465990-HS2025-0:
Theoretical ecology and evolution, research practical
7 steps

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Check-in

Something you remember from yesterday, or something that you kept thinking (or dreaming ;-)) about between yesterday and today

Plan for today

Define your project

Start your project's github repository

Start your project!

Person 1: create your GitHub repository online as a public repository

Person 1: Add the other person(s) as an owner/admin

Person 2: Add Teachers with "write" permission

Person X: add base code from yesterday

Person X+1: tag base code

Step 1: formulate the question

What do you want to know?

Describe the model in the form of a question.

Boil the question down! Make it as explicit and tangible as possible.

Start with the simplest, biologically reasonable description of the problem.

Step 2: Determine the basic ingredients of the model

Define the variables in the model.

Describe any constraints on the variables (e.g., larger than 0; very small; has to be an integer; …)

Describe any interactions between variables.

Decide whether you will treat time* as discrete or continuous.

Choose a time scale (e.g., generations, minutes, etc.)

Define the parameters in the model.

Describe any constraints on the parameters (e.g., between 0 and 1)

*or whatever your independent variable is (see following slide)

Variables & Parameters

A (dependent) variable of a model is a quantity that changes as the function of another (independent) variable. In E & E we are often* interested in dynamical models, in which a variable (or several) changes with time.

A parameter is a quantity that remains constant over a "run" of the model.

Typically**, variables are plotted on the x and/or y axis when you want to visualize the dynamic behavior of a model.

Typically**, in such a visualization, plots show different parameter values as individual lines in the plot.

*but can also be space, environment, temperature, etc.
**but see other examples later

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Models in discrete vs. continuous time

Discrete-time models track changes to a variable in discrete time steps.

In a continuous-time model, variables can change at any point in time.

As time steps become infinitesimal (i.e. approach 0), discrete and continuous time models become indistinguishable.
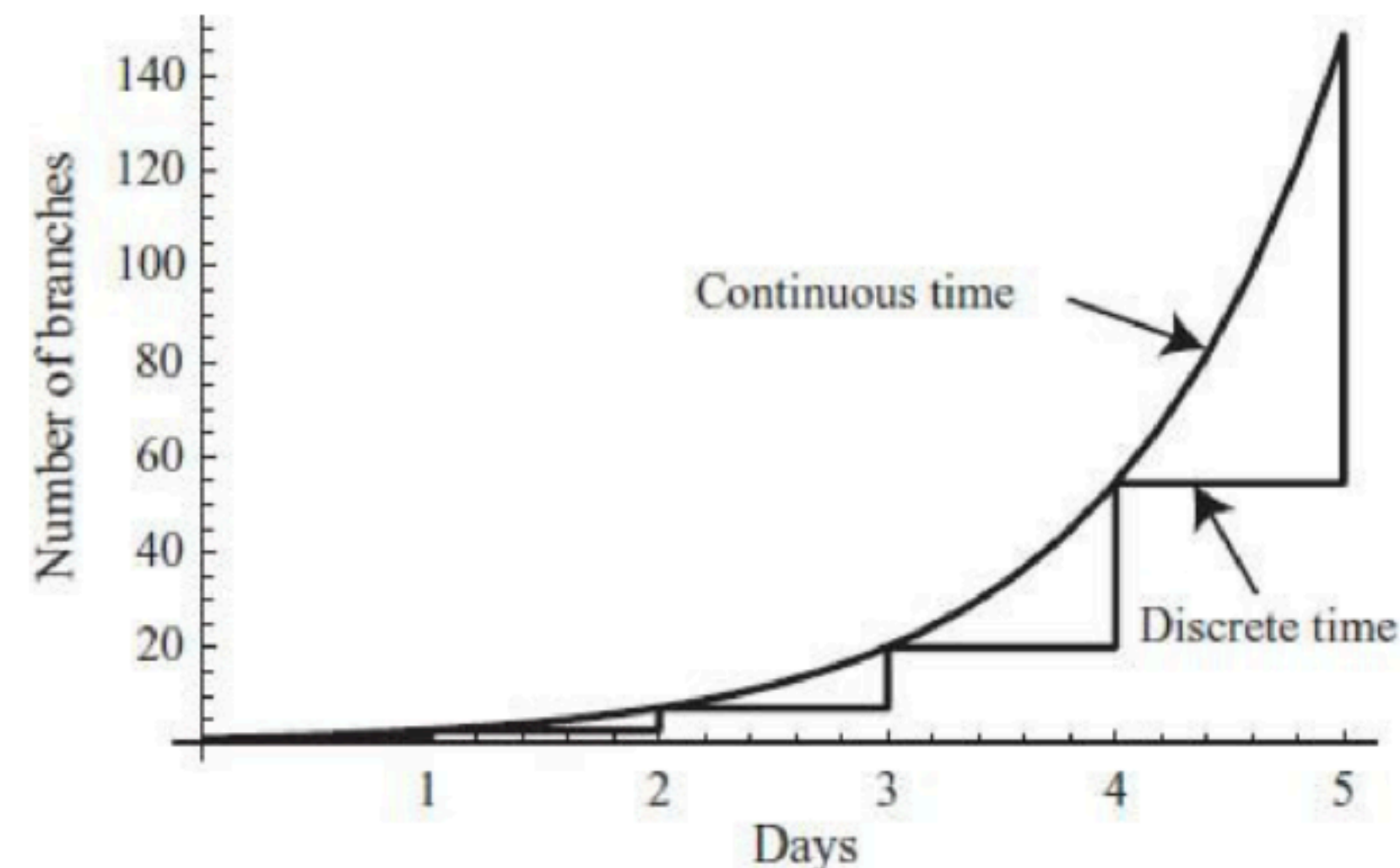
Equilibria and why they are important

