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Research Paper

The Pictorial Integral of Malaria Control with Maple

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ABSTRACT
The pictorial integral of malaria control with maple has been derived to eradicate larvae, pupae and adult Anopheles mosquitoes using natural predators to eradicate "copepods, tadpoles and purple swallows" (an organism that eats mosquitoes). The new model is a control flowchart of the predator-prey interaction model in the mosquito life cycle, considering an open population of mosquitoes and predators. These models provide a solid understanding of malaria control in our environment, especially when models are based on vector population ecology and a solid understanding of transmission-relevant parameters and variables Model equations were derived using parameters and variables from the model Stability analysis of free equilibrium states was analyzed simultaneously using equilibrium point, Maple software, elimination and substitution methods. Therefore, the number of larvae that pupate is almost zero, and the number of pupae that turn into adults is minimal, and the number of adults that escape to the vector stage is negligible, this means that the life cycle could be disrupted at the end of the larval, pupal and adult stages with the introduction of natural enemies, with the natural implication that there will be no adult Anopheles mosquito for transmission of the malaria, and we also use maple for the symbolic and numerical solution and graphically presented the results. The contribution of this research to knowledge is to produce the mathematical formula and the biologically sound methods that will contribute to the eradication of the adult Anopheles mosquito, which will also lead to the eradication of malaria in our society.

Keywords: *Pictorial; Integral; Control; Malaria; Maple*

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I. Introduction

The *Anopheles* vector system in Nigeria and of course in sub-Saharan Africa is probably the strongest that exists for human *Plasmodium*. Contact with human vectors, particularly An. *gambiae* s.l., shows remarkable stability and flexibility, resulting in extremely high vaccination rates under different seasonal and geographic ecological conditions (Mokuolu et al., 2018). Malaria remains a leading cause of death and disease in most tropical regions of the world, where it is endemic in 106 countries. In 2010, out of a total of 216 million cases of malaria, around 81% occurred in Africa and 13% in Southeast Asia1. The majority (91%) of the estimated 665,000 malaria deaths occur in Africa and primarily affect children under the age of five (86%). In America in 2010 there were more than 670,000 confirmed cases of malaria with 133 deaths from malaria. The transmission is active in 21 countries and puts approximately 20% of the US population at risk. Malaria severely limits economic development and is a cause of poverty in most countries where the disease is endemic. Malaria remains an ongoing problem in sub-Saharan Africa, and while great strides have been made over the past 15 years, millions of people are still at risk of contracting the parasite (Patouillard et al., 2017).

Africa offers a stable and ecologically diverse ecosystem and hosts the world's highest vectors of malaria (Bernard et al., 2020) and is expected to remain so in the future. Climate change (Adigun et al., 2015). The main vectors of *Anopheles* malaria in sub-Saharan Africa are *Anopheles funestus* s.s. and three members of the *Anopheles gambiae* complex: *An. Gambiae* s.s., *Anopheles coluzzii* and *Anopheles arabiensis* (Molinaro et al., 2015), which play a role in the transmission of malaria in their distribution area, e.g. the groups *Anopheles moucheti* and *Anopheles* nili (Rajeswari, 2017) and another of secondary or random vectors (Antonio-nkondjio et al., 2006). Considering that the genus *Anopheles* includes more than 500 species worldwide, of which only a few are considered important species for the transmission of malaria (Garcia Guerra et al., 2014). The morphological identification of species is crucial for allocating scarce resources solely to the fight against malaria vectors. Species groups and species complexes are common within the genus *Anopheles* (Harbach &

Besansky, 2014) and this complicates vector control because not all species in a complex share similar behaviors or similar roles in transmission malaria disease (Vanelle et al., 2012a).

Mosquitoes of the family *Culicidae* are considered a nuisance and a major public health problem because their females feed on human blood and therefore transmit extremely harmful diseases such as malaria, yellow fever and *filariasis* (Tsoka-Gwegweni & Okafor, 2014). They are estimated to transmit diseases to more than 700 million people each year and are responsible for the death of around 1 in 17 people ("Malaria Policy Advisory Committee to the WHO: Conclusions and Recommendations of Eighth Biannual Meeting (September 2015)," 2016). Effective transmission of mosquito-borne diseases requires successful contact between female mosquitoes and their hosts (Vanelle et al., 2012b). Among *Anopheles*, members of the genus *Anopheles* are best known for their role in the global transmission of malaria and *filariasis* ("Malaria Policy Advisory Committee to the WHO: Conclusions and Recommendations of Fifth Biannual Meeting (March 2014)," 2014). Among these diseases, malaria, caused by the *Plasmodium* parasite, is one of the deadliest diseases in the world ("Malaria Policy Advisory Committee to the WHO: Conclusions and Recommendations of Sixth Biannual Meeting (September 2014)," 2015). ("Malaria Vaccine: WHO Position Paper, January 2016 – Recommendations," 2018) reported approximately 207 million cases of malaria in 2012, of which 200 million (80.0%) were on the affected continent. Patterns of disease spread, transmission, and intensity depend on the degree of urbanization and distance from vector breeding sites (MCNAMARA, 2005). The endemicity of malaria in each region is determined, among other things, by native *Anopheles* mosquitoes, their abundance, diet, resting behavior and *Plasmodium* infectivity (Atta & Reeder, 2014). The Federal Ministry of Health in Abuja reported that at least 50.0% of Nigerians suffer from some form of malaria, making it the most significant health problem in Nigeria (UM & AN, 2016). The high transmission rate and prevalence of malaria is the result of the various mosquito breeding sites, including convenient water reservoirs such as cans, old tires, tree holes, cisterns, open pools, drains, streams and ponds (McKenzie, 2014). Part of the fight is the official observance of April 25 each year, beginning in 2008, as World Malaria Day (CDC Weekly, 2020). Arms-only people face a variety of barriers when assessing malaria prevention, particularly with respect to knowledge of mathematical modeling and vector biology (Emmanuel et al., 2020).

Table 1: Model Variables and Parameters Defined

In table below, variables and parameters used in the new model are defined

Variables	**Description**
A(t)	Number of adult mosquitoes at time(t)
E (t)	Number of eggs at time(t)
L(t)	Number of larvae at time(t)
P(t)	Number of pupae at time(t)
N(t)	Total population
$\boldsymbol{C_P}$(t)	Number of natural Predator for larva at time(t) (Copepods)
T_p(t)	Number of natural Predator for pupa at time(t)(Tadpoles)
P_m(t)	Number of natural Predator for Adult at time(t) (Purple Martins)
Parameters	**Description**
b_1	Natural birth rate of adult class
b_2	Natural birth rate of copepods class
b_3	Natural birth rate of tadpoles' class
b_4	Natural birth rate of purple martins' class
μ_1	Natural death rate of adult class
μ_2	Natural death rate of egg class
μ_3	Natural death rate of larva class
μ_4	Natural death rate of pupa class
μ_5	Natural death rate of purple martins' class
μ_6	Natural death rate of copepods class
μ_7	Natural death rate of tadpoles' class
β_1	Induce death rate of adult due to chemical and environmental conditions
β_2	Induce death rate of egg due to chemical and environmental conditions
β_3	Induce death rate of larva due to chemical and environmental conditions
β_4	Induce death rate of pupa due to chemical and environmental conditions
β_5	Induce death rate of purple martins' due to chemical and environmental conditions

β_6	Induce death rate of copepods due to chemical and environmental conditions
β_7	Induce death rate of tadpoles' due to chemical and environmental conditions
η	The incidence rate (the rate at which adult mosquitoes oviposit)
σ	The proportion at which egg harsh to larva
λ	The proportion of larva that transform to pupa
π	The proportion of pupa that transform to adult
α	The probability at which mosquito larva are eaten up by copepods
ω	The probability at which mosquito pupa are eaten up by tadpoles
γ	The probability at which mosquito adult are eaten up by purple matins
C	The average temperature of the water culture
N_L	Number of larva been eaten up by copepods at time(t)
N_P	Number of pupa been eaten up by tadpoles at time(t)
N_A	Number of adult been eaten up by purple martins at time(t)

Mathematical Formulation

The new model is a control flowchart of the predator-prey interaction model in the mosquito life cycle that considers an open population of mosquitoes and predators. The population is subdivided according to the life cycle of mosquitoes and natural predators. In the life cycle of a mosquito, the population is divided into four compartments: Egg compartment E(t), Larval compartment L(t), Pupal compartment P(t), Adult compartment A(t) and natural Predator divided into three divisions. Copepods $C_P(t)$, Tadpoles $T_P(t)$, and Purple Martins $P_M(t)$.

The following diagram describes the flux control of the predator-prey interaction; it will be useful in formulating models.

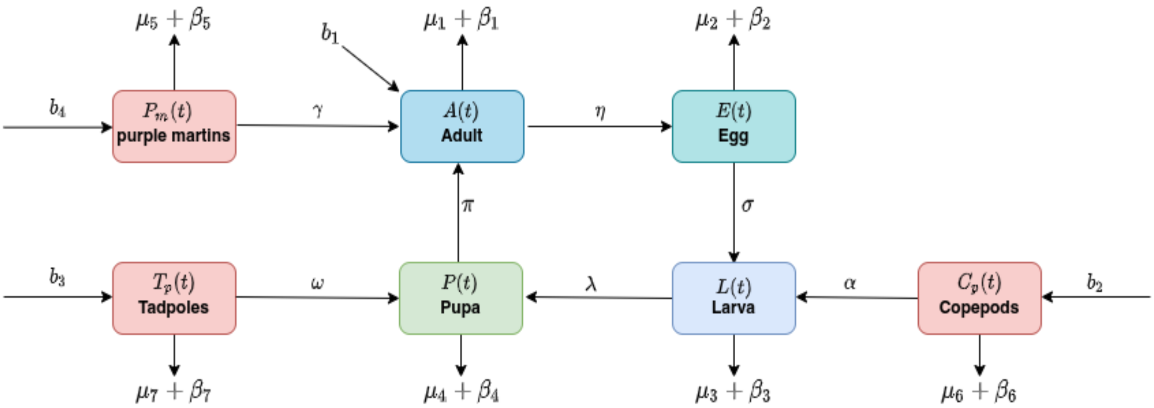

Figure 1: Flow Control Diagram of Predator-prey Interaction Model in Mosquito Life-Cycle

The Model Equations

From the above assumptions and flowchart, the following equations are derived

Model Equations for Mosquito Life-Cycle

$$\frac{dA}{dt} = b_1 + \gamma P_m(t) + \pi P(t) - (\mu_1 + \beta_1 + \eta)A(t) \quad \dots \ (1)$$

$$\frac{dE}{dt} = \eta A(t) - (\mu_2 + \beta_2 + \sigma)E(t) \quad \dots \ (2)$$

$$\frac{dL}{dt} = \sigma E(t) + \alpha C_P(t) - (\mu_3 + \beta_3 + \lambda)L(t) \quad \dots \ (3)$$

$$\frac{dP}{dt} = \lambda L(t) + \omega T_p(t) - (\mu_4 + \beta_4 + \pi)P(t) \quad \dots \ (4)$$

