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T4 ________________	**A**	F4 ________________

2019

MCM/ICM

Summary Sheet

(Your team's summary should be included as the first page of your electronic submission.)

DAM: Dragon Analysis Model about Requirements and Impact

Summary

Dragon exists from the Late Triassic to the end of the Cretaceous, and many archaeologists now study its fossils. In order to clearly understand the dragon's characteristics, behaviors, habits, diet and the environment, and comprehensively evaluate the dragon's ecological requirements and ecological impact, we considered the ecological requirements and ecological impacts. We have established a model group to explore the dragon's related life activities.

First, based on the description of the dragon in the "A Song of Ice and Fire", we determined the basic growth information of the dragon. Then based on the Bertalanffy model, we analyze the effects of different food conditions and derive the growth equation of the dragon. Then we combined the weight of the dragon during hatching and the body weight after one year of growth to determine the parameters, and finally obtained the growth model of the dragon under different food conditions. In addition, we found that the dragon's water requirement can be linearly related to body weight and ambient temperature to some extent.

Next, we discussed the impact of dragons on ecology. Based on the predation relationship, we study the effects of dragons on other organisms. Analysis of the relationship between the number of dragons and the number of other organisms over a period of time. Then we refer to the PSR model, select the eight indicators of the dragon's stress on the environment and the state of the environment, and combine the AHP and the normalization method to determine the extent of the dragon's impact on the environment.

Further, we analyze the basal metabolic rate and body weight of animals to obtain a power function relationship between them.Various exercise situation weights were obtained by AHP analysis. Finally, combined with the ratio of the basal metabolic energy to the energy intake, the energy intake is obtained.

Besides, based on the reference data, we found that the living area of the dragon is linearly related to the weight and quantity to some extent. According to the weight and quantity of the dragon, we can roughly estimate the living area of the dragon.

Finally, when the climate changes, we analyze the changes in the above model. The model established in this paper allows us to understand the survival of the dragon. We understand the knowledge of mathematical modeling more thoroughly.

Keywords: dragon; ecological impact; ecological requirements; energy expenditures; climate conditions

Content

1 Introduction

1.1 Background

Dragon is a magical species in the fiction "*A Song of Ice and Fire*" [1]that exists as a partner in the protection of human territory. They feed on fish, aquatic invertebrates, and other land animals. Before eating, dragons are fond of roasting the food with dragon flame.

Dragons are exceedingly powerful in nature. Different from ordinary animals, weight of dragons can always growing. In addition, dragons are so large that they can swallow the entire mammoth, breath fire, fly great distances and resist tremendous trauma. Apart from dragon flame, their claws and teeth on the wings are extremely sharp[2]. Dragon scales are the most important means of protection for dragons and can withstand most flames. Dragons are social animals that live in huge caves and breed by producing scaly eggs. As with other animals that migrate, dragons might travel to different regions of the world with very different climates. Its powerful wings allow the dragon to migrate in a large range and have a high survival rate.

Our work and research pay more attention to the dragon characteristics, behaviors, habits, diet and interaction with their environment.

1.2 Restatement of The Problem

The dragon is a reptile with body scales and sharp teeth and claws. When hatched, the dragons are small, roughly 10 kg, but the adult dragon could grow up to swallow the entire mammoth. As with other animals that migrate, dragons might travel to different regions of the world with very different climates.

Many factors influence the development and survival of the dragon, and climate is the most important factor. The climate affects the source of biological food, and the amount of food in the dragon changes, which in turn affects the growth and development of the dragon. We assume climate change as changes in air temperature and relative humidity.

The problems that we need to solve in this paper are:

1. Consider the food, climate impact, and establish a dragon growth model.
2. Definite ecological impact of dragons, including biological impacts and environmental impacts.
3. Determine the energy consumption and calorie intake of dragons.
4. Calculate the area required by the three dragons.
5. Designate community area for one dragon for varying levels of assistance that can be provided to the dragons.
6. Analyze the impact of climate on dragon.
7. provide guidance about how to maintain the realistic ecological underpinning of the fiction "*A Song of Ice and Fire*", with respect to climate change.

1.3 Our Work

Based on dragon characteristics, behaviors, habits, diet and interaction with their environment, we comprehensively analyzed the ecological impact and requirements of the dragons. Afterward, we analyzed the energy expenditures and calorie intake of dragons. We have established different mathematical models to characterize them, as shown in Figure. 1. Subsequently, we defined the living area of dragons. Finally, based on the model built in this paper, we carried out model validity test and sensitivity analysis on the survival of a dragon. The model building relationship is shown in Figure. 1. The core model includes ERM (Ecological Requirements Model), EIM (Ecological Impact Model), CIEEM (Caloric Intake and Energy Expenditures Model) and LAM (Living Area Model)

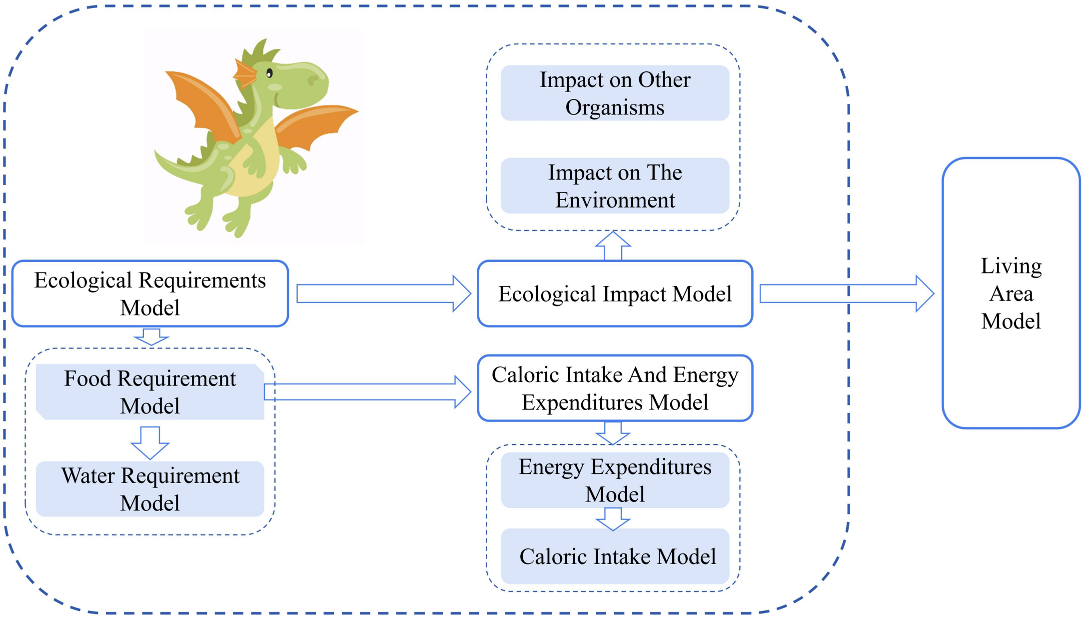


Figure. 1 Research work flow chart.

2 General Assumptions and Symbol Description

2.1 General Assumptions

In order to make the model fit the physical situation, we make the following assumptions to simplify our analysis and model:

- Weight of dragon has been growing until death.
- Factors that affect the survival of the dragon are mainly food, water and climate, regardless of its natural enemies and human activities.
- Ecological Impact of dragons can be considered to include the following two parts: impact on animals and plants, and impact on the environment.
- Energy expenditures of dragons mainly includes two parts: basal metabolic energy and energy consumed by migration
- The living area of the dragon is related to the quantity, intimacy, and the average weight of the dragon.

Each of our assumptions is justified and is consistent with the basic fact.

2. 2 Symbol Description

Table 1: Symbol Description.

Symbol	Description	Symbol	Description
Wt	The weight of Dragon [kg]	$z_{\min}$	Minimum element value in z
S	Dragon's surface area [m^2]	CII	Comprehensive impact index
A_s	Assimilation rate	D_{BMR}	The basal metabolic rate of the dragon
k	Dragon growth rate parameter	E_b	Daily basal metabolic energy of the dragon [J/d]
t	The age of the dragon [year]	E_i	Daily calorie intake of the dragon [J/d]
M	An approximation of the dragon's body weight saturation value [kg]	A	Living area of the dragon [m^2]
F	The weight of food [kg]	D	Number of dragons [ind]
V	The amount of water the dragon needs [kg]	r	Intimacy between dragon and dragon
C_{R1}	The ability of the dragon to prey on other animals	ρ	Habitat distribution density of the dragon [ind/m^2]
I_{R2}	The mortality rate when the dragon survives alone	a_2	The influence factor of temperature on plants
C_{R2}	The ability of other animals to support the dragon	N	Amount of plants [kg]
z	A matrix consisting of raw data for each indicator	H_0	Optimum relative humidity

3 Ecological Requirements Model

Food and water are important factors in maintaining the normal life of the dragon. In order to discuss the ecological requirements of the dragons, we have established an ecological requirements model (ERM), which includes food requirement model (FRM) and water requirement model (WRM).

3. 1 Food Requirement Model

The amount of food a dragon needs is closely related to its growth. The growth of the dragon can be described by referring the *Von Bertalanffy growth model*[3]. As shown in Figure. 1, the growth rate of a living organism in a complete growth process usually has a common feature of slow-fast-slow, as well as the growth of a dragon.

