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#### **ECOLOGICAL AND MATHEMATICAL MODELING TOOLS USAGE IN NATURAL SCIENCES TEACHERS TRAINING**

**Abstract.** *The article deals with the the state of applying the modelling method in training future Natural Sciences teachers.*

*The peculiarities of modelling and forecasting as methods of teaching and research activity in training future Natural Sciences teachers (Biology, Ecology, Chemistry, Natural Sciences) are explored. The expediency of their application as means of introduction into the educational process the principle of "learning through research", which ensures the organization of educational process on the basis of research activities and the involvement of students in scientific work is substantiated. Examples of using ecological and mathematical modelling tools in the organization of education and scientific work of postgraduate students in the field of 014 Secondary Education, Biology, Natural Sciences, 101 Ecology and Rational Use of Natural Environment are provided. Modelling the state and forecasting the development of hydroecosystems by means of fuzzy sets on the basis of input and output parameters, presented both quantitatively and qualitatively, are highlighted. Forecasting the development of ecosystems is realised based on the theory of stochastic processes and the theory of chains by Markov tools usage. The method of developing students' competence to use ecological-mathematical modeling is offered. It involves a combination of students' academic and research activities, their classroom and independent work. A list of the disciplines in which it is expedient to familiarize students with the indicated method is singled out. The mentioned methodology enables integration of biological, ecological and mathematical disciplines and information technologies in the complex study of natural processes. It stimulated the development of master students' ability to integrate the perception (vision) of environmental problems, the formation of strategic research skills.*

**Keywords:** *teacher training, integration, tools, modelling, forecasting.*

**Formulation of the problem.** Progressive modernization of higher education takes place in Ukraine. Its purpose is to train teachers of a new generation and to provide conditions for the formation and development of modern alternative models of professional and personal development of teachers. Increasingly important is the problem of introducing the principle of "learning through research". The search for technologies combining scientific (research) and educational activities is done, which forms the innovative scientific and educational environment. The principle of educational activity of science and prognostication is becoming dominant which means the establishment of stable ties between the content of study and scientific research [3, 10]. An effective means of its implementation is the organization of students' activities on the research principles of acquiring knowledge, subject competencies and their realization through research approaches in the organization and implementation of professional activities.

The main disadvantage of educational research is the selection for the parameterization of a limited number (sometimes one or several) of the statistical characteristics of objects. This does not allow us to

adequately assess the nature of natural (environmental) phenomena. Their characteristic at best is close to reality, and often does not meet it. As a result, the scientific and practical value of such research projects (individual teaching and research tasks, master's work) is ineffective, taking into account the cost of experimental research. Students have a false idea of the "ease" and "simplicity" of achieving their scientific result. Therefore, the modeling method plays an important role in the study of natural systems. It involves the creation of artificial or natural systems (models) that imitate the essential properties of the original [3, 4, 7, 10]. It is a means for organizing the educational process on the basis of research and research activities and attracting students to scientific work. Due to the particularity of the object of study, the question of using computer modeling in training future teachers of natural sciences is substantially actualized. There is a contradiction between the expediency of integrating students' academic and scientific activities in the process of their professional training and the lack of educational and methodological support for the organization of the educational process [1]. Thus our research aims at eliminating this contradiction.

**The purpose of the research.** To identify the possibilities and ways of using ecological and mathematical modeling in natural sciences teachers(masters) training.

**Objectives of the study:**

1. To investigate the state of using modelling method in training the teachers of natural sciences.
2. Describe the tools of ecological and mathematical modeling.
3. Describe the possibility of applying the method on specific models (environmental state of the hydro ecosystem).
4. To substantiate the methodology of formation of students' skills to use ecological and mathematical modeling in natural sciences teachers training.

**Research methods:**

*theoretical:* analysis of the problem based on the study of works on biological, ecological, mathematical sciences and information technologies, methods of teaching natural sciences; systematization, comparison, modeling and generalization of scientific-theoretical and experimental data for clarification and specification of the essence of the main definitions of the research, modeling of the methods of formation of students' competence in using ecological and mathematical modeling;

*empirical:* study of normative documents, conversations with teachers and students; pedagogical observation, analysis of training sessions, which contain in its content the possibility of using the modeling method, which made it possible to determine the actual state of the problem in practice; questioning, testing of students and teachers;

*experimental methods* - recording and forming experiments for revealing the state of the problem in teaching and substantiation of the effectiveness of the proposed method of forming students' competence in using ecological and mathematical modeling

*statistical methods* - criterion t Student, correlation analysis.

The experimental study was carried out in Ternopil Volodymyr Hnatyuk National Pedagogical University. The experiment covered 528 students and 106 teachers of natural sciences. Its goal: to assess the state of implementation of the principle of "learning through research" into the educational process; definition of the quality of the use of modeling as a method of teaching and research activities and scientific knowledge in training the future teachers of natural sciences (biology, ecology, chemistry, natural sciences).

