Fluctuating interaction network and time-varying stability of a natural fish community

Understanding the mechanisms underlying community stability is key to ecosystem conservation and management, as a fluctuating (less stable) community is vulnerable to catastrophic shifts. Theoretical studies have indicated that multispecies interactions play a critical role in determining the stability of the community. For example, species diversity, the topology of the interaction network, the distribution of interaction strengths, and the composition of interaction types can affect community stability. Although experimental and observational studies support this theory, these studies have assumed that the network structure is static; this assumption is unlikely to be true in nature, considering the changing environment. Thus, evidence from natural ecosystems remains scarce, owing to the challenges of tracking rapid changes in interspecific interactions and identifying the effect of such changes on large-scale community dynamics.

To test current ecological theory in a natural system, Professor Chih-hao Hsieh from the Institute of Oceanography and PhD student Chun-Wei Chang from Academia Sinica, together with an international research team, analyze time series data from a 12-year-long dataset of fortnightly collected observations of a marine fish community in Maizuru Bay, Japan. The researchers observe that short-term changes in interaction networks influence overall community dynamics and show that the strengths and even types of interactions change over time; in other words, the interaction network is dynamic rather than static (Figure 1). Moreover, the dynamical pattern of the network critically affects the stability of the community over time. Specifically, the team finds seasonal patterns in dynamic stability for this fish community that broadly support the expectations of current ecological theory: the dominance of weak interactions and

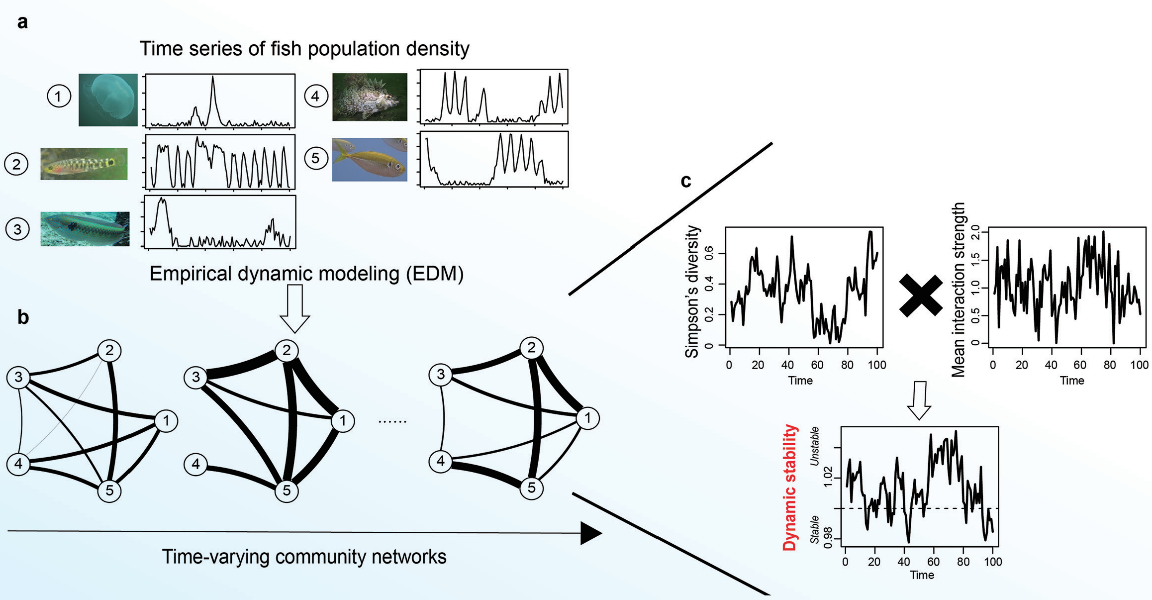

Figure 1. Based on the empirical time series data collected from the natural fish community in Maizuru Bay, Japan (a), empirical dynamic modeling (EDM) was used to reconstruct the interaction network among fish species at each time step (b). The structure of the networks is highly dynamic, in which some of the important network properties, including (c) mean interaction strength and dynamic stability, fluctuate over time. In particular, dynamic stability is a critical index measuring the tendency of a dynamical system to return to its original state upon perturbation. Interestingly, networks with many weak interactions and high diversity usually facilitate dynamic stability. (Fish photo credit: Reiji Masuda)

higher species diversity during summer months are associated with higher dynamic stability and smaller population fluctuations.

By developing a widely applicable analytical framework for nonlinear time series, the team finds that interspecific interactions, community network structures, and community stability are dynamic properties and that linking fluctuating interaction networks to community-level dynamic properties is key to understanding the maintenance of ecological communities in nature. These findings have important implications for ecosystem management and conservation. Most excitingly, relating fluctuating interaction networks to community stability provides a promising approach for determining how to systematically maintain natural ecological communities. The research also highlights the importance of long-term time series monitoring for ecosystem management.

References

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Confocal pump-probe backscattering microscopy for investigating single nanomaterials

In recent decades, ultrafast optical spectroscopy has provided a fundamental understanding of carrier dynamics (such as electrons and phonons) in many emergent materials, such as nanomaterials and 2D materials. Nevertheless, these materials typically possess spatial inhomogeneity, and it is therefore highly desirable to integrate ultrafast spectroscopy and optical microscopy to provide full spatiotemporal characterization of nanosized features. Here, we demonstrated a novel confocal pump-probe microscopy with a backscattering scheme for measuring isolated single nanomaterials. In contrast to the widely used transmission pump-probe microscopy, the confocal scheme provided axial sectioning capability, which enabled a subfemtoliter detection volume when combined with a tightly focusing objective.

However, the marriage between microscopy and spectroscopy is not a trivial task. For example, in a typical ultrafast spectroscopy setup, a pump and probe beams are employed, and nonlinear optical generation has typically been utilized to spectrally separate the pump/probe beams. Nevertheless, in a microscopy setup, when the wavelengths of the pump/probe beams are far from each other, the chromatic aberration of a high-NA microscopic objective lens becomes a serious issue.

In our study, to circumvent the aforementioned issues, we used sharp spectral filters to separate the spectra from the same optical pulses to create a pump beam and a probe beam. The pump and probe spectra and the original optical pulses (no filter) are shown in Figure 1(a). Because their spectra were directly divided from the full bandwidth of the original pulses, the wavelengths of the pump and probe beams were very similar, and the aberration effect was minimized. This method also reduced the complexity of the pump-probe microscopy geometry, eliminating the need, for example, for additional optical parametric oscillators (amplifiers).

For example, we studied the phonon dynamics of single gold nanoparticles by using a