The impacts of environmental conditions on species growth

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Abstract. When scientists discover new species, their characteristics, behaviour patterns, habits, diet, and their ways of interacting with our current environment need to be thoroughly understood. In order to have a deeper understanding of these problems, we have built different models to analyse growth patterns of those species. Firstly, we modified Gompertz model to derive a new model to analyse the growth of these species. Secondly, we used entropy evaluation method to digitalize natural environment considering temperature, rainfall, biodiversity etc. Those data were then used for further analyses. Thirdly, we used BP neural network to analyse the relationship between ecological factors and animals’ weight. A new model has been built to reflect the animals’ weight and their corresponding ecological situations.

1. Introduction

Thousands of species around the world are still undetected by humans. When scientists discover new creatures, they need to analyze their characteristics, behavior, habits, diet, and interaction with their environment. They need to figure out the ecological impact and requirements, energy expenditures, caloric intake, and living area that the species need, and build a model to analyze how the ecological community support them.

In order to better simulate these undiscovered creatures, we assumed that they conform to Kleiber’s law. Their metabolic rates scale to the $\frac{3}{4}$ power of the their masses. Symbolically, if $q_0$ is their metabolic rate and $M$ the their mass, then Kleiber's law states that $q_0 \sim M^{\frac{3}{4}}$[1].

In order to simply the situation, we didn’t need to take their reproduce into account. We assumed that the species conform to the general growth rules, that is to say, they would grow up slower until they are mature.

2. The growth model of species

2.1. Growth model.

We used the modified Gompertz model to simulate the growth model of creatures. The Gompertz curve (Fig 1), is a type of mathematical model for a time series and is named after Benjamin Gompertz. It is a sigmoid function which describes growth as being slowest at the start and end of a given time period, which can greatly reflect the general rules of animals’ growth. Potential growth is a continuous process that results in a single, smooth growth curve and a similarly smooth growth rate curve when plotted against size [2].
\[ W = A \times (\exp(-\exp(-G_0 - (B \times t)))) \]  
\[ \frac{dW}{dt} = B \times W \times \ln(A/W) \]

In the formula (1), \( W \) is the weight of the animal (kg), \( A \) is the animal’s mature weight (kg), \( B \) is the growth rate parameter used in that particular model, \( t \) is time (days) and \( G_0 = -\ln(-\ln(W_b/A)) \) is a transformed initial degree of maturity at birth.

![Gompertz](image)

**Figure 1. Growth curve.**

We used Matlab to fit the growth curves in different regions, and we can see the specific data[3] of creatures’ growth model in temperate zone and tropical zone from Table 2 (which was calculated by the results of 4.4.3). As we can see, the parameters in Table 2 are within the margin of error.

In the Table 1, the R-square>0.95 which means the function is significant to explain the data. And then the expected assumption is proved.

**Table 1. Specific data of growth curve in two regions**

| General model          | Climate      | Coefficients | Goodness of fit |
|------------------------|--------------|--------------|-----------------|
|                        |              |  \( a \)    | \( b \)        | \( c \)        | \( \text{SSE} \) | \( \text{R-square} \) | \( \text{Adjusted R-square} \) | \( \text{RMSE} \) |
| \( f(x) = a \times (\exp(-c-(b \times x))) \) | Temperate zone | 2852 | 0.1166 | -1.476 | 1.471e+05 | 0.9874 | 0.9823 | 171.5 |
|                        | Tropical zone | 4056 | 0.06695 | -1.661 | 3943 | 0.9998 | 0.9997 | 36.26 |

2.2. *The community indicator*

2.2.1. *The entropy evaluation method.* We used the entropy method to confirm the weight of each indicators which is temperature, rainfall, and species richness, respectively. The entropy is a standard to measure uncertainty in information theory. The less the amount of information, the smaller the uncertainty and the smaller the entropy. While, the larger the amount of information, the larger the uncertainty and the larger the entropy[4].