The formative stage of the experiment had been conducted for two years (2017-2019 years) involving 101 students. Its goal was to test the effectiveness of the proposed method. Students of experimental groups, studied according to our methodology, in control groups - according to the traditional one. Before the beginning of the experimental work and after its completion, diagnostic sections were performed in the control (C) and experimental (E) groups. Their purpose was to determine the level of formation of students' competence in using the method of modeling and level of mastering the knowledge on fundamental disciplines.

The level of formation of each skill (initial, average, sufficient, high) for each student was determined on the basis of the analysis of tasks performance. Formula:  $R = X_{\text{average}}$  was used for the determination of the numerical value of the indicator of the average group level of the formation of skills [6, 7, 10].

The coefficient of growth in the formation of skills (k) was determined by the formula:  $k = R_{2\text{year}} / R_{1\text{year}}$ , where  $R_{2\text{year}}$  is the average group index of the formation of the research skills in second year students,

$R_{1\text{year}}$  is the average group index of the formation of the research skills in first year students.

The validity of the difference in the rates between the individual groups was evaluated using the Student's t-test. According to the monitoring of the proposed tasks performance, the operating component was evaluated as an integral result of the formation of a complex skill. The analysis of the links between

the components of research skills was conducted using correlation analysis.

### **Presentation of the main research material.**

#### **1. THE STATE OF USING THE MODELING METHOD IN TRAINING OF FUTURE TEACHERS OF NATURAL DISCIPLINES.**

Results of the questioning of teachers of natural sciences.

All surveyed teachers (100%) answering the questionnaires mentioned that in the teaching process they use the tasks, the solution of which requires the application of scientific knowledge methods, in general, and modeling, in particular. 20 (18.87%) respondents actively use such tasks in lectures and practical classes; 88 (83,02%) when organizing independent work of students; 72 (67,92%) in group work. The overwhelming majority of teachers (92.45%) seek to develop students mental skills- the ability to compare, analyze, generalize. Answering the question "Do you set a special goal during your classes to develop students' skills in modeling natural processes?" 42 teachers (39.62%) answered "No". This indicates a lack of attention to the formation of an important component of the learning competence of future teachers.

At the same time, 43.40% (46 teachers) focus on the formation of students' skills, which are components of modeling. For example, for the formation of the ability to observe the vast majority of teachers organizes independent observations, preliminary discussing his plan - 86.79% (92). A small proportion of respondents gives tasks that require observation without prior discussion of its plan. Only a quarter of teachers believe that they form the ability to observe the organization by monitoring the activities of the teacher.

Often, in the study of natural systems, descriptive models are used (89 people (83.96%), which allow the information to be expressed and reproduced in a concise way. However, in educational practice, such models tend to carry only a descriptive function and are used only for the purpose of knowledge formation. The didactic potential of the model in forming the operational component of skill is not used.

Constructive models that serve as a benchmark and allow you to use the acquired knowledge in new situations are used by 88 people (83.02%). The use of heuristic models for the purpose of mastering knowledge, generalization and systematization is practiced by only 63 people (59.43%). 9 teachers (8.49%) mentioned that they did not use modelling at training sessions. The reason for this was the lack of time in the class. Only one teacher considers the main reason that he does not have sufficient theoretical and methodological training.

The ways of designing models by teachers in postgraduate students training are analyzed. The following are described: sequence diagram of stages (chalk and board) (75%), paper-cardboard models (84,91%), animation on a marker board (30,19%). "Comics", prepared by students (phased processes), role models, modeling using information and communication technologies (7.55%). The reason for the low level of computer modeling in teaching fundamental disciplines the teachers see in the lack of software skills.

We have found that in natural science teachers training, traditional forms of scientific research work are widely used, such as preparation of scientific abstracts and participation in scientific seminars, conferences; organization of research activities within laboratory and practical classes; participation in extra curriculum activities, elective courses; work in scientific laboratories of departments; preparation and publication of scientific materials, etc. However, as the experience shows, these forms of student activity have a number of disadvantages: there is a discrepancy between the content of academic activities and research. The organization of training is dominant, the research activity is subordinated to educational activity, it is carried out additionally and requires separate organizational, material and time resources. Moreover the research work is assessed as a separate type of activity that is not sufficiently taken into account in assessing the quality of the specialist training and concerns mainly persons who have shown interest in this type of activity and strive for a research career [1].

#### **2. CHARACTERISTICS OF ECOLOGICAL-MATHEMATICAL MODELING TOOL**

To study the processes occurring in nature, it is expedient to apply modern methods of ecological and mathematical tools. To study the extent and density of the influence of chemical elements, biological compounds and other factors of the natural environment it is helpful to apply methods based on correlation-regression analysis. This theory is widely used in economic, social, biological and environmental and other studies. Below is an example of a tool used for the practical application of correlation-regression analysis in studies of natural systems.

