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# Study on sumatran rhinoceros based on ecological game model

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**Abstract.** In this paper, the survival status of the sumatran rhinoceros was studied, the ecological game of the sumatran rhinoceros was put forward according to the critically endangered status, the differential dynamical system model of the sumatran rhinoceros and food was established, and the relationship between the parameters in the model and the land and environmental conditions was discussed. According to the value range of the four indicators, the ecological environment was divided into three conditions of food abundance, food shortage and critical state, so as to obtain the impact and requirements of the sumatran rhinoceros on the ecological environment. The results show that the sumatran rhinoceros lives in cycles under different land area conditions. Analysis from the perspective of the evolution of the ecological environment, the sumatran rhinoceros and food together form an ecological system, the abundant of food can cause sumatran rhinoceros populations, the number of the sumatran rhinoceros too much then can reduce the quantity of food, after reducing the number of the sumatran rhinoceros and will cause the increase in the number of food, this phenomenon is called ecological cycle, namely three environmental situation circulation phenomenon over time. Finally, according to the differential equation, migration is one of the ways that the sumatran rhino can continue to survive when the ecological environment changes.

## 1. Establish ecological competition model

The impact and requirements between the dragon and the ecological environment are proposed in the topic, so the impact between the living space area and the living conditions of the dragon is discussed here, which can be divided into three situations : (A) the area is large enough for the dragon to grow normally; (B) the area is so small that *dicerorhinus sumatrensis* cannot survive; (C) limited in size, *dicerorhinus sumatrensis* can survive, but cannot grow normally.

## 2. The relationship between the number of food and the number of *dicerorhinus sumatrensis*

In the fixed area, let  $x$  represent the amount of existing food (such as the total weight of grass on the ground), and  $y$  represent the number of *dicerorhinus sumatrensis*, then the differential equation model can be established **【1】** :

The system of differential equations is

$$x' = ax + by$$

$$y' = ax + gy$$

$x'$ ,  $y'$  is the derivative with respect to time.  $a$ ,  $b$ ,  $c$ ,  $g$  are the coefficients. When  $a > 0$ , it means that the growth rate of food quantity is proportional to the number of food, and  $b < 0$  means that if there are more *dicerorhinus sumatrensis*, the number of food decreases.  $C > 0$ , means when there's a lot of grass,



the number of *dicerorhinussumatrensis* increases.  $G > 0$  means that the growth rate of *dicerorhinussumatrensis* is proportional to the number of *dicerorhinussumatrensis* **【2】**. If  $g$  is less than 0, it means there are more *dicerorhinussumatrensis* and there will be fewer.

By on, the differential equations of coefficient determines the food quantity and the influence of the relationship between the number of the dragon, consulting relevant literature, the available coefficient  $a$  is the growth index, coefficient of  $b$  is prey index, coefficient of  $c$  is support index, coefficient of  $g$  is aging index, and the weight of the temperature, precipitation, the dragon is the main influence factors of the four indicators.

### 2.1. The growth indexes were analyzed

Growth index  $a$  directly determines the growth rate of grass, so growth index  $a$  is mainly determined by temperature and precipitation **【3】** :

$$a = \pm \begin{cases} 0.02T + 0.00026P & T \in [20,26] \quad P \in [1500,2000] \\ 1 - 0.02(|T - 22| + 22) - 0.00026(|P - 1600| + 1600) \end{cases}$$

Where  $T$  is the temperature in units of °C;  $P$  stands for precipitation in mm/year.

### 2.2. Prey indicators were analyzed

Predation indicator  $b$  is the fundamental indicator to measure the predation ability of the dragon. The predation ability of the dragon is determined by its growth condition and physical condition, so the predation indicator  $b$  is determined by the weight of the dragon:

$$b = \pm 0.02m$$

Where,  $m$  represents the weight of the dragon in kilograms.

### 2.3. Analyze the supporting indicators

Supporting index  $c$  is a fundamental indicator to measure the amount of energy the land can provide to the dragon. The amount of energy the land can provide to the dragon is determined by the amount of food the dragon eats. Therefore, supporting index  $c$  is determined by the weight of the dragon:

$$c = 1.6m \times 0.018$$

Where,  $m$  represents the weight of the dragon in kilograms.

### 2.4. Analysis of aging indexes

Aging index  $c$  is one of the important indices for the growth of the dragon, the dragon of the growth is not only related to how much their harvest energy, also related to the ecological environment of living space, therefore, aging index  $c$  being under the joint action of various factors, according to a large number of animal experimental data and empirical formula derivation, given a specific scope:

$$c \in [0.2,0.5]$$

## 3. Three situations in which the dragon and the ecological environment affect each other

Through the above specific analysis of the four indicators, the corresponding relationship between the different value ranges of the four indicators and the three situations can be obtained:

When  $b < 0$ ,  $a > 0$  and  $y$  are large enough, and there are enough *dicerorhinussumatrensis*,  $ax + by < 0$ ,  $x' < 0$ , the growth rate of food is negative, indicating the decrease of food. When there are fewer *dicerorhinussumatrensis*,  $ax + by > 0$ , the amount of food increases.

When  $g < 0$ ,  $c > 0$ , only enough food,  $cx + gy > 0$ , the number of *dicerorhinussumatrensis* increased. When the number of food was less and the number of *dicerorhinussumatrensis* reached a certain number,  $cx + gy < 0$ , the number of *dicerorhinussumatrensis*.

