ABSTRAK

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Judul : **Analisis Model Mangsa-Pemangsa Tiga Kompartemen dengan Efek Difusi, Waktu Tunda, serta Pemanenan**

Model mangsa-pemangsa tiga kompartemen (mangsa, pemangsa menengah, pemangsa puncak) dikembangkan dengan mengintegrasikan efek difusi spasial, waktu tunda diskrit (gestasi dan konversi biomassa), serta pemanenan proporsional pada dua level trofik terbawah. Tujuan penelitian adalah merumuskan model, menganalisis dinamika kestabilan lokal dan bifurkasi Hopf akibat variasi waktu tunda, serta menentukan strategi pemanenan berkelanjutan berdasarkan konsep *Maximum Sustainable Yield* (MSY). Metode yang digunakan meliputi analisis titik kesetimbangan, linierisasi dengan matriks variasi, kriteria Routh–Hurwitz, serta simulasi numerik menggunakan GNU Octave pada domain spasial satu dan dua dimensi. Hasil penelitian menunjukkan bahwa titik kesetimbangan interior koeksistensi eksis dan stabil asimtotik lokal pada kondisi tertentu. Waktu tunda tunggal maupun ganda memicu bifurkasi Hopf ketika melewati nilai kritis ($\tau_1^* = 0.6191$, $\tau_2^* = 148.8016$ tanpa pemanenan), sementara difusi murni tidak menghasilkan instabilitas Turing. Pemanenan pada laju aman ($h_1 = 0.1, h_2 = 0.3$) meningkatkan nilai kritis waktu tunda (menjadi $\tau_1^* = 1.0738$, $\tau_2^* = 166.1013$) dan menjaga koeksistensi, berbeda dengan pemanenan MSY matematis yang menyebabkan kepunahan spesies. Kesimpulannya, integrasi difusi, waktu tunda, dan pemanenan menghasilkan dinamika kompleks, dengan waktu tunda sebagai destabilisator utama dan pemanenan terkendali sebagai agen stabilisasi yang memperlambat terjadinya bifurkasi Hopf.

Kata Kunci: Model Mangsa-Pemangsa Tiga Kompartemen, Difusi, Waktu Tunda, Pemanenan, *Maximum Sustainable Yield* (MSY), Bifurkasi Hopf, Kestabilan Lokal

ABSTRACT

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Title : ***Three-Compartment Prey-Predator Models Analysis with The Effects of Diffusion, Delay, and Harvesting***

A three-compartment predator-prey model (prey, middle predator, top predator) is developed by integrating spatial diffusion, discrete time delays (gestation and biomass conversion), and proportional harvesting on the two lower trophic levels. The objectives are to formulate the model, analyze local stability dynamics and Hopf bifurcation due to time delay variations, and determine a sustainable harvesting strategy based on the Maximum Sustainable Yield (MSY) concept. Methods include equilibrium analysis, linearization using a variation matrix, Routh–Hurwitz criterion, and numerical simulations with GNU Octave in one- and two-dimensional spatial domains. The results show that a positive interior coexistence equilibrium exists and is locally asymptotically stable under certain conditions. Single or double time delays trigger Hopf bifurcation when exceeding critical values ($\tau_1^* = 0.6191$, $\tau_2^* = 148.8016$ *without harvesting), while pure diffusion does not produce Turing instability. Harvesting at safe rates* $(h_1 = 0.1, h_2 = 0.3)$ *increases the critical delay values (to* $\tau_1^* = 1.0738$, $\tau_2^* = 166.1013$*) and maintains coexistence, in contrast to the mathematical MSY harvesting that leads to species extinction. In conclusion, the integration of diffusion, time delays, and harvesting yields complex dynamics, with time delays as the main destabilizer and controlled harvesting as a stabilizing agent that delays the onset of Hopf bifurcation.*

Keywords: Three-Compartment Predator-Prey Model, Diffusion, Time Delay, Harvesting, Maximum Sustainable Yield (MSY), Hopf Bifurcation, Local Stability