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THE STRUCTURE AND SOME FEATURES OF THE MATHEMATICAL MODEL FOR STUDY OF THE INFLUENCE FOOD PREFERENCES OF ZOOPLANKTON ON THE DYNAMIC BEHAVIOR OF *N–P–Z–D* PLANKTON FOOD WEB

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Summary

In this work the properties of the *N–P–Z–D* model of plankton food web were investigated. The model takes into account that there are certain food preferences in the diet of zooplankton. The additional mathematical model, which is able to generate some of the fundamental rules of food behavior, was developed. It gives the possibility to explore the impact of changing food preferences in the diet of zooplankton on the dynamic behavior of the entire of plankton system.

Results

The aim of the study was to investigate of the dynamic behavior of a spatially homogeneous mathematical model of four-component plankton system. The model includes nutrients (*N*), phytoplankton (*P*), zooplankton (*Z*) and plankton detritus (*D*) (Podgornyj, 2012). In the model the grazing of zooplankton by fish was described by the linear dependence. The function of Holling IItype is used for describing of grazing phytoplankton by zooplankton. An important feature of the model is the use of non-linear dependence in the description of mineralization of detritus. The model takes into account the negative impact of the phytoplankton metabolites on the development of zooplankton. The model structure also suggests that zooplankton can feed upon phytoplankton (with the value for coefficient of food preference P_{Phyto}) and plankton detritus (with the value for coefficient of food preference P_{Detr}). The numerical model experiments were carried out for different values of the coefficients of food preferences P_{Phyto} and P_{Detr} in feeding of zooplankton.

As a result, it was shown that a changes in the parameters of the model leads to a successive changes of types of dynamic regimes. The steady node, steady focus and limit cycle can be observed in the system. The certain combinations of parameter values in the system lead to a series of successive bifurcations of period-doubling and then to the chaotic oscillations. It was also found that there are such ranges of change for parameter values within which there are several successive periodic and chaotic oscillations of the system. In natural conditions the zooplankton organisms are able to change their food preferences in depending on environmental conditions and actively choose between food sources. Such choice has to follow from some basic properties of the nonlinear dynamical system, which provides exploratory behavior of animals, and leads to the most effective functioning of the whole plankton system. Thus, zooplankton should be considered as a kind of "dynamic agent" which independently creates biologically plausible rules of your searching behavior and changes of food preferences in depending on the current state of the system. The additional model, which realizes the change of food preferences in feeding of zooplankton (it is determined by the value of food preferences coefficient $P_{food} = P_{Detr} / P_{Phyto}$), was introduced into the basic model of the plankton food chain. It is assumed that this sub-model consists of the three oscillators and has the single food sensor. All oscillators at any time are in the active state. Activating the oscillator influences on the other two oscillators which determine the tendency for change of the coefficient of food preference of zooplankton in a given time. As a result, of functioning of these oscillators on output we get the activating (F), left (L) and right (R) tendencies respectively. All the tendencies on each time step change in accordance with the one-dimensional logistic map (Nepomnyashchikh, Podgornyj, 2003):

$$F_{t+\tau} = \lambda^{F}_{t} (1 - F_t),\ L_{t+\tau} = \lambda^{L}_{t} L_t (1 - L_t),\ R_{t+\tau} = \lambda^{R}_{t} (1 - R_t),$$

where $0 < F_t, L_t, R_t < 1;\ 0 < F_{t+\tau}, L_{t+\tau}, R_{t+\tau} < 1;\ 0 < \lambda_t^F, \lambda_t^L, \lambda_t^R < 4$ and τ is the time step. It is assumed that the values of model parameters $\lambda_t^F, \lambda_t^L, \lambda_t^R$ affect the internal and external noise as well as take into account what was the food stimulation in the previous time step and stimulation at a given time. The dynamic features of the sub-model are caused noise-induced the phase transitions which explained by a combination of stability behavior with his probabilistic modification by an external signal (Nepomnyashchikh, Podgornyj, 2003). The considered model the "dynamic agent" reproduces a minimal set of rules search of food common for many organisms. Using the calculated values of tendencies $L_{t+\tau}$ and $R_{t+\tau}$ we can estimate the absolute difference $\Delta P_{t+\tau}$ $\left| L_{t+\tau} \square R_{t+\tau} \right|$ between these values. Thus if $L_{t+\tau} > R_{t+\tau}$ then $(P_{food})_{t+\tau} = (P_{food})_t - \Delta P_{t+\tau}$ and otherwise,

$(P_{food})_{t+\tau} = (P_{food})_t + \Delta P_{t+\tau}$

References

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