When the nonlinear terms are not considered, the equations can be expressed as matrix **【4】** :

$$X' = AX \quad X = \begin{pmatrix} x \\ y \end{pmatrix} \quad A = \begin{pmatrix} a & b \\ c & g \end{pmatrix}$$

Find the characteristic roots of matrix A,  $|A-rE|=0, r_1, r_2$

Then, the solution of the equation can be expressed as:

$$x = x_1 e^{r_1 t} + x_2 e^{r_2 t}$$

$$y = y_1 e^{r_1 t} + y_2 e^{r_2 t}$$

Where  $x_1, x_2, y_1$  and  $y_2$  are constants. The characteristic root is:

$$r = \frac{a+g}{2} \pm \sqrt{cb + \left(\frac{a-g}{2}\right)^2}$$

When the characteristic root  $r_1$  is  $p$  plus  $q$ ,  $r_2$  is  $p$  minus  $q$ ,  $p$  is real,  $q$  can be imaginary. There are

$$x = x_1 e^{(p+q)t} + x_2 e^{(p-q)t} = e^{pt} (x_1 e^{qt} + x_2 e^{-qt})$$

$$y = y_1 e^{(p+q)t} + y_2 e^{(p-q)t} = e^{pt} (y_1 e^{qt} + y_2 e^{-qt})$$

From the above expression, when  $p+q>0, p-q>0, t \rightarrow \infty, x, y \rightarrow \infty$ , it means that the dragon and the food grow with time. When  $p+q < 0$ , and  $p-q < 0, t \rightarrow \infty, x, y \rightarrow 0$ , means that the dragon and the food decrease with time. When  $p=0$  and  $q=Qi$  is an imaginary number, the solution can be written as

$$x = x_1 \sin(Qt) + x_2 \cos(Qt)$$

$$y = y_1 \sin(Qt) + y_2 \cos(Qt)$$

At this time, it is the periodic solution, indicating that the number of *dicerorhinus sumatrensis* and food fluctuates with time, and it is a critical state.

According to the relationship between the four indicators and three situations above, we can insert three groups of data corresponding to three different situations:

Table.1 three groups of data corresponding to three different situations:

Environmental conditions	a.	b	c	g
The food is enough	0.6	0.5	0.1	0.2
Lack of food	0.6	0.2	0.8	0.2
Critical state	0.3	0.2	0.5	0.3

Logistic-Volterra model was introduced to analyze the relationship between *dicerorhinus sumatrensis* and food in the above three situations **[5]** So, *dicerorhinus sumatrensis* is seen as predators, and food is seen as prey. According to the above differential equation, when the number of *dicerorhinus sumatrensis* and food fluctuates with time in the critical state, the model has periodic solutions and is more representative. Therefore, the relationship between predators and prey in the critical state is emphatically analyzed:

3.1. Volterra model was used for analysis:

$$x' = ax + by$$

$$y' = cx + gy$$

Take  $a=0.3, b=-0.2, c=0.5, g=-0.3$ , and use ode45 function function of matlab to make numerical solution and plot analysis.

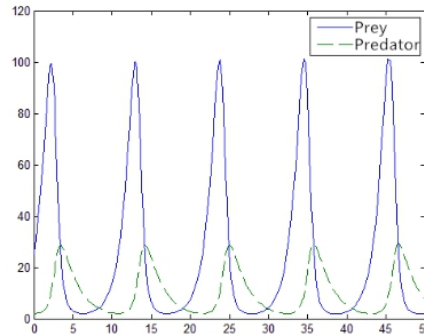


FIG.1 changes of prey and predator over time

As can be seen from the two graphs above, when the environmental conditions are in a critical state, the predator and prey live together and the number changes periodically from time to time.

### 3.2. Logistic-Volterra model was used for analysis

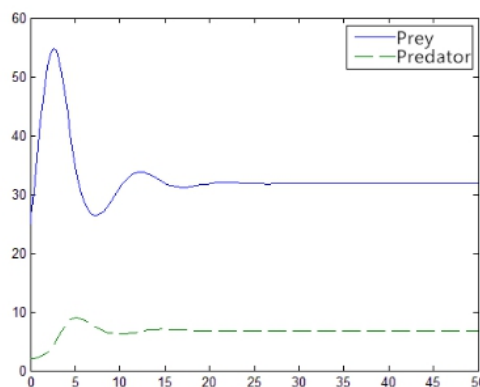


FIG.2 changes of prey and predator over time

At this point, the population number of predator and prey no longer changes in a significant cycle, but tends to a stable value. In the phase diagram of predator and prey, the curve changes from a simple closed curve to a curve that tends to a point.

## 4. Result analysis

The results of the above differential model and the Logistic-Volterra model show that when the land area is large enough, the dragon will grow with time. When the area is very small, it is difficult for the dragon to survive. When the area is finite, that is, in a critical state, the dragon lives in a periodic form. Analysis from the perspective of the evolution of the ecological environment, the dragon and food constitute an ecosystem, the number of food abundance the rise in the Numbers of the Jackie chan, the number of the dragon too much then can reduce the quantity of food, after reducing the number of dragon and will cause the increase in the number of food, this kind of phenomenon be ecological cycle, namely three environmental situation circulation phenomenon over time.

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