

RESEARCH ARTICLE

Analyzing Dynamics, Bifurcations, and Chaos in a Discrete Predator–Prey System With Ricker Growth: A Theoretical and Empirical Investigation

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ABSTRACT

This study presents a comprehensive analysis of a discrete-time predator–prey model, uniquely combining rigorous theoretical investigation with empirical validation using four decades of moose–wolf interaction data. The proposed model incorporates a Ricker-type growth function for the prey population, which inherently ensures the positivity of solutions, a crucial aspect of ecological realism. Our qualitative analysis identifies biologically feasible equilibrium points and examines their local stability to delineate conditions for species coexistence or extinction. The rich and bifurcating dynamical behavior of the model is studied by using center manifold theory and normal forms to investigate codimension-one bifurcations, specifically transcritical and period-doubling bifurcations. Furthermore, the first Lyapunov exponent is explicitly derived to characterize Neimark–Sacker bifurcations emerging from the positive fixed point. The research also explores complex codimension-two bifurcations, including fold-flip and strong resonances (1:2, 1:3, and 1:4), revealing intricate pathways between stability, periodic oscillations, and chaotic regimes. To bridge theoretical control strategies with practical wildlife management, the Ott-Grebogi-Yorke (OGY) method is applied to mitigate chaotic dynamics, offering ecological interpretations for the necessary perturbations. This work thereby provides a robust framework for understanding and managing complex ecological systems through the synergy of mathematical modeling and long-term empirical data. Numerical simulation is provided to illustrate the theoretical discussion.

MSC2020 Classification: 37N25, 92D40, 39A30, 37G15, 37G10

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