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2019

MCM/ICM

Summary Sheet

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

Type a summary of your results on this page. Do not include the name of your school, advisor, or team members on this page.

In the fictional television program *Game of Thrones*, there are three dragons fed by the character "Mother of Dragons". This literal output gave the dragons the capability to grow continually, fly, breathing fire and immune tremendous trauma. Now think about this scenario seriously: these dragons are to be raised in the nowadays real world. There would be a number of realistic problems need addressing.

The first series of problems to work out are those connected with energy. We first built up a time-dependent model to describe the variation of dragons' weight. Basing on the conclusion of the mass model, we built up a creatures' growth model by using a nonlinear differential equation set. We quantized the energy possessed by dragons. The growth of dragons is regarded as the increase of the dragon's energy and the increase is considered to be the rise in the amount of energy unit. The outcomes indicate the energy possessed by each dragon, the energy increase of energy unit in unit time and the energy stored in the ecosystem. Through these two models, we calculated the energy demand for raising the dragons as well as the area required. Due to the fact that the resources in the real world are limited, we also simulated the maximum weight of the dragons after approximately 40 years by using Richard function. Additionally, the ingestion rate is introduced here to make out the intake of the dragon.

The second series of problems to figure out is about the migration. We analyzed the impact of the climate in distinctive regions. When migrating to different regions, the dragons are likely to trouble to adjust to the different ecological environment. Furthermore, if dragons are to migrate from arid or temperate regions to arctic regions, the route shall be formulated carefully in order to minimize the effect brought about by climate change. According to the climate map, we have suggested the relative ideal route to follow when migrating. Specific indications on migration are also provided.

We also tested the sensitivity of the model. Given different environmental temperature, the condition of growth rate varies according to the feature of the dragons. The circumstance is quite different when considering the dragons as homothermal and poikilothermal. Weakness and strengthens of our models are discussed as well.

Based on our conclusions, we also wrote a letter seriously stating the realistic ecological underpinning of raising dragons. We hope that with our illustrations, raising the dragons in the real world is no more a visional imagination, but assumption with scientific analysis!

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Game of Ecology: The Dragons' Growth and Migration

Content

1 Introduction

The well-known television series *Game of Thrones*, based on the novel *A Song of Ice and Fire*, invents a fictional world in which dragons exist and are raised by a specific person. The dragons weigh merely 10 kilograms when hatched, gaining weight of 20 to 30 kilograms after a year's growth. The dragons have seldom been expected to appear and live in the actual world. Now with further imagination, this fantastic creature could go beyond the literary output and enter our world to start their new lives at present. There would be a number of realistic problems remain to be fixed when considering the circumstances of the scenario with three dragons. Remarkably, the dragons' features exceed our common sense to some extent. Therefore, we should renew our cognition of the fictional creatures.

- Given adequate food and proper conditions, the dragons will be able to grow continually without a maximum figure.
- The dragons could breathe fire as they are willing to.
- They are capable of covering long distance by flying with their wings for migration.
- They possess quite strong bodies and are immune to enormous trauma.

Apparently, when the dragons are supposed to be maintained and grow today, there are far too many detailed conditions to think over and there are also too many problems that may occur, regardless vital or insignificant. As a result, we are going to choose a few important problems from the ones that are more likely to be obstacles when raising dragons. Simultaneously, we will propose corresponding conclusions and available solutions by analyzing the problem and modeling. Our model will be established based on the assumptions, which are set according to the background information. As for the problems we chose, they will be stated and analyzed briefly and primarily later.

2 Restatement and Analysis of the Problems

To maintain and grow the dragons which come from the virtual world, among a variety of problems need dealing with, we are going to address these following issues.

- The requirement for and the impact on the ecological environment. As for this event, we will regard the environment as a container storing the necessary energy to sustain the surviving and growing of all the creatures within it. In other words, energy will be taken as the criterion to assess the scale of the requirement and impact. Admittedly, the ecological environment contains a number of factors and features, however, estimating all of them is obviously too enormous a work. Consequently, we will only take energy into consideration.

