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A Study on Biodiversity Mechanism by the Creativity Theory of Ecosystem

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1. Introduction

The mechanisms of biodiversity have been intensively studied in recent decades. Significant attention has been given to finding those mechanisms that explain the patterns of species richness found changing with latitudinal gradients (Hubbell, 1979; Jablonski, 2006; Lyons, 1999; Root, 1988). A large number of these species richness hypotheses have been proposed, and new ones continue to appear, with the total now exceeding thirty (Hawkins et al., 2003; Huston, 1979; Ritchie & Olf 1999). Yet there remains considerable controversy about the hypotheses that underlie the observed patterns of biodiversity (Kerswell, 2006; Willing et al., 2003).

The theories of local determinism generally try to find a few key environmental factors and establish their simple relationships with species richness in that distinct environment (Ricklefs, 2006). By doing so, the species richness could hopefully be predicted by measuring these environmental factors and their results could then become the principles of biodiversity conservation. Initially a single prominent factor is regressed against species richness, for example, the *species-energy hypothesis*, *species-area hypothesis*, or *species-productivity hypothesis* treats the single factor of energy, area, and productivity, respectively, as the most important factor to influence species richness (Allen et al., 2002; Mittelbach et al., 2001; Turner et al., 1988). Later on multiple factors are used to explain the causes of biodiversity, such as the *hypothesis of water-energy dynamics* that suggests the link between water-energy and species richness is widespread and generally strong (Hawkins et al., 2003). Ironically, more and more environmental factors are found to be important, and the relationships between these factors and species richness are variants according to different locations and scales.

The theories of community explain the forces that maintain species diversity from the aspect of community ecology, for example the *niche-assembly theory* asserts that species co-occur in a community only when they differ from one another in resource use. But this theory has some difficulties to explaining the diversity often observed in species-rich communities such as tropical forests (Zhou & Zhang, 2006). The *neutral theory*, on the other hand, assumes that all individuals of all species in a tropically similar community are ecologically equivalent. The number of species in a community is controlled by species extinction and immigration, and speciation of new species (Hubbell, 2001). Based on the fundamental processes of birth, death, dispersal and speciation, neutral theory presented a mechanism that generates species abundance distributions remarkably similar to those observed in nature, however controversy persists (McGill, 2003). Some ecologist believe that the most important task

ahead is to integrate niche and neutral theories, that is to add more processes in neutral theories and more stochasticity in niche theories (Alonso & McKane, 2004; Chave, 2004). This demonstrates that there is a strong wish for the ecologists to search for a general principle about the mechanisms of biodiversity (Tilman, 1999). Nevertheless such integration only within the community ecology may not solve the existing problems and identify the general principle embraced. Ricklefs (2006) pointed out that to assess the relative roles of local ecological constraint compared to regional and historical unfolding of diversity-environment relationships, we must abandon localized concepts of the community and adopt historical (particularly phylogenetic) and geographic methods to evaluate the evolution of diversity within large regions and its influence on diversity at local scales.

Although many hypotheses have been proposed and ecologists have amassed a wealth of detail to explain global patterns in species richness, there is no integrated hypothesis of how the ecosystems work as a whole evolved entity. For example, local determinism explains the biodiversity gradients from a physical environment perspective, and the theories of community consider more about ecological processes or population dynamics. Moreover, it is inappropriate to run a regression of species richness against environmental factors by treating the species richness as a dependent variable and the environmental factors as independent variables. This is because from the aspect of ecosystems, both species richness and physical environments are independent variables and their interactions contribute to the properties of the ecosystems. Therefore species richness itself through interactions among species also contributes to further species richness. In addition, we all agree that biodiversity is the emergent property of ecosystems through interactions of physical environments and organisms after a long evolutionary history. In contrast, there have been few studies on such indicators to reflect the ecosystem's potential of emerging properties, which undoubtedly influences our effort to understand the mechanisms of biodiversity thoroughly. Obviously, it is necessary to establish an integrated theory to study the causes of biodiversity by embracing *system thinking*, and regarding the ecosystem as an entity and treating biodiversity as the emergent property of the ecosystems.

