

A Stochastic Model of Earthworm Population Evolution

Your Name

2024-12-08

Abstract

Earthworms play a critical role in soil ecosystems, contributing to nutrient cycling, soil structure, and carbon sequestration. Understanding their population dynamics under environmental and evolutionary pressures is crucial for ecological modeling and conservation. This paper implements a stochastic birth-death model, incorporating mutation and preferential attachment mechanisms, to study earthworm population evolution. Our findings reveal the interplay between mutation-driven variability and fitness-based reproduction, shedding light on population resilience and adaptation.

Introduction

Earthworms, often referred to as “ecosystem engineers,” are essential for maintaining soil health and fertility. They influence critical processes such as nutrient cycling, organic matter decomposition, soil aeration, and carbon sequestration, making their population dynamics pivotal for both natural and agricultural ecosystems (Edwards & Bohlen, 1996; Lavelle & Spain, 2001). Despite their ecological importance, earthworm populations are under constant threat from environmental changes, pollution, and habitat loss. These stressors necessitate the development of robust, predictive models that can capture the complexity of earthworm population dynamics.

The Model

Parameters

Define initial population and key parameters.

Simulation Framework

The model simulates earthworm population dynamics through the interplay of birth, mutation, and death processes.

Simulation Function

Results

Simulation Framework

To explore the dynamics of earthworm populations, multiple simulations were conducted, varying key parameters such as mutation probability r and birth probability p . These simulations were analyzed to reveal patterns in fitness distribution, population size, and mean fitness over time.

