BREAKING DOWN ECOSIM

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CONTENTS

Main Equation

PDE

The main equations of Ecosim model are the next.

$$\frac{\partial B_i}{dt} = g_i \sum_j Q_{ji} - \sum_j Q_{ij} + I_i - (M_i + F_i + e_i)B_i \qquad (1)$$

Where B_i is the Biomass of the ith functional group, g_i is the net growth efficiency, Q_{ij} is the j consumption over group i, I_i is the net immigration of group i, and M_i, F_i, e_i are the natural and other mortality rate, Fishing rate and emigration rate of group i respectively.

Main Equation

Dimensional Analysis

If we go through a dimensional Analysis of every term in the equation, from a naive approach.

$$\frac{\partial B_i}{dt} = g_i \sum_j Q_{ji} - \sum_j Q_{ij} + I_i - (M_i + F_i + e_i)B_i \qquad (2)$$

$$[MT^{-1}] = [MM^{-1}][M] - [M] + [M] - ([T^{-1}] + [T^{-1}] + [T^{-1}])[M] \qquad (3)$$

Please note that g_i is just $(Q/B)_i$, and also that this is a naive approximation because units make no sense. So consumption and Immigration ought be related to a time unit.

Main Equation

Types of Functional Groups

–Producers, in which the consumption (firs term in the RHS) is replaced by a production term :

$$f_i = \frac{r_i B_i}{(1 + B_i h_i)} \tag{4}$$

Where $h_i = (r_i(P/B)_i - 1)/B_i$, and r_i is an user given maximum (P/B) relation per functional group.

–Consumers, consumption rates must be determined.

–Detritus, which have consumption over and where mortality and unassimilated fractions goes.

Consumption

First Approach

The first approach is just the primitive Lotka-Volterra one

$$Q_{i,j}(B_i, B_j) = a_{ij} B_i B_j \tag{5}$$

Where a_{ij} is the instantaneous mortality rate on prey i caused by one unit of predator j biomass, and it could be estimated from diet matrix and Ecopath biomasses and consumptions results.

$$a_{ij} = Q_{ij}/(B_i B_j) \tag{6}$$

By doing that, the time unit must be the same as the Ecopath one.

Consumption

First approach results

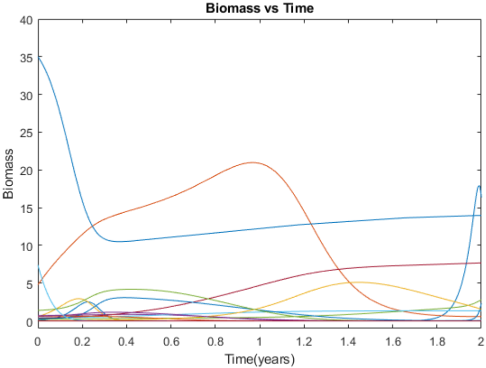

Figure – Plain Lotka-Volterra Approximation

Consumption

First approach comments

–The assumption here is that the preys are always available for the predators, and that they can eat as fast as light, which is not true.

–That's why there are a lot of oscillations in the plot, and that causes also a numerical stability problem, because the time step must be really small to ensure it ($1E^{-6}$ years).

–This kind of approximations are good for chemical processes that takes little time to come about, but not for fishes which must deal with searching for preys, catch and eat them.

Consumption

Second Approach

The second approach is a Lotka-Volterra modified to include a vulnerability factor on every relation prey-predator. Let's call it Plain Foraging Arenas. The assumption is that every prey pool B_i have an available component to each consumer j, V_{ij}

$$\frac{V_{ij}}{dt} = \tilde{\nu}_{ij}(B_i - V_{ij}) - \nu_{ij}V_{ij} - a_{ij}V_{ij}B_j \tag{7}$$

"That is, V_{ij} gains biomass from the currently unavailable pool $(B_i - V_{ij})$ at rate ν_{ij}, biomass returns to the unavailable state at rate $\nu_{ij}V_{ij}$, and biomass is removed from V_{ij} by the consumer at a mass-action encounter rate $a_{ij}V_{ij}B_j$" (Walters, 97).

