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BIFURCATION AND NUMERICAL ANALYSIS OF A GENERALIZED GAUSE-TYPE PREDATOR-PREY MODEL

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Abstract. We analyze a generalized predator-prey model of Gause-type with functional and numerical responses, which model the effects of environmental changes in the ecosystem. Stability analysis of the associated equilibria is carried out, and bifurcation behavior of the model, such as transcritical and Hopf, is discussed. A non-standard numerical scheme is designed and used to illustrate the rich dynamics of the model with the Holling-types II and III response functions. It is proven that the scheme has the same asymptotic and bifurcation behaviors as the model, and is free of scheme-failures often arising in standard methods. To support these facts, simulations are performed and the results compared with those obtained by the Runge-Kutta 4 (RK4) method. Erroneous chaotic behavior, not encountered in either the continuous model or the proposed non-standard scheme, is observed in the discrete solutions produced by the RK4 method.

Keywords. Predator-prey models, functional and numerical responses, Hopf bifurcation, transcritical bifurcation, limit cycles, finite-difference methods.

AMS (MOS) subject classification: Primary, 34C23, 92D25; Secondary, 34D23.

1 Introduction

Predator-prey models have had a long history in dynamical analysis of species interactions in ecosystems. Since the early studies by Lotka [17] and Volterra [29], various models have been introduced and developed in order to describe different aspects of natural life, including persistence, extinction and cycles. In the development of these models, the functional response of predator to prey has played a major role, and contributed to a better understanding of the behavior of predator and prey populations in nature. This functional response describes the change in the rate of exploitation of prey by a predator as a result of a change in the prey density. The sensitivity of dynamical behavior of different species to small changes in the functional response suggests that this response is a crucial factor in the modeling interactions and an essential component of predator-prey models [1, 3, 6, 12, 23, 24].

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