Equilibrium: "*a state of balance or a stable situation where opposing forces cancel each other out and where no changes are occurring*" (drawn from Google)

In modelling, equilibria represent the long-term states of a dynamical process.

Thus, theoretically, over long time scales during which forces remain constant, equilibrium states are the most likely states to be observed.

Therefore, if a model predicts a polymorphic equilibrium, this predicts that a natural population which is subject to the same forces, will most likely be polymorphic when sampled.

Alternatively, if you sample many populations and find them to be polymorphic, you may propose (ideally simple) models that predict polymorphic equilibria - and you can try out which forces are necessary or sufficient to produce polymorphic equilibria in the model.

Step 3: Qualitatively describe the biological system

Visualize the model setup, e.g. life cycle, genomic architecture, etc.

Visualize how you expect variables to change for different parameters. Think of limiting cases.

Create tables that report all possible outcomes of the model run.

Limiting cases - an extremely important aspect of modeling

Wikipedia: "*In mathematics, a limiting case of a mathematical object is a special case that arises when one or more components of the object take on their most extreme possible values.*"

Examples: i) A circle is a limiting case of an oval. ii) A point is a limiting case of a circle. iii) When studying a model of two islands with migration m between them, m=0 (and thus, a model of two populations without migration) is a limiting case.

Limiting cases lead to a simpler version of the model (e.g. if m=0) that often can be mathematically solved, more easily be studied/understood, or for which the solution/behavior is known.

If the behavior of your model for limiting cases does not make sense, there is a good chance you have a bug in your equations or simulations!

Step 4: Quantitatively describe the biological system

Write down the equations *or the code/algorithm.*

Check the equations*/code* carefully. Do the limiting cases make sense? Are the units conserved?

Think about whether the results from the model can address the question. What are the limitations?

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Step 5: Analyze the equations/simulations

Simulate and visualize model runs for different parameter combinations.

Choose and perform appropriate analyses.

Make sure that the analyses can address the problem.

Step 6: Checks and balances

Check the results against data or any known special cases.

Determine how general the results are

Consider alternatives to the simplest model

Extend or simplify the model as appropriate and repeat steps 2-5

Step 7: Relate the results back to the question

Do the results answer the biological question? How?

Are the results counterintuitive? Why?

Interpret the results verbally, and describe conceptually any new insights into the biological process.

Describe potential experiments that could be used to evaluate the model predictions.