The general view of the linear regression model on which it is possible to conduct the study is given in formula 1.

$$y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \dots + \alpha_m x_m + \varepsilon \quad (1)$$

where -  $\alpha_0, \alpha_1, \dots, \alpha_m$  unknown parameters;

$\varepsilon$  - random variable;  $y$  - dependent variable;  $x_1, x_2, \dots, x_m$  are independent variables.

Below is a practical example of the use of correlation-regression analysis in hydro-environmental studies.

$$y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \varepsilon, \quad (2)$$

where  $y$  - level of water pollution by certain types of chemical compounds;  
 $x_1$  - the level of average concentration of phosphates and physical and chemical parameters of water;  
 $x_2$  - the level of organization of a non-waste production, the use of reverse water supply.

The least squares method is used to find the estimates of the model  $\alpha_i$  parameters. The essence of this method is that the estimates of the parameters are such that the sum of the squares of the deviations of

the observational in practice of the values  $y$  of the indicator from the theoretical  $\hat{y}$  was minimal [2]. STATISTICA 10.0 and Microsoft Excel application software packages can be used to handle the statistical database.

When using the actual data on the parameters  $x_1, x_2, x_2$ , the linear regression model will look like:

$$y = 38,71 - 0,022x_1 + 2,284x_2 \quad (3)$$

To verify the model for adequacy, the value of the estimated determination coefficient  $\bar{R}^2$  according to formula 4 is determined.

$$\bar{R}^2 = 1 - \frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2 / (n-k)}{\sum_{i=1}^n (y_i - \bar{y})^2 / (n-1)} \quad (4)$$

where  $n$  - number of observations;

$y_i$  - values of  $y$  which are observed in practice;

$\hat{y}_i$  - theoretical values of  $y$ , found by the regression equation;

$\bar{y}$  - average value of  $y$ ;

$k$  - number of parameters of the regression model.

If the value of the estimated determination coefficient of the built econometric model (3) will be, for example,  $R^2 = 0,96$ , (the model explains 96% variance of the variable  $y$ ) and indicates the adequacy of the model to the investigated processes. If the figure is below 50%, this indicates inadequacy of the constructed model, so it is necessary to change the research indicators.

Another criterion for the quality of the model is Fisher's criterion. For a constructed econometric model, the Fisher's F-statistic is  $F(2,2) = 28,506$ . The specified F-statistic is higher than its table value. Consequently, the econometric model constructed is adequate according to Fisher's criterion and can be used for further research.

With the help of the coefficient of elasticity, we will determine how much the value of  $y$  changes, if each of the factors changes by 1%.

The elasticity factor will be determined by the following formula 5.

$$E_i = \frac{x_i}{y} \frac{\partial y}{\partial x_i}. \quad (5)$$

With the help of the coefficient of elasticity, we will determine how much the value of  $y$  changes, if each of the factors changes by 1%. In order to determine the coefficient of elasticity, instead of  $x_i$  and  $y$ , in the formula (5) we take the mean  $\bar{x}_i$  and  $\bar{y}$ .

If the values of the coefficients of elasticity for each of the two factors are positive, conclusions can be drawn about their positive impact on improving the quality of water resources, which corresponds to the economic content of the phenomena under study.

Also, one of the advanced methods of studying the dynamics of biological, hydroecological and other natural processes in modern scientific schools is a study based on the theory of fuzzy sets. This theory allows us to investigate both quantitative and qualitative factors that influence the resultant variable.

### 3. OPPORTUNITIES OF APPLICATION OF THE METHOD ON SPECIFIC MODELS (ECOLOGICAL STATE OF HYDROECOSYSTEMS)

Below is an example of the application of the theory of fuzzy sets in hydroecological studies.

*Materials and methods for studying the content of phosphates and physical and chemical parameters of water and developing a model based on fuzzy sets:*

Samples from the Zbruch River within the Medobory Nature Reserve (Gusiatynskiy District, Ternopil Oblast, Ukraine) were used to study the content of phosphates and physico-chemical parameters of water. Sampling of water was carried out from five different points of the river in plastic samplers of 1 dm<sup>3</sup> in the upper third of the total depth. During sampling, the temperature of the water was measured by an mercury thermometer with a price of 0.1 °C. The pH value was measured using the ionizer EV-74, and the oxygen content dissolved in water was determined using an oxygen meter AJA-101M (country of origin - Ukraine). To determine the concentration of phosphorus in water, a spectrophotometric method using ammonium molybdate (NH<sub>4</sub>)<sub>2</sub>MoO<sub>4</sub> was used [8].

