RESEARCH ON THE EFFECT OF SOIL HEAVY METAL ELEMENTS IN THE POTENTIAL HABITATS OF GIANT PANDAS (*AILUROPODA MELANOLEUCA*)

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Abstract. By building a geochemical (heavy metal) niche model for giant pandas, this paper researched and analyzed the restriction of Cr, Hg and Pb in the soil in Pingwu County, Sichuan Province on the giant pandas' selection of habitats. According to the model analysis, in this study area, Cr has the largest impact on the giant pandas' selection of habitats. In this habitat, the maximum bearing value of Cr is 70×10^{-6} mg/kg; the maximum bearing value of Hg is 462.8×10^{-9} mg/kg; and the maximum bearing value of Pb is 37.94×10^{-6} mg/kg. If the content of the above three heavy metal elements exceeds their respective maximum bearing value, the encounter rate of the giant pandas in this area will decrease to 0, and the giant pandas will no longer choose this area as a habitat.
Keywords: *endangered species, ecological niche model, habitat selection, pollutant, Pingwu County*

Introduction

As a symbol of China, an endangered species and a world-class protected animal, the giant panda, *Ailuropoda melanoleuca* (David, 1869) receives much attention from the global scientific research circles. The heavy metal pollutants in a giant panda habitat enter and accumulate in the bodies of the giant pandas and other animals along the food chain, and thus pose a threat to their health and even life. To better select habitats for pandas and thus better protect them, we carried out this study. With an ecological niche model, we studied and analyzed how the three elements of Cr, Hg and Pb in soil in Pingwu County of Sichuan restricted the habitat selection of pandas, to find out the influence of the content of the three heavy metallic elements in soil on the habitat selection of pandas under natural conditions, and finally determine an area in Pingwu County with a minimum influence of the three heavy metallic elements on pandas, as an effective reference for the habitat selection of pandas.

General Situation of the Study Region

The number of giant pandas in Sichuan Province takes up over 70% of the global wild pandas, while Pingwu County in Sichuan Province is honored as the number one county in the world for pandas. This location also appears to be an important transition zone between panda species A and B (Hu, 2005). The area belongs to the Himalayan-Hengduan Mountains, one of the core global biodiversity areas. The reserve maintains typical natural

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ecological systems and this one in particular is the most intact ecosystem within its latitude region. It has representation and typicality that is outstanding on a global scale.

Review of Literature

The influence of heavy metal elements on the giant pandas has been studied for a long time. For instance, Liu and Wang (1988) took 43 panda samples from Minshan Mountains and 10 from Qionglai Mountains, and then tested the normal value range of 10 trace elements, including Pb, by analyzing the trace elements in the panda hair. A direct path for pollutants, including heavy metals, to enter the bodies of the giant pandas and other animals is their food bamboo (de Almeida Curi et al., 2012), thus many researches have been carried out based on the content of heavy metals in the food. For example, Wang (2011) tested how much different concentrations of Pb and Cd were absorbed and accumulated in 5 kinds of bamboos, including potted bamboo in laboratory and simulated black bamboo. Liu (2015) from Chinese Academy of Sciences analyzed the exposure of the endangered animals in Qinling Mountains, including giant pandas, to heavy metals (Cr, Pb, Hg and As), and made a comparison in heavy metals between the habitats of the wild giant pandas and the giant pandas in captivity. Through research, Zheng et al. (2016) found that traffic could be an important source of heavy metallic pollution in soil in habitats of pandas, as expressways increased the concentration of toxic metal in these places. Tian et al. (2019) observed high potential risks to pandas that were exposed to Pb, As and Hg in a study. Zhao (2019) found that concentrations of heavy metal in feces and bamboo samples were positively correlated, which meant that polluted bamboo could be a major direct source of pollutants to which pandas were exposed.

As mentioned above, some scholars have noticed the harmful impacts of heavy metals on the giant panda and other relevant endangered animals. In addition, to carry out an efficient analysis on the potential habitats of giant pandas, we have to consider the distribution of heavy metal elements in the study area. But at present, there are very few reports on the effect of heavy metal elements on the giant pandas' selection of habitats. So, this paper built a niche model of heavy metals, researching and analyzing the restriction of Cr, Hg and Pb in soil on the giant pandas' selection of habitats, in hope of providing reference for analyses of giant panda habitats in future.