- Energy consumptions and intake of the dragons. Similar to most of the creatures in the world, dragons also need adequate energy to make a living. What's different is that the intake will be used not only for growth but also for generating fire.
- The area required for feeding dragons. Flying offers a lot larger space for doing sports and entertainment to the dragons than merely living on the ground. Thus, the space for raising these dragons is approximately equal to the area demanded to provide enough energy for the dragons.
- The effect caused by climate and migration. As stated above, the dragons might fly and migrate to zones with various climates. For example arid regions, tropical regions, temperate regions, and arctic regions. With distinctive natural conditions, the requirement for feeding the dragons varies from zone to zone. Besides, the route of migration and different climate region that the dragons fly through also determines the requirement.

As for the former three questions, we set up a mass dependent model to figure out the energy-related issues. The premise of this model is that a time-dependent model, which simulates the variation of dragons' weight, ought to be established first. Then, by relying on the mass model's conclusion, we can use the mass-dependent model to carry out further analysis of the energy-related problems.

When it comes to the questions associated with climate and migration, a migration route model is suitable for fixing the relative problems. In that the dragons may be exposed to various kinds of climates as they pass by different climate zones, a better route will be less ecological demanding. Therefore, it is of significance to search for ideal routes through modeling.

3 Assumptions and Notations

The general assumptions and notations in our models are clarified as below. If there are additional instructions that apply to the particular situation, they will be specially indicated when necessary.

3.1 Assumptions

- All the creatures along with the environment build up an ecosystem. In the beginning, the energy is totally stored in the plants within the ecosystem. No external energy will be added into the ecosystem during the whole process. The energy in the ecosystem decreases inherently and continuously to supply the creatures except for the plants.
- The dragons are the consumer of the highest level, without competitors in the ecosystem.
- The average lifespan of the dragons is equal to that of human-beings', the dragons will not die naturally within the research scope. The three dragons have no descendant. The dragons consume or obtain the same amount of energy in unit time. The body types of the dragons have no limitation and the dragons could enlarge their size and mass constantly.
- The dragons possess the capability of flying, which is their approach to migration.

- The dragons could resist tremendous trauma. Consequently, natural disasters such as extreme weather will not lead to death or injury within the research scope.
- The dragons breathe fire regularly and the flames among they three possess no differences, each fire breathed will contribute to autologous energy consumption and energy loss in the ecosystem. The amount of consumption and loss is based on the specific ratio respectively as well as the energy possessed by the dragons.
- Assimilation takes up 25% of intake, the rate is expressed as u; the energy transmission efficiency between two trophic levels is 0.2, expressed as h; the dragon is located in the fourth trophic level; the energy given out by unit plant is 9000kJ, expressed as p; dragons need 9000 kilocalories of energy to gain unit weight，the constant is expressed as q; the weight of plant in unit area is 10 grams, expressed as n.

3.2 Notations

t	Time passed in the model.
$x(t)$	The energy possessed by each dragon.
$S(t)$	Energy possess by the ecosystem .
γ	Energy generated by unit area of plants.
$CIR(x)$	The area dragons live in .
ε	Energy conversion rate(from plants to the ecosystem).
S_0	The initial energy of the system.
D	Ecosystem's decreased energy in unit time.
$\mu(S)$	The energy increase of energy unit in unit time.
δ	Energy conversion rate(from the ecosystem to creature growth).
m	The fire breathing frequency.
k_1	Energy consumption rate for each fire breathed.
k_2	Energy loss rate in the ecosystem caused by each flame.
q	Energy to gain unit weight.
u	Assimilation takes up 25% of intake.
h	The energy transmission efficiency between two trophic levels.
p	The energy given out by unit plant.
n	The weight of the plant in unit area.

4 Model One-Creatures' Growth Model

This model mainly aims at figuring out the problems that are concerned with energy in the dragons' growing process, including:

- The dragons' requirement for energy in the ecosystem and energy loss, namely the impact done to the ecosystem when breathing fire.

