Set -7: Competitive exclusion and predator-prey dynamics

Dhananjay Vora (2020001417)* and Kashish Shroff (202001425)†
Dhirubhai Ambani Institute of Information & Communication Technology, Gandhinagar, Gujarat 382007, India
CS302, Modeling and Simulation

In this report, we studied the Principle of Competitive Exclusion in Population Biology for two species in nature and modelled Predator-Prey dynamics for species living in same ecological territory.

I. COMPETITIVE EXCLUSION

A. Introduction

In nature, the struggle for survival between two closely related species, contending for the same scarce food supply and living area, almost always results in the total extinction of one species.

B. Model

The logistic equation for this model is given by the following coupled equations,

$$\dot{x} = Ax - Bx^2 - \alpha xy \tag{1}$$

$$\dot{y} = Cy - Dy^2 - \beta xy \tag{2}$$

Here $x(t)$ and $y(t)$ are the population densities of species X and Y respectively. Taking $A = 0.21827$ and $C = 0.06069$ in all cases. Also α and β are competition parameters.

C. Results

1. For $x(0) = 0.5$, $y(0) = 1.5$, $B = D = 0$, $\alpha = 0.05289$ and $\beta = 0.00459$

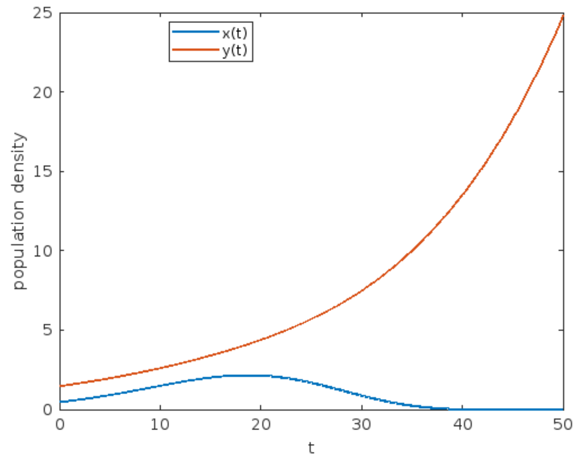

fig. 1. Plot of Population density vs Time

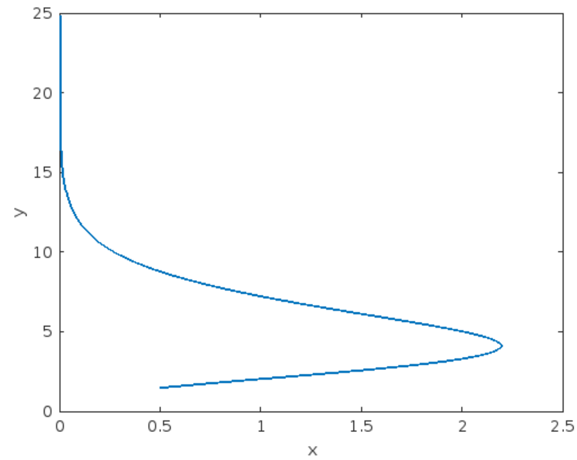

fig. 2. Plot y vs x

*Electronic address: 202001417@daiict.ac.in
†Electronic address: 202001425@daiict.ac.in

2. *For* $x(0) = 0.5,\ y(0) = 0.5,\ B = 0.017,\ D = 0.010,$ $\alpha = 0.05289$ *and* $\beta = 0.00459$

