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The Homogeneity of Distributional Patterns of the Global Terrestrial Animal, Plant and Microorganism under the Influence of Ecological Conditions

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Abstract: The world animal geographical regionalization scheme and the plant geographical regionalization scheme have been formulated by zoologists and botanists respectively since the biogeography has been established. This research team initially confirmed the homogeneity of Chinese animal and plant geography. To explore the relationship between the distribution pattern of global animals, plants, and microorganisms, global 141,814 genera of terrestrial animals, 17,526 genera of plants, 21,321 genera of microorganisms, and their major taxa were analyzed using their proposed SGF (Similarity General Formula) and a new multivariate similarity clustering analysis method. Almost identical analytical results were obtained, meeting the requirements of statistics, geography, ecology and biology respectively. The expected consistency of their distribution pattern was achieved for the first time. We prove that the earth's ecological conditions affect the homogeneity and accumulation of the distribution of animals, plants and microorganisms. Homogeneity determines the distribution pattern of global kinds of biological consistency, accumulation determines the impact of the evolutionary period on the breadth of distribution, microorganisms appear earliest, plants second, animals later, and their average distribution domain decreases in turn, reflecting these differences. Therefore, this study not only provides a theoretical basis and quantitative basis for the establishment of geographical regionalization scheme but also advances the development of biogeography to a new stage and raises the theory of biogeographic analysis to a new height.

Key words: Distribution pattern, clustering analysis, terrestrial biology, homogeneity, geographical regionalization.

1. Introduction

There are more than 2 million kinds of creatures living on the earth. They spread all over the world in different life forms. The drift of land blocks, the uplift of the ground, the change of climate and the barrier of the ocean affect the reproduction and diffusion of organisms. Organisms also build their own distribution pattern with their own evolution and adaptability. The analysis and summary of biological distribution law and formation mechanism, and then the division of geographical distribution area is the research category of biogeography. It is one of the important basic disciplines for people to protect biodiversity and make rational, effective and sustainable use of natural resources [1-3].

In 1761, after the French naturalist G. Buffon opened the prelude of biogeography [4], in 1858, the British ornithologist P. Sclater first identified six areas and gave them classic names [5]. In 1876, A. R. Wallace, a British zoologist, accepted Sclater's plan. He drew a famous "Wallace's line" between Kalimantan Island and Sulawesi Island as the boundary between the Oriental and Australian Kingdom based on the distribution boundary of marsupials [6]. His "the geographical distribution of animals" is also honored as the foundation work of animal geography [7].

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German A. von Humboldt is the founder of phytogeography. He believes that the world will be divided into many natural regions, each with its own unique animal and plant clusters [8]. Swiss botanist A. de Candolle rapidly developed his work and defined 20 such natural areas [9]. In 1879, German botanist A. Engler used a map to define in detail the boundaries of four “kingdom” of plants: the Panarctic, the Paleotropical, the South American and the paleooceania [10]. Except for minor modifications made by some philosophers in the 19th century [11, 12], the six boundary zoning schemes of mammals and flowering plants are almost unchanged [13].

People’s universal acceptance and long-term use naturally shows its reasonable core, but there is no need to hide the fact that these conclusions obtained by qualitative methods inevitably have imbalances in the determination of division standards and boundaries. In the 20th century, on the one hand, people discussed the historical achievements and existing problems of early scholars [14-16], on the other hand, they actively tried to equip biogeography with quantitative analysis [17-23].

In the 21st century, people pay more attention to biogeographic zoning, and put forward various and different geographical zoning schemes for different biological groups with different methods [24-30]. British C.B. Cox proposed to change the global flora into five boundaries [24]. Wu Zhengyi of China proposed to add the paleo Mediterranean flora and the East Asian flora kingdoms [25]. S. Proches of South Africa conducted cluster analysis on the distribution of bats and divided the world into 10 geographical regions [26]. German H. Kreft uses Simpson formula and UPGMA (Un-weighted Pair Group Means Algorithm) method to gather the world into seven boundaries [27]. Danish B.G. Holt et al. used the same method to analyze more than 20,000 species of terrestrial mammals, amphibians and non-marine birds, dividing the world into 11 realms [28]. The American Ruida M. Rueda also analyzed these animals and believed that it was not necessary to modify Wallace scheme [29]. With regard to these arguments that “flowers are becoming more and more attractive”, the Mexican J. J. Morrone lamented that geographical division is a ghost hindering the development of biogeography [30].

Compared with the heated discussion of higher biogeographic zoning, lower organisms are very lonely. In fact, entomologists have been exploring and analyzing the distribution pattern of insects. However, the number of insect species is huge, the individuals are small, the public awareness is low, it is difficult to grasp the whole, and the progress is relatively slow. However, hundreds of papers have been published on various aspects of Entomology [31-33]. It is gratifying that in the past 20 years, some insect groups have been analyzed in succession, and their own opinions on geographical division have been put forward [34-36].

Although microorganisms, like animals and plants, widely exist and play an important role in all terrestrial ecosystems in the world, microbial geography is a new research field [37-39]. Its classification and distribution research is still in the stage of species description, and new species, genera, families and even new orders are emerging [40-42]. Flora composition, distribution range, ecological type, diffusion mechanism, influencing factors, regional characteristics and analysis methods related to microbial geography are gradually discussed and deepened [43-45]. However, there is no one who has made a preliminary attempt on the global geographical division of microorganisms so far.

After trying and comparing various quantitative analysis methods, we proposed a new SGF (Similarity General Formula) [46] and its supporting MSCA (Multivariate Similarity Clustering Analysis Method) [47]. Through the analysis and verification of different geographical regions, different biological categories, different taxonomic levels and different ecological groups, we can obtain faster, more accurate and more reasonable analysis results than traditional methods [48-54], and preliminarily confirm the homogeneity of the distribution pattern of animals and plants in China [55]. So what is the relationship among animals, plants and microorganisms in the world? No one at home or abroad has made such an attempt.

In view of the simplicity and rapidity of the MSCA method, based on the analysis of global insects [56], we conducted cluster analysis [57-61] on the genus level elements of terrestrial animals, plants and microorganisms in the world to compare their relationships and possible differences, and compared with traditional methods.

2. Materials and Methods

2.1 Global Terrestrial Biodiversity

There are a vast number of biological species in the world. The terrestrial organisms involved in this study include animals, plants, fungi, bacteria, viruses, etc., a total of 8 realms, 115 phyla, 356 classes, 1,352 orders, 8,714 families, 180,661 genera and 2,133,007 species (Table 1). The species distribution information comes from taxonomic monographs and catalogues [62-77] compiled by biological taxonomists, databases [78-86] compiled by biological professional websites, and some newly published new species and new distribution data [87-93] supplemented at any time. In order to improve the utilization rate of distribution data and the clarity of analysis results, this study uses “genus” as BBU (Basic Biological Unit) for analysis.

2.2 Division of Basic Geographic Units and Construction of Database

According to the topographic, climatic and other ecological conditions and the detailed degree of biological distribution data, the global land (except Antarctica) is divided into 67 BGU (Basic Geographic Units) (Fig. 1) [56]. The number of BGUs varies from continent to continent, including 6 in Europe, 25 in Asia, 9 in Africa, 10 in Oceania, 9 in North America and 8 in South America. Among them, there are 21 BGUs dominated by plains, 11 by hills, 12 by mountains, 11 by plateaus, 5 by deserts and 7 by islands. There are 27 BGUs in the tropical zone, 34 BGUs in the temperate zone and 6 BGUs in the cold zone.

Build the database with Microsoft Access, take each BGU as each column and each BBU as each row. The administrative region records of each biological distribution in a genus are converted into BGU records and summarized into the genus distribution, which are entered into the database. If there is a distribution, it is recorded as “1”, and if there is no distribution, it is not recorded. The number of biological genera of each BGU is shown in Table 2.

Table 1 Biodiversity of global terrestrial biota.