Model Equations for Natural Predators

$$\frac{dC_P}{dt} = b_2 - (\mu_6 + \beta_6 + \alpha)C_P(t) \quad \dots \ (5)$$

$$\frac{dT_p}{dt} = b_3 - (\mu_7 + \beta_7 + \omega)T_p(t) \quad \dots \ (6)$$

$$\frac{dP_m}{dt} = b_4 - (\mu_5 + \beta_5 + \gamma)P_m(t) \quad \dots \ (7)$$

$$N_1 = A(t) + L(t) + P(t) + E(t) \quad \dots \quad (8)$$

$$N_2 = P_m(t) + C_P(t) + T_p(t) \quad \dots \quad (9)$$

$$N(t) = N_1(t) + N_2(t)) \quad \dots \quad (10)$$

$$\frac{dN}{dt} = b_1 + \gamma P_m(t) + \pi P(t) - (\mu_1 + \beta_1 + \eta)A(t) + \eta A(t) - (\mu_2 + \beta_2 + \sigma)E(t) + \sigma E(t) + \alpha C_P(t) - (\mu_3 + \beta_3 + \lambda)L(t) + \lambda L(t) + \omega T_p(t) - (\mu_4 + \beta_4 + \pi)P(t) + b_2 - (\mu_6 + \beta_6 + \alpha)C_P(t) + b_3 - (\mu_7 + \beta_7 + \omega)T_p(t) + b_4 - (\mu_5 + \beta_5 + \gamma)P_m(t) \quad \dots \quad (11)$$

Maple result for A(t), E(t), L(t), P(t) and N(t) are shown below

$$solve\left(\left\{M_1 \cdot \mathrm{A(t)} - \pi \cdot \mathrm{P(t)} = \mathrm{b}_1 + \frac{\gamma \cdot b_4}{M_5}, \eta \cdot A(t) - M_2 \cdot E(t) = 0, \sigma \cdot E(t) - M_3 \cdot L(t) = -\frac{\alpha \cdot b_2}{M_6}, \lambda \cdot L(t) - M_4 \cdot P(t) = -\frac{\varpi \cdot b_3}{M_7}, A(t) + E(t) + L(t) + P(t) + \frac{b_2}{M_6} + \frac{b_3}{M_7} + \frac{b_4}{M_5} = N(t)\right\}, [A(t), E(t), L(t), P(t), N(t)]\right)$$

$$\Big[\Big[A(t) = -\frac{M_2\left(M_7\,\gamma\,b_4\,M_6\,M_4\,M_3 + M_7\,b_1\,M_5\,M_6\,M_4\,M_3 + \varpi\,b_3\,M_6\,M_5\,M_3\,\pi + \lambda\,M_7\,M_5\,\alpha\,b_2\,\pi\right)}{M_5\left(\pi\,\eta\,\lambda\,\sigma - M_1\,M_2\,M_3\,M_4\right)M_7\,M_6},$$

$$E(t) = -\frac{\eta\left(M_7\,\gamma\,b_4\,M_6\,M_4\,M_3 + M_7\,b_1\,M_5\,M_6\,M_4\,M_3 + \varpi\,b_3\,M_6\,M_5\,M_3\,\pi + \lambda\,M_7\,M_5\,\alpha\,b_2\,\pi\right)}{M_5\left(\pi\,\eta\,\lambda\,\sigma - M_1\,M_2\,M_3\,M_4\right)M_7\,M_6},$$

$$L(t) = -\frac{1}{M_5\left(\pi\,\eta\,\lambda\,\sigma - M_1\,M_2\,M_3\,M_4\right)M_7\,M_6}\left(M_7\,M_1\,M_2\,\alpha\,b_2\,M_5\,M_4 + M_7\,\gamma\,b_4\,\eta\,\sigma\,M_6\,M_4 + M_7\,b_1\,M_5\,\eta\,\sigma\,M_6\,M_4 + \eta\,\varpi\,\sigma\,b_3\,M_6\,M_5\,\pi\right), P(t) =$$

$$-\frac{M_1\,M_2\,M_3\,M_5\,\varpi\,b_3\,M_6 + \lambda\,M_7\,M_1\,M_2\,\alpha\,b_2\,M_5 + \lambda\,M_7\,\gamma\,b_4\,\eta\,\sigma\,M_6 + \lambda\,M_7\,b_1\,M_5\,\eta\,\sigma\,M_6}{M_5\left(\pi\,\eta\,\lambda\,\sigma - M_1\,M_2\,M_3\,M_4\right)M_7\,M_6},$$

$$N(t) = -\frac{1}{M_6\,M_7\,M_5\left(\pi\,\eta\,\lambda\,\sigma - M_1\,M_2\,M_3\,M_4\right)}\big(\lambda\,M_7\,M_1\,M_2\,\alpha\,b_2\,M_5 + M_7\,\gamma\,b_4\,\eta\,M_6\,M_4\,M_3 + M_7\,b_1\,M_5\,\eta\,M_6\,M_4\,M_3 + \eta\,\varpi\,b_3\,M_6\,M_5\,M_3\,\pi + \lambda\,M_7\,M_5\,\alpha\,b_2\,M_2\,\pi + M_7\,b_1\,M_5\,\eta\,\sigma\,M_6\,M_4 + \eta\,\varpi\,\sigma\,b_3\,M_6\,M_5\,\pi + M_7\,\gamma\,b_4\,\eta\,\sigma\,M_6\,M_4 + \lambda\,M_7\,M_5\,\alpha\,b_2\,\eta\,\pi + M_1\,M_2\,M_3\,M_5\,\varpi\,b_3\,M_6 + M_7\,M_1\,M_2\,\alpha\,b_2\,M_5\,M_4 + M_7\,\gamma\,b_4\,M_6\,M_4\,M_3\,M_2 + M_7\,b_1\,M_5\,M_6\,M_4\,M_3\,M_2 + \varpi\,b_3\,M_6\,M_5\,M_3\,M_2\,\pi + b_3\,M_6\,M_5\,M_4\,M_3\,M_2\,M_1 + b_4\,M_6\,M_7\,M_4\,M_3\,M_2\,M_1 + b_2\,M_7\,M_5\,M_4\,M_3\,M_2\,M_1 + \lambda\,M_7\,\gamma\,b_4\,\eta\,\sigma\,M_6 + \lambda\,M_7\,b_1\,M_5\,\eta\,\sigma\,M_6 - \lambda\,b_3\,M_6\,M_5\,\eta\,\sigma\,\pi - \lambda\,b_4\,M_6\,M_7\,\eta\,\sigma\,\pi - \lambda\,b_2\,M_7\,M_5\,\eta\,\sigma\,\pi\big)\Big]\Big]$$

Maple result for A(t), E(t), L(t), and P(t) are shown below;

$$solve\left(\left\{M_1\cdot \mathrm{A(t)} - \pi\cdot \mathrm{P(t)} = \mathrm{b}_1 + \frac{\gamma\cdot b_4}{M_5}, \eta\cdot A(t) - M_2\cdot E(t) = 0, \sigma\cdot E(t) - M_3\cdot L(t) = -\frac{\alpha\cdot b_2}{M_6}, \lambda\cdot L(t) - M_4\cdot P(t) = -\frac{\varpi\cdot b_3}{M_7}\right\}, [A(t), E(t), L(t), P(t)]\right)$$

$$\left[\left[A(t) = -\frac{M_2\left(M_7\gamma b_4 M_6 M_4 M_3 + M_7 b_1 M_5 M_6 M_4 M_3 + \varpi b_3 M_6 M_5 M_3 \pi + \lambda M_7 M_5 \alpha b_2 \pi\right)}{M_5\left(\pi\eta\lambda\sigma - M_1 M_2 M_3 M_4\right) M_7 M_6},\right.\right.$$

$$E(t) = -\frac{\eta\left(M_7\gamma b_4 M_6 M_4 M_3 + M_7 b_1 M_5 M_6 M_4 M_3 + \varpi b_3 M_6 M_5 M_3 \pi + \lambda M_7 M_5 \alpha b_2 \pi\right)}{M_5\left(\pi\eta\lambda\sigma - M_1 M_2 M_3 M_4\right) M_7 M_6},$$

$$L(t) = -\frac{1}{M_5\left(\pi\eta\lambda\sigma - M_1 M_2 M_3 M_4\right) M_7 M_6}\left(M_7 M_1 M_2 \alpha b_2 M_5 M_4 + M_7\gamma b_4 \eta\sigma M_6 M_4 + M_7 b_1 M_5 \eta\sigma M_6 M_4 + \eta\varpi\sigma b_3 M_6 M_5 \pi\right), P(t) =$$

$$\left.\left. -\frac{M_1 M_2 M_3 M_5 \varpi b_3 M_6 + \lambda M_7 M_1 M_2 \alpha b_2 M_5 + \lambda M_7 \gamma b_4 \eta\sigma M_6 + \lambda M_7 b_1 M_5 \eta\sigma M_6}{M_5\left(\pi\eta\lambda\sigma - M_1 M_2 M_3 M_4\right) M_7 M_6}\right]\right]$$

We conclude that if the natural predators introduced are large, the number of larvae leading to pupae will be almost zero and the number of pupae developing into adults will be zero, which will prolong the life cycle of the interrupted Anopheles mosquito. Therefore, in our society, there will be no adult Anopheles mosquitoes for the transmission of malaria parasites.

List of Numerical Experiments of the Model

The following experiments are carried out

Experiment 1: Effect of introducing one natural predator, copepod on mosquitoes' larva ($C_p = 500\ T_p = 0, and\ \ P_m = 0$).

Experiment 2: Effect of introducing two natural predators, copepod and tadpole on mosquitoes' larva and pupa respectively ($C_p = 500, T_p = 500\ and P_m = 0$).

Experiment 3: Effect of introducing three natural predators, copepod, tadpole and purple martins on mosquitoes' larva, pupa and adult respectively ($C_p = 500, T_p = 500\ and\ P_m = 130$).

Experiment 4: Comparison of the effect of introducing one, two and three natural predator on larva.

Experiment 5: Comparison of the effect of introducing two and three natural predator on pupa.

Experiment 6: Effect of introducing one natural predator, tadpole on mosquitoes' pupa($T_p = 500$).

Experiment 7: Effect of introducing two natural predators, tadpole and purple martins on mosquitoes' pupa and adult respectively ($C_p = 0, T_p = 500\ and\ P_m = 130$).

Experiment 8: Comparison of the effect of introducing one, two and three natural predator on pupa.

Experiment 9: Comparison of the effect of introducing two and three natural predator on adult.

Experiment 10: Effect of introducing one natural predator, purple martins on mosquitoes' adult ($P_m = 130, C_p = 0, and\ T_p = 0$).
Experiment 11: Effect of introducing two natural predators, copepod and purple martins on mosquitoes' larva and adult respectively ($C_p = 500, T_p = 0\ and\ P_m = 130$).
Experiment 12: Comparison of the effect of introducing one, two and three natural predator on adult.
Experiment 13: Comparison of the effect of introducing two and three natural predator on adult.
Experiment 14: Effect of introducing low rate of natural predators, copepod, on mosquitoes' larva ($C_p = 500$).
Experiment 15: Effect of introducing high rate of natural predators, copepod, on mosquitoes' larva ($C_p = 2000$).
Experiment 16: comparison of the effect of introducing low and high rate of natural predators, copepod, on mosquitoes' larva.
Experiment 17: Effect of introducing low rate of natural predator, copepod, on mosquitoes' pupa ($T_p = 2000$).
Experiment 18: Effect of introducing high rate of natural predator, tadpole, on mosquitoes' pupa ($T_p = 2000$)
Experiment 19: Comparison of the effect of introducing low and high rate of natural predators, tadpole on mosquitoes' pupa.

