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Dynamics of Anopheles Mosquito Life Cycle- Break-up Involving External Parameters with Nonlinear Feedback Mechanism

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Abstract: In this paper, the dynamics of anopheles mosquito life cycle breakups is derived. The anopheles mosquito life cycle break- up is derived using nonlinear feedback mechanism. The anopheles mosquito life cycle break - up is caused by external parameters such as chemicals, electrical action etc. The nonlinear feedback mechanism gives a systematic procedure for selecting a controller in anopheles life cycle. The break-ups are derived using Lyapunov stability theory. The nonlinear scheme is a recursive procedure that links the choice of a Lyapunov function with the design of a controller and guarantees global stability performance of anopheles life cycles.

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1. INTRODUCTION

Malaria is transmitted in humans by female anopheles. Female anopheles take blood meals to carry out egg production, thereby causing a linkage between the human and the mosquito. Anopheles life cycle depends on several natural factors but temperature and humidity are the most sensitive natural factors in their life cycle. In general 30-40 female anopheles species transmit malaria in nature. The life stage of the Anopheles mosquito is categorized into four stages such as egg, larva, pupa and adult. The first three stages egg, larva, pupa are in aquatic ([1], [2], [3], [4]). These three stages mostly depend on aquatic temperature ([5], [6], [7]). Once adult Anopheles mosquitoes have emerged, the temperature and humidity may transmit malaria successfully. In recent years, a nonlinear method has been developed for designing controllers to control the dynamical systems ([8], [9]). A common concept of the method is the design of a globally stable control dynamical system. The nonlinear feedback method is based on the mathematical model of the examined system, introducing new variables into it in a form depending on the state variables, controlling parameters, and stabilizing functions. The difficult work of a stabilizing dynamical system is the removal of nonlinearities caused in the system and influencing the stability of its operation ([10], [11], [12], [13], [14], [15]). The use of nonlinear feedback method creates an additional nonlinearity and eliminates undesirable nonlinearities from the system. In this paper, a model for the dynamics of Anopheles mosquito life cycle is constructed and nonlinear feedback control design is proposed to break-up the mosquito life cycle. The feedback control technique is applied at every stage of the mosquito life cycle. Lyapunov function is utilized to determine the feedback control. This paper is organized as follows. In section 2, the system of differential equation is modeled. This differential equation represents the life cycle of Anopheles mosquito. In section 3, the life cycle break-up using feedback mechanism is demonstrated. In section 4, the simulation work is demonstrated and in section 5, a summary of the results obtained in this paper is presented.

2. DYNAMICS OF ANOPHELES MOSQUITO LIFE CYCLE- BREAK-UP MODEL DESCRIPTION

For modelling Anopheles mosquito life cycle, the following assumptions are made.

1. The total population of Anopheles mosquito life cycle consists of four forms, such as adult, egg, larva and pupa.
2. In every stage, the natural death rate is considered uniformly.
3. Let bN be the existing population, where b is natural birth rate at adult stage.
4. k is the controller in egg stage at the rate α.
5. s is controller in larva stage at the rate γ.

Fig 1 depicts the flow diagram of Anopheles mosquito life cycle.

