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MATHEMATICAL MODELING OF THE DYNAMICS OF PHYTOPLANKTON POPULATIONS USING SYSTEMS OF NONLINEAR DIFFERENTIAL EQUATIONS

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Анотація

Оцінка екологічного стану водного об'єкта та прогнозування його змін у результаті антропогенного впливу здійснено з використанням вдосконалених математичних моделей динаміки популяцій фітопланктону у водних екосистемах на основі системи нелінійних диференціальних рівнянь. При моделюванні динаміки популяцій у водних екосистемах використовуються системи нелінійних диференціальних рівнянь, а екологічний стан водойм описується фазовим портретом коливань. Розв'язання системи нелінійних диференціальних рівнянь при моделюванні динаміки популяцій фітопланктону у водному середовищі здійснено за допомогою наближених числових методів із застосуванням системи рекурентних рівнянь. Інтегральний екологічний стан водойм оцінюється шляхом обчислення індексів Сімпсона та Шеннона щодо відносної кількості частинок фітопланктону кожного виду.

Ключові слова: фітопланктон, водні екосистеми, рекурентні рівняння, динаміка популяції, фазовий портрет.

Abstract

Assessment of the ecological state of a water body and forecasting its changes as a result of anthropogenic impact using improved mathematical models of the dynamics of phytoplankton populations in aquatic ecosystems based on a system of nonlinear differential equations. When modeling the dynamics of populations in aquatic ecosystems, systems of nonlinear differential equations are used, and the ecological state of water bodies is described by the phase portrait of oscillations. The solution of a system of nonlinear differential equations in modeling the dynamics of phytoplankton populations in an aquatic environment was carried out using approximate numerical methods using a system of recurrent equations. The integral ecological state of water bodies is estimated by calculating the Simpson and Shannon indices for the relative abundance of phytoplankton particles of each species.

Keywords: phytoplankton, aquatic ecosystems, recurrent equations, population dynamics, phase portrait.

Introduction

When assessing the complex impact of pollutants on the ecological state of a water body using a synergistic approach, it is necessary to take into account the impact on biological indicators, in particular, indicators of biomass and species composition of phytoplankton. It is impossible to assess the state of an ecosystem only by physicochemical parameters, since its main characteristic, the state of hydrobiota, is not taken into account. Analytical control is complicated by the synergistic effect of most chemical compounds. One of the important components of monitoring and control of water quality is a comprehensive assessment of the ecological status of surface water bodies subject to anthropogenic pollution. The reaction of hydrobiota depends not only on individual physicochemical factors, but also on their interaction. Integral assessment of the biological usefulness of water as a habitat of biota, taking into account various manifestations of chemical interaction - additivity, synergism, antagonism, can be obtained using the biotesting method, which was used in environmental practices in many countries, when society realized the danger to human health toxic water pollution.

Results

In a number of modern studies [1-6], the synergetic theory of managing complex natural-man-made systems is being developed, which can be used to assess the ecological state of water bodies. At the same time, the properties of the ecosystem, its synergistic characteristics are manifested in the interaction with environ-

mental factors. Ecosystems meet the requirements for systems that are self-organizing: non-closure, instability, non-linearity, dynamic hierarchy. Therefore, ecosystem approaches should be considered from the point of view of a synergistic concept using a systematic approach to conduct a study of changes in their state [6]. The formalization of bifurcation processes in the biosphere is inextricably linked with an understanding of the synergistic patterns of the evolutionary development of biota. The reaction to the seemingly insignificant changes in the environment (appearance of polutants, introductions, invasions, etc.) is characteristic primarily of the "living substance" of the biosphere: individuals, species, biocenoses. If the changes relate to certain boundary conditions that ensure the maintenance of the equilibrium of an ecosystem, then with time a significant restructuring of its structure and functioning is possible, up to the destruction of the ecosystem itself [6].

In [1] developed methodological approaches to assessing the ecological safety of ecosystems, based on the establishment of a comprehensive indicator of the degradation of environmental components, which allows the assessment of non-additive properties of multi-scale aquatic ecosystems. The analysis of the causes and limits of sustainability of complex ecosystems is carried out, which allows predicting their response to direct or indirect human influence, as well as solving environmental management problems using a synergistic approach.

To assess the ecological status of water bodies using a synergistic approach, it is necessary to monitor the dynamics of populations of aquatic organisms, which will determine the phase portrait of oscillations of the dynamics of populations of aquatic organisms.

An improved mathematical model of the dynamics of phytoplankton populations in aquatic ecosystems based on the solution of a system of nonlinear differential equations by approximate numerical methods using a system of recurrent equations, which allows to take into account the synergistic interaction of pollutants.

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