

Original Research Article

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## Density Dependent Logistic Growth Model for Yellow Stem Borer

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### ABSTRACT

#### Keywords

Yellow stem borer,  
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The pest population density is controlled by logistic growth model. The logistic model is applied to find out the carrying capacity, equilibrium level and its solutions. In this model time varies continuously and the population is unstructured. The population members are of homogeneous group. By using the logistic growth model, the Equilibrium levels and maximum supportable population that is carrying capacity and the stability of equilibrium state of the important rice pest stem borers are calculated.

### Introduction

Food is the basic human need and enough to feed the growing population of developing nations is one of the biggest challenges faced by modern world. Rice is one of the top most food grains in world wide. The major problem faced by the rice cultivating farmers in India is managing host of pest. The pest population density controlling by logistic growth model. The population of carrying capacity, pest population tends to equilibrium level and the solution using logistic model. The major problem for rice cultivation is controlling the pest population. In this model the time varies

continuously and the population is unstructured. The population members are a homogeneous group. Using the logistic growth model which is the equilibrium levels and maximum supportable population that is carrying capacity and the stability of equilibrium states of the important rice pest stem borer. The borer population tends to equilibrium level, not tends to economic injury level and the borer population of carrying capacity using the stability condition.

In population ecology, density-dependent processes occur when population growth rates are regulated by the density of a

population. The relatively little experimental data and the conditions that may promote strong vs. weak density dependence in a particular species. To incorporate density dependence into a predictive fabric for population dynamics, the magnitude, causes, and correlates of variation in the strength of density dependence will need to be understood. One factor that is expected to be related to the strength of density dependence (i.e. slope of the relationship between density and per capita growth rate) is population growth rate at low density. This expectation is based on the monotonic definition of density dependence that is included in the most widely used single species models of population dynamics.

Population sizes that are less than K, the population will increase in size: at population sizes that are greater than K the population size will decline; and at K itself the population neither increases nor decreases. The carrying capacity is therefore a stable equilibrium for the population, and the model exhibits the regulatory properties classically characteristic of intraspecific competition. For the continuous time model, birth and death are continuous. The net rate of such a population will be denoted by  $dN/dt$ . This represents the 'speed' at which a population increases in size, N, as time, t, progresses. It describes a sigmoidal growth curve approaching a stable carrying capacity, but it is only one of many reasonable equations that is in the following fig (Fig. 1 and 2).

The population growth rate  $\frac{1}{N} \frac{dN}{dt}$

$$\frac{dN(t)}{N(t)\{a-bN(t)\}} = dt \quad N(t) = \frac{a}{b + \left(\frac{a-bN_0}{N_0}\right)e^{-at}}$$

put  $k=a/b$  is the carrying capacity

$$N(t) = \frac{k}{1 + \left(\frac{k-N_0}{N_0}\right)e^{-rt}}$$

### Steady and equilibrium states

A steady state  $\bar{N}$  of the logistic model differential equation  $\frac{dN}{dt}$  is defined as the limiting value of N (t) if it exists as t becomes large.

An equilibrium state  $N_e$  of the logistic model of the differential equation N(t) satisfies the equation  $\frac{dN}{dt}=0$

The logistic model  $\frac{dN}{dt}=rN \left(\frac{K-N}{K}\right)$  Solution of the equation is  $N(t) = \frac{k}{1 + \left(\frac{k-N_0}{N_0}\right)e^{-rt}}$  at  $=N_0$

The equilibrium state are  $N_{e1}=0$  and  $N_{e2}=k$ .

The steady states of a population depend on the value of initial size  $N_0$  and two equilibrium states  $N_1$  and  $N_2$  with  $N_1 < N_2$  three possibilities arise. Let  $N_0 < N_1$  and  $f(N) > 0$  in the interval  $(0, N_1)$  then as t increases from  $t=0, N(t)$  increases steadily from  $N_0$  and its maximum value is  $N_1$ . This means that  $N(t) \rightarrow N_1$  as  $t \rightarrow \infty$  So  $\bar{N} = N_1$

Let  $N_1 < N_0 < N_2$  and  $f(N) > 0$  in  $(N_1, N_2)$  In this case  $N(t)$  monotonically increases from  $N_0$  at  $t=0$  and its maximum value is  $N_2$  so that  $N(t) \rightarrow N_2$  as  $t \rightarrow \infty$ . Hence  $\bar{N} = N_2$

Let  $N_0 > N_2$  and  $f(N) > 0$  in  $(N_2, \infty)$ . It is clear that for this case  $N(t)$  increase from  $N_0$  without any bound as t increase from  $N_0$  without any bound as t increase and so  $\bar{N} = \infty$ . Similarly for  $f(N)$  in the following Table 1.

