**Model Description**

**Purpose**: To evaluate to conditions in which cooperative behavior evolve in a population, when individuals can move between groups and when selection is based on individual fitness.

**State variables and scales**

Assume a population of N agents and M groups in which the agents can be located. At each time step, all agents may contribute to the public good in their group, and the created public good is evenly divided among the agents in the group. Each agent i contributes a continuous level *xi* [0,1] to the public good, and therefore the income of agent i, *πi*, is defined as

 (1)

**Process overview and scheduling**

During a time step first the contributions of agents are defined, then the income of agents are calculated using equation 1, and finally the values of *xi* for the next generation and their locations are defined.

Each time step there is a probability η that the value of *xi* is drawn from a uniform distribution between 0 and 1. The fitness of an agent is equal to its individual income. The agents in the next round are generated based upon the fitness of the agent proportional to the fitness of the other agents in the total population (not just the agent’s group). In particular, we generate N agents for each generation, and for each of these agents, the probability of selecting an agent in Generation t for replication in Generation t+1 is

 (2)

The offspring is not a perfect copy of its parent agent because a perturbation from a normal distribution with mean 0 and variance η is added to the cooperation level. There is also a probability μ for each agent that it migrates to a randomly selected group.

Note that for each group there is a dilemma between individual and group rationality. However, if *B ≥ NGi* the agent will receive positive returns on its own contribution, thus it would always be beneficial to contribute. In fact, the unrestricted game only becomes a public good dilemma when the group size group exceeds a certain level (NGi > B). Nevertheless, we also include the situation in our analysis with a stricter condition, such that

if *B ≥ NGi* (3)

For this stricter condition, it is always to an individual’s advantage to contribute nothing to the group, and the game always presents a true dilemma. Hence we will run the model for constrained (equation 3) and unconstrained conditions.

**Design concepts**

*Emergence*. Level of cooperation

*Adaptation*. Population adapts to conditions

*Fitness*. Based on income from public good and individual decision

*Prediction*. Agents have no ability to predict.

*Sensing*. Agents do not sense

*Interaction*. Agents interact at the group level (playing public good game) and the whole population level (reproduction)

*Stochasticity*. Mutation and migration probabilities

*Collectives*. Groups

**Initialization**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Description | range | Default value |
| N | Number of agents | [1,1000] | 1000 |
| M | Number of groups | [1,15] | 10 |
| B | Multiplier for the public good | [0, 40] | 40 |
| η | Mutation rate | [0, 0.05] | 0.006 |
| μ | Migration rate | [0, 0.05] | 0.006 |