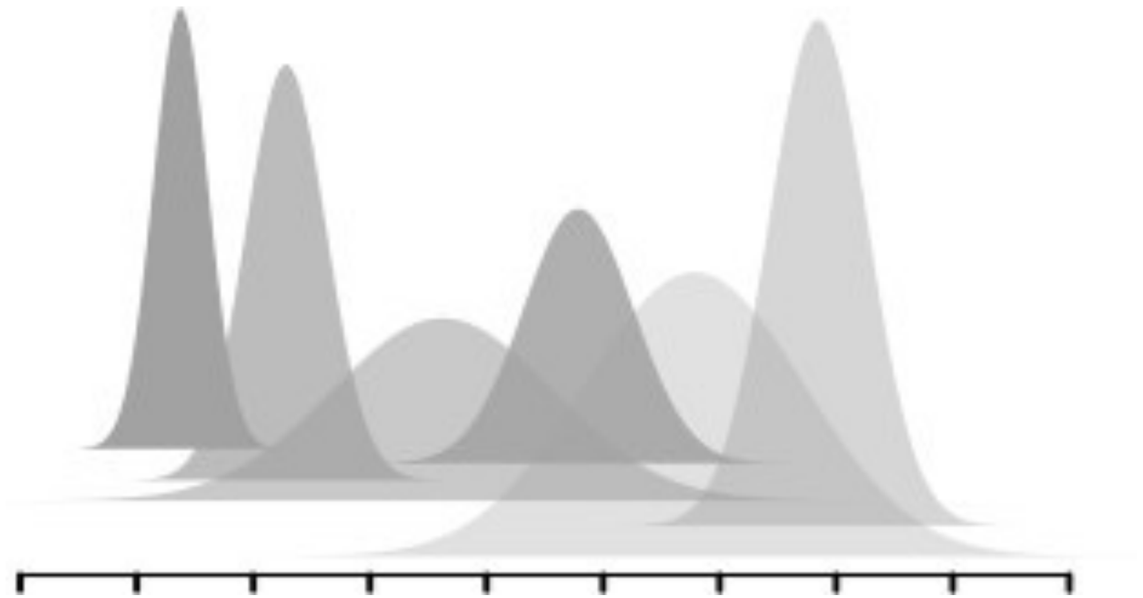
4.1 How To Use Ecological Models



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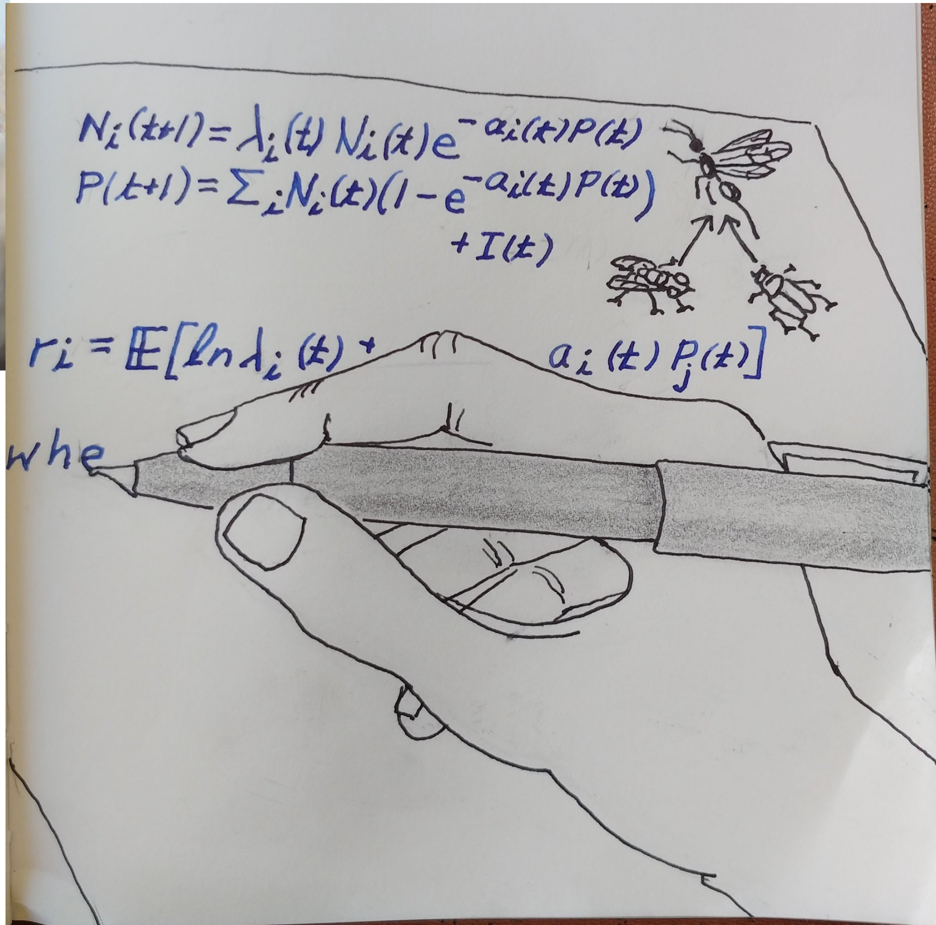
Why use theory?

