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Simulation: Predators & Prey

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Abstract

Wolves and sheep (or predators and pray) is a classic population simulation and model that describes the dynamics of biological system. Our model builds up on this classic simple representation with introducing more complex behaviors and more agents. That way we can explore more complex population relationships and population curves.

Our goal is to model more complicated ecosystem and find balanced in this ecosystem using as much realistic inputs as we can. Also we want to explore only prey behavior in situations where are no predators and different types of prey compete with each other. Last but not least we introduce humans in to the simulation and want to test the theory that they will dominate the ecosystem.

In the future we can build up on this model and introduce even more species and more complex behaviors to find more interesting data and explore more complex relationships.

Keywords: simulation, agent-based, model, NetLogo, predators, prey, wolves, sheep

1 Problem definition

Predators and Prey is a classic description of population dynamics model which explores relationships in biological system between predatory and prey species. This problem tries to find causality between prey and predator agent numbers and their influences and interactions with each other. This problem can be also explored via differential equations called Lotka-Volterra equations:

$$\frac{dx}{dt} = ax - bxy$$

$$\frac{dy}{dt} = cxy - dy$$

Where *x* is the number of prey, *y* number of predator, fractions represent growth rates over time, *t* is time and *abcd a*re positive real parameters describing the interaction of the two species. (1)

Our goal is to model more complex biological ecosystem and find more interesting data that could show us how this dynamic system would behave in reality in nature. We build up on the simple model from Wilensky (2007) and we are going to use NetLogo 5.

Because we want to explore not only predator and prey relationship but even relationships between only preys we need to add more than species. Also we want to have more predators and since our other goal is to explore human impacts we also introduce human into the environment.

And since we are also interested in more complex behavior we model not existing species called “werewolf” which can only reproduce by infecting other agents.

2 Method

2.1 Methods and tools

We need to simulate multi-agent dynamic system so we first need to select proper software. Since the problem we are expanding is already been done in smaller complexity using NetLogo we are going to select the same software and build up on existing models.

Since we build up on existing model we only need to add our new agents and program our new behavior. We only use NetLogo 5.3.1 (version from February 29, 2016) and its features which means we are only using its plaintext code editor and basic UI editor.

We need to develop UI and add more user input sliders for our new variables and also add our new agents to the plot chart.

Using NetLogo is a good choice since this software is great for simulating dimensionless environment and can handle a lot of agents (up to thousands). Also since our simulation is educative and we don't need more polished and intricate features NetLogo offers good value for its learning curve for the user.

2.2 Description

Our simulation consists of 5 agent types and two non-agent entities (grass and berries). Agents are explained lower in more detail. All these agents interact in dimensionless environment displayed as a 2D plane. All agents gather as much energy as possible via eating and then reproduce as much as possible. Prey can be eaten when predator is nearby. Predator can be eaten if he wins a fight.

This means that every time two predators meet up, they have to fight with each other. And if a predator cannot defend himself he becomes pray. This is determined by chance (randomly generated number times agent's attack strength).

Two prey we have in a simulation are mice and sheep. They only eat grass or berries which grow on patches. Mice are much more fast and can breed really fast so their population can get out of hand very quickly. Sheep are much bigger - they provide more energy - but also slower and breeding is more difficult.

All turtles[1] have:

Energy - is consumed when moving around and is replenished by eating, if it hits 0 the agent will die. Energy is also used for reproducing.

Attack - this is the attack force modifier for the turtle; bigger it is the bigger the chance for turtle to win the fight

Speed - bigger the speed, more patches can be crossed in one move

Movement modifier - this is used to decrease/increase the movement cost for some agent types

Patches can grow grass and some patches (determined by random chance) can grow berries which provide more energy.

2.3 Agents

2.3.1 Mice

Mice are herbivore, small, they can breed easily and are fast. They also provide small amount of energy.

Attack	0
Speed	2
Starting energy	80
Movement modifier	0.1
Shape	Mouse
Color	Gray
Reproducing energy cost	100

2.3.2 Sheep

Sheep are a bigger herbivore that can eat grass or berries. They provide more energy than mice.

