1.020 Ecology II: Engineering for Sustainability
Spring 2008

Lecture 08_4 Outline: Population Modeling, Pesticide Impact

Motivation/Objective
Develop alternative models to examine impacts of pesticide on a pest (prey) population and on a predator that feeds on the pest population. Consider implications of different model assumptions.

Approach
1. Define system, compartments, fluxes. Identify unknowns (predator biomass M_1 and prey biomass M_2).
2. Write mass balance equation for each compartment (rate form)
3. Develop alternative expressions (models) for gain and loss terms in each compartment's mass balance eq.. Relate these expressions to unknown biomasses.
4. For each model, specify inputs, solve the set of coupled nonlinear mass balance eqs. for the unknowns (MATLAB).
5. Examine impacts of initial conditions and other inputs that change character of time response.

Concepts and Definitions:
Ecosystem models are typically structured like chemical kinetics models.
System compartments are populations/species, chosen for convenience
Each compartment's unknown = population/species biomass (kg dry weight, kg m^{-2}, or kg $m-^{3}$).
Biomasses are not conservative: mass gains and losses need not sum to zero over all compartments.
Compartment gain and loss terms selected to yield realistic growth properties, carrying capacities, etc. -- no single model is appropriate for all situations.

Population (biomass balance) eqs:
Lotka-Volterra predator-prey model (1=prey, 2 = predator):

$$\frac{dM_1}{dt} = r_1 M_1 - \beta_{12} M_1 M_2 \qquad \frac{dM_2}{dt} = \beta_{21} M_1 M_2 - r_2 M_2$$

Lotka-Volterra model with logistic growth for prey (more realistic):

$$\frac{dM_1}{dt} = r_1 M_1 \left(1 - \frac{M_1}{K_1}\right) - \beta_{12} M_1 M_2 \qquad \frac{dM_2}{dt} = \beta_{21} M_1 M_2 - r_2 M_2$$

Holling model (more coefficients):

$$\frac{dM_1}{dt} = r_1 M_1 \left(1 - \frac{M_1}{K_1}\right) - \left(\frac{aM_1}{1 + aT_1 M_1}\right) M_2 \qquad \frac{dM_2}{dt} = r_2 M_2 \left(1 - \frac{M_2}{kM_1}\right)$$

Model results:
Note equilibria, oscillations, sensitivity to coefficients in gain/loss terms