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Singular Spectrum Analysis of Hydroecological Parameter Dynamics of Lake Naroch' in the Years 1978–2015

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Abstract—Singular Spectrum Analysis (SSA) has been used to decompose continuous series of data on certain characteristics of Lake Naroch' ecosystem during the vegetative seasons of years 1978–2015 into a long-time trend, a periodic component, and a residue not amenable to decomposition. The contribution of each component to changes in this variable has been assessed. The trends accounted for 78–97% of parameter variability, and the periodic components accounted for 2.5–15%. The fluctuations of phytoplankton and zooplankton biomass dynamics were the most diverse, and the contribution of these components was the greatest (15 and 8%, respectively). The periodic components in the changes of all parameters could be divided into four groups according to period duration (17–22, 7–15, 4–7, and less than 4 years). Multidimensional factor analysis of seven biotic parameters was performed in order to identify fluctuations in the ecosystem. Five major factors accounting for 93.6% of ecosystem changes together were identified, and each factor variable was subjected to SSA analysis. The period durations were similar for the oscillatory components identified. The first factor was interpreted as a trophic status of the water body, the second was taken to be the geographical location that defines the amount of solar radiation energy available, the third was taken to be the availability of biogenic elements (phosphorus in particular), and the fourth was interpreted as specific developmental cycles of live components of the ecosystem.

Keywords: Narochanskie Lakes, multiannual dynamics, SSA method, trends, cyclic components, factor analysis, main factor interpretation

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Monitoring of the characteristics of a specific water body yields series of parameter values measured according to the same procedure in specific time intervals. Each of the obtained series has the appearance of a set of rather chaotically scattered points when plotted on the time axis. This raises two questions: (1) are there any regularities in the changes in water body characteristics and (2) can these regularities be revealed by analysis of the time series derived from the monitoring?

The first question is obviously valid, since any natural water body is a complex self-regulated system influenced by the environment and composed of several interacting subsystems, such as communities of bacteria, phyto- and zooplankton, fishes, macrophytes, and other ecosystem components. Each subsystem possesses adaptation mechanisms that enable its existence under changing environmental conditions. Population-specific mechanisms include the formation of spores or latent eggs, fertility changes, changes in egg or organism size, expansion of the food spectrum, migration, species replacement, and others. The ecosystem reacts to temporary environmental changes, including those related to human activity, via certain changes in parameters and returns to the initial state after cessation of the external impact. Thanks to this, we can talk about the stability and the specific trophic status of a particular water body.

If the external impact is forceful and prolonged and the system cannot withstand it, ecosystem status changes and ecosystem destruction can ensue. For instance, this was observed in the Shchuchii Bay of Lake Ladoga in the late 1980s [1]. However, small natural fluctuations in environmental conditions, to which the ecosystem responds with parameter changes, usually occur against the backdrop of global natural cycles. Autooscillations, which are common for complex autoregulated systems, are often superimposed on the aforementioned changes. For instance, these changes can be manifested as population size