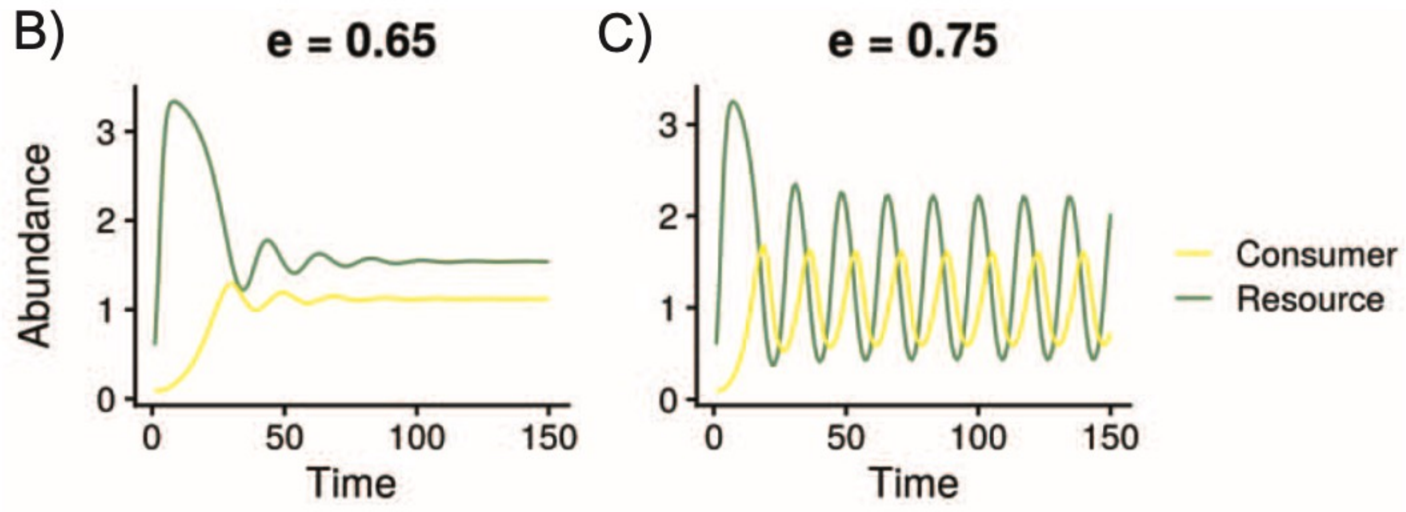
"A model is a representation of a particular thing, idea, or condition"

