# Quantitative Modeling in Context

BIOE 148
NOVAK
LECTURE #1

"All models are wrong, but some are useful." - Box

"No model can be general, precise, and realistic." - Puccia + Levins

"Make your theory as simple as possible, but no simpler." - Einstein.

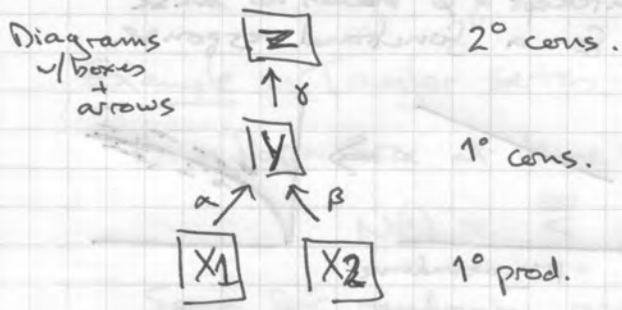
## Categories by Type

Lots of categories - too many to list
Many different motivations and approaches - eg. Tim + Jackson reading

$\Rightarrow$ Context for what we want to cover in course

### Conceptual Models vs. Mathematical models

Ideas
Hypotheses




parameters

$$Y = \alpha X1 + \beta X2 \qquad Z = \gamma Y$$

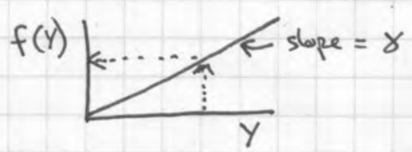
State variable

### Qualitative vs. Quantitative

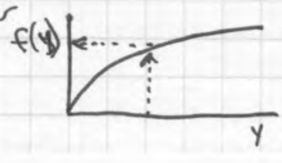
$$\Delta Z > 0 \text{ if } \begin{cases} \Delta Y > 0 \text{ and } \gamma > 0 \\ \Delta Y < 0 \text{ and } \gamma < 0 \end{cases}$$

### Static vs. Dynamic

Feeding rate of Z on Y is a function of Y : $f(Y) = \gamma Y$




could be nonlinear




$f'(Y) > 0$

$Z_{t+1} = \gamma Y_t \quad : \quad Z(Y)$

$Y_{t+1} = \alpha X1_t + \beta X2_t - \gamma Z_t \quad : \quad Y(X1, X_2, Z)$

$X1_{t+1} = -\alpha Y_t \quad : \quad X1(Y)$

$X2_{t+1} = -\beta Y_t \quad : \quad X2(Y)$

Many other types of categories - Individual based, Spatially explicit, etc.

But categories can quickly breakdown

eg 1. Dynamic models contain static models

eg 2. Typically interested in qualitative predictions from quantitative models.

## Categories of Purpose

Quantitative models are tools for evaluating hypotheses/conceptual models

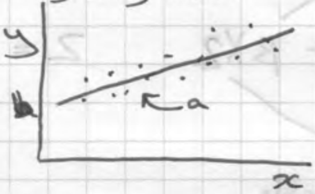
Traditionally:

Statistical Models vs. Process Models

Statistical Models: Hypothesis testing, Parameter Estimation

$\Rightarrow$ Inference

e.g Regression



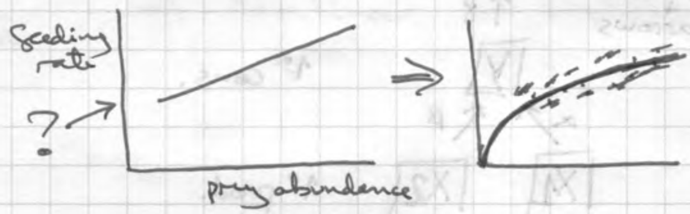

$y = ax + b$

slope (a), intercept (b)

$\Rightarrow$ Pattern ~~explanation~~ (eg. ANOVA, t-tests)

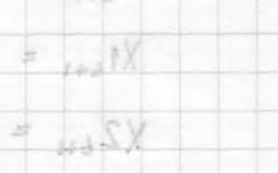
Process Models: 1st principles Analytical, Simulation-based Numeric methods

e.g intercept of Ø makes no sense for a functional response




$\Rightarrow$ Mechanism

Modern day Quantitative Modeling Combines Statistics + Process Modeling



New world of statistical process-model fitting + model-comparison

# Model Complexity

Criticism of theoretical ecology: "Where's the reality?"

"Too simple" - "Irrelevant" - "Real world is way more complex than a handful of parameters and state variables"

"Theory applies in general everywhere, but nowhere in particular."

- Model-fitting shown that low-dimensional models can explain most of observed variation
- Low-dimensional models allow:
  - Identify + focus on most critical parameters, variables + processes
  - Explore uncertainty
  - Decision making tools
  - ⇒ General understanding

"No model can be general, precise, and realistic" - Puccia + Levins '85

## Example: Taylor series applied to Lynx-Hare dynamics

Hare Popn Size at time t - $N(t)$

$$N(t) = \sum_{n=0}^{\infty} \beta_n t^n = \beta_0 \cancel{t^0}^{\,1} + \beta_1 t^1 + \beta_2 t^2 + \ldots + \beta_n t^n$$

Same for randomly generated numbers (Group exercise)

What have we learned from polynomial fit?

Statistical model = perfect fit!

Process model = understanding

$$\frac{dN}{dt} = N(\alpha - \beta L)$$

$$\frac{dL}{dt} = L(e\beta N - d)$$

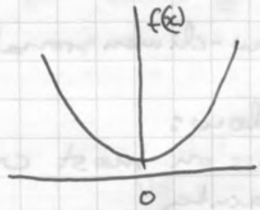
# Linear vs. Nonlinear Models

$f(x) = \alpha + \beta x$

variable - $x$
parameters - $\alpha$ and $\beta$


$\Rightarrow$ Linear model

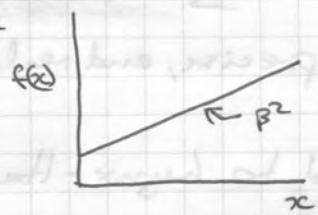
$f(x) = \alpha + \beta x^2$




$\Rightarrow$ "Nonlinear" for ecologists + mathematicians ("nonlinear in state variable")

$\Rightarrow$ "Linear" for statistician (in parameters)

$f(x) = \alpha + \beta^2 x$




$\Rightarrow$ "Linear" for ecologists + mathematicia

$\Rightarrow$ "Nonlinear" for statistician (nonlinear in parameters)

Remember to bring laptops to class