The objective of this paper is to study the mechanisms of biodiversity by establishing a new theory from the aspect of ecosystem creativity. Here we develop an integrated theory, which we call Creativity Theory of Ecosystems (CTE), to study the mechanisms of biodiversity with a different perspective compared to more conventional approaches. Basing our theory on system thinking, the CTE establishes a model according to four concepts of creativity, energy, environment diversity and adaptability and the relationships among them. Chiefly by introducing the adaptability as one of the independent variables, the CTE model not only integrates biotic and abiotic factors but also combines spatial and temporal scales needed to predict plant species richness. This new approach is a very general theory and can be applied to any ecosystem because it is premised on system thinking, and is not tied to any specific scale or particular experimental design. A quantitative test of CTE was also conducted with statistical methods according to data obtained for species richness and environmental factors from 27 provinces of China.

2. Creativity Theory of Ecosystems (CTE)

An ecosystem is one of the complex systems whose properties are not fully explained by an understanding of its component parts (Gallagher & Appenzeller, 1999). It is an essential approach for an ecologist to view the ecosystem as an evolved entity, by doing so we find

that biodiversity patterns actually are the self-creations of the global ecosystems after a long history of interactions among organisms and physical environments in different scales. It is clear that biodiversity is one of the most prominent emergent properties for the ecosystems, and creativity can naturally be employed as an indicator for the potential of yielding emergent features. Thus, the CTE is based on four main concepts:

1. Ecosystem creativity is a measure of an ecosystem's potential to yield emergent properties. There are three indispensable factors influencing ecosystem creativity. These include energy, environmental diversity, and adaptability within the ecosystem.
2. Energy is the most fundamental of the ecosystems and can be regarded as the capacity for doing work being associated with material bodies or for motion with systems, thus there cannot be creation without energy involved. The higher the energy input, the more emergent properties would be produced within a system. This quality has been proved by species richness distribution of birds (Hawkins, 2003; Root, 1988; Turner, 1988), Lizard (Scheibe, 1987), vascular plants (Mittelbach et al., 2001), benthic marine algae (Kerswell, 2006), etc. So energy is generally positively related to ecosystem creativity.
3. Environmental diversity is defined as environmental complexity of the ecosystems, which at least will include spatial heterogeneity and climatic variability. Theoretically the more heterogeneous and complex the physical environments, the more complex the plant and animal communities will be, and the higher the species diversity (Krebs, 2001). Ecological studies have also shown positive relationships between environmental complexity and species diversity for many groups of organisms, including mammals, lizards, plankton, marine gastropods, reef fish, algae and plants (Manuel, 2002). Analysis using 85 data sets ranging from plants to vertebrates and invertebrates on publications, Hawkins et al (2003) found that climatic variables were the strongest predictors of richness in 83 of the 85 cases. This finding offers widespread support for the hypothesis that climate in general has a major influence on diversity gradients across large spatial extents. It is obvious that environmental diversity has a positive relationship with ecosystem creativity.
4. Adaptation is an ordinary phenomenon within the biotic kingdom and has been considered as a primary force in evolution (Zhang, 1998). Global biodiversity today can also be interpreted as the result of organism adaptation, because organisms change their material environment as well as adapt to it (Lovelock, 2003). Naturally, using adaptability as a measure of adaptation for the ecosystems should be a reasonable indicator to understand biodiversity mechanisms from the aspect of an organism's contribution. Adaptability can be defined as the quality or state of being adaptable, where adaptable means capable of being adapted or suitable without change (Gove, 1976). With this concept, it is clear that adaptability includes a continuum of states from adaptable (without change) to not adaptable (maximum change). Because creation must involve changes, and great creation means great changes, adaptability therefore is negatively related to creativity. This relationship has been demonstrated by Buckling et al. (2003) with the bacterium *Pseudomonas fluoresceus*, that adaptation itself is likely to limit a population's ability to diversify. In general, local adaptation to source habitats can limit local adaptation in sinks and restrict the use of alternate niches (Urban, 2006).

Based on the above definitions we find that ecosystem creativity is positively correlated with energy (e) and environmental diversity (d), but negatively correlated with adaptability (a) of the ecosystems. We then introduce creativity index (CI) as an indicator to reflect the creativity of ecosystems. We can write CI as

$$CI = f(e, d, a) \quad (1)$$

Generally speaking, in this equation energy can be easily understood and measured, however environmental diversity and adaptability are problematic. Because there is no single parameter to completely express environmental diversity, it is probably wise to consider it according to spatial scales. Freestone & Inouye (2006) found that the mechanisms driving species coexistence and diversity in serpentine seeps appear scale-dependent. Willis & Whittaker (2002) classified the spatial scales in five categories as local, landscape, regional, continental, and global. It is becoming increasingly apparent that the factor best accounting for patterns of biodiversity seems to be delimited by scale. Consequently, d is a variable of scale-dependent in Eq. (1).

