Model Description

This is a model description of a replication of the model described in Boyd et al (2003). The model description follows the ODD protocol for describing individual- and agent-based models (Grimm et al. 2006) and consists of seven elements. The first three elements provide an overview, the fourth element explains general concepts underlying the model's design, and the remaining three elements provide details. Additionally, details of the software implementation are presented.

Purpose
The purpose of the model is to investigate under which condition cooperation emerge when agents play public good games and they can sanction defectors at a small cost. In other words when does altruistic punishment evolve?

State variables and scales
There are 128 groups, and each group has a size n which is varied in the simulations.
Each agent can cooperate (contributing to the public good) or defect (not contributing to the public good). If it can cooperate it may also be able to punish defectors within the group. Individuals interact by imitation with members of other groups by a small probability in which they can encounter each other and imitate the strategy of the better agent. With a small probability agents can also encounter in a conflict. Groups with more cooperators have a higher chance to replace the other group.

Process overview and scheduling
Each agent first decides whether to cooperate or defect.
Then each cooperator decides whether to punish.
Then agents may imitate strategies of other agents.
Finally there might be intergroup conflict where one group replaces the other.
Each generation there is a small change of mutation for each agent (e.g. cooperator flips to a defector).

Design concepts

Emergence. Emergence of agents who contribute to the public good.

Adaptation. Groups adapt their composition of agents by imitation, mutation and intergroup conflict. Hence due to multilevel selection.

Fitness. The fitness of a group for conflict relates to the frequency of cooperators.

Interaction. Individuals interact indirectly via contribution to the public good, and directly due to imitation. Groups interact directly via intergroup conflict.

Stochasticity. Probabilities of mutation, whom to imitate and which groups are connected for conflict.

Initialization
Initially all groups, but one, consist only of defectors. One group consists of only cooperators.

Input
Default Parameter values
b = 0.5; benefit if everyone cooperates
c = 0.2; cost of cooperation

p = 0.8; cost of being punished
k = 0.2 ; cost of punishing
m = 0.01 ; mixing rate
μ = 0.01 ; mutation rate
ex = 0.015; probability of conflict

Submodels
The payoff for a cooperator is

$1 + bx – c$

Where x is the frequency of cooperators.

The payoff for a defector is

$1 + bx – p\ y$

Where y is the frequency of punishers

The payoff for a punisher is

$1 + bx – c – k\ (1-x)$

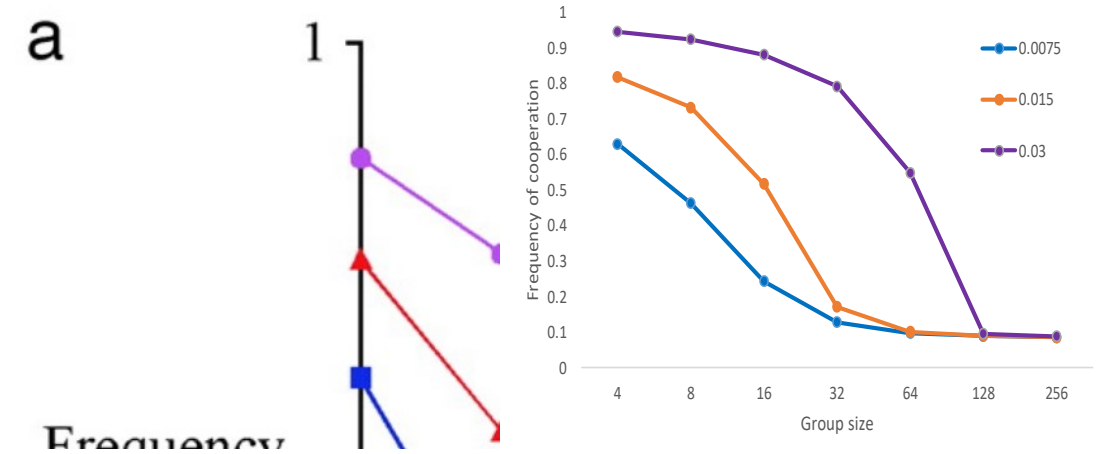
There is a small probability (0.02) that a cooperator makes a mistake and defects.

Imitation
Individuals encounter other group members with probability *1-m* and an individual from another group with probability *m*. An individual *i* who encounters an individual *j* imitates *j* with probability $W_j/(W_j + W_i)$, where W_x is the payoff of individual *x* in the game, including the costs of any punishment received or delivered. This leads to selection of higher payoff deriving strategies and migration of strategies between groups.

Intergroup conflict
In each time period, groups are paired at random, and with probability ε intergroup conflict results in one group defeating and replacing the other group. The probability that group *i* defeats group *j* is $1/2(1 + (d_j – d_i))$, where d_q is the frequency of defectors in group *q*. This means that the group with agents, who are more likely to defect, is more likely to lose a conflict. As a consequence, cooperation is the sole target of the resulting group selection process.

