

Final report for the Focus Innovation Session

Mathematical modeling of adaptive cycle

Date and venue: 13th – 15th of July 2026, Bled, Slovenia

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Report: The primary objective of the session was to establish a new interdisciplinary collaboration dedicated to the mathematical description of the adaptive cycle. Although the adaptive cycle is a well-established conceptual framework in resilience science, many of its underlying mechanisms remain insufficiently understood from both rigorous mathematical and quantitative perspectives. By combining expertise in systems ecology, network dynamics, operator and spectral theory, and differential game theory, the meeting provided a unique setting for identifying mathematical tools capable of capturing the transitions between the different phases of the cycle.

Over the course of three days, the participants developed a common conceptual framework linking ecological processes and their thermodynamic interpretation with both linear and non-linear dynamical systems. Particular attention was devoted to the role of interaction networks in ecosystem evolution and to possible mathematical formulations based on generalised Lotka–Volterra systems with adaptive interaction coefficients. The discussions also explored how methods from differential game and spectral theory could be incorporated into this framework to model structural changes in ecological networks driven by competing biological objectives.

Beyond the scientific discussions, the meeting successfully connected researchers from three Working Groups of the mSPACE COST Action, strengthening interactions between communities that rarely collaborate directly. The interdisciplinary composition of the group, including both senior scientists and an early-career researcher, created an environment conducive to the exchange of ideas across disciplinary boundaries. The strong representation of women, which is still uncommon at meetings focused on pure mathematics, was another notable feature of the session.

The session concluded with the identification of the major research challenges and the definition of directions for a long-term interdisciplinary research program that will provide the mathematical foundations for adaptive systems theory.