Table 2: Numerical values of the variables and parameters

Variables/Parameters	Values	Source
A(t)	500	Assumed
E (t)	100000	Guerra, (2014)
L(t)	90000	Assumed
P(t)	80000	Assumed
N(t)	270000	Assumed
$\mathbf{C_P}$(t)	500	Practical
T_p(t)	500	Practical
P_m(t)	130	Assumed
b_1	0.02	Olivier, (202)
b_2	0.21	Gearty, (2021)
b_3	0.9	Calef, (1973)
b_4	0.5	Joshua,(1971)
μ_1	0.4	Mathews, (2020)
μ_2	0.3	Clements, (1981)
μ_3	0.2	Couret, (2014)
μ_4	0.1	Mondragon, (2020)
μ_5	0.5	Jervis, (2019)
μ_6	0.02	Charyl, (2011)
μ_7	0.01	Szekely, (2022)
β_1	$40^o C$(0.3)	Beck-Johnson,, (2013)
β_2	$37^o C$(0.57)	Sukiato, (2019)
β_3	$28^o C$(0.0110)	Adam, (2014)
β_4	$28^o C$(0.0110)	Adam, (2014)
β_5	$25^o C$ (0.13)	Fred, (2014)
β_6	$40^o C$(0.01)	Jiang, (2014)
β_7	$35^o C$(0.02)	Halsbank-Lenk,(2014)
η	0.002	Practical
σ	0.00004	Practical
λ	0.00005	Practical
π π	0.01	Practical
α	0.5	Practical
ω	0.5	Practical
γ	0.9	Practical

Experiment 1: Effect of introducing one natural predator, copepod on mosquitoes' larva.

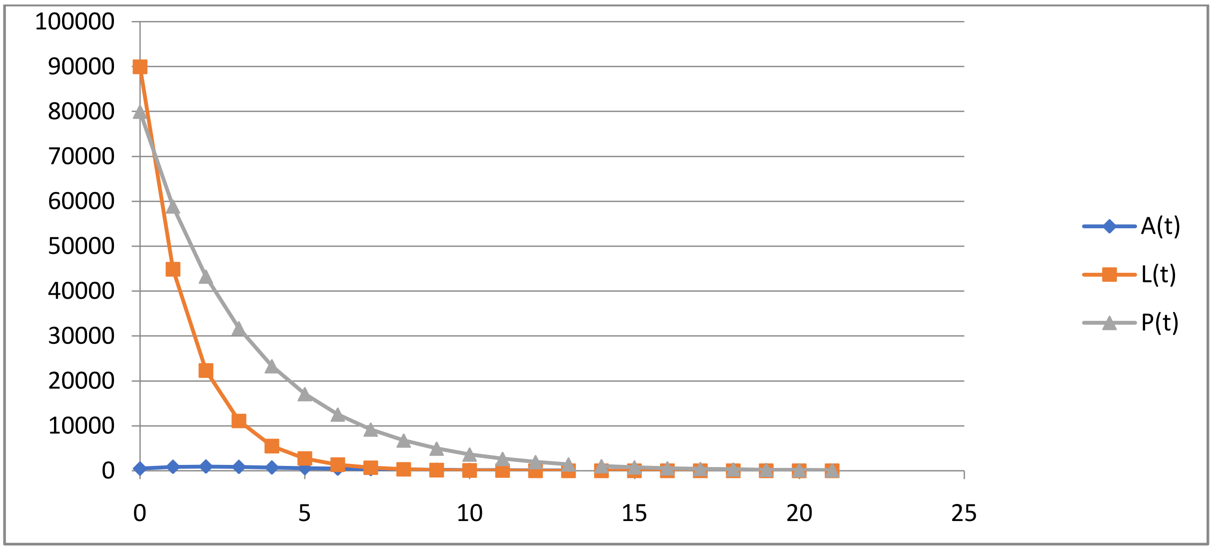

Figure 3: Number of mosquitoes' larva when one natural predator, copepod was introduced($C_p = 500, T_p = 0, P_m = 0, \alpha = 0.5,\ \mu_6 = 0.02,\ \beta_6 = 0.01\ and\ b_2 = 0.21$).

Experiment 2: Effect of introducing two natural predators, copepod and tadpole on mosquitoes' larva and pupa respectively.

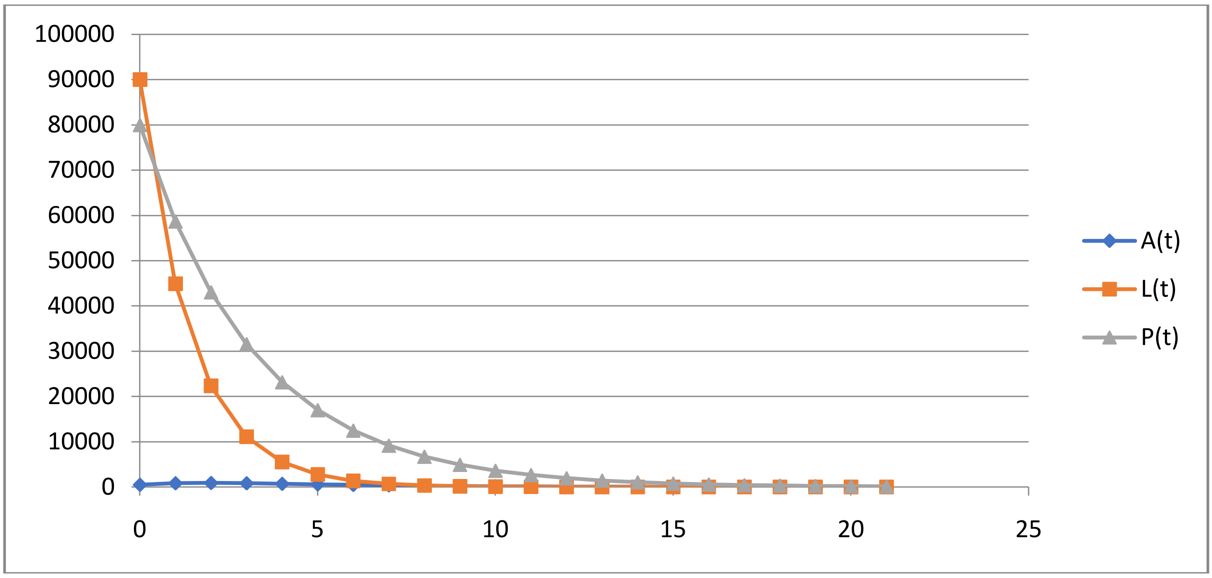

Figure 4: Number of mosquitoes' larva and pupa when two natural predators, copepod and tadpole are introduced respectively($C_p = 500, T_p = 500,\ P_m = 0,\ \alpha = 0.5,\ \mu_6 = 0.02,\ \beta_6 = 0.01,\ b_2 = 0.21, \omega = 0.5,\ \mu_7 = 0.01,\ \beta_7 = 0.02\ and\ b_3 = 0.9$)

Experiment 3: Effect of introducing three natural predators, copepod, tadpole and purple martins on mosquitoes' larva, pupa and adult.

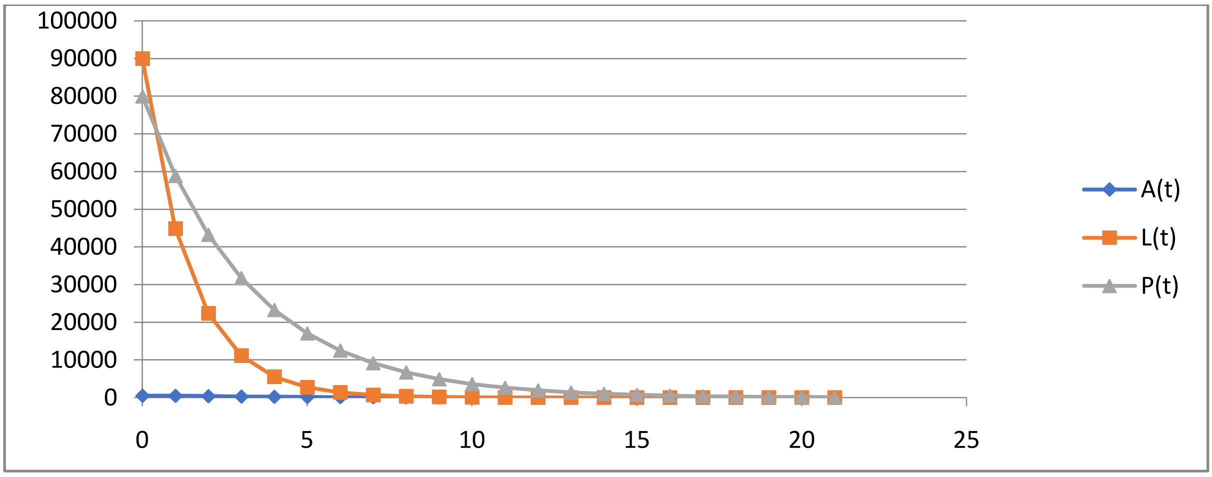

Figure 5: Number of mosquitoes' larva, pupa and adult, when three natural predators, copepod, tadpole and purple martins are introduced respectively $(C_p = 500, T_p = 500,\ P_m = 130, \alpha = 0.5,\ \mu_6 = 0.02,\ \beta_6 = 0.01,$ $b_2 = 0.21,\ \omega = 0.5,\ \mu_7 = 0.01,\ \beta_7 = 0.02, b_3 = 0.9,\ \gamma = 5,\ \mu_5 = 0.5,\ \beta_5 = 0.13\ and\ b_4 = 0.5)$.

Experiment 4: Comparison of the effect of introducing one, two and three natural predator, copepod on mosquitoes' larva.

