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COMPLEX SYSTEMS BIOPHYSICS

The Stability of Recurrent Properties of the Hydrobiological Characteristics of a Lake Ecosystem under Conditions of Changing Anthropogenic Load

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Abstract—An analysis of the long-term dynamics of hydroecological characteristics of the Naroch lake system (Belarus) for the period from 1979 to 2018 is presented. During this period, there was a sharp change in the anthropogenic load on the watershed of the Naroch ecosystem, associated with the implementation of measures for its ecological improvement, as well as the invasion of the *Dreissena polymorpha* Pallas mollusk. It is shown that the change in the external load on the lake ecosystem led to significant changes in the amplitude of fluctuations in the concentrations of hydroecological characteristics, while the predictability of such fluctuations changed insignificantly.

Keywords: long-term dynamics, biogenic load, numerical recurrent analysis, lake ecological systems
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INTRODUCTION

Assessment of the impact of anthropogenic load on the functioning of lake ecological systems is a demanding and challenging task. The main difficulty in solving such a problem is the inability to directly measure factors related to anthropogenic impact; therefore, it is necessary to separate changes in ecosystem behavior caused by the variability of natural factors from those caused by changes in anthropogenic pressure on the system. To solve this problem, it is necessary to have a large number of field observations of both the dynamics of hydrobionts as well as the dynamics of hydrochemical and hydrological characteristics of the ecosystem, followed by their analysis by both linear and nonlinear methods. A number of requirements are imposed on such data, namely, the duration and continuity of observations, the uniformity of measurement methods throughout the entire measurement time, and the regularity and synchronicity of observations. These requirements are met by the data obtained as a result of long-term continuous observations of the dynamics of hydroecological characteristics of the Naroch lake system (Republic of Belarus). As a result of long-term monitoring, a number of external factors were identified that significantly determined the stages of evolution of the ecosystems of the Naroch lakes and their current state [1, 2]. It was shown that intensive biogenic load in the form of active agricultural production in the catchment area of the lake ecosystem led to progressive eutrophication of reservoirs by the end of the 1980s. Since the end of the 1980s, a program of ecological rehabilitation of the Naroch lakes began to be carried out, including the conversion of farmland (replacing more than 2000 hectares of arable land with pastures and hayfields), the afforestation of 683 hectares of the water protection zone, the removal of nine livestock farms outside the catchment and the improvement of eight remaining farms, the organization of a bypass collector for collecting, subsequent purification and discharge of wastewater from the Naroch resort zone [3]. Due to the purposeful reduction of the biogenic load, the concentrations of nitrogen and phosphorus significantly decreased and the water transparency increased [1, 2, 4]. Another factor that significantly affected the functioning of the Lake Naroch system was the invasion of a powerful filter feeder, the *Dreissena polymorpha* Pallas mollusk, into the lakes in the late 1980s [1, 5]. Both of these factors led to the bentification of the ecosystem, that is, the displacement of the processes of transformation of matter from the water column to the bottom layer [1, 2]. The processes