BIOL 650 - Environmental Analysis and Modeling
Part II - Dynamic Modeling

I. Parable of the Elephant. What is a model?
II. Quantities or qualitites of interest in an ecological model:
    A. Environmental variables (temp, light, chemical concentrations...)
    B. Physiological variables (body temp, oxygen consumption, enzyme activity,...)
    C. Population variables (# of individuals, biomass of individuals, birth rate, feeding rate...)
    D. Community variables (diversity, biomass by guild...)
    E. Ecosystem variables (energy flow, elemental cycling...)
III. Types of models
    A. Word (verbal) models
    B. Diagramatic models
    C. Physical models
    D. Mathematical models
IV. Uses of models
    A. General: synthesis, analysis, instrumentation
    B. Science: understanding, prediction, control
    C. Conceptual framework for organizing research, mechanism to summarize large quantities of data and identify areas of ignorance, all “what-if”scenarios by managers.
V. Types of Mathematical Models
    A. Empirical vs. Mechanistic
    B. Static vs. Dynamic
    C. Spatially heterogeneous vs. Spatially homogeneous
    D. Stochastic vs. Deterministic
    E. Example: the leaky bucket
VI. Constraints on Model Structure
    A. Realism vs. Precision vs. Generality
    B. Data quality and degree of mechanistic understanding
VII. The Modeling Process
    A. Classical View (single working hypothesis, sequentially modified)
    B. Multiple working hypothesis
VIII. Qualitative Model Formulation
    A. Forrester diagrams
        1. Objects/state variables compartments (boxes)
        2. Material flows (solid lines with bow ties and arrows)
        3. Information flows (dotted lines with arrows)
        4. Sources and sinks (clouds)
        5. Parameters (small circles with line through it)
        6. Auxillary variables (larger circle)
        7. Driving variables/forcing function (diamond)
    B. Some examples: herbivore system, population growth
    C. Multiple state variables

D. Multiple flow variables
E. Errors & uses of Forester diagrams
F. Steps in qualitative model formulation
    1. Identify state variables (those whose levels you want and others that need to vary dynamically, i.e. through time)
    2. Identify flows among the state variables
    3. Identify controls on the flow rates
    4. Identify auxilliary and driving variables
G. Model simplification
    1. Occam's razor
    2. Eliminate state variables
    3. Make stronger assumptions
    4. Remove temporal complexity
    5. Remove spatial complexity

IX. Quantitative Model Formulation
- A. State variables, inputs, outputs
- B. Finite difference equations vs. differential equations
- C. Translating Forester diagrams
- D. Dynamic relative rates
    1. Per capita rates
    2. Donor vs. Recipient control
    3. Feedback: positive vs. negative
    4. Self-inhibition
    5. Extrinsic
    6. Saturation
- E. Mass Action
- F. Conservation of mass and energy
- G. Multiple controlling factors
    1. Secondary influence vs. Multiple primary factors
    2. Liebig's law model
    3. multiplicative model
    4. arithmetic average model
    5. harmonic mean model
    6. additive rates model
- H. Discontinuous functions
- I. Driving variables
- J. Useful functions
- K. Summary of quanititative model formulation

X. Numerical Techniques
- A. Differential vs. Difference equations
- B. Analytical vs. Numerical solution of differential equations
- C. Euler method
- D. Runge-Kutta (2nd order="Improved Euler")
- E. Parameter estimation
    1. Direct linear regression
    2. Tranformed linear regression
    3. Polynomial regression
    4. Multiple linear regression
    5. Nonlinear regression

XI. Model Validation
- A. Definition
- B. Criteria
- C. Difficulties
- D. Geometry of validation
- E. Conditions for validation
- F. Unreplicated vs. replicated systems
- G. Model discrimination
- H. Sensitivity analysis

XII. Models of Growth
- A. Homogeneous populations
  - 1. Unlimited environment
  - 2. Limited environment
    - -logistic
    - -Monod
  - 3. Effect of temperature on growth
  - 4. Growth and light
- B. Age-specific population models
  - 1. Mortality patterns
  - 2. Fecundity patterns
  - 3. Life tables
  - 4. Leslie matrix
  - 5. Limited environment
  - 6. Fisheries models

XIII. Models of Environmental Factors
- A. Light
  - 1. Annual cycle
  - 2. Daily cycle
  - 3. Effects of cloud cover and backscatter
  - 4. Reflection
  - 5. Absorption of light in a water column
- B. Temperature
  - 1. Annual cycle
  - 2. Heat budgets/balance
    - a. Lake
    - b. Camel
    - c. Lake stratification
- C. Oxygen
  - 1. Sources and sinks
  - 2. Dissolved oxygen modeling

XIV. Compartment Models and the Flow of Materials
- A. Material cycling and energy flow
- B. Nitrogen vs. Phosphorus
- C. Phosphorus in a lake
- D. Global carbon cycling
- E. Energy flow
- F. Silver Springs Model