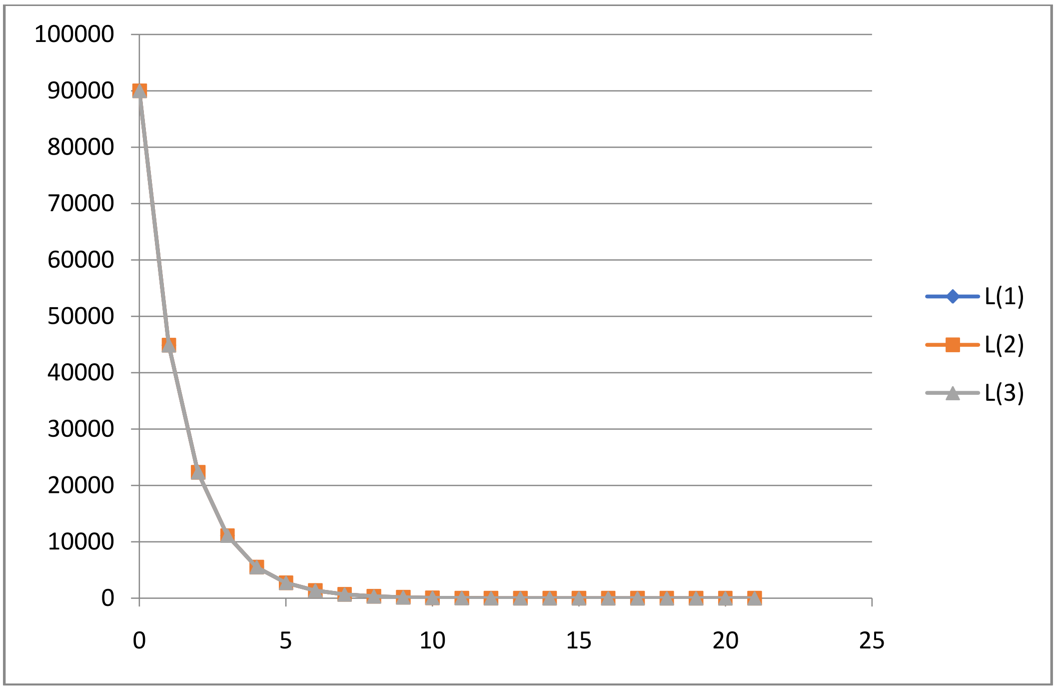

Figure 6: Number of mosquitoes' larva when one, two and three natural predators tadpoles are compared on larva respectively ($T_{1,2,\&3} = 500,\ \omega = 0.5,\ \mu_7 = 0.01,\ \beta_7 = 0.02,\ and\ b_3 = 0.9$)

Experiment 5: Comparison of the effect of introducing two and three natural predator, purple martins on mosquitoes' adult.

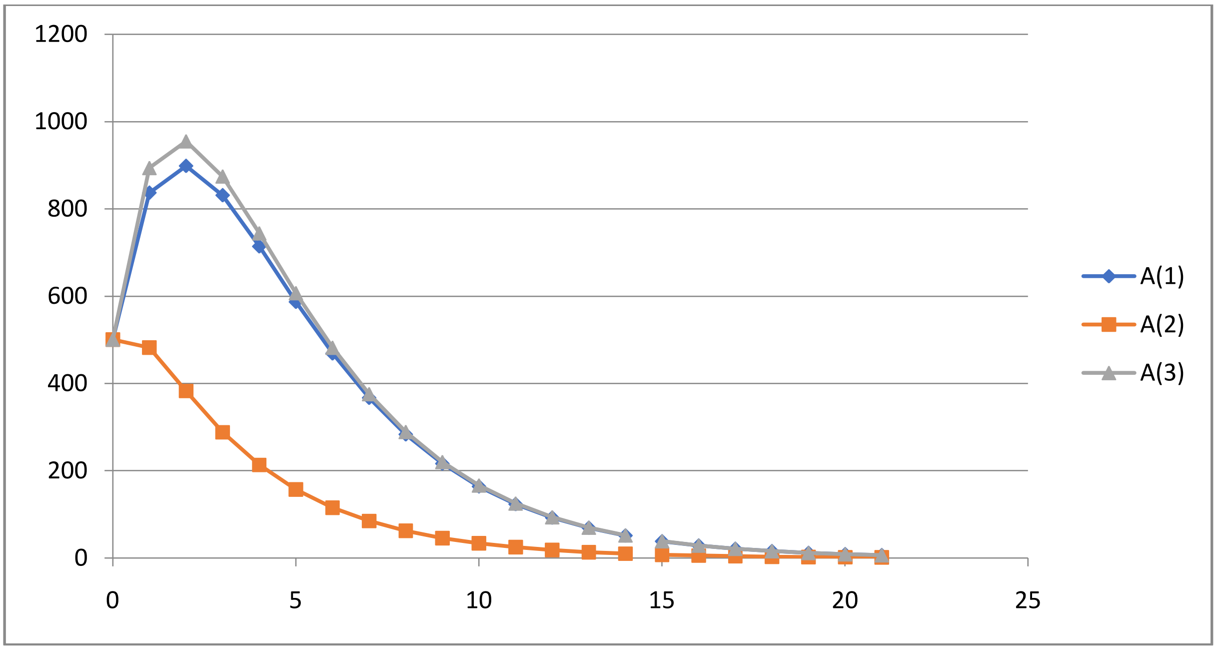

Figure 7: Number of mosquitoes' adult when two and three natural predator, purple martins are compared respectively ($P_{2\&3} = 500, \gamma = 5,\ \mu_5 = 0.5,\ \beta_5 = 0.13, and\ \ b_4 = 0.5$).

Experiment 6: Effect of introducing one natural predator, tadpole on mosquitoes' pupa.

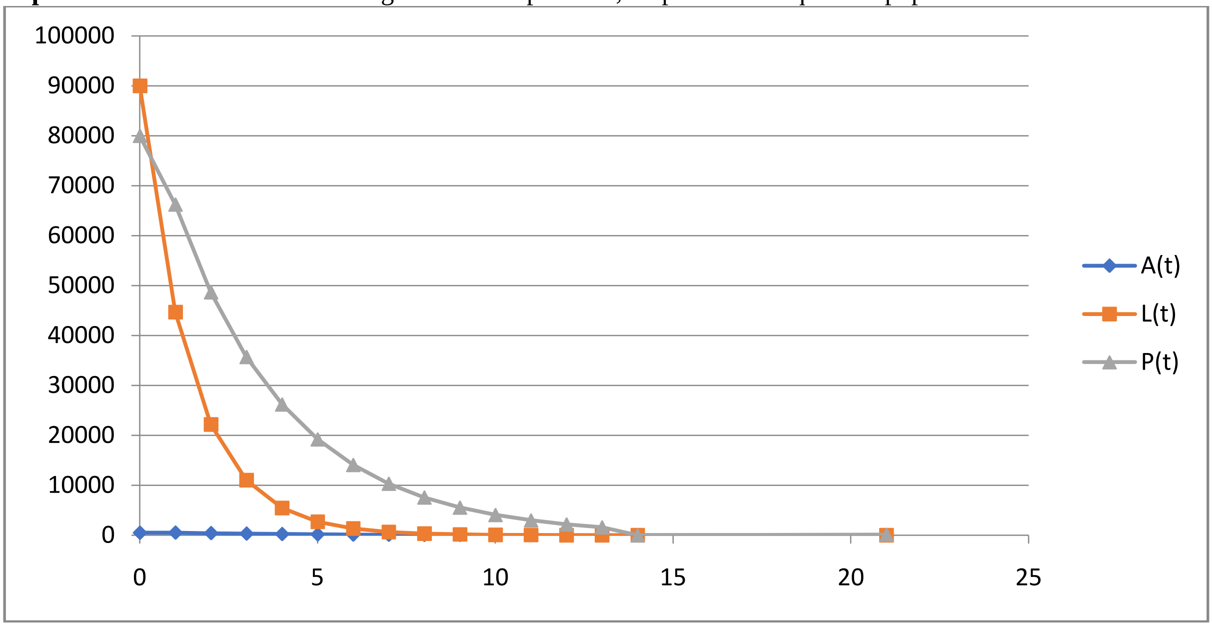

Figure 8: Number of mosquitoes' pupa when one natural predator, tadpole was introduced to mosquito pupa ($T_m = 500\ C_p = 0,\ P_m = 0,\ \omega = 0.5,\ \mu_7 = 0.01,\ \beta_7 = 0.02,\ and\ \ b_3 = 0.9$).

Experiment 7: Effect of introducing two natural predators, tadpole and purple martins on mosquitoes' pupa and adult respectively.

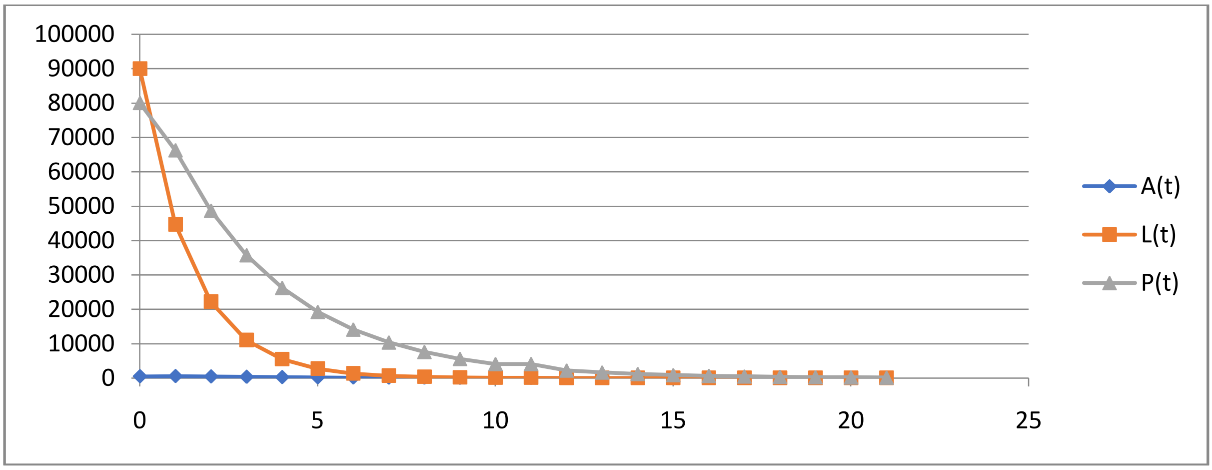

Figure 9: Number of mosquitoes' pupa and adult when two natural predators, tadpole and purple martins are introduced respectively ($T_p = 500, P_m = 130,\ C_p = 0, \omega = 0.5,\ \mu_7 = 0.01,\ \beta_7 = 0.02,\ b_3 = 0.9,\ \gamma = 5,$ $\mu_5 = 0.5,\ \beta_5 = 0.13, and\ \ b_4 = 0.5$).

Experiment 8: Comparison of the effect of introducing one, two and three natural predator on pupa.

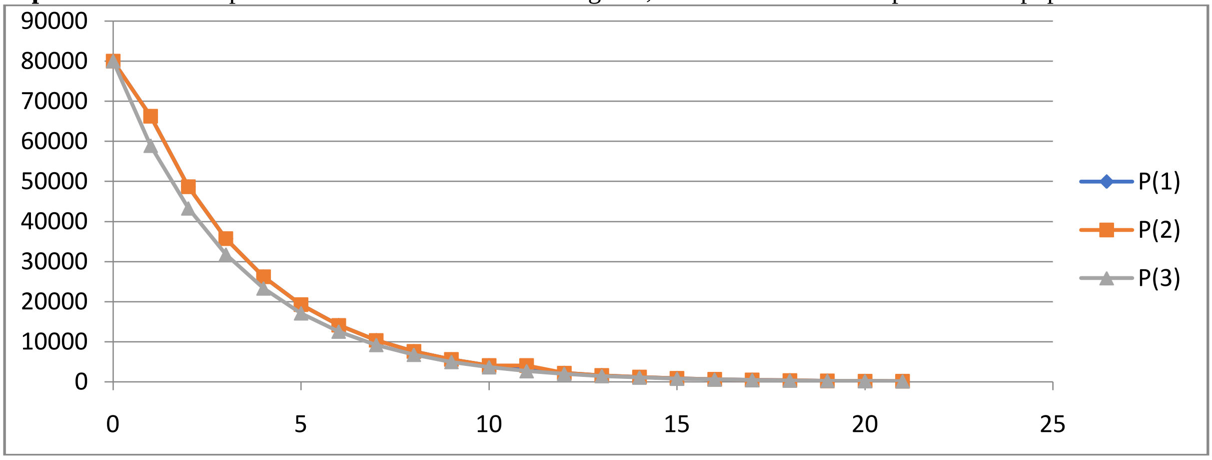

Figure 10: Number of mosquitoes' pupa when one, two and three natural predators are compared respectively ($T_{1,2\ \&3} = 500,\ \omega = 0.5,\ \mu_7 = 0.01,\ \beta_7 = 0.02,\ and\ b_3 = 0.9$).

