New Approach to the Problem of Forecasting Population Peaks of Rodents Based on DMDS

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Introduction

Population peaks of rodents is the dangerous evidence of misbalance in communities of living organisms due to the fact that these animals are potential agricultural pests and reservoirs of certain dangerous infectious diseases. Sharp climate changes, which have now global scale, along with other problems have sharpened this danger. This circumstance determines an importance of investigations of systemic factors, that determine the stability of rodents number.

There is a well-known approach to the problem of stability of ecological systems, which links the stability with indices of diversity and uniformity of different species. Appropriate methods are proposed by Shannon, MacArthur and other authors [1-3]. Mathematical apparatus for assessing diversity and uniformity is widely used since the second half of 20th century.

In practice, these methods are used for limited number of measurements of indices for diversity and uniformity of system in certain instants of time. These indices give some ground for conclusion about the presence or absence of stability.

For modelling ecological systems with the use of the apparatus of discrete modelling of dynamic systems with feedback (DMDS) [4] another approach is possible. It has showed its positive properties in some situations [5-7]. Discrete dynamic system has a trajectory that has a finite (though, maybe very large) period length. Thus, the number of different combinations of values (hereinafter referred to as its states) of the system components within the period is finite. These states ordinary correspond to steps — instants of time for the. So if on the basis of experimental data the dynamic system, which is the best suited to these data, is identified, it can be stated that a set of its states (trajectory of system) is also the most probable for real ecological system, from which the data were collected. If you know that this ecological system has stable (or another selected) type of dynamics, so according to one-time or relatively few registrations of its states, it’s possible in some situations to make conclusions about the presence of certain type of dynamics in our system.

Generally speaking, we assume that the studied ecological system may have few fixed number of types of dynamics, caused by sufficiently different nature of intra- and inter-component relations. In this case we can, preliminarily having identified these types of dynamics by DMDS, in the future with a certain probability to identify these types of dynamics by few number of observations over system. In this case the results of DMDS, i. e. the sets of states of the discrete model, belonging to trajectory, are used classifying mentioned types of dynamics.

Methods

In our work we have chosen the community of small Mammalia as a sample of real ecological system. The data about small Mammalia from the steppe zone of Kharkiv region of Ukraine for time period 1990-2000 were used.

Field material was collected and processed by standard methods [8].

In the study the sets of states of dynamical system from the period of its trajectory were found with help of DMDS. These sets determine the types of community dynamics of small Mammalia for two selected periods. 1st period — before population peak of species Sylvaemus uralensis, which had disrupted the stability of the community in 1996, 2nd — after peak, when the state of the community had stabilized.

Note, that the choice of criterion of stability for the system is enough hard problem. In the study this problem was solved in frameworks of practical aspects, in connection with undesirability of sharp increase of fluctuation amplitudes (in the form of population peak) of number of animals, which are potential agricultural pests and reservoirs of infectious diseases.
These sets of states were compared to each other in order to establish their predictive value for registration of stable or unstable type of dynamics for rodents community.
DMDS with use of Liebig-like low was applied [4], the number of levels was equal to 3. For DMDS the data on population dynamics of four species, including Sylvaemus uralensis and other three species, were used. These three species were chosen on the basis of the greatest differences between Pearson correlation coefficients (with Sylvaemus uralensis) before and after this population peak.
The models obtained with the help of DMDS give us the sets of states for all steps of period of the system trajectory. These sets describe the types of dynamics for the community for two mentioned periods. The systemic aspects of these periods are following:
- 1st: loss of stability by small Mammalia community;
- 2nd: restoring of stability.

The analysis of the sets of states was supplemented by analysis of the relations structure between these species, obtained by DMDS.

Results

For DMDS simulation four species of small Mammalia were selected by described above manner: Sylvaemus uralensis, Microtus rossiameridionalis, Mus musculus and Sylvaemus sylvaticus. And the structure of relations between species of this group was constructed.
Since two periods before and after the population peak of Sylvaemus uralensis were selected, we call these two periods the period of loss of stability and the period of restoring of stability, respectively.
Numerical tests with models of these two periods revealed two types of dynamics of system, which characterized by time periods consisting of 15 steps (now we say about time periods of models, not real periods). For these periods of the model there exist only two states common to them both. Moreover, mentioned states don’t belong to adjacent steps, and this gives the possibility for developing methods of diagnosis of these types of dynamics by two adjacent observations of species number.
On the other hand, inter-species relations obtained by DMDS allow to form working hypothesis, according to which restoring stability of the system occurred due to negative effect of Microtus rossiameridionalis onto Sylvaemus uralensis, and the loss of stability is related with absence of such effect.

Discussion

The results of this paper, obtained by DMDS, may be useful to developing methods for forecasting population peaks of rodents which are potential agriculture pests and reservoir of dangerous infectious diseases, as mentioned. These methods have one feature: it is necessary to make up normalization (standardization) of data on small animals number, obtained in field studies. This feature is required by conditions of DMDS using.
It should also be remembered, that DMDS is mainly the tool for working hypotheses generation. These hypotheses should be later verified by other methods. Taking into account current and near-future capabilities of information technology (including those that based on apparatus of DMDS), we can say that results obtained in the present study give a perspective to special approach to assessing the state of natural systems, which can supplement widely used present approach, proposed by Shannon, MacArthur [1-3] and others. For example, this approach can be based on normalized and standardized sets of states of systems at certain instants of time (related with stable/unstable types of dynamics), stored in special databases.

Conclusion

Results of present work allow to develop new methods for forecasting population peaks of communities of small Mammalia. Their features lay in using DMDS for investigation of real ecologic and biological systems. Classification algorithm promises to be cost-effective, because it requires relatively small amount of field studies. This algorithm is based on difference between trajectories of modelled discrete systems, related with different types of dynamics.

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