Singh, Anuraj; **Deolia, Preeti**

Dynamical analysis and chaos control in discrete-time prey-predator model. (English)

Zbl 1451.92267
Commun. Nonlinear Sci. Numer. Simul. 90, Article ID 105313, 23 p. (2020).

Summary: In this work, a discretized two-dimensional Leslie-Gower prey-predator model is investigated. The results for the existence and uniqueness and the conditions for the local asymptotic stability of the solutions are determined. It is also exhibited that the discrete system undergoes Neimark-Sacker, flip and fold bifurcation under certain conditions. The discretized system exhibits wide range of complex dynamical behavior viz. periodicity, quasi periodicity and chaos with respect to different parameters. Further, three control methods: state feedback, pole-placement and hybrid control are deployed to control the chaos in the system. Under certain conditions, chaos and bifurcation of the system are stabilized through the control strategies. The extensive numerical simulation is done to demonstrate the analytical findings.

MSC:

92D25 Population dynamics (general)
34H10 Chaos control for problems involving ordinary differential equations
34C23 Bifurcation theory for ordinary differential equations
93B52 Feedback control

Keywords:

Neimark-Sacker bifurcation; flip bifurcation; chaos; feedback control

Full Text: DOI

References:

[1] Freedman, H. I., Deterministic mathematical models in population ecology, vol. 57 (1980), Marcel Dekker Incorporated · Zbl 0448.92023

[2] Leslie, P.; Gower, J., The properties of a stochastic model for the predator-prey type of interaction between two species, Biometrika, 47, 3/4, 219-234 (1960) · Zbl 0103.12502

[3] Kot, M., Elements of mathematical ecology (2001), Cambridge University Press

[4] Aziz-Alaoui, M.; Okiye, M. D., Boundedness and global stability for a predator-prey model with modified Leslie-Gower and holling-type II schemes, Appl Math Lett, 16, 7, 1069-1075 (2003) · Zbl 1063.34044

[5] Edelstein-Keshet, L., Mathematical models in biology (1988), McGraw-Hill: McGraw-Hill New York · Zbl 0674.92001

[6] Wikan, A.; Kristensen, O., Prey-predator interactions in two and three species population models (2019), Discrete Dyn Nat Soc

[7] Yuan, S.; Song, Y., Bifurcation and stability analysis for a delayed Leslie-Gower predator-prey system, IMA J Appl Math, 74, 4, 574-603 (2009) · Zbl 1201.34132

[8] Gakkhar, S.; Singh, A., Complex dynamics in a prey predator system with multiple delays, Commun Nonlinear Sci Numer Simul, 17, 2, 914-929 (2012) · Zbl 1243.92051

[9] Ma, Z.; Wang, S., A generalized predator-prey system with multiple discrete delays and habitat complexity, Jpn J Ind Appl Math, 1-22 (2019)

[10] Maiti, A. P.; Dubey, B.; Tushar, J., A delayed prey-predator model with crowley-martin-type functional response including prey refuge, Math Methods Appl Sci, 40, 16, 5792-5809 (2017) · Zbl 1383.37073

[11] 1250047-1 · Zbl 1291.37117

[12] Kumar, S.; Kharbanda, H., Chaotic behavior of predator-prey model with group defense and non-linear harvesting in prey, Chaos Solitons Fractals, 119, 19-28 (2019)

[13] Jana, S.; Chakraborty, M.; Chakraborty, K.; Kar, T., Global stability and bifurcation of time delayed prey-predator system incorporating prey refuge, Math Comput Simul, 85, 57-77 (2012) · Zbl 1258.34161

[14] Hastings, A.; Powell, T., Chaos in a three-species food chain, Ecology, 72, 896-903 (1991)

[15] Liu, W.; Cai, D., Bifurcation, chaos analysis and control in a discrete-time predator-prey system, Adv Differ Equ, 2019, 1, 11 (2019) · Zbl 07012079

[16] Zhao, M.; Xuan, Z.; Li, C., Dynamics of a discrete-time predator-prey system, Adv Differ Equ, 191, 1-18 (2016)