Attack	0
Speed	1
Starting energy	100
Movement modifier	0
Shape	Sheep

[1] Turtle is a NetLogo terminology for agent

Color	White
Reproducing energy cost	120

2.3.3 Wolves

Wolves are a classic predator that can eat mice, sheep or humans.

Attack	1
Speed	1.2
Starting energy	100
Movement modifier	0
Shape	Wolf
Color	Brown
Reproducing energy cost	190

2.3.4 Werewolves

These are a special kind of an agent. They are strong but their breeding is much more complex. They have to "infect" other turtle that dies and werewolf is born. These turtles are in the model for much more complex population behavior. They can eat mice, sheep, wolves and humans.

Attack	1.2
Speed	1.5
Starting energy	120
Movement modifier	-0.2
Shape	Newwolf
Color	Black
Reproducing energy cost	300

2.3.4.1 Humans

Humans can dominate all turtles. They are only omnivorous turtles so they can eat mice, sheep, werewolves, wolves and also berries.

Attack	1.9
Speed	1.7
Starting energy	250
Movement modifier	-0.5

Shape	Person
Color	Blue
Reproducing energy cost	250

2.4 User inputs

We provide several slider inputs for the user which are used to influence the most important variables in the model. These inputs are:

- Number of mice (number of agents from this species at the start of the simulation)
- Number of sheep
- Number of wolves
- Number of werewolves
- Number of humans

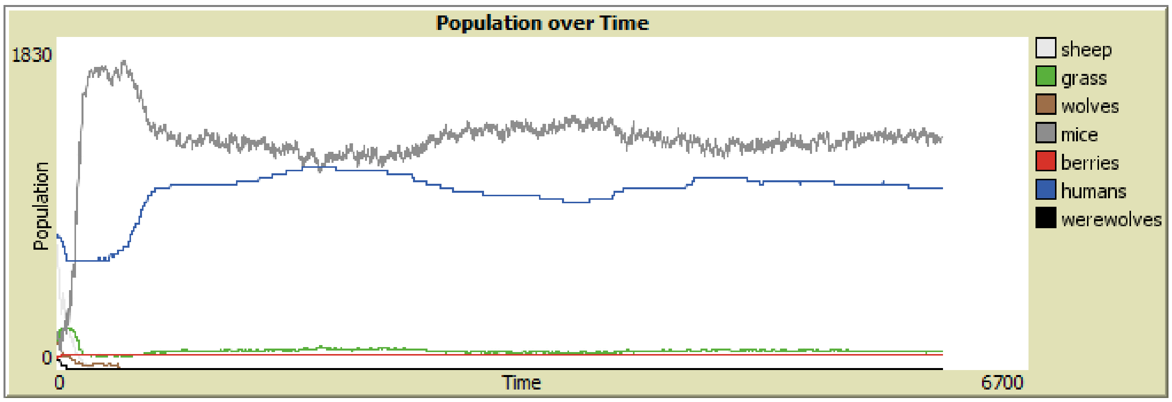
- Energy from grass (energy gained from eating)
- Energy from berries
- Energy from mice
- Energy from sheep
- Energy from wolves
- Energy from werewolves
- Energy from humans

- Movement cost (energy cost of each move)
- Grass regrowth rate (rate of grass replenishment at each patch)
- Berries regrowth rate

3 Results

3.1 Case 1: Balance

In this case we try to simulate real world scenario. Goal is to find a dynamic equilibrium and find out which turtles are going to be left.