Consumption

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Consumption

Second Approach

Taking an equilibrium assumption

$$V_{ij} = \frac{\tilde{\nu}_{ij} B_i}{(\nu_{ij} + \tilde{\nu}_{ij} + a_{ij} B_j)} \tag{9}$$

And that rates ν and $\tilde{\nu}_{ij}$ can be assumed the same, then

$$V_{ij} = \frac{\nu_{ij} B_i}{(2\nu_{ij} + a_{ij} B_j)} \tag{10}$$

Consumption

Second Approach

The flow rates are

$$\nu_{ij} = \frac{(Q/B)_j B_j D_{ij} \chi_{ij}}{B_i} = \frac{Q_{ij} \chi_{ij}}{B_i} \tag{11}$$

Where $(Q/B)_i$ is the consumption-biomass Ecopath relation of predator, B are the biomasses, D_{ij} is the diet relation between prey-predator, χ_{ij} is the user given vulnerability.

Consumption

Second Approach

Then $a_{i,j}$ can be computed as follow

$$a_{ij} = \frac{2Q_{ij}\nu_{ij}}{(\nu_{ij}B_iB_j - Q_{ij}B_j)} \tag{12}$$

Where $(Q/B)_i$ is the consumption-biomass Ecopath relation of predator, B are the biomasses, $D_{i,j}$ is the diet relation between prey-predator, $\chi_{i,j}$ is the user given vulnerability. In other words, the relation between net consumption times vulnerability factors and prey biomasses.

Consumption

Second Approach

And finally consumptions are

$$C_{ij} = \frac{a_{ij}\nu_{ij}B_iB_j}{(2\nu_{ij} + a_{ij}B_j)} \tag{13}$$

Here there is a limitation in the available biomass for consumption based on vulnerabilities. The term "arena" is nothing but every relation prey-predator.

Consumption

First approach results

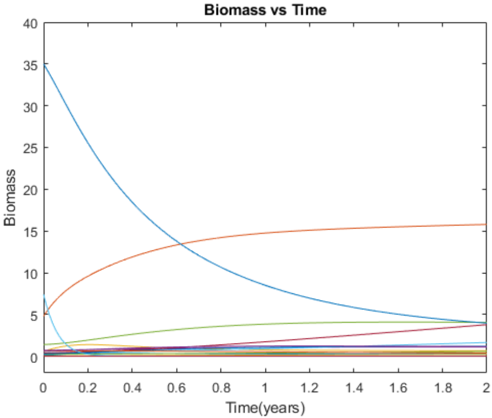

FIGURE – Plain Foraging-Arena Approximation

Consumption

Third Approach

The third approach adds some modifications : a feeding time $Ftime$ limitation and switching relation Rs, i.e., prey selection of predator based on abundance. a_{ij} and v_{ij} are modified in the next way

$$\tilde{a}_{ij} = a_{ij} Ftime_j Rs_{ij} \tag{14}$$

$$\tilde{\nu}_{ij} = \nu_{ij} Ftime_j \tag{15}$$

Consumption

Third Approach

And consumption is :

$$C_{ij} = \frac{\tilde{a}_{ij}\tilde{\nu}_{ij}B_iB_j}{(\nu_{ij}hden_j + \tilde{\nu}_{ij}hden_j + \tilde{a}_{ij}B_j)} \tag{16}$$

Where $hden_j$ is a limitation to the maximum consumption of every predator, and is updated every time step ; as well as $Ftime$, but in Ecosim is updated every month.

Consumption

Third Approach

Updating feeding time :

$$Ftime_j^{m+1} = 0.1 + 0.9 Ftime_j^m (1 - Fadj_j + Fajd_j Qopt_j / CBlast_j) \tag{17}$$

Where $Fadj$ is an input parameter for adjust Feeding Times, $Qopt$ is the optimal consumption, and $CBlast$ is the actual consumption over biomass rate. And in differential form (deducted for updating every time step) :

$$\frac{\partial Ftime}{\partial t} = 0.1(1 - Ftime_j) - 0.9 Ftime_j Fadj_j \left(1 + \frac{Qopt_j}{CBlast_j}\right) \tag{18}$$

Consumption

Third Approach

Updating $hden$:

$$hden_j = 0.5(1 + htime_j hdent_j) + 0.5 hden_j \tag{19}$$

Where $htime_j$ is a handling time factor for predators, and hdent :

$$hdent_j = \sum_i \tilde{a}_{ij} Vbiomij \tag{20}$$

Where $Vbiom_{ij}$ is the vulnerable biomass in every arena.

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