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Determinism versus randomness in plankton dynamics: The analysis of noisy time series based on the recurrence plots

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Abstract: The quantitative analysis of recurrence plots while applied to mathematical models was shown to be an effective tool in recognizing a frontier between deterministic chaos and random processes. In nature, however, unlike mathematical models, deterministic processes are closely intertwined with random influences. As a result, the non-structural distributions of points on the recurrence plots, which are typical of random processes, are inevitably superimposed on the aperiodic structures characteristic of chaos. Taking into account that the stochastic impacts are an inherent feature of the dynamics of populations in the wild, we present here the results of the analysis of recurrence plots in order to reveal the extent to which irregular phytoplankton oscillations in the Naroch Lakes, Belarus, are susceptible to stochastic impacts. We demonstrate that numerical assessments of the horizon of predictability T_{pr} of the dynamics under study and the average number P_{d} of the points that belong to the diagonal segments on the recurrence plots can furnish insights into the extent to which the dynamics of both model and phytoplankton populations are affected by random components. Specifically, a comparative analysis of the values of T_{pr} and P_{d} for the time series of phytoplankton and the time series of random processes allows us to conclude that random components of the phytoplankton dynamics in the Naroch Lakes do not prevent recognition of chaotic nature of these dynamics.

Keywords: Chaos, randomness, recurrence quantification analysis, plankton dynamics.

MSC-2010: 37M10, 65P20

1 Introduction

Irregular time series typical of the population dynamics [18] are quite often found to be chaotic [14]. This implies, on the one hand, a deterministic nature of these time series, and on the other hand their own internal instability in the absence of external impacts. However, when studying natural systems, only in rare cases it is possible to consider these systems as isolated from exogenous noise. Therefore, when analyzing results of laboratory experiments or data of field observations we should discard purely deterministic approaches in assessing chaoticity of the noisy time series in favor of assessment of the horizon of predictability as a characteristic of complexity of the processes underlying the observed irregular dynamics. In this regard, a pressing question arises: how strong is the impact of erratic and uncontrollable factors of different nature that are due to both inevitable measurement errors and environmental fluctuations, on predictability of the variable population size [3, 6, 12, 19, 20]?

Quantitative assessment of the horizon of predictability of even comparatively short time series, which are typical of field observations, can be carried out by the recurrence quantification analysis [21]. In the con-

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