Mathematical modeling using the principles of fuzzy logic requires the choice of a method for constructing membership functions that will ensure the formalization of fuzzy terms. The theory of fuzzy sets gives the opportunity to use different methods of constructing membership functions. Therefore, it is advisable to identify a number of criteria that would help solve the issue of their construction. The specific type of membership functions is determined on the basis of additional assumptions about the properties of these functions (symmetry, monotony, continuity of the first derivative, etc.), taking into account the specificity of the existing uncertainty and the real situation. In particular, fuzzy numbers with a triangular membership function  $\mu(t)$  are called triangular fuzzy numbers and denote  $\bar{t} = (t_{\min}, t_c, t_{\max})$  where  $t_{\min}, t_{\max}, t_c$  respectively, the minimum, maximum value, and some assessment of the central value (mathematical expectation, mod, median, etc.) of a particular parameter and have a membership function [9].

$$\mu(t) = \begin{cases} \frac{t - t_{\min}}{t_c - t_{\min}}, & \text{для } t_{\min} \leq t \leq t_c \\ \frac{t - t_{\max}}{t_c - t_{\max}}, & \text{для } t_c \leq t \leq t_{\max} \end{cases} \quad (6)$$

Fuzzy set of tools and MATLAB software using the Fuzzy Logic Toolbox extension were used to develop a model for estimating the level of integrated use and protection of water resources, the control variable models (content of phosphates and physico-chemical indicators of water) were determined on the basis of the analysis of the current state of the object. To describe the input and output variables of the model, Fuzzy Inference System and Membership Function Editor were used. The construction of rules for fuzzy output was carried out by means of the Rule Editor. In the process of modeling, the analysis of the results at different values of the input variables was carried out and an estimation of the adequacy of the model by the Mamdani method was done [6].

The advantage of the proposed method for modeling multifactorial dependencies based on fuzzy logic is that this tool allows you to use not only quantitative experimental data (input-output), but also qualitative dependencies, which are formed according to the linguistic rules of "IF-THEN". The combination of expert and experimental data makes it possible to significantly reduce the number of necessary experimental data.

*Results of mathematical modeling of estimation of level of complex use and protection of water resources.*

The content of phosphate ions in the water of the Zbruch River and the main physical and chemical parameters of water (dissolved oxygen, hydrogen content and water temperature) by the results of selected samples are given in Table 1.

Table 1

Average concentration of phosphates and physical and chemical indicators of the Zbruch River ( $M \pm m$ ;  $n=5$ )

| months | phosphate ions ( $PO_4^{3-}$ ),<br>$mg \cdot 10^{-2}/dm^3$ | dissolved oxygen ( $O_2$ ),<br>$mg/dm^3$ | hydrogen content (pH),<br>mole/l |
|--------|--|--|----------------------------------|
| IV     | 1,2±0,04   | 10,08±0,007                              | 7,63±0,008                       |
| V      | 1,9±0,002  | 9,76±0,006                               | 8,44±0,007                       |
| VI     | 0,7±0,03   | 9,44±0,006                               | 7,08±0,009                       |
| VII    | 1,0±0,03   | 8,80±0,006                               | 8,24±0,008                       |
| VIII   | 1,8±0,04   | 8,08±0,004                               | 6,87±0,008                       |
| IX     | 0,4±0,02   | 8,48±0,004                               | 7,60±0,008                       |
| X      | 0,7±0,04   | 9,04±0,004                               | 8,61±0,008                       |

The indicators presented in the table will be used in the future as input parameters in the development of a model for assessing the level of integrated use and protection of water resources in the MATLAB environment. For this purpose, the main factors with which modeling can be implemented are determined.

The input parameters of the model can range from two to eight elements, more than eight input parameters are not recommended, since the model can then be very cumbersome, and allow inaccuracies in intermediate and final models.

For the conducted modeling, it is advisable to make a database and knowledge base. In table 2, a fragment is presented what the database and rules look like for a fuzzy set model.

The level of integrated use and protection of water resources in hydro ecosystems based on the theory of fuzzy logic can be denoted as: G1 - high, G2 - medium, G3 - low. The indicated parameters G1, G2, G3 characterize the hydro-ecological situation in the region, and the result of model experiments is the percentage variable -  $\gamma$  (from 0 to 100%) - the level of preventive, procedural and reclamation methods of integrated use and protection of water resources.

A fragment of the established rule base for the developed model is presented. The more rule options this base contains, the closer the model based on fuzzy sets is to the real situation. When changing the environmental situation, you can add both model parameters as well as rules base and knowledge bases.

Table 2

Knowledge base of the model for assessing the level of environmental control of water resources

| Value | Rules |   |   |   |   |   |   |   |   |   |   |   |
|-------|-------|---|---|---|---|---|---|---|---|---|---|---|
| $y_1$ | l     | m | l | l | m | l | l | m | m | h | h | h |
| $y_2$ | l     | l | l | l | l | m | c | m | h | l | h | h |
| $y_3$ | l     | l | l | l | h | m | l | m | h | h | l | h |
| $y_4$ | l     | m | l | l | m | m | l | m | m | h | h | h |
| $y_5$ | l     | l | l | l | h | l | h | l | l | l | h | m |
| $y_6$ | l     | l | l | l | l | l | l | l | h | h | h | h |
| $y$   | l     | l | l | l | m | m | m | m | h | h | h | h |

l – low, m – medium, h - high

Implementation of the modeling of the definition of integrated use and protection of water resources can be implemented in information products with elements of artificial intelligence such as Matlab and Statistica.

