1.020 Ecology II: Engineering for Sustainability
Spring 2008

Lecture 08_5 Outline: Closed Cycles, Nutrient Enrichment

Motivation/Objective
Develop a model to track nitrogen mass in dissolved, phytoplankton, and zooplankton compartments. Assess impact of nutrient enrichment.

Approach
1. Define system, compartments, fluxes. Identify unknowns (dissolved nitrogen mass N_d, phytoplankton nitrogen mass N_p, and zooplankton nitrogen mass N_z)
2. Write mass balance equation for each compartment (rate form)
3. Relate terms in each balance eq. to unknowns and other inputs
4. Specify growth, predation, and other coefficients, solve the set of coupled mass balance eqs. for the unknowns (MATLAB)
5. Examine time-dependence of compartment masses with and without nutrient enrichment.

Concepts and Definitions:
System compartments provide mass labels, chosen for convenience.
Each compartment's unknown = mass of a specified conservative constituent in that compartment.
Constituent mass is conservative but can move between compartments: mass gains and losses must sum to zero over all compartments.
For ecological modeling conservative constituent = limiting nutrient (in this example: nitrogen)
Arrange compartments in a closed cycle (all mass remains within system compartments)
Relate compartments by specifying mass fluxes (such as uptake, grazing, death) between them.

Compartment mass balance eqs:

$$\frac{dN_d}{dt} = \dot{m}_{boundary,1} + d_p N_p + d_z M_z - g_p\left(\frac{N_d}{N_{dh}+N_d}\right)N_p + (1-\varepsilon)g_z\left(\frac{N_p}{N_{ph}+N_p}\right)N_z$$

Plankton death Dissolved uptake Grazing residue

$$\frac{dN_p}{dt} = g_p\left(\frac{N_d}{N_{dh}+N_d}\right)N_p - d_p N_p - g_z\left(\frac{N_p}{N_{ph}+N_p}\right)N_z$$

Dissolved uptake Phyto death Grazing uptake

$$\frac{dN_z}{dt} = g_z\left(\frac{N_p}{N_{ph}+N_p}\right)N_z - (1-\varepsilon)\,g_z\left(\frac{N_p}{N_{ph}+N_p}\right)N_z - d_z N_z$$

Grazing uptake Grazing residue Zoo death

Model Results:
Note effect of changing enrichment level and coefficients that control mass fluxes.