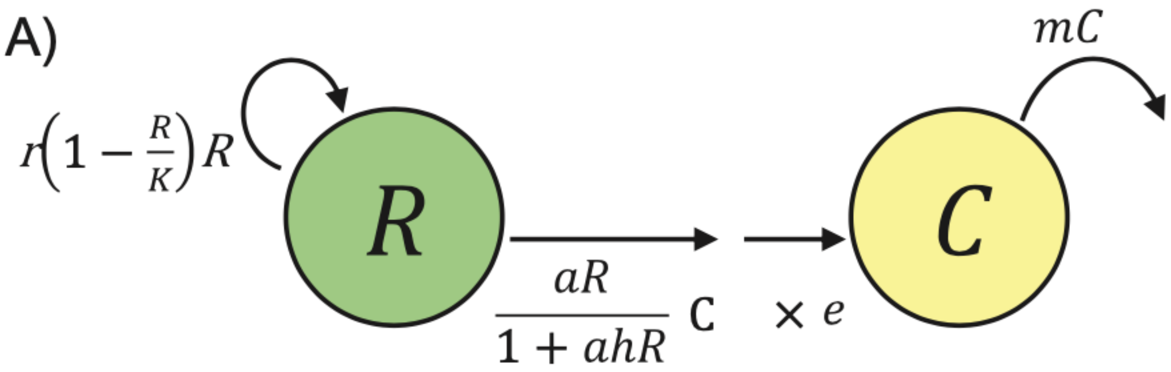


How to understand a mathematical model?

$$\frac{dR}{dt} = rR\left(1 - \frac{R}{K}\right) - \frac{aR}{1 + ahR}C$$

$$\frac{dC}{dt} = e\frac{aR}{1 + ahR}C - mC$$





parameter	
r	population growth rate
K	carrying capacity
m	death rate
a	clearance rate (the area or volume cleared of prey per predator per prey unit time)
h	handling rate (the amount of time a consumer spends handling each prey item (e.g., time to kill, eat, digest, etc.) that would otherwise be spent searching for prey)
e	the conversion rate of consumed resources into new consumer individuals

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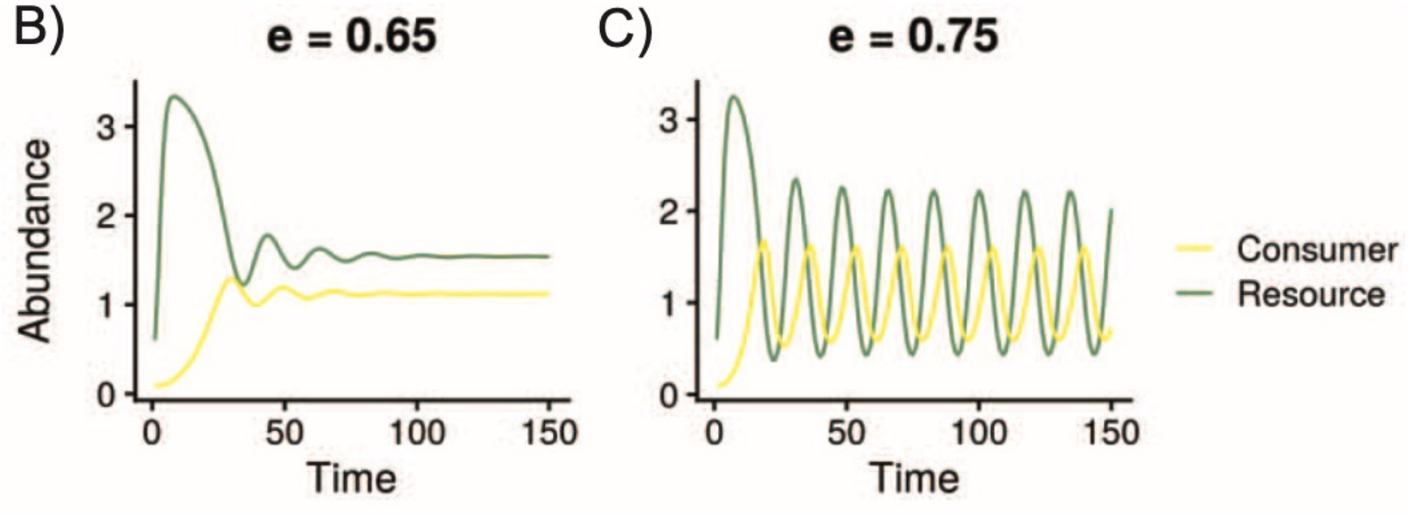


state variables – R, C

parameters – r, K, a, h, e, m

"Rosenzweig-MacArthur consumer-resource model where both the consumer (with density represented by the variable C) and the resource (with density R) grow and impact each other (Rosenzweig and MacArthur 1963)"

What is theory?

