The Art of Modelling

Overview of the modeling process

Bio534
Meeting #3
Fall 2011

Announcements & Assignments

READ
– Patten & Van Dyne pers. Com.

LABORATORY
- Lab1 due before Lab on Wednesday

Questions & Concerns?

Daily Objectives

At the end of today's meeting, you should be able to:

- Characterize the fundamental modeling relationship
- Identify steps in the classic protocol for building quantitative models
- Explain differences between the classic modeling protocol and the use of alternative models

Modeling Relationship

The Formal Modeling Relation

Q: What does the model tell you about the natural system?

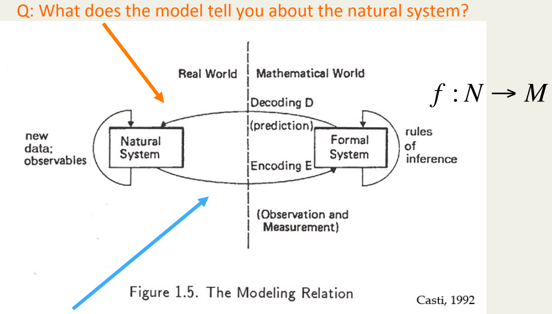


Figure 1.5. The Modeling Relation

Casti, 1992

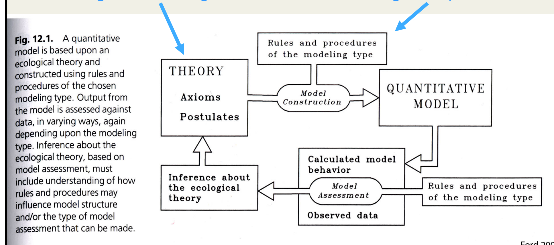
This abstraction process is key to model making.

Q: What do you include in the model and how do you formally represent it?

Quantitative Models Relate Theory to Observations

Background knowledge

Modeling "Theory"



Ford 2000

Constraints on Models

Three properties of models (Levins 1966)

Realism
degree with which the model mimics the real world

Precision
accuracy of model predictions

Generality
the number of systems or situations to which the model correctly applies

All three cannot be maximized simultaneously: Tradeoffs exist

All Models are Wrong, Some are Useful

G.E.O. Box

Modelling Process

An abstract understanding of modeling process

Models are Problems: Problem Solving

Understand the problem
What is the question?

Devise a plan to solve the problem
How to solve it

Execute the plan
Search for the model
Search for the answer

Check the correctness of the answer
– Was the answer right?
– How do we know this

Polya 1973, as in Haefner

Classic Modeling Protocol

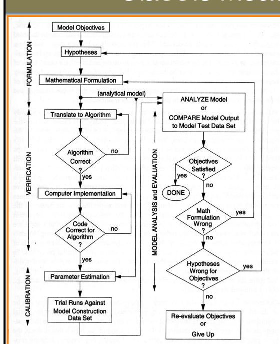


Figure 2.1: The classical approach to the modeling process, showing the four basic stages. In this approach, alternative models are developed sequentially, conditional on the failure of a previous model.
Also See Figure 1 in Jackson et al. 2000

- State project objectives
- Obtain background information
- System conceptualization
  - Specify model components, connections, and controls
  - Specify model boundaries
- Represent formally (Math)
  - Construct diagram
  - Write equations or algorithms
- Est. parameters, IC's and calibrate equations with data
- Implement model (encoding), simulate, and analyze
- Evaluate model (verify, validate)
- Sensitivity analysis
- Use and Revise.

Recursive!

Alternative Models

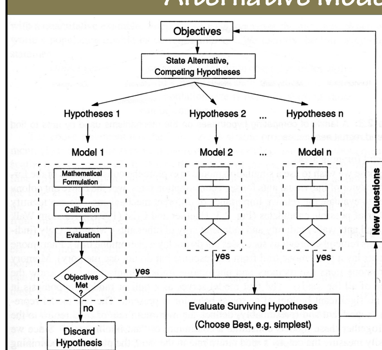


Figure 2.2: Another view of the modeling process, in which alternative hypotheses and models are developed and tested independently.
Haefner 2005

Modeling as Search through the space of possible models guided by theory and data

Model = Hypothesis?

Hypothetico-deductive science

Null model

Neutral model

Anatomy of a Mathematical Model

Bound the system of interest (scale, level, space, time)

Identify & categorize

Components, Connections, & Controls – 3 C's of modeling

State Variables – describe the "state" of the system component, change in time

- Storages (M L^{-2} or M L^{-3})
- currency (energy or matter)
- Aggregation problem – how to lump or split components

Driving Variables – force the system behavior, outside of system boundary

Auxiliary Variables – other variables of interest in the system (eg, growth rate)

Parameters – constant within a model, but may vary between systems

Constants – universal – don't vary across systems (eg Avogadro's number)

Flows (M L^{-2} T^{-1} or M L^{-3} T^{-1})

- processes that generate fluxes

Modeling Questions

- How do we use models in ecological science?
- What features characterize "good" models?
- How can we represent a natural process *N* in a formal system *M*?
- How can we compare two models of the same natural process?
- How can we identify key features of a natural system?
- How does a given system relate to its subsystems?
- When can two systems that behave similarly be considered as models of each other?
- How complex should a model be?

Part of our quest this semester is to address these questions
(see schedule overview in syllabus)