Prey-Predator Coexistence

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1 Abstract

In this work, conditions, under which preys can survive in a closed system with predators, are examined by agent-based modeling. Different parameters are considered during simulation. Due to numerous combination of parameters, around 6000 simulations were carried out. Some of the major parameters are warning of predators between preys, whether preys can prepare a trap and have camouflage skills. Results show that there are parameter combinations that can bring about equilibrium even after long iterations.

2 Introduction

Coexistence of species in a closed system is one of the major topics inspected under the union of different fields namely evolution, game theory, mathematics, computer science etc. One reason of attraction to this phenomenon is that it is too complex for analytic explanation or simple modeling. Besides, there are numerous parameters that can give edge to one species over another.

A few of relationship classes are possible between biological organisms such as mutualism, commensalism, parasitism etc. Similar to parasitism, predation is a consumer-resource interaction. Main concern of this work is to enlighten the factors leading to the preys' survival in the long run despite the natural adversity.

3 Rules and Parameters

Simulations are done based on agent-based modeling. Two species, a prey and a predator, are randomly born on a conventional grid-like, torus-shaped map because using a bordered map rather than torus caused preys to be easily cornered and go extinct quickly. Predators have an aggressive tendency against preys. They lock on preys and chase to kill until either the prey is caught or out of sight.

Both species are assumed to have the same vision quality in terms of range and angle. Predators have better speed and worse stamina in all simulations due to their explosive nature. Simulation starts with the equal number of agents for both species.

The total population is kept constant during all the simulation. When an agent dies somehow, an agent from the rest is picked and allowed for reproduction.

3.1 Warning Mechanism

Preys run away from only one predator until the distance is far enough. For the predators to be seen by preys, they need to be in sight of preys which is probabilistic. Additionally, preys can signal each other to be aware of a close predator. This mechanism gives slight advantage to preys while being alert.

3.2 Trap Mechanism

Preys are smart enough to prepare a trap with a probability p_t while they are not being chased. Once a trap is installed, it will remain intact until a predator falls into it and dies.

3.3 Camouflage

Randomly chosen areas on the map are camouflage area for preys to hide. A predator can't spot a prey while hiding unless the predator is not already chasing it.

4 Results and Experiments

4.1 Experiments

Variant parameters as follows:
n in grid size$(nxn) = [100, 200, 500]$
speed(prey, predator) $= [(1, 2), (2, 3)(3, 4), (4, 5)]$
stamina(prey, predator) $= [(5, 8), (10, 13), (15, 18), (20, 23), (30, 33), (50, 53)]$

camouflage area percentage with respect to total area $= [0.0, 0.1, 0.15, 0.20, 0.25]$ **warning mechanism** $= [False, True]$
trap mechanism $= [False, True]$
trap probability $= [0.2, 0.4, 0.6, 0.8]$

There are 5760 combination of different parameters in total. Simulation for each combination is done and frequency results of each species are reported after 200 iterations.

Before the simulations are started, a visual environment is set for testing functionality of properties and interaction between agents.

A system is assumed to be in equilibrium if the frequency of preys are between 0.4 and 0.6 so such systems are filtered after all the simulations are finished. Barely half of the data was in equilibrium. Among those states, histogram of every parameter, pair and trio of parameters are inspected and the ones with the significant effect on results are presented here.

4.2 Results

The most effective property among all is the grid size. The obvious trend can be seen in Fig 1. This is probably due to sparse population of agents and low possibility of encounter.

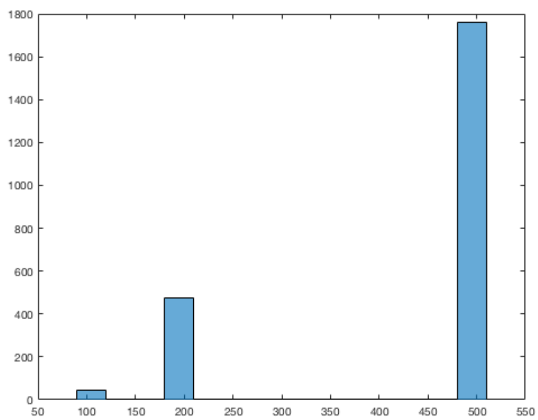

Figure 1: Histogram of grid size(n) for states in equilibrium

Trapping mechanism also help preys survive for long periods. The mechanism were present in 66% percent of equilibria. Besides, as in Fig 2, increasing probability of trapping helps in small portions but consistently. Since trapping can be seen as an offensive move of preys, it is more effective when encountering is more likely. Therefore, its contribution is subsided as the total grid area gets larger.

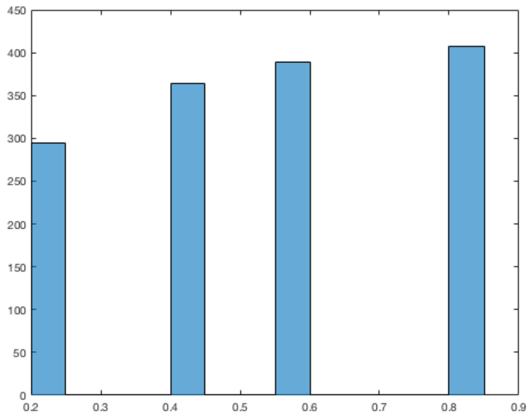

Figure 2: Histogram of trapping probability for states in equilibrium

Even though the contribution of camouflage is small compared to grid size and trapping, it still has a visible effect on the results Fig 3. When camouflage is taken into consideration with total area, the results showed that having larger camouflage area does not help when the total area is small.

It would be fair to advocate that large map size boosts the effect of defensive skills while alleviating offensive skills.

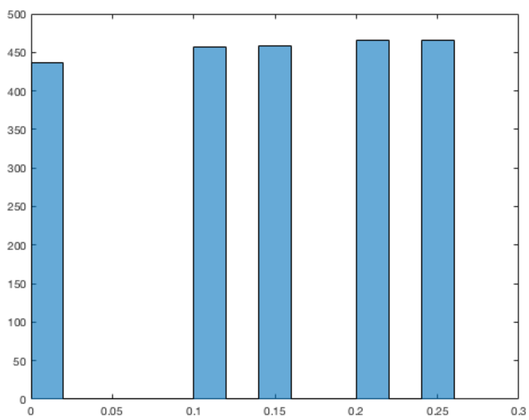

Figure 3: Histogram of proportion of camouflage area to total area for states in equilibrium

Results suggest that communication has no impact whatsoever in helping survival of preys. Even though stamina might be expected to make a difference in large maps, there were no visible indication of that either.

5 Restrictions and Conclusion

It is a difficult task to investigate the impact of many parameters since the combination of them increases exponentially. This became the bottleneck of this work and it was doomed to be done with a small range of parameters.

In this work, positive effect of grid size, trapping and camouflage on preys' survival has been shown. Additionally, we also see that influence of offensive actions are negatively correlated with map size whereas that of defensive actions are positively correlated.