Model implementation

Model is implemented in Net Logo 4.0.3 in August 2008. The results in the figure below are done with Netlogo 6 in March 2019 and shows we get similar patterns of the published results of Boyd et al. (2003). Each result is the average of 100 simulations where the original results of only 10 simulations. Like Boyd et al. (2003) we use for each simulation the average of the last 1000 time steps of a 2000 time step simulation. At the left you find the results published in Boyd et al. (2003) and at the right the replication in Netlogo. The simulation explore the consequences of the frequency of wars with and without altruistic punishment, and the level of mixing with and without altruistic punishment.


a
1
Frequency
Frequency of cooperation
1
0.9
0.8
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4
8
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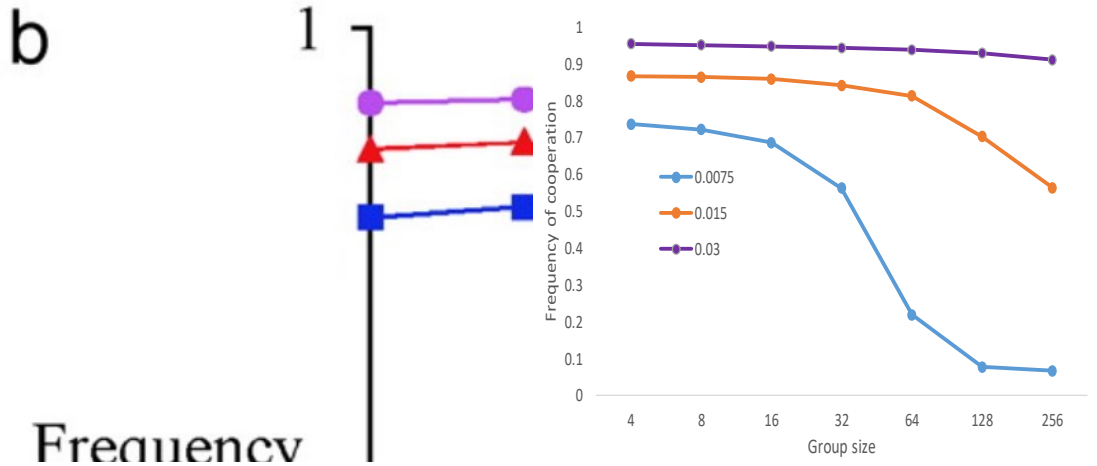
32
64
128
256
Group size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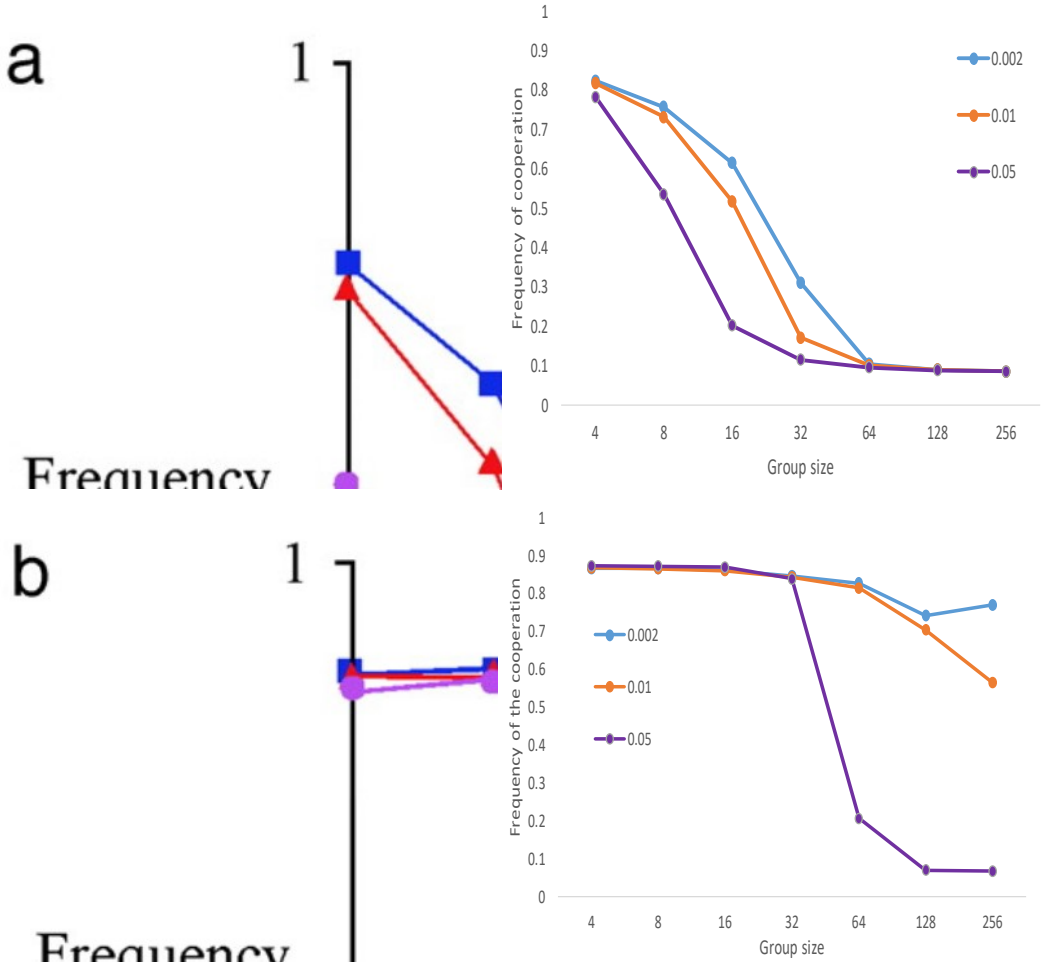

References

Boyd, R., Gintis, H., Bowles, S. & Richerson, P. J. (2003) The evolution of altruistic punishment, *Proceedings of the National Academy of Science of the United States of America* 100(6): 3531-3535

Grimm, V., U. Berger, F. Bastiansen, S. Eliassen, V. Ginot, J. Giske, J. Goss-Custard, T. Grand, S. Heinz, G. Huse, A. Huth, J.U. Jepsen, C. Jørgensen, W.M. Mooij, B. Müller, G. Pe'er, C. Piou, S.F. Railsback, A.M. Robbins, M.M. Robbins, E. Rossmanith, N. Rüger, E. Strand, S. Souissi, R.A. Stillman, R. Vabø, U. Visser, D.L. DeAngelis (2006) A standard protocol for describing individual-based and agent-based models. *Ecological Modelling* 198:115-126