- The energy expenditure and intake of the dragons
- Additionally, the area demand for raising the dragons in the ecosystem

4.1 Mass Model

Due to the fact that this model's objective problems are strongly related to the mass of the dragons, we will first establish a premise model to estimate the weight of the dragons. Growth curve reflects the individual regular variation of entirety or portion during development. In that the dragons could continuously grow, the development trend of the dragons' weight might be considered following the Malthusian growth model hereon:

$$\frac{dy_t}{dt} = r \cdot y_t$$
$$y_t = y_0 \cdot e^{rt}$$

Where: r refers to the rate of natural increase
y_0 refers to the initial weight

Whereas, owing to the limitation of food amount and environmental factors, only the fore part of the curve actually follows that of the Malthusian growth model, deviation appears in the hind part. Thus, we decide to replace the Malthusian curve with Logistic, Bertalanffy and Gompertz formula. Through doing research on the growth curve and the result of the three curve-fitting, we are able to learn about the dragons' dynamic growth process, it is also available to predict their growth rhythm.

The Logistic, Bertalanffy and Gompertz formula belong to Richard curve. As a matter of fact, all of them could be demonstrated by:

$$y_t = a(1 - be^{-rt})^{1/(1-C)}$$,[1]

When C is equal to 2, y_t is the Logistic curve,

$$y_t = a/(1 - be^{-rt})$$

When C is equal to $\frac{2}{3}$, y_t is the Bertalanffy curve,

$$y_t = a(1 - be^{-rt})^3$$

When C is equal to 1, y_t is the Gompertz curve,

$$y_t = ae^{-be^{-rt}}$$

Where: y_t= weight at the age of t
a= maximum weigh

r= growth speed parameter when approaching maximum weight
b = time parameter when reaching the maximum growth rate

As for the three formulas, we provided proper data (shown in Figure 1) for curve-fitting, the numerical result of the simulation is shown in Figure 2.

Age(year)	0	1	2	3	4	5
Body weight(kg)	10.96	29.6	56.6	98.04	152.64	222.56

Figure 1(Retrieved from: Chinese Journal of Animal Science)

Model (with 95% confidence bounds)	a	b	r
Logistic model	380.5 (351.5, 409.5)	3.194 (3.037, 3.35)	0.7053 (0.6407, 0.7699)
Gompertz model	596.4 (412.7, 780.2)	4.118 (3.773, 4.462)	0.2803 (0.2072, 0.3534)
Bretalanffy model	1046 (103.1, 1989)	0.8095 (0.7692, 0.8498)	0.1357 (0.04578, 0.2256)

Figure 2 Fitting Result

Basing on the result of the previous curve-fitting, in order to make out the growth rate, we calculated the differentiation to obtain the curves' derivative and established the two graphs (original function shown in Figure 3and derived function shown in Figure 4). The data's outcome illustrates that all of the three nonlinear models fit the dragon's growth curve well and could offer weight forecasts for the dragons. Having taken the weight curve simulated by the Logistic,

