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ABSTRACT

Title of the Thesis: Model Based Study on the Dynamics of Coral Reef Ecosystem with Special Emphasis in Disease and its Control

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Coral reefs are among the most ecologically diverse and economically important ecosystems on Earth, offering vital services such as coastal protection, fisheries support, and tourism revenue. However, they are increasingly threatened by both biotic and abiotic stressors, with coral diseases emerging as a major driver of degradation. In this thesis we present a series of mathematical models that examine the dynamics of coral reef ecosystems, with a focus on disease transmission, coral recovery, and the influence of ecological interactions. We begin by developing a model that explores the interactions between susceptible and infected coral colonies, examining how waterborne disease transmission, macroalgae overgrowth, and fish grazing affect coral health. The analysis reveals a tri-stability regime, where disease transmission rate (λ), recovery rate (ω), and grazing intensity (g) collectively shape ecosystem stability. Fish grazing emerges as a key factor in limiting macroalgae dominance, thereby supporting coral recovery and resilience. Extending this framework, we incorporate incubation time delays to capture the latent period of coral diseases. The resulting delay differential model shows that beyond a critical delay threshold, the system undergoes a Hopf bifurcation, leading to periodic oscillations in coral and macroalgae populations and also delay control oscillation due to recovery. This highlights how time-dependent factors can destabilize reef dynamics and underscores the importance of enhancing recovery processes to mitigate disease impacts. Further, we investigate the role of zooplankton as disease vectors, particularly in the spread of White Band Disease (WBD). Using a five-dimensional eco-epidemiological model, we find that zooplankton-mediated transmission is more detrimental than direct contact transmission. Increased mutualism with phytoplankton is shown to promote coral resilience, while bifurcation analysis reveals critical thresholds for disease-driven instability. Finally, we examine fish predation as a dual force both facilitating disease spread and suppressing competitive macroalgae. Our findings identify a non-linear relationship, where both very low and high levels of fish predation can favor coral persistence. A tipping point is observed beyond which disease prevalence declines, highlighting the complex interplay between disease virulence, transmission, and biotic regulation. The thesis concludes by outlining potential avenues for future research.

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