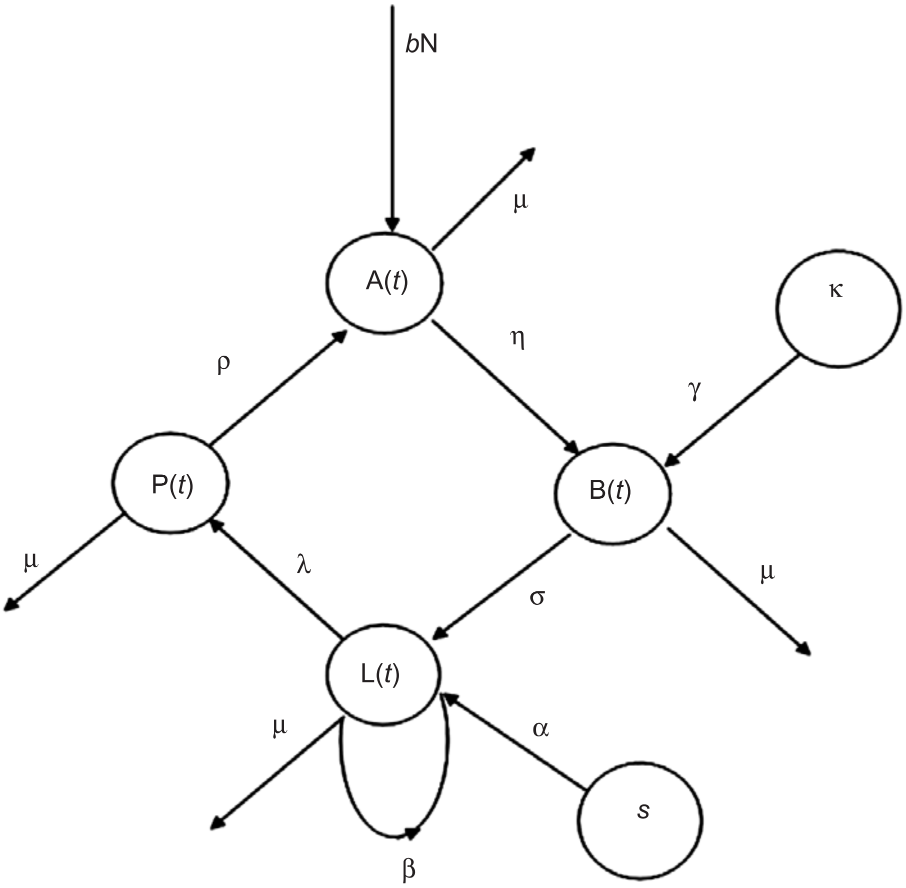

Figure 1: Flow Diagram of Anopheles mosquito life cycle

The Mathematical Model of Anopheles mosquito life cycle ([13]) is given below:

$$\begin{aligned}\frac{dP}{dt} &= \lambda L-(\mu+\rho)P\\ \frac{dL}{dt} &= \sigma B-(\lambda+\beta+\mu)L+\alpha S\\ \frac{dB}{dt} &= \eta A+\gamma K-(\lambda+\mu)B\\ \frac{dA}{dt} &= bN+\rho P-(\mu+\eta)A \end{aligned} \tag{1}$$

where A is the number of adult mosquito at time t, B is the number of eggs at time t, L is the number of larva at time t, P is the number of pupa at time t, b is the natural birth rate at adult stage, η is the rate of adult mosquito oviposit, σ is the rate, that eggs harsh to larva, λ is the rate of larva push up to pupa, ρ is rate of pupa push to adult mosquito, γ is the death rate of external parameters at eggs stage, α is the death rate of external parameter at larva stage, β is the death rate of larva eat-ups the larvas, μ is the normal death rate at all stages and N is the total mosquito population.

The external parameters S and K are defined as

$$\begin{aligned} S &= -\frac{\lambda}{\alpha}P;\\ K &= -\frac{\sigma}{\gamma}L. \end{aligned}$$

3. DYNAMICS OF ANOPHELES MOSQUITO LIFE CYCLE- BREAK-UP INVOLVING EXTERNAL PARAMETERS WITH NONLINEAR FEED BACK MECHANISM

In this section, the feedback mechanism technique is used to break the Anopheles mosquito life cycle involving external parameters

3.1. Theorem

The modified dynamics anopheles mosquito life cycle break-up is asymptotically stable with the following nonlinear controls:

$$\begin{aligned} \mu_1 &= -\lambda L\,;\\ \mu_2 &= -\sigma B-\alpha S\\ \mu_3 &= -\eta A-\gamma K\,;\\ \mu_4 &= -bN-\rho P\,;\\ \mu_5 &= -c\,;\\ \mu_6 &= -d \end{aligned} \tag{2}$$

Proof : The candidate Lyapunov function is taken as

$$V = \frac{1}{2}\left(P^2+L^2+B^2+A^2\right) \tag{3}$$

Differentiation of (3) along the trajectories of the system (1), after some calculation gives

$$\begin{aligned} \dot{V} = {} & P[\lambda L-(\rho+\mu)P+u_{1a}+u_{1b}]+ L[\sigma B-(\beta+\lambda+\mu)L+\alpha S+u_{2a}+u_{2b}]\\ & + [\eta A+\gamma K-(\lambda+\mu)B+u_{3a}+u_{3b}]+ A[bN+\rho P-(\eta+\mu)A+u_{4a}+u_{4b}] \end{aligned} \tag{4}$$

Substituting equation (2) into (4) leads to the relation

$$\dot{V} = -(\rho+\mu)P^2 - (\beta+\lambda+\mu)L^2 - (\lambda+\mu)B^2 - (\eta+\mu)A^2 \tag{5}$$

Thus by Lyapunov stability theory [17], the modified dynamics of anopheles mosquito life cycle with nonlinear feedback controls provided by (2) is asymptotically stable.