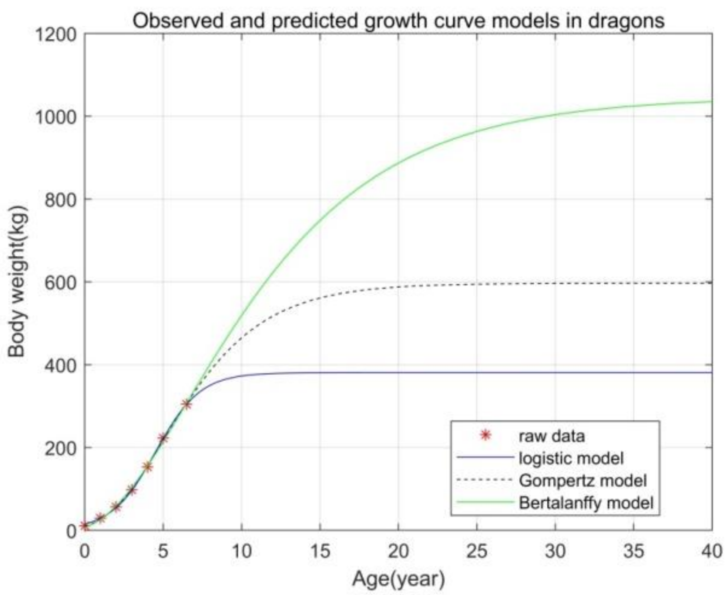


Figure 3

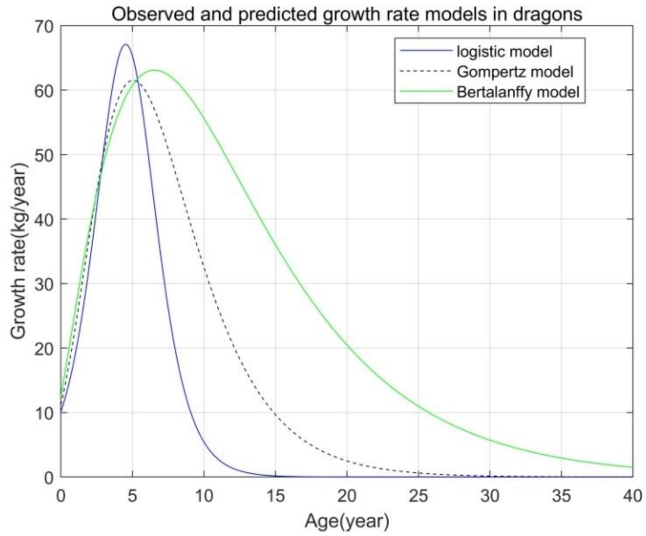


Figure 4

Bertalanffy and Gompertz formula into consideration, we predicted the time-dependent mass of the three dragons. When given limited food resource and ecological condition, the maximum weights, which may be reached when the three dragons' weight keeps stable, simulated by the three formulas are 380.5kg, 596.4kg and 1046kg respectively. These predictions conform to the conditions and assumptions of the issue.

Fitting outcome

Model	Maximum weight(kg)	Energy consumption(cal)	Intake(kJ)	area(m^2)
Logistic model	380.5	3.4245×10^6	5.7338×10^7	2.3891×10^8
Gompertz model	596.4	5.3676×10^6	8.9872×10^7	3.7447×10^8
Bretalanffy model	1046.0	9.4140×10^6	1.5762×10^8	6.5676×10^8

Note: Energy = Maximum weight * q, Intake = (Energy/u)*4.1858518, Area = [(Intake*3/h^3)/p]*1000/n

4.2 Creatures' Growth Model: Quantization

In regard to the gain in the dragons' weight, we deem it equivalent to the increase in energy. We quantize the energy of dragon, namely the energy of a dragon is integer times of energy unit. The growth of dragons, which is the energy assimilated by dragons is shown as the rise in the number of energy unit. Consequently, we reckon that a dragon is equivalent to a population and every energy unit is an individual. From this point of view, we use the Logistic growth model to describe the growth of this population, which is the increase in energy.

Before the dragons enter the ecosystem, the energy in the ecosystem decreases inherently to meet the needs for the maintenance and growth of other creatures in the ecosystem. The decrease rate is an invariable constant D:

$$\frac{dx}{dt} = D$$

After the dragons are integrated with the ecosystem, because of the participation of the three dragons, more natural resource, which is considered energy within this problem, will be consumed. Thus, as the consumption rises, the amount of energy in the ecosystem is going to decrease at a relatively higher velocity. As a consequence, the dragons' energy utilization will be affected directly.

The speed of the dragons' growth, namely the increase rate of the number of energy unit is:

$$\frac{\partial x}{\partial t} = x\mu(S)$$

The decrease rate of energy in the ecosystem is equivalent to the inherent decrease rate plus the consumption rate of the energy used for the growth of dragons. The growth is treated as the rise in the number of energy unit in the dragons hereon and the decrease rate of energy in the ecosystem is demonstrated as the equation below:

$$\frac{\partial S}{\partial t} = D - \frac{1}{\delta}\mu(S)x$$

With all the statements above as well as the notations clarified previously, the equation set is listed as follow:

$$\begin{cases} \dfrac{\partial x}{\partial t} = x\mu(S) \\ \dfrac{\partial S}{\partial t} = D - \dfrac{1}{\delta}\mu(S)x \\ \dfrac{\partial S}{\partial x} = \dfrac{1}{\delta}\mu(S)t \end{cases}$$

$$S = \gamma \cdot CIR(x) \cdot \varepsilon$$

Solve the equation set and the expected solutions are: $S(t)$, $\mu(S)$ and $x(t)$.

