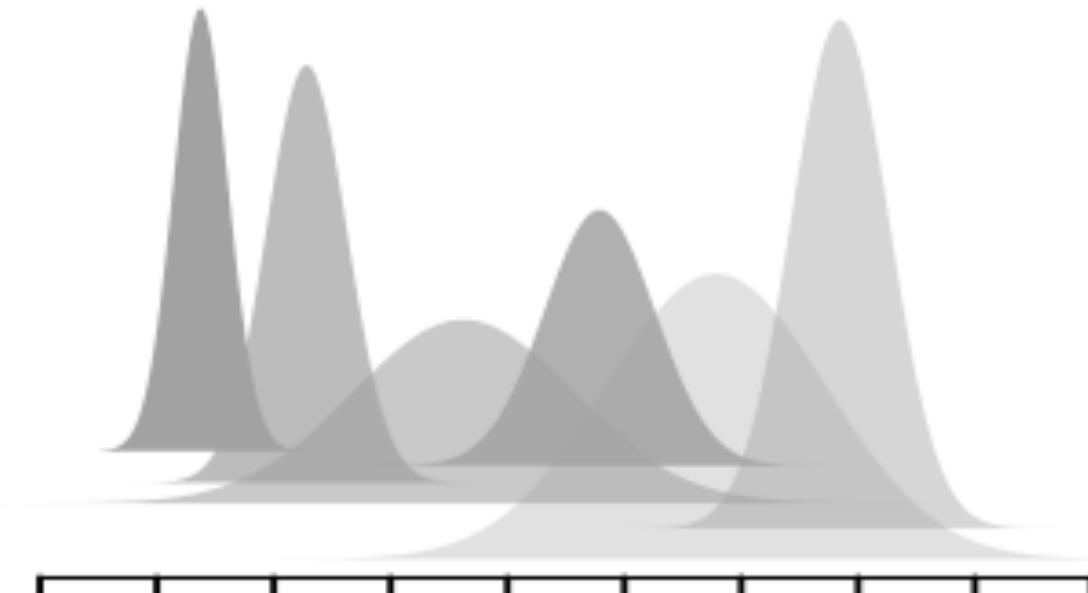


1.1 Introduction to Models in Ecology



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University of Duisburg-Essen**

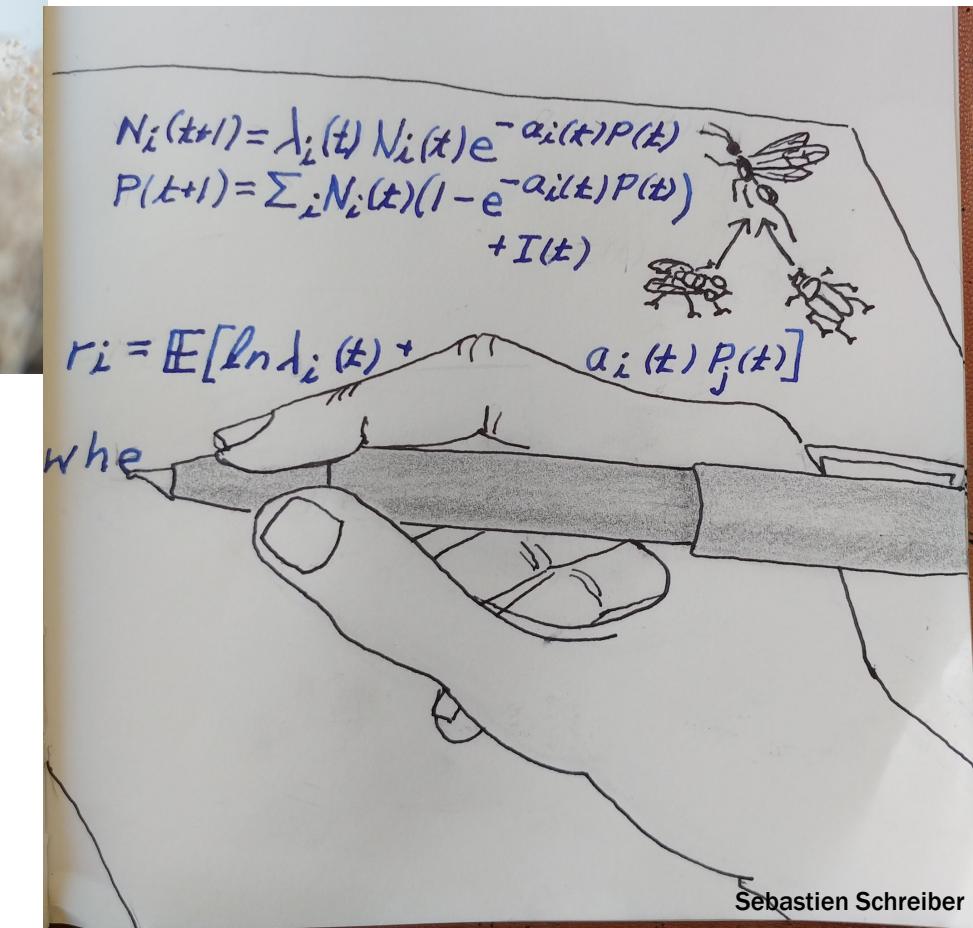
jelena.pantel@uni-due.de

What is a model?

“A *model* is a representation of a particular thing, idea, or condition.”



— Leland Jackson and colleagues (2000)

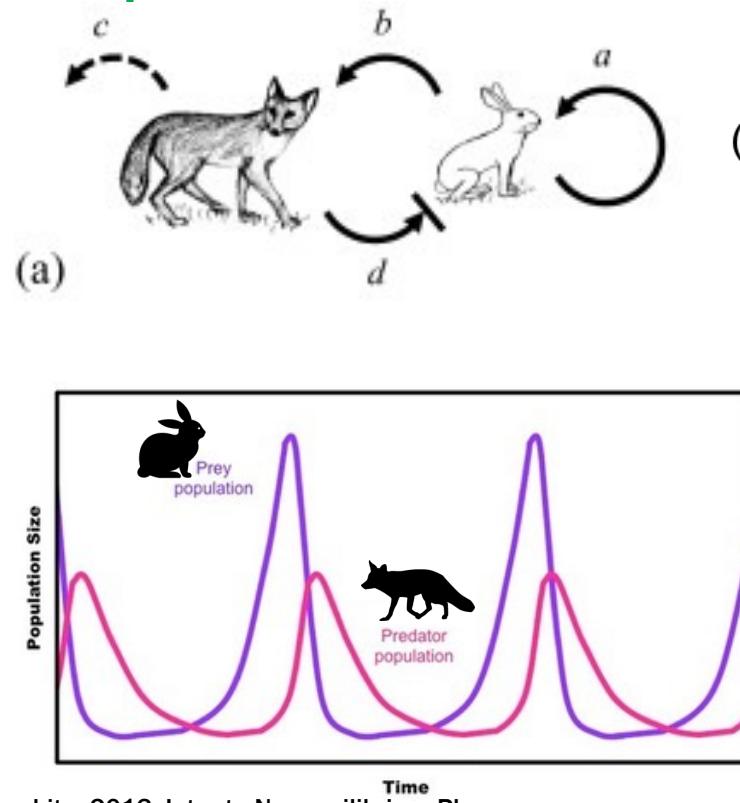


What is a model?

“The *modeling process* is the series of steps taken to convert an idea first into a conceptual model and then into a quantitative model”

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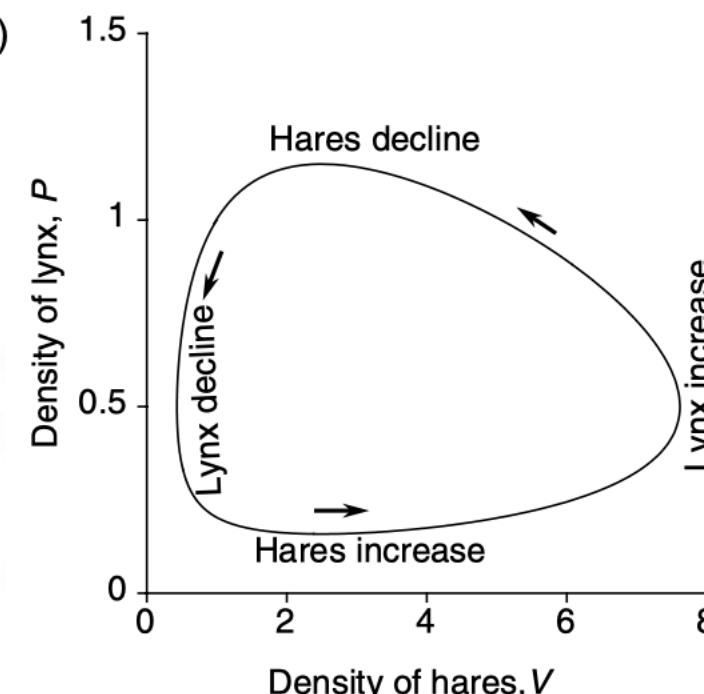
Step 1. Formulate a conceptual model