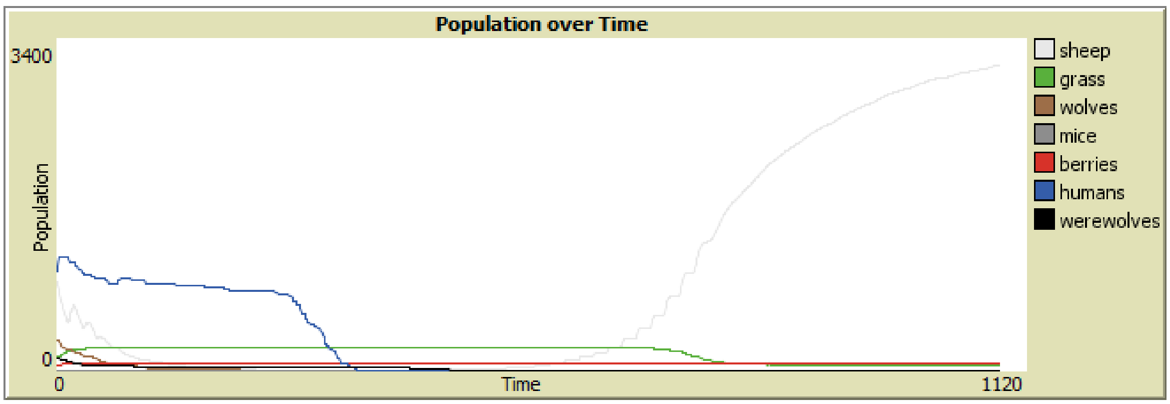
Obrázek 1 Balanced system (author)

As we can see with these realistic settings we can reach a dynamic balance between mice and humans. Mice can no longer reproduce more because they have no more grass and berries and if human numbers go up mice go down and humans start to decline as well.

3.2 Case 2: Sheep domination

Now we turn off mice and set movement cost to a much lower number. This means sheep can reproduce much more easily.

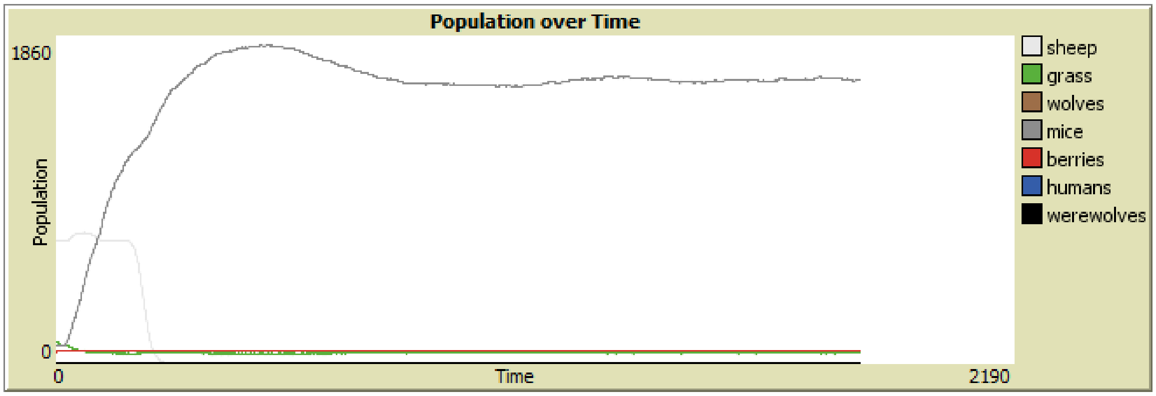
We did not find the balance in the ecosystem between the prey and predators. Sheep managed to survive because the predator numbers were too small and without mice they had much less food then in the first case. This meant that sheep population skyrocketed (to about 3000 sheep) and then found balanced (around 1500 sheep) between population and grass/berries.



Obrázek 2 Sheep domination (author)

3.3 Case 3: Prey infestation

In this case we turn on only mice and sheep to find out if the mice will dominate - as is expected.