2.2.2. *The calculation of community index.* Select \( n \) communities, \( m \) indicators. We select 7 regions as the different communities (lined out in Table 2), 5 indicators that are rainfall, temperature, sunshine, species richness and area.
Table 2. The regions’ number and their climate

| Number (j) | Region                               | Climate                  |
|------------|--------------------------------------|--------------------------|
| 1          | Yellowstone national park             | Temperate continental climate |
| 2          | Qingshan national nature reserve      | Temperate marine climate  |
| 3          | Yosemite national park                | Mediterranean climate     |
| 4          | Asia kaziranga national park          | Tropical monsson climate  |
| 5          | Semala wildlife reserve               | Tropical grassy climate   |
| 6          | Xishuangbanna nature reserve          | Tropical rainy climate    |
| 7          | Greenland national park               | Polar climate             |

Table 3. The results of entropy method

| Number | Average annual rainfall (mL/year) | Temperature (°C) | Average annual sunshine | Species richness | Area (km²) | Score       |
|--------|-----------------------------------|------------------|-------------------------|-----------------|------------|-------------|
|        | Highest                           | Lowest           |                         |                 |            |             |
| 1      | 400                               | 33               | -20                     | 4               | 410        | 430.00      | 0.08242    |
| 2      | 450                               | 27               | -2                      | 5               | 391        | 1800.00     | 0.07909    |
| 3      | 650                               | 22               | 4                       | 4               | 350        | 2417.76     | 0.116157   |
| 4      | 1750                              | 35               | 18                      | 5               | 320        | 3983.17     | 0.044535   |
| 5      | 700                               | 30               | 24                      | 6               | 545        | 3885.77     | 0.050105   |
| 6      | 2200                              | 32               | 18                      | 7               | 539        | 2849.00     | 0.049832   |
| 7      | 100                               | -25              | -45                     | 1               | 250        | 972000      | 0.577862   |
| Weight | 0.13530652                        | 0.05236          | 0.06959                 | 0.0605258       | 0.090048   | 0.59217     |

As above, the entropy evaluation method objectively shows the community index of different regions with very different climate conditions. However, as you can see in the Table 3, the 7th region, Greenland, has a much higher score because of its large area.

3. The animal’s ecological mass model

3.1. Select the main indicators and representative animals

According to the ecological factor, we selected the temperature, living space, energy intake and community index as the four main indicators of each region. For the purpose of improving the accuracy of estimation, we selected 36 kinds of samples from different regions and different species.

3.2. Animals mass and metabolism

According to the Kleiber’s law, the animals’ metabolic rate scales to the ¾ power of the its mass. We explained it in symbol that if \( q_0 \) is the animal's metabolic rate, and \( M \) the its mass, then Kleiber's law states that \( q_0 \sim M^{3/4} \). So, we regard the mass of animals as the only indicator reflecting the growth situation.

3.3. BP network to analyze the data of animals related with region conditions

We used BP neutral network to figure out the creatures' characteristics, especially mass and size. Therefore, we make a preliminary estimate of the organism based on ecological principles.

We selected seven location samples in three regions (arid region, temperate region and arctic region). Every sample represented a certain climate. We got four indicators of every climate which are temperature, rainfall, biological diversity and the index of the community. After that we chose some representative animals and collected the basic features such as intake, amount, length and mass. Then
we used the data to train the net and made some slight adjustments according to the MSE and the graph of learning.

BP neural network is the primary method in our modeling process. We used it to analyze correlation between variables. The procedure conforms the instructions above.

The BP neural network results of animals and the unknown creatures are listed in Fig 2.

![Figure 2. BP neural network results](image)

3.4. The relationship between living space and body length

We collected the area and animals living space and body length of seven different regions, for the purpose to analyze the relationship between area and body length of creatures in different regions. In the Fig 9, we can see body length is positive correlation of region area and mass in a certain way. The relationship of mass and area and body length is reflected in the formula (8), where \( x \) is the mass, \( y \) is the area, \( z \) is the body length.

\[
z = p_{00} + p_{10}x + p_{01}y + p_{20}x^2 + p_{11}xy + p_{02}y^2
\]  

(3)

Where \( x \) is normalized by mean 3544 and std 634.2, where \( y \) is normalized by mean 3394 and std 2968, and \( p_{00} = 4.864, p_{10} = 0.1949, p_{01} = 2.011, p_{20} = -0.7401, p_{11} = 3.044, p_{02} = -2.352 \).
Figure 3. Body length vs mass, area

4. Conclusion
In this paper, we built the models to analyze the growth and living conditions of unknown creatures. Firstly, we built the growth model and energy distribution model based on reality and our assumption according to Gompertz model. Then we used entropy evaluation method quantify the condition of community, which is also an important indicator to measuring the growth situation of creatures. In the next part, we built an animal mass model to analyze the relationship between ecological factors and animals’ living situation. We improved the animals’ model to obtain the unknown creatures’ mass model according to the characteristics of them.

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