Materials and Methods

Maximum Entropy and Niche Theory

Niche theory can be used to explain and predict the distribution range of a giant panda habitat. The person who first proposed niche theory is Grinnell (1917), while the one who first treated niche theory mathematically is Hutchinson and Macarthur (1959). The core idea of mathematical treatment is that every organism is restricted by different factors in the natural environment, there is a suitable quantizing interval for all these factors, and the composite factors in the interval are concrete indexes for this organism's existence and multiplication. Species niche is a collection of the composite factors of all the intraspecific organisms. The concept of maximum entropy was proposed by Jaynes and Cummings (1963). Maximum entropy is derived from information science, and at present, it has been applied to economics, ecology and the relevant inter-disciplines. Maximum entropy has a good confinement effect on incomplete information-based probability distribution. Its purpose is to infer unknown information by full use of incomplete

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information, and take known information as a constraint value, with the probability distribution meeting the condition for entropy value maximization. Incomplete information comes from entropy theory, which was proposed by Shannon (1948). As the amount of information increases, entropy value decreases. When it is used for forecasting, no tendentious hypothesis will be made, but on the premise that the existing information is indeed contained, when the entropy value is maximized, redundant information will be completely excluded, so that the uncertainty of unknown information should be reduced. Set a random variable ξ, which may have n possibilities, including A1, A2, A3,…An, and for the appearance of each possibility, there may be a probability, which equals to p1, p2, p3,…, pn, so the information entropy H (*Eq.1*) is:

$$H(\xi) = \sum_{i=1}^{n} p_1 \log \frac{1}{p_i} = -\sum_{i=1}^{n} p_i \log p_i \quad \text{(Eq.1)}$$

MaxEnt Model

Phillips et al. (2004) developed MaxEnt model based on the above maximum entropy and niche theory. According to the known distribution range of a species based on environmental factors, this model calculates the maximum entropy value corresponding to the distribution rule of this species, and predicts the potential distribution area of this species. That is, a constraint condition needs to be determined first in accordance with the environmental characteristics of the target species' habitat, and then the maximum entropy can be calculated in line with this constraint condition. The predicted distribution range of this species is the probability distribution of this species when entropy reaches its maximum.

Since its development by Phillips et al. (2004) MaxEnt model has gone on a good run and been used by many scholars to predict habitats of animals and plants. Prates-Clark et al. (2008) based on a maximum entropy model, researched the distribution law of three tree species in the Amazon Basin and predicted their distribution using MODIS data and other relevant remotely sensed data. Hernandez et al. (2006) discovered in their research that despite the limited number of biologic points, the result would also be reliable, and the precision could meet the requirements, suggesting that it is applicable despite a small number of sample points. With the constant improvement of the model, more and more people have applied it to the analysis of habitats. Thus, this paper constructed a niche for the giant pandas in Pingwu County using this mode.

Niche Model for the Heavy Metals in the Habitat of Giant Pandas in Pingwu County

Data Source

This paper primarily built a niche model for heavy metals with Cr, Hg and Pb in the soil as analysis objects. The map data of heavy metals (*Fig. 1*) comes from a WWF topic: Follow-up Study of Evaluations on the Ecological Environment in the Habitat of Giant Pandas in Pingwu County; the data of giant panda distribution come from the routine monitoring of Xiaohegou Nature Reserve in Pingwu County.

Attribute of heavy metal element data is extracted from the geochemical element map of this region, and the comparison in grade between these three elements is shown in *Fig. 2*.