The relationship between energy stored in dragon and the mass of dragon has been mentioned in the assumption part, $q \cdot y_t = x$.

4.3 Refined Model: Fire Breathing

When it comes to the situation after the dragons enter the ecosystem, we refined the present model. It is given in the introduction that the dragons are capable of breathing fire. This will lead to a decline in the number of energy units. With further thoughts, if we suppose the fire breathed will destroy the natural resource, more energy loss will be conducted by dragons and the energy to provide for the dragons would decrease simultaneously. We took these factors into consideration and came up with two proportional constants, k_1 and k_2, thus, based on the previous model, we brought in the destruction factor. The refined equation set is illustrated below.

$$\begin{cases} \dfrac{\partial x}{\partial t} = x\mu(S) - mk_1 x \\ \dfrac{\partial S}{\partial t} = D - \dfrac{1}{\delta}\mu(S)x - mk_1 k_2 x \\ \dfrac{\partial S}{\partial x} = \dfrac{1}{\delta}\mu(S)t + mk_1 t \end{cases}$$

4.4 Ingestion Rate

Turnbull reckons that if the ingestion rate falls below the critical value, the growth rate is zero. If the ingestion rate outnumbers the critical value, the growth rate and ingestion rate follows a linear relation:[2]

$$G = W\ (I - C)$$

The model has a high fitting degree. Close correlation is shown when it comes to homothermal animals. Nevertheless, in the research of *Mukerji & LeRoux*, the fitting value of W and C do not agree to the reality.

As for the Ectotherm, the ingestion rate and growth rate follow the nonlinear relationship:

$$G = W\ (lnI - C)$$

The newly proposed individual growth rate model is:

$$G = Go\ [1 - e^{-B(I-C)}]$$

where:

Go is the invariable maximum growth rate given that ingestion rate approaches infinite.

B is a value that describes the relationship between maximum rate and growth rate. The larger the value of B is, the closer G approaches the maximum growth rate. Under such circumstance, the food ingestion (I) is relatively small, which means that the individual utilization of food intake varies depending on different individual. It is connected with the creature’s metabolic rate.

C indicates the critical value of individual ingestion rate. When I is equal to, G is equal to zero.

These two models are widely utilized and they are of certain applicability.

According to the research, this model fits the correlation of growth rate with ingestion rate well and the correlation coefficient exceeded 0.05. The W and C agree to the reality.