Step 2. Formulate a quantitative model

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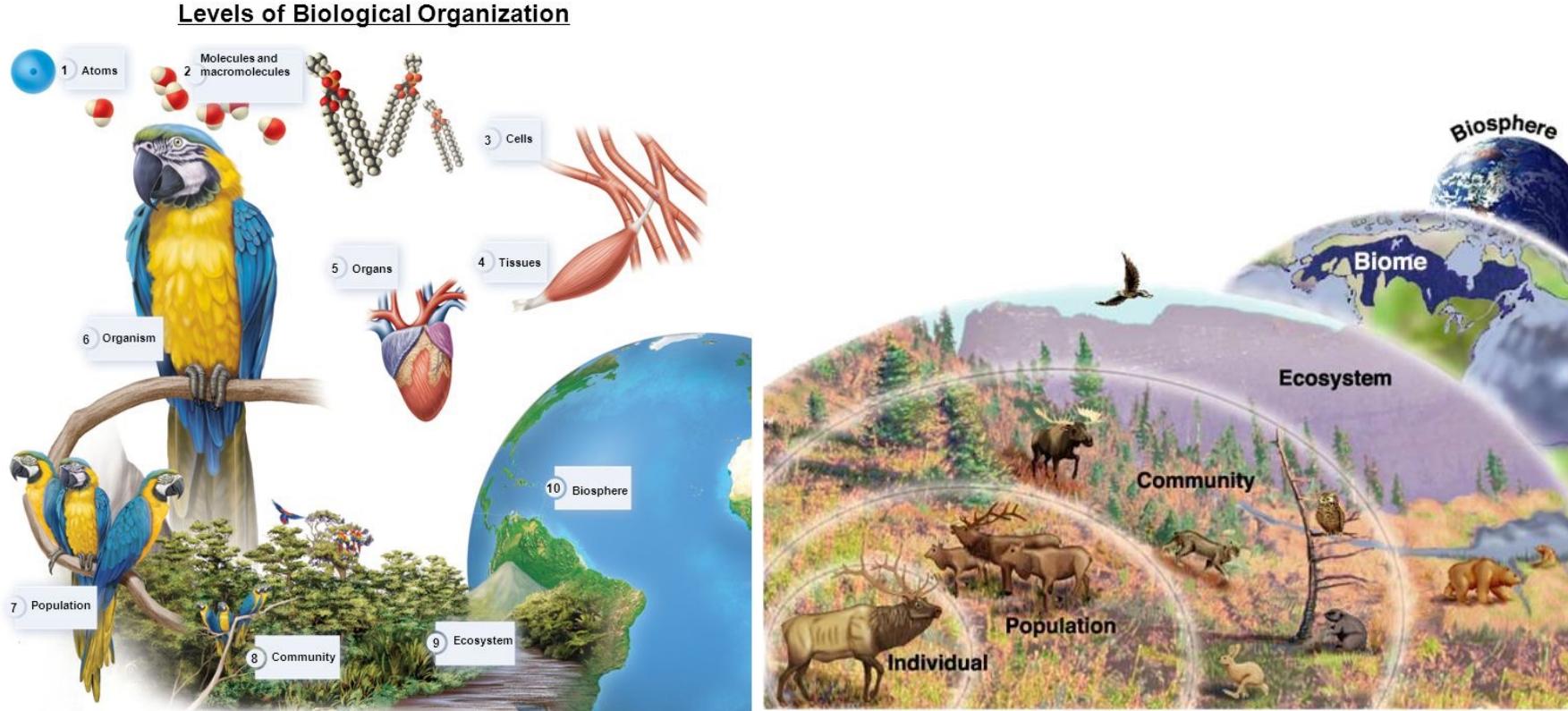


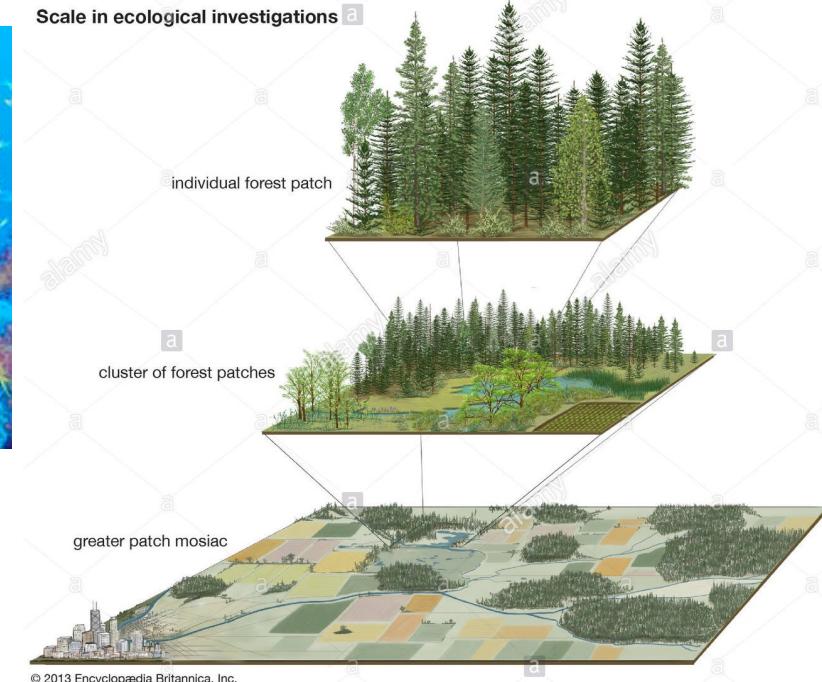
Step 3. Learn about study system through analysis of model behavior

What is ecology?

The study of interactions between organisms and their environment, and with one another

The science that investigates the abundance and distribution of organisms





What should we consider in ecological models?

“A *model* is a representation of a particular thing, idea, or condition.”

But what degree of representation is needed?

— Leland Jackson and colleagues (2000)



What should we consider in ecological models?

“. . . In that Empire, the craft of Cartography attained such Perfection that the Map of a Single province covered the space of an entire City, and the Map of the Empire itself an entire Province. In the course of Time, these Extensive maps were found somehow wanting, and so the College of Cartographers evolved a Map of the Empire that was of the same Scale as the Empire and that coincided with it point for point.”

— Jorge Luis Borges
A Universal History of Infamy
1975



What should we consider in ecological models?

“A model is a representation of a particular thing, idea, or condition.”

But what degree of representation is needed?

— Leland Jackson and colleagues (2000)



- Topography / elevation?
- Water bodies?
- Location of each tree in a forest?

Models are not ‘real’ – they are idealized versions of the real world

What should we consider in ecological models?

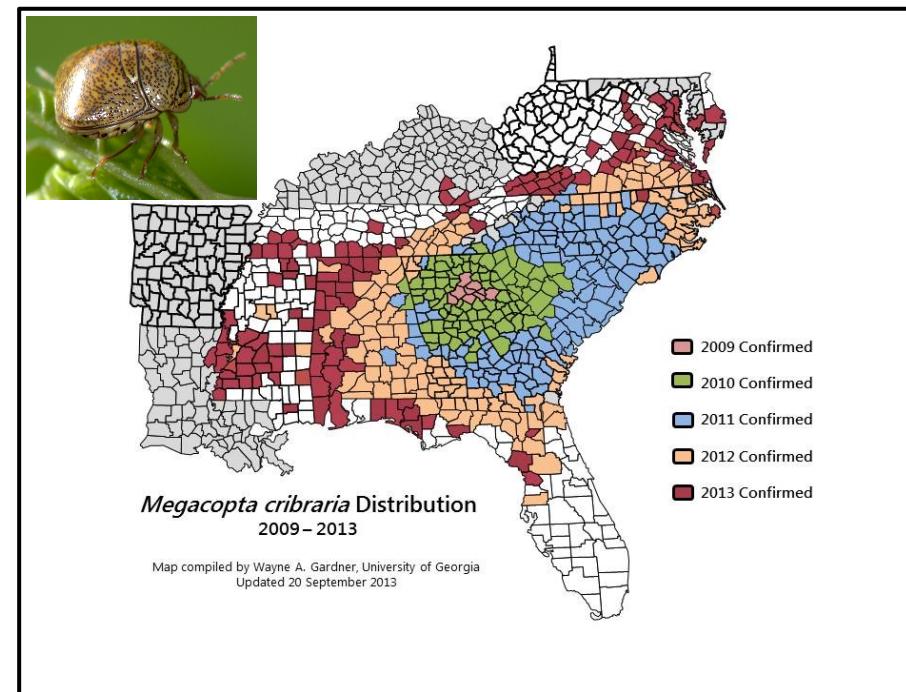
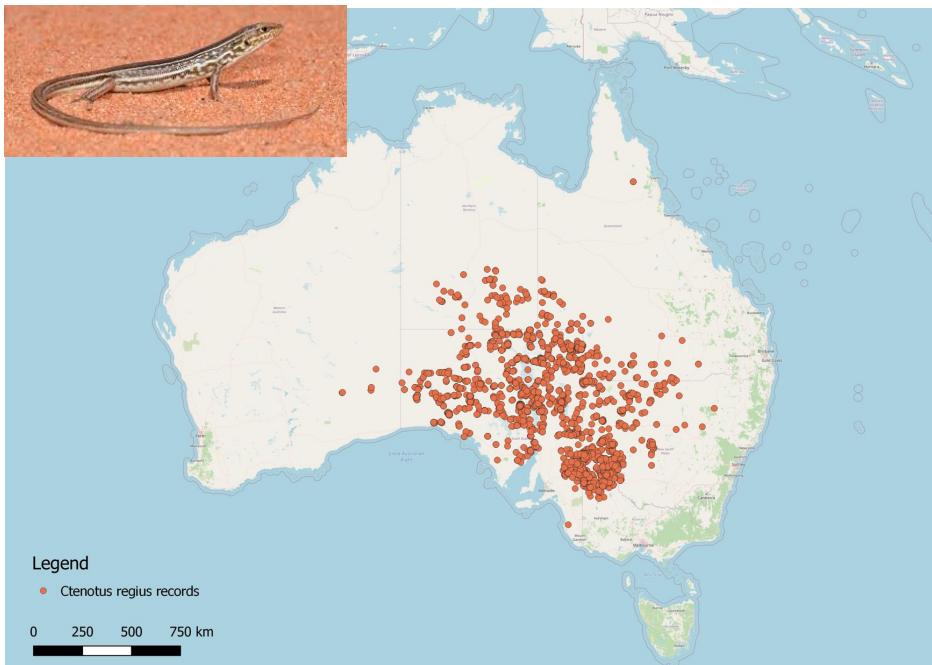
“The *modeling process* is the series of steps taken to convert an idea first into a conceptual model and then into a quantitative model”