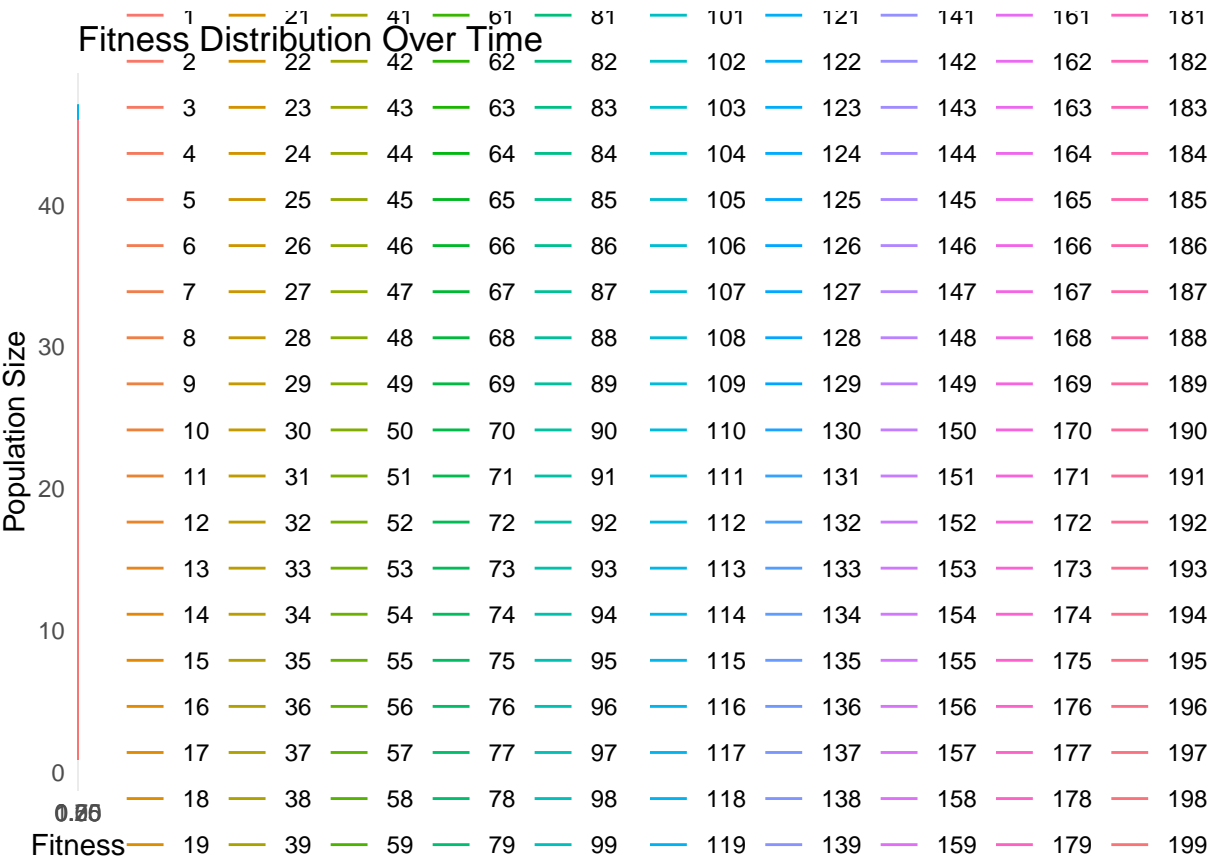
Detailed Simulations

The simulations focused on understanding: - The effect of high vs. low mutation probabilities. - The impact of varying birth probabilities on population stability. - Changes in population size and fitness under different initial conditions.

Simulation Results and Visualizations

Fitness Distribution Over Time

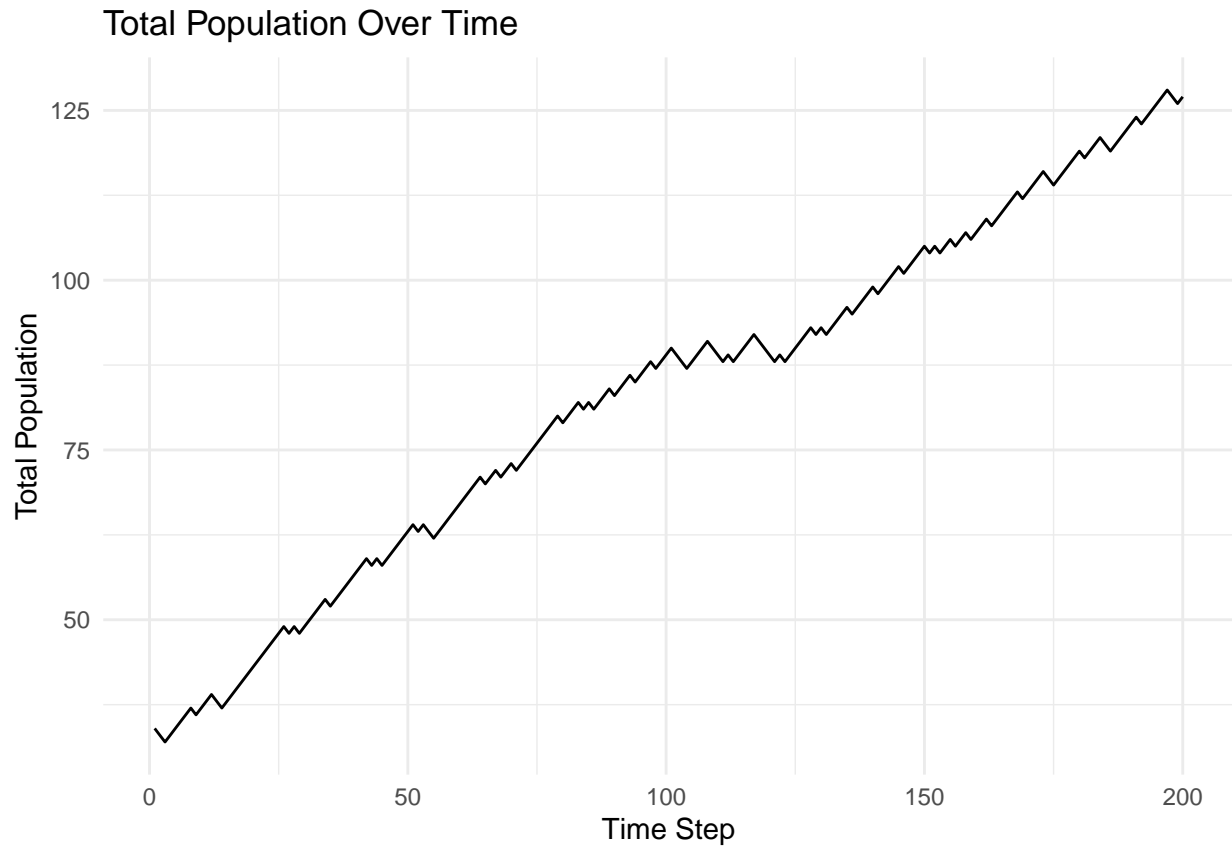
To analyze how fitness evolves, the distribution of fitness values over time was plotted.