According to the definitions, an ecosystem is completely adaptable to its environmental conditions if there are no changes occurring, but the ecosystem displays some non-adaptable quality if there are emergent properties occurring after a certain period of evolutionary time. Thus the more emergent properties that appear within the ecosystem the bigger the changes become and the lower the level of adaptability. We then can calculate the a value by the reciprocal of the ecosystem's changed rate with the following equation:

$$a = 1/(N-n)/n = n/(N-n) \quad (2)$$

Where, n is the number of original properties at time t_1 , N is the number of properties at time t_2 , Δt ($\Delta t = t_2 - t_1$) is the evolutionary time of an ecosystem. Thus, $N-n$ is the number of emergent properties and $(N-n)/n$ is the changed rate of ecosystem properties during evolutionary time period Δt .

Apparently we measure the adaptability of the ecosystem from historical and evolutionary aspects, because in the biological sense current adaptations are the result of selection that was in progress at some time in the past (Ridley, 2004). We actually judge the adaptability from differences between current properties of the ecosystem and its properties in the past. This then implies that our a value is also a variable that is time-scale-dependent. In addition, though the ecological processes of competition and predation (Bush, 2003; Fine et al., 2006; Schmitz, 2006; Straub, 2006) are greatly different within evolutionary time periods, the Bible teaches us to judge a tree by its fruit. Correspondingly, we judge the perfection of an organism by its power to survive and multiply (Egbert Giles Leigb, 1971) or in our hypotheses by the final emergent properties of ecosystems.

If the a variable in Eq. (1) is replaced by Eq. (2), the model yields: $CI = f(e, d, a) = f[e, d, n/(N-n)]$, Since a is negatively correlated with creativity, the above equation should be:

$$CI = f[e, d, (N-n)/n] \quad (3)$$

Hence, CTE treats the ecosystems as a consolidated entity, and biodiversity is its emergent property through interactions among organisms and environments after evolving through a certain spatial and temporal scale. For an ecosystem the higher the energy input the more diversified environments become and the less adaptability. Subsequently, the greater the creativity also means the higher the biodiversity.

However, due to the combinations among the variables of e , d , and a could be various forms such as plus, multiplication, power, etc., and the CI model (3) is only a functional equation that cannot be calculated directly. This is a reflection of complexity of the ecosystems, i.e., one cannot predict the creativity of every ecosystem with a single combination of these

variables because the variables of d and a are spatial and temporal dependent, respectively. Thus to calculate the CI value quantitatively we need to specify ecosystems in spatial and temporal scales and find the relationship among variables for certain scale ecosystems. We then test the CTE with the methods of Principal Component Analysis (PCA) and regression for ecosystems on a regional scale.

3. Test of the CTE

3.1 Material and methods

China, with a vast area of 9.6 million km², is an ideal region to test CTE. Its territorial distance from south to north is 5500km, including tropic, subtropic, temperate warm and temperate cool zones. From China's east to west is 5200km, including a great expanse of land from the Pacific Ocean to Mt. Everest with the terrain rising gradually. Due to the various geographic and climatic conditions, China is one of the regions with the most abundant displays of biodiversity in the world (Shi, 1991).

We collected the data from 27 provinces (22 provinces and 5 autonomous regions) in China (Table 1 in Appendix 1) Three municipalities directly under the Central Government (Beijing, Tianjing, Shanghai) were excluded because their relative small areas have been strongly influenced by urbanization. The data from the Chongqing municipality was included in Sichuan province. The areas of Hong Kong, Macao, and Taiwan were not included because we were unable to get relevant data.

