How does Personality affect an Predator-Prey System?

Jitendra Padmanabhuni[1], Shohel Ahmed[2], Hao Wang[2]

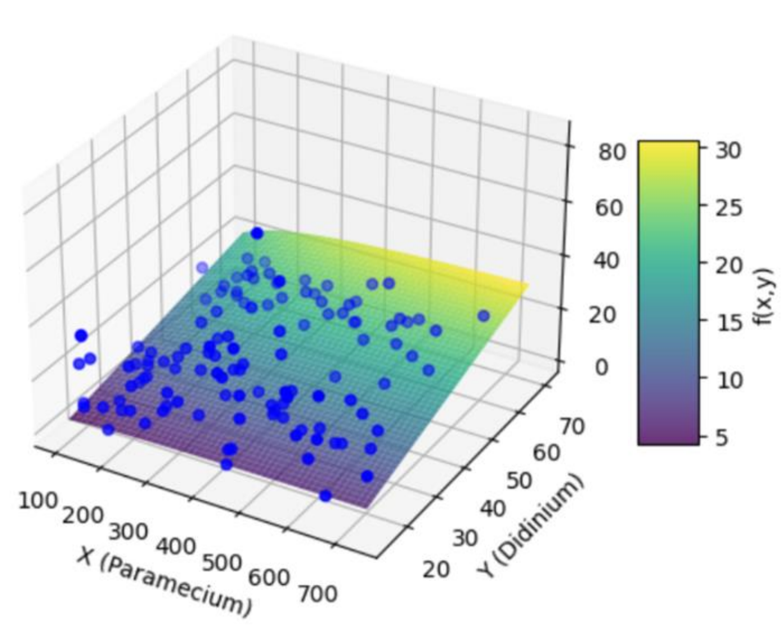
[1]Department of Mathematics, IIT Kharagpur, [2]Department of Mathematical & Statistical Sciences, University of Alberta

MOTIVATION

- Today there are increasingly vulnerable species that require conservation efforts at the earliest. It is thus important to be able to identify how endangered a species is.
- There are several models that try to predict the populations of animal systems over time. We improve upon these models by incorporating a few key ideas:
  - It's not just the size of a population group that determines the future populations of a system but their personality as well!
  - A predator is bolder when it's prey availability is low or when it's competition is high.
  - A bolder predator is more likely to be hunted by an external predator.

JUSTIFICATION

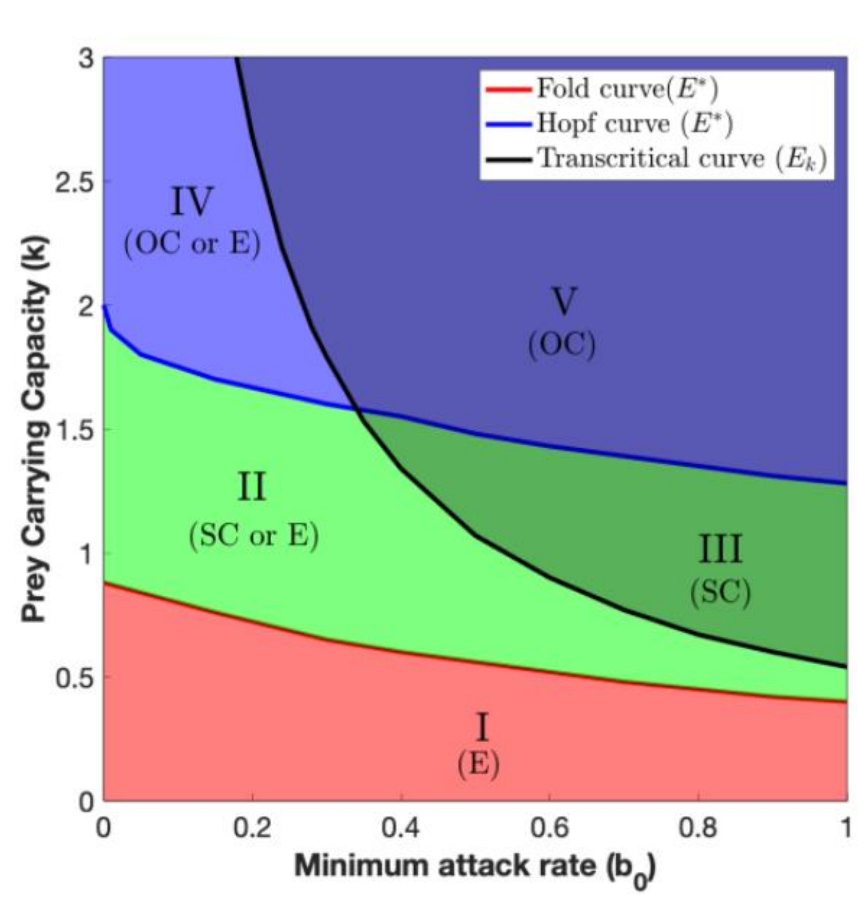
Fitted functional response f(x, y) results for model (1) with coefficient of Determination $R^2 = 0.7$