Realms	No. of Phyla	No. of Classes	No. of Orders	No. of Families	No. of Genera	No. of Species
Animalia	20	63	373	4,631	141,814	1,334,834
Archaea	2	9	15	35	134	528
Bacteris	29	49	112	443	2,893	16,636
Chromista	13	68	291	1,280	5,577	79,122
Fungi	9	47	211	855	10,454	162,763
Plantae	15	41	215	1,006	17,526	527,776
Protozoa	11	43	80	295	831	4,809
Viruses	16	36	55	169	1,432	6,539
Total	115	356	1,352	8,714	180,661	2,133,007

Fig. 1 BGUs of the world.

01 Northern Europe, 02 Western Europe, 03 Central Europe, 04 Southern Europe, 05 Eastern Europe, 06 European Russia,11 Middle East, 12 Saudi Arabia, 13 Yemen and Oman, 14 Plateau of Iran, 15 Central Asia, 16 Western Siberia,17 Eastern Siberia, 18 Ussuriregion, 19 Mongolia, 20 Plateau of Pamir, 21 Northeastern region of China, 22 Northwestern region of China, 23 Qinghai-Xizang region of China, 24 Southwestern region of China, 25 Southern region of China, 26 Centre-eastern China, 27 Taiwan region of China, 28 Korea Peninsula, 29 Japan, 31 Himalayan region, 32 Indian and Sri Lanka, 33 Myanmar, 34 Indochina Peninsula, 35 Philippines, 36 Indonesia, 37 New Guinea, 38 Islands of Pacific Ocean, 41 Northern Africa, 42 Western Africa, 43 Central Africa, 44 Reaches of Congo river, 45 Ethiopia region, 46 Tanzania region, 47 Angola region, 48 South Africa, 49 Madagascar, 51 Western Australia, 52 Northern Territory, 53 South Australia, 54 Queensland, 55 New South Wales, 56 Victoria, 57 Tasmania, 58 New Zealand, 61 Eastern Canada, 62 Western Canada, 63 Mts. Eastern US, 64 Plain Central US, 65 Hills Central US, 66 Mts. Western US, 67 Mexico, 68 Central America region, 69 Caribbean Islands, 71 Venezuela, 72 Plateau Guyana, 73 Northern Mt. Andes, 74 Amazon Plain, 75 Plateau Brazil, 76 Bolivia, 77 Argentina, 78 Southern Mt. Andes.

Table 2 The number of biotic genera of BGUs in the world.

BGU	Animal	Plant	Micro-organism	BGU	Animal	Plant	Micro-organism
01	8,188	3,556	6,341	44	4,560	2,256	613
02	10,437	3,342	6,751	45	2,940	1,703	609
03	9,183	2,941	5,626	46	5,545	2,623	897
04	12,146	3,498	6,386	47	5,026	2,567	1,967
05	3,682	1,407	2,509	48	7,060	3,444	2,625
06	3,068	1,684	2,515	49	4,830	2,903	1,359
11	5,080	2,028	2,592	51	5,784	2,410	3,641
12	2,048	911	1,315	52	3,993	1,690	2,057
13	1,943	1,018	919	53	3,319	2,041	2,051
14	3,768	1,459	1,350	54	9,608	3,123	4,067
15	3,129	1,102	1,030	55	8,607	3,209	4,537
16	1,865	826	871	56	5,932	2,674	3,007

Table 2 to be continued

17	5,159	1,259	1,609	57	3,737	1,817	3,104
18	3,237	1,045	597	58	4,015	2,918	5,242
19	1,603	697	243	61	6,178	1,772	4,466
20	1,540	1,216	663	62	7,280	2,565	3,895
21	4,729	1,004	1,496	63	10,750	4,081	6,301
22	2,391	732	447	64	8,242	2,796	4,906
23	2,957	788	1,083	65	7,008	2,465	3,967
24	6,308	2,212	929	66	10,313	4,144	5,436
25	8,936	2,745	2,663	67	12,016	4,547	3,979
26	11,624	2,989	3,899	68	12,037	3,863	3,164
27	8,837	2,210	2,461	69	4,808	2,880	2,517
28	2,330	1,248	2,337	71	5,221	3,163	2,049
29	8,060	2,582	4,669	72	3,964	2,243	1,250
31	3,418	2,057	1,194	73	9,353	4,772	2,904
32	7,481	2,970	3,527	74	6,618	3,727	2,747
33	4,834	1,913	912	75	7,722	4,073	3,031
34	7,013	3,012	1,922	76	3,828	3,233	781
35	4,858	2,206	1,598	77	5,748	2,615	2,375
36	9,614	3,583	3,567	78	3,569	2,039	2,911
37	5,436	2,800	1,280	BDR (Basic Distribution Records)	392,971	163,933	176,283
38	5,323	3,294	2,930	BBU	141,814	17,526	21,321
41	5,272	2,124	2,836	BGU	67	67	67
42	5,071	3,026	2,167	AW (Average Wealth)	5,865	2,447	2,631
43	2,792	2,092	294	ADT (Average Distribution Territory)	4.76	9.63	11.65

2.3 Clustering Method

SGF is defined as the similarity coefficient between any number of regions and is the proportion of the average number of common species in each region participating in the analysis to the total species [46]:

$$SI_n = \sum H_i/nS_n = \sum(S_i\text{-}T_i)/nS_n$$

In the formula, SI_n is the similarity coefficient of n geographical units to be compared, S_i, H_i and T_i are the number of species, common species and unique species of geographical units I respectively, and $H_i = S_i - T_i$, S_n is the total number of species of geographical units to be compared. Each value required for calculation can be easily obtained from the query page of the database. Both manual calculation and computer software analysis are very convenient.

The MSCA method [47] used with SGF is that the similarity coefficients of any group are directly calculated from the original data, which is not limited by the clustering order. It can even calculate the total similarity coefficients of 67 BGUs first. Finally, the clustering graph is arranged according to the similarity coefficient.

In order to compare the analysis results, the SSM (Sum of Squares Method) with the best effect is selected from a variety of current clustering methods to analyze the global animals, plants and microorganisms respectively.

SSM, also known as ward's method [22], uses the similarity coefficient formula [18] of Polish scholar J. Czekanowski, also known as Sørensen formula [21]: SI=2C/(A+B). The calculation process of this method is complex, and the calculation is completed by software SPSS (Statistical Package for Social Sciences).

3. Analysis Results

3.1 Global Terrestrial Animals

There are 33 phyla, 101 classes, 650 orders, 14,037 families, 221,803 genera, 1,784,672 species of fauna in the world. Excluding deep-sea species and fossil species, there are 392,980 BDR, of 141,814 genera of terrestrial animals for analysis in 67 BUGs. AW is 5,865 genera/geographical unit, ADT, is 4.76 geographical unit/genus. Fig. 2 shows the clustering results of MSCA method. The GSC (General Similarity Coefficient) is 0.066. On the similarity level of 0.300, 67 BUGs first gather into 20 SUC (Small Unit Crowds) of a-t, and on the similarity level of 0.200, they gather into 7 LUCs (Large Unit Crowds) of A-G. The constituent units of each group are adjacent and connected, which conforms to the geographical principle, each large group is basically a relatively independent continental block, and each small group has a relatively unique ecological environment within the large group, which conforms to the ecological principles. The degree of similarity within each group is higher than that between groups, which conforms to the statistical principle. Each group has its own unique biological groups, which are different from other groups and conform to biological principles.

3.2 Global Terrestrial Plants

Fig. 3 shows the MSCA clustering results of 17,526 genera of terrestrial plants for analysis. BDR, AW and ADT were 163,933, 2,447 and 9.63 respectively. The GSC of 67 BUGs was 0.141, more than twice that of animals'. At the similarity level of 0.430, 67 BUGs were clustered into 20 SUCs, and the groups with the same composition as animals were marked with the same letters, also a-t; at the similarity level of 0.310, 7 LUCs are aggregated into A-G. Compared with animals, only unit 31 of each LUC moved from group C to group B, and the rest had no difference; the composition of each SUC is also basically the same. Some units move. For example, units 74, 75 and 76 exchange small group positions. These movements occur between two adjacent groups, and do not violate the principles of geography.