4. NUMERICAL SIMULATION

In this paper, the dynamics of anopheles mosquito life cycle non linear feedback control is analyzed. It is observed that the each stage is feasible. If the death rate of the mosquito population remains a certain threshold value then the stage is feasible. Moreover all the solutions converges to the origin.

For the numerical simulations, the fourth-order Runge Kutta method is used to solve the system of Anopheles mosquito life cycle differential equations with feedback mechanism *u*. The parameters of the anopheles mosquito life cycle dynamics taken in random. The initial values of the dynamics are also chosen as random.

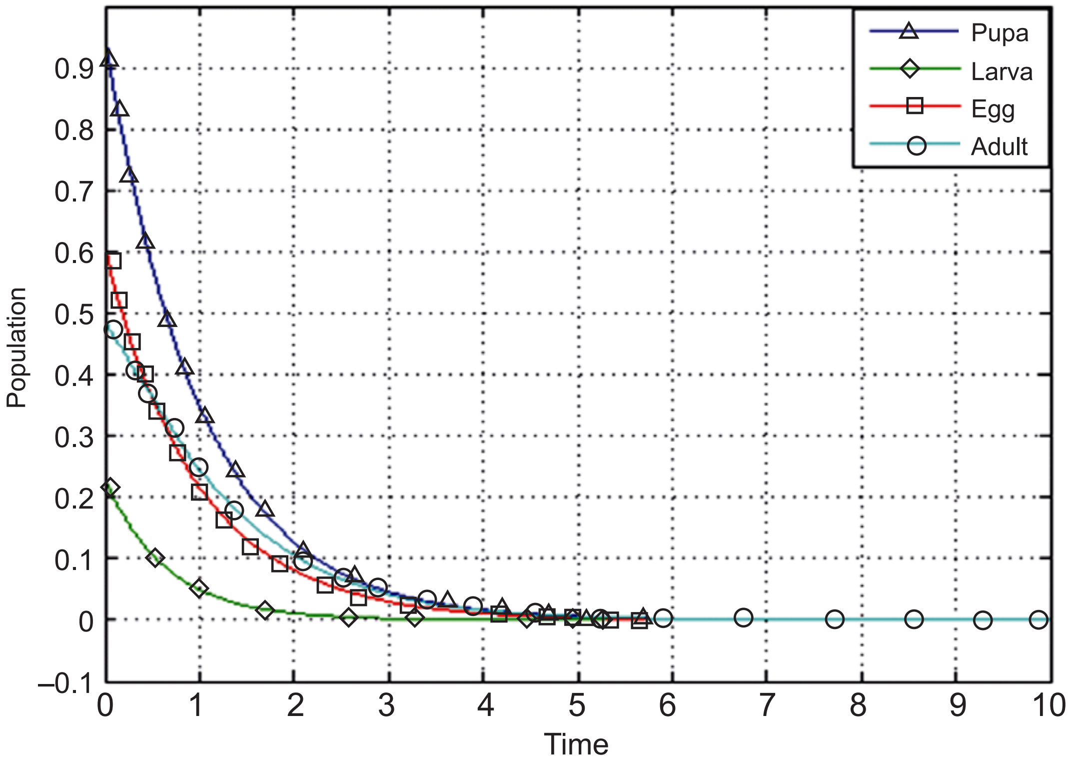

Figure 2: Depicts the stability of deterministic anopheles mosquito model

5. CONCLUSION

In this paper, we investigate dynamics of anopheles mosquito life cycle- break-up involving external parameters with nonlinear feedback mechanism. Global stability properties of the model are investigated by using Lyapunov function. Also we suggested the deterministic model is robust. We show that the Anopheles Mosquito model is global asymptotically stable by constructing suitable Lyapunov function. Moreover all the solutions converge to the positive equilibrium. Finally, numerical examples are given and diagrams are presented which supports our results.

REFERENCES

[1] Abadi Abay Gebremeskel and Harald Elias Krogstad, "Mathematical Modelling of Endemic Malaria Transmission", *American Journal of Applied Mathematics*,2015, Vol-3; No-2; 36-46.