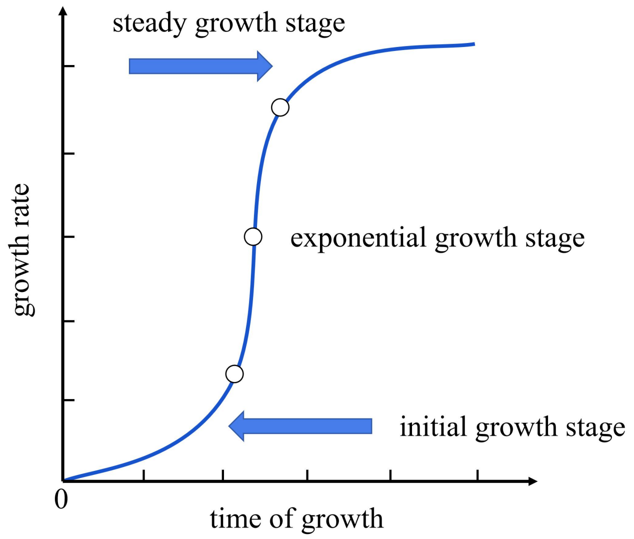


Figure. 2 Sigmoid form curve of growth process.

The *Von Bertalanffy* equation mainly describes the growth form of the dragon. This paper combines the characteristics of the dragon's growth, and the growth model is improved to:

$$W_t = \mathrm{M}(1 - \exp(-kt))^{\frac{1}{(1-2/3)}} \qquad \text{Eq. 1}$$

When growing, the surface area S and body weight W_t of the dragon conforms to the allometric relationship, and this relationship can be expressed as:

$$S = cW_t^{2/3} \qquad \text{Eq. 2}$$

Where c and S are related to the magnitude of the W_t measurement index.

According to the Bertalanffy suppose, the weight growth rate of the dragon is the difference between the assimilation rate A_s and the alienation rate A_l. The assimilation rate A_s is proportional to the surface area of the dragon(Eq. 3), The rate of alienation A_l is proportional to the weight of the dragon(Eq. 4). The relationship can be expressed as:

$$A_s = \eta W_t^{2/3} \qquad \text{Eq. 3}$$

$$A_l = \gamma W_t \qquad \text{Eq. 4}$$

$$\frac{dW_t}{dt} = \eta W_t^{2/3} - \gamma W_t \qquad \text{Eq. 5}$$

Where η , γ are parameters related to species type and environmental conditions.

General solution of Eq. 5 is

$$W_t = \left\{ \frac{\eta}{\gamma} + c\exp[-(1-\frac{2}{3})\gamma t] \right\}^{\frac{1}{(1-2/3)}} \qquad \text{Eq. 6}$$

Assuming that the initial condition of dragon growth is t=0, Wt=0, combining Eq. 5, and a special solution can be obtained. See Equation 5.

$$W_t = \left\{ \frac{\eta}{\gamma} - \frac{\eta}{\gamma} \times \exp[-\gamma(1-\frac{2}{3})t] \right\}^{\frac{1}{(1-2/3)}} \qquad \text{Eq. 7}$$

When $t \to \infty$, $W_t = (\frac{\eta}{\gamma})^{1/(1-2/3)}$ .And for $(\frac{\eta}{\gamma})^{1/(1-2/3)} = \mathrm{M}$， $\gamma(1-\frac{2}{3}) = k$

Therefore, Eq. 7 can be written as:

$$W_t = \mathrm{M}(1\text{-}\exp(-kt))^{\frac{1}{(1-2/3)}} = \mathrm{M}(1\text{-}\exp(-kt))^3 \qquad \text{Eq. 8}$$

Where M is an approximation of the dragon's body weight saturation value, k is a parameter proportional to the growth rate.

(1) Determination of M

The dragon continues to grow throughout their life, it has no upper limit on its weight. The weight of the dragon is affected by its age t, the weight of food F . The body weight increases with the increase of t and F ,and the growth rate gradually becomes gentle. We try to describe this change using a logarithmic function, the effect on the weight of dragon can be expressed as follows.

$$\mathrm{M} = \lambda \cdot t \cdot \ln(t \cdot \mathrm{F}) \qquad \text{Eq. 9}$$

Under ideal environmental conditions, the growth equation of the dragon is:

$$W_t = \mathrm{M}(1 - \exp(-k_{\max} t))^3 \qquad \text{Eq. 10}$$

(2) The relationship between k and $k_{\max}$

The richness of food resources will affect the growth rate of the dragon, and the influence factor of the amount of food on the growth rate is a_1 .Therefore, in actual conditions, the maximum growth rate parameter $k_{\max}$ of the dragon has the following relationship with the growth rate parameter k[8]. Expressed by Eq. 11.

$$k = a_1 k_{\max} \qquad \text{Eq. 11}$$

In this paper, the growth rate parameter of the dragon increases with the increase of the weight of the food. The closer the k is to $k_{\max}$, the smaller the increase. When k=$k_{\max}$, the growth rate parameter of the dragon is no longer increased. Therefore, the growth function with the weight F of the food can be expressed as:

$$a_1 = \begin{cases} 1 - e^{-\lambda F}, & 0 < F < F_w \\ 1, & F \geq F_w \end{cases} \qquad \text{Eq. 12}$$

Where F_w is corresponding food weight when k is exactly equal to $k_{\max}$, $\lambda = 1.63$.
Eq. 12 can be represented by Figure 3.

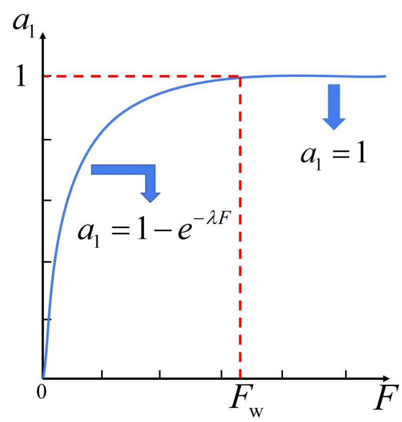


Figure. 3 The growth factor of the growth rate parameter varies with food weight.

In summary, combined with Eq. 8 and Eq. 9, we can get the food requirement model:

$$W_t = \begin{cases} \ln(t \cdot F) \cdot [1\text{-}\exp(-k_{\max} t)]^3, F > F_w \\ \ln(t \cdot F) \cdot [1\text{-}\exp(-(1-e^{-\lambda F}) k_{\max} t)]^3, 0 \le F \le F_w \end{cases} \quad \text{Eq. 13}$$

3. 2 Water Requirement Model

The size of water the dragon needs is proportional to its body weight W_t and can be expressed as[5]:

$$V \propto 0.06 W_t \quad \text{Eq. 14}$$

At the same time, the air temperature will affect the amount of water the dragon needs, and the proportional relationship can be expressed as:

$$V \propto e^{\frac{T}{T_0}-1} \quad \text{Eq. 15}$$

Combining Eq. 14 and Eq. 15, the relationship between the weight of the dragon and the amount of water the dragon needs and the temperature of the environment can be expressed by the following formula:

$$V = 0.06 W_t e^{\frac{T}{T_0}-1} \quad \text{Eq. 16}$$

In summary, the greater the weight of a dragon, the more water it needs to carry out life activities. When the temperature of the environment is higher than the optimum height, the amount of water the dragon needs also increases rapidly. This relationship can be represented by Figure. 4.

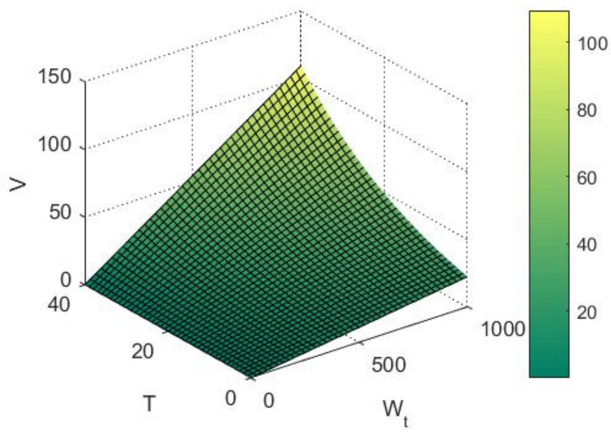


Figure. 4 The relationship between the amount of water required temperature, weight.

4 Ecological Impact Model

The dragon is absolutely powerful in nature and can be considered as no competitors. This paper establishes ecological impact model, including two aspects: impact on other organisms and impact on the environment.

Based on the predation relationship between dragons and other organisms, we studied the impact of dragons on other organisms and determined the relationship between the number of dragons and the number of other organisms. In addition, we used AHP to analyze the impact of dragons on the environment and to assess the extent of the dragon's interference with the environment.

4. 1 Impact on Organisms

When organisms live independently, the growth of quantity $R(u)$ should obey the Malthusian model[9]. When the dragon is present, being eaten by the dragon is an important cause of death of other creatures.The encounter between the two species is accidental. The chance of encounter is proportional to the population size of the two groups. Therefore, the correction based on the Malthusian model can be expressed by the following formula.

$$\frac{dR}{du} = I_{R1}R - C_{R1}DR \qquad \text{Eq. 17}$$

Where u is time, I_{R1} is the growth rate of other animals living independently, C_{R1} is the ability of the dragon to prey on other animals, D is the number of dragons.

