Dynamic Modeling of Population Dynamics

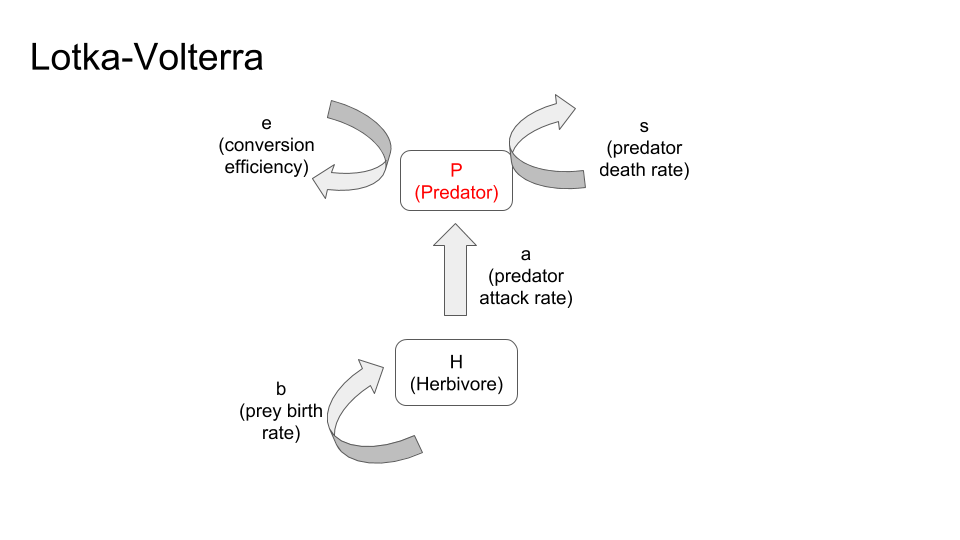
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Introduction to Biocomputing

Final Project- Dynamic Modeling

*I.**Lotka-Volterra Model*

**1. Conceptual model**

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**2. Role of each parameter**

- Prey birth rate (b)- When prey birth rate increases, the amplitudes in both the predator and prey lines increases, but the number of cycles is unaffected. When the prey birth rate decreases, the amplitudes decrease and the number of cycles in a given length of time also decreases.

-Predator attack rate (a)- When predator attack rate increases, the delay in the predator population increasing or decreasing with respect to the prey shortens, and when the predator attack rate decreases, the number of predator-prey cycles in a given length of time increases. Conversely, when the predator attack rate decreases, the delay in the predator population increasing or decreasing with respect to the prey lengthens, and the number of predator- prey cycles in a given length of time decreases.

-Conversion efficiency of prey to predators (e)- Increasing the conversion rate decreases the difference between the amplitudes of the two populations, while decreasing the conversion rate increases the difference between the amplitudes. Decreasing the conversion rate decreases the number of predator-prey cycles in a given length of time, while increasing the conversion rate increases the number of cycles.

-Predator death rate (s)- Increasing predator death rate increases number of cycles and the amplitude of the prey population. Decreasing predator death rate decreases number of cycles and the amplitude of the prey population.

**3. Role of predators**

In the Lotka-Volterra Model, predators rely on the prey population for their survival, but also decrease the prey population. As the prey population increases, the predator population increases slowly, but as the prey population decreases, the predator population decreases after a delay.

**4. Relationship between parameter values and predator-prey cycle length**

-Prey birth rate (b)- When prey birth rate increases the number of cycles is unaffected. When the prey birth rate decreases the number of cycles in a given length of time also decreases.

-Predator attack rate (a)- When predator attack rate increases the number of predator-prey cycles in a given length of time increases. Conversely, when the predator attack rate decreases the number of predator- prey cycles in a given length of time decreases.

-Conversion efficiency of prey to predators (e)- Increasing the conversion rate increases the number of predator-prey cycles in a given length of time slightly, while decreasing the conversion rate decreases the number of cycles slightly.

-Predator death rate (s)- Increasing predator death rate increases number of cycles and the amplitude of the prey population. Decreasing predator death rate decreases number of cycles and the amplitude of the prey population.