Experiment 9: Comparison of the effect of introducing two and three natural predator purple martins on adult.

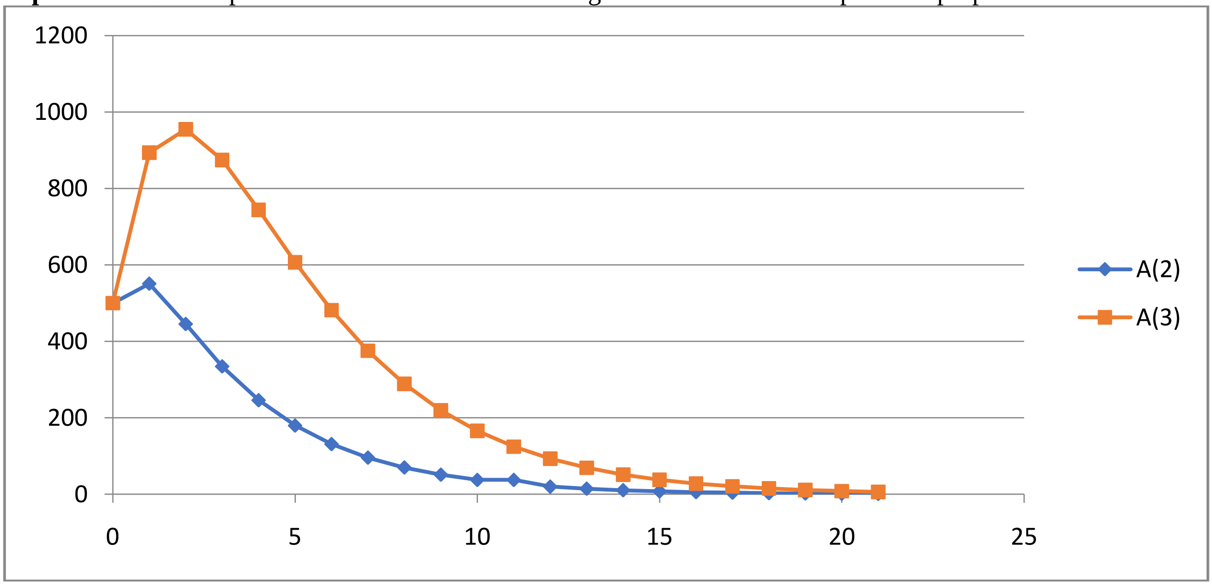

Figure 11: Number of mosquitoes' adult when two and three natural predators, purple martins are compared respectively ($P_{2\&3} = 130, \gamma = 5,\ \mu_5 = 0.5,\ \beta_5 = 0.13\ and\ b_4 = 0.5$).

Experiment 10: Effect of introducing one natural predator, purple martins on mosquitoes' adult.

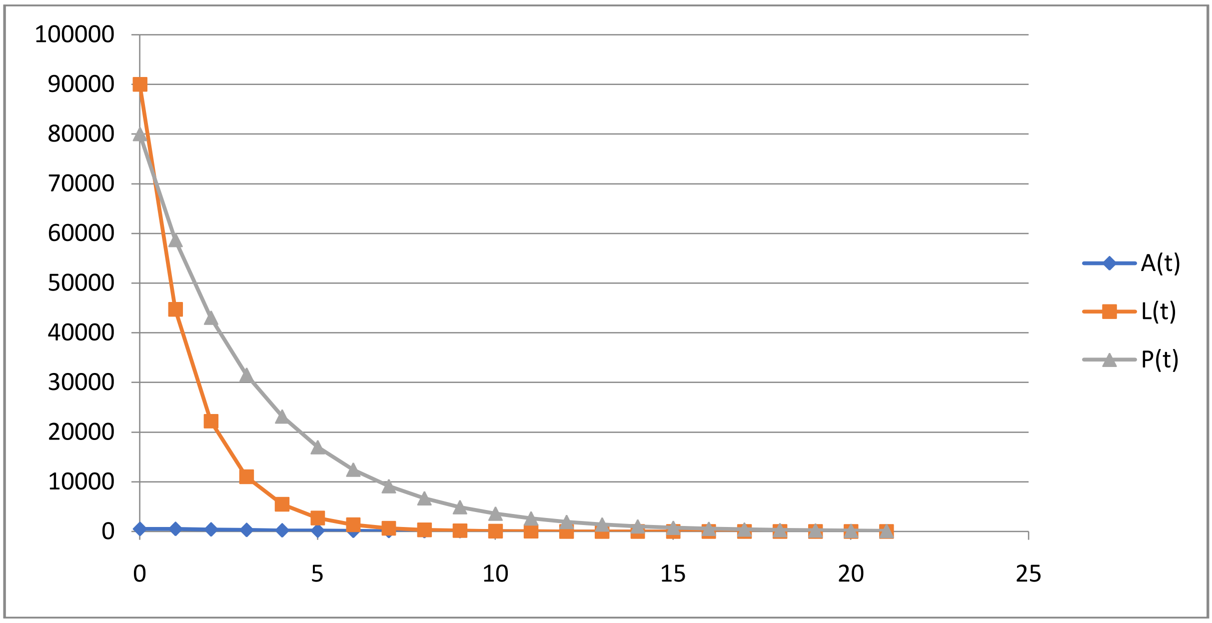

Figure 12: Number of mosquitoes' adult when one natural predator, purple martins was introduced to mosquito adult ($P_m = 130, C_p = 0, T_p = 0, \gamma = 5,\ \mu_5 = 0.5,\ \beta_5 = 0.13\ and\ b_4 = 0.5$).

Experiment 11: Effect of introducing two natural predators, copepod and purple martins on mosquitoes' larva and adult respectively.

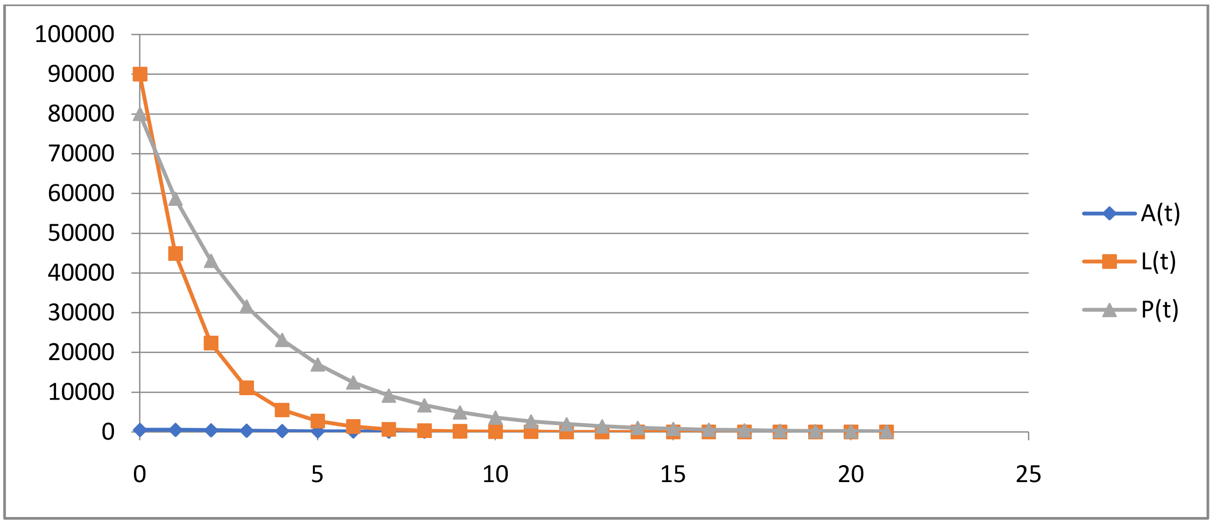

Figure 12: Number of mosquitoes' larva and adult when two natural predators, copepod and purple martins are introduced respectively ($C_p = 500, P_m = 130,\ T_p = 0,\ \alpha = 0.5,\ \mu_6 = 0.02,\ \beta_6 = 0.01,\ b_2 = 0.21,\ \gamma = 5,$ $\mu_5 = 0.5,\ \beta_5 = 0.13\ and\ b_4 = 0.5$).

Experiment 12: Comparison of the effect of introducing one, two and three natural predator on adult.

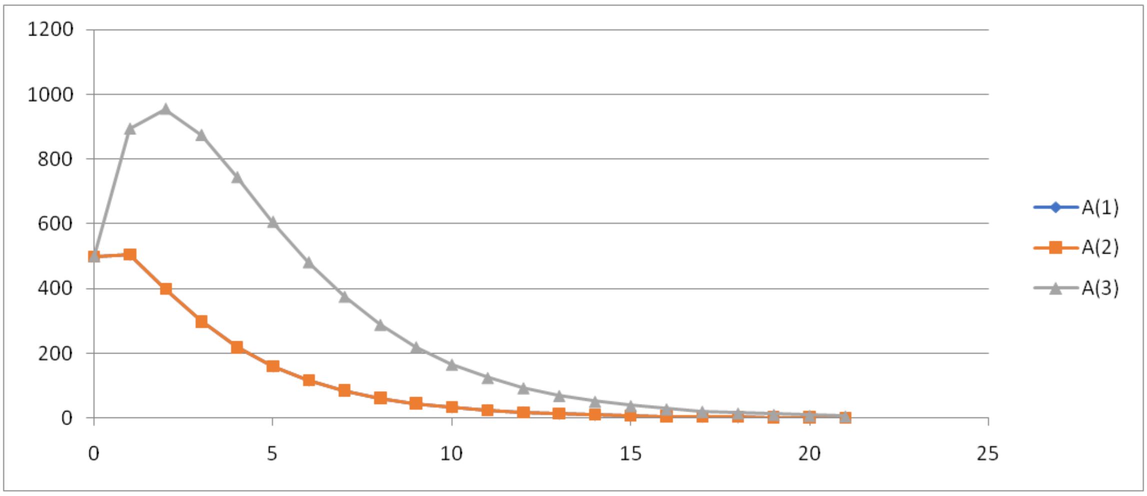

Figure 14: Number of mosquitoes' adult's when one, two and three natural predator, purple martins are compared respectively ($P_{1,2\&3} = 130,\ \omega = 0.5,\ \mu_7 = 0.01,\ \beta_7 = 0.02,\ and\ b_3 = 0.9$).

Experiment 13: Comparison of the effect of introducing two and three natural predator, copepod on larva.

