# Population dynamics (foxes and rabbits)

Trains: for-loops

## Question:

The number of predators and prey in a region depend on each other. Let's make the following assumptions for a model describing these relationships between foxes (predator) and rabbits (prey):

Rabbits have unlimited food supply. Thus, the rabbit population increases by 5% each day as the net result of birth and natural death. At the same time, the rabbit population is decreased by the presence of foxes. The decrease is proportional to the number of encounters between rabbits and foxes. The more foxes there are, the more rabbits are being caught and the more rabbits there are, the easier it is for foxes to catch the rabbits. Specifically, each day the rabbit population is reduced by 0.0002\*(number of foxes)\*(number of rabbits).

The fox population decreases by 10% per day as the net result of birth and natural death independent of the number of rabbits. The presence of rabbits has a positive influence on the number of foxes. This depends on how many rabbits are being caught and this is again dependent on the number of foxes as well as the number of rabbits. The increase amounts to 0.0001\*(number of foxes)\*(number of rabbits) each day.

Note that in order to calculate the changes in fox and rabbit populations, you should use the fox and rabbit numbers from the start of the day.

## Warm-up 1:

Simulate how large the rabbit population will be in the absence of foxes after 40 days (initial population: 1000, increase of 5% a day). Don’t calculate the outcome directly, but use a loop instead. The program should go through this loop 40 times and increase the population by 5% each time it goes through the loop.

Answer (white): 7039 rabbits

## Warm-up 2:

If foxes are present, the daily change in rabbit population (prey) will be: 0.05\*rabbit-0.0002\*fox\*rabbit. Simulate the hypothetical case that the fox population does not change and is always 100. What will the rabbit population be after 10 days if it starts with 1000? Your program should work with float without rounding, except for the final answer, which is to be rounded down to an integer.

Answer: 1343

## Exercise 1:

Enter the numbers of foxes and rabbits respectively after 200 days, if there are 100 foxes and 1000 rabbits present in the beginning. Your program should work with float without rounding, except for the final answer, which is to be rounded down to an integer (manually).

Answer: 1379 rabbits, 58 foxes

## Exercise 2:

Use the same predator and prey model as for the previous unit, but test how many foxes and rabbits are present after 1542 days instead of 200.

Answer: -298914 rabbits, -216 foxes

The above artefact may be prevented by updating the populations each hour instead of each day. This decreases the probability of negative populations, since the number of animals that die during an hour is smaller than the number that die during a day. In addition, since the populations are updated more often, a decrease in population size will more quickly lead to a decrease in death rate, since death rate depends on population size.

Change the model and update the populations each (simulated) hour. Assume that the population change per hour is equal to the population change per day divided by 24. For example, in day one the rabbit population increases by 30 (50 rabbits (net) born, 20 eaten by a fox) whereas in hour one the rabbit population increases by 30/24 (50/24 born, 20/24 eaten).

Simulate 200 days.

Answer: 1514 rabbits, 142 foxes

By updating the model each hour, the negative populations disappeared. However, the model would be somewhat more realistic if birth and death rates would be continuously adjusted to the current population sizes.

Change the model and update the populations each minute now instead of each hour. Simulate 200 days again.

Answer: 1510 rabbits, 146 foxes

The difference in results between updating every hour and updating every minute was not that large. If you would update the populations every second, you would find that the results are, rounded to whole animals, the same as for updating every minute. You can check this if you like, even though this may require some computational time.

It thus seems not to make a difference any more to use smaller time steps.