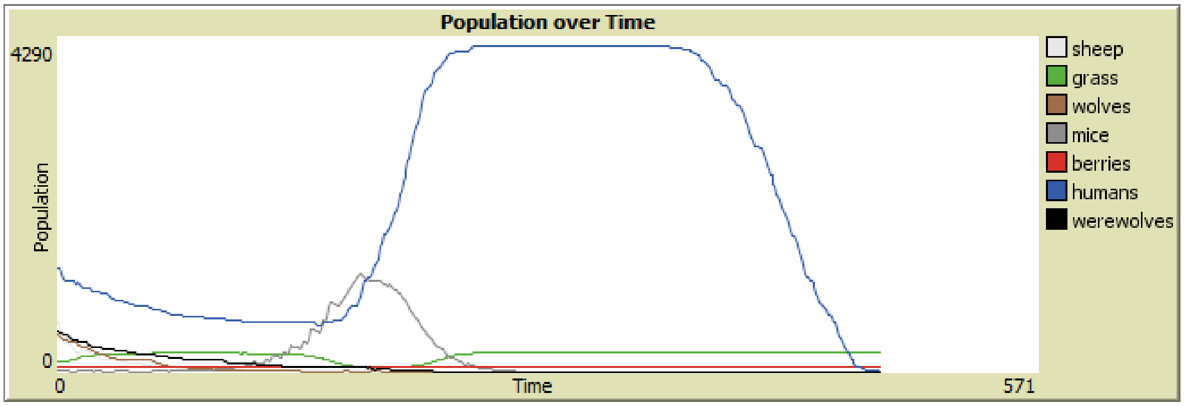


Obrázek 3 Prey infestation (author)

And hypothesis is confirmed - since mice need lot less energy to produce then sheep they quickly gain numbers and start to eat a lot of grass and berries. This makes sheep extinct and mice find balance.

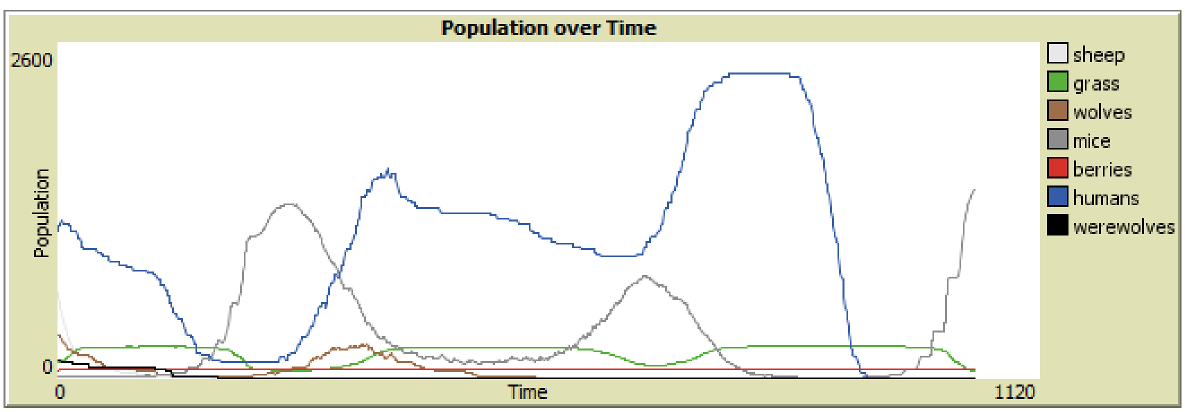
3.4 Case 4: Humans

In the last case we give humans small advantage in starting numbers. Plan is for them to dominate the landscape. But usually they kill all other predators and then just sheep or mice (depending who wins for the herbivores) and humans are left. Then human population gets out of control and since they eat all sheep/mice they die out because berries are not enough food.



Obrázek 4 Human domination (author)

In some tries we can see little bit of a balance but still either humans eat all of the prey or the prey survives and then dominate.



Obrázek 5 Human balance (author)

4 Conclusion

This simulation provides much more detailed look into Predators & Prey problem. Because there is a lot more variables it is harder to find dynamic equilibrium. But if this balance is found it is usually between one predator and one prey. That is the most important finding. Also it quite nicely mirrors nature – if an agent can reproduce easily and has little or no predators it will quickly intestate the whole system.

Also it is quite interesting to play with different inputs and in the future this simulation could be made even more complex, with more agents, more dynamic behaviors and all of the variables made as user inputs (speeds, attacks, random seeds etc.)

5 Bibliography

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6 Attachments

Esterka_sim_wolf-sheep.nlogo