What does the ecologist
wish to *understand*?



Often *why* species occur
where they occur, what
determines *if* species
will occur

— Leland Jackson and colleagues (2000)



What should we consider in ecological models?

“The *modeling process* is the series of steps taken to convert an idea first into a conceptual model and then into a quantitative model”

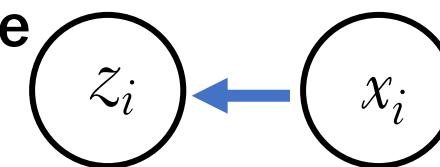
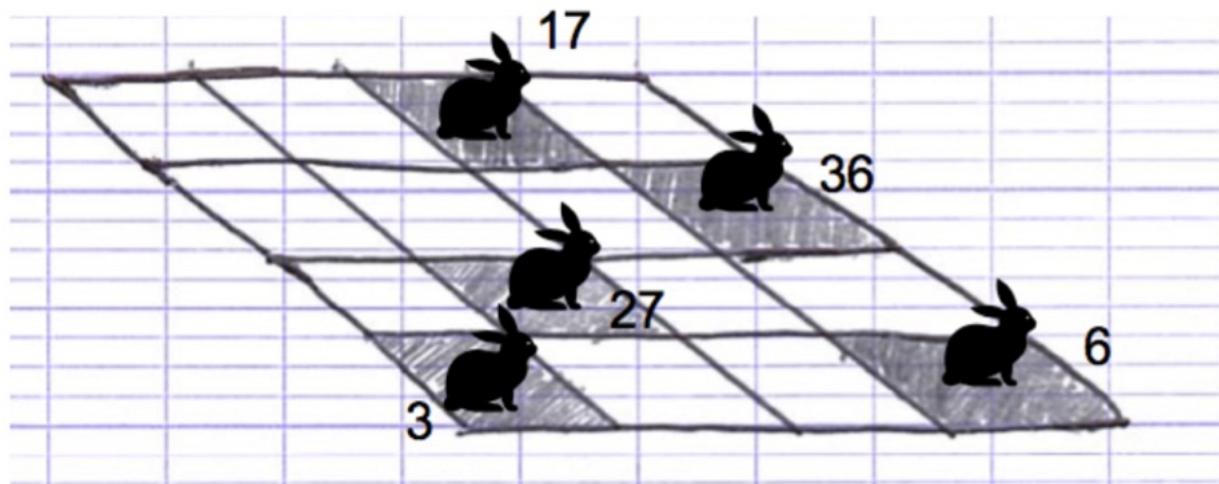
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Verbal exercise 1. What determines the abundance distribution of this rabbit?



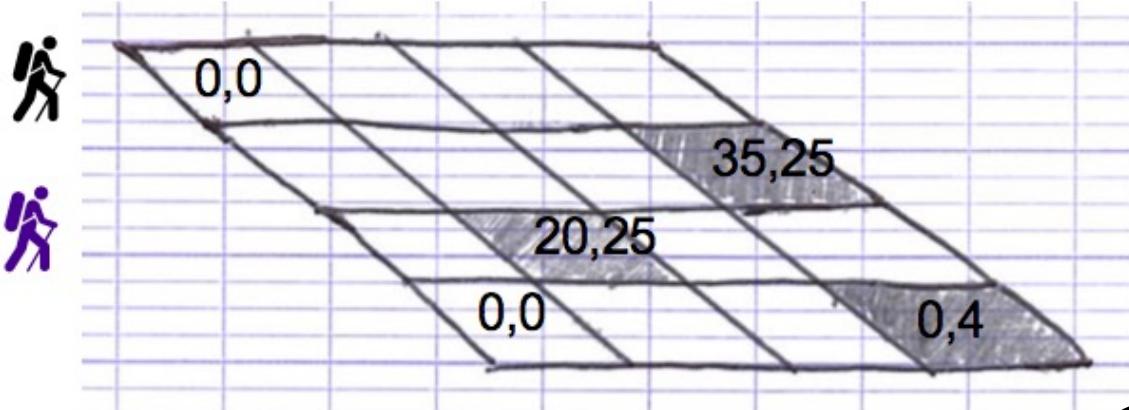
What is the *relationship* of the drivers (x_i) to the response (z_i)?

$$z_i = f(x_i)$$

Do the factors cause an increase in rabbits? A decrease?

Verbal exercise 1. What determines the abundance distribution of this rabbit?

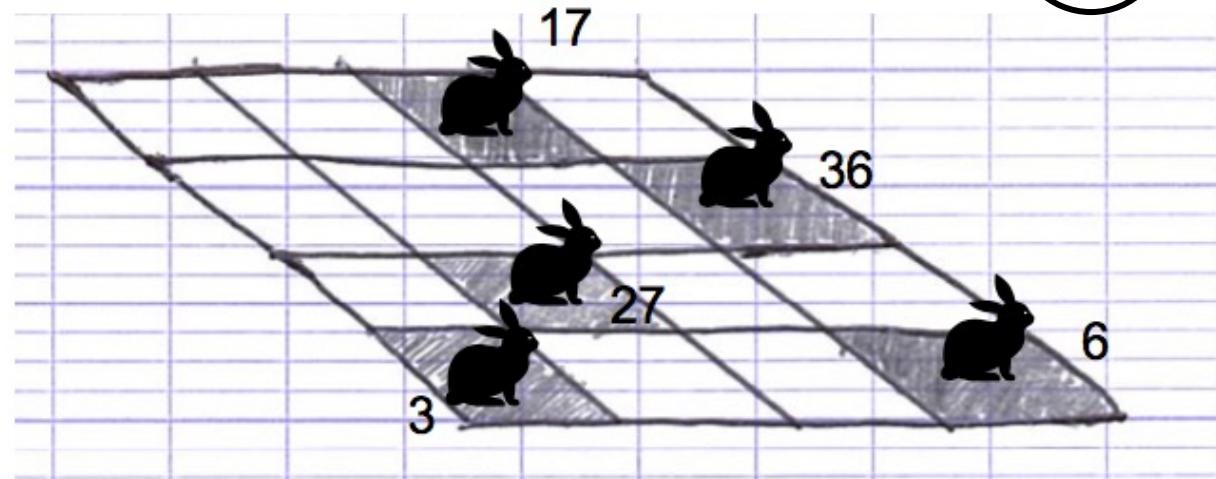
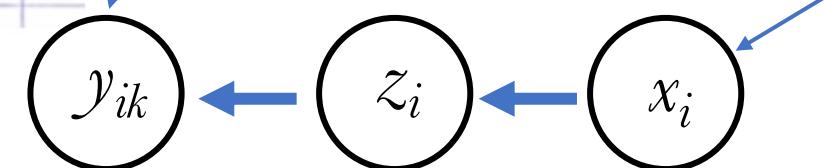
I. Scenario 1. Model of species distribution in a landscape



