Finite population evolutionary game for water supply sanitation boards

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Introduction

Safe drinking water and sanitation are essential to human well-being. They were recognized as a human right in 2010 by the UN General Assembly [1]. Access to improved water sources and basic sanitation imply a better quality of life: it reduces water-related diseases and shorten the time spent in collecting water, helping to achieve more productivity, a better education, gender equality and diminishing poverty [2].

Sanitation Boards

Sanitation Boards (SBs) are community projects that provide drinking water to more than 25% percent of the population of Paraguay [3]. Although there are several successful SBs, for others, sustain the service over the time is difficult due to the high rate of non-payment reached [4]. We consider that this situation can be seen as a cooperation problem for which several evolutionary games models are formulated.

Methodology

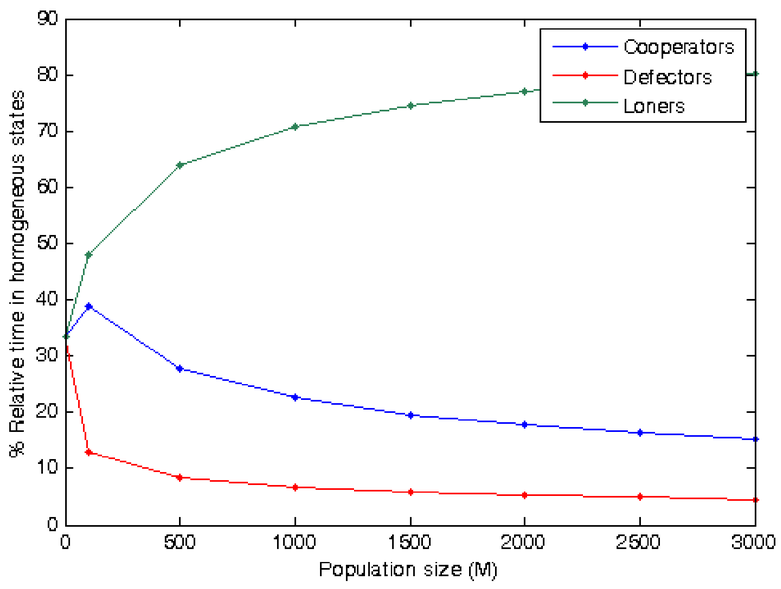
We use models obtained from the literature [5] and analyzed how the stationary distribution of the system and the probabilities to switch from one state to the other changes with the number of individuals to know if there is a particular population size or a range that cause the system to spent most of the time in the homogeneous state of cooperators (or punisher if the SB applies punishment).

The probabilities to change from one state to another is given by the transition matrix:

$$\begin{pmatrix} 1-\rho_{yx}-\rho_{zx}-\rho_{wx} & \rho_{xy} & \rho_{xz} & \rho_{xw} \\ \rho_{yx} & 1-\rho_{xy}-\rho_{zy}-\rho_{wy} & \rho_{yz} & \rho_{yw} \\ \rho_{zx} & \rho_{zy} & 1-\rho_{xz}-\rho_{yz}-\rho_{wz} & \rho_{zw} \\ \rho_{wx} & \rho_{wy} & \rho_{wz} & 1-\rho_{xw}-\rho_{yw}-\rho_{zw} \end{pmatrix}$$

And the stationary distribution of the system is given by the right eigenvector to the largest eigenvalue of the matrix.

Results and Conclusions



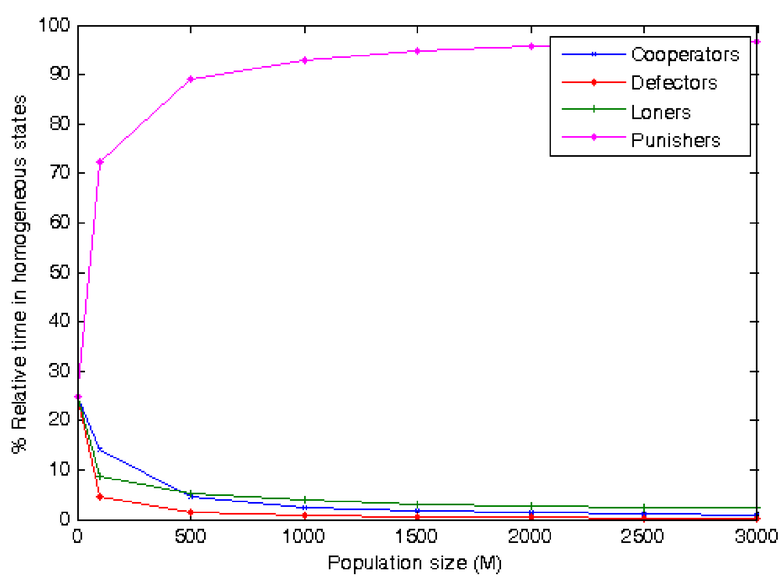


Figure 1: Relative time in homogeneous states as a function of population size. Parameters: N=5, r=3, c=1, s=0.249, l=1 (a) b= 1, g=0.3 (b)

The principal changes in the stationary distribution occur in small populations (M between 100 and 500). In voluntary games without punishment, the system spent most of the time in solitary state and the time increases as the population increases (Figure 1:a). With punishment, the system spent most of the time in punisher state even with small populations (Figure 1:b).

In SBs, participation is generally non-compulsory. SBs have mechanism to impose fines and shut down the service if it is necessary, but it is difficult to implement in small communities because the authorities work ad honorem and try to avoid conflicts with neighbours [4]. Larger SBs hire people to administrate the board. If punishment is difficult to apply, it seems better to have small SBs, for $M = 100$ the relative time spent in cooperation and loner states are quite similar but when the population increments, the time spent in cooperation state drops down while time in loner state moves upward. If punishment is possible, even for small population the system spent most of the time in the punisher state, but the effect is more noticeable for M larger than 500.

References

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