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Modeling Regime Shifts in Freshwater Ecosystems: A Fractional-Order Analysis of Climate-Induced Transitions

Communication Info

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Abstract

This study presents a fractional-order mathematical model to investigate aquatic ecosystem resilience under climate change [1], using Morocco's Aguelmam Azegza Lake as a case study. We formulate a system of fractional-order differential equations describing interactions between water levels (W), aquatic vegetation (A), and migratory bird populations (O) [2]. Theoretical analysis using fixed-point theorems establishes existence and uniqueness of solutions, while Ulam-Hyers stability confirms robust behavior [3]. Numerical simulations using the L_1 approximation method reveal that higher fractional orders ($\alpha = 0.8$) introduce stabilizing memory effects, mitigating instabilities observed in classical models [4]. Parameter optimization significantly enhances system stability. Our findings demonstrate that fractional-order models capture ecosystem memory effects more accurately, providing a theoretical foundation for sustainable lake management under climate-induced pressures [5].

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