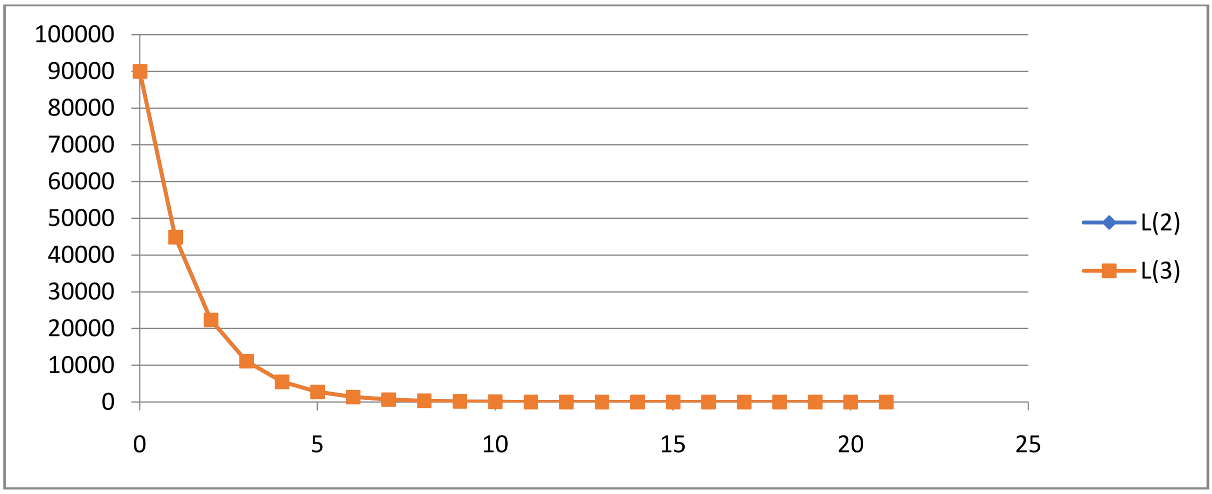

Figure 15: Number of mosquitoes' larva when, two and three natural predators are compared respectively ($C_{2\&3} = 500,\ \omega = 0.5,\ \mu_7 = 0.01,\ \beta_7 = 0.02\ and\ b_3 = 0.9$).

Experiment 14: Effect of introducing low rate of natural predators, copepod on mosquitoes' larva ($C_p = 200$).

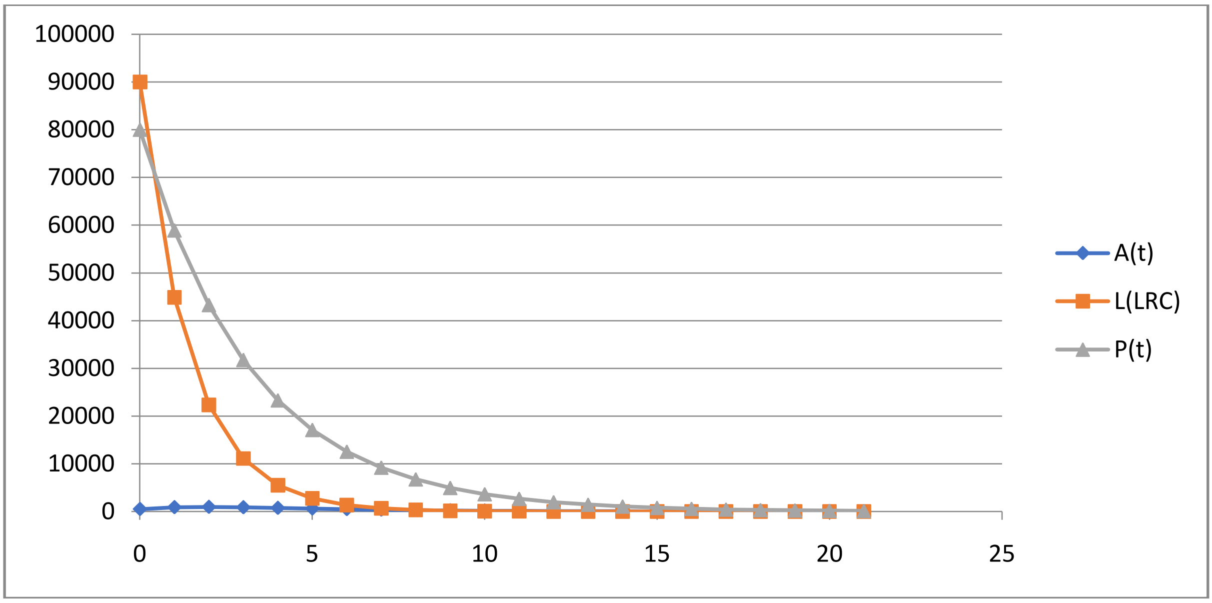

Figure 16: Number of mosquitoes' larva when low rate of natural predator, copepod was introduced to mosquitoes' larva ($C_p = 200, T_p = 0, P_m = 0, \alpha = 0.5,\ \mu_6 = 0.02,\ \beta_6 = 0.01\ and\ \ b_2 = 0.21$).

Experiment 15: Effect of introducing high rate of natural predator, copepod on mosquitoes' larva ($C_p = 2000$).

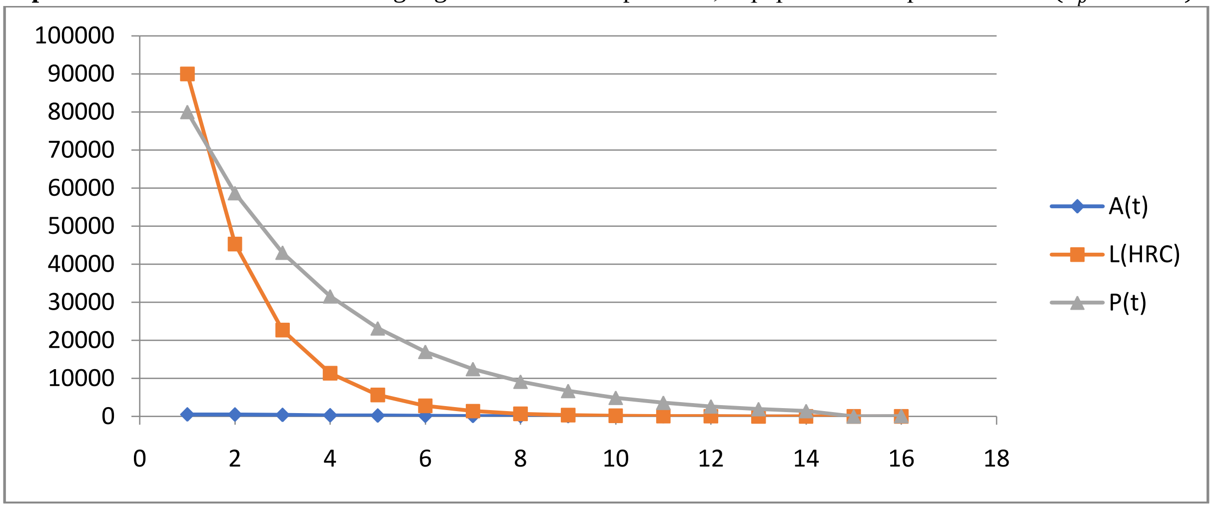

Figure 17: Number of mosquitoes' larva when high rate of natural predator, copepod was introduced to mosquitoes' larva($C_p = 2000,\ \alpha = 0.5,\ \mu_6 = 0.02,\ \beta_6 = 0.01\ and\ b_2 = 0.21$).

Experiment 16: Effect of introducing low rate of natural predator, tadpole on mosquitoes' pupa ($T_p = 200$).

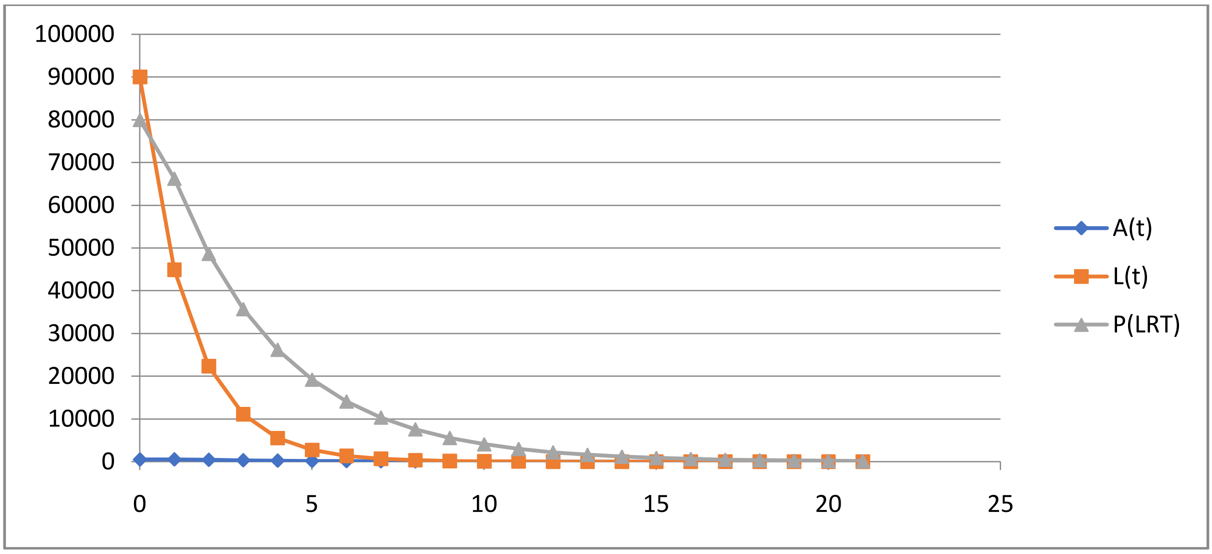

Figure 18: Number of mosquitoes' pupa when low rate of natural predator, tadpole was introduced ($T_p = 200$, $\omega = 0.5,\ \mu_7 = 0.01,\ \beta_7 = 0.02\ and\ b_3 = 0.9$).

Experiment 17: Comparison of the effect of introducing low and high rate of natural predator, copepod on mosquitoes' larva.

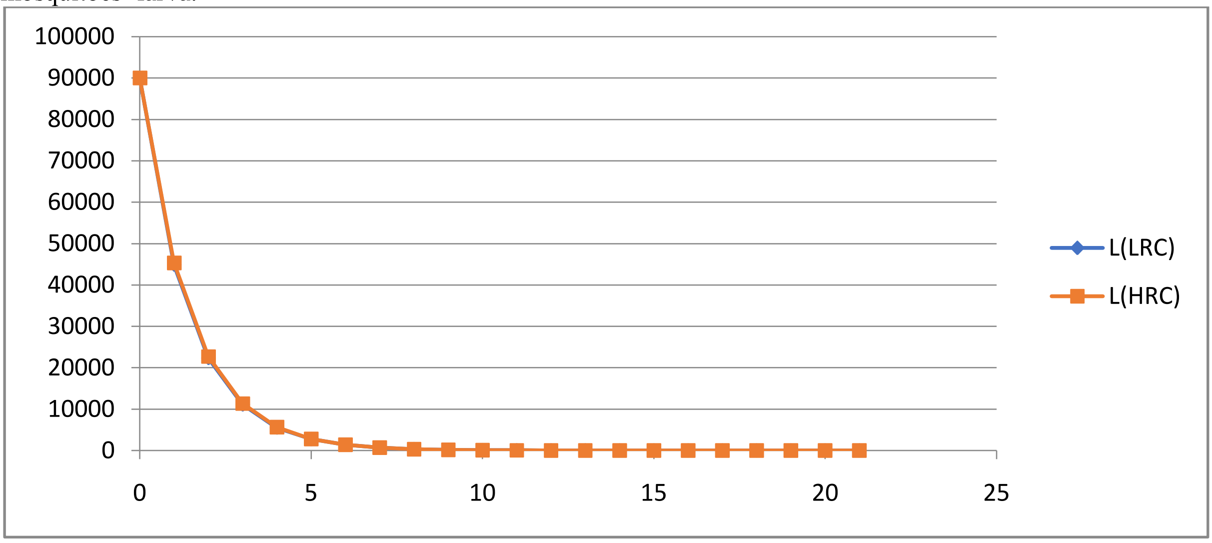

Figure 19: Number of mosquitoes' larva when low and high rate of natural predator, copepod are compared respectively ($C_{L\&H} = 200\&2000,\ \ \alpha = 0.5,\ \mu_6 = 0.02,\ \beta_6 = 0.01\ and\ b_2 = 0.21$

Experiment 18: Effect of introducing high rate of natural predator, tadpole on mosquitoes' pupa ($T_p = 2000$).