The dragon's growth rate and natural mortality rate are directly proportional to the population $D(u)$, and the part that meets other animals can survive, so its effective birth rate is proportional to the number of two species.

$$\frac{dD}{du} = -I_{R2}D + C_{R2}DR \qquad \text{Eq. 18}$$

Where I_{R2} is the mortality rate when the dragon survives alone, C_{R2} is the ability of other animals to support the dragon.

The growth regularity of other animals and dragons can be described by ordinary differential equations (Volterra model).

$$\begin{cases} \dfrac{dR}{du} = I_{R1}R - C_{R1}DR \\ \dfrac{dD}{du} = -I_{R2}D + C_{R2}DR \end{cases} \quad (I_{R1} > 0, I_{R2} > 0, C_{R1} > 0, C_{R2} > 0) \qquad \text{Eq. 19}$$

4. 2 Results about Impact on Organisms

Simplify the Volterra model (Eq. 19) to obtain separable variable equations, we can get :

$$\frac{-I_{R2} + C_{R2}}{R} dR = \frac{I_{R1} - C_{R1}D}{D} dD \qquad \text{Eq. 20}$$

Then the two sides can be integrated to get the general solution of D.

$$(R^{I_{R2}} e^{-C_{R2}R})(D^{I_{R1}} e^{-C_{R1}D}) = \sigma \qquad \text{Eq. 21}$$

Where the constant σ is determined by the initial conditions of the number of dragons and other animals.

The solution of Eq. 19 describes the variation of the number of other animals and dragons over time, but the analytical solution of it cannot be obtained, so it needs to be solved by a numerical algorithm.
For $I_{R1} = 4, C_{R1} = 0.9, I_{R2} = 0.9, C_{R2} = 0.8$, combining with Eq. 19 and Eq. 21, we can get:

$$\begin{cases} \dfrac{dR}{du} = 4R - 0.9DR \\ \dfrac{dD}{du} = -0.9D + 0.8DR \end{cases} \qquad \text{Eq. 22}$$

$$(R^{0.9}e^{-0.8})(D^{4}e^{-0.09D}) = \sigma \qquad \text{Eq. 23}$$

For $R_1 = 3$, $D_1 = 10$, $R_2 = 3$, $D_2 = 3$, We can use Matlab to obtain the numerical solution of the model and show the variation of the number of other organisms and dragons with time, as shown in Figure. 3, Figure. 4.

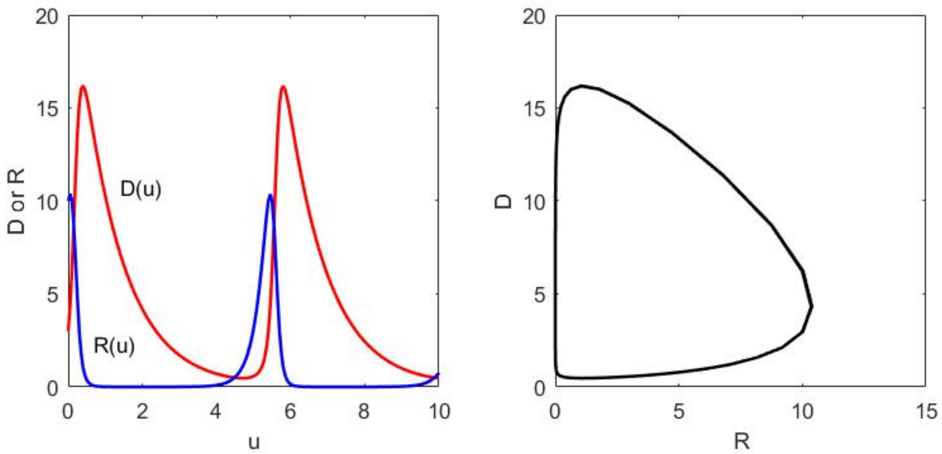


Figure. 5 The impact of dragons on other organisms ($R_1 = 3$, $D_1 = 10$).

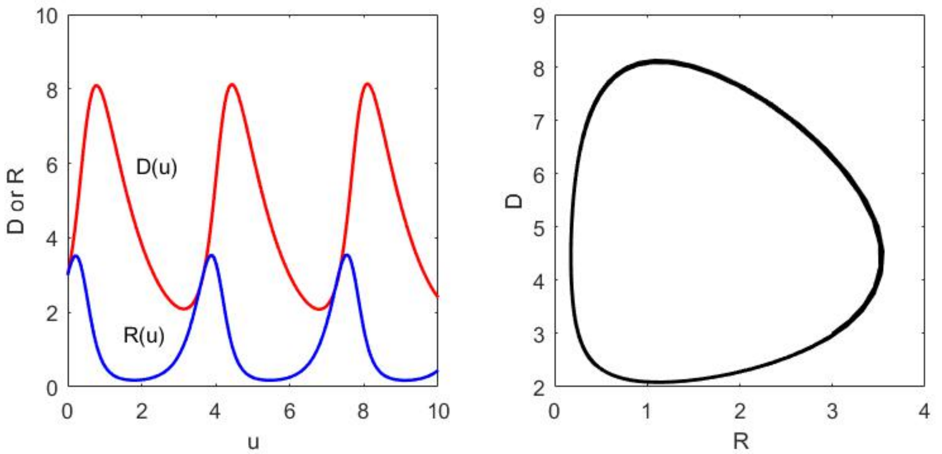


Figure. 6 The impact of dragons on other organisms ($R_2 = 3$, $D_2 = 3$).

4. 3 Impact on The Environment

In order to evaluate the impact of the dragon on the environment, we built a comprehensive evaluation model based on the PSR model[4](Pressure-State-Response). This article assumes that the dragon survives in an ideal environment and is not affected by human activities. Therefore, we analyzed the two aspects of “the pressure of the dragon on the environment” and the “state of environmental ”, and selected eight indicators that can effectively reflect the degree of influence. The evaluation system is summarized as the project layer, the element layer, and the indicator layer. The structure of each level is shown in the following table.

Table. 1 Relevant indicators of the "Dragon-to-biological impact" evaluation system.

Project layer	Element layer	Indicators layer
The pressure of the dragon on the environment	Dragon's population basic information	Number of dragons (C1)
		Living area of the dragon (C2)
	Dragon's life activity information	Dragon metabolism (C3)
		Dragon's influence on other animals (C4)
The state of environmental	Environmental sustainability	Size of space (C5)
		Specie richness (C6)
	Environmental climatic conditions	The annual average temperature (C7)
		The average annual precipitation (C8)

To determine the weight of each indicator, this paper uses AHP to construct two pairwise comparison matrix based on the eight indicators of the above two aspects. The matrix is represented by Table. 2, Table. 3 below respectively.

Table. 2 Pairwise comparison matrix between C1,C2,C3,C4.

	C1	C2	C3	C4
C1	1	1/2	3	1/2
C2	2	1	4	1
C3	1/3	1/4	1	1/5
C4	2	1	5	1

Table. 3 Pairwise comparison matrix between C5,C6,C7,C8.

	C5	C6	C7	C8
C5	1	1/5	2	2
C6	5	1	4	4
C7	1/2	1/4	1	1
C8	1/2	1/4	1	1

Through the AHP to calculate the above matrix and pass the consistency test, the weight coefficient for each indicator can be obtained. The calculation results are shown in the table below.

Table. 4 Weight coefficient for each index.

C1	C2	C3	C4	C5	C6	C7	C8
0.1177	0.2127	0.0455	0.2241	0.0736	0.2355	0.0454	0.0454

4. 4 Results about Impact on The Environment

(1) Normalization

In order to eliminate the difference in dimensions, we normalize the raw data of different evaluation indicators. Specifically, we classify the indicators C1, C2, C3 and C4 as positive indicators. The higher the value of such indicators, the greater the impact of the dragon on the environment. Normalization can be achieved with the following formula.

$$Z=(z-z_{\min})/(z_{\max}-z_{\min}) \quad \text{Eq. 24}$$

We classify C5, C6, C7 and C8 as reverse indicators. The larger the value of such indicators, the more fragile the environment. Normalization can be achieved with the following formula.

$$Z=(z-z_{\max})/(z_{\min}-z_{\max}) \quad \text{Eq. 25}$$

Where z is a matrix consisting of raw data for each indicator, Z is a matrix consisting of the normalized results of the raw data of each indicator, $z_{\min}$ is minimum element value in z, $z_{\max}$ is maximum element value in z.

By normalizing the raw data for each indicator, the normalized values of each indicator can be obtained, as shown in the following table.

Table. 5 Normalized results of raw data for each indicator.

C1	C2	C3	C4	C5	C6	C7	C8
0.0833	1.0	0	0.375	1	0.9326	0.9067	0

(2) Comprehensive Evaluation

Based on the PSR model, we determined the extent of the impact on the environment of the Dragon. The comprehensive impact index (CII) in the PSR model is used to reflect the extent to which the dragon has an impact on the environment. Use Eq. 26 to determine.

$$CII = CPI + CSI \quad \text{Eq. 26}$$

Where CPI is comprehensive pressure index, CSI is comprehensive state index.

CPI reflects the stress conditions of the entire environment:

$$CPI = 100\sum_{j=1}^{b_1} G_j Z_j \quad \text{Eq. 27}$$

Where b_1 is the number of evaluation indicators related to 'the pressure of the dragon on the environment' ($1 \le b_1 \le 4$), Z_j is the normalized value of the Cj of 'Dragon's pressure on the environment' ($0 \le Z_j \le 1$), G_j is the weight of Cj.