3.3 Global Terrestrial Microorganisms

Fig. 4 shows the MSCA analysis results of 21,321 terrestrial microorganisms for analysis. BDR, AW and ADT are 184,685, 2,756 and 12.20 respectively, and GSC is 0.140, which is almost the same as that of plants' and more than twice that of animals'. At the similarity level of 0.190, like animals and plants, 7 LUCs are gathered. Compared with plants, the composition of each group has not changed except that unit 25 moved from group C to group B and unit 38 moved from group C to group E. The movement of these two units also conforms to the principles of geography. Some SUCs that are the same or similar to animals and plants can also be distinguished under each group, but there is no unified horizontal line to divide them.

3.4 Comparison with Traditional Clustering Methods

Among the currently popular traditional clustering methods, SSM with the best effect is selected to analyze animals, plants and microorganisms respectively (Figs. 5-7). Compared with Figs. 2-4, it can neither achieve the clustering degree of each group nor achieve the clustering results basically consistent with the three groups.

3.5 Clustering Results of Different Order Meta Biological Groups under the Realms

In order to eliminate the possibility of contingency, we also analyzed different phyla, classes, orders and families of animals, plants and microorganisms (Table 3), and obtained consistent clustering results. The results of 37,470 genera of animals excluding insects are consistent with that of 141,814 genera of animals, which proves that they are not affected by the wide variety and large proportion of insects. Although the