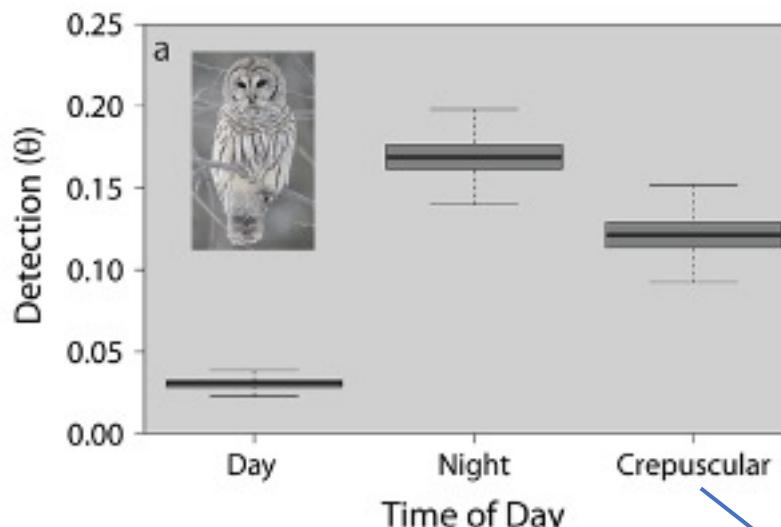
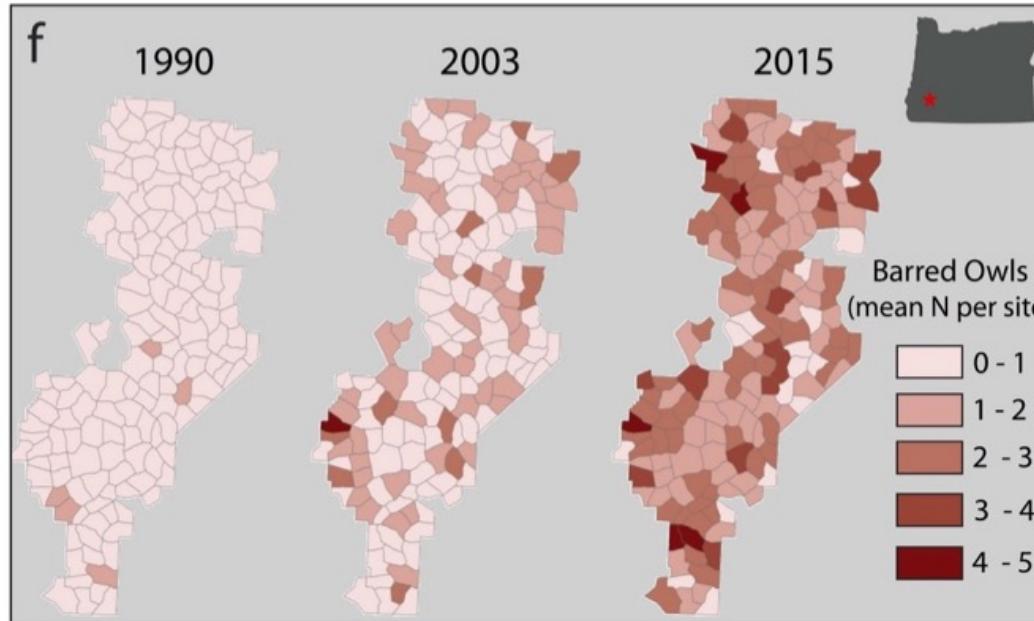
Our observation(s)

The true value

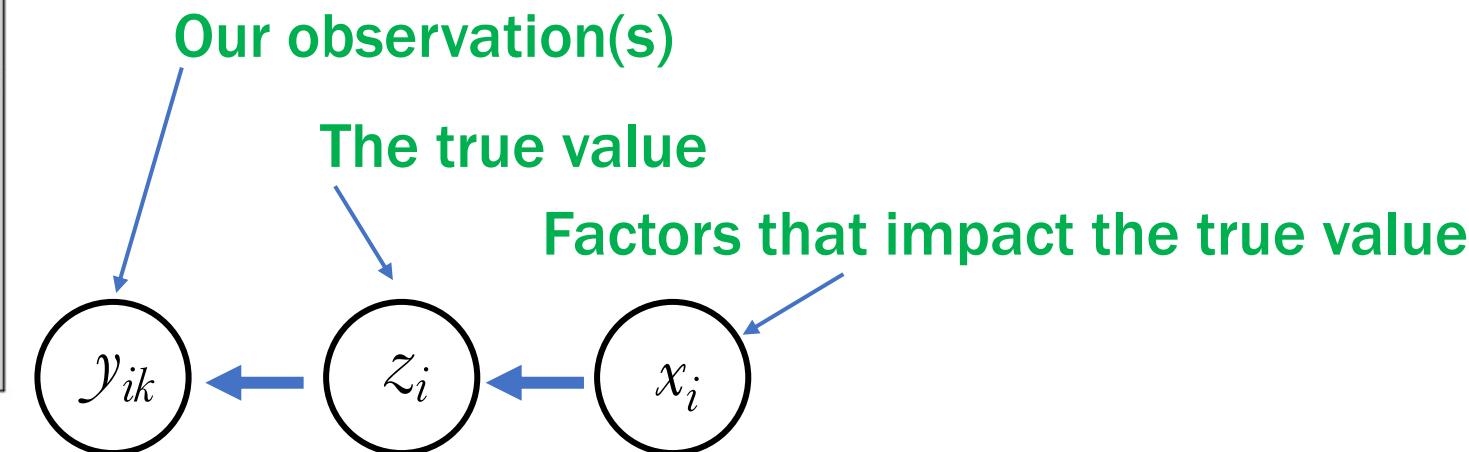
Factors that impact the true value



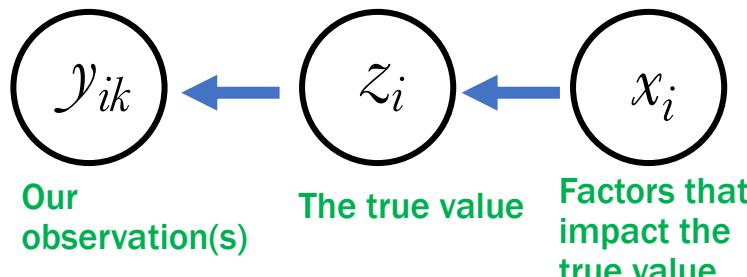
Verbal exercise 1. What determines the abundance distribution of this owl?



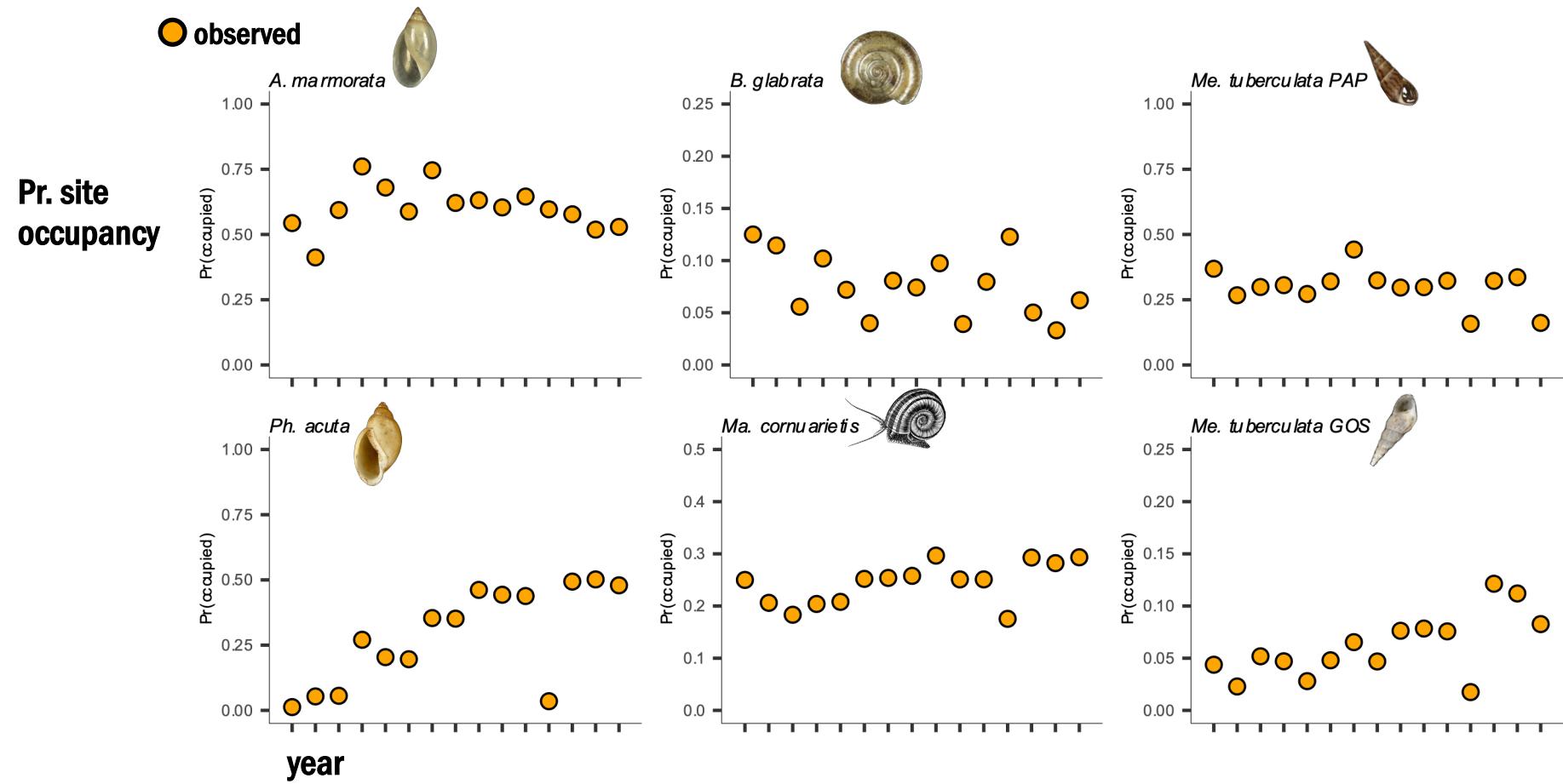
twilight (transition from light to darkness)