An explanation of an ecological phenomenon, that explains how an ecological process works or why an ecological pattern is observed

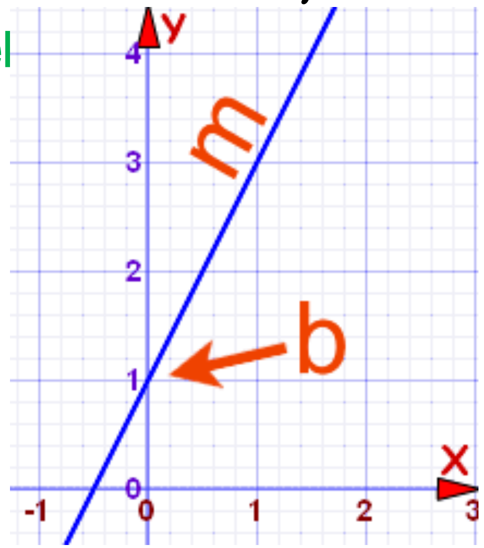
An idea becomes scientifically useful when expressed as a testable *theory*, often in the form of a *mathematical model*

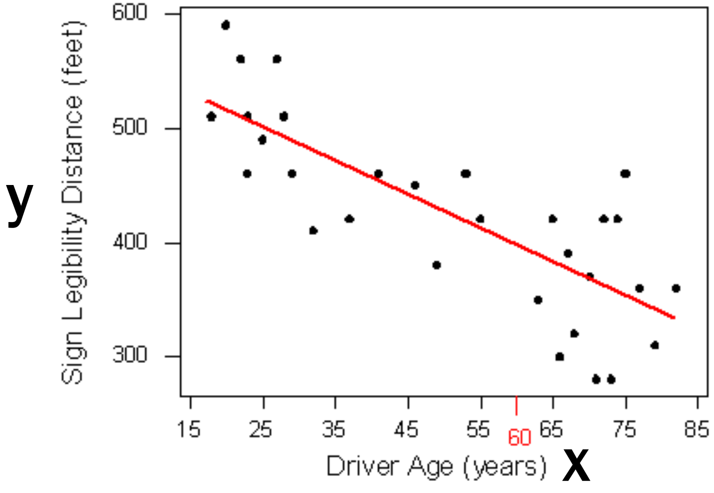
A *mathematical model* is an equation or a set of equations that describes how different aspects of a system relate to one another

Example 1. Formula for a line → Linear model

$$y = mx + b$$

m - slope
b - y-intercept (where line crosses y-axis.... value of y when x=0)





Grainger et al, 2022

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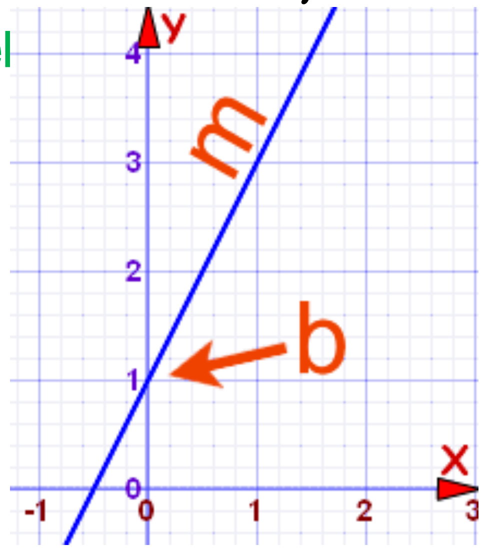
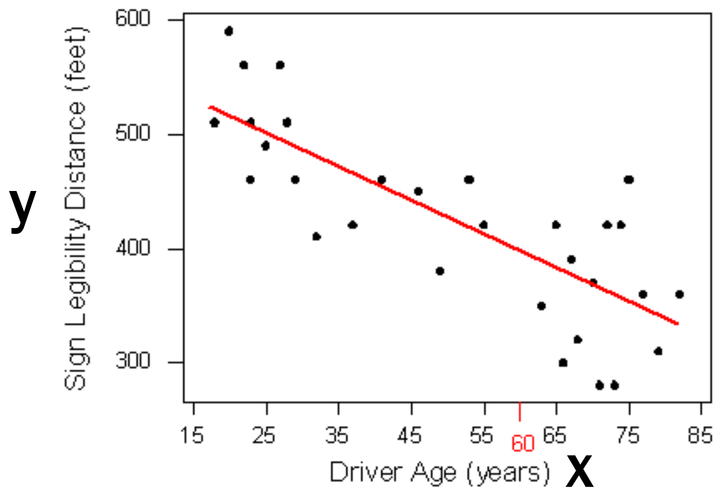