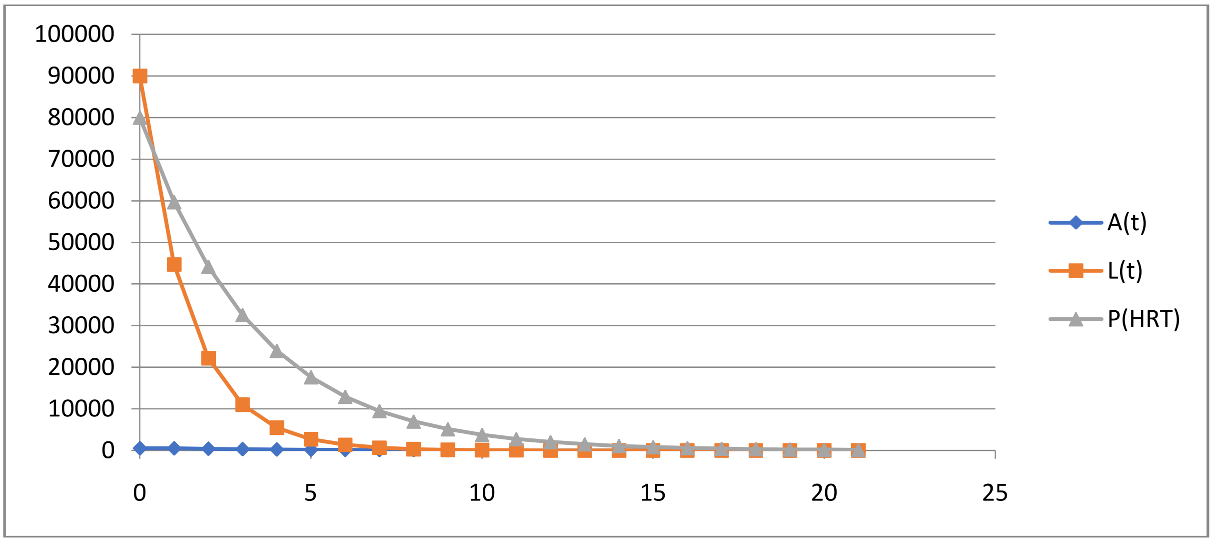

Figure 20: Number of mosquitoes' pupa when high rate of natural predator, tadpole was introduced to mosquitoes' pupa ($T_p = 2000,\ \omega = 0.5,\ \mu_7 = 0.01,\ \beta_7 = 0.02\ and\ b_3 = 0.9$).

Experiment 29: Comparison of the effect of introducing low and high rate of natural predator, tadpole on mosquitoes' pupa.

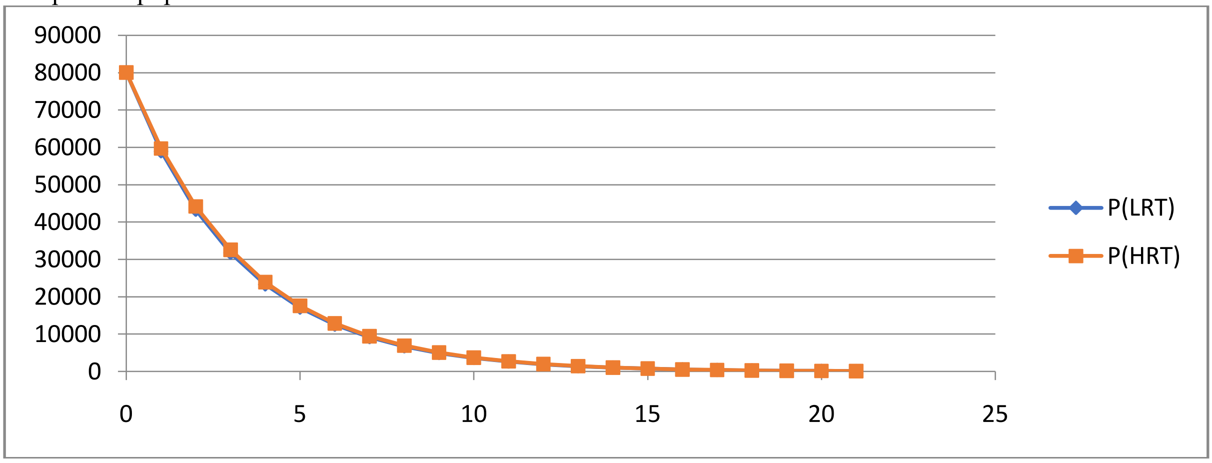

Figure 21: Number of mosquitoes' pupa when low and high rate of natural predator, tadpole is compared respectively ($T_{L\&H} = 200\&2000, \omega = 0.5,\ \mu_7 = 0.01,\ \beta_7 = 0.02\ and\ b_3 = 0.9$).

II. Discussion of Results

The pictorial integral of malaria control with maple is presented. In the introduction, we discussed the prevalence of mosquitoes in our society, where two million deaths are due to malaria parasites in sub-Saharan Africa in general and Nigeria in particular, one third of which are children. In Material and Methods, we discuss model formulation and description, define model variables and parameters, make assumptions, and present the model showing the flow control diagram of predator-prey interaction in model. Three natural predators (copepods, tadpoles, and crimson swallows) were introduced into the model at larval, pupal, and adult stages, and model equations for mosquito and predator life cycles were derived.

The new model used the variables and parameters shown in Table 1. These variables and parameters are chosen with the thresholds obtained in the steady-state disease-free stability analysis of the model. In the analytical output, the model analysis showed the existence of a single disease-free steady state that is locally and asymptotically stable. These threshold parameters mentioned in Table 2 above should be considered when implementing the above model to provide control measures aimed at reducing the prevalence of the malaria parasite in our society and consequently eradicating mosquito disease in Nigeria. Regarding the numerical results, numerical experiments performed using the variables and parameter values in Table 2 and applying disease-free steady-state stability conditions yield the following results:

In Experiment 1, the effect of introducing a natural predator, copepod, on mosquito larvae was studied, and the numerical values of variables and parameters were analyzed as shown in Table 2, solved and numerical simulation with Graphical representation of the result was performed as in figure 3. Predator was introduced, this indicates that the number of larvae has decreased significantly and they have pupated.

In experiment 2, the effect of the introduction of two natural predators, copepods and tadpoles, on mosquito larvae and pupae was studied, and the numerical values of the variables and parameters were those given in the tables 2 which have been analyzed, solved and executed numerically with the result plotted as in Figure 4 When two natural predators were introduced, the number of pupal, larvae were greatly reduced and the conversion of pupae to adults was minimal.

In Experiment 3, the effect of the introduction of three natural predators (copepods, tadpoles and purple swallows) on mosquito larvae, pupae and adults was studied, and the numerical values of variables and parameters were analyzed with the solution shown in Table 2 and run a numerical simulation plotting the result as shown in Figure 5 when three natural enemies are introduced simultaneously. Infection in the adult Anopheles mosquito population is significantly slowed down and thus eradicated, and the probability of transmission from the adult Anopheles mosquito to the human population is very low.

In Experiment 4, in which the effects of the introduction of one, two and three natural predators on the larvae were compared, the numerical values of the variables and parameters shown in Table 2 were analyzed and resolved, and a Numerical simulation was performed with graphical representation of the results, shown in Figure 6 when one, two and three predators were examined. This result shows that the infection rate in Figure 6 decreases significantly to avoid reinjection of malaria, which is the prevention strategy in the fight against malaria.

In Experiment 5, the comparison of the effect of the introduction of two and three natural predators, swallows, on adult mosquitoes and the numerical values of the variables and parameters in Table 7 were studied, analyzed, solved and carried out a numerical simulation with the graph result, as shown in Figure 7 when two and three natural predators were introduced, respectively. The result shows that the infection rate in Figure 7 decreases significantly. To prevent reinfection with malaria, the transmission rate must be close to zero.

In Experiment 6, the effect of introducing a natural predator, tadpoles, on mosquito pupae was studied, and the numerical values of variables and parameters were examined as shown in Table 2 and a numerical simulation with graph has been analyzed, solved and run. The presentation of the result and the graphical result in Figure 8 shows that when a natural predator, the tadpole, has been introduced, the infection in the Anopheles mosquito adult population has slowed and the probability of transmission from nymph to adult population is very low.

In Experiment 7, the effect of the introduction of two natural predators, tadpoles and swallows, on mosquito pupae and adults was studied, and the numerical values of the variables and parameters were those given in Table 2, they have been analyzed and resolved numerically using a graphical simulation. The result is shown in Figure 9, which confirms that the infection in the adult Anopheles mosquito population slows down significantly and the probability of becoming an adult Anopheles mosquito is very small.

In Experiment 8 comparing the effect of introducing one, two and three natural enemies into mosquito pupae, and the numerical values shown in Table 2 and the graphical result shown in Figure 10 when one, two and three natural enemies are present, respectively, entered and verified. The result shows that the infection rate in Figure 10 decreases significantly. To avoid reinjection of malaria, the transmission rate must be close to zero.

In experiment 9, a numerical simulation was analyzed, solved and carried out with a graphical representation of the result in the comparison of the effect of the introduction of two and three natural enemies on adult mosquitoes and the numerical values of the variables and parameters shown in Table 2 and Figure 11 shows that the infection rate drops enough to prevent malaria infection.

In Experiment 10, the effect of the introduction of a natural predator, purple swallow, on adult mosquitoes was studied, and the numerical values of variables and parameters were analyzed as shown in Table 2 resolved and numerical simulation. The result shown in Figure 12 after the introduction of a natural predator, the purple swallow, is quite stagnant in adult Anopheles mosquitoes and the transmission rate is very weak.

In Experiment 11, the effect of the introduction of two natural predators, copepods and purple swallows, on mosquito larvae and adults, respectively, was examined, and the numerical values of variables and parameters were examined, as shown in Tables 2. Solve and run a numerical simulation with a graphical representation of the result shown in Figure 13 when two natural predators, copepods and purple swallows, are introduced. Infection in the adult Anopheles mosquito population is significantly slowed down and thus eradicated, and the probability of transmission from the pupa to the adult Anopheles mosquito population is very low.

