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THE ECO-ENVIRONMENTAL MODEL OF *RHINOCEROS* EXTINCTION IN CHINA

Based on historical documents about *Rhinoceros* coming from the past three thousand two hundred years it is shown of how *Rhinoceros* in China tended to contract their range due to man-made destruction of their environment.

Key words: Humans, *Rhinoceros*, extinction.

1. INTRODUCTION

The logistic equation expresses profoundly the essential relation between population numbers N_t and environmental capacity K:

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$

and

$$N_t = \frac{K}{1 + e^{q - rt}}$$

Within a certain area S_o and under stable conditions K remains unchanged with time. Since the report by Elton (1942) on cyclic fluctuations in small rodent populations there have been extensive studies on how K changes with time. Thus, K is not a constant, but it is better to say that $K = K_{(t)}$, and for the environment fluctuating with time $K = K_{(t)} = K_o + K_1 \cos(2\pi (t)\tau)$. Where: K – maximum environmental capacity: r – innate growth rate, q – constant equal to r_{to}, N_o – starting numbers, t_o – starting time.

Though $K_{(t)}$ is not a constant, it is still a variable: flickering around an equilibrium. Hence, in a long period the capacity $K_{(t)}$ remains mainly stable, and one can regardthe population existent area (S) unchanged, regardless of its size or quality. Such a model, however, does not apply to most of the existing populations.

At present, the environmental conditions for most populations seriously deteriorate. For instance, forests, marshes, swamps, lakes, seas and rivers are being polluted and/or destroyed by human activities. The existing population area and the environmental quality are all changing, andhence $K_{(t)}$ changes accordingly to the variation in the population area S. In this model, named the eco-environmental model of population change, the parameter $K_{(t)}$ is affected by S,i.e., $K = K_{(t,\ s)}$.

Let us take S to measure area, S is the *Rhinoceros'* maximum area and unit area has a capacity δ_o in S_o. Thus, $K_{(t,\ s)} = \delta_o S_t$. When the area is gradually deteriorating (or its character is changing) then $S = S_{(t)}$ or $S = S_{(\delta,\ t)}$, and $K_{(t,\ s)} = \delta_o S_{(t)}$. When $S_{(t)} \rightarrow 0$ the population will tend to decrease and finally may become extinct.

The *Rhinoceros* species in China have experienced that process. The original environment affected by man gradually vanished and this resulted in extinction of the *Rhinoceros* during the last 3 thousand years.

2. *RHINOCEROS* EXTINCTION IN CHINA

The historical documents on the distribution of *Rhinoceros* in China are unique and detailed. They provide records on that what happened even as far as 3 400 years ago. And this forms a trustworthy information to formulate ecological principles of *Rhinoceros* extinction.

Wen Huan Ran (1981) judged from the *Rhinoceros* character in ancient books that there had been *Rhinoceros unicornis, R. sondaicus* and *Dicerorhinus sumatrensis.* All of them disappeared from China. 3 200 years ago (Shang Dynasty) vivid pictographs on bones show *Rhinoceros* and places where King Shang captured them (Fig. 1). One can conclude that the northern border of the *Rhinoceros'* distribution was "Hua" from the record in Jiaguwen of Shang Dynasty, that indicated of how many (normally 5-6, sometimes 11 or 12 up to 16) were captured at several places north of Huang River and south of Tai Hang Mountains. According to our country's ancient geography works, Shang Hai Zhing, in Mt Nu Chuang (at present Mt Mi Gang), located at the upper section of Jing River near Mt Liu Pan, there were many tigers, leopards and *Rhinoceros,* including *D. sumatrensis.* In Mt Xun Wu (Mt Quwu now), north of Mt Liu Pan, there lived tigers, leopards, yaks, *Rhinoceros* and *D. sumatrensis,* similarily to those in Mt Zhong Shou. Shang Hai Zhing describes also Mt Zuozi (Mt Table) that was Mt Da Xian then (north of Yin Cuan city and east of Huang River), as rich in *Rhinoceros* and yaks. Mt Quwu and Mt Table are all situated at 37–38°N. It means that the northern border of distribution of *Rhinoceros* was that far north some 3 000 years ago.

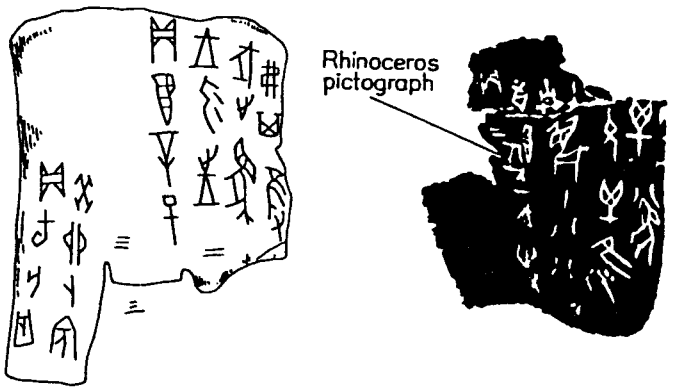

Fig. 1. Pictographs on bones. They indicate that a king of Shang Dynasty captured *Rhinoceros* some 3 400–3 200 years ago (1 400–1 200 B.C.)