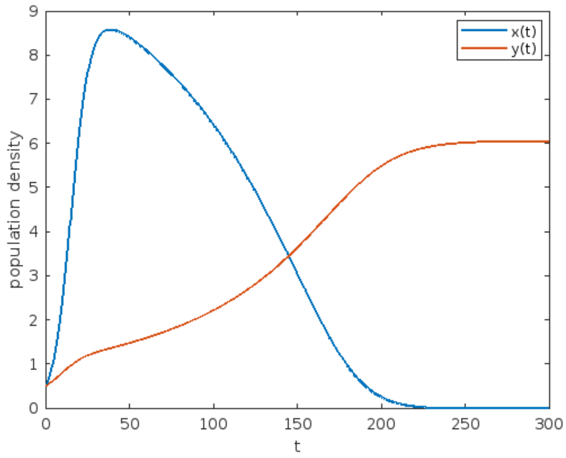

fig. 3. Plot of Population density vs Time

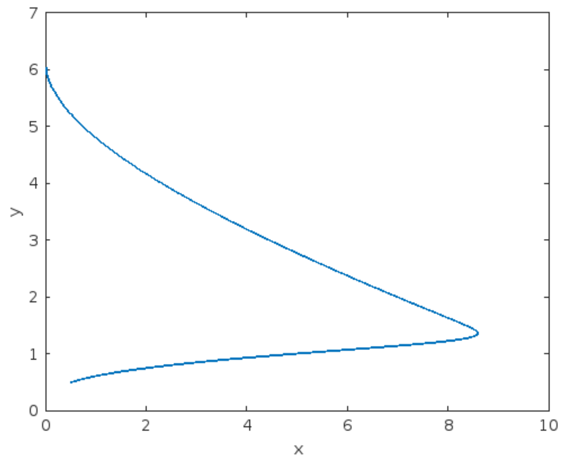

fig. 4. Plot y vs x

3. *For No Competition take* $x(0) = 0.5,\ y(0) = 0.5,$ $B = 0.017,\ D = 0.010$ *and* $\alpha = \beta = 0$

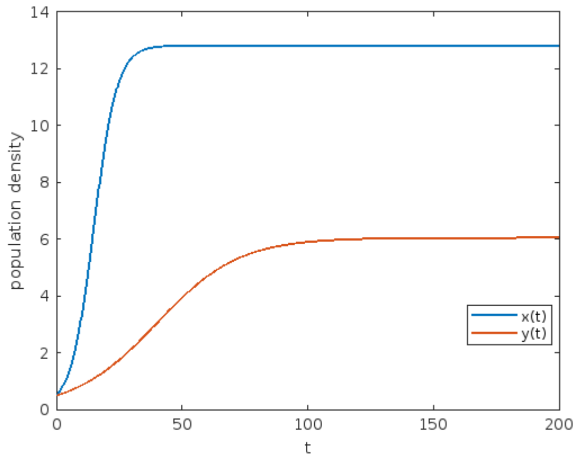

fig. 5. Plot of Population density vs Time

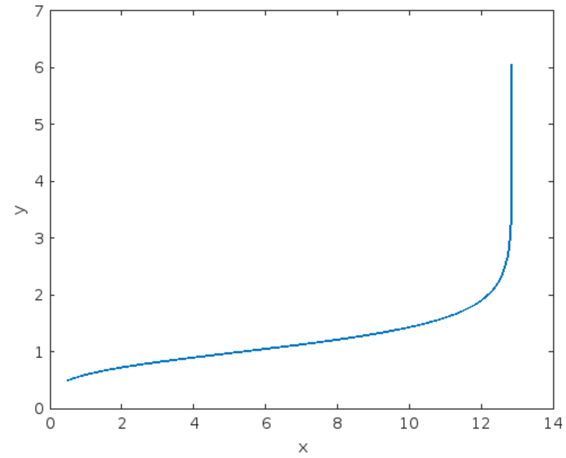

fig. 6. Plot y vs x

Max values		
Condition	x	y
When $B = D = 0$	2.1908	24.9
When $B = 0.017$ and $D = 0.010$	8.59	6.069
For no competition	12.84	6.069

D. Conclusions

- Only when x and y are coupled together in the cross terms does the competitive interaction become operative. Thus, with no competition population densities of both species grows and then saturates.

- More of these formulae can be written down with more species. (n order system).