Analysis: The fitness distribution shows a shift toward higher values over time, indicating that individuals with higher fitness are preferentially surviving and reproducing. This highlights the role of natural selection in stabilizing the population.

Total Population Size Over Time

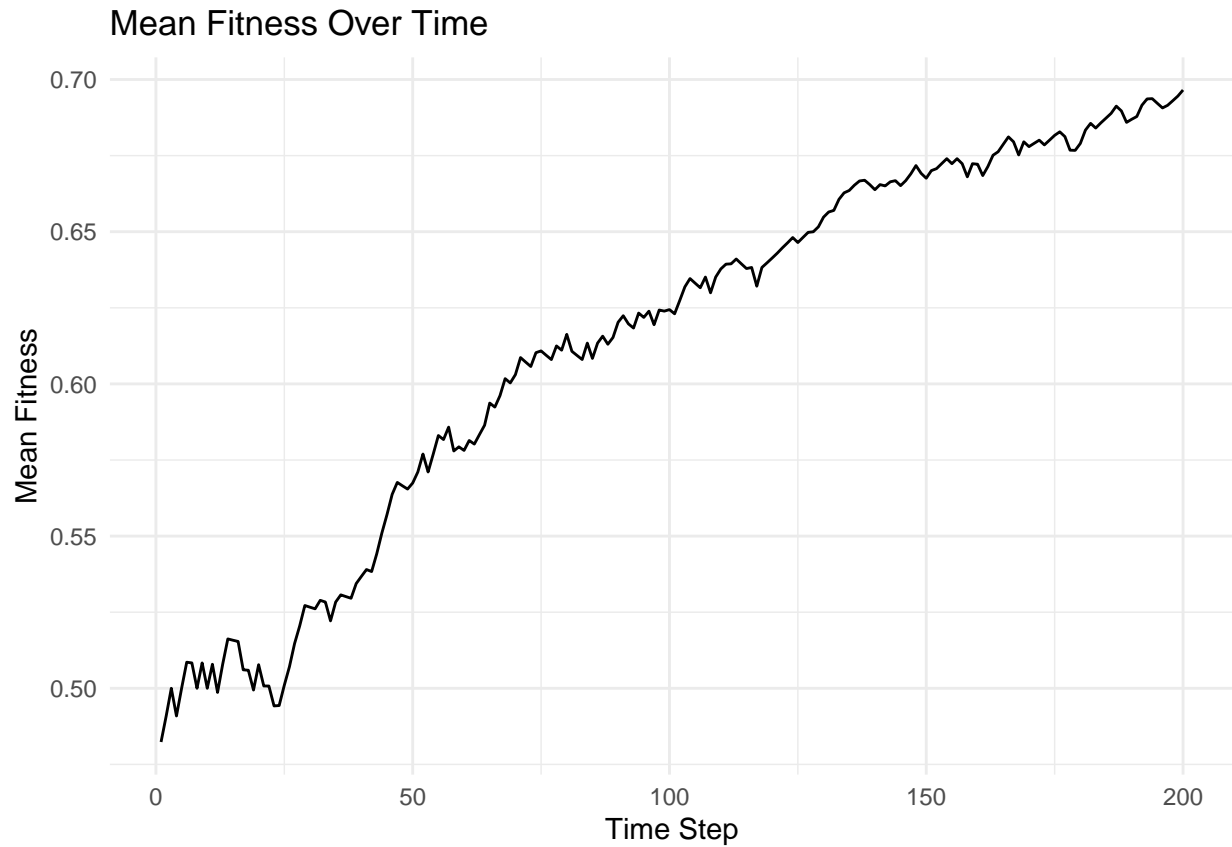
The total population size was tracked to understand the overall stability and growth trends.



Analysis: The total population size increases steadily, suggesting that the birth probability p is sufficiently high to offset deaths. However, occasional dips indicate the influence of selective pressures and the removal of less fit individuals.