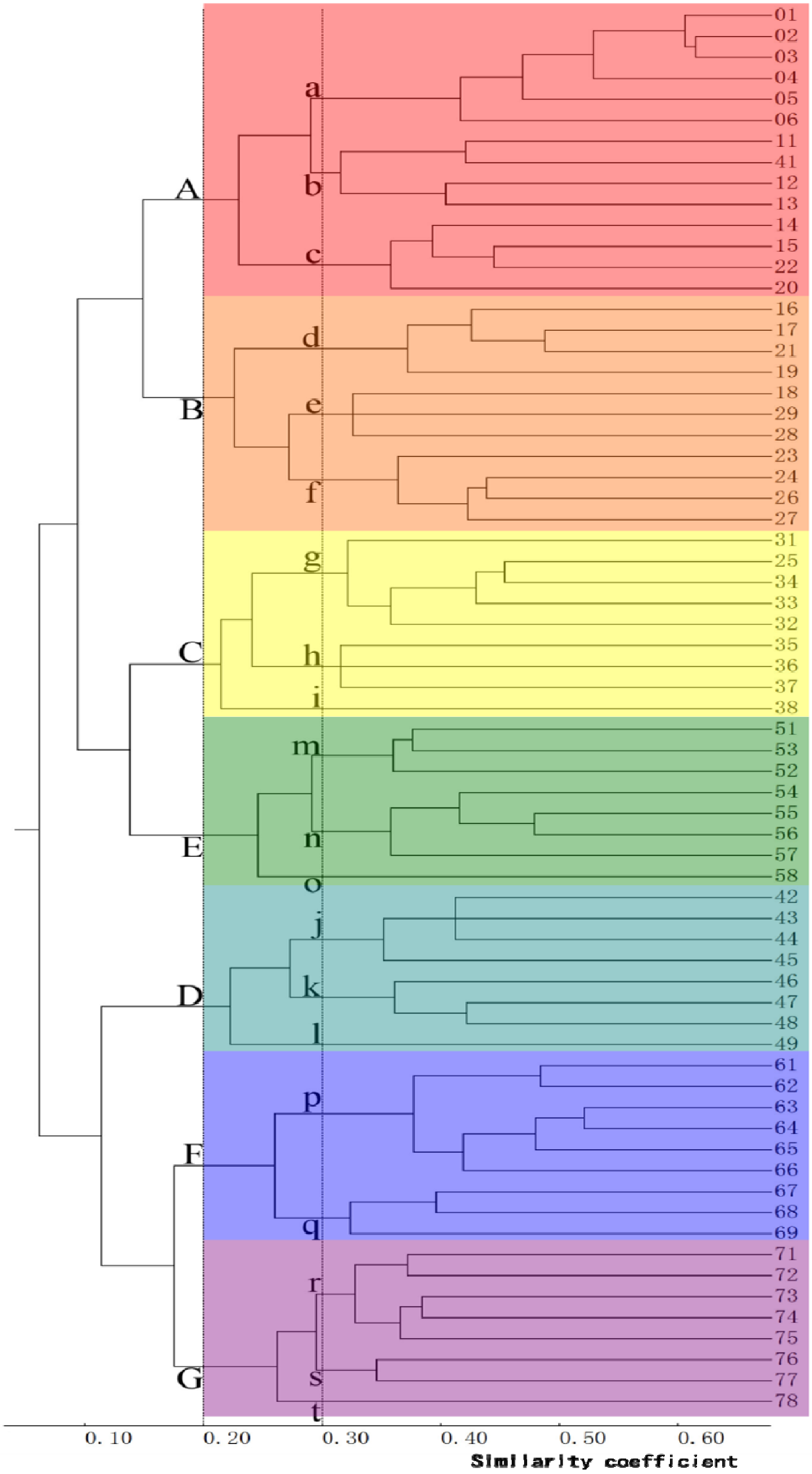

Fig. 2 **Clustering tree of animal by MSCA.**

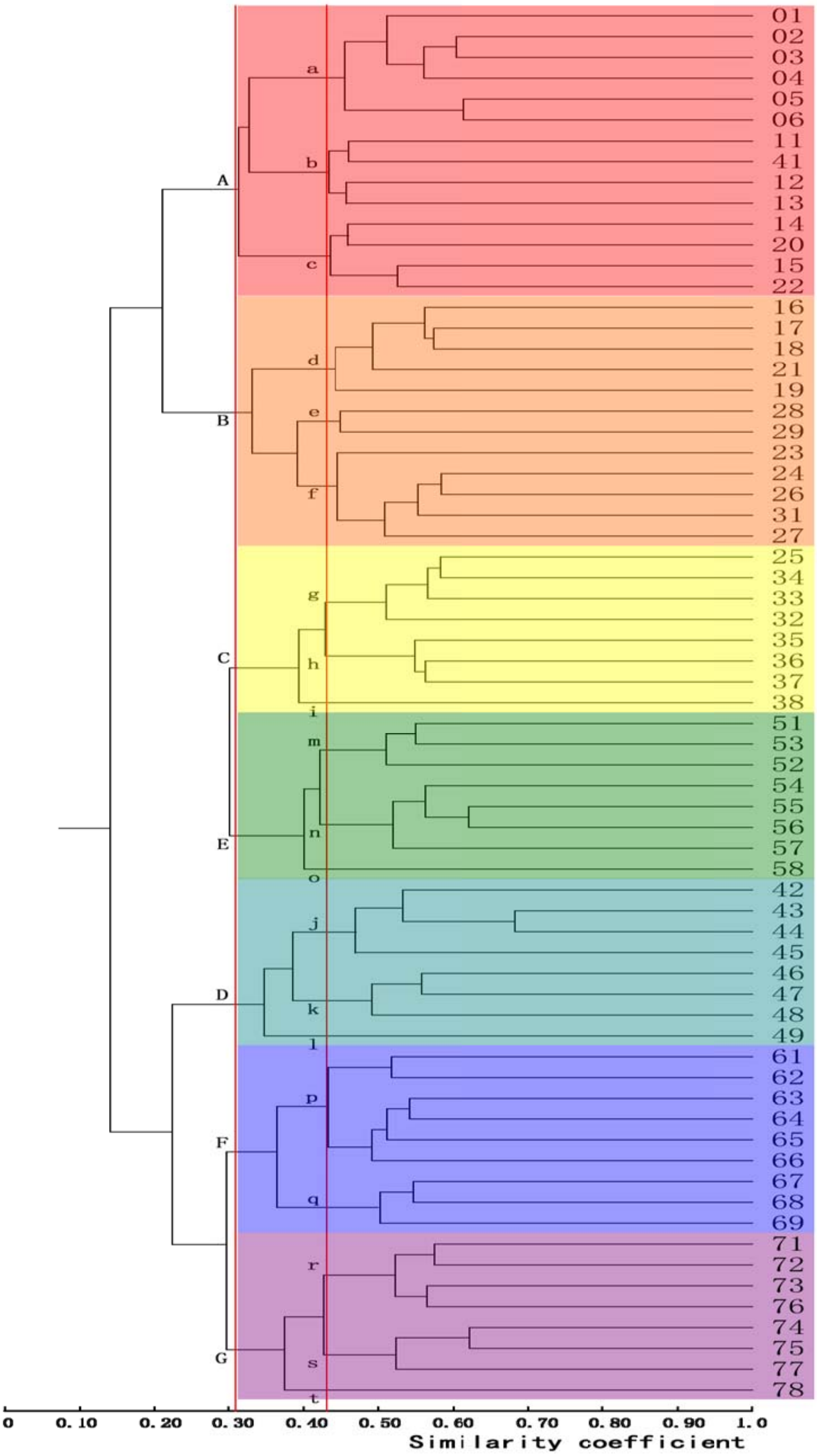

Fig. 3 Clustering tree of plant by MSCA.

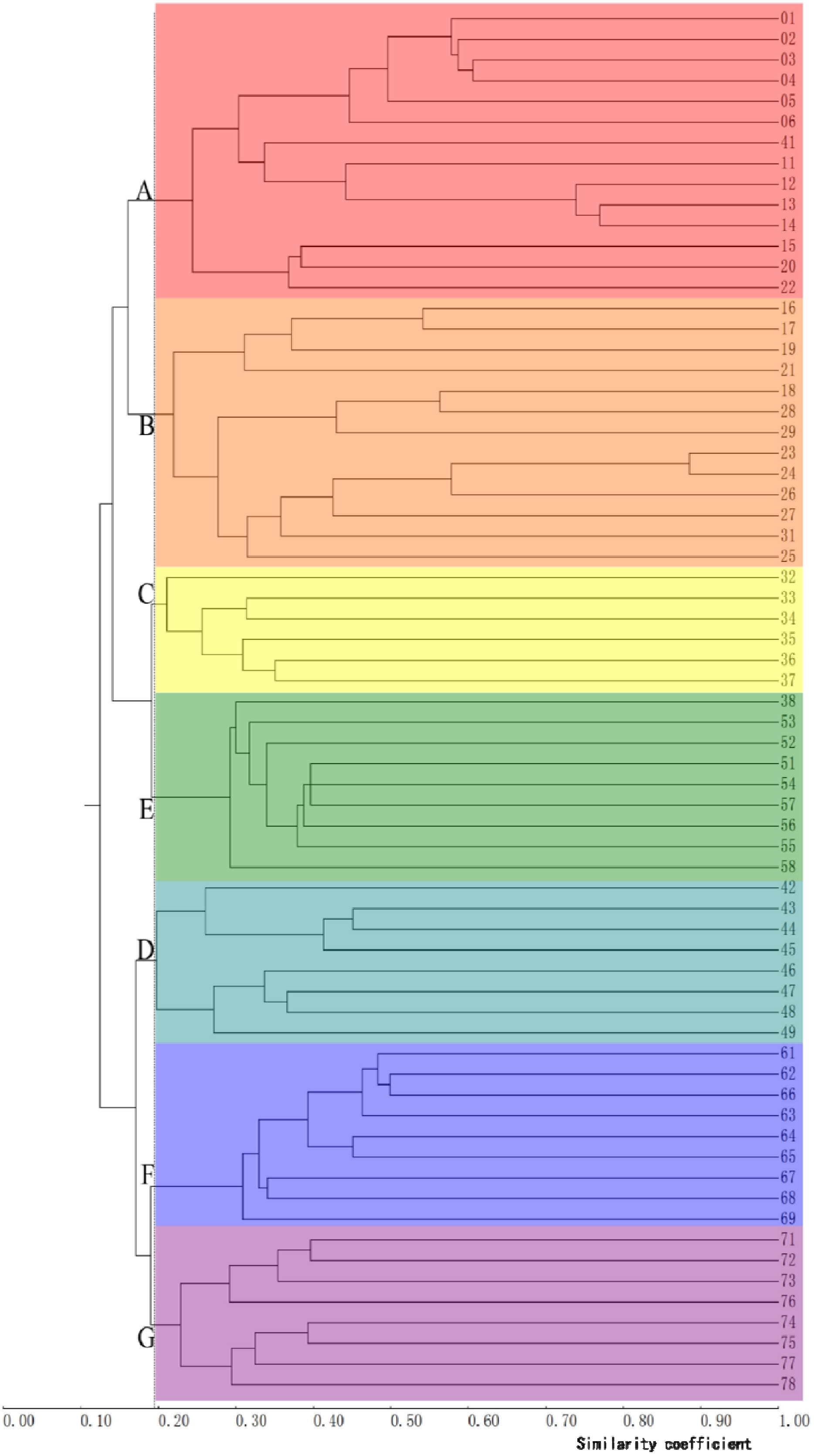

Fig. 4 Clustering tree of microorganism by MSCA.