Graphic representation of the model for assessing the level of integrated use and protection of water resources should be graphical, as it visualizes the links between input elements and the resulting indicator.

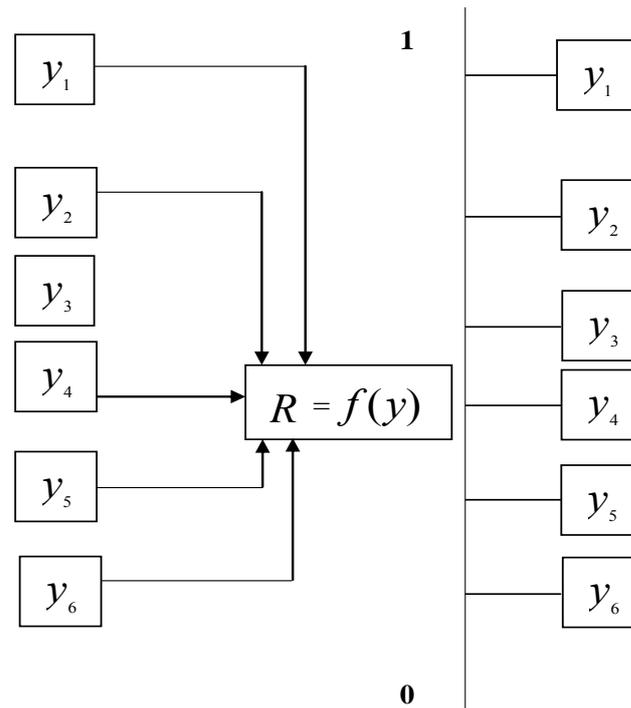


Figure 1. Graphical representation of the construction of a model for modeling the level of environmental monitoring of water resources based on the theory of fuzzy sets.

This model can be improved and expanded with specific tasks for the study of the relevant parameters and their boundaries. When encoding the parameters of the model, further development of programming on models of estimation of the state of hydro ecosystems will be developed, which will allow the community of cities to monitor the level of pollution and carry out comprehensive measures to eliminate the factors that cause the deterioration of water and ecosystems in general within a specific territorial unit.

The application of the theory of fuzzy sets in the research and study of natural sciences is a new and promising area of application of the technique based on the theory of fuzzy modeling. Using modern information systems like Matlab and Statistica can enable teachers to visualize the calculations and modeling, moreover modern information systems with artificial intelligence elements memorize all intermediate calculation models that allow students to learn from mistakes and improve their skills.

The promising direction of fuzzy modeling of economic systems is the use of the integrated software environment MATLAB. Fuzzy modeling in the MATLAB environment is carried out using the Fuzzy Logic Toolbox extension, which implements many functions of fuzzy output and fuzzy logic. The most convenient is the graphical interactive simulation mode MATLAB, in which the user can create and edit the functionality of the individual terms of the fuzzy output system.

In addition, MATLAB contains tools for constructing and viewing a fuzzy rule system that is designed to convert the input variable values of the management process into output variables based on the use of fuzzy rules. Fuzzy Logic Toolbox, interactive fuzzy output system development is the most effective in constructing complex systems with a large number of variables and rules for fuzzy output. In this case, the task of variables and the functions of their term terms in graphical mode, as well as the visualization of rules, can significantly reduce the complexity of developing a fuzzy model, reduce the number of possible errors, and reduce the time of modeling.

To predict natural and socio-economic studies, teachers can apply a forecasting methodology based on the theory of Markov chains. This technique is interesting in that it allows you to explore environments that have a stochastic nature of dynamic changes.

In the works of Ukrainian and foreign scientists, almost no attention was paid to the method of forecasting economic, social processes, ecological studies with the application of methods based on the theory of Markov chains with discrete states.

It should be noted that mostly economic, social and natural processes develop as random processes under the influence of random factors. In order to predict the future state of these processes, it is necessary to construct their probable model.