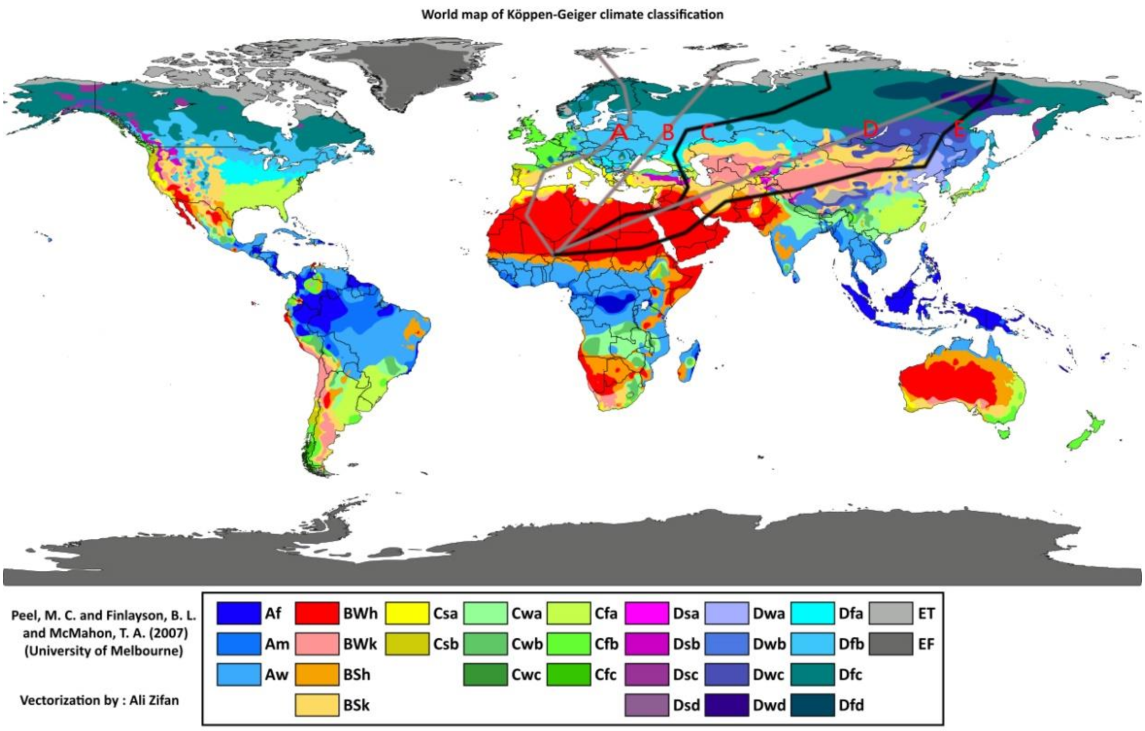
5 Model Two-Migration Model

In this model, we will analyze the dragons' migration and discuss indications that are significant.

The energy demand for dragons' growth relies on the output of natural resource in the ecological environment. Also, the creatures' growth rate depends on to what extent do the creatures adapt to the environment. Due to the influence of geographical factors, for example, the variety of climate[1], ocean current, sea land thermal difference, altitude, latitude and rainfall, the energy requirement for growth and the energy inherent decrease rate of ecosystems vary.

When dragons enter zones with different climate, they may expend certain amount of energy on adjusting to the environment, in which process the growth rate of the dragons would fall. After the dragons have adapted to the environment, the growth rate will go up to the ordinary trend. In this ecosystem, the relative growth rate in our model changes as well.

During the dragons' migration, affected by other creatures' migration aroused by ocean current and rainfall difference, dragons have to migrate correspondently in order to satisfy the need for food ingestion. Take gnu in Tanzania, Africa as an example, they migrate as the rainy season begins and ends. If the dragons live in exactly the same ecosystem with gnus, the former have to follow the latter when they migrate. As a consequence, dragons must face different types of climate such as BWh[3] and Cwa, where enormous distinction exists. These distinctions include but not limited to: rainfall, temperature, community quantity, and energy transfer efficiency. Owing to these factors, the food ingestion rate and energy transfer rate would change, contributing to the variation in the dragons' growth rate.



[1] Classified according to Köppen climate classification.

Furthermore, think over the extreme ET climate: There are few creatures and communities in the ecosystem. The growth rate will definitely decrease because an apparent fall takes place in the food ingestion, thanks to the tough climate.

Hence, while choosing the route for migration, we should avoid going through too wide a range of climates or passing several temperature zones once. Flying too much in one flight is not advised and extreme weathers deserve noticing, too.
As indicated in the map above, route A and route B are both ideal choices when migrating.

6 Sensitivity Analysis

Energy generation rate and growth rate, these two variables are affected by a number of factors, for example, temperature, humidity, altitude, latitude, sunshine and so on. To some extent, the artificial regulation would contribute to change in the two variables. Therefore, predicting the two rates with univariate function is not accurate enough. We will only consider the temperature's impact on growth rate and resting metabolic rate[4] hereon.

Analyzing the experimental data, the average ingestion rate in the temperature range of 4 to 28 centigrade degree is 8.8%, without halting feeding or death. The ingestion rate of fish rises as the temperature goes up. The trend is opposite after reaching the peak at 24 centigrade degree. One-way analysis of variance reveals that temperature affects the ingestion rate of fish greatly ($P<0.01$).

Within a range of 12 to 24 centigrade degree, the fish's specific growth rate is a positive value, with positive growth manifested. When the temperature falls outside the range, the growth appears to be negative growth. One-way analysis of variance demonstrates that temperature affects the specific growth rate of fish to a large extent.[5]

Basing on the researches, we conclude that usually, creature's maximum ingestion and specific growth rate obviously vary from species to species. The outcome of our creatures' growth model is dependent on the ingestion rate and specific growth rate. If the influence of temperature is also true for the dragons, the conclusion acquired, namely area required to raise the dragons might be quite different.