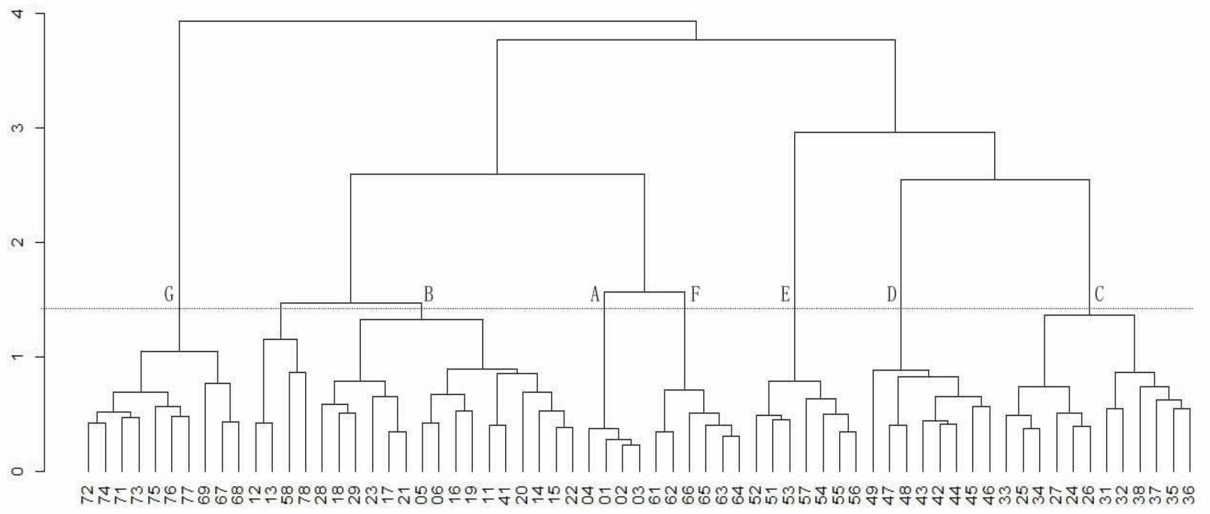

Fig. 5 **Clustering tree of animal by SSM.**

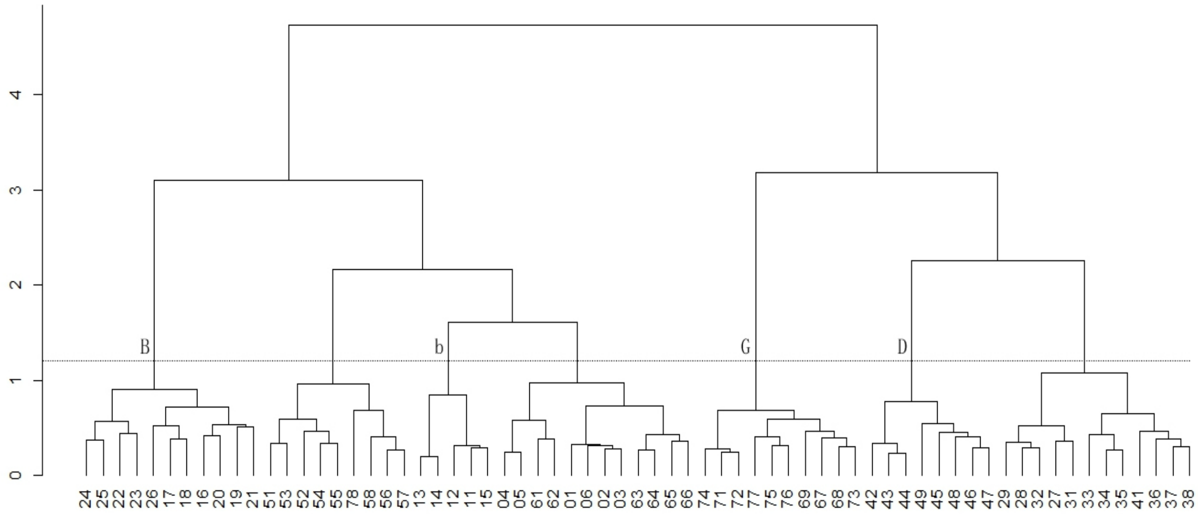

Fig. 6 **Clustering tree of plant by SSM.**

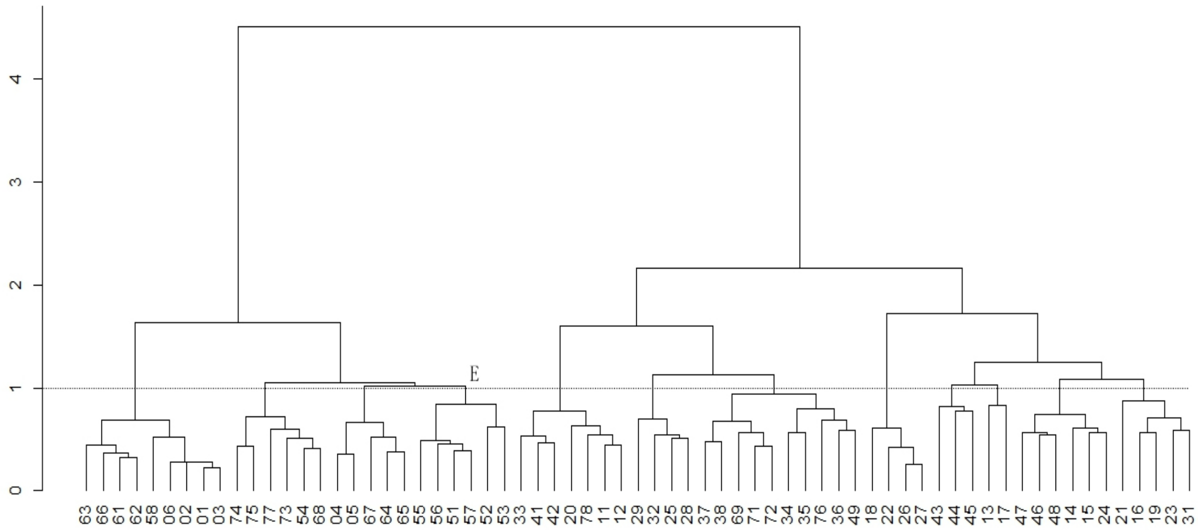

Fig. 7 **Clustering tree of microorganism by SSM.**

Table 3 Clustering results of every analysis items.

Realms	Phylum	Class	Order	Family	No. of Genera	GSC	Line for LUC	No. of LUC	Line for SUC	No. of SUC
Animalia					141,814	0.066	0.200	7	0.300	20
	Animal except insect				37,470	0.071	0.200	7	0.340	20
	Chordata				6,890	0.085	0.290	7	0.430	19
		Mammalia			1,374	0.086	0.240	7		
		Aves			2,335	0.127	0.330	7	0.540	19
		Actinopterygii			1,484	0.055	0.180	7		
		Reptilia			1,138	0.056	0.220	7		
		Amphibia			539	0.048	0.190	7		
	Arthropoda				120,379	0.059	0.200	7	0.300	20
		Arachnida			12,269	0.055	0.180	7		
			Araneae		4,567	0.062	0.180	7		
		Insecta			104,344	0.058	0.200	7	0.300	20
			Odonata		794	0.086	0.210	7		
			Plecoptera		308	0.057	0.170	8		
			Blattodea		490	0.070	0.250	7		
			Isoptera		284	0.093	0.350	7		
			Mantodea		459	0.048	0.270	7		
			Orthoptera		4,630	0.035	0.150	7		
				Acridoidea	1,690	0.034	0.140	7		
				Tettigojioidea	1,405	0.036	0.140	7		
				Grylloidea	769	0.042	0.160	7		
			Thysanoptera		782	0.054	0.160	7		
				Thripidae	288	0.058	0.160	7		
			Hemiptera		13,251	0.052	0.180	7	0.270	19
				Cicadellidae	2,364	0.044	0180	8		
				Miridae	1,502	0.050	0.180	7		
			Neuroptera		598	0.081	0.240	7		
				Myrmeleontidae	190	0.070	0.240	7		
			Coleoptera		38,537	0.050	0.170	7	0.300	20
				Carabidae	2,754	0.078	0.220	7		
				Chrysomelidae	2,590	0.077	0.230	7		
				Coccinellidae	567	0.102	0.230	7		
				Scarabaeoidea	4,063	0.050	0.180	8		
				Curculionidae	6,558	0.032	0.120	7		
				Beetles in freshwater	926	0.092	0.230	7		
			Diptera		14,002	0.076	0.190	7	0.270	20
				Bomybyliidae	239	0.103	0.250	6		
				blood-sucking Diptera	1,014	0.112	0.290	7		
			Trichoptera		658	0.069	0.190	7		
			Lepidoptera		18,051	0.061	0.200	7	0.260	18
				Geometridae	2,006	0.071	0.200	7		
				Noctuidae	3,331	0.056	0.180	7		
				Butterflies	1,891	0.078	0.280	7		

Table 3 to be continued

			Hymenoptera		8,761	0.075	0.180	7	0.300	20
				Vaspoidea	1,102	0.089	0.230	7		
				Apidae	191	0.124	0.380	7		
			Other others		3,995	0.051	0.200	7	0.300	19
		Other classes			3,766	0.093	0.230	7		
Different ecological groups										
		Freshwater insects			6,522	0.083	0.220	7		
		Economic environment insects			46,137	0.052	0.200	7	0.290	19
		Carnivorous insects			23,767	0.078	0.210	7	0.320	20
		Medical important insects			4,544	0.089	0.250	7	0.370	20
Different historical periods										
		Currently the world's Mammal Species			6,887	0.036	0.140	7		
		Pre-Wallace Era 1876 Species			2,378	0.073	0.210	7		
Plantae					17,526	0.141	0.310	7	0.430	20
	Non-vascular Plants				3,272	0.166	0.280	7		
	Vascular Plants				14,254	0.135	0.300	7	0.440	20
	Ferns and Gymnosperms				462	0.312	0.450	7		
	Angiosperm				13,792	0.130	0.300	7	0.450	19
	Liliophyta				2,969	0.124	0.300	7	0.430	19
			Asparagales		1,209	0.094	0.260	7	0.390	19
			Poales		1,033	0.166	0.360	7	0.500	19
			Other orders		727	0.124	0.250	8	0.400	20
	Magnoliophyta				10,823	0.128	0.290	7	0.440	20
			Apiales		546	0.099	0.235	7		
			Asterales		1,034	0.114	0.290	7	0.420	20
			Brassicales		460	0.123	0.280	6		
			Caryophyllales		791	0.099	0.230	7	0.400	19
			Ericales		411	0.130	0.300	7		
			Fabales		860	0.138	0.290	7	0.460	20
			Lamiales		1,169	0.138	0.300	8		
			Other orders		5,552	0.100	0.250	7	0.410	19
Microorganism					21,321	0.140	0.190	7		
Protozoa and Chromista					6,408	0.124	0.180	7		
Viruses					1,432	0.052	0.120	7		
Fungi					10,454	0.133	0.210	7		
	Ascomycota				7,552	0.112	0.170	7		