**5. Models:**

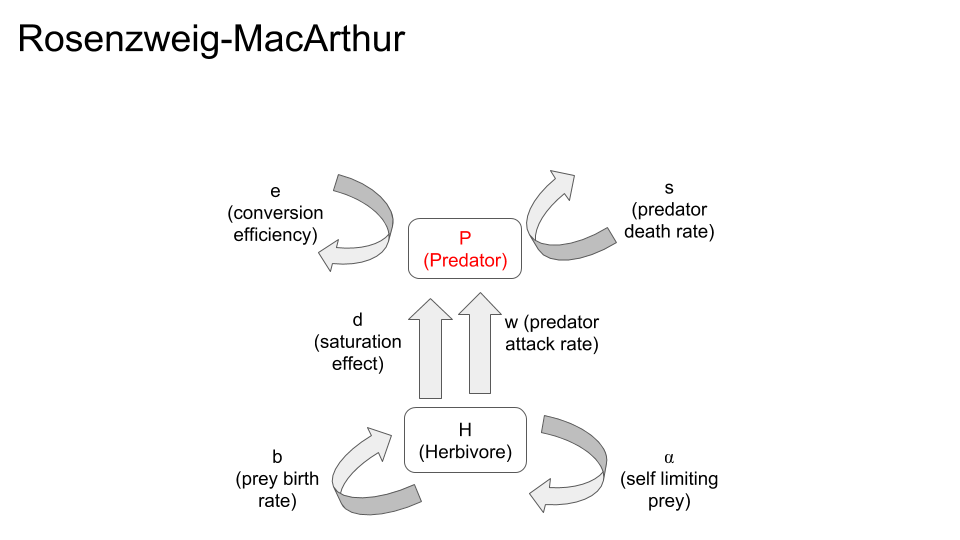
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| **Figure 1. Lotka-Volterra Simulation with Initial Conditions.** Parameters- b=0.5, a=0.02, e=0.1, s=0.2 |

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| **Figure 2. Lotka-Volterra Simulation with changes to Prey Birth Rate (A, B) and Predator Attack Rate (C, D).** Panel (A) demonstrates a fourfold increase in prey birth rate, while panel (B) displays a two-fold decrease in prey birth rate. The change in panel (C) is a two-fold increase in predator attack rate, while panel (D) illustrates a two-fold decrease in predator attack rate. |

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| **Figure 3. Lotka-Volterra Simulation with changes to Conversion Efficiency (A, B) and Predator Death Rate (C, D).** Panel (A) demonstrates a two-fold increase in conversion efficiency, while panel (B) displays a two-fold decrease in conversion efficiency. The change in panel (C) is a two-fold increase in predator death rate, while panel (D) illustrates a two-fold decrease in predator death rate. |

*II. Rosenzweig-MacArthur Model*

**1. Conceptual model**



**2. How dynamics differ from LV?**

Rather than demonstrating a sinuous frequency like in the Lotka-Volterra model, the Rosenzweig-MacArthur model under the initial conditions demonstrates an equilibrium for both populations, rather than a cyclical pattern.

**3. What causes dynamics to differ between LV and RM**

The difference in dynamics is caused by the addition of the *w* term*,* which depicts the self-limiting nature of the prey population,and *d* term,which demonstrates the saturating functional response to predators as a result of prey density. The result of adding these factors is an increased influence of the ecological footprint and carrying capacity for prey populations in the absence of predators, as well as the effect saturation effect on the predator due to abundant prey.

**4. Relationship between parameter values and predator abundance**

- Prey birth rate (b) - When prey birth rate increases the number of cycles is unaffected. When the prey birth rate decreases the number of cycles in a given length of time also decreases.

- Predator attack rate (a) - When predator attack rate increases the number of predator-prey cycles in a given length of time increases. Conversely, when the predator attack rate decreases the number of predator- prey cycles in a given length of time decreases.

- Conversion efficiency of prey to predators (e) - Decreasing the conversion rate decreases the number of predator-prey cycles in a given length of time, but increasing the conversion rate makes little difference on the number of cycles.