[17] Yuan, R.; Jiang, W.; Wang, Y., Saddle-node-hopf bifurcation in a modified Leslie-Ggower predator-prey model with time-delay and prey harvesting, J Math Anal Appl, 422, 2, 1072-1090 (2015) · Zbl 1306.34132

[18] Li, L.; Wang, Z. J., Global stability of periodic solutions for a discrete predator-prey system with functional response, Nonlinear Dyn, 72, 3, 507-516 (2013) · Zbl 1269.92070

[19] Asheghi, R., Bifurcations and dynamics of a discrete predator-prey system, J Biol Dyn, 8, 1, 161-186 (2014)

[20] Sapora, A.; Cornetti, P.; Carpinteri, A., Wave propagation in nonlocal elastic continua modelled by a fractional calculus approach, Commun Nonlinear Sci Numer Simul, 18, 1, 63-74 (2013) · Zbl 1253.35203

[21] Machado, J. T.; Mata, M. E., Pseudo phase plane and fractional calculus modeling of western global economic downturn, Commun Nonlinear Sci Numer Simul, 22, 1-3, 396-406 (2015)

[22] Meral, F.; Royston, T.; Magin, R., Fractional calculus in viscoelasticity: an experimental study, Commun Nonlinear Sci Numer Simul, 15, 4, 939-945 (2010) · Zbl 1221.74012

[23] Aghababa, M. P.; Borjkhani, M., Chaotic fractional-order model for muscular blood vessel and its control via fractional control scheme, Complexity, 20, 2, 37-46 (2014)

[24] Miller, K. S.; Ross, B., An introduction to the fractional calculus and fractional differential equations (1993), Wiley · Zbl 0789.26002

[25] Matouk, A.; Elsadany, A.; Ahmed, E.; Agiza, H., Dynamical behavior of fractional-order Hastings-Powell food chain model and its discretization, Commun Nonlinear Sci Numer Simul, 27, 1-3, 153-167 (2015)

[26] Li, H.; Zhang, L.; Hu, C.; Jiang, Y.; Teng, Z., Dynamical analysis of a fractional-order predator-prey model incorporating a prey refuge, J Appl Math Comput, 54, 435-449 (2017) · Zbl 1377.34062

[27] Panja, P., Stability and dynamics of a fractional-order three-species predator-prey model, Theory Biosci, 138, 2, 251-259 (2019)

[28] Alqurana, M.; Al-Khaled, K.; Sardar, T.; Chattopadhyaya, J., Revisited Fisher's equation in a new outlook: afractional derivative approach, Physica A, 438, 5, 81-93 (2015)

[29] El-Saka, H. A.A.; Lee, S.; Jang, B., Dynamic analysis of fractional-order predator-prey biological economic system with holling type II functional response, Nonlinear Dyn, 96, 1, 407-416 (2019) · Zbl 1437.37119

[30] Rajasekar, S.; Murali, K.; Lakshmanan, M., Control of chaos by nonfeedback methods in a simple electronic circuit system and the Fitzhugh-Nagumo equation chaos, Solitons Fractals, 8, 9, 1545-1558 (1997)

[31] Srivastava, M.; Agrawal, S.; Das, S., Synchronization of chaotic fractional order Lotka-Volterra system, Int J Nonlinear Sci, 13, 4, 482-494 (2012) · Zbl 1394.34131

[32] Din, Q., Complexity and chaos control in a discrete-time prey-predator model, Commun Nonlinear Sci Numer Simul, 49, 113-134 (2017)

[33] Alidousti, J., Stability and bifurcation analysis for a fractional prey-predator Scavenger model, Appl Math Model, 81, 342-355 (2020)

[34] 409-15

[35] Singh, A.; Elsadany, A. A.; Elsonbaty, A., Complex dynamics of a discrete fractional-order Leslie-Gower predator-prey model, Math Methods Appl Sci, 42 (2019) · Zbl 1423.39022

[36] Alidousti, J.; Ghafari, E., Dynamic behavior of a fractional order prey-predator model with group defense, Chaos Solitons Fractals, 134, 109688 (2020)

