# ABSTRACT

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Title of the Thesis: **Spatial Heterogeneity & Ecological Patterns: Their Role in Species Persistence**

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This thesis explores the intricate interplay between space, species interactions, and environmental change, uncovering how populations survive, adapt, or collapse across complex landscapes. It places particular emphasis on the role of spatial pattern formation in shaping ecological stability, persistence, and collapse. Using reaction–diffusion frameworks, the study demonstrates how local interactions, dispersal processes, and feedback mechanisms give rise to diverse spatiotemporal structures, such as Turing patterns, regular and chaotic oscillations, and multiscale vegetation mosaics, that closely mirror dynamics observed in predator–prey systems, grazing landscapes, and arid ecosystems. These emergent patterns are not merely mathematical constructs but ecological realities, where self-organization governs resilience and coexistence. The work further reveals how external drivers such as harvesting, productivity gradients, and climate variability interact with intrinsic instabilities to transform or destabilize these patterns, at times pushing systems toward tipping points and extinction. By integrating analytical bifurcation theory with extensive numerical simulations, the thesis advances a comprehensive understanding of how ecological patterns emerge, persist, and evolve, offering predictive insights into ecosystem resilience and vulnerability under environmental change.

More specifically, Chapter 2 introduces nonlinear saturated harvesting in predator-prey systems, showing how bifurcations, diffusivity ratios, and harvesting pressures reshape dynamics and spatial structures. Chapter 3 turns to plant–herbivore interactions in heterogeneous landscapes, demonstrating how herbivore dispersal and initial conditions lead to bistability, spatial heterogeneity, and shifts between bottom-up and top-down control. Chapter 4 investigates adaptation in arid ecosystems through a two-layer model incorporating root plasticity and soil stratification, highlighting how multiscale vegetation structures and niche partitioning arise under water limitation. Chapter 5 adds temporal environmental variability by modeling stochastic prey growth in predator–prey systems, illustrating how synchrony, diffusion, and climate fluctuations can either facilitate persistence or precipitate collapse. Chapter 6 expands the classical framework by considering hyperbolic reaction–diffusion systems, which capture finite-speed propagation and wave-driven instabilities absent in parabolic models, uncovering novel mechanisms of pattern selection. Finally, Chapter 7 synthesizes the major findings, acknowledges limitations, and outlines future directions, reinforcing the broader contribution of this thesis: a predictive and mechanistic understanding of how ecological patterns emerge and transform under the combined influence of space, adaptation, and environmental change.


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