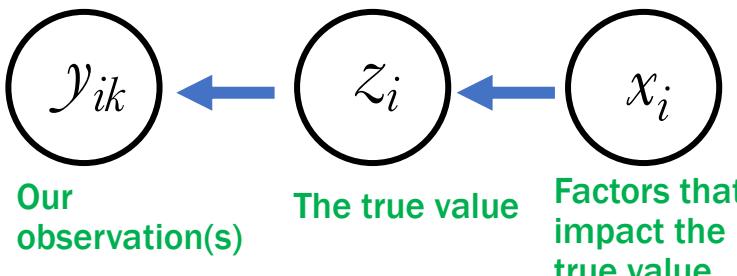
Verbal exercise 1. What determines the occurrence of these snails?



Annual metapop occupancy (p_t) - shows quality of fit of model to data

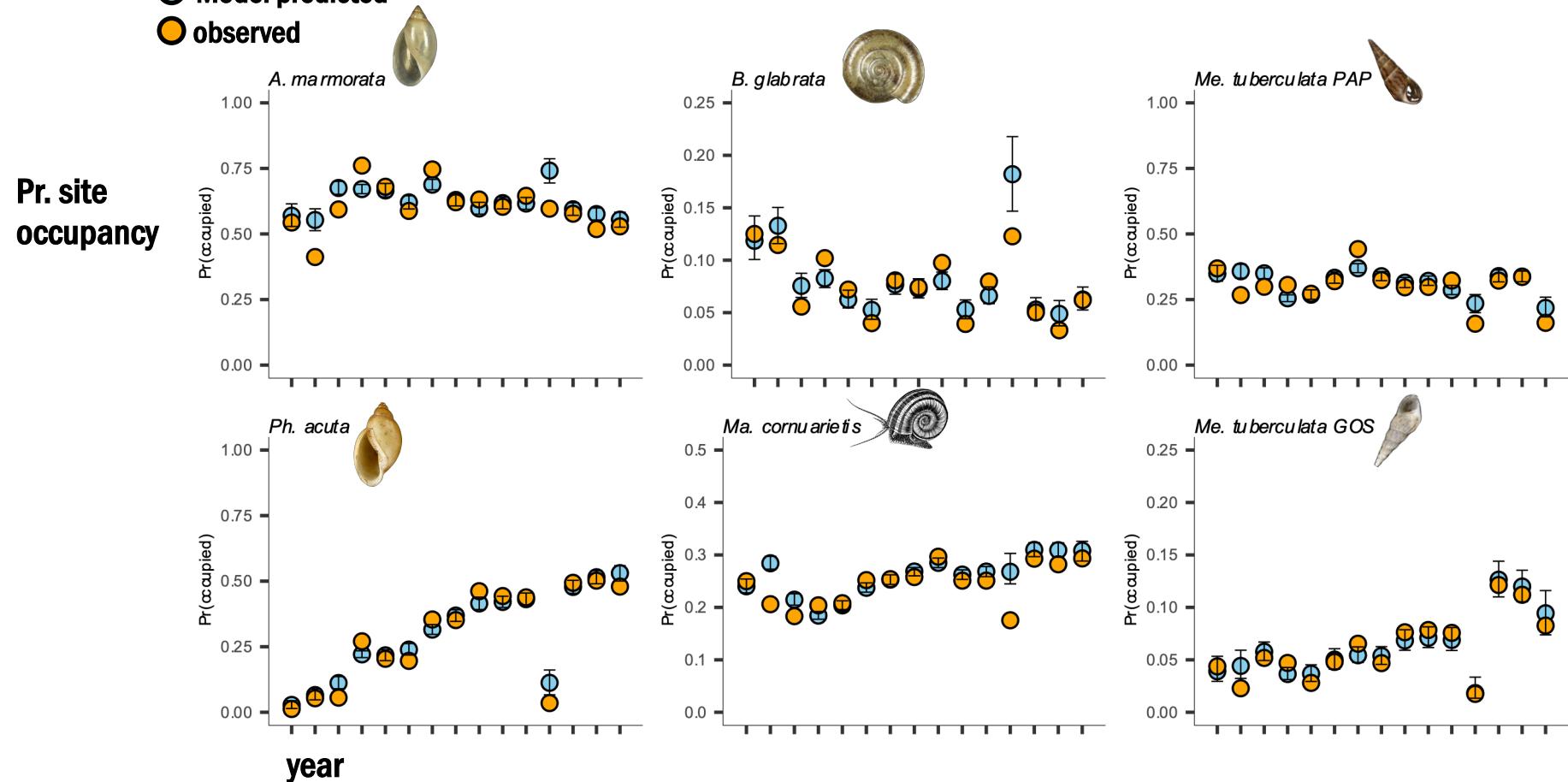


Verbal exercise 1. What determines the spatial abundance distribution of these snails?