The variables were collected and determined as follows:

1. Animal species richness. The number of terrestrial vertebrate species (including birds, reptiles, amphibians, and mammals) was used to indicate the animal species richness. Data were taken from Editorial board for series of natural resources in China (1995) and Editorial board for the complete series of Chinese agriculture (1998).
2. Plant species richness. The number of vascular plant species (including pteridophyte, gymnosperm, and angiosperm) was used to indicate the plant species richness. Data were taken from publications related to the flora and vegetation for every selected province (see Appendix 1).
3. Energy (e). Energy input was estimated by annual mean temperature. Data were available online from the Scientific Database of the Chinese Academy of Science (<http://www.sdb.ac.cn/>).
4. Environmental diversity (d). We used annual precipitation, altitude difference (maximum minus minimum altitudes), and land area to estimate environmental diversity. Water availability is a critical factor to constrain species distribution and altitude difference is the most prominent geographic feature in China. Area is also employed as a variable to influence environmental diversity because the areas were greatly different among provinces. The combination of these three factors can predict the d variable in regional scale very well. Data were taken from the publication Editorial board for series of natural resources in China (1995) and Editorial board for the complete series of Chinese agriculture (1998) and online from (<http://www.sdb.ac.cn/>).
5. Reciprocal of adaptability (a^{-1}). According to Eq. (2): $a^{-1} = 1/a = 1/n/(N-n) = (N-n)/n$, this actually is the changed rate of ecosystem properties during evolutionary time period Δt . Because we treated every province as a consolidated entity, and it is impossible to

measure the complete properties of the ecosystems, we used the animal species richness at present-day (N) to estimate the ecosystem properties. We then assumed that the number of original properties (animal species richness) at the processes occurring was 1, that is $n = 1$. The evolutionary time period (Δt) might be over the last 10000 years, i.e., since the end of the last glacial period (Willis 2002).

CI values for every province were calculated from Eq. (3) by the following steps and methods: First, the data (from Table 1 in Appendix 1) were normalized using the standard deviation method (Xu, 2002) in order to eliminate influences caused by different units and dimensions (Table 2 in Appendix 1). Second, a Principal Component Analysis (PCA) was performed on the e , d and a^{-1} in an effort to reduce the dimensionality of the data sets. The varimax rotation was used to simplify the interpretation of the results. Two components accounted for 87.63% of variance in e , d and a^{-1} depending on the eigenvalues, percent of variance, and cumulative percent (Table 3 in Appendix 1). The major components of the first factor are temperature, precipitation, and the reciprocal of adaptability (Table 4 in Appendix 1). This is consistent with the natural situation in China where there are two most prominent climatic features of temperature increasing from north to south and precipitation decreasing from east to west. Factor 2 is composed of altitude difference and area (Table 4 in Appendix 1), each of which reflects the geographic characteristics in China. From the rotated component matrix (Table 4 in Appendix 1) and component score coefficient matrix (Table 5 in Appendix 1), we find the component score coefficient rotated matrix for all the provinces, which were F1 and F2 (Table 6 in Appendix 1). Finally, the CI value (Table 6 in Appendix 1) was estimated by the integrated factor ($\sum F$) according to the percent of variance for F1 and F2:

$$CI = \sum F = \% \text{ of variance for component 1} \times F1 + \% \text{ of variance for component 2} \times F2 \\ = 0.55569 \times F1 + 0.32065 \times F2$$

Therefore, CI represents integrated levels of energy, reciprocal of adaptability, and environmental diversity in terms of annual precipitation, altitude difference, and area. CI value is above average if it is positive, and below average if negative.

In order to test the CTE we took the plant species richness as the emergent property of the ecosystem for each province and as the dependent variable, where CI was the independent variable. We ran regressions on the normalized data using the equation: plant species richness = $a + b(CI) + c(CI)^2$, in linear, quadratic and cubic models. Only the best model was shown in Table 1. The results were compared with that of conventional methods, i.e., *energy-hypothesis*, *spatial heterogeneity hypothesis*, *area hypothesis*, and *water-energy dynamic hypothesis*, with a multiple regression equation of: plant species richness = $a + b(\text{energy or area...}) + c(\text{energy or area...})^2$ also in linear, quadratic and cubic models. In order to be as liberal as possible in discovering patterns, relationships were considered significant if $P < 0.05$. The majority of relationships considered significant had $P < 0.01$.

3.2 Results

Regression analysis shows (Table 1) relationships that are almost exactly those predicted by the CTE hypotheses. We find the CI value is the best predictor with the cubic model and accounted for 94.0% of the variation in plant species richness ($F=137.516$, $P<0.0001$), whereas model with an integrated environmental factor excluding adaptability can only account for 42.3% of the variation in plant species richness ($F=20.054$, $P<0.0001$). The models

with a single parameter of temperature, altitude difference, or land area are not ideal and account for 12.3%, 17.6%, and 28.0% of the variation in plant species richness respectively, with less F value and $P < 0.05$. The model with multiple parameters of temperature, precipitation, and altitude difference shows much better than that of models with a single parameter, and account for 59.3% of the variation in plant species richness ($F = 19.915$, $P < 0.001$), and is far behind the CI model.