### Stability of equilibrium states

Equilibrium states can be classified as 'stable' and 'unstable' or locally stable and asymptotically stable. An equilibrium state of logistical differential equation is stable if for each  $\epsilon > 0$ , there exists  $\delta > 0$ , such

that  $\|N(0) - N_e\| < \delta \Rightarrow \|N(t) - N_e\| < \varepsilon$  for all  $t \geq 0$

If the system moves away from the equilibrium after small displacements, then the equilibrium is called unstable. The condition for equilibrium state to be stable is If at an equilibrium points  $N=N_e$  of the logistic differential equation,  $f'(N_e) < 0$ , then the system is stable at that point, otherwise it is unstable.

Using  $a=0.1$  and  $b=2$  (a & b value of Udayakumar and Sujatha, 2016) Where a&b is calculated by least square method by life table analysis of rice stem borer) then the carrying capacity  $K = \frac{a}{b} = \frac{0.1}{2} = 0.05$  and  $r=a=0.1$  In this value the stem borer in the laboratory condition is tend to equilibrium state.

$$N(t) = \frac{0.05}{1 - 0.9995e^{-0.1t}}$$

The two equilibrium points  $N_{e1}=0$  and  $N_{e2}=0.05$ .

### Results and Discussion

Models for population growth in a limited environment are based on two fundamental one is the population have the potential to increase logistically and that there is density dependent feedback that progressively reduce s the actual rate increase.

Density dependent relationship in single species rice stem borer its equilibrium level  $N_{e1}=0$  and  $N_{e2}=0.05$ . In this equilibrium level is  $N_0 > N_{e2}$  and  $f(N) > 0$  in  $(N_{e2}, \infty)$   $N(t)$  increase form  $N_0$  without any bound as t increases in the control condition.

Fig.1

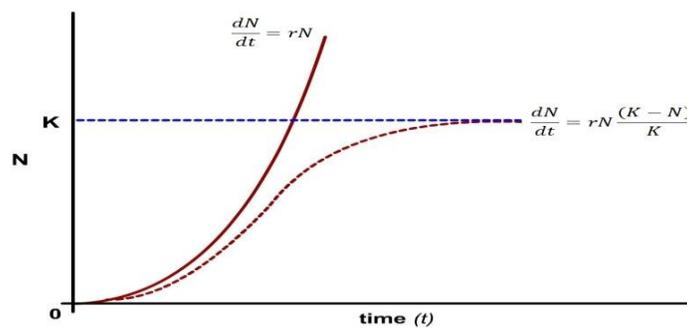
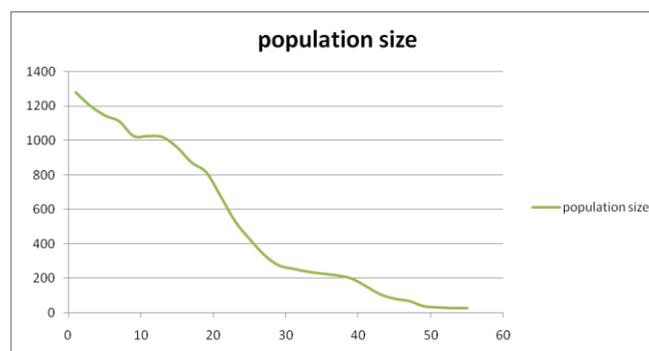


Fig.2



**Table.1**

Stages x	Time	population size	Number of dying during x
<b>Eggs</b>	1	1280	78
	3	1202	56
	5	1146	34
	7	1112	86
	9	1026	0
<b>Larvae</b>	11	1026	6
	13	1020	60
	15	960	88
	17	872	56
	19	816	140
	21	676	146
	23	530	102
	25	428	91
	27	337	61
	29	276	20
	31	256	17
	33	239	11
	35	228	10
	37	218	18
	39	200	44
	41	156	48
	43	108	26
45	82	13	
<b>Pupae</b>	47	69	30
	49	39	7
	51	32	4
<b>Adult</b>	53	28	
	55	28	

Position of $N_0$	Sign of $f(N)$	
	$f(N)>0$	$f(N)<0$
$N_0 < N_1$	$N_1$	0
$N_1 < N_0 < N_2$	$N_2$	$N_1$
$N_0 > N_2$	$\infty$	$N_2$

## References

- Hassell. M.P. 2001. Density –Dependence in Single-Species Population. Page no. 283-295 Insect Population Ecology. Blackwell scientific Pulications, Oxford.
- Manjunathan, G., Basavarajppa, K.S., and Katiyar, V.K., Mathematical modeling on Industrial pollution and spread of infection disease using population growth model for epidemis.” International Journal of Innovative Research in Science.
- Ranganathan, C.R. A First course in Mathematical Models of Population Growth (With MATLAB Programs ).
- Udayakumar, S., P. Sujatha and P. Yasotha. 2016. Key mortality factors of *Scirpophaga incertulas* (Rice stem borer) infesting Rice. Internal journal of Mathematics and its Application.

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