- Predator death rate (s) - Increasing predator death rate increases number of cycles and the amplitude of the prey population. Decreasing predator death rate decreases number of cycles and the amplitude of the prey population.

- Self-limiting prey (w) - When the self-limiting effect is increased and prey reach carrying carrying capacity more quickly and a crash in the predator population. Conversely, decreasing the self-limiting nature In the absence of predators, prey become self-limiting in the increased competition for limited resources.

- Saturation effect (d) - The abundance of prey eventually leads predators to become saturated and take in prey at a constant rate.

Fourfold Increase in prey birth rate, decreases the predator equilibrium population, and increases the prey equilibrium population. Two-fold increase in prey birth rate seems to not affect equilibrium populations too much; however, does lead to a slight increase in prey population following the stabilization of the predator population.

Two-fold increase of Conversion efficiency changes the nature of the relationship from equilibrium to cyclical. Decrease in conversion efficiency leads to a total decline of predator population, and an increase in prey population until carrying capacity is reached.

Increase of predator death rate leads to decline of predators and an increase in prey population until carrying capacity. Conversely, a decrease in predator death rate shifts the relationship from equilibrium to cyclical again.

An increase of the self-limiting nature of the prey leads to an immediate eradication of predators and simultaneous carrying capacity of the prey

Increase in saturation effect sees the same response as the self-limiting A decrease in the saturation effect sees the return of a cyclical relationship, only this time, there appears to be a lag

Increase in predator attack rate sees a simultaneous decline in prey population until the predator population arrives at zero and the prey populations increase to carrying capacity.

A decrease in predator attack rate allows for a cyclical pattern between populations.

**5. Models:**

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| **Figure 4. Rosenzweig-MacArthur Simulation with Initial Conditions.** Parameters: *b* = 0.8, *a* = 0.001, *e* = 0.07, *s* = 0.2, *d* = 400, *w* = 5. |

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| **Figure 5. Rosenzweig-MacArthur Simulation with changes to Prey Birth Rate (A, B) and Conversion Efficiency (C, D).** Panel (A) demonstrates a four-fold increase in prey birth rate, while panel (B) displays a two-fold decrease in prey birth rate. The change in panel (C) is a two-fold increase in conversion efficiency, while panel (D) illustrates a two-fold decrease in conversion efficiency. |

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| **Figure 6. Rosenzweig-MacArthur Simulation with changes to Predator Death Rate (A, B) and Self-Limiting Prey (C, D).** Panel (A) demonstrates a two-fold increase in predator death rate, while panel (B) displays a two-fold decrease in predator death rate. The change in panel (C) is a two-fold increase in self-limiting prey, while panel (D) illustrates a two-fold decrease in self-limiting prey. |

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| **Figure 7. Rosenzweig-MacArthur Simulation with changes to Saturation Effect (A, B) and Predator Attack Raate (C, D).** Panel (A) demonstrates a two-fold increase in saturation effect, while panel (B) displays a two-fold decrease in saturation effect. The change in panel (C) is a two-fold increase in predator attack rate, while panel (D) illustrates a two-fold decrease in predator attack rate. |

*III. Paradox of Enrichment*

**1. What happens as carrying capacity increases?**

As carrying capacity increases, the equilibrium between the predator and prey destabilizes and causes a more regular fluctuation like seen in the Lotka-Volterra model.

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| **Figure 8. Rosenzweig-MacArthur Simulation with changes to Self Limiting Prey Rate.** Panel (A) ⍺=0.00125(B) ⍺=0.0009 (C) ⍺=0.0006 (D) ⍺=0.0005. |

**2. Why do we see Paradox of Enrichment?**

The Paradox of Enrichment shows that as the carrying capacity of a population following dynamics of the Rosenzweig-MacArthur Model increase, the equilibrium established between predators and preys destabilizes and instead the populations follow a cyclical pattern. This occurs because although the prey population can grow unbound with a high carrying capacity, the predator population can only grow unbound for so long before crashing from overpopulation. This further leads to destabilization of the prey population since the prey population grows beyond the carrying capacity when the predator population falls and the prey population subsequently falls dramatically.