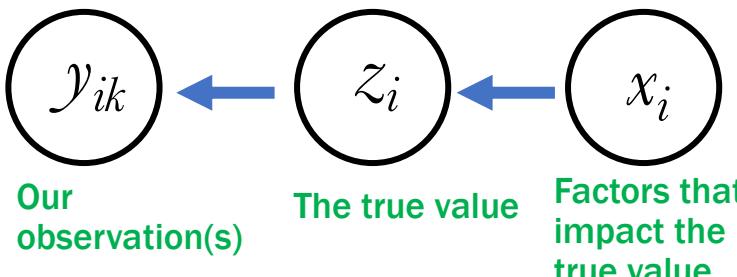


Annual metapop occupancy (p_t) - shows quality of fit of model to data

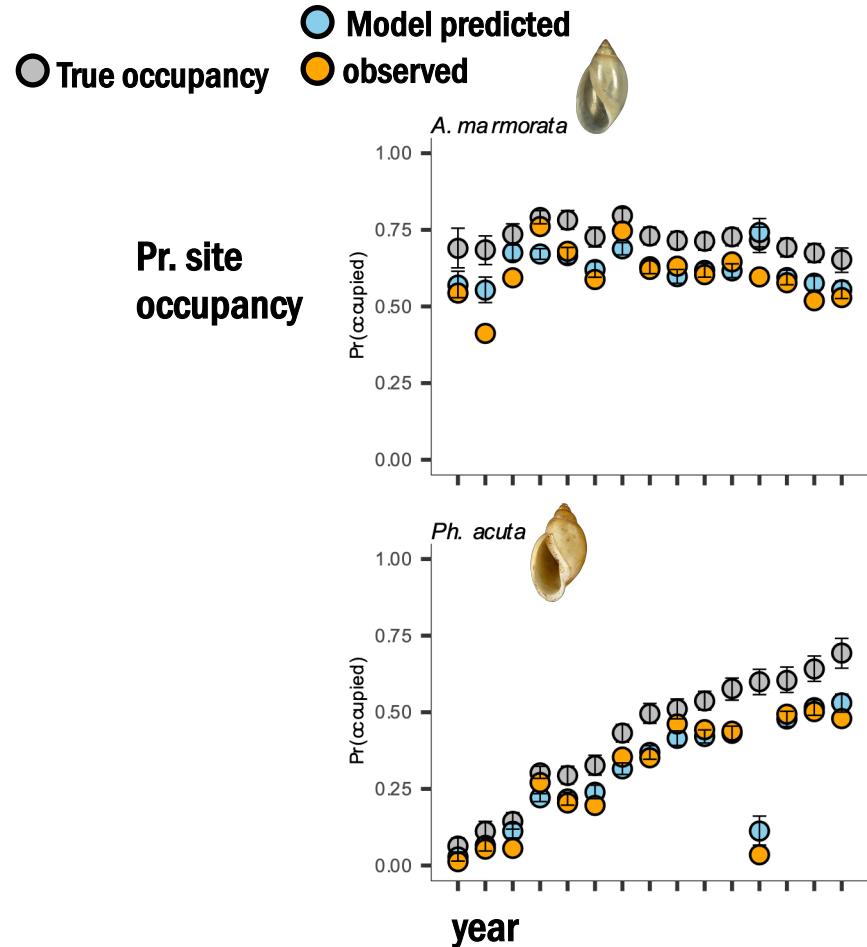
- Model predicted
- observed



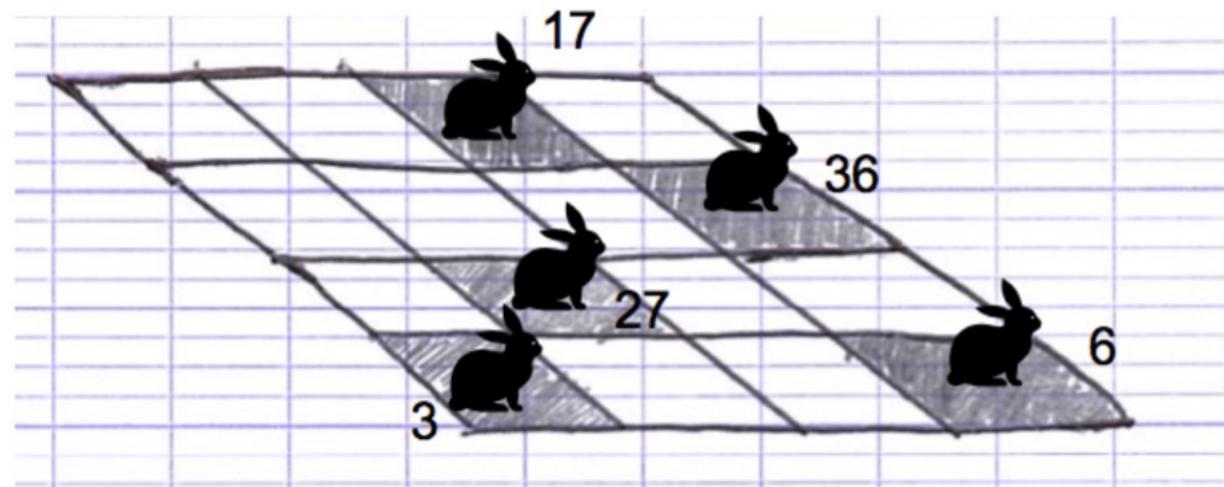
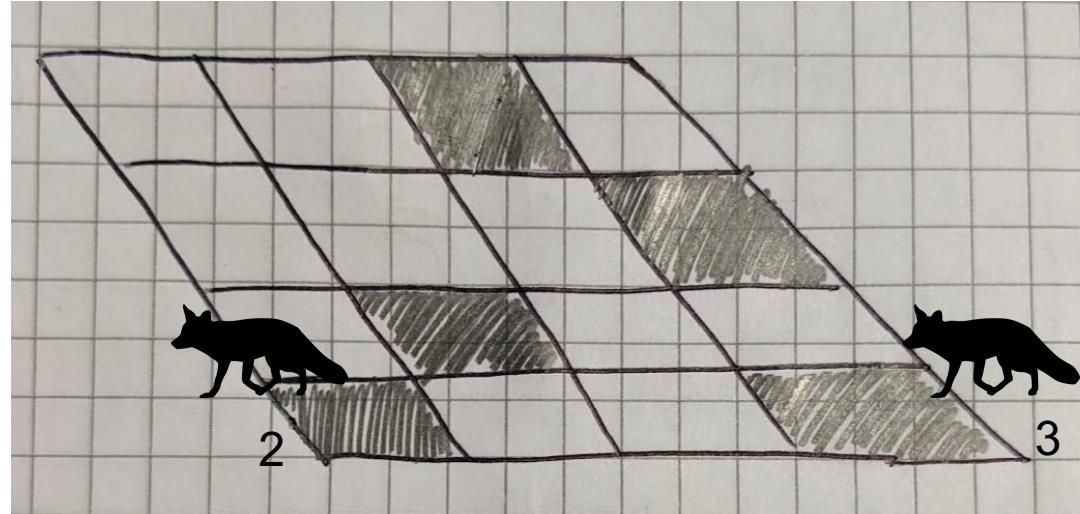
Verbal exercise 1. What determines the spatial abundance distribution of these snails?



Annual metapop occupancy (p_t) - shows quality of fit of model to data

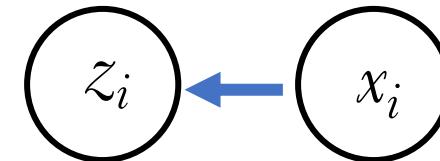


Verbal exercise 1. What determines the abundance distribution of this rabbit?



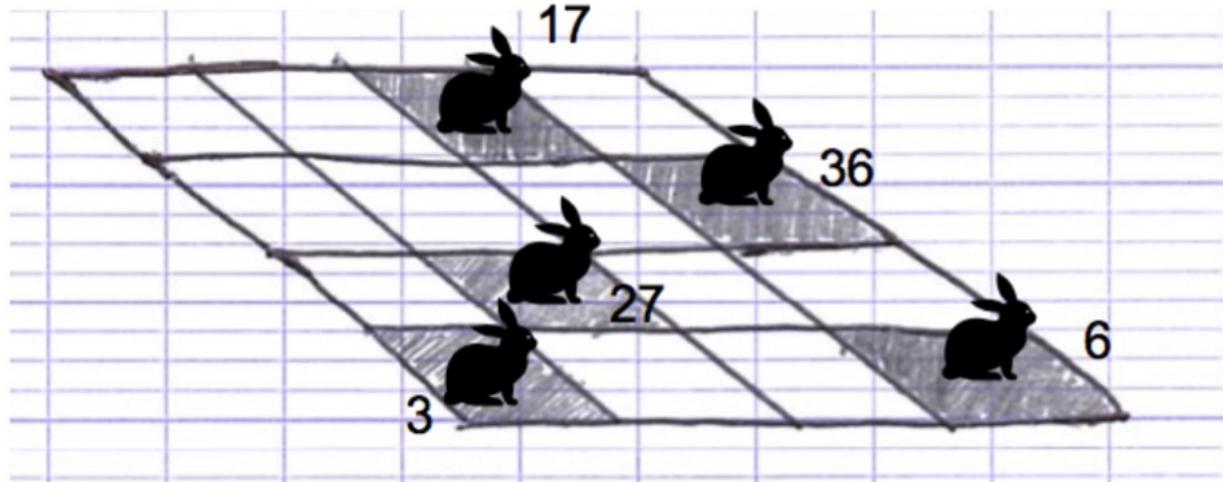
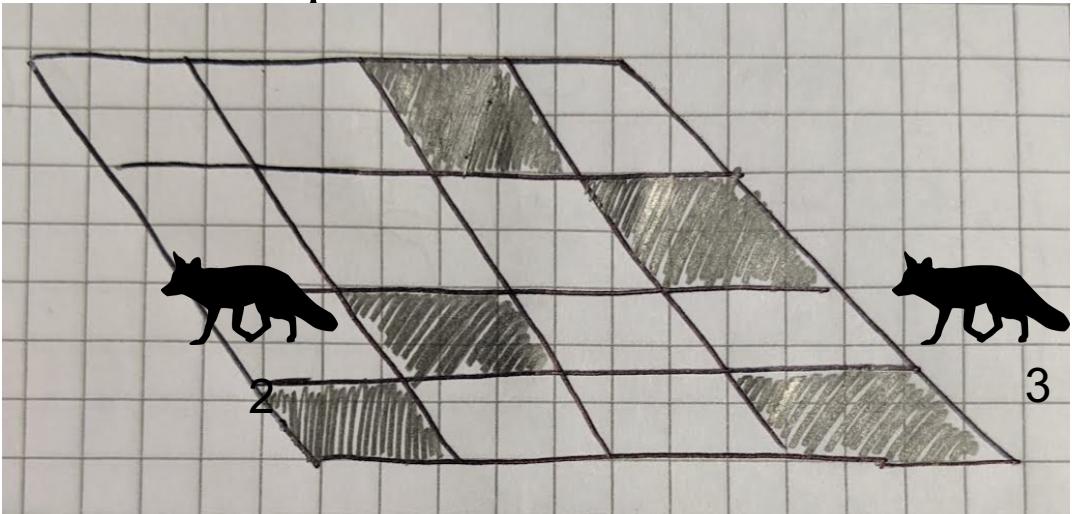
Steps in the process of building a model

- Step 1. Formulate a conceptual model
- Step 2. Formulate a quantitative model
- Step 3. Learn about study system through analysis of model behavior



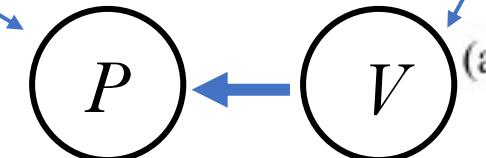
What should we consider in ecological models?