state variables – y, x
parameters – m,b

$$y = mx + b$$

b = 525
m = -1.77

if x = 60, y = 433

How to use a mathematical model?

Approach 3: Use the mathematical equations

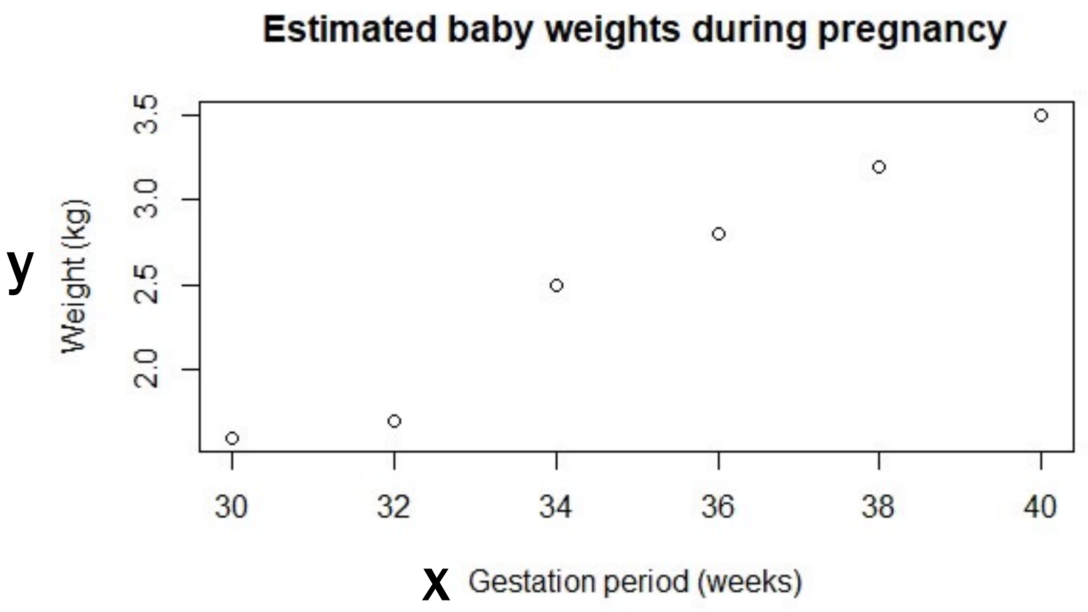
model fitting (aka “fitting models to data”) - collect measurements of the response and predictor variables in the model, and then use statistical techniques to estimate the values of free parameters (those whose values are unknown) that best match the relationship observed in the data