In Experiment 12, the comparison of the effect of introducing one, two and three natural predators on adult mosquitoes and the numerical diagram in Table 2 were analyzed and solved, and a numerical simulation was performed with a graphical representation of the result as indicated in 14 at the introduction of one, two or three natural predators. The result shows that the infection rate in Figure 14 decreases significantly to prevent new malaria infection.

In Experiment 13, the effect of the introduction of two and three natural predators on mosquito larvae was compared with the numerical values of the variables and parameters presented in Table 2, and a numerical simulation with graphical representation was analyzed, resolved and carried out results shown in Figure 15, when two and three natural predators were introduced, respectively. The result shows that the infection rate in Figure 15 decreases to prevent malaria infection.

In Experiment 14, the effect of introducing a low rate of natural predators, copepods, on mosquito larvae was investigated, and the numerical values of variables and parameters were presented in Tables 2, analyzed, solved and a numerical simulation was played with a graphical representation of the result as shown in Figure 16. Low rate of natural predators, copepods have been introduced. Infection in adult Anopheles mosquitoes has decrease and the percentage of transmission is low.

In Experiment 15, the effect of introducing a high level of natural predators, copepods, on mosquito larvae was studied, and the numerical values of variables and parameters were analyzed, solved and executed. as shown in Table 2 a numerical simulation with a graphical representation of the result, as shown in Figure 17. High levels of natural predators, copepods, have been introduced. Infection in adult mosquitoes of the Anopheles family is fairly stagnant and is therefore well on the way to eliminating malaria infection.

In Experiment 16, the effect of introducing a low number of natural predators, tadpoles, into the mosquito pupa was investigated, and the numerical values of variables and parameters are shown in Tables 2, and the graphical result shown in Figure 18. Low rate of natural predators, introduction of copepods reduced infection in adult Anopheles mosquitoes.

In experiment 17, the effects of the introduction of low and high rate of natural predators, copepods, on mosquito larvae were studied, analyzed, solved and numerical simulations were carried out with numerical values of variables and parameters, as shown in Table 2. The representation of the resulting result in Figure 19 is shown when low and high levels of natural predators, copepods, were introduced. The infection in adult mosquitoes of the Anopheles family is quite stagnant due to the low and high rate of natural predators introduced at the same time, therefore in the process of elimination, and the percentage of transmission is almost nil.

In Experiment 18, the effect of introducing a high rate of natural predators, tadpoles, into the mosquito pupa and the numerical values of the variables and parameters presented in Table 2 were analyzed and resolved, and performed a numerical simulation performed in the graphical representation of Figure 20 when a high level of the natural predator, the tadpole, was introduced. Infection in adult mosquitoes of the Anopheles family was almost nil.

In Experiment 19, the comparison of the effects of introducing low and high numbers of natural predators, tadpoles, into the mosquito pupa and the numerical values of the variables and parameters as shown in Table 2 and the Graphical result in Figure 21 shows that low and high rates of natural predators, copepods, were introduced. Infection in adult mosquitoes of the Anopheles family is fairly stagnant, and therefore on the way to elimination, and the percentage of transmission is low.

Considering the total population, the effect of the introducing three natural predators, one, two and three, on the larva, larva and pupa and larva, pupa and adult (copepods, tadpoles and martens) respectively (compare Figure 3 and 4 with Figure 5 and 6). The infectious agent content is greatly reduced and the infection of the egg, larva and pupa is eradicated, but persists at a low level in the adult Anopheles mosquito.

When assessing the total population, the effect of introducing two natural predators one and two on pupae, pupae and adults (tadpoles and house swallows) was examined (compare Figure 7 and 8 with Figure 9 and 10). The infectious agent content is greatly reduced and the infection of the egg, larva and pupa is eradicated, but persists at a low level in the adult Anopheles mosquito.

When assessing the total population, the effect of introducing two natural predators, one and two, on the adult, larva and adult (swallow and copepod) respectively (compare Figure 11 and 12 with Figure 13 and 14). The infectious agent content is greatly reduced and the infection of the egg, larva and pupa is eradicated, but persists at a low level in the adult Anopheles mosquito.

When examining the total population, the effect of introducing low and high rate natural predators (copepods) on the larvae was introduced and studied (compare Figure 15 and 16 with Figure 17 and 18). The infectious agent content is greatly reduced and the infection of the egg, larva and pupa is eradicated, but persists at a low level in the adult Anopheles mosquito.

When analyzing the total population, the impact on the introduction of pupae of a high and low rate of natural predators, one (tadpole) was introduced and examined (compare Figure 19 and 20 with Figure 21). The infectivity of the adult Anopheles mosquito remains at a low level.

Finally, to understand the effects of introducing three natural enemies (copepods, tadpoles and house swallows) on larvae, pupae and adults when three natural enemies are introduced each, Figures 3, 4, 5 …21 specify the representations to deliver. It could be clearly observed that the transmission speed was reduced to the indispensable minimum. This could be achieved since research should focus on formulating models that capture preventive strategies based on stability analysis to prevent the onset of the disease and thus eradicate it.

III. Conclusion

We state that based on the ideas of maple, we conclude that if the introduced natural predators are large, the number of larvae that will pupate will be close to zero and the number of pupae that will develop into adults will be zero, which will lengthen the life cycle of the interrupted Anopheles mosquito. Therefore, in our society there will be no adult Anopheles mosquitoes that transmit malaria pathogens.

References

[1]. Adigun, A. B., Gajere, E. N., Oresanya, O., & Vounatsou, P. (2015). Malaria risk in Nigeria: Bayesian geostatistical modelling of 2010 malaria indicator survey data. Malaria Journal, 14(1). https://doi.org/10.1186/s12936-015-0683-6

[2]. Antonio-nkondjio, C., Kerah, C. H., Simard, F., Awono-ambene, P., Chouaibou, M., Tchuinkam, T., & Fontenille, D. (2006). Complexity of the Malaria Vectorial System in Cameroon: Contribution of Secondary Vectors to Malaria Transmission. Journal of Medical Entomology, 43(6), 1215–1221. https://doi.org/10.1093/jmedent/43.6.1215

[3]. Atta, H., & Reeder, J. (2014). World Malaria Day 2014: invest in the future. Defeat malaria. Eastern Mediterranean Health Journal, 20(04), 219–220. https://doi.org/10.26719/2014.20.4.219

[4]. Bernard, K. A., Pacheco, A. L., Burdz, T., Wiebe, D., & Bernier, A.-M. (2020). Corynebacterium godavarianum Jani et al. 2018 and Corynebacterium hadale Wei et al. 2018 are both later heterotypic synonyms of Corynebacterium gottingense Atasayar et al. 2017, proposal of an emended description of Corynebacterium gottingense Atasayar et al. 2017. International Journal of Systematic and Evolutionary Microbiology, 70(5), 3534–3540. https://doi.org/10.1099/ijsem.0.004153

[5]. CDC Weekly, C. (2020). The 13th World Malaria Day — April 25, 2020. China CDC Weekly, 2(17), 277–277. https://doi.org/10.46234/ccdcw2020.071

[6]. Emmanuel, A. Y., & Omini, A. A. (2020). A Mathematical Model for the Eradication of Anopheles Mosquito and Elimination of Malaria. International Journal of Healthcare and Medical Sciences, 61, 1–14. https://doi.org/10.32861/ijhms.61.1.14

[7]. Garcia Guerra, G., Al Hamarneh, Y. N., Tsuyuki, R. T., & Garros, D. (2014). ABSTRACT 105. Pediatric Critical Care Medicine, 15, 29. https://doi.org/10.1097/01.pcc.0000448834.89804.0a

[8]. Harbach, R. E., & Besansky, N. J. (2014). Mosquitoes. Current Biology, 24(1), R14–R15. https://doi.org/10.1016/j.cub.2013.09.047

[9]. McKenzie, F. E. (2014). Challenges in malaria modeling. Malaria Journal, 13(S1). https://doi.org/10.1186/1475-2875-13-s1-o14

[10]. Malaria policy advisory committee to the WHO: conclusions and recommendations of fifth biannual meeting (March 2014). (2014). Malaria Journal, 13(1), 253. https://doi.org/10.1186/1475-2875-13-253

[11]. Malaria Policy Advisory Committee to the WHO: conclusions and recommendations of sixth biannual meeting (September 2014). (2015). Malaria Journal, 14(1). https://doi.org/10.1186/s12936-015-0623-5

[12]. Malaria vaccine: WHO position paper, January 2016 – Recommendations. (2018). Vaccine, 36(25), 3576–3577. https://doi.org/10.1016/j.vaccine.2016.10.047

[13]. MCNAMARA, D. (2005). CDC Web Site Offers Malaria Telediagnosis, Tx Guidelines. Internal Medicine News, 38(4), 68. https://doi.org/10.1016/s1097-8690(05)71660-7

[14]. Mokuolu, O. A., Ajumobi, O. O., Ntadom, G. N., Adedoyin, O. T., Roberts, A. A., Agomo, C. O., Edozieh, K. U., Okafor, H. U., Wammanda, R. D., Odey, F. A., Maikore, I. K., Abikoye, O. O., Alabi, A. D., Amajoh, C., & Audu, B. M. (2018). Provider and patient perceptions of malaria rapid diagnostic test use in Nigeria: a cross-sectional evaluation. Malaria Journal, 17(1). https://doi.org/10.1186/s12936-018-2346-x

[15]. Molinaro, A., & Edozieh, K. (2015). ChemInform Abstract: Chemistry of Lipid A: At the Heart of Innate Immunity. ChemInform, 46(12), no-no. https://doi.org/10.1002/chin.201512327

[16]. Patouillard, E., Griffin, J., Bhatt, S., Ghani, A., & Cibulskis, R. (2017). Global investment targets for malaria control and elimination between 2016 and 2030. BMJ Global Health, 2(2), e000176. https://doi.org/10.1136/bmjgh-2016-000176

[17]. Rajeswari, A. R. (2017). MOSQUITOE DIVERSITY IN ERODE DISTRICT, TAMIL NADU, INDIA. World Journal of Pharmaceutical Research, 474–482. https://doi.org/10.20959/wjpr20179-8828

[18]. Tsoka-Gwegweni, J., & Okafor, U. (2014). Haematological alterations in malaria-infected refugees in South

[19]. UM, C., & AN, C. (2016). Malaria among the Geriatric Population in Parts of South-Eastern Nigeria: Prevalence, Complications and Co-morbidity with Non-communicable Diseases. Epidemiology: Open Access, 06(02). https://doi.org/10.4172/2161-1165.1000237

[20]. Vanelle, P., & et al. (2012a). ChemInform Abstract: Targeting the Human Malaria Parasite Plasmodium falciparum: In vitro Identification of a New Antiplasmodial Hit in 4-Phenoxy-2-trichloromethylquinazoline Series. ChemInform, 43(5), no-no. https://doi.org/10.1002/chin.201205194

[21]. Vanelle, P., & et al. (2012b). ChemInform Abstract: 4-Thiophenoxy-2-trichloromethylquinazolines Display in vitro Selective Antiplasmodial Activity Against the Human Malaria Parasite Plasmodium falciparum. ChemInform, 43(9), no-no. https://doi.org/10.1002/chin.201209176