CSI reflects the state of the environment:

$$CSI = 100\sum_{i=5}^{b_2} G_i Z_i \quad \text{Eq. 28}$$

Where b_2 is the number of evaluation indicators related to 'the state of the environment' ($5 \le b_2 \le 8$), Z_i is the normalized value of the Ci of 'The state of the environment ($0 \le Z_i \le 1$), G_i is the weight of Ci.

In summary, we can get the CII of the dragon's impact on the environment. The results are shown in the table below.

Table. 6 Evaluation results on 'Dragon's impact on the environment.

CPI	CSI	CII
30.6563	33.4475	64.1038

Based on the relationship between the degree of influence and the numerical value of CII, it can be judged that the dragon has serious interference to the environment, and the impact is large. In the long run, the entire ecosystem will be seriously damaged.

5 Caloric Intake and Energy Expenditures Model

This paper believes that dragon's energy expenditures mainly includes two parts: basal metabolic energy and energy consumed by migration. Based on the energy consumption model of carnivorous animals, this paper uses AHP to analyze the weight of the three modes of travel in the migratory activities, and determine the total energy consumption of the dragon. In addition, we think the calorie intake of the dragon, including the amount of manure and assimilation. By studying the relationship between basal metabolism and assimilation, we can determine the calorie intake of the dragon.

5. 1 Energy Expenditures Model

5. 1. 1 Basal Metabolic Rate

The dragon is a carnivore and weight is the most important factor affecting the basal metabolic rate. Based on the study of the energy and body weight of 62 carnivores, we can get the relationship between basal metabolic rate and body weight of carnivores. As shown in Figure. 7.

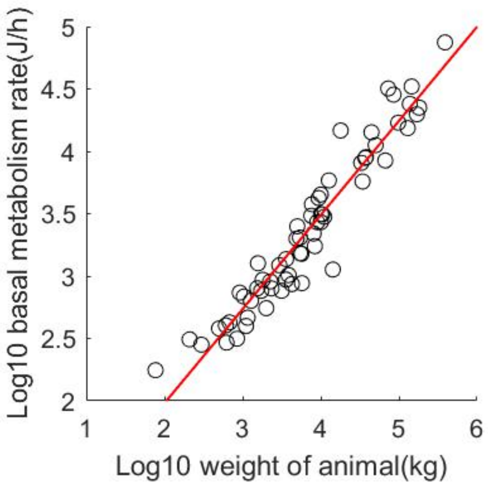


Figure. 7 $\log 10$ basal metabolic rate as a function of $\log 10$ weight of animal.

Based on Figure. 5, the basal metabolic rate as a function of animal body weight can be expressed by Eq. 27.

$$\mathrm{Log}_{10}(\mathrm{BMR}) = 0.754 \cdot \log_{10}(\mathrm{mass}) + 0.472 \qquad \text{Eq. 29}$$

When Eq. 29 is take out of logarithms, it becomes:

$$\mathrm{BMR} = 2.96 m^{0.754} \qquad \text{Eq. 30}$$

Where m is mass in kilograms.The unit of BMR is J/h.

Therefore, we can also use this relationship to describe the relationship between the basal metabolic rate of the dragon and its body weight.

The basal metabolic rate of the dragon is $\mathrm{D}_{\mathrm{BMR}}$, so the relationship between $\mathrm{D}_{\mathrm{BMR}}$ and body weight Wt can be show:

$$\mathrm{D}_{\mathrm{BMR}} = 2.96 W_t^{0.754} \qquad \text{Eq. 31}$$

So the daily basal metabolic energy of the dragon E_{b} is:

$$\mathrm{E}_b = 24 \times \mathrm{D}_{\mathrm{BMR}} = 71.04 W_t^{0.754} \qquad \text{Eq. 32}$$

The unit of E_{b} is J/d.

5. 1. 2 Migration Energy Consumption

As with other animals that migrate, dragons might travel to different regions of the world with very different climates. In the process of migration, it takes a long time and a long distance to travel. During the migration process, assume that they are alternately carried out in three ways: walking, running, and flying , and mainly flying. In order to determine their respective weights, we use AHP to solve the problem by constructing a judgment matrix in three ways: walking, running, and flying.

The evaluation matrix is shown in Table. 7.

Table. 7 Matrix for judging migration mode.

	fly	run	walk
fly	1	7	9
run	1/7	1	3
walk	1/9	1/3	1

The results calculated by AHP are shown in Table. 8.

Table. 8 The weight of migration mode.

Migration mode	fly	run	walk
weight	0.7854	0.1488	0.0658

Therefore, the energy consumption during the migration of the dragon is:

$$E_q = 0.7854E_f + 0.1488E_r + 0.0658E_w \qquad \text{Eq. 33}$$

Where E_f is the energy consumption of flying during dragon migration, E_r is the energy consumption of running during dragon migration, E_w is the energy consumption of walking during dragon migration.

Generally, the average animal's energy consumption during flight is about 40 times that of the basal metabolic energy[3]. So we can get:

$$E_f = 40E_b \qquad \text{Eq. 34}$$

When the animal is running, the energy consumption will be three times that of the basal metabolic energy. So we can get:

$$E_r = 3E_b \qquad \text{Eq. 35}$$

The energy expenditure of animals while walking can be regarded as equal to the amount of basal metabolic energy. So we can get:

$$E_w = E_b \qquad \text{Eq. 36}$$

Based on the above relationship, the energy consumption of the dragon during migration is about 32 times that of the basal metabolic energy.

$$E_{\mathrm{q}} = 32E_{\mathrm{b}} = 2273.28W_t^{0.754} \qquad \text{Eq. 37}$$

5. 2 Caloric Intake Model

The dragon is a warm-blooded animal, so the energy is in line with this relationship: intake = assimilation amount + fecal volume. Among them, the amount of feces in carnivores is usually 21% of the amount of food. Of the assimilation amounts, 68% were used for breathing, 23% for growth, and 9% for urine. Therefore, the basic metabolic energy accounts for about 72% of the total calorie intake. It can be known that the daily calorie intake of the dragon E_i is:

$$E_i = E_b / 0.72 = 98.67 W_t^{0.754} \quad \text{Eq. 38}$$

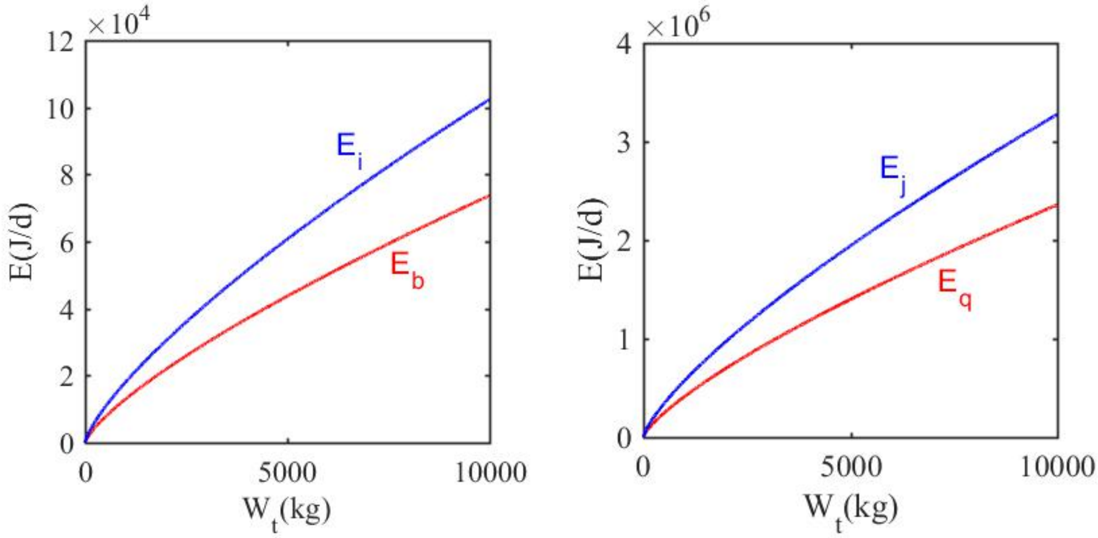
The unit of E_i is J/d.

When the dragon conducts migratory activities, it consumes more energy than usual. We can know the daily calorie intake during the dragon migration E_j is:

$$E_j = E_q / 0.72 = 3157.3 W_t^{0.754} \quad \text{Eq. 39}$$

The unit of E_j is J/d.

From the above analysis, it can be known that the energy expenditures and caloric intake requirements of dragons are proportional to the basal metabolic energy. Moreover, the basal metabolic energy is exponentially related to the weight of the dragon, so the energy expenditures and caloric intake requirements can be obtained as a function of the weight of the dragon. The above relationship can be represented by Figure. 8 .



(a) Migration activity (b) Daily activities

Figure. 8 The energy expenditures and caloric intake requirement of dragons.

6 Living Area Model

6. 1 Living Area Model

This paper believes that the dragon can continue to breed, referring to the bee colony effect, it can be considered that the intimacy between the dragon and the dragon increases with its quantity, which can be expressed by the following functional relationship.

$$r = \log_2(D+1) \quad \text{Eq. 40}$$

Where r is the intimacy between the dragon and the dragon, D is the number of dragons.