The last 3 200 years of the Chinese history can be divided into eight historical periods, each lasting 400 years, approximately. The area with *Rhinoceros* contracted southwardly (Fig. 2). However, the withdrawal of Rhinoceros at the eastern coast had a higher rate than that in the mainland (Fig. 2). That process was simultaneous to the spread of the Chinese population. Finally, *Rhinoceros* vanished somewhere at the west of Yu Nan 200 years ago.

3. HUMAN POPULATION AND ENVIRONMENT

The relationship between the border of *Rhinoceros* range and human population density in the period of Tang Dynasty is very symptomatic: among 34 states where *Rhinoceros* lived 32 had human population density less than 2.9 per km^2 (in 10 of them the density was less than 1.0), and the density in 2 of them was 3.17 and 3.03, respectively (Fig. 3). In the next distinguished period, i.e. that of Song Dynasty, the range of *Rhinoceros* contracted further to south-west (Fig. 3), and in the states of human population density less than 2.9 per km^2 these animals were present. Contrary to that, no *Rhinoceros* existed in the states with the density higher than 3.0 per km^2.

The fact of gradual contraction of the geographical range of *Rhinoceros* in the historical documents of the last 3 200 years points out to the importance of the area rather than the environmental capacity for the *Rhinoceros* extinction in China.

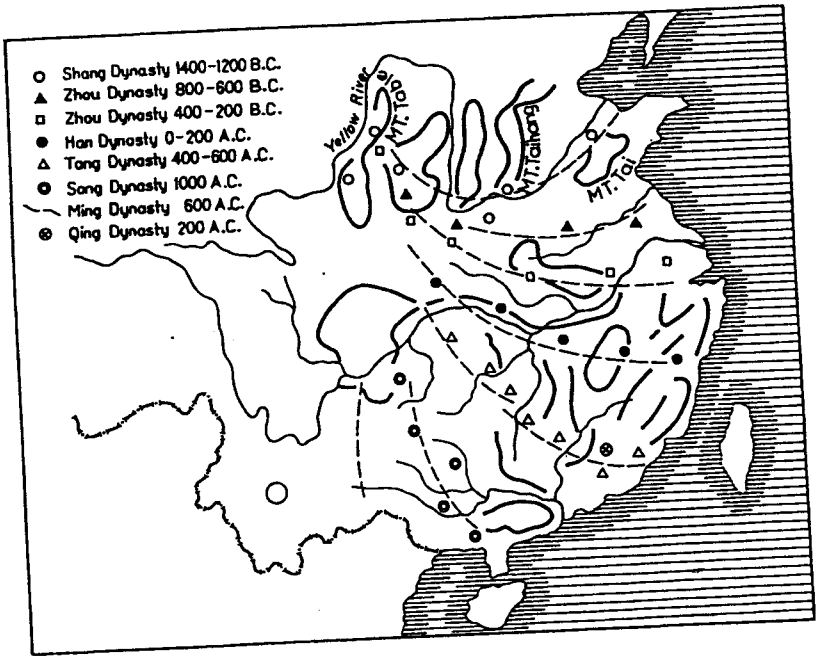

Fig. 2. Approximate course of *Rhinoceros'* extinction in China
a – Shang Dynasty (1 400–1 200 B.C.), *b* – Zhou Dynasty (800–600 B.C.), *c* – Zhou Dynasty (400–200 B.C.), *d* – Han Dynasty (0–200), *e* – Tang Dynasty (400–600), *f* – Song Dynasty (about 1 000), *g* – Ming Dynasty (about 1 600)

4. ECO-ENVIRONMENTAL MODEL OF *RHINOCEROS* EXTINCTION

Suppose, the *Rhinoceros* maximal occupied area (in the period of Shang Dynasty to that of Zhou Dynasty) was S_o, and the *Rhinoceros* density per unit area, δ_o, was constant. The *Rhinoceros* existent area changed from S_o to $S_{(t)}$ during 3 200 years, and $S_{(t)} \leq S_o$. Hence, on the average:

$$a = 1/T,\ T = t_o - t_{(s=0)}$$

where: t_o – starting time for the model (3 200 years ago), $t_{(s=0)}$ ending time (200 years ago).

Therefore: a – 3.33 (101964), and the existent area yearly decrease is $S_{(t)} = S_o - a\ S_o t$.

