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TITLE: Community ecology in 3D: Tensor decomposition reveals spatio-temporal dynamics of large ecological communities

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ABSTRACT:

Understanding spatio-temporal dynamics of biotic communities containing large numbers of species is crucial to guide ecosystem management and conservation efforts. However, traditional approaches usually focus on studying community dynamics either in space or in time, often failing to fully account for interlinked spatio-temporal changes. In this study, we demonstrate and promote the use of tensor decomposition for disentangling spatio-temporal community dynamics in long-term monitoring data. Tensor decomposition builds on traditional multivariate statistics (e.g. Principal Component Analysis) but extends it to multiple dimensions. This extension allows for the synchronized study of multiple ecological variables measured repeatedly in time and space. We applied this comprehensive approach to explore the spatio-temporal dynamics of 65 demersal fish species in the North Sea, a marine ecosystem strongly altered by human activities and climate change. Our case study demonstrates how tensor decomposition can successfully (i) characterize the main spatio-temporal patterns and trends in species abundances, (ii) identify sub-communities of species that share similar spatial distribution and temporal dynamics, and (iii) reveal external drivers of change. Our results revealed a strong spatial structure in fish assemblages persistent over time and linked to differences in depth, primary production and seasonality. Furthermore, we simultaneously characterized important temporal distribution changes related to the low frequency temperature variability inherent in the Atlantic Multidecadal Oscillation. Finally, we identified six major sub-communities composed of species sharing similar spatial distribution patterns and temporal dynamics. Our case study demonstrates the application and benefits of using tensor decomposition for studying complex community data sets usually derived from large-scale monitoring programs.

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