II. PREDATOR-PREY DYNAMICS

A. Model

The logistic equation for this model is given by the following coupled equations,

$$\dot{x} = Ax - Bxy - \epsilon x \tag{3}$$

$$\dot{y} = -Cy + Dxy - \epsilon y \tag{4}$$

Here $x(t)$ and $y(t)$ are the population densities of prey species X and predator species Y respectively. Taking $A = 1$, $B = 0.01$, $C = 0.5$ and $D = 0.005$ in all cases. Also ϵ is parameter of human interference. For no interference $\epsilon = 0$ and with interference $\epsilon = 0.1$.

B. Results

1. Without human interference, $\epsilon = 0$.

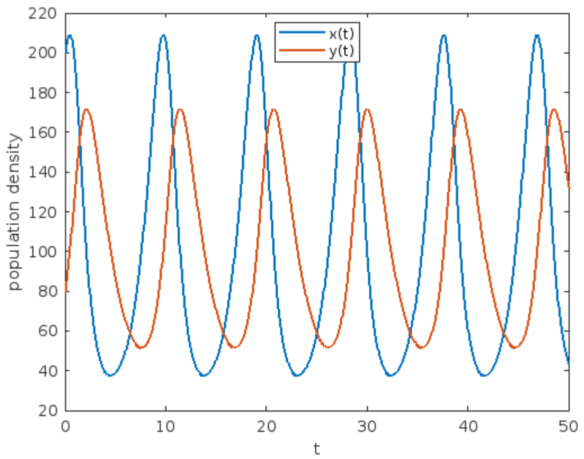

fig. 1. Plot of Population density vs Time

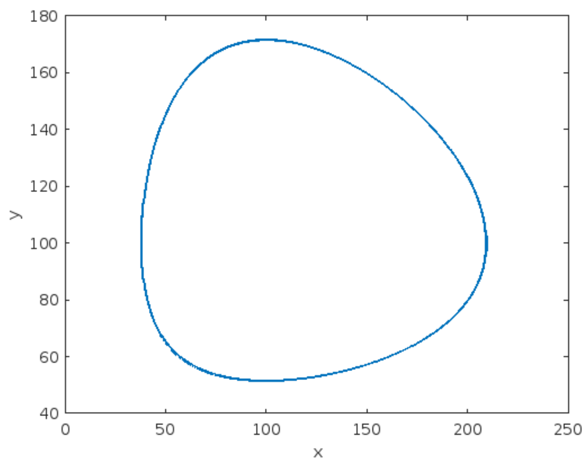

fig. 2. Plot y vs x

2. With human interference, $\epsilon = 0.1$.

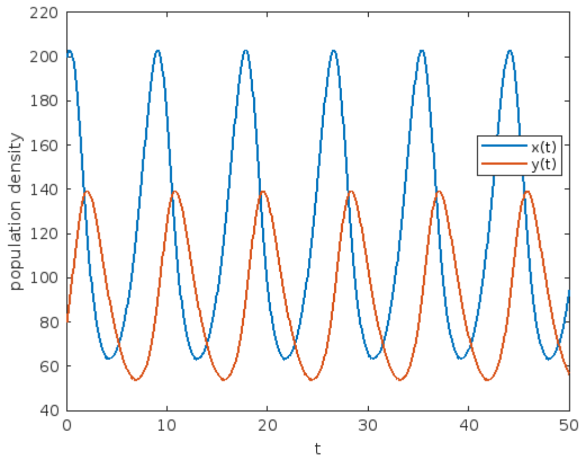

fig. 3. Plot of Population density vs Time

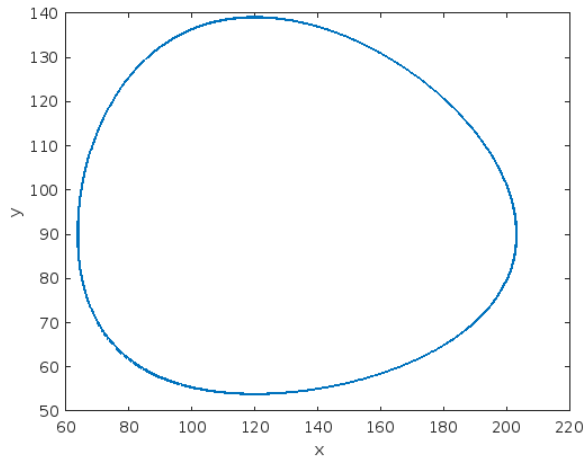

fig. 4. Plot y vs x

3. When $x(0) = 200$ and $y(0) = 0$.

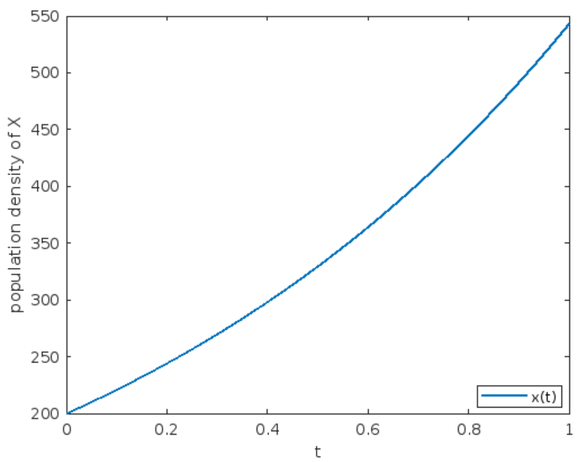

fig. 5. Plot of Population density of X (Prey) vs Time

4. When $x(0) = 0$ and $y(0) = 80$.

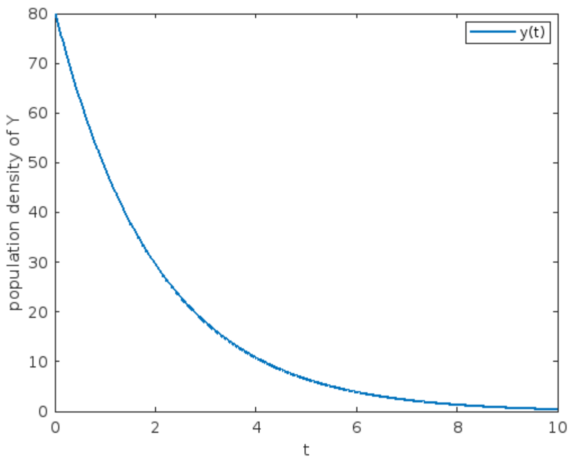

fig. 6. Plot of Population density of Y (Predator) vs Time

Max values	
Condition	y
Without Human Interference	171.7422
With Human Interference	139.2045

C. Conclusions

- We can conclude by comparing the graphs that with human interference in a region with two species i.e. predator and prey, the population density of predator species decreases.
- When there is only prey species in the region, the population density of prey species grows as there will be abundant food supply and competition among the prey species won't be intense.
- When there is only predator species in the region, the population density of predator species falls down as it is unsustainable and with growing number their growth rate decreases.

[1] Nair, R., Nagarjuna, G. and Ray, A.K., 2009. Finite-size effects in the dependency networks of free and open-source software. arXiv preprint arXiv:0901.4904.

[2] Mullick, A. and Ray, A.K., 2016, October. Nonlinear dynamics of bimodality in vehicular traffic. In Journal of Physics: Conference Series (Vol. 755, No. 1, p. 012009). IOP Publishing.

[3] Ray, A.K. (2010). Modeling Saturation in Industrial Growth. In: Basu, B., Chakravarty, S.R., Chakrabarti, B.K., Gangopadhyay, K. (eds) Econophysics and Economics of Games, Social Choices and Quantitative Techniques. New Economic Windows. Springer, Milano. https://doi.org/10.1007/978-88-470-1501-2$_1$4