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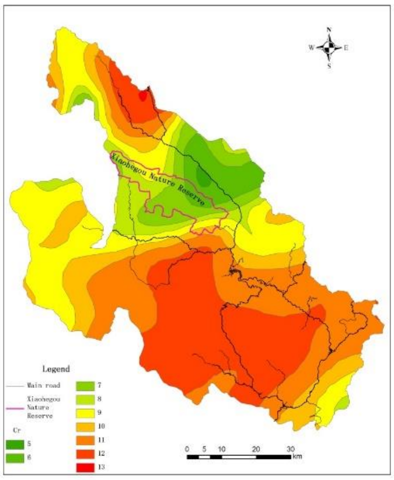
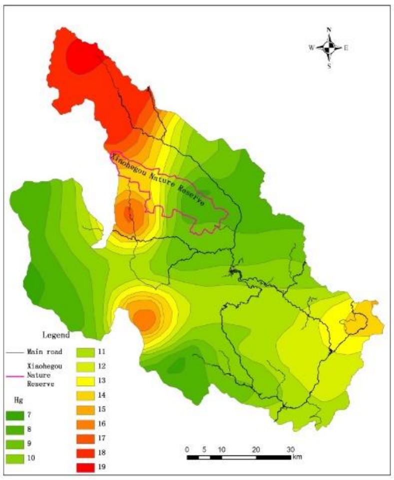
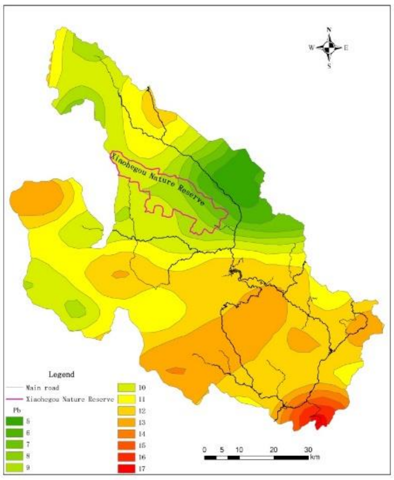


A. *Cr*



B. *Hg*



C. *Pb*

Figure 1. *Distributionof Heavy metal in Pingwu*

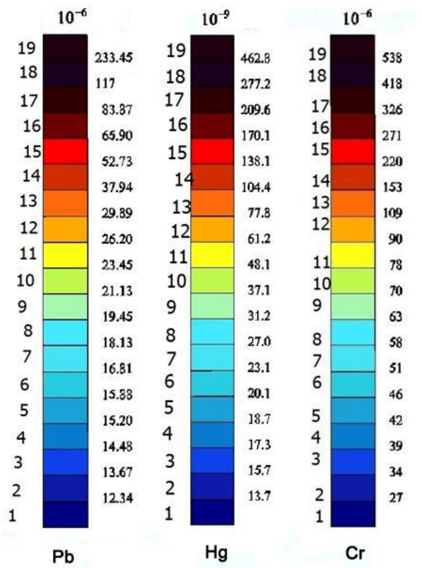


Figure 2. *Element Grade and Content Comparison (element unit mg/kg)*

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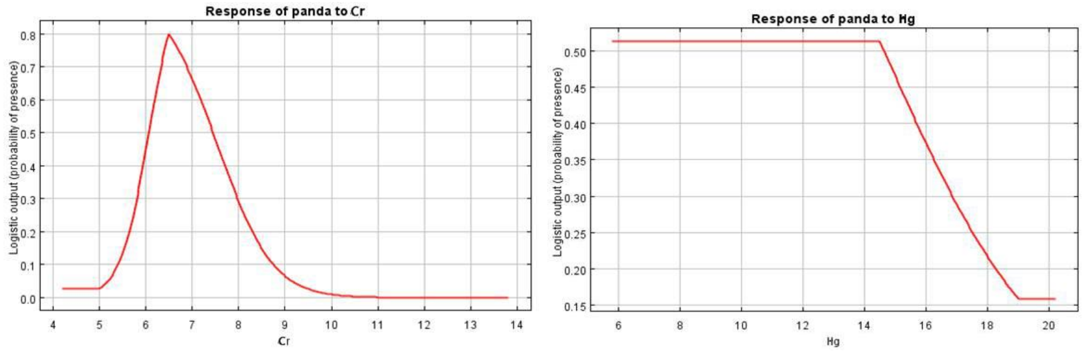
Result

In *Fig. 3*, the horizontal ordinate indicates the variation range of heavy metal value, and the vertical coordinate shows a natural logarithm of heavy metal value's contribution to the suitability of the giant panda habitat. The value is directly proportional to habitat suitability, and for the giant pandas, the more suitable the habitat is, the higher their encounter rate is.