ecological environment of medical insects, parasitic or predatory carnivorous insects, aquatic insects living in fresh water, and economic environment insects attacking agricultural and forestry crops or wild plants is significantly different, the clustering results are also relatively consistent. There is no significant difference between the analysis results of 6,887 known mammals and 2,378 known mammals in the Wallace era before 1,876. The analysis results of vascular plants and non-microtubule plants, angiosperms and gymnosperms, monocotyledons and dicotyledons are consistent. Microorganisms, whether large fungi or small viruses, are also divided into 7 large unit groups.

4. Conclusion and Discussion

Terrestrial animals, plants and microorganisms in the world are biological groups with different evolutionary periods, survival modes and metabolic forms, and their research forms an independent discipline. In the more than 250 years since the establishment of biogeography, people have paid more attention to the distribution of mammals and flowering plants, and paid little attention to the distribution characteristics of lower organisms, let alone the relationship between them. In this study, SGF and MSCA methods were used to analyze the global terrestrial animals, plants, microorganisms and their main groups, which revealed and proved the homogeneity of their distribution pattern for the first time in the world. This not only provides a theoretical basis and quantitative basis for the establishment of a unified geographical zoning scheme for the world, but also advances the development of biogeography to a new stage of multivariate comparison and raises the theory of biogeography to a new height of unified analysis.

There are three reasons for this incredible analysis:

(1) Survival dependence formed by the food chain. Plants produce organic substances, animals directly or indirectly enjoy these organic substances, and microorganisms decompose organic residues. The three closely combine to form an organic unity of material circulation.

(2) The homogeneity and accumulation of the effects of eco-environmental conditions on biological distribution. The genus level elements of living organisms all appeared in the Cenozoic era. The current situation of the world continent in the Cenozoic era has been formed. The uplift of mountains, climate change and ocean barrier have the same impact on different biological groups. Although different biological groups have different tolerance to environmental change, the direction of impact is the same. The time of biological evolution also marks them with the brand of the times. Microorganisms appeared earliest and distributed most widely, and the widestADT was 11.65; Plants took the second place, ADT was 9.63; Animals were the latest, ADT was 4.76.

The inherent relationship formed by the internal causes of organisms must also be revealed by appropriate methods. People have long expected the consistency of distribution patterns of mammals and flowering plants [19], but due to the analytical ability of traditional analysis methods, it is difficult to achieve such a degree, whether the currently respected UPGMA [21] or the ward's method [22]. The division method of BGU also affects the analysis results. In this study, the current popular grid cell method is not used to divide BGU, which is widely used in micro scale field experiments or meso scale field investigations, and is not suitable for macro scale geographical zoning. Because the field experiment has strict and unified investigation and measurement methods, it is necessary to set up repetition to reduce human error; although there is no repetition in field investigation, it ensures the unity of personnel, methods, time and investigation depth. However, for geographical zoning analysis, the biological data used are not the result of actual investigation based on the grid method, but the result of long-term accumulation by taxonomists. It is impossible to be consistent in terms of personnel, time, depth and attention to groups. The artificial differences between BUGs will affect or even cover up the natural differences. The division of BGU according to ecological conditions seems rough, but it can better reflect the natural differences.

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References

[1] Crisp, M. D. 2009. "Phylogenetic Biome Conservatism on a Global Scale." *Nature* 458: 754.

[2] Ladle, R. J., and Whittaker, R. J. 2011. *Conservation Biogeography*. Chichester, UK: Wiley-Blackwell.

[3] Lomolino, M. V., Riddle, B. R., and Whittaker, R. J. 2010. *Biogeography* (4th ed.), edited by Sunderland, M. A. New England: Sinauer Associates.

[4] Buffon, C. 1761. *Histoire Natyrelle*. Paris: Academic Francaise.

[5] Sclater, P. L. 1858. "On the General Geographical Distribution of the Members of the Class Aves." *J. Proc. Linn. Soc. Lond* 2: 130-45.

[6] Wallace, A. R. 1863. "On the Physical Geography of the Malay Archipelago." *Royal Geographical Society* 7: 205-12.

[7] Wallace, A. R. 1876. *The Geographical Distribution of Animals*. Cambridge: Cambridge Univ. Press.

[8] Humboldt, A. V., and Bonplad, A. 1805. *Essaisur la Geographie des Plantes*. Paris: Levrault, Schoell. (in French)

[9] Candolle, D. A. 1820. *Essaielementaire de geographiebotanique. Dictionnaire des Sciences Naturelles* (Vol. 18). Strasbourg: Levrault.

[10] Engler, A. 1879. *Versucheiner Entwicklungsgeschichte der Pflanzenwelt*. Leipzig: Engelmann.

[11] Darlington, P. J. J. 1957. *Zoogeography: The Geographic Distribution of Animals*. New York: John Wiley; London: Chapman & Hall.

[12] Takhtajan, A. 1978. *Floristic Regions of the World*. Berkeley: University of California Press.

[13] Cox, C. B., and Moore, P. D. 2005. *Biogeography: An Ecological and Evolutionary Approach* (11th ed.). Oxford: Blackwell Publishing Ltd.

[14] Simpson, G. G. 1977. "Too many Lines: The Limits of the Oriental and Australian Zoogeographic Regions." *Proc. Am. Phil. Soc*. 121: 107-20.

[15] Morrone, J. J. 2002. "Biogeographical Regions under Track and Cladisticscrutiny." *Journal of Biogeography* 29: 149-52.

[16] Whittaker, R. J., Riddle, B. R., Hawkins, B. A., and Ladle, R. J. 2013. "The Geographical Distribution of Life and the Problem of Regionalization: 100 Years after Alfred Russel Wallace." *Journal of Biogrography* 40: 2209-14.

[17] Jaccard, P. 1901. "Distribution de la flore alpine dans le bassin des Dranses et dansquelquesrégionsvoisines." *Bull. Soc. Vaud. Sci. Nat.* 37:241-72.

[18] Czekanowski, J. 1913. *Zarys method statystycznych w zastosowaniu do antropologii*. Warszawa: Towarzystwo Naukowe Warszawskie. (in Polish)

[19] Szymkiewicz, D. 1934. "Une contribution statistique a la geigraphiefloristique." *Acta Soc. Bot. Pol.* 11: 3.

[20] Simpson, G. G. 1943. "Mammals and the Nature Continents." *Am. J. Sci.* 241: 1-31.

[21] Sørensen, T. 1948. "A Method of Establishing Groups of Equal Amplitude in Plant Sociology Based on Similarity of Species Centent and Its Application to Analysis of the Vegetation on Danish Commons." *K. Dan. Vidensk. Selsk. Biol. Skr.* 5 (4):1-34.

[22] Ward, J. H. 1963. “Heirarchical Grouping to Optimise an Objective Function.” *J. Amer. Stat. Ass.* 58: 236-44.

[23] Cox, C. B. 2010. “Underpinning Global Biogeographical Schemes with Quantitative Data.” *Journal of Biogeography* 37: 2027-8.

[24] Cox, C. B. 2001. “The Biogeographic Regions Reconsidered.” *J. Biogeogr.* 28: 511-23.