3.3 Discussion

The CTE successfully predicts the plant species richness distribution in provinces of China. This success comes mainly from our new system thinking approach of study. First, we treat every province as a consolidated ecosystem (though their land areas may differ greatly), and that plant species richness is one of its emergent properties through the interactions of biotic and abiotic factors. Conventional approaches using equal and small area quadrat as the basic studying unit actually divide the ecosystems into many small component parts. This approach is probably reasonable for a small scale evaluation within a community or landscape, but is inappropriate for a large spatial scale like China with its 9.6 million km² land area, and distances exceeding 5000 km from south to north and east to west. Adding up all of the component parts is not equal to a whole ecosystem. This also explains why Willis and Whittaker (2002) concluded that variables that best account for species richness on a local spatial scale may not be the same as those accounting for richness at regional spatial scales.

Secondly, we use an integrated factor from the results of PCA to calculate CI , which represents the contribution weights of every independent variable to the whole system. This approach is much better than the single variable model of temperature, precipitation, or area, because species richness is the emergent property of ecosystems through interactions of multiple factors. So a single factor model cannot explain the ecosystem property, especially on a large scale. On the other hand, though model established by multiple variables with stepwise regression fits better than a single variable model, it has a major drawback from the aspect of system thinking. This is because it selects variables only considering the correlations between dependent and independent variables, but neglects the interactions among variables. For instance, the last model in Table 1 only selects altitude difference and precipitation and rejects temperature. But we well know that nothing will happen in the real world without energy input. Thus, Hawkins et al. (2003) concluded that the interaction between water and energy provides a strong explanation for globally extensive plant and animal diversity gradients. Those analyses that do not include water-energy variables are missing a key component for explaining the broad-scale patterns of diversity. In our theory we not only consider correlation, but also pay great attention to the indispensable components of the emergent properties of ecosystems.

Finally, and most importantly, we introduce adaptability into the independent variables. This is estimated by the changed rate of animal species richness in an evolutionary time scale. In this way, we not only integrate biotic and abiotic factors but also combine spatial and temporal scales to predict plant species richness. This is a brand new approach when compared to the conventional hypotheses. Our results show that the changed rate of animal species richness has a great influence on plant species richness. Not only do theoretical works support this, but also empirical studies at the population and community levels have

documented that herbivores can reduce a plants' potential distribution, restricting them to a subset of habitats that they might physiologically tolerate (Harley, 2003). More studies demonstrated that higher trophic-levels can have important effects on plant diversity and ecosystem properties (Fine, 2006; Schmitz, 2006).

Variable	Regression	Degrees of freedom	F value	P
Plant species richness - CI, in cubic				
Coefficient of determination (R ²)	0.940	3/23	137.516	0.0000
Constant	-0.184			
CI	0.818			
CI ²	0.293			
CI ³	0.432			
Plant species richness - integrated environmental factor of temperature, precipitation, altitude difference, and area, in linear				
Coefficient of determination (R ²)	0.423	1/25	20.054	0.0001
Constant	-6.377E-07			
Integrated factor	0.935			
Plant species richness - temperature, in linear				
Coefficient of determination (R ²)	0.123	1/25	4.656	0.0407
Constant	-7.407E-11			
Temperature	0.396			
Plant species richness - altitude difference, in linear				
Coefficient of determination (R ²)	0.176	1/25	6.553	0.0169
Constant	-1.247E-10			
Altitude difference	0.456			
Plant species richness -area, in inverse				
Coefficient of determination (R ²)	0.280	1/25	11.132	0.0027
Constant	0.132			
Land area	0.201			
Plant species richness - temperature, precipitation and altitude difference, in linear				
Coefficient of determination (R ²)	0.593	2/24	19.915	0.000
Constant	-2.11E-10			
Altitude difference	0.761			
Precipitation	0.714			

Table 1. Regression analysis of plant species richness against CI value and other environmental variables

	Area	Altitude difference	Annual precipitation	Annual Mean air temperature	Animal species richness
Plant species richness	0.0648	0.4557	0.3886	0.3962	0.9239
<i>P</i>	0.748	0.017	0.045	0.041	0.000