Among the habitats of dragons, topography, food, and water are the main factors determining the appropriate habitat. The dragon is a large carnivorous animal whose habitat density is a function of body weight. At the same time, consider the influence of the intimacy between the dragon and the dragon on the habitat density. The above relationship can be expressed by the following formula.

$$\rho = W_t^{-0.8} r \zeta \quad \text{Eq. 41}$$

Where ρ is the habitat density, ζ is density correction factor.

Because the area required for supporting dragons, the number of dragons and population density can be expressed as:

$$A(D) = \frac{D}{\rho} \qquad \text{Eq. 42}$$

Therefore, the required area for supporting the dragon can be written as:

$$A(D) = \frac{D}{W_t^{-0.8}\log_2(D+1)\zeta} \qquad \text{Eq. 43}$$

The relationship of Eq. 40 can be represented by Figure. 6 .

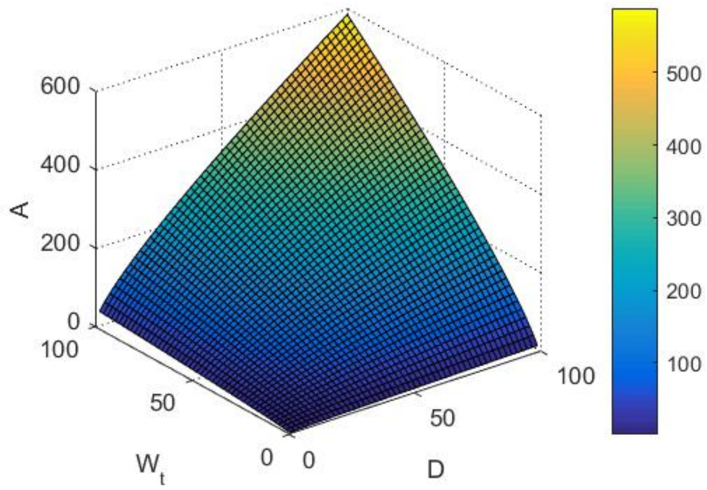


Figure. 9 The relationship between the living area of and the weight and quantity

6. 2 Results about Living Area Model

According to Eq. 45, we can know that when the number D of dragons is 3 and ζ=0.001 , Eq. 43 can become:

$$A(3) = \frac{3000}{2W_t^{-0.8}} \qquad \text{Eq. 44}$$

The area required to support three dragons can be approximated to a certain extent as being related only to the weight of the dragon.The relationship between the living area and body weight of the three dragons can be represented by the following figure.

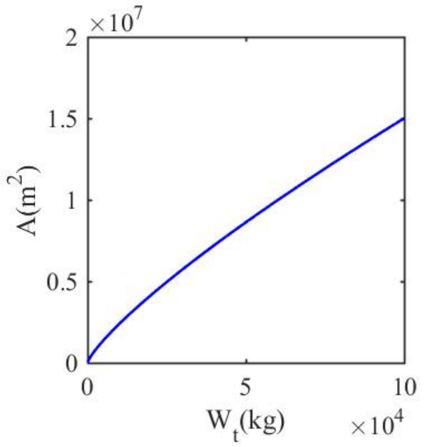


Figure. 10 Relationship between living area and body weight of three dragons.

As can be seen from Figure. 10, the living area of the three dragons increases with the increase in body weight. Considering that the dragon's weight is constantly changing, this article only needs to discuss their functional relationship.

7 Model Analysis and Application

7. 1 Climate Impact

The dragon has migratory activities and encounters different climates. This paper simplifies climate change into changes in temperature and relative humidity. Temperature and relative humidity changes do not affect the food requirements of the dragon, but will affect the vegetation coverage and affect the food source of the dragon. According to Eq. 15, it can be seen that the growth of the dragon will be affected. This section discusses changes in the amount of food under changes in temperature and relative humidity[5].

(1) Temperature effect

The amount of plant growth under optimal conditions is set to $\mathrm{N}_{\max}$, and the influence factor of temperature on plants is a_2. The actual amount of plant growth N and $\mathrm{N}_{\max}$ have the following functional relationship.

$$\mathrm{N}=\begin{cases} a_2 \mathrm{N}_{\max}, 0 \le a_3 \le 1, \mathrm{T} \ne \mathrm{T}_0 \\ N_{\max}, \mathrm{T}=\mathrm{T}_0 \end{cases} \qquad \text{Eq. 45}$$

Where T_0 is the optimum temperature.

Because the effect of temperature on plant photosynthesis is shown in Figure. 9 Therefore, the trend of influence factor a_2 with temperature can be described by Gauss function.

$$a_2=\frac{1}{\sqrt{2\pi}}\exp\left[\frac{-(T-T_0)^2}{2\sigma_T^2}\right] \qquad \text{Eq. 46}$$

Where σ_T is the variances of temperature distribution.

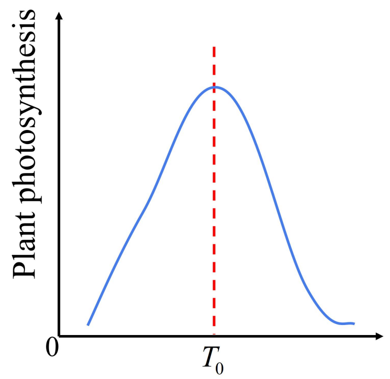


Figure. 11 Temperature influence.

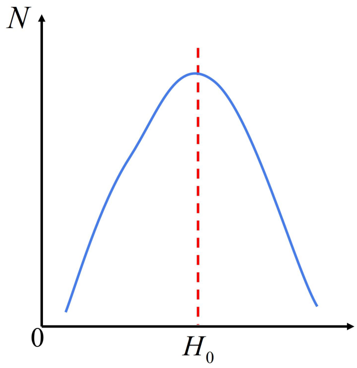


Figure. 12 Relative humidity effect.

(2) Relative humidity effect

The influence factor of temperature on plants is a_3 .The actual amount of plant growth N and $\mathrm{N}_{\max}$ have the following functional relationship.

$$\mathrm{N}=\begin{cases} a_3 \mathrm{N}_{\max}, 0 \le a_3 \le 1, \mathrm{T} \ne \mathrm{T}_0 \\ N_{\max}, \mathrm{T}=\mathrm{T}_0 \end{cases} \qquad \text{Eq. 47}$$

Since the influence of humidity on the amount of plants is shown in Figure. 10, the trend of the influence factor a_3 with relative humidity can be described by Gauss function.

$$a_3 = \frac{1}{\sqrt{2\pi}} \exp\left[\frac{-(\mathrm{H}-H_0)^2}{2\sigma_H^2}\right] \quad \text{Eq. 48}$$

Where H_0 is the optimum relative humidity.

(3) Climate impact

Based on the effects of temperature and relative humidity, we can know the impact of climate on the amount of plant . Expressed by Equation 3.

$$\mathrm{N} = a_2 a_3 \mathrm{N}_{\max} \quad \text{Eq. 49}$$

Based on the energy transfer principle of the food chain, we can know that the amount of food the dragon needs is proportional to the amount of the plant. Therefore, the amount of food is expressed under the influence of climate:

$$F' = a_2 a_3 F \quad \text{Eq. 50}$$

Therefore, based on the limitations of food and climatic factors, the dragon's weight growth model changes to:

$$W_t' = \begin{cases} \ln(\mathrm{t} \cdot a_2 a_3 F) \cdot [1\text{-}\exp(-k_{\max} t)]^3, a_2 a_3 \mathrm{F} > \mathrm{F_w} \\ \ln(\mathrm{t} \cdot a_2 a_3 F) \cdot [1\text{-}\exp(-(1-\mathrm{e}^{-a_2 a_3 \lambda F})\mathrm{k}_{\max}\,\mathrm{t})]^3, 0 \le a_2 a_3 \mathrm{F} \le \mathrm{F_w} \end{cases} \quad \text{Eq. 51}$$

From the above analysis, it can be known that when the climate changes, the influence factors a_2 and a_3 change, which causes the amount of plant to change, and the dragon's food quantity changes, thereby causing the dragon's body weight to change. Therefore, it can be judged that the climate has a great influence on the establishment of the entire model of this paper.

7. 2 Dragon Living Community Area

Based on the ecological requirements, ecological impacts and comprehensive analysis of energy expenditures and caloric intake requirement of dragons, this paper analyzes the community area which is necessary to support a dragon for varying levels of assistance that can provided to the dragon.

We discusses how the weight of a dragon changes when considering the average relative humidity and average temperature of the three climates in arid, warm temperate, and arctic regions, respectively.

Based on the living area model, we can get that when the number D of dragons is 1 and ζ=0.001 , the living area is:

$$A(1) = \frac{1000}{W_t^{-0.8}} \quad \text{Eq. 52}$$

Based on the ecological requirement model, the growth equation of the dragon is as follows.

$$W_t = \begin{cases} \ln(\mathrm{t} \cdot F) \cdot [1\text{-}\exp(-k_{\max} t)]^3, \mathrm{F} > \mathrm{F_w} \\ \ln(\mathrm{t} \cdot F) \cdot [1\text{-}\exp(-(1-\mathrm{e}^{-\lambda F})\mathrm{k}_{\max}\mathrm{t}]^3, 0 \le \mathrm{F} \le \mathrm{F_w} \end{cases} \quad \text{Eq. 53}$$

So living area can be expressed as:

$$A(1)=\begin{cases}\dfrac{1000}{\left(\ln(\mathrm{t}\cdot F)\cdot[1\text{-}\exp(-k_{\max}t)]^{3}\right)^{-0.8}}, \mathrm{F}>\mathrm{F_w}\\ \dfrac{1000}{\left(\ln(\mathrm{t}\cdot F)\cdot[1\text{-}\exp(-(1-\mathrm{e}^{-\lambda F})\,\mathrm{k}_{\max}\mathrm{t}]^{3}\right)^{-0.8}}, 0\le \mathrm{F}\le \mathrm{F_w}\end{cases} \quad \text{Eq. 54}$$

It can be known from Eq. 54 that the factors determining the area of a dragon community are the age of the dragon and the amount of food required. In addition,the amount of food is affected by the climate, which is the effect of temperature and relative humidity.