“The *modeling process* is the series of steps taken to convert an idea first into a conceptual model and then into a quantitative model”

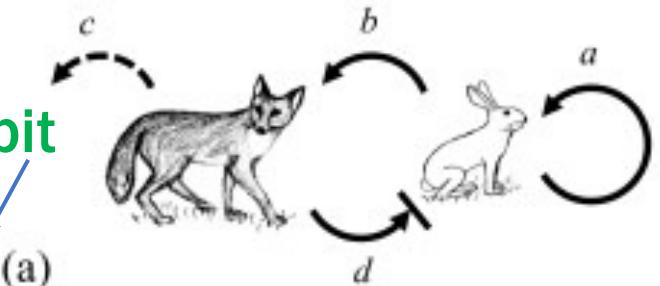


Number of foxes

Number of rabbit



— Leland Jackson and colleagues (2000)



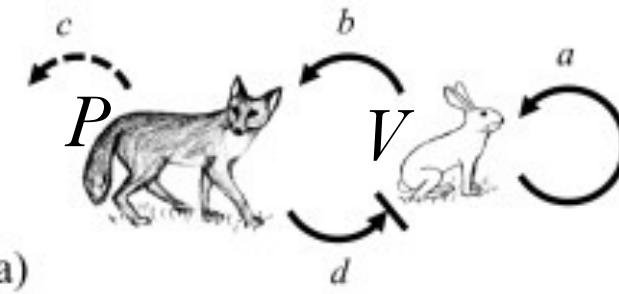
- How does $P(N_{\text{fox}})$ impact $V(N_{\text{rabbit}})$?
- How does N_{rabbit} impact N_{fox} ?
- Some other factors that impact N_{fox} and N_{rabbit}
 - a → rabbit population growth rate (+ for N_{rabbit})
 - b → the rate at which fox encounter rabbit (not 100% of all rabbits are eaten) (+ for N_{fox} , - for N_{rabbit})
 - d → ‘conversion’ of consumed rabbit into new foxes (+ for N_{fox})
 - c → mortality rate of the foxes (- for N_{fox})

What should we consider in ecological models?

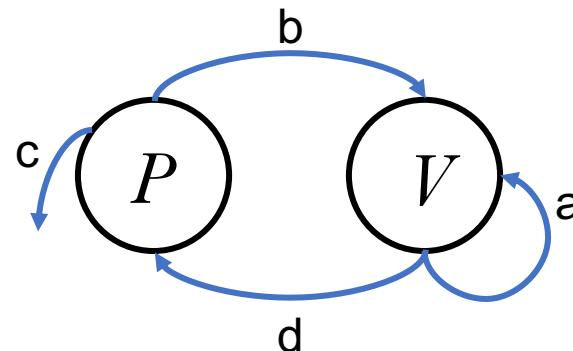
“The *modeling process* is the series of steps taken to convert an idea first into a conceptual model and then into a quantitative model”

Step 1. Formulate a conceptual model

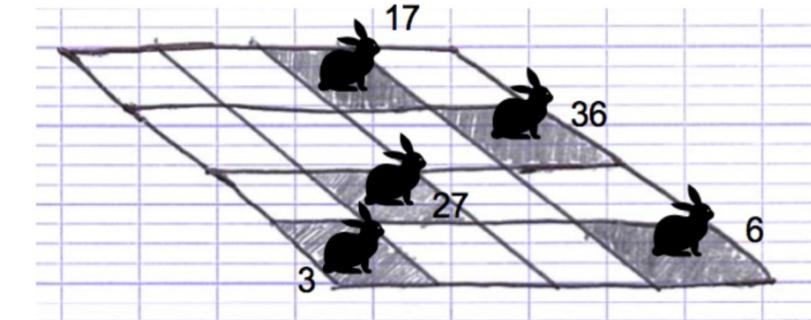
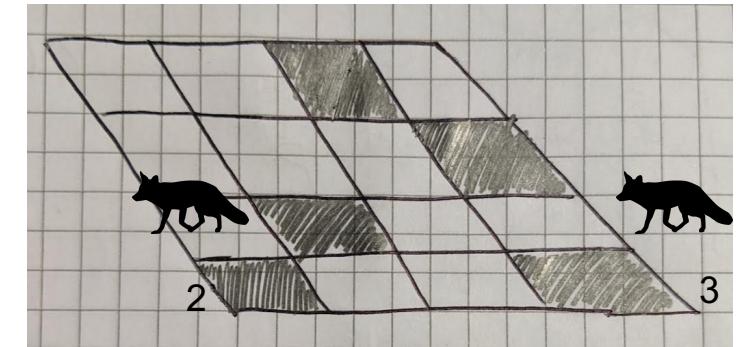
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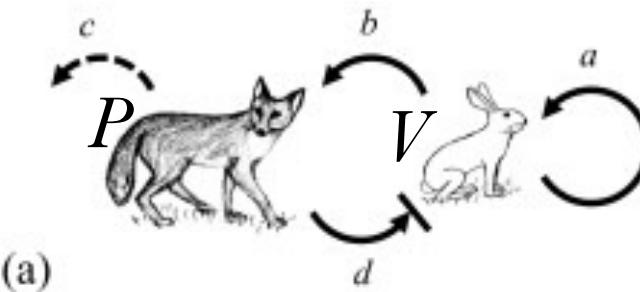
- A diagram with boxes/circles and arrows
- Circles are *state variables*, that describe the state of the system
- The arrows illustrate *relationships* among states
- A decision is to be made: what *currency / units* represent the interactions between states? Here we used N, number of individuals (P for rabbit, V for fox)



What should we consider in ecological models?

“The *modeling process* is the series of steps taken to convert an idea first into a conceptual model and then into a quantitative model”

Step 1. Formulate a conceptual model



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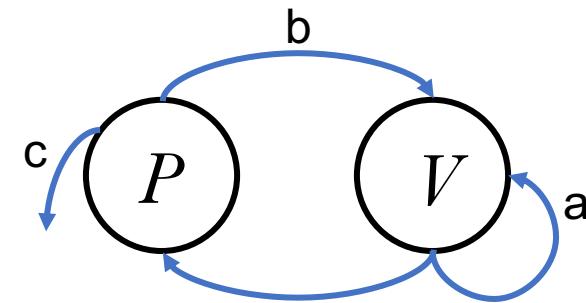
— Leland Jackson and colleagues (2000)

- A diagram with boxes/circles and arrows

Step 2. Formulate a quantitative model

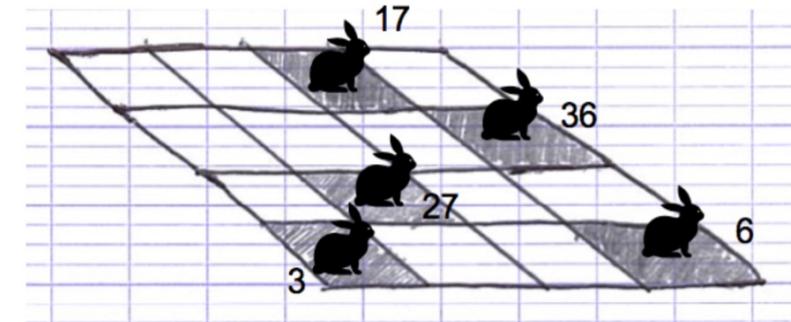
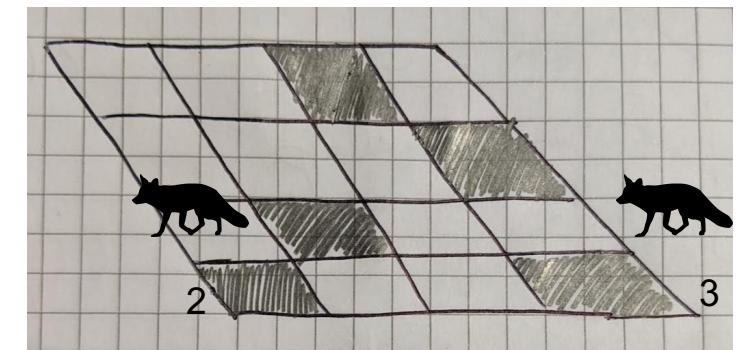
- A set of mathematical expressions which arranges the **coefficients** (a,b,c,d) and the **variables** (V,P) from the conceptual model

$$\begin{aligned} V &\rightarrow +a, -b \\ P &\rightarrow +d, -c \end{aligned}$$



$$\frac{dV}{dt} = aV - bVP$$

$$\frac{dP}{dt} = -cP + dVP$$

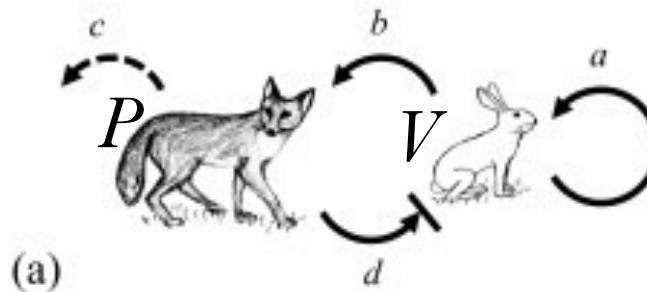


What should we consider in ecological models?