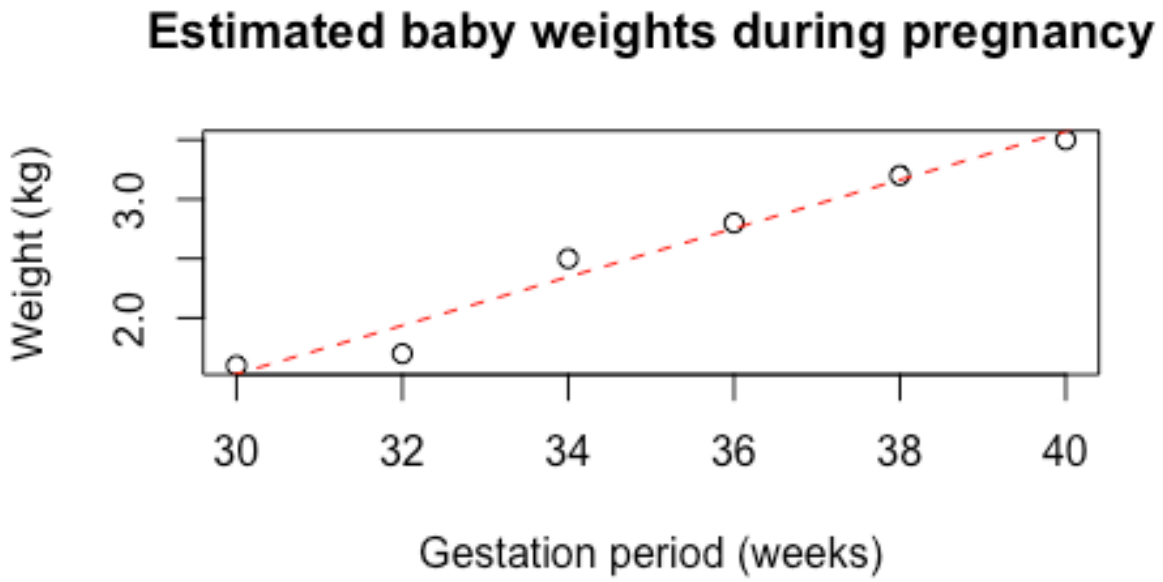
```
Coefficients:
(Intercept)    gestation
    -4.6000       0.2043

> confint(model, level = 0.95)
                 2.5 %      97.5 %
(Intercept) -6.3862379 -2.8137621
gestation    0.1534916  0.2550798
```

Example 1. Linear causal model (linear regression)

$$y = mx + b$$
$$weight = m(gestation\ period) + b$$



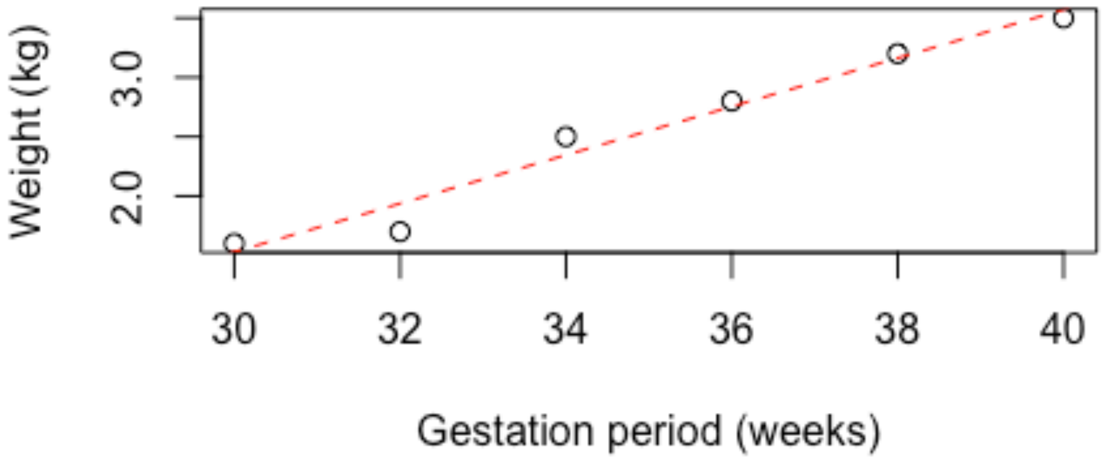


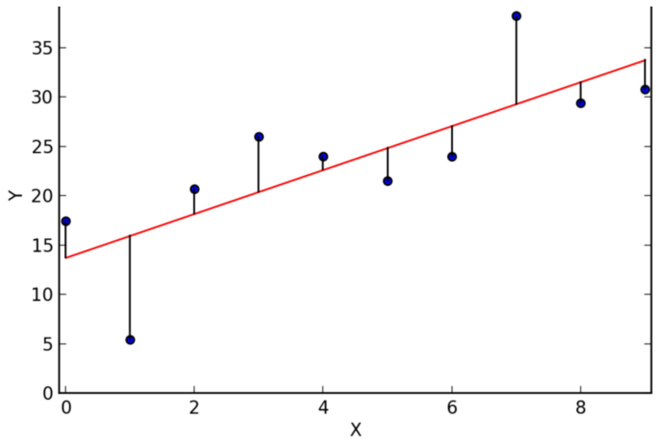
How to use a mathematical model?