This article takes the age of the dragon to be 1 year old and discusses the area of the community it needs. The relationship between community size and body weight can be represented by Figure. 13.

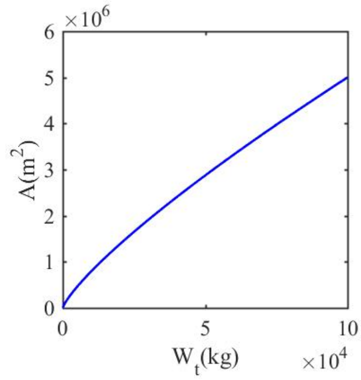


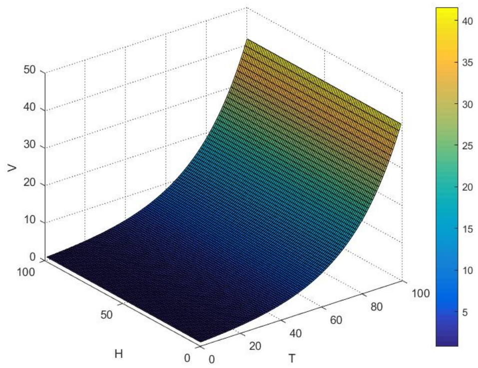
Figure. 13 Relationship between community size and body weight (age = 1).

Similarly, based on the ecological requirements model and caloric intake and the energy expenditures model, we can know the relationship among the weight of dragon, ecological requirements, energy expenditures and caloric intake requirements. Below we will discuss the amount of water and food needed for the four different ages when the dragon lives in the community. First, based on the water requirement model, we can get the relationship between the amount of water needed by the dragon and the body weight.

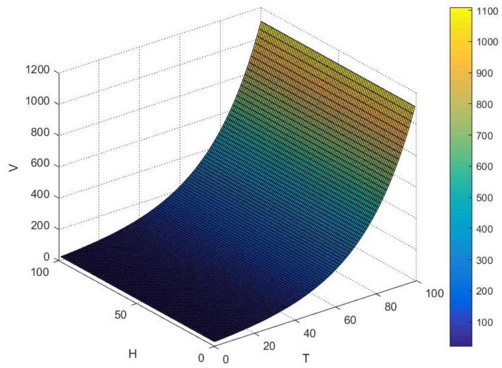
The amount of water the dragon needs is:

$$V=0.06W_{\mathrm{t}}\mathrm{e}^{\frac{T}{T_0}-1} \quad \text{Eq. 55}$$

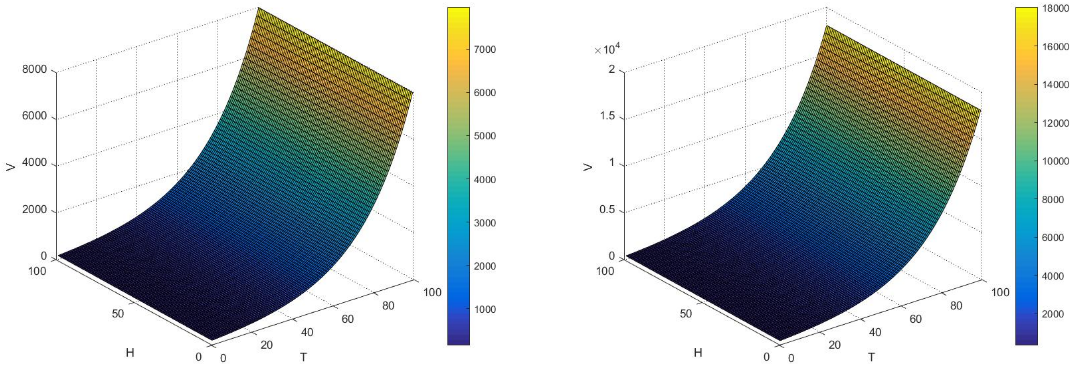
Figure. 14 shows the relationship between water demand and climate change at four different ages.



(a) At the age of 1



(b) At the age of 10



(c) At the age of 50 (d) At the age of 100

Figure. 14 Relationship between water demand and climate change.

Then based on the caloric intake and energy expenditures model, we can get the relationship between dragon energy intake and body weight.

The daily calorie intake of the dragon is:

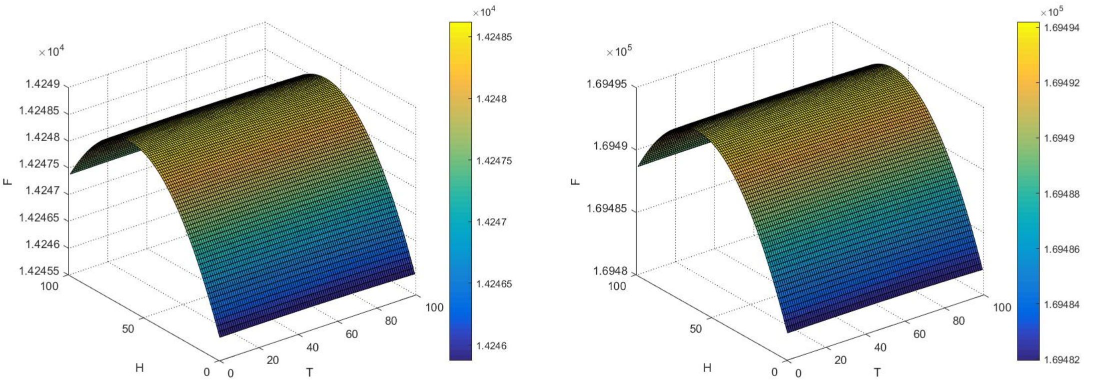
$$\mathrm{E_i} = \mathrm{E}_b / 0.72 = 98.67 W_t^{0.754} \quad \text{Eq. 56}$$

So the amount of food the dragon needs in the community every day is:

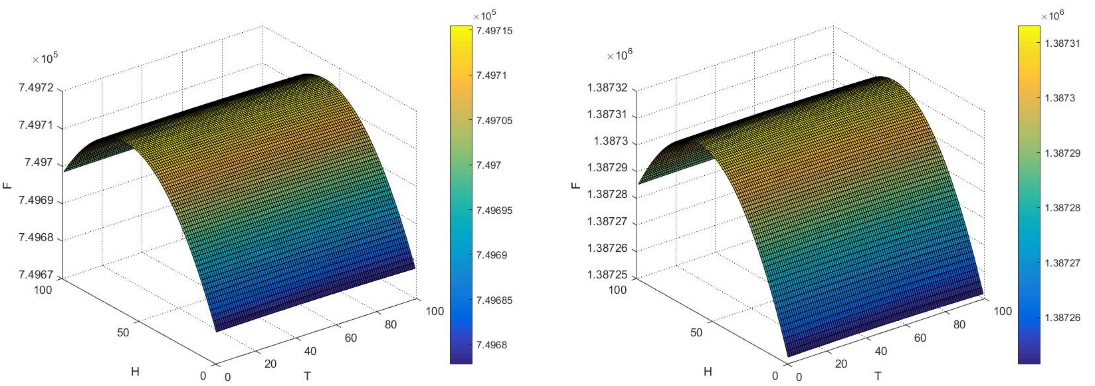
$$F = 98.67 W_t^{0.754} / BF \quad \text{Eq. 57}$$

Where BF is 1kg of food contains energy.

Figure. 15 shows the relationship between caloric intake and climate change at four different ages.



(a) At the age of 1 (b) At the age of 10



(c) At the age of 50 (d) At the age of 100

Figure. 15 Relationship between caloric intake and climate change.

8 Sensitivity Analysis

In the impact on the environment model, we use the comprehensive impact index (CII) to characterize the extent to which the dragon has an impact on the environment. The sensitivity of this model is closely related to the comprehensive impact index, so the sensitivity we define for this model is:

$$S_t = (CII_b - CII_a) / CII_a \qquad \text{Eq. 58}$$

Where S_t is sensitivity, CII_a is the original comprehensive impact index, CII_b is the original combined impact index after the change.

In the impact on the environment model, when the pairwise comparison matrix of the pressure of the dragon on the environment is:

Table. 9 Original Pairwise comparison matrix

	C1	C2	C3	C4
C1	1	1/2	3	1/2
C2	2	1	4	1
C3	1/3	1/4	1	1/5
C4	2	1	5	1

When the other conditions remain unchanged, the original combined impact index (CII) is 64.1038.

When changing the pairwise comparison matrix of the pressure of the dragon on the environment, it becomes:

Table. 10 Changed pairwise comparison matrix

	C1	C2	C3	C4
C1	1	1/3	3	1/2
C2	3	1	4	1
C3	1/3	1/4	1	1/5
C4	2	1	5	1

When other conditions remain unchanged, the comprehensive impact index becomes 65.7523, which is CII_b=65.7523 . The calculated sensitivity is 2.57%.