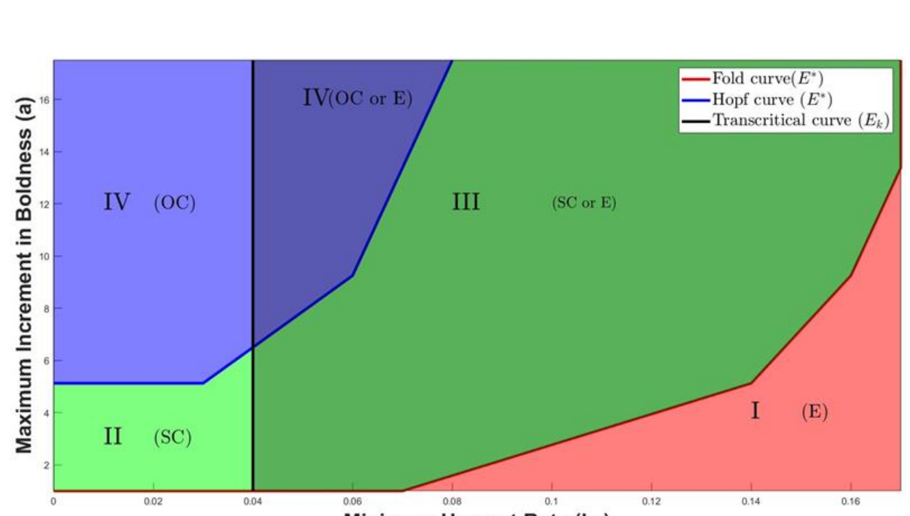


Data collected from DeLong et al. (2014).

RESULTS

The Bifurcation Diagram between the Prey Carrying Capacity (k) and the Minimum Attack Rate of the Predator (b_0)





The Bifurcation Diagram between the Maximum increment in Boldness (a) and the Minimum Harvest Rate of the Predator (b_1)

THE MODEL

The Rosenzweig-MacArthur Predator-Prey Model

- $$\underbrace{\frac{dx}{dt}}_{\text{Change in prey density over time}} = \underbrace{b(x)x}_{\text{gain from growth}} - \underbrace{f(x,y)y}_{\text{loss from predation}}$$
  $$\underbrace{\frac{dy}{dt}}_{\text{Change in predator density over time}} = \underbrace{ef(x,y)y}_{\text{gain from growth}} - \underbrace{m\,y}_{\text{loss from death}}$$

$$b(x) = r\left(1 - \frac{x}{k}\right),$$

where r is the intrinsic growth rate and k carrying capacity.

$$f(x,y) = \frac{\beta x}{1 + \beta h x}$$

where β is the attack rate, and h handling time.

Our Model (Personality is Introduced)

$$\begin{cases} \dfrac{dx}{dt} = rx\left(1 - \dfrac{x}{k}\right) - \dfrac{\beta xy}{1 + \beta hx}, \\ \dfrac{dy}{dt} = e\dfrac{\beta xy}{1 + \beta hx} - my - H(x,y)y \end{cases}$$

$$\beta(x,y) = b_0 B(x,y)$$

$$B(x,y) = 1 + \frac{a}{c\left(\frac{x}{y}\right) + 1} = 1 + \frac{ay}{cx + y}$$

$$H(x,y) = b_1 B(x,y)$$

DISCUSSION

- **From the Bifurcation Diagrams, we can see how to identify the state of the system and how varying a particular model parameter can drive a system from one state to another.**
- **This analysis can be helpful in driving out invasive species, identifying species at risk and in need of conservation efforts and many more.**
- **We aim to perform more work in this area by tweaking aspects of our model such as the Harvesting Function and see if our model is further validated by real-life scenarios.**