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Simulation of a stochastic predator-prey model with external fluctuations

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Abstract

We have built a stochastic predator-prey model for educational purposes in the interactive modelling environment VensimPLE*. The predator-prey model is simulated using Gillespie's stochastic simulation algorithm. A external fluctuation source is added to the model. Population dynamics are studied under different parameter values. External fluctuations effectively change the phase portrait. This model allows to understand and investigate the different evolution dynamics in a very simple way.

Keywords: predator-prey, simulation, stochastic

1 Introduction

Gillespie's stochastic simulation algorithm was made by Daniel T. Gillespie to simulate chemical and biochemical systems of reactions [1-2] and it is widely used today especially in astrochemistry [3]. To better understand the problem, we have built a simple stochastic predator-prey model avoiding the assumption that the rate of prey death equals the rate of predator birth (which is usually the case for chemical reactions) and on top of that we add an external fluctuation term.

2 Predator–prey Vensim model

The sketch of the model is shown in FIG. 1

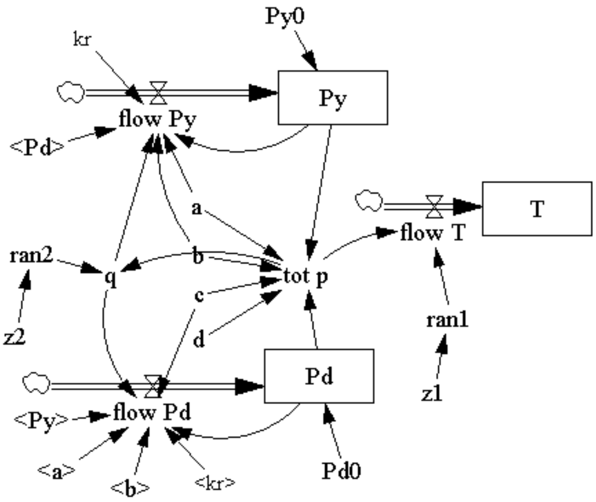

FIGURE 1 Predator-prey model sketch

The corresponding differential equations (deterministic case) are

$$\frac{dPy}{dt} = a \cdot Py - b \cdot Py \cdot Pd + f(t)$$
$$\frac{dPy}{dt} = c \cdot Py \cdot Pd - d \cdot Pd + f(t),$$

where Py stands for the number of prey and Pd for the number of predators; f(t) is the external fluctuation term which conforms to a uniform distribution; a, c are birth rate coefficients and b and d are death rate coefficients for the prey and predators respectively.

VensimPLE code for realising the Gillespie algorithm in the model:

*Flow Py=IF THEN ELSE(q<ABS(a*Py), 1, IF THEN ELSE(q<ABS(a*Py+b*Py*Pd), -1, 0))+ kr*RANDOM UNIFORM(0, 1, 5),*
*Flow Pd=IF THEN ELSE (q<ABS(a*Py+b*Py*Pd+ c*Pd*Py), 1, -1)+ kr*RANDOM UNIFORM(0, 1, 25)*
*tot p=ABS(a*Py)+ABS(b*Py*Pd) +ABS(c*Pd*Py)+ABS(d*Pd)*
*Flow T=-1/tot p*LN(ran1)*

Parameter values were chosen a=0.04, b=0.01, c=0.04, d=1.4, Py0=30, Pd0=20, kr=0, TIME STEP=1, FINAL TIME=4000. The Parameter kr characterizes the intensity of fluctuations.

Here we show the population dynamics (Figure 2) and the phase portrait (Figure 3).

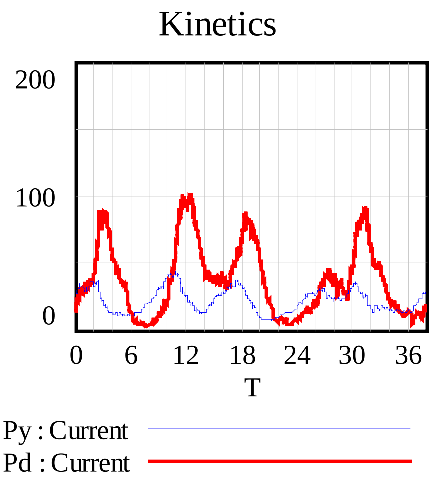

FIGURE 2 Predator-prey kinetics. Kr=

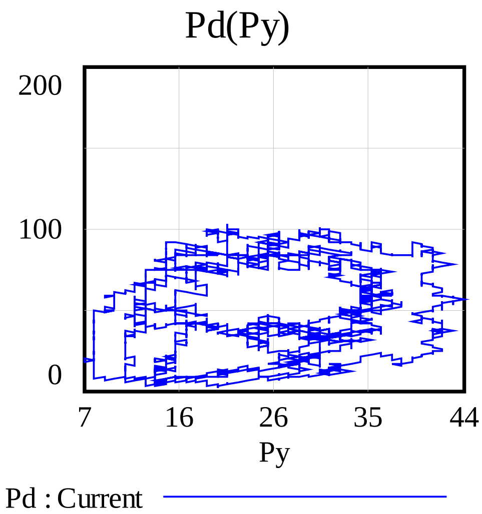

FIGURE 3 Predator-prey phase diagram.kkr=0

In the case of kr=0.134 we see more pronounced periodicity (Figure 4). And a more concentrated phase portrait (Figure 5).

*Ventana Systems. Inc software

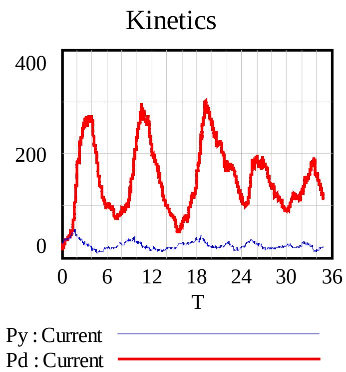

FIGURE 4 Predator-prey kinetics, .kr=0.134

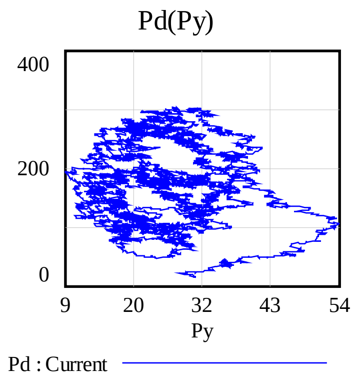

FIGURE 5 Predator-prey phase picture, kr=0.134

7 Conclusions

A simple demonstration of a stochastic predator-prey model is built in VensimPLE. It is very easy to change the parameters of the simulation in Vensim which gives the possibility to find different interesting features of the model. This model is easily reproducible and different scenarios can be evaluated visually immediately.

Acknowledgments

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References

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