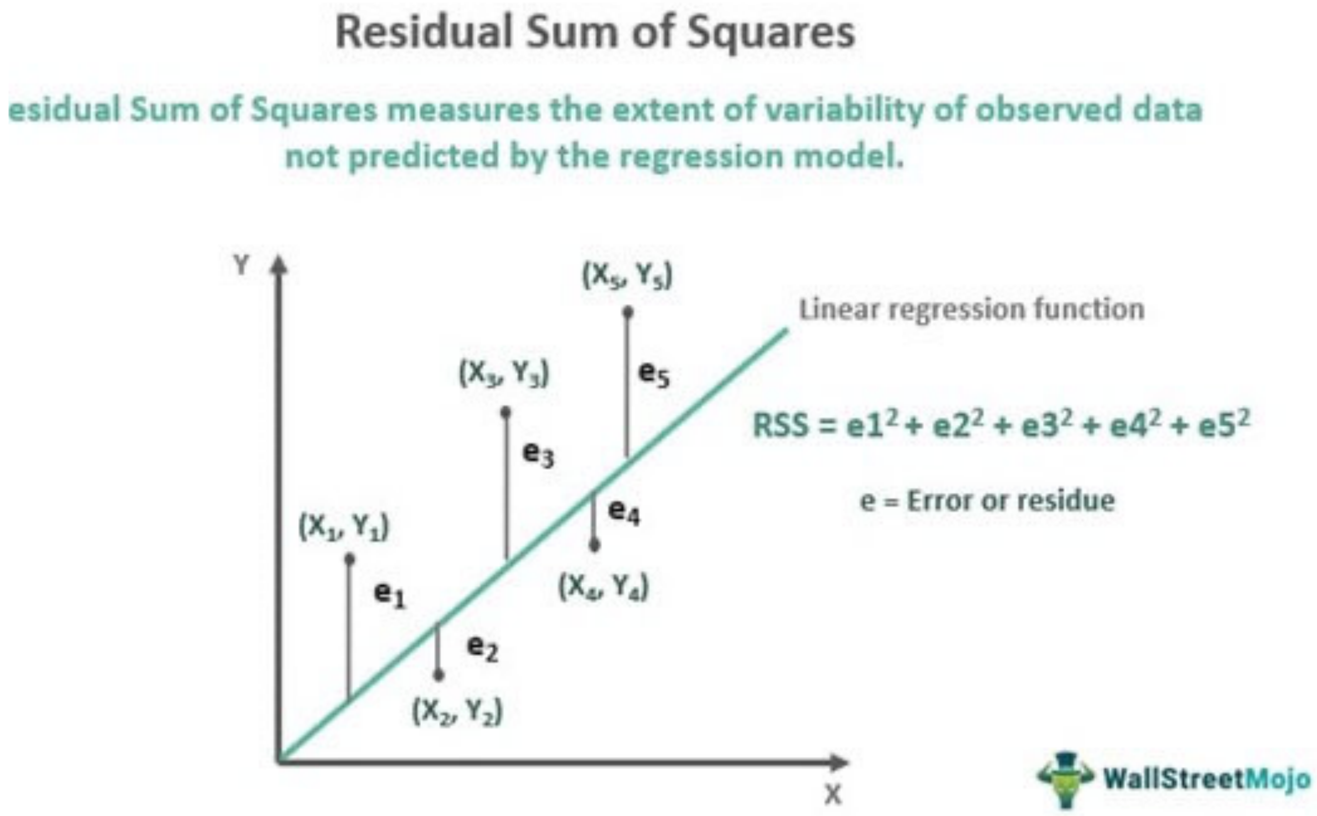
$$weight = m(gestation\ period) + b$$

Least squares regression (line that minmizes sum of squared distances from observed points to model-fit line)

