with another composite population, which population overtakes the other and which strategy survives last?





Discussion

3 Key take-aways

- Food availability patterns.
- Life conditions: signalling & survival costs.
- Altruists can do better even in competitive settings.

Hypothesis

Mutation favours variety because the higher the numbers of one population, the more likely it is to obtain members from another population.

Hard life conditions favour cooperation because chances of survival through sheer randomness are slim.

A high number of food sources might increase the probability for altruists to find a food source with no profiteers and the probability for profiteers to find a food with no altruists, which gives altruists the edge since all place where they are mixed will likely favour profiteers but they will do better than lone profiteers on the places where they are alone.