



Contribution ID: 26

Type: **Invited Talk**

From Individual Bites to Ecosystem Patterns: Size-Structured Dynamics in Aquatic Food Webs

Aquatic ecosystems are shaped by countless interactions between individual organisms - but how do these microscopic encounters scale up to the large-scale patterns we observe in nature? How sensitive are these systems to human influence? Since the 1960s, research has revealed that body size plays a central role in structuring aquatic food webs, acting as a “master trait” that governs how biomass, abundance, and production are distributed across species.

In this work, we propose and analyze a deterministic jump-growth model that links individual-level feeding interactions to ecosystem-level structure. The model is formulated as a kinetic equation for coalescing particles and is derived from an underlying stochastic, individual-based description of predator-prey dynamics. At its core lies the assumption that ecosystem dynamics are driven by binary interactions: predators consume prey, assimilating a fraction of their biomass and thereby growing, while contributing to plankton production.

By studying this equation across multiple parameter regimes, we explore how simple rules at the level of individual interactions can generate emergent, size-structured patterns characteristic of aquatic ecosystems. We present analytical results alongside numerical simulations, offering insights into the mechanisms that shape food-web structure and their potential sensitivity to external perturbations.

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Session Classification: Invited talk