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Resilience, rapid transitions and regime shifts: fingerprinting the responses of Lake Żabińskie (NE Poland) to climate variability and human disturbance since 1000 AD

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Rapid ecosystem transitions and adverse effects on ecosystem services as responses to combined climate and human impacts are of major concern. Yet few quantitative observational data exist, particularly for ecosystems that have a long history of human intervention. Here, we combine quantitative summer and winter climate reconstructions, climate model simulations and proxies for three major environmental pressures (land use, nutrients and erosion) to explore the system dynamics, resilience, and the role of disturbance regimes in varved eutrophic Lake Żabińskie since AD 1000.

Comparison between regional and global climate simulations and quantitative climate reconstructions indicate that proxy data capture noticeably natural forced climate variability, while internal variability appears as the dominant source of climate variability in the climate model simulations during most parts of the last millennium. Using different multivariate analyses and change point detection techniques, we identify ecosystem changes through time and shifts between rather stable states and highly variable ones, as expressed by the proxies for land-use, erosion and productivity in the lake. Prior to AD 1600, the lake ecosystem was characterized by a high stability and resilience against considerable observed natural climate variability. In contrast, lake-ecosystem conditions started to fluctuate at high frequency across a broad range of states after AD 1600. The period AD 1748-1868 represents the phase with the strongest human disturbance of the ecosystem. Analyses of the frequency of change points in the multi-proxy dataset suggests that the last 400 years were highly variable and flickering with increasing vulnerability of the ecosystem to the combined effects of climate variability and anthropogenic disturbances. This led to significant rapid ecosystem transformations.