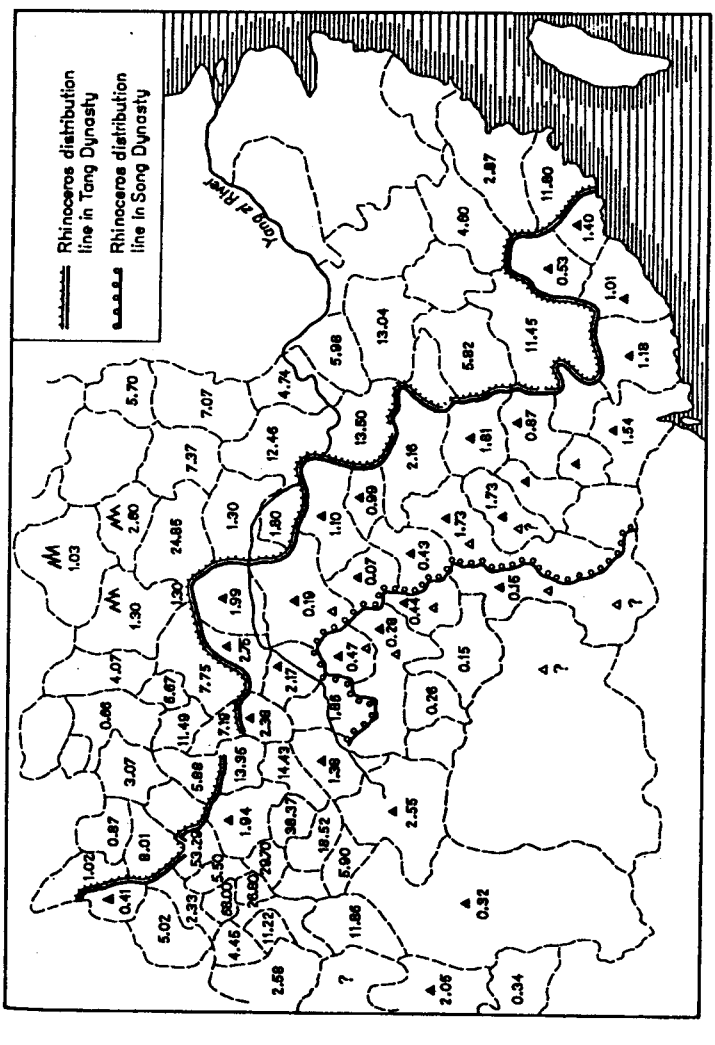

Fig. 3. Distribution of *Rhinoceros* and human population density. Numbers denote humans per kilometer^2. Triangles denote presence of *Rhinoceros* (dark for Tang Dynasty, light for Song Dynasty)

a – *Rhinoceros* northern range (Tang Dynasty), *b* – *Rhinoceros* northern range (Song Dynasty)

Consequently:

$$K_{(t,s)} = \delta_o S_{(t)} = (1 - at)\,\delta_o S_o$$

$$N_{(t,s)} = \frac{K_{(t,s)}}{1 + e^{q-rt}} = \frac{(1 - at)\,\delta_o S_o}{1 + e^{q-rt}}$$

5. CONCLUSIONS

We would like to conclude that the parameter r, that is the innate growth rate, supposedly remained constant within the 3 000 years of *Rhinoceros* extinction in China, and the real cause of the extinction was limitation of the habitable area due to expanding human population. It is also unreasonable to expect that the reason for the extinction was climate. If the reason were climatic conditions then the rate of the extinction should be slower in the coastal zone than in the central mountain area. Besides, we would like to suggest that the extinction time for a population can be deduced from the presented model, providing the necessary estimates of the parameters are known.

6. STRESZCZENIE

EKO-ŚRODOWISKOWY MODEL WYNISZCZENIA POPULACJI NOSOROŻCA *(RHINOCEROS)* W CHINACH

Piktogramy znalezione na kościach zwierząt (fig. 1) stanowią najstarsze (3400–3200 lat temu) źródło informacji o rozmieszczeniu nosorożców w Chinach. Można prześledzić zmianę północnej granicy zasięgu nosorożców w kolejnych okresach historii Chin (fig. 2). Kurczenie się zasięgu nosorożców wiąże się z ekspansją populacji ludzkiej, szybszą na wybrzeżu niż w głębi kraju (fig. 3). Nosorożce ustępowały z danej prowincji Chin, gdy zagęszczenie populacji ludzkiej wzrastało ponad 3 osoby na km^2. Sformułowano matematyczny model ekstynkcji nosorożców oparty na równaniu logistycznym, w którym pojemność środowiska jest wyrażona przez przestrzeń dostępną dla populacji.

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