Table 2. Partial Correlation Coefficients between plant species richness and area, altitude difference, precipitation, temperature, and animal species richness

In addition, we find an interesting phenomenon that the geographical area has a very weak partial correlation coefficient with plant species richness, and the best model is an inverse one. This finding is counter to the *area hypothesis* (Table 2, Table 1). We postulate that the *area hypothesis* mainly considers a small scale, and that the pattern of species richness increasing with area will not exist if the area exceeds a critical size. Lyons & Willing (1999) also found that area effects on species richness for bats and marsupials are a minor importance at the area scales of 1000-25000km². We believe that the smallest area in our study (33900km² Hainan Province) may have been sufficiently large to have sampled most taxa as a regional species pool within China.

4. Conclusions

The mechanism of biodiversity is a complex issue that needs additional study from both system-specific models, and a more general theoretical framework that subsumes system-specific models as special cases (Fox, 2006). By embracing system thinking and regarding an ecosystem as an entity, and by treating biodiversity as the emergent property of the ecosystem, the Creativity Theory of Ecosystems integrates biotic and abiotic factors and combines spatial and temporal scales into a single model. Among the three variables of the model, the introduction of an adaptability variable is a unique and most important innovation. This enables our model to embrace both biotic and temporal factors. Thus we believe that the CTE provides a new approach to the study of the mechanisms of biodiversity from the aspect of a general theoretical framework. In addition, using the methods of PCA, the CI can be quantitatively calculated and will successfully predict plant species richness distribution on a regional scale within China. This demonstrates that the Creativity Theory of Ecosystems is feasible and promising.

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6. Appendix 1

6.1 Tables of basic data and steps for CI value calculation by PCA

Provinces (or Autonomous region)	Area ($\times 10^4 \text{Km}^2$)	Altitude difference (m)	Annual Precipitation (mm)	Annual Mean temperature ($^{\circ}\text{C}$)	Animal species richness (No. of species)	Plant species richness (No. of species)
Anhui	13.98	1860	1192.1	15.06	535	3644
Fujian	12.14	2148	1588.3	18.21	809	4709
Gansu	45.4	5258	292.48	6.88	821	4164
Guangdong	17.8	1922	1762.5	21.53	829	6621
Guangxi	23.67	1941	1596.7	21.13	878	7148
Guizhou	17.61	2763	1125.5	15.19	910	6665
Hainan	3.39	1863.1	1670.5	24.9	561	3585
Hebei	18.77	2879	518.31	10.31	540	2888
Henan	16.7	2123	739.38	13.5	428	3779
Heilongjiang	45.46	1366	518.62	1.97	496	1846
Hubei	18.59	3105.4	1216.3	15.45	546	4295
Hunan	21.17	2076	1438.4	16.82	578	4705
Jilin	18.74	2686	644.19	4.33	410	2516
Jiangsu	10.26	624.7	1025.8	14.9	480	2492
Jiangxi	16.69	2138	1665.8	17.54	531	4552
Liaoning	14.59	1348	666.54	8.58	477	1358
Inner Mongolia	118.34	3474.4	284.13	4.84	506	2781
Ningxia	5.18	2756	279.56	8.22	384	1647
Qinghai	72.12	5210	339.37	1.17	398	2703
Shandong	15.7	1530	676.2	12.35	450	1616
Shanxi	15.6	2878	491.29	8.64	405	2751
Shanxi(Xi'an)	20.56	3647	631.29	11.5	564	3813
Sichuan	56.71	7476	935.72	12.68	1006	9249
Tibet	120.1	7348.13	506.78	3.91	730	5780
Xinjiang	166.49	8765	132.81	7.26	560	3500
Yunnan	39.4	6663.6	1133	16.46	1314	15444
Zhejiang	10.53	1933	1441.7	15.99	638	4579

Table 1. The data on climate, environmental diversity, and species richness for the 27 provinces in China.