[25] Wu, Z. Y. 2011. *Floristics of Seed Plants from China.* Beijing: Science Press, pp. 1-485. (in Chinese)

[26] Procheş, Ş. 2005. “The World’s Biogeographical Regions: Cluster Analyses Based on Bat Distributions.” *Journal of Biogeography* 32: 607-14.

[27] Kreft, H., and Jetz, W. 2010. “A Framework for Delineating Biogeographical Regions Based on Species Distributions.” *Journal of Biogeography* 37: 2029-53.

[28] Holt, B. G., Lessard, J. P., Borregaard, M. K., Fritz, S. A., Araújo, M. B., Dimitrov, D., Fabre, P. H., Graham, C. H., Graves, G. R., Jønsson, K. A., Nogués-Bravo, D., Wang, Z., Whittaker, R. J., Fjeldså, J., and Rahbek, C. 2013. “An Update of Wallace’s Zoogeographic Regions of the World.” *Science* 339: 74-8.

[29] Rueda, M., Rodríguez, M. Á., and Hawkins, B. A. 2013. “Identifying Global Zoogeographical Regions: Lessons from Wallace.” *Journal of Biogeography* 40: 2215-25.

[30] Morrone, J. J. 2018. “The Spectre of Biogeographical Regionalization.” *Journal of Biogeography* 45 (2): 282-8.

[31] Gressitt, J. L. 1958. “Zoogeography of Insects.” *Ann. Rev. Entomol.* 3: 207-30.

[32] Munroe, E. 1965. “Zoogeography of Insect and Allied Groups.” *Ann. Rev. Entomol.* 10: 325-44.

[33] Gressitt, J. L. 1974. “Insect Geography.” *Ann. Rev. Entomol*. 19: 293-321.

[34] Bolton, B. 1995. “A Taxonomic and Zoogeographical Census of the Extant Ant Taxa (Hymenoptera: Formicidae).” *Journal of Natural History* 29: 1037-56.

[35] Morse, J. C., Barnard, P. C., and Holzenthal, K. W. 2011. *Trichoptera World Checklist.* http://www.entweb.clemson.edu/database/trichopt/index.htm.

[36] Vashchonok, V., and Medvedev, S. 2013. *Fleas (Siphonaptera).* http://www.zin.ru/Animalia/Siphonaptera.

[37] Lumbsch, H. T., and Huhndorf, S. M. 2010. Myconet Volume 14 Part One. Outline of Ascomycota-2009. *Fieldiana Life Earth Sci.* 1: 1-922.

[38] Tedersoo, L., Bahram, M., and Põlme, S. 2014. “Global Diversity and Geography of Soil Fungi.” *Science* 346: 1256688.

[39] Treseder, K. K., Maltz, M. R., and Hawkins, B. A. 2014. “Evolutionary Histories of Soil Fungi Are Reflected in Their Large-Scale Biogeography.” *Ecology Letters* 17: 1086-93.

[40] Boonmee, S., Rossman, A.Y., Lui, J. K., Li, W. J., Dai, D. Q., Bhat, J. D., Jones, E. B. G., McKenzie, E. H. C., Xu, J. C., and Hyde, K. D.. 2014. “Tubeufiales, ord. nov., Integrating Sexual and Asexual Generic Names.” *Fungal Diversity* 68: 239-98.

[41] Boonmee, S., D’souza, M. J., Luo, Z., Pinruan, U., Tanaka, K., Su, H. Y., Bhat, D. J., McKenzie, E. H. C., Jones, E. B. G., Taylor, J. E., Phillips, A. J. L., Hirayama, K., Eungwanichayapant, P. D., and Hyde, K. D. 2016. “Dictyosporiaceaefam. nov.” *Fungal Diversity* 80: 457-82.

[42] Thambugala, K.M., Hyde, K.D., Tanaka, K.,Tian, Q., Wanasinghe, D. N., Ariyawansa, H. A., Jayasiri, S. C., Boonmee, S., Camporesi, E., Hashimoto, A., Hirayama, K., Schumacher, R. K., Promputtha, I., and Liu, Z. Y. 2015. “Towards a Natural Classification and Backbone Tree for *Lophiostomataceae*, *Floricolaceae*, and *Amorosiaceaefam. nov*.” *Fungal Diversity* 74: 199-266.

[43] Chaudhary, V. B., Lau, M. K., andJohnson, N. C. 2008. “Macroecology of Microbes—Biogeography of the Glomeromycota.” In *Mycorrhiza*, edited by Varma, A. Berlin, Heidelberg: Springer, pp. 529-563.

[44] Wu, B., Tian, J. Q., Bai, C. M., Xiang, M., Sun, J., and Liu, X. 2013. “The Biogeography of Fungal Communities in Wetland Sediments along the Changjiang River and Other Sites in China.” *Journal of Systematic and Evolutionary Microbiology* 7: 1299-309.

[45] Yang, T., Adams, J.M., Shi, Y.,He, J.-S., Jing, X., Chen, L., Tedersoo, L., and Chu, H. 2017. “Soil Fungal Diversity in Natural Grasslands of the Tibetan Plateau: Associations with Plant Diversity and Productivity.” *New Phytologist* 215: 756-65.

[46] Shen, X. C., and Wang, A.P. 2008. “A Simple Formula for Multivariate Similarity Coefficient and Its Contribution Rate in Analysis of Insect Fauna.” *Journal of Henan Agricultural Sciences* 37 (7): 67-9. (in Chinese)

[47] Shen, X. C., Sun, H., and Zhao, H. D. 2008. “A Discussion about the Method for Multivariate Similarity Analysis of Fauna.” *Acta Ecologica Sinica* 28 (2): 849-54. (in Chinese)

[48] Shen, X. C., Sun, H., and Zhao, H. D. 2007. “Species Diversity and Distribution Patterns of Noctuidae (Lepidoptera) in China.” *Acta Entomologica Sinica* 50 (7): 709-19. (in Chinese)

[49] Shen, X. C., Ren, Y. D., Wang, A. P., and Zhang, S. J. 2010. “A Multivariate Similarity Clustering Analysis for Geographical Distribution of Insects, Spiders and Mites in Henan Province.” *Acta Ecologica Sinica* 30 (16): 4416-26. (in Chinese)

[50] Shen, X. C., Liu, X. T., Ren, Y. D., Shen, Q., Liu, X. G., and Zhang, S. J. 2013. “The Multivariate Similarity Clustering Analysis and Geographical Division of Insect

Fauna in China." *Acta Entomologica Sinica* 56: 896-906. (in Chinese)

[51] Shen, X. C., Zhang, B. S., Zhang, F., and Liu, X. T. 2013. "Worldwide Distribution and Multivariate Similarity Clustering Analysis of Spiders." *Acta Ecologica Sinica* 33 (21): 6795-802. (in Chinese)

[52] Shen, X. C., Lu, J. Q., Ren, Y. D., Shen, Q., Liu, X. T., and Yang, L. L. 2020. "Clustering Analysis and Biogeographical Division of the Distribution of Insects in the World." *Technology Review* 38 (13): 83-95. (in Chinese)

[53] Shen, Q. 2014. "Multivariate Similarity Clustering Analysis for Distribution of the Medical Insect in China." *Actaparasitologica let medicaentomologica Sinica* 21 (3): 165-71. (in Chinese)

[54] Shen, X. C., Zhang, S. J., Shen, Q., Hu, G. L., and Lu, J. Q.2021. "Multivariate Similarity Clustering Analysis: A New Method Regarding Biogeography and Its Application in Global Insects." *Integrative Zoology* 16: 390-403. doi: 10.1111/1749-4877.12485.

[55] Shen, X. C. 2018. "The Homogeneity of Distribution Pattern of Chinese Terrestrial Biota." *Open Journal of Nature Science* 6 (4): 373-82.doi: 10.12677//ojns.2018.64048.