In the creatures' growth model, when quantizing the energy of the dragons, the inherent energy decrease rate is likely to be a variable, rather than the constant in our model. The rate is restricted by the ecosystem, for example, the distribution of communities, the quantity of population, the temperature and the rate of photosynthesis.

7 Conclusions

- The maximum masses of the three dragons probably fall into a range of about 300 to 1000 kilograms. Provided with realistic ecological environment, the resources are limited, therefore, the dragons will approach the maximum value gradually and tend to remain stable. When referring to different curves in the mass model, the outcome varies to some extent.

- The requirement for ecosystem and impact on it is shown as the requirement for provided energy and energy loss done to the ecosystem. The former is calculated and the value is approximately $9.4140 \times 10^6 cal$. The latter could be solved through the nonlinear differential equation set when a numerical solution is given.

- The expenditure of dragons is the sum of energy used for the maintenance and growth as well as generating fire. The intake of the dragons is revealed by the ingestion rate and creatures' growth model in model one. The relationship between intake and expenditure could be inferred by relating both of them to the energy possessed by the dragon.

- The area demand for raising dragons is roughly $656.76km^2$. An ecosystem with such an area is expected capable of providing adequate energy to support the energy requirement of the three dragons. What's more, since all the relative assumed rate are based on the data of a normal ecosystem, we could consider, in the area of such size, there will not see an obvious disturbance in the ecological balance.

- Among all the climate conditions, temperature is one of the most crucial factors to our analysis. As is shown in the sensitivity analysis, temperature determines the ingestion rate and the growth rate, which are the basis of our creatures' growth model. Once the dragons are similar to fish in this aspect, then the variation in temperature could greatly influence the calculated results, namely energy and area required. Nevertheless, if the two rates alter little when temperature changes, it is still an important factor, however, our outcome would hardly change.

- In order to maintain ecological underpinning of raising the dragons even when migrating, an appropriate choice of route is vital. By formulating the route, it is feasible to avoid a sharp change in climate. Therefore, we provided several reasonable routes to follow.

8 Strengths & Weaknesses

8.1 Strengths

- The rise in the energy possessed by dragons is used to take the place of mass increase, the model creatively quantizes the energy of the dragons. Then, the dragons' growth model is equivalent to the Logistic growth model. The analogy addresses the very problem.

- The analysis on growth rate took various factors into consideration. This heightens the objectivity of the creatures' growth model.

8.2 Weaknesses

- Solving the nonlinear differential equation set demand for an exact numerical solution, which is unreachable at present stage. Consequently, the simulation could not be carried out.

- All the data derives from research on other kinds of creatures. These data may lead to deviation when used for studying dragons.

9 An Outlook of Models

Besides the situation given here, the creatures' growth model could also be used for addressing other problems. The core of this model is quantization. The whole energy of the dragon is quantized into energy units. The problem is then applied to a relative model. The model may also be used for solving similar problems such as studying the pattern of dissolving and crystal melting.

A Letter to the Author

Dear Mr. George R.R. Martin,

We are more than flattered to write this letter to talk about our thoughts on raising the dragons created by you. Due to the fact that readers, as well as audiences, were accustomed to expecting your dragons to live in the world of your novel, seldom do people imagine raising the dragons in our world. Now, we envisaged a fantastic scenario: the dragons are to be raised in the real world!

To provide feasible instructions on raising the dragons, we first build up a mathematical model, called ***Creatures' Growth Model***. In this model, we made several assumptions according to the features you set for the dragons. They include flying, breathing fire and resistance to trauma. We assume that the dragons will be raised by you since the moment they are hatched. The purpose of it is to figure out the details of raising them. Here are the conclusions.