Provinces (or Autonomous region)	Area	Altitude difference	Annual Precipitation	Annual Mean temperature	Animal species richness	Plant species richness	a ⁻¹ §
Anhui	-0.547	-0.668	0.571	0.472	-0.398	-0.267	-0.398*
Fujian	-0.594	-0.530	1.367	0.991	0.860	0.109	0.860
Gansu	0.256	0.964	-1.236	-0.877	0.915	-0.084	0.915
Guangdong	-0.449	-0.638	1.717	1.539	0.952	0.783	0.952
Guangxi	-0.300	-0.629	1.384	1.473	1.177	0.969	1.177
Guizhou	-0.454	-0.234	0.437	0.494	1.323	0.799	1.323
Hainan	-0.818	-0.667	1.532	2.095	-0.278	-0.288	-0.278
Hebei	-0.425	-0.179	-0.783	-0.311	-0.375	-0.534	-0.375
Henan	-0.478	-0.542	-0.339	0.215	-0.889	-0.219	-0.889
Heilongjiang	0.257	-0.905	-0.782	-1.686	-0.577	-0.902	-0.577
Hubei	-0.429	-0.070	0.620	0.536	-0.347	-0.037	-0.347
Hunan	-0.363	-0.564	1.066	0.762	-0.200	0.107	-0.200
Jilin	-0.425	-0.271	-0.530	-1.297	-0.971	-0.665	-0.971
Jiangsu	-0.642	-1.261	0.237	0.446	-0.650	-0.674	-0.650
Jiangxi	-0.478	-0.535	1.523	0.881	-0.416	0.053	-0.416
Liaoning	-0.531	-0.914	-0.485	-0.596	-0.664	-1.074	-0.664
Inner Mongolia	2.119	0.107	-1.253	-1.213	-0.531	-0.572	-0.531
Ningxia	-0.772	-0.238	-1.262	-0.656	-1.091	-0.972	-1.091
Qinghai	0.938	0.941	-1.142	-1.818	-1.026	-0.599	-1.026
Shandong	-0.503	-0.827	-0.465	0.025	-0.788	-0.983	-0.788
Shanxi	-0.506	-0.179	-0.837	-0.587	-0.994	-0.582	-0.994
Shanxi(Xi'an)	-0.379	0.190	-0.556	-0.115	-0.264	-0.208	-0.264
Sichuan	0.544	2.029	0.056	0.080	1.764	1.710	1.764
Tibet	2.164	1.967	-0.806	-1.366	0.497	0.487	0.497
Xinjiang	3.349	2.648	-1.557	-0.814	-0.283	-0.318	-0.283
Yunnan	0.102	1.639	0.452	0.703	3.178	3.896	3.178
Zhejiang	-0.635	-0.633	1.072	0.625	0.075	0.063	0.075

Notes: § $a^{-1} = (N-n)/n$, where N is the animal species richness, n is 1, first calculated it from table 1, then normalized it.

* The data are normalized by standard deviation method with the following equations:

$$x'_{ij} = \frac{x_{ij} - \bar{x}_j}{s_j} \quad (i = 1, 2, \dots, m; j = 1, 2, \dots, n)$$

where,

$$\bar{x}_j = \frac{1}{m} \sum_{i=1}^m x_{ij} \quad s_j = \sqrt{\frac{1}{m} \sum_{i=1}^m (x_{ij} - \bar{x}_j)^2}$$

x_{ij} are the original data from table 1, x'_{ij} are the normalized data

Table 2. The normalized data from Table 1

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.778	55.569	55.569	2.778	55.569	55.569
2	1.603	32.065	87.634	1.603	32.065	87.634
3	0.373	7.453	95.087			
4	0.159	3.181	98.269			
5	0.087	1.731	100.000			
Component	Rotation Sums of Squared Loadings					
	Total	% of Variance	Cumulative %			
1	2.284	45.681	45.681			
2	2.098	41.953	87.634			

Note: Component 1 and 2 accounted for 87.63% of variance in e , d and a^{-1} depending on the initial eigenvalues in percent of variance and cumulative percent, which fulfill the requirements of cumulative percent for the two components larger than 80.00%, and of total initial eigenvalues larger than 1. So, we need only calculate the two components, F1 and F2, and they can represent the integrated level of the total variables.

Table 3. Total Variance Explained

	Component	
	1	2
Annual Mean Temperature	0.895	-0.305
Annual Precipitation	0.884	-0.343
a^{-1}	0.730	0.578
Altitude difference	-0.113	0.953
Area	-0.396	0.803

Note: The major components of the first factor (F1) include temperature, precipitation, and the reciprocal of adaptability (a^{-1}); F2 is composed of altitude difference and area.