[56] Shen, X. C. 2021. *Insect Geography of the World*. Zhengzhou: Henan Science and Technology Press, pp. 1-541. (in Chinese)

[57] Shen, X. C., Ren, Y. D., Ma, X. J., Lu, J. Q., Ren, Y. D., Shen, Q., Liu, X. T., and Yang, L. L. 2018. "Clustering Analysis and Biogeographical Regionalization of Distribution Patterns of Dicotyledonous Plants in the World." *Botanical Research* 7 (4): 405-17. doi: 10.12677/br.2018.74049.

[58] Shen, Q., Ma, X. J., Ren, Y. D., and Shen, X. C. 2018. "The Distribution Patterns of Main Ecological Groups of Insects in the World and Its Ecological Significance." *International Journal of Ecology* 7 (3): 170-84. doi:10.12677/ije.2018.73019.

[59] Shen, Q., You, Z. X., Ma, X. J., and Shen, X. C. 2020. "Biogeography of Medically Important Insects Using Quantitative Analysis." *Global Journal of Medical Research: G Veterinary Science and Veterinary Medicine* 20 (1): 1-11.

[60] Shen, Q., Ma, X.J., You, Z. X., and Shen, X. C. 2021. "The Distributional Patterns of Medical Insects in the World and Its Relation with Other Biota." *International Journal of Ecology* 10 (4): 558-75. doi: 10.12677/ije.2021.104064. (in Chinese)

[61] Shen, Q., Lu, J. Q., Zhang, S. J.,You, Z. X., Ren, Y. D., and Shen, X. C. 2022. "The Bio-Geographical Regions Division of Global Terrestrial Animal by Multivariate Similarity Clustering Analysis Method." *Open Journal of Ecology* 12 (3): 236-55. doi:10.4236/oje.2022.123014.

[62] Ruggiero, M. A., Gordon, D. P., Orrell, T. M., Bailly, N., Bourgoin, T., Brusca, R. C., Cavalier-Smith, T., Guiry, M. D., and Kirk, P. M. 2015. "A Higher Level Classification of All Living Organisms." *PLoS ONE* 10: e0119248.

[63] Bolton, B. 1995. *A New General Catalogue of the Ants of the World.* Cambridge: Harvard University Press.

[64] Brown, J.W. 2005. *World Catalogue of Insects. Volume 5 Tortricidae (Lepidoptera).*Stenstrup: Apollo Books.

[65] Del Hoyo, J., Elliot, A., and Sargatal, J. 1992. *Handbook of the Birds of the World* (Vol. 1-14). Barcelona: Lynx Edicions.

[66] Greuter, W., McNeill, J., Barrie, F.,Burdet, H.-M., Demoulin, V., Filgueiras, T. S., Nicolson, D. H., Silva, P. C., Skog, J. E., Trehane, P., Turland, N. J., and Hawksworth, D. L. 2000. "International Code of Botanical Nomenclature (Saint Louis Code)." *Regnum Vegetabile* 138: 1-474.

[67] Higgins, P. J., and Davies, S. J. J. F. 1996. *Handbook of Australian, New Zealand & Antarctic Birds (Volume 3-7). Snipe to Pigeons*. Melbourne: Oxford University Press.

[68] Knight, K. L., and Stone, A. 1977. *A Catalog of the Mosquitoes of the World (Diptera: Culicidae)*. Maryland: Entomological Society of America.

[69] Lee, O. 2012. *University of British Columbia Herbarium (UBC): Fungi Collection*. Kelowna: University of British Columbia.

[70] Munari, L., and Mathis, W. H. 2010. *World Catalog of the Family Canacidae (Including Tethinidae) (Diptera). Zootaxa* 2471: 1-81.

[71] Simkin, J. 2017. *BLS Lichen Database: Scotland 1700-2016*. London: British Lichen Society.

[72] Sotelo, H., Castañeda-Alvarez, N. P., and Endresen, D. 2016. "A Global Database for the Distributions of Crop Wild Relatives." Centro Internacional de Agricultura Tropical.

[73] Tai, F. L. 1979. *Syllogefungorum Sinicorum*. Beijing: Science Press.

[74] Yang, D., Zhang, K. Y., Yao, G., and Zhang, J. H. 2007. *World Catalog oh Empididae (Insecta: Diptera)*. Beijing: China Agricultural University Press.

[75] Yang, D., Zhu, Y. J., Wang, M. Q., and Zhang, L. L. 2006. *World Catalog of Dolichopodidae (Insecta: Diptera).*Beijing: China Agricultural University Press.

[76] Yin, X. C., Shi, J. P., and Yin, Z. 1996. *A Synonymic Catalogue of Grasshoppers and Their Allies of the World (Orthoptera: Caelifera).* Beijing: China Forestry Publishing House.

[77] Liu, J. K., Hyde, K. D., Jones, E. B. G., Ariyawansa, H. A., Bhat, D. J., Boonmee, J., et al.2015. "Fungal Diversity Notes 1-110: Taxonomic and Phylogenetic Contributions to Fungal Species." *Fungal Diversity* 72: 1-197.

[78] Barber-James, H., Sartor, M., and Gattolliat, J. L. 2013. *World Checklist of Freshwater Ephemeroptera Species.* http://fada. biodiversity.be/group/show/35.

[79] Eades, D. C., Otte, D., and Cigliano, M. M. 2014.*OrthopteraSpecies File* (Version 5.0/5.0).http://orthoptera.speciesFile.org.

[80] GBIF.2014*Animalia*. http://gbif.org/species/1.

[81] GBIF. 2016. *Bacteria*.https://gbif.org/species/3.

[82] GBIF. 2018. *Plantae*. http://gbif.org/species/6.

[83] GBIF. 2018. *Fungi.* http://gbif.org/species/5.

[84] Gill, F., Wright, M., and Donsker, D. 2009. *IOC World Bird Names* (Version 2.2). http://worldbirdnames.org.

[85] The Plant List. 2013. *The Plant List* (Version 1).Accessed on March 25, 2019. http://www.theplantlist.org.

[86] USDA. 2017. Plant Database. Accessed on September 26, 2017.https://plant.USDA.gov.

[87] Gusmão, L. F. P, Monteiro, J. S., and Castañeda-Ruiz, R.F. 2017. "*Tretoheliocephalacompacta*gen. & sp. nov. from the Brazilian Semi-arid Region." *Mycotaxon* 132: 453-8.

[88] Solé, F., Marandat, B., and Lihoreau, F. 2020. "The Hyaenodonts (Mammalia) from the French Locality of Aumelas (Hérault), with Possible New Representatives from the Late Ypresian." *Geodiversitas* 42 (13): 185-214.

[89] Mcgrath, A. J., Anaya, F., and Croft, D. A. 2020. "New Proterotheriids from the Middle Miocene of Quebrada Honda, Bolivia, and Body Size and Diversity Trends in Proterotheriid and Macraucheniid Litopterns (Mammalia)." *Ameghiniana* 57 (2): 159-88.

[90] Li, Q., Li, X. Y., Jackson, S. M., Li, F., Jiang, M., Zhao, W., Song, W. Y., and Jiang, X. L. 2019. "Discovery and Description of a Mysterious Asian Flying Squirrel (Rodentia, Sciuridae, *Biswamoyopterus*) from Mount Gaoligong, Southwest China." *ZooKeys* 864: 147-60.

[91] Moura, J. F., Góis, F., and Galliari, F. C. 2019. "A New and Most Complete Pampathere (Mammalia, Xenarthra, Cingulata) from the Quaternary of Bahia, Brazil." *Zootaxa* 4661 (3): 401-44.

[92] Pavan, A. C., Bobrowiec, P. E. D., and Percequillo, A. R. 2018. "Geographic Variation in a South American Clade of Mormoopid Bats, *Pteronotus* (*Phyllodia*), with Description of a New Species." *Journal of Mammalogy* 99 (3): 624-45.

[93] Miranda, F. R., Casali, D. M., Perini, F. A., Machado, F. A., and Santos, F. R.2017. "Taxonomic Review of the Genus *Cyclopes* Gray, 1821 (Xenarthra: Pilosa), with the Revalidation and Description of New Species." *Zoological Journal of the Linnean Society* 183 (3): 687-721.