A. *Response Curve of Cr to the Giant Panda Encounter Rate* **B.** *Response Curve of Hg to the Giant Panda Encounter Rate*

Figure 3. *Response Curve of Cr and Hg to the Giant Panda Encounter Rate*

According to *Fig. 3A*, as Cr content increases to Grade 10 (70×10^{-6} mg/kg), the giant panda encounter rate decreases to 0, suggesting that the maximum bearing value of Cr (*Fig. 3B*) in the habitat of giant pandas in this area is 70×10^{-6} mg/kg; before Hg content increases to Grade 15 (138.1×10^{-9} mg/kg), the probability of giant pandas' appearance is always stable, but as Hg content increases to 19 (462.8×10^{-9} mg/kg), this probability keeps decreasing to 0 from time to time, suggesting that Hg has a great effect on giant pandas. This effect is not obvious when Hg content is lower than 138.1×10^{-9} mg/kg, but if it's higher than 138.1×10^{-9} mg/kg, great harm will be done to the giant pandas. Maximum bearing value of Hg in the habitat soil in this area equals to 462.8×10^{-9} mg/kg.

As Pb content (*Fig. 4*) increases to Grade 14 (37.94×10^{-6} mg/kg), the giant panda encounter rate decreases to 0. So, the maximum bearing value of Pb in the habitat soil in this area is 37.94×10^{-6} mg/kg. The contribution of these three elements is shown in *Table 1*.

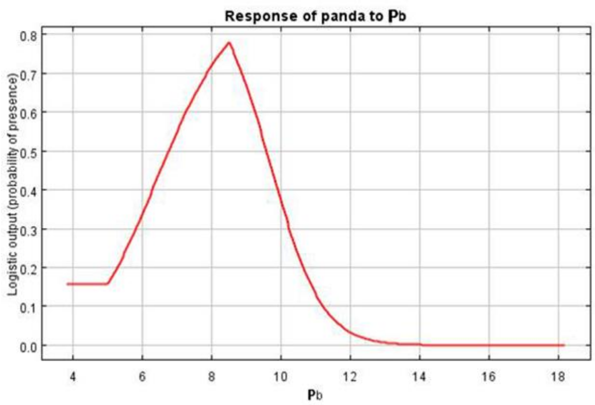


Figure 4. *Response Curve of Pb to the Giant Panda Encounter Rate*

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Table 1. *Contribution of Heavy Metal Elements*

Cr contribution	89.413
Hg contribution	2.033
Pb contribution	8.554

It can be seen from *Table 1* that among these three heavy metal elements, Cr has the largest impact on the giant panda habitat, accounting for 89.413%, followed by Pb, accounting for 8.554%; Hg has the least impact on the giant panda habitat in Pingwu County, accounting for 2.033%. The result of the analysis by MaxEnt model is shown in *Fig. 5*.