The random process occurring in the system S is called the Markov process, if for any time t0 the probability of any state of the system in the future (for t > t0) depends only on its state in the present time (at t = t0) and does not depend on when and how the system came to this state. In other words, in the random process of Markov, the future state of the system depends on the present time and does not depend on the "background" of the process. The most interesting for economic forecasting is the Markov random process (Markov chains) with discrete states. We will assume that for each state of the system known probability of transition to another state in one step. Denote by pij the probability of transition of system S from state i to state j over a period of time from t0 to t. Supposing system S has n possible states S1, S2, ..., Sn. Let us write the transition probabilities pij in the form of the transition matrix ||pij||:

$$||p_{ij}|| = \begin{pmatrix} p_{11} & p_{12} & p_{1j} \\ p_{21} & p_{22} & p_{2j} \\ p_{n1} & p_{n2} & p_{nj} \end{pmatrix} \tag{7}$$

The sum of all elements of each line of the matrix is 1, that is

$$\sum_{j=1}^n p_{ij} = 1 \tag{8}$$

since for a time interval t the Markov chain is from condition i will necessarily go into one of the admissible states j.

The square matrix ||pij|| is called stochastic, since all its elements are not negative, and the sum of all elements of each line of the matrix is equal to one. To completely specify the Markov chain, in addition to the matrix of transition probabilities, we must have the vector of the initial state of the pi system. The vector-string pi is called a probabilistic vector. It is obvious that all elements of the vector are inseparable, and the sum of elements is equal to one, i.e.

$$\sum_{j=1}^n p_{ij}(t_0) = 1 \tag{9}$$

The initial state of the system can be set using a probabilistic line vector, one of whose elements is equal to 1, and all other elements are equal to 0.

It is proved that the vector of probabilities of the Markov chain at time t equals the product of the probability vector at the initial moment t0 on the transition matrix [7], i.e.

$$p(t) = p(t_0) * ||p_{ij}|| \tag{10}$$

We give a practical application of the method of forecasting in the study of the content of metals in the silt (see Table 3), based on reservoirs of Ternopil. As a result of study, extremely high metal content of all investigated groups was found. For the biogenic group of metals, low mobility (exchange fund with water) is found to be 1-5%, and the vast majority of them, most likely, are recorded in colloids, humic complexes of silt and other organic substances.

Table 3.

The content of metals in the bottom sediments

| Metal content<br>mg / kg dry the<br>sediment | MPS * mg / m <sup>3</sup> | Sampling sites                    |                                   |                                   |                                   |                                   |                                   |                                   |                                   |
|--|---------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|
|  |                           | 1                                 | 2                                 | 3                                 | 4                                 | 5                                 | 6                                 | 7                                 | 8                                 |
| Biogenic                                     |                           |                                   |                                   |                                   |                                   |                                   |                                   |                                   |                                   |
| Sodium                                       | nl.                       | <u>18760,1</u><br>215,6<br>(1,2%) | <u>20465,3</u><br>230,5<br>(1,1%) | <u>24830,1</u><br>315,3<br>(1,2%) | <u>22680,5</u><br>306,9<br>(1,3%) | <u>33180,2</u><br>389,1<br>(1,1%) | <u>29040,5</u><br>430,9<br>(1,5%) | <u>28300,2</u><br>339,6<br>(1,2%) | <u>20860,3</u><br>271,8<br>(1,3%) |
| Cobalt                                       | 5,0                       | <u>19,4</u><br>8,7<br>(45%)       | <u>32,2</u><br>15,3<br>(48%)      | <u>33,4</u><br>15,0<br>(45%)      | <u>30,5</u><br>12,1<br>(40%)      | <u>30,4</u><br>12,9<br>(43%)      | <u>19,9</u><br>9,5<br>(47%)       | <u>29,4</u><br>13,2<br>(45%)      | <u>21,0</u><br>9,0<br>(43%)       |

According to the data presented in Table 3 on the content of metals in the bottom sediments, we make a forecast of the situation for the next two seasonal periods according to Markov chain theory. This theory allows one to make predictions of a factor, including the possibility of random effects on the environment, and investigates the greatest probability of presence of a factor in the most favorable state.

Realization is carried out in software Matlab. Predicting the content of cobalt in bottom sediments for the next 4 seasons, for possible monitoring of the situation.

We represent the predicted calculations of the content of cobalt in the bottom sediment for two seasons for the near future, modeled according to the theory of Markov chains and implemented in the software Matlab.

In 2016, the cobalt content in the bottom sediments of the reservoir with the highest probability of 0.1302 will be 33.4 units [5, 9]