9 Strengths and Weaknesses

9. 1 Strengths

- Our model fully considers the main factors of the dragon's impact on the environment, and can objectively measure the extent of the dragon's impact on the environment.
- Our model studies the relationship between aquaculture area and the weight of the dragon, and provides guidance for the livestock industry to expand the area.
- Our model successfully simulated the effects of climate on the growth of plants and animals.
- Our model considers all aspects of the dragon. The model is complete and highly mobile, and can be used as a reference for studying other animals.

9. 2 Weaknesses

- The optimum temperature for plant growth in warm temperate zones comes from Guangzhou and is not sufficiently representative.
- In the dragon's impact on the environment model, fewer factors are considered.

10 Conclusion and Future Work

10. 1 Conclusion

From the above analysis,we can come to a conclusion that dragon can affect ecosystems to a large extent, mainly in the impact on other organisms and the environment. Based on the Bertalanffy model, we analyzed the effects of different food conditions, deduced the growth equation of the dragon, and determined the parameters in combination with the known conditions of the dragon hatching and the weight after one year of growth, and finally obtained the growth model of the dragon under different food conditions.

We use the AHP algorithm to analyze the weights of various sports situations to calculate the energy consumption of the dragon during migration. Finally, combined with the ratio of the basic energy consumption to the intake, the intake in the first two states is obtained. The living area of the dragon is closely related to the weight and quantity. In arid regions, warm temperate zones and the Arctic, the climate affects the vegetation through temperature and soil moisture, which affects the dragon's food intake and thus affects the dragon's life activities

10. 2 Future Work

As mentioned in the shortcomings, we only considered a limited number of factors when building the model. In the future we can propose the following solutions that can make the model more complete:

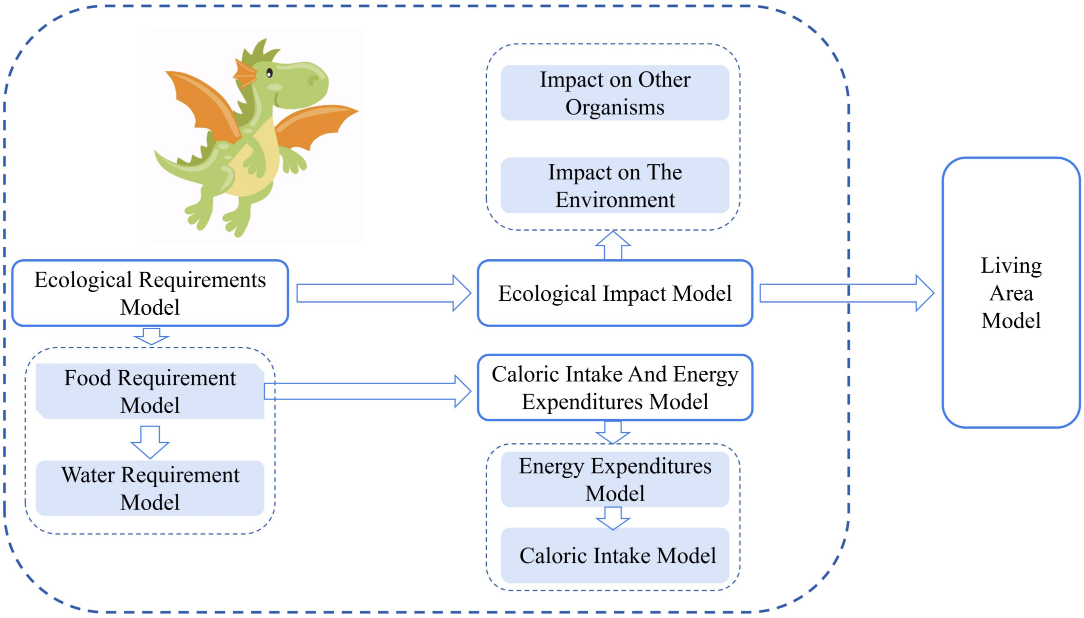
- Consider the energy that the dragon needs to consume when it squirts out the flame, while looking for more accurate data that determines the energy intake of the dragon, establishing a complete energy consumption and intake model.
- Consider more factors that can characterize climate change, such as wind speed, precipitation, solar exposure, etc., to accurately determine the relationship between the weight of the dragon and other parameters.
- The dragon's growth equation is optimized based on the actual situation to meet the requirements of the dragon's infinite growth, which can make the model more rigorous.

11 A letter to George RR

Dear Mr. George RR:

We are honored to be able to get in touch with your excellent work when we participate in this mathematical modeling competition. Based on the description of the dragon in the work, we have completed the basic judgments of the dragon's characteristics, behaviors, habits, diet and the environment. This has been very helpful for us to carry out research on the mathematical model of the dragon. From the results of the modeling, we feel that it is necessary to share with you the results of our research on the dragon.

In this modeling work, we mainly studied the ecological requirements, ecological impact, energy consumption and intake, living area and other issues of the dragon, and established related models. The specific process can be seen in the figure below.



Below we would like to share the results of our research with you to show respect for you and your work. In particular, the impact of climate on dragon life activities. The energy consumption of the dragon during migration is about 32 times that of the basal metabolic energy.

$$E_q = 32E_b = 2273.28W_t^{0.754}$$

The daily calorie intake during the dragon migration E_j is:

$$E_j = E_q / 0.72 = 3157.3W_t^{0.754}$$

After considering the climate impact, we can get the weight of the dragon:

$$W_t' = \begin{cases} \ln(t \cdot a_2 a_3 F) \cdot [1\text{-}\exp(-k_{max} t)]^3, a_2 a_3 \mathrm{F} > \mathrm{F_w} \\ \ln(t \cdot a_2 a_3 F) \cdot [1\text{-}\exp(-(1 - \mathrm{e}^{-a_2 a_3 \lambda F}) \mathrm{k_{max}}\, \mathrm{t})]^3, 0 \le a_2 a_3 \mathrm{F} \le \mathrm{F_w} \end{cases}$$

Through analysis, we found that during the migration process, the amount of food changed due to changes in temperature and relative humidity. The figure below is a relationship diagram. If the dragon needs normal life activities, the dragon must have enough food.

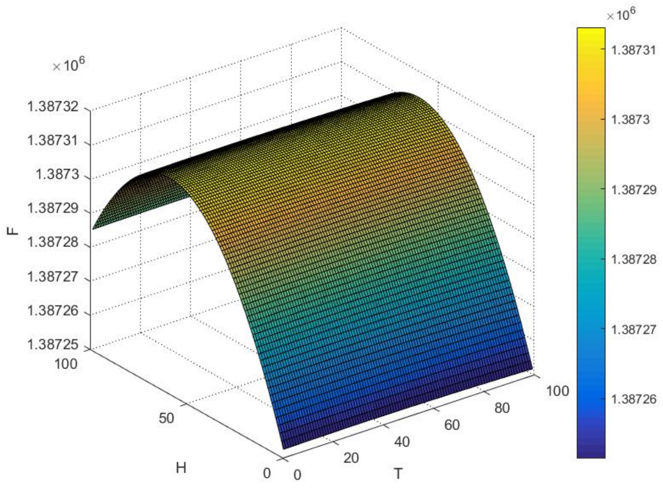


Figure.1 The relationship between the amount of food and climate change

The energy demand and weight of the dragon will change during the migration from arid regions to temperate regions and to arctic regions. The dragon trainer needs to ensure that the food is sufficient for the dragon to have the energy to fight.

In addition, according to the model test, the dragon was born with 10kg, only 20-30kg after one year. The shape of the dragon needs to grow a long time to reach a large size.

Among them, water is very important for the survival of the dragon. The relationship between the weight of the dragon and the water demand during migration is shown in the figure below.

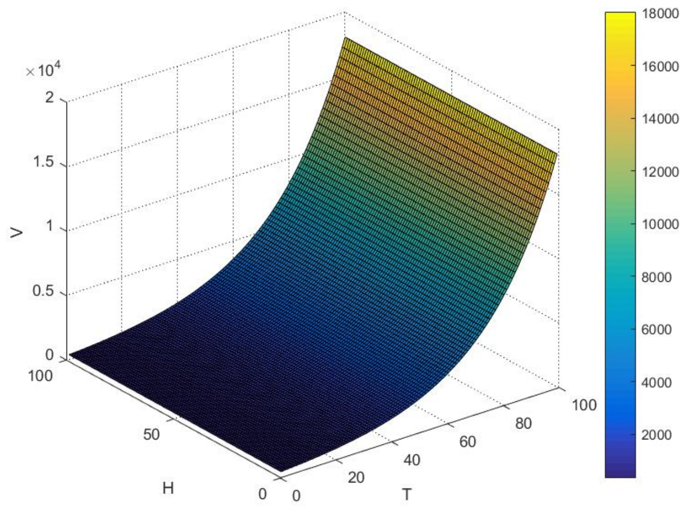


Figure.2 The relationship between the weight of the dragon and the water demand

Our study of the impact of climate on the life activities of dragons is not deep enough. But we can basically make sure that the dragon needs enough food and water to save life during the migration. I hope our results will give you some inspiration. Thank you for reading.