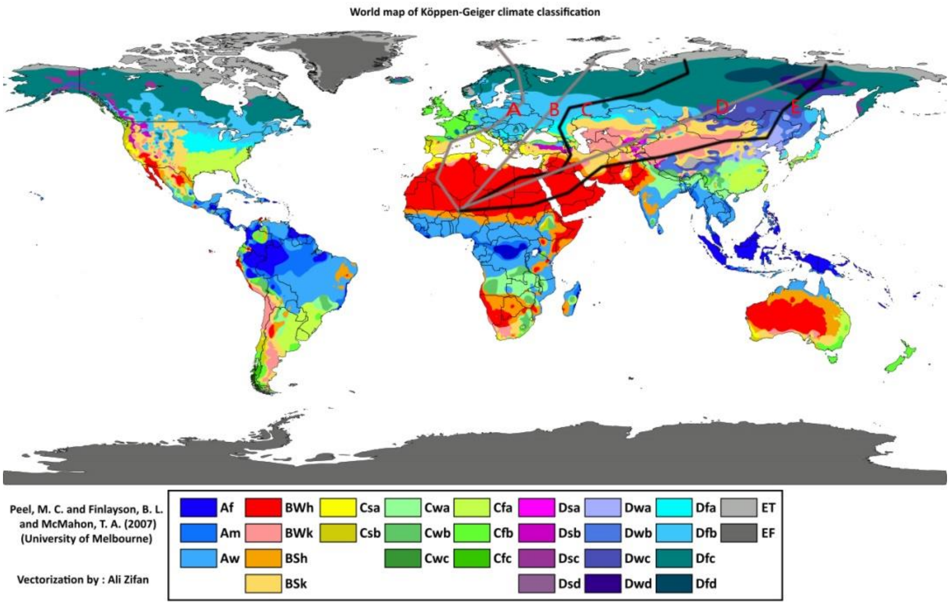
● The weight of a grown-up dragon is supposed to fall into a range of 300 to 1000 kilograms. Admittedly, the dragons could grow throughout their lives as long as given adequate food. However, since the natural resource in the real world would not be infinite, the access to these resources are also limited, there would certainly exist a maximum of the dragons' weights. 300 to 1000 kilograms is a possible range of the maximum. Please notice that food resource will play a significant role in raising the dragons. We reckon that feeding the dragons artificially is also acceptable if you are not willing to raise the dragons in the wild.

● The area demand for raising the three dragons (after they have grown up) is approximately 656 square kilometers. Attention please, this is statement merely apply to raising they three without artificial interference. In other words, if you want to raise them without bothering taking care of them frequently, ensure that you can provide such a region for your dragons. Needless to say, this area should be fertile so as to meet the fundamental requirements of raising the dragons. If the dragons are to be fed in an arid zone, the demanded area might enlarge correspondently, allowing for less energy is provided within the same area. Fortunately, the dragons seem to have no natural enemies. They could adapt to various food chains.

● Moderate climate condition is vital. According to our analysis of ingestion rate, temperature will influence the ingestion rate of creatures. The extent of the effect, however, varies from species to species. Now that the temperature's impact on the dragon is still unknown, we will state the possible circumstances to you.

- If the dragons' circumstance resembles that of fish: according to researches, the ingestion rate of fish changes a lot when the temperature increases or decreases. Therefore, you had better keep the dragons in a region with a relative mild climate. Then the dragons may gain weight easier and quicker, according to the simulation of our model. Otherwise, you may find them growing slowly and even losing weight. Under such circumstance, you may also need to observe for a period of time to find out at what temperature range will the dragons grow rapidly.

- If the effect of the temperature is not evident: Comparing to the first circumstance, this circumstance will be much easier for you to feed the dragons, Because of the ingestion rate is relatively stable, the temperature would not be a dominating factor to influence the growth of the dragons.



- Choose an appropriate route for migration. The dragons may follow the migrating prey or simply move to different zones. During this process, the dragons would cover a long distance. The flight cost much energy. Simultaneously, it is also probable that the dragons have to spend some time to adjust to the new ecological environment. The ingestion rate could be lower than the expected value. To ensure that the dragons are in good condition, or at least could stay alive, it is of vital importance to choose a proper route to satisfy the dragons’ needs for energy. According to the climate distribution of different regions, we have drawn a route map basing on the world climate map. These routes could even enable you to lead your dragons from arid or temperate regions to arctic regions. Notice that do not cross several climate zones once. The time used for adaption may longer then. Try to raise your dragons in temperate regions rather than arctic regions. Extreme ecological conditions would certainly influence the ingestion and the growth of the dragons.

With the conclusion of our analysis, the basic ecological requirement and suggestion are all listed. Hope that the tips in our letter will make things different!

Best wishes!

Sincerely, Team 1911920.

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