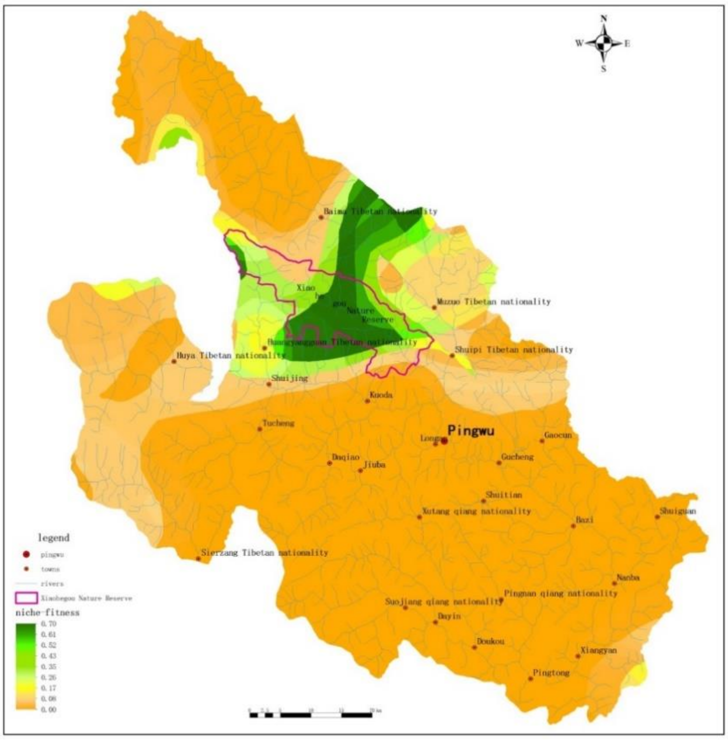

Figure 5. *Suitable Region for MaxEnt Model*

Precision Evaluation of Operation Results

For the giant panda habitat niche model, ROC (Receiver Operator Characteristic Curves) and AUC (the area under curves) were used to test the reliability of predicting outcomes. The larger the value is, the more strongly environment variables are correlated with the geographical distribution model of the predicted species, and the higher the predicting reliability is. AUC ranges from 0 to 1, and its interval division is shown as follows: when AUC ranges between 0.5 and 0.7, model evaluation is less reliable; when AUC ranges between 0.7 and 0.9, model evaluation is reliable; when AUC is greater than 0.9, model evaluation is highly reliable. AUC is insusceptible to the threshold value, and the evaluation result is objective and has a wide application (Duan, 2015). In the heavy metal niche model, the AUC of the simulation result training set is 0.965 (*Fig. 6*), suggesting that the predictive effect is good, and the result is available.

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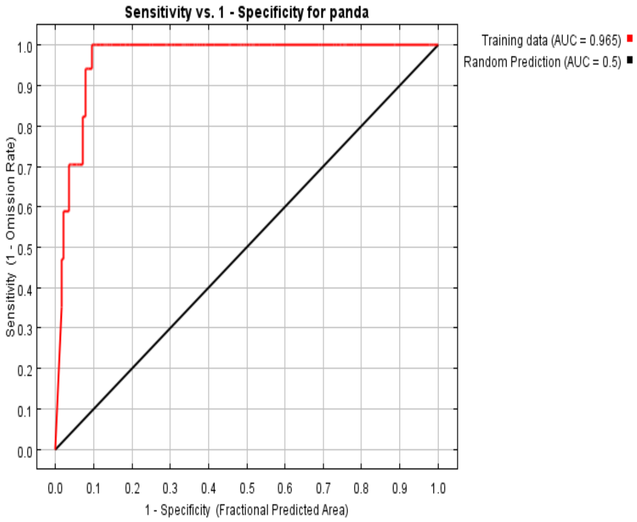

Figure 6. *Predicting Result of Heavy Metal Niche Model ROC & AUC*

Discussion

Many scholars have their own opinions on wildlife conservation (Liu et al., 2018; Kija et al., 2020; Pédarros et al., 2020). Some of the contents and conclusions of this paper have been described in the author's previous Chinese articles (Zhang, 2016). But at present, there are very few reports on the effect of geochemical (heavy metal) elements on the giant pandas' selection of habitats. In order to provide reference for more researchers, we tried to extract part of the information, by building a geochemical (heavy metal) niche model, this paper researched and analyzed the restriction of Cr, Hg and Pb in the soil in Pingwu County, Sichuan Province on the giant pandas' selection of habitats, and calculated the maximum bearing value of three elements in the giant panda habitat in the study area, in hope of providing reference for analyses of giant panda habitats in future. But due to the immaturity of the existing research on the mechanization of heavy metals' effect on the giant pandas, this paper suggests just taking it as an appropriate reference for the selection of potential habitats, rather than taking it as the main judgment basis for predictions of potential habitats in order to avoid ignoring the areas containing over-high bearing capacity. This paper studied the influence of the content of the three heavy metallic elements in soil on the habitat selection of pandas. The analysis shows that the content of heavy metal in soil will finally influence the habitat selection of pandas, which coincides with the research findings of Tian et al. (2019) that "we should attach greater importance to regional heavy metal pollution to protect this animal species". Major limitations of this paper lie in that the study fails to include other factors in this region such as the content of heavy metal in plants and the feces or hair samples of this targeted species, which will be further discussed in follow-up research.

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