

## **ONE-PARAMETER BIFURCATION ANALYSIS OF PREY-PREDATOR MODEL WITH HARVESTING STRATEGIES**

(Analisis Dwcabangan Satu-Parameter bagi Model Mangsa-Pemangsa dengan Strategi Penuaian)

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### *ABSTRACT*

This study investigates the effect of changes in the parameter of harvesting effort in both prey and predator species. As we know, prey and predator correlate to each other. Thus, it is important to know the dynamics of their population when the interaction is affected by the harvesting activity. To do this, we consider an ecological model of prey-predator interactions with the presence of harvesting effort. Then, we employ stability analysis, bifurcation analysis and numerical simulations to illustrate the dynamical behaviours of the prey-predator system. This study also analyses the behaviour of prey-predator interactions as the harvesting parameters of prey and predator species are varied. With the help of mathematical software such as XPPAUT and Matlab, a few graphs of bifurcation, phase plane, and time series are plotted. Maple software is used to find the Jacobian matrix and also the critical points. By using bifurcation analysis, there is an occurrence of one transcritical bifurcation point. Our finding demonstrates that as the harvesting parameter exceeds the transcritical bifurcation point, the prey-predator system changes from stable to unstable or vice versa.

*Keywords:* harvesting activity; prey-predator model; stability analysis; transcritical bifurcation

### *ABSTRAK*

Kajian ini menyelidik kesan perubahan parameter penuaian kepada spesies mangsa dan pemangsa. Seperti yang diketahui, mangsa dan pemangsa saling berhubung. Oleh itu, adalah penting untuk diketahui dinamik populasi mangsa dan pemangsa apabila interaksi tersebut dipengaruhi oleh aktiviti penuaian. Untuk tujuan tersebut, digunakan model ekologi (perikanan) mangsa-pemangsa dengan melibatkan aktiviti penuaian. Kemudian, digunakan analisis kestabilan, analisis dwcabangan dan simulasi berangka untuk menggambarkan tingkah laku dinamik sistem mangsa-pemangsa. Kajian ini juga menganalisis tingkah laku interaksi mangsa-pemangsa apabila parameter penuaian spesies mangsa dan pemangsa berubah. Beberapa jenis graf telah dibina dengan menggunakan bantuan perisian matematik seperti XPPAUT dan Matlab. Perisian Maple juga digunakan untuk mencari matrik Jacobi dan juga titik kritikal. Dengan menggunakan analisis dwcabangan, didapati wujud satu titik dwcabangan transkritikal. Hasil kajian menunjukkan bahawa apabila parameter penuaian melebihi titik dwcabangan transkritikal, sistem mangsa-pemangsa berubah daripada stabil kepada tidak stabil dan juga sebaliknya.

*Kata kunci:* aktiviti penuaian; model mangsa-pemangsa; analisis kestabilan; dwcabangan transkritikal

## References

- Abdul Satar H. & Naji R.K. 2019. Stability and bifurcation of a prey-predator-scavenger model in the existence of toxicant and harvesting. *International Journal of Mathematics and Mathematical Sciences* **2019**(4): 1-7.
- Ang T.K., Safuan H.M. & Kavikumar J. 2018. The impacts of harvesting activities on prey-predator fishery model in the presence of toxin. *Journal of Science and Technology* **10**(2): 128-135.
- Chakraborty K., Das K. & Kar T.K. 2013. An ecological perspective on marine reserves in prey-predator dynamics. *Journal of biological physics* **39**(4): 749-776.
- Chakraborty K. & Das K. 2015. Modeling and analysis of a two-zooplankton one-phytoplankton system in the presence of toxicity. *Applied Mathematical Modelling* **39**(3-4): 1241-1265.
- Das T., Mukherjee R. & Chaudhuri K. 2009. Harvesting of a prey-predator fishery in the presence of toxicity. *Applied Mathematical Modelling* **33**(5): 2282-2292.
- Dubey B. 2007. A prey-predator model with a reserved area. *Nonlinear Analysis: Modelling and Control* **12**(4): 479-494.
- Fitzgerald C.J., Shephard S., McLoone P., Kelly F.L. & Farnsworth K.D. 2019. Evaluating management options for two fisheries that conflict through predator-prey interactions of target species. *Ecological Modelling* **410**, 108740.
- Hussein S. 2010. Predator-prey modelling. *Undergraduate Journal of Mathematical Modeling: One +Two* **3**(1), art. 20.
- Kar T. 2003. Selective harvesting in a prey-predator fishery with time delay. *Mathematical and Computer Modelling* **38**(3-4): 449-458.
- Kar T.K. & Matsuda H. 2007. Global dynamics and controllability of a harvested prey-predator system with Holling type III functional response. *Nonlinear Analysis: Hybrid Systems* **1**(1): 59-67.
- Lv Y., Yuan R. & Pei Y. 2013. A prey-predator model with harvesting for fishery resource with reserve area. *Applied Mathematical Modelling* **37**(5): 3048-3062.
- Manaf Z.I.A. & Mohd M.H. 2019. Bifurcation analysis of the prey-predator models incorporating herd behaviours. *IOP Conference Series: Earth and Environmental Science* **380**, 012009.
- Sahoo B., Das B. & Samanta S. 2016. Dynamics of harvested-predator-prey model: role of alternative resources. *Modeling Earth Systems and Environment* **2**(3): 1-12.
- Shatnawi M.T. 2016. The effects of harvesting and time delay on prey-predator systems. *Journal of Advances in Mathematics and Computer Science* **17**(2): 1-15.
- Stevens A.N.P. 2012. Dynamics of Predation. *Nature Education Knowledge* **3**(10), 46.
- Strogatz S.H. 2018. *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering*. 2nd Ed. Boca Raton, Florida: CRC Press.
- Yang H. & Jia J. 2017. Harvesting of a predator-prey model with reserve area for prey and in the presence of toxicity. *Journal of Applied Mathematics and Computing* **53**(1-2): 693-708.

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