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THE MODELLING OF AN AQUATIC ECOSYSTEM AS HYPERCYCLE

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Introduction

One of the characteristic features of ecosystems behaviour is cyclic changes of component biomasses and numbers. They are observed both in natural objects and in artificial ecosystems.

Application of Lotka – Volterra and energy flow models to systems containing more than two components demonstrates reducing of oscillation amplitude and stabilization of components parameters at fixed levels. Another fact hardly simulated with the use of existing approaches is "paradox of plankton" – coexisting of two or more species in the same ecological niche (Hutchinson, 1961). To explain it researchers are forced to find any, though very small differences in ecological characteristics of these species, such as optimal temperatures or oxygen contents, growth rates, nutrient thresholds for growth, mortality, time and duration of mass development, albeit the last can be not the cause but effect of coexistence.

Some authors have explained "paradox of plankton" using hypercycles proposed for understanding of early stages of evolution. They have created model of phytoplankton populations affecting each other by the extracellular products causing toxic or stimulating action.

The purpose of present contribution is the demonstration of modelling method allowing coexistence of more than one identical species in plankton community with the unlimited oscillations duration and without exometabolitic regulation.

Results and discussion

Nicolis and Prigozhin (1977) basing on the following suggestions:
$A + X \xrightarrow{k} 2X$, $X \xrightarrow{d} A$, $A + X = N = const$, where A – food, X – component biomass, N – general organic matter content in closed system, k, d – growth and death rate coefficients, obtained $\frac{dX}{dt} = kX(N - X) - dX$, These equations are identical to those used for description of autocatalytic processes, where component X serves as catalyst for self-creation from substance A. Such autocatalytic and self-reproduction units can be regarded in cycles called hypercycles (Eigen, Schuster, 1979).

Ecosystem also can be described as hypercycle, where every next trophic level obtains material from previous level to reproduce itself as autocatalyst. Phytoplankton obtains nutrients from bacteria to create organic matter with the use of external energy (solar irradiation). Zooplankton feeding on phytoplankton obtains organic matter for growth. Bacteriae in turn get food supply from zooplankton corpses.

Of course, this scheme is idealized as bacteriae obtain food from phytoplankton extracellular products and dead phytoplankton cells, zooplankton can consume not only phytoplankton but

also bacteriae etc. Nevertheless this scheme represents the most important ways of energy and matter transfer in closed ecosystem including producers, consumers and reducers.
Dynamics of components is determined by following system of equations

$$\begin{aligned} dx_1/dt &= f(x_1,\mu_1,\phi(x_3)) - g(x_1,\varphi(x_2)), \\ dx_2/dt &= f(x_2,\mu_2,\phi(x_1)) - m(x_2), \\ dx_3/dt &= f(x_3,\mu_3,\phi(x_2)) - m(x_3), \end{aligned} \tag{1}$$

where x_i – biomasses, f – growth functions, m – death functions, g – grazing function, ϕ – effectiveness of energy and matter conversion (for phytoplankton – relation between bacteriac concentration and nutrients availability) between components, φ – effectiveness of grazing, μ – maximum growth rate. Indices mean: 1 – phytoplankton, 2 – zooplankton, 3 – bacteriae. Function parameters were calculated on the ecosystem stability condition $dx_i/dt = 0$.

Also author investigated a system including two species of phytoplankton (x_{11}, x_{12}) competing for nutrient supply and two species of zooplankton (x_{21}, x_{22}), and bacteriae. Biomasses for these newly introduced species at stability state were x_{12}=0.33x_{11}, x_{22}=0.1x_{21}. System was described by

$$\begin{aligned} dx_{11}/dt &= f(x_{11},\mu_{11},\phi(x_3),\xi(x_{11},x_{12})) - g(x_{11},\varphi(x_{21})), \\ dx_{12}/dt &= f(x_{12},\mu_{12},\phi(x_3),\xi(x_{12},x_{11})) - g(x_{12},\varphi(x_{22})), \\ dx_{21}/dt &= f(x_{21},\mu_{21},\phi(x_{11})) - m(x_{21}), \\ dx_{22}/dt &= f(x_{22},\mu_{22},\phi(x_{12})) - m(x_{22}), \\ dx_3/dt &= f(x_3,\mu_3,\phi(x_{21},x_{22})) - m(x_3), \end{aligned} \tag{2}$$

where ξ – competition for nutrients function.

Dynamics of model (1) after external influence shows its returning to the stability point. Such behaviour is characteristic for stable non-linear systems.

There are no oscillations in this system, it always returns to stable state after initial biomasses changes. Hypercycles with not more than three components are shown to become stable with equilibrium concentrations of components regardless with initial concentrations.

Model (2) demonstrates oscillation behaviour around stability point but never reaches it.

Conclusions

Presented model of two competing hypercycles shows:

1. Simultaneous coexistence of two phytoplankton species obtaining nutrients from the one source.
2. Auto-oscillations of all the components included in model in constant environmental conditions, similar to those observed in real ecosystems.

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