Table 4. Rotated Component Matrix

	Component	
	1	2
Annual Mean Temperature	0.371	-0.0609
Annual Precipitation	0.382	-0.0399
a^{-1}	0.419	0.391
Altitude difference	0.0709	0.474
Area	-0.0820	0.360

Table 5. Component Score Coefficient Matrix

Provinces (or Autonomous region)	F1§	F2※	% of Variance for component 1	% of Variance for component 2	CI*
Ningxia	-1.10848	-0.70104	0.55569	0.32065	-0.84075973
Heilongjiang	-1.23733	-0.43886	0.55569	0.32065	-0.82829237
Jilin	-1.06291	-0.56709	0.55569	0.32065	-0.77248587
Shanxi	-0.90525	-0.57085	0.55569	0.32065	-0.68608143
Qinghai	-1.52923	0.51429	0.55569	0.32065	-0.68487073
Liaoning	-0.69384	-0.81544	0.55569	0.32065	-0.64703079
Shandong	-0.50111	-0.83787	0.55569	0.32065	-0.54712483
Inner Mongolia	-1.29225	0.71707	0.55569	0.32065	-0.48816191
Henan	-0.4076	-0.75018	0.55569	0.32065	-0.46704446
Hebei	-0.53405	-0.31812	0.55569	0.32065	-0.39877142
Jiangsu	-0.05018	-1.09471	0.55569	0.32065	-0.37890329
Shanxi (Xi'an)	-0.31057	-0.10938	0.55569	0.32065	-0.20765334
Anhui	0.2189	-0.70929	0.55569	0.32065	-0.1057933
Hubei	0.31361	-0.37556	0.55569	0.32065	0.053846627
Gansu	-0.35612	0.99807	0.55569	0.32065	0.122138823
Hunan	0.58149	-0.56129	0.55569	0.32065	0.14315054
Jiangxi	0.71499	-0.70264	0.55569	0.32065	0.172011277
Xinjiang	-1.07383	2.43101	0.55569	0.32065	0.182786764
Zhejiang	0.66299	-0.57856	0.55569	0.32065	0.182901649
Tibet	-0.63809	1.97223	0.55569	0.32065	0.277815317
Hainan	1.24772	-0.87933	0.55569	0.32065	0.411388362
Guizhou	0.90862	0.19321	0.55569	0.32065	0.566863834
Fujian	1.23396	-0.24656	0.55569	0.32065	0.606639768
Guangdong	1.58504	-0.25305	0.55569	0.32065	0.799650395
Guangxi	1.52001	-0.08699	0.55569	0.32065	0.816761013
Sichuan	0.87298	1.80694	0.55569	0.32065	1.064501567
Yunnan	1.84052	1.96399	0.55569	0.32065	1.652511952

Notes: § F1=-0.0820×area+0.0709×altitude difference + 0.371 × precipitation + 0.382 × temperature + 0.419 × a^{-1}

※ F2=0.360×area+0.474×altitude difference -0.0609 × precipitation -0.0399 × temperature + 0.391 × a^{-1}

* CI= $\sum F = \% \text{ of variance for component 1} \times F1 + \% \text{ of variance for component 2} \times F2 = 0.55569 \times F1 + 0.32065 \times F2$

Table 6. Component score coefficient rotated matrix and CI values for all the provinces

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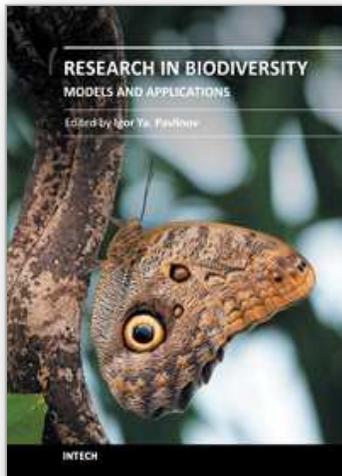
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The book covers several topics of biodiversity researches and uses, containing 17 chapters grouped into 5 sections. It begins with an interesting chapter considering the ways in which the very biodiversity could be thought about. Noteworthy is the chapter expounding pretty original "creativity theory of ecosystem". There are several chapters concerning models describing relation between ecological niches and diversity maintenance, the factors underlying avian species imperilment, and diversity turnover rate of a local beetle group. Of special importance is the chapter outlining a theoretical model for morphological disparity in its most widened treatment. Several chapters consider regional aspects of biodiversity in Europe, Asia, Central and South America, among them an approach for monitoring conservation of the regional tropical phytodiversity in India is of special importance. Of interest is also a chapter considering the history of the very idea of biodiversity emergence in ecological researches.

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