[2] F. O. Faithpraise1, J.Idung, B. Usibe, C. R. Chatwin, R.Young and P.Birch, "Natural control of the mosquito population via *Odonata*and *Toxorhynchites",IJIRSET,* 2014,Vol-3;No-5; 12898- 12911.

[3] Michael T White, Jamie T Griffin, Thomas S Churcher, Neil M Ferguson, María-Gloria Basáñez and Azra C Ghani, "Modelling the impact of vector control interventions on Anopheles gambiae population dynamics", *White et al. Parasites & Vectors*, 2011, Vol-4;No-153.

[4] Yau MA,**"**A Mathematical Model to Break the Life Cycle of Anopheles Mosquito",*Shiraz E-Medical Journal*,2011,Vol-12;No-3; 120- 128.

[5] Godwin Ray Anugboba Okogun, "Life-table analysis of *Anopheles* malaria vectors: generational mortality as tool in mosquito vector abundance and control studies",*J VECT BORNE DIS*, 2005, 45-53.

[6] Nakul Chitnis , Thomas Smith & Richard Steketee, "A mathematical model for the dynamics of malaria in mosquitoes feeding on a heterogeneous host population" *Journal of Biological Dynamics*,2014,Vol-2;No-3; 259- 285.

[7] Philip A Eckhoff, "A malaria transmission-directed model of mosquito life cycle and ecology", *Eckhoff Malaria Journal*, 2011;No-10; 303.

[8] Joydip Dhar, Manisha Chaudhary, Randhir Singh Baghel and A.C. Pandey, "Mathematical Modelling and Estimation of Seasonal Variation of Mosquito Population: A Real Case Study", *Bulletin of Parana´s Mathematical Society*, 2014,Vol-33;No-2; 165- 176.

[9] Céline Christiansen-Jucht, Kamil Erguler, Chee Yan Shek, María-Gloria Basáñez and Paul E. Parham, " Modelling *Anopheles gambiae s.s.* Population Dynamics with Temperature- and Age-Dependent Survival", *International Journal of Environmental Research and Public Health*, 2015,Vol-12; 5975-6005.

[10] Laura C. Norris and Douglas E. Norris, " Phylogeny of anopheline (Diptera: ulicidae) species in southern Africa, based on nuclear and mitochondrial genes" *Journal of Vector Ecology*, 2015,Vol-40;No-1; 16-27.

[11] Henny Sesanti, Arsunan, A.A and Hasanuddin Ishak, " Potential Test of Papaya Leaf and Seed Extract(Carica Papaya) as Larvicides against Anopheles MosquitoLarvae Mortality. SpinJayapura, Papua Indonesia", *International Journal of Scientific and Research Publications*, 2014,Vol-4; No-6.

[12] Lindsay M. Beck-Johnson, William A. Nelson, Krijn P. Paaijmans, Andrew F. Read, Matthew B. Thomas and Ottar N. Bjørnstad, "The Effect of Temperature on Anopheles Mosquito Population Dynamics and the Potential for Malaria Transmission" *Temperature and Vectorial Capacity in Mosquitoes*, 2013, Vol-8; No-11.

[13] Suresh Rasappan , Naresh Kumar Jothi and Jagadeesan Subramani, "Dynamics of Anopheles Mosquito Life Cycle Break-up using Backstepping Control", *International Conference on Mathematical Sciences* ,Elsevier Proceeding- 2014.

[14] M.W. Smith, M.G. Macklin, C.J. Thomas, "Hydrological and geomorphological controls of malaria transmission", Earth-Science Reviews, 2013,Vol. 116, pp. 109-127,

[15] Calistus N. Ngonghala, Gideon A. Ngwa, Miranda I. Teboh-Ewungkem, "Periodic oscillations and backward bifurcation in a model for the dynamics of malaria transmission", Mathematical Biosciences, 2012, Vol. 240, pp. 45-62,

[16] Nathaniel J. Balmert, Samuel S.C. Rund, John P. Ghazi, Peng Zhou, Giles E.Duffield, "Time-of-day specific changes in metabolic detoxification and insecticide resistance in the malaria mosquito Anopheles gambiae ", Journal of Insect Physiology, 2014,Vol. 64, pp. 30-39.

[17] W. Hahn, The Stability of Motion, Berlin, Germany: Springer-Verlag (1967).