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Step 1. Formulate a conceptual model

— Leland Jackson and colleagues (2000)



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- A diagram with boxes/circles and arrows

Step 2. Formulate a quantitative model

- A set of mathematical expressions which arranges the **coefficients** (a,b,c,d) and the **variables** (V,P) from the conceptual model

Step 3. Learn about study system through analysis of model behavior

- Predictions can be made for the value of the **state variables** (V,P) under various circumstances

$$\frac{dV}{dt} = aV - bVP$$

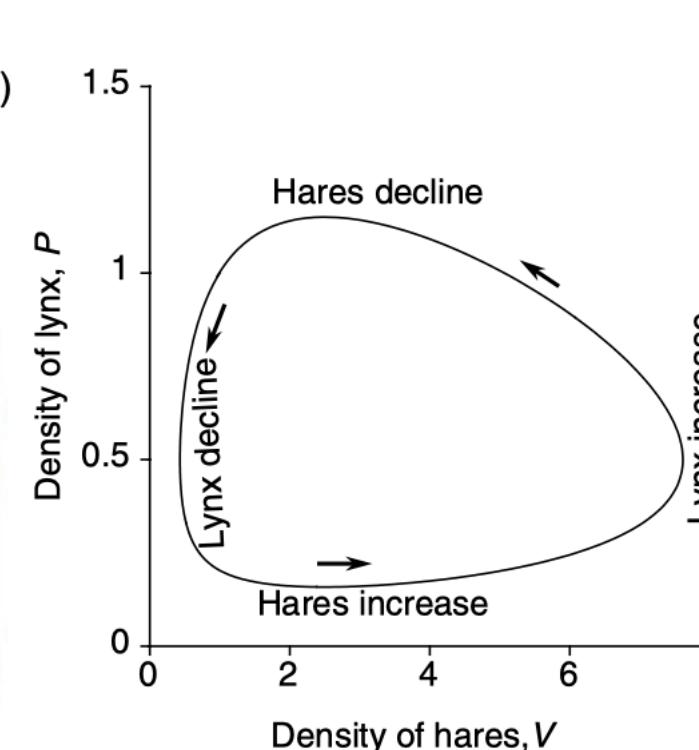
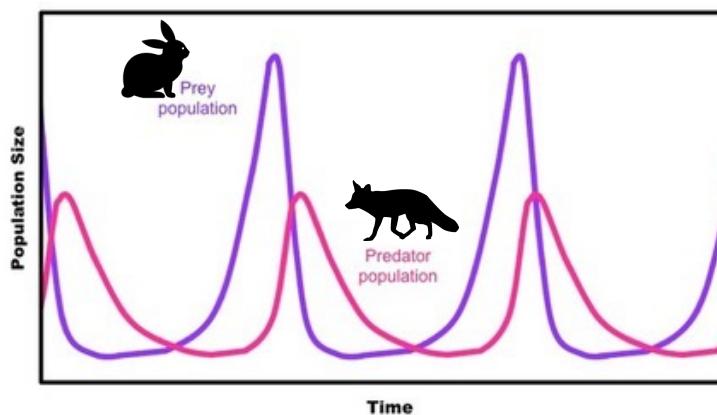
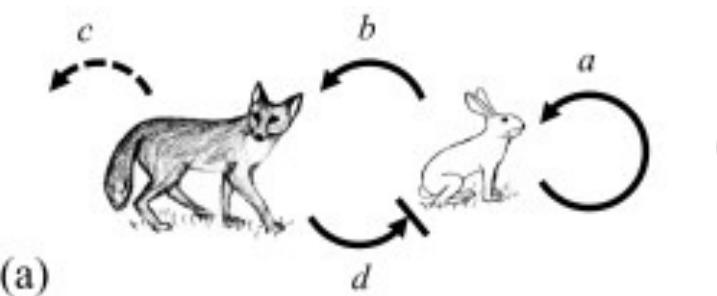
$$\frac{dP}{dt} = -cP + dVP$$

What should we consider in ecological models?

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Predictions can be made for the value of the state variables (V,P)

— Leland Jackson and colleagues (2000)



$$\frac{dV}{dt} = aV - bVP$$
$$\frac{dP}{dt} = -cP + dVP$$

We use models to understand biology – here, how populations are regulated, how species can stably coexist

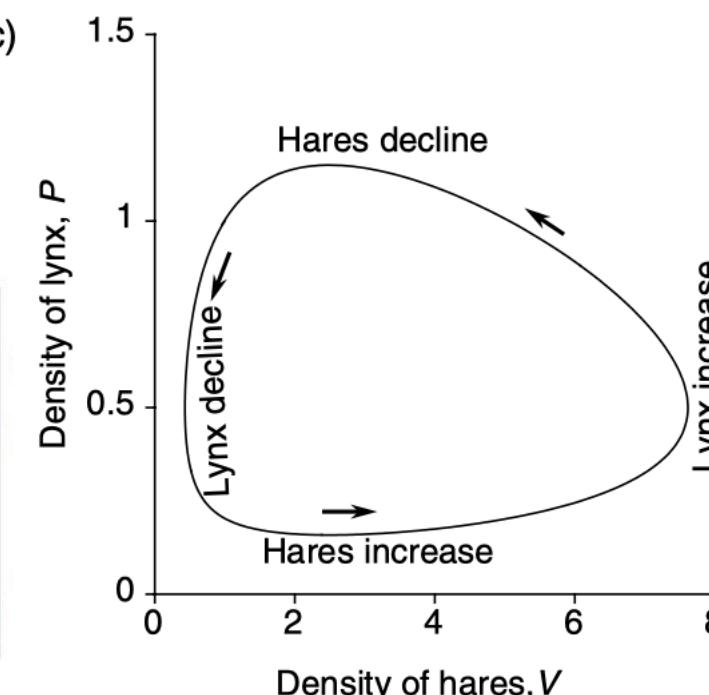
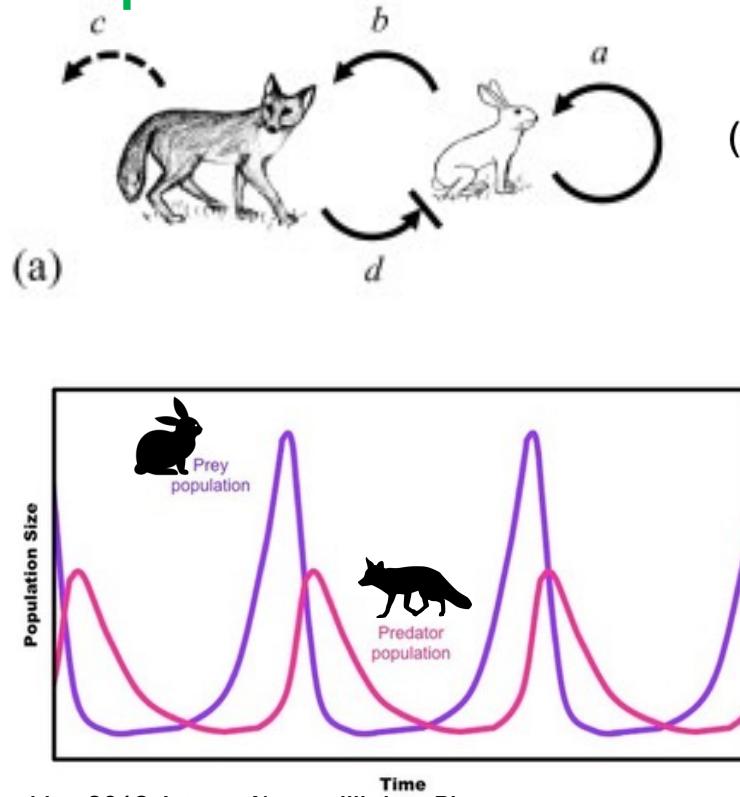
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Step 1. Formulate a conceptual model



Step 2. Formulate a quantitative model

$$\frac{dV}{dt} = aV - bVP$$

$$\frac{dP}{dt} = -cP + dVP$$

Step 3. Learn about study system through analysis of model behavior