Estimated baby weights during pregnancy





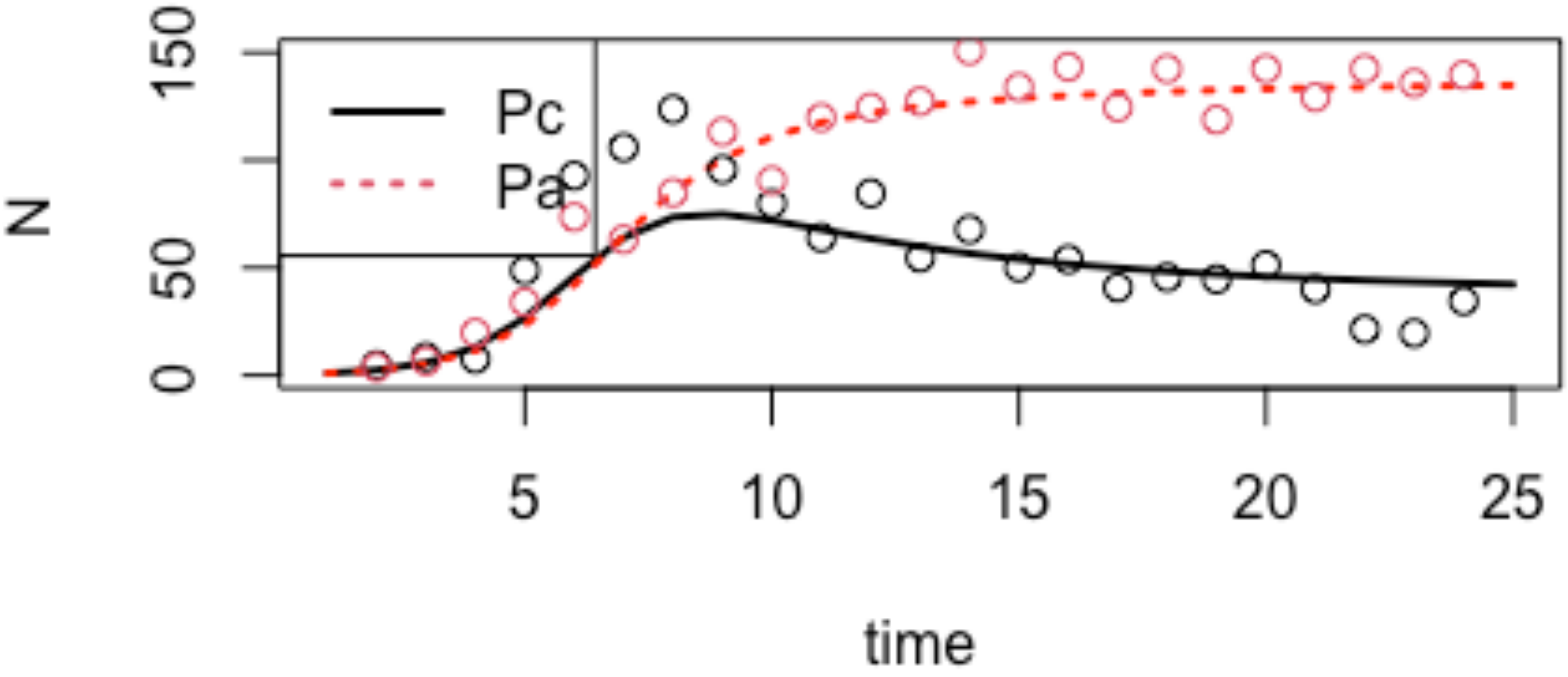


How to use a mathematical model?

Lotka Volterra model

$$\frac{dn_i}{dt} = rn_i\left(1 - \frac{n_i + \alpha_{ij}n_j}{K_i}\right) \qquad \frac{dn_j}{dt} = rn_j\left(1 - \frac{n_j + \alpha_{ji}n_i}{K_j}\right)$$

Non-linear least squares regression – find parameter values that minimize sum of squared distances from observed points to model-fit line



Paramecium caudatum

Paramecium aurelia