Yours,
MCM Team

12 References

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13 Appendices

13. 1 Solution of Ecological Requirements Model

(1) weight.m file

```
function [ Wt ] = weight( t,T,H,F0,Kmax )
   % t:age， T:temperature， H:humidity， F0:saturated food， Kmax:growth rate
      if(nargin<5)
         Kmax=10;
      end
      if(nargin<4)
         Kmax=10;
         F0 = 100000;
      end
      if(nargin<3)
         Kmax=10;
         F0 = 100000;
         H = 60;
      end
      if(nargin<2)
         Kmax=10;
         F0 = 100000;
         H = 60;
         T = 30;
      end
   F=Find_F(T,H,F0);
   M = 5.*t.*log(t.^5.*F);
   Wt=weight1(t,M,Kmax);
   end

   function Wt=weight1(t,M,Kmax)
   Wt=M.*(1-exp(-Kmax.*t)).^3;
end

function F=Find_F(T,H,F0)
   % F0:saturated food
   % T:temperature， T0:optimum temperature
   % H:humidity， H0:optimum humidity
   a_H=0.25;
   a_T=0.25;
   T0=30;
   H0=60;
   b_H=1000;
   b_T=10000;
   N1=(a_H/(sqrt(2*pi))).*exp(-(H-H0).^2/(2*b_H.^2));
   N2=(a_T/(sqrt(2*pi))).*exp(-(T-T0).^2/(2*b_T.^2));
   F=N1.*N2.*F0;
end
```

(2) water.m file

```
clc,clear;
Wtr = 1:1000/40:1001; % the range of Weight
Tr = 0:40;            % range of temperature
[Wt,T] = meshgrid(Wtr,Tr);
```

```
V = 0.06*Wt.*exp(T./25-1);
% the relationship between the water demand of dragons and body weight and
temperature
figure('position',[100,100,320,320])
surf(Wt,T,V);colorbar;
grid on;set(gca,'GridLineStyle',':','GridColor','k','GridAlpha',1); % grid lines use
dashed lines
set(gca,'XLim',[0 1000]);% the data display range of the X axis is [0,1000]
xlabel('W_{t}'); ylabel('T'); zlabel('V')
```

13. 2 Solution of Ecological Impact Model

(1) zhibiao.m file

```
function  dy=zhibiao(t,y)
    IR1 = 4;    % growth rate of other organisms living independently
    IR2 = 0.9;  % death rate when the dragon is alone
    CR1 = 0.9;  % the ability of the dragon to pluck other creatures
    CR2 = 0.8;  % other creatures' ability to support dragons
    dy=zeros(2,1);
    dy(1)=CR1*y(2)*y(1)-IR2*y(1);  % y(1) represents dragon， y(2) represents other
    creatures
    dy(2)=IR1*y(2)-CR2*y(2)*y(1);
end
```

(2) organism.m file

```
D = [3, 3]; % the initial number of dragons
R = [10,3]; % the initial number of other creatures
for i=1:2
    figure('position',[200,200,700,300])
    [T,Y]=ode45('zhibiao',[0:0.05: 10],[D(i),R(i)]);
    subplot(1,2,1);
    plot(T,Y(:,1),'-r',T,Y(:,2),'b','linewidth',1.5)
    xlabel('u');ylabel('D or R');
    gtext('R(u)'),gtext('D(u)');
    subplot(1,2,2)
    plot(Y(:,2),Y(:,1),'-k','linewidth',1.5)
    xlabel('R');ylabel('D');
end
```

(3) AHP.m file

```
function [ w ] = AHP(A)
    %AHP weighted function
    [n,n]=size(A);
    x=ones(n,100);
    y=ones(n,100);
    m=zeros(1,100);
    m(1)=max(x(:,1));
    y(:,1)=x(:,1);
    x(:,2)=A*y(:,1);
    m(2)=max(x(:,2));
    y(:,2)=x(:,2)/m(2);
    p=0.0001;i=2;k=abs(m(2)-m(1));
    while  k>p
      i=i+1;
      x(:,i)=A*y(:,i-1);
```

```
    m(i)=max(x(:,i));
    y(:,i)=x(:,i)/m(i);
    k=abs(m(i)-m(i-1));
  end
  a=sum(y(:,i));
  w=y(:,i)/a;
  t=m(i);
  %The following is the consistency test
  CI=(t-n)/(n-1);RI=[0 0 0.52 0.89 1.12 1.26 1.36 1.41 1.46 1.49 1.52 1.54 1.56 1.58
1.59];
  CR=CI/RI(n);
  if CR<0.10
     disp('The consistency of this matrix is acceptable!');
     disp('CI=');disp(CI);
     disp('CR=');disp(CR);
  end
end
```

(4) **normolize.m file**

```
function [ pre_normal,sta_normal ] = normolize(pre_ori,sta_ori)
  %% normalized
  % normalize the raw data of the dragon's stress on the environment
  pre_normal = (pre_ori-min(pre_ori))/(max(pre_ori)-min(pre_ori));
  % environmental state raw data normalization
  sta_normal = (sta_ori-max(sta_ori))/(min(sta_ori)-max(sta_ori));
end
```

(5) environment,m file

```
clear,clc
pressure = [1 1/2 3 1/2;     % pressure comparison matrix
         2 1 4 1;
         1/3 1/4 1 1/5;
         2 1 5 1  ];
state = [1 1/5 2 2;          % stste comparison matrix
       5 1 4 4;
       1/2 1/4 1 1;
       1/2 1/4 1 1];
pre_ori = [3 25 1 10];       % original data of stress
sta_ori = [7 20 25 200];      % original data 0f state
pre_weights = 0.6*AHP(pressure); % dragon's weight on environmental stress
indicators
sta_weights = 0.4*AHP(state);    % environmental status weight
% normalized
[pre_normal,sta_normal]= normolize(pre_ori,sta_ori);
% weighting
CPI = 100*sum(pre_weights'.*pre_normal);
CSI = 100*sum(sta_weights'.*sta_normal);
CII = CPI+CSI;
```

13. 3 Solution of Caloric Intake and Energy Expenditures Model

(1) energy.m file

```
clc,clear
Wt = 0:10000
```

```
Eb = 71.04*Wt.^(0.754);   % Eq
Ei = 98.67*Wt.^(0.754);   % Ei
Eq = 2273.28*Wt.^(0.754); % Eq
Ej = 3157.3*Wt.^(0.754);  % Ej

% the image of Eb and Ei
figure('position',[100,100,320,320])
plot(Wt,Eb,'-r','linewidth',1.5)
hold on
plot(Wt,Ei,'-b','linewidth',1.5)
gtext('E_{b}','Color','red','FontSize',14);
gtext('E_{i}','Color','blue','FontSize',14);
set(gca,'FontName','Times New Roman','FontSize',13)
xlabel('W_{t}(kg)')
ylabel('E(J/d)')
set(gca,'LineWidth',1)

% the image of Ej and Eq
figure('position',[100,100,320,320])
plot(Wt,Eq,'-r','linewidth',1.5)
hold on
plot(Wt,Ej,'-b','linewidth',1.5)
gtext('E_{q}','Color','red','FontSize',14);
gtext('E_{j}','Color','blue','FontSize',14);
set(gca,'FontName','Times New Roman','FontSize',14)
xlabel('W_{t}(kg)')
ylabel('E(J/d)')
set(gca,'LineWidth',1)
set('XLim',[0,10000])
```

13. 4 Solution of Living Area Model

(1) **lam.m file**

```
%% to plot relationship between living area and the number and weight of dragons
clc,clear;
Dr = 1:2:100;   % range of the number of dragons
Wtr = 1:2:100;  % range of weight
figure('position',[100,100,400,400])
[D,Wt] = meshgrid(Dr,Wtr);
A = D*1000./(Wt.^(-0.8).*log2(D+1));
surf(D,Wt,A); colorbar;
grid on;set(gca,'GridLineStyle',':','GridColor','k','GridAlpha',1); % grid lines use
dashed lines
xlabel('D'); ylabel('W_{t}'); zlabel('A')
```

13. 5 Solution of Dragon Living Community Area

(1) **community.m file**

```
%% the model of community
clc,clear,close all
t = 100       % age
T = 1:100;    % temperature
```

```
H = 1:100;    % relative humidity
D_1 = 1;      % the number of dragon is 1
T0 = 25;      % the optimum temperature is 25 degrees
BF = 0.1;     % conversion rate
[T,H] = meshgrid(T,H)
%% living area required for raising one dragons
% daily food demand
Fw = 98.67.*weight(t,T,H).^(0.754)./BF
%% daily water demand
V = 0.06.*weight(t,T,H).*exp(T/T0-1);
 % Relationship between living area and weight
Wt = 10:100000;
A_1 = 1*1000./(Wt.^(-0.8)*log2(3+1));
figure('position',[100,100,320,320])
plot(Wt,A_1,'b','linewidth',1.5);
xlabel('W_{t}(kg)'); ylabel('A(m^{2})')
set(gca,'FontName','Times New Roman','FontSize',14)
set(gca,'LineWidth',1)
% The relationship between daily food demand and temperature and humidity
figure('position',[100,100,650,500])
surf(T,H,Fw)
colorbar
grid on;set(gca,'GridLineStyle',':','GridColor','k','GridAlpha',1);
xlabel('T');ylabel('H');zlabel('F')
% The relationship between daily water demand and temperature and humidity
figure('position',[100,100,650,500])
surf(T,H,V)
colorbar
grid on;set(gca,'GridLineStyle',':','GridColor','k','GridAlpha',1);
xlabel('T'); ylabel('H'); zlabel('V')
```