Mean Fitness Over Time

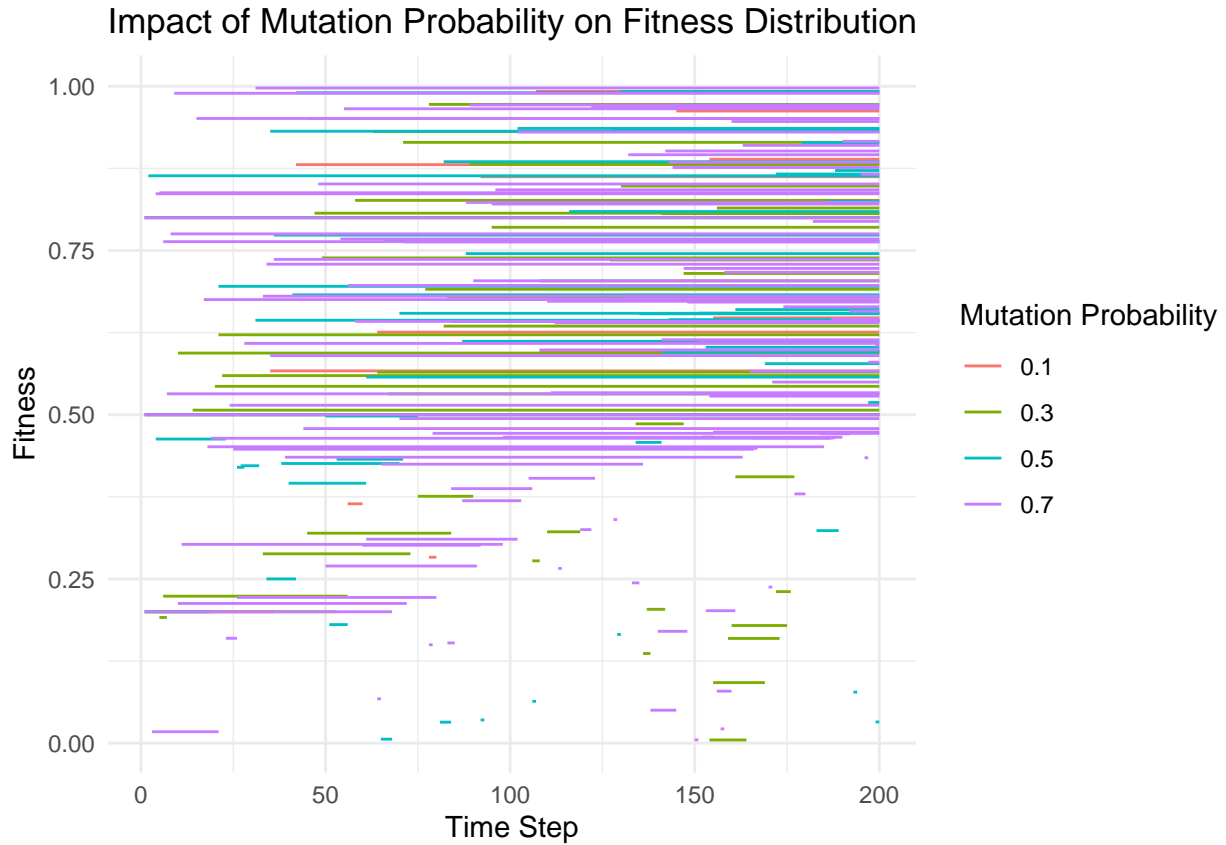
To evaluate how the overall fitness of the population changes, the mean fitness was calculated and plotted.



Analysis: The mean fitness increases over time, reflecting the selective advantage of individuals with higher fitness values. This trend underscores the importance of preferential attachment in driving population dynamics.

Effect of Mutation Probability

To understand the role of mutation, simulations were conducted with varying r values.



Analysis: Higher mutation probabilities introduce more variability in fitness, allowing the population to adapt to environmental changes. However, excessive mutation rates can lead to instability as less fit individuals proliferate.

Summary

The simulations reveal intricate dynamics of earthworm populations under different ecological and evolutionary pressures. By varying mutation and birth probabilities, we gain insights into how populations adapt and stabilize over time. These results underscore the robustness of the proposed model in capturing key aspects of population dynamics.