In Figure 2 we will present the implementation in the software of prediction Matlab of processes based on stochastic elements based on the method of forecasting the theory of Markov chains.

```

MATLAB R2018a
HOME PLOTS APPS
New Variable Analyze Code Preferences Community
New Script Live Script New Open Compare Import Data Save Workspace Open Variable Run and Time Favorites Run and Time Simulink Layout Set Path Add-Ons Help
Request Support Learn MATLAB
FILE VARIABLE CODE SIMULINK ENVIRONMENT RESOURCES
C:\Program Files\MATLAB\R2018a\bin
Current Folder
Name
worker.bat
mw_mpiexec.bat
mexutils.pm
mexsetup.pm
mexext.bat
mex.pl
mex.bat
mcc.bat
mbuild.bat
matlab.exe
lcldata_utf8.xml
lcldata.xsd
lcldata.xml
deploytool.bat
win64
Details
Workspace
Name Value
Command Window
A=[19.4, 32.2, 33.4, 30.5, 30.4, 19.9, 29.4, 21.0]
A = 19.4000 32.2000 33.4000 30.5000 30.4000 19.9000 29.4000 21.0000
S=19.4+32.2+33.4+30.5+30.4+19.9+29.4+21.0
S = 216.2000
C=[216.2000, 216.2000, 216.2000, 216.2000, 216.2000, 216.2000, 216.2000, 216.2000]
C = 216.2000 216.2000 216.2000 216.2000 216.2000 216.2000 216.2000 216.2000
rdivide(A,C)
ans = 0.0897 0.1489 0.1545 0.1411 0.1406 0.0920 0.1360 0.0971
>> B= [0.0897, 0.1489, 0.1545, 0.1411, 0.1406, 0.0920, 0.1360, 0.0971; 0.1489, 0.1545, 0.1411, 0.1406, 0.0920, 0.1360, 0.0971, 0.0897; 0.1489, 0.1545, 0.1411, 0.1406, 0.0920, 0.1360, 0.0971, 0.0897; 0.1411, 0.1406, 0.0920, 0.1360, 0.0971, 0.0897, 0.1489, 0.1545; 0.1406, 0.0920, 0.1360, 0.0971, 0.0897, 0.1489, 0.1545, 0.1411; 0.0920, 0.1360, 0.0971, 0.0897, 0.1489, 0.1545, 0.1411, 0.1406; 0.1360, 0.0971, 0.0897, 0.1489, 0.1545, 0.1411, 0.1406, 0.0920; 0.0971, 0.0897, 0.1489, 0.1545, 0.1411, 0.1406, 0.0920, 0.1360]
P=[0, 0, 1, 0, 0, 0, 0, 0]
P = 0 0 1 0 0 0 0 0
p1=[P*B]
p1 = 0.1545 0.1411 0.1406 0.0920 0.1360 0.0971 0.0897 0.1489
p2=[p1*B]
p2 = 0.1243 0.1254 0.1302 0.1254 0.1243 0.1242 0.1220 0.1242
p3=[p2*B]
In 2016, the cobalt content in the bottom sediments of the reservoir with the highest probability of 0.1302 will be 33.4 u

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Figure 2 Implementation in the software of prediction of processes on the basis of stochastic elements on the basis of the method of forecasting the theory of Markov chains

By analyzing the results of the simulation presented in Figure 2, we can state that in 2016, the cobalt content in the bottom sediments of the reservoir with the highest probability of 0.1302 will be 33.4 units [5, 9].

The use of modern teachers and students in the educational and scientific research of modern methods of forecasting, and the application of the future informational resources, significantly improves the quality of the work carried out.

Computer information technologies in science and education (training) (3 cr.) Theme "Basic concepts of mathematical statistics", "Fundamentals of modeling and fuzzy logic theory in forecasting processes", "Theory of stochastic processes (Markov chains instrument." Mathematical methods and computer modeling in biology (4 cr.) Theme "Correlation and regression analysis", "The statistical processing biological experiment", "factor analysis". Population Biology, ecosystemology and biosferology (5 cr.) Theme "Structure and dynamics of populations." "Structure and levels of ecosystems", "Structure of biosphere", "Circulation of substances". Social ecology and problems of environmental use (5 cr.) On the topic "Legal aspects of the interaction of society and nature", "Pedological aspects of the interaction of society and nature", "Technological aspects of the interaction of society and nature" "Environmental monitoring (5 cr.) Of the topic "Surface water monitoring", "Monitoring of atmospheric air", "Monitoring of soils". Ecotoxicology, bioindication and expertise (5 cr.) The theme "Transformation of toxicants in the natural environment", "Mechanisms of toxicaction", "Integral approaches to the assessment of

environmental toxicity". Scientific practice (4 cr.) - Modeling of biological processes. Master's work - Mathematical and statistical processing of experimental data.

**Conclusions.** Research and forecasting based on the Markov chain method, correlation-regression analysis, fuzzy set theory will increase the competences and skills of future natural science teachers, moreover the use of modern information systems such as Matlab allows you to visualize research and calculations and process large amounts of information in a short time.

The use of the methodology of modeling natural systems contributes not only to strengthening the students of basic knowledge about ecological systems, but also motivates their study and application in predicting their dynamics, argues the need and ability to participate in environmental management with a view to ensuring the sustainable development of ecosystems and territories and nature conservation

