

Population Dynamics: Conceptual Foundations, Mathematical Models and Applications

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Abstract

Population dynamics is the field of biology that examines how and why populations change over time. This article provides a comprehensive overview of population dynamics, covering its conceptual basis, mathematical modelling approaches, and practical applications. We review the historical foundations of the discipline—from early theories of exponential growth and resource limitation to the development of the logistic growth model and classical predator–prey interactions. Fundamental equations are presented and explained in detail, with all variables and parameters clearly defined. We then apply these models to illustrative scenarios and present the results with professional graphs, demonstrating key behaviours such as exponential increase, stabilisation at carrying capacity, and cyclic oscillations in interacting species. In the discussion, we interpret the results in an ecological context, evaluate the strengths and limitations of each model, and consider extensions of the basic models. We also discuss the role of stochastic events, spatial structure, and interspecific interactions in shaping real-world population dynamics, and conclude with a reflection on future research directions in the field.

Keywords: population dynamics; exponential growth; logistic model; predator–prey interactions; mathematical biology; population ecology; conservation

1. Introduction

Population dynamics is the study of the causes behind changes in population size and composition over time. It seeks to understand how birth, death, immigration, and emigration rates—as well as interactions with the environment and other species—determine population trajectories. This field is a cornerstone of ecology and evolutionary biology, offering insights into phenomena such as species abundances, extinction risks, and the outcomes of biological interactions. The conceptual basis of population dynamics has deep historical roots, intertwining observational biology with mathematical reasoning. In this introduction, we outline key developments in population dynamics theory—from early conceptual advances to the formulation of foundational mathematical models—and discuss how these ideas have shaped modern population ecology.

1.1 Historical Foundations of Population Dynamics

Mathematical Foundations Of Population Dynamics

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