[37] Santra, P. K.; Mahapatra, G. S.; Phaijoo, G. R., Bifurcation and chaos of a discrete predator-prey model with Crowley-Martin functional response incorporating proportional prey refuge, Math Probl Eng, 5309814-5309818 (2020)

[38] Pyragas, K., Continuous control of chaos by self-controlling feedback, Phys Lett A, 170, 6, 421-428 (1992)

[39] Chen, G., On some controllability conditions for chaotic dynamics control, Chaos Solitons Fractals, 8, 9, 1461-1470 (1997)

[40] Singh, A.; Gakkhar, S., Controlling chaos in a food chain model, Math Comput Simul, 115, 24-36 (2015)

[41] Chakraborty, K., Ecological complexity and feedback control in a prey-predator system with holling type III functional response, Complexity, 21, 5, 346-360 (2016)

[42] Auerbach, D.; Grebogi, C.; Ott, E.; Yorke, J. A., Controlling chaos in high dimensional systems, Phys Rev Lett, 69, 24, 3479 (1992) · Zbl 0964.37502

[43] Yang, L.; Liu, Z.; Mao, J.m., Controlling hyperchaos, Phys Rev Lett, 84, 1, 67 (2000)

[44] Chakraborty K. Ecological complexity and feedback control in a prey-predator system with holling type III functional response. Complexity 21(5):346-360.

[45] 1850062-29 · Zbl 1390.39060

[46] Podlubny, I., Fractional differential equations: an introduction to fractional derivatives, fractional differential equations, to methods of their solution and some of their applications, vol. 198 (1998), Elsevier

[47] Rainville E. Special functions. New York: Macmillan.

[48] Caputo, M., Linear models of dissipation whose q is almost frequency independent ii, Geophys J Int, 13, 5, 529-539 (1967)

[49] Pp. 963-968

[50] Elaydi, S. N., Discrete chaos: with applications in science and engineering (2007), Chapman and Hall/CRC

[51] Romeiras, F. J.; Grebogi, C.; Ott, E.; Dayawansa, W., Controlling chaotic dynamical systems, Physica D, 58, 1-4, 165-192 (1992) · Zbl 1194.37140

[52] Luo, X. S.; Chen, G.; Wang, B. H.; Fang, J. Q., Hybrid control of period-doubling bifurcation and chaos in discrete nonlinear dynamical systems, Chaos Solitons Fractals, 18, 4, 775-783 (2003) · Zbl 1073.37512

[53] Chen, G.; Dong, X., From chaos to order-perspectives and methodologies in controlling chaotic nonlinear dynamical systems, Int J Bifurcation Chaos, 3, 6, 1363-1409 (1993) · Zbl 0886.58076

[54] Ogata K., Yang Y. Modern control engineering, vol. 4, London. 2002.

[55] Yuan, G.; Yang, Q. G., Bifurcation, invariant curve and hybrid control in a discrete-time predator-prey system, Appl Math Model, 39, 8, 2345-2362 (2015) · Zbl 1443.92172

[56] Shen, J.; Lam, J., Non-existence of finite-time stable equilibria in fractional-order nonlinear systems, Automatica, 50, 2, 547-551 (2014) · Zbl 1364.93690

[57] Kaslik, E.; Sivasundaram, S., Non-existence of periodic solutions in fractional-order dynamical systems and a remarkable difference between integer and fractional-order derivatives of periodic functions, Nonlinear Anal Real World Appl, 13, 3, 1489-1497 (2012) · Zbl 1239.44001

[58] Tavazoei, M. S.; Haeri, M., A proof for non existence of periodic solutions in time invariant fractional order systems, Automatica, 45, 8, 1886-1890 (2009) · Zbl 1193.34006

[59] Danca, M.-F.; Fečkan, M.; Kuznetsov, N. V.; Chen, G., Complex dynamics, hidden attractors and continuous approximation of a fractional-order hyperchaotic PWC system, Nonlinear Dyn, 91, 4, 2523-2540 (2018) · Zbl 1392.34005