The proposed method of formation of students' competence in ecological-mathematical modeling allows it to be used in the organization of educational and scientific work of the post graduate students in the field of training. 014 Secondary education Biology, Natural Sciences, 101 Ecology and Rational Use of the Natural Environment. The use of this tool ensures the integration of biological, ecological, mathematical disciplines and information technologies in the complex study of natural processes. On the basis of the analysis of the contents of educational material and research activities, the topics, problems and types of works were identified, in the study and implementation of which it is expedient to effectively apply methods of computer modeling of environmental processes based on models of Markov chains.

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### ВИКОРИСТАННЯ ІНСТРУМЕНТАРІЮ ЕКОЛОГО-МАТЕМАТИЧНОГО МОДЕЛЮВАННЯ В ПРОЦЕСІ ПІДГОТОВКИ ВЧИТЕЛІВ ПРИРОДНИЧИХ ДИСЦИПЛІН

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**Анотація.** Досліджено стан використання методу моделювання в процесі підготовки майбутніх учителів природничих дисциплін. Висвітлено особливості застосування моделювання та прогнозування як методів навчально-дослідницької діяльності та наукового пізнання при підготовці майбутніх учителів природничих дисциплін (біологія, екологія, хімія, природничі науки). Обґрунтовано

доцільність їх застосування як засобів впровадження в освітній процес принципу «навчання через дослідництво», що забезпечує організацію освітнього процесу на засадах пошуково-дослідницької діяльності та залучення студентів до наукової роботи. Наведено приклади використання інструментарію економіко-математичного моделювання в організації наукової роботи магістрів напрямку підготовки 014 Середня освіта Біологія, Природничі науки, 101 Екологія та раціональне використання природного середовища при моделюванні: стану і прогнозуванні розвитку гідроекосистем із застосуванням інструментарію нечітких множин на основі вхідних та вихідних параметрів, представлених як в кількісному, так і в якісному вимірах; впливу чинників (гідрофізичних, гідрохімічних та токсикологічних показників) на стійкість екосистем на основі кореляційно-регресійного аналізу. Прогнозування розвитку екосистем здійснювалось на основі теорії стохастичних процесів інструментарієм ланцюгів Маркова. Запропоновано методику формування у студентів умінь використовувати еколого-математичне моделювання. Вона передбачає поєднання навчальної, навчально-дослідної та дослідницької діяльності студентів, їх аудиторної та самостійної роботи. Виокремлено перелік дисципліни, на яких доцільно знайомити студентів із зазначеним методом. Використання зазначеної методики дозволило забезпечити інтеграцію біологічних, екологічних та математичних дисциплін та інформаційних технологій у комплексному вирішенні проблеми. Це стимулювало розвиток у магістрів умінь цілісного сприйняття (бачення) проблем довкілля, формування стратегічних дослідницьких умінь.

**Ключові слова:** підготовка вчителів, інтеграція, інструментарій, моделювання, прогнозування.

### **ИСПОЛЬЗОВАНИЕМ ИНСТРУМЕНТАРИЯ ЭКОЛОГО-МАТЕМАТИЧЕСКОГО МОДЕЛИРОВАНИЯ В ПРОЦЕССЕ ПОДГОТОВКИ УЧИТЕЛЕЙ ЕСТЕСТВЕННЫХ ДИСЦИПЛИН**

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**Аннотация.** Исследовано состояние использования метода моделирования в процессе подготовки будущих учителей естественных дисциплин. Освещены особенности применения моделирования и прогнозирования как методов учебно-исследовательской деятельности и научного познания при подготовке будущих учителей естественных дисциплин (биология, экология, химия, естественные науки). Обоснована целесообразность их применения как средств внедрения в образовательный процесс принципа «обучение через исследовательскую», что обеспечивает организацию образовательного процесса на основе поисково-исследовательской деятельности и привлечения студентов к научной работе. Приведены примеры использования инструментария экономико-математического моделирования в организации научной работы магистров направления подготовки 014 Среднее образование Биология Естественные науки, 101 Экология и рациональное использование природной среды при моделировании: состояния и прогнозирования развития гидроекосистем с применением инструментария нечетких множеств на основе входных и выходных параметров, представленных как в количественном, так и в качественном измерениях; влияния факторов (гидро, гидрохимических и токсикологических показателей) на устойчивость экосистем на основе корреляционно-регрессионного анализа. Прогнозирование развития экосистем осуществлялось на основе теории стохастических процессов инструментарием цепей Маркова. Предложена методика формирования у студентов умений использовать эколого-математическое моделирование. Она предусматривает сочетание учебной, учебно-исследовательской и исследовательской деятельности студентов, их аудиторной и самостоятельной работы. Выделены перечень дисциплины, на которых целесообразно знакомить студентов с указанным методом. Использование указанной методики позволило обеспечить интеграцию биологических, экологических и математических дисциплин и информационных технологий в комплексном решении проблемы. Это стимулировало развитие у магистров умение целостного восприятия (видение) проблемам окружающей среды, формирования стратегических исследовательских умений.

**Ключевые слова:** подготовка учителей, интеграция, инструментарий, моделирование, прогнозирование.