Global Ecology and Conservation 16 (2018) e00509

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: http://www.elsevier.com/locate/gecco

Original Research Article

Different nation, different ecology: Comparison of ecological research features in China and the US during the recent three decades

Tian-Yuan Huang [a], Bin Zhao [a, *], Sheng-Qi Dai [a], Hong Li [a], Jun Ma [a], Xiang-Ming Xiao [a, b]

[a] Ministry of Education Key Laboratory for Biodiversity Science and Ecological Engineering, and Coastal Ecosystems Research Station of the Yangtze River Estuary, Fudan University, Shanghai, China
[b] Department of Microbiology and Plant Biology, College of Arts and Sciences, University of Oklahoma, Norman, OK, USA

ARTICLE INFO

Article history:
Received 12 November 2018
Received in revised form 14 December 2018
Accepted 14 December 2018

Keywords:
America
China
Co-word analysis
Ecological society of America
Ecological society of China
Ecology
Keyword diversity
Network analysis

ABSTRACT

Global ecological problems demand joint effort of ecologists worldwide. The last three decades had seen an exponential growth of ecological literature. However, international collaboration did not catch up in the same pace, which might be due to the deficiency of comprehension and communication among multinational ecologists. In our study, we reviewed the literature information from 15,706 publications in journals published by the Ecological Society of America (ESA) and 28,756 publications in journals published by the Ecological Society of China (ESC). According to our findings, American papers contained more information than Chinese papers, but as paper volume increased rapidly, journals from China were able to cover a wider range of topics in ecology than the US. Considering the research content, American ecologists preferred carrying out ecological research on the theoretical level, while Chinese ecologists devoted more effort into applied ecology (especially agricultural ecology). Despite the different perspectives on ecology, both countries attached great importance to global topics such as climate change and biodiversity, which might lead to further collaboration on international ecological programs.

1. Introduction

Despite the ascending trend of author number in ecology papers across the world, international collaboration in ecological research did not seem to follow the momentum accordingly (Parreira et al., 2017). Facing great challenges in the new era of ecology, it is crucial for ecologists to understand the language of one another (Thompson et al., 2001), and the division of perspectives within ecology could be harmful to the credibility of the discipline (Edwards, 1995). Therefore, we are in the midst of great urgency to recognize scientific characteristics of ecological research in different regions. This could remove the misunderstandings and promote communication and comprehension among ecologists from various local areas.

Representing different economic entities, the largest emerging economies, China and the largest developed country, the US, differs from each other in many aspects, including politics, economy, culture and education. These differences would

* Corresponding author.
E-mail address: zhaobin@fudan.edu.cn (B. Zhao).

https://doi.org/10.1016/j.gecco.2018.e00509

definitely influence their development of ecology. In addition, ecological researchers from both countries have established their own national ecological societies to improve communication among ecologists and advance the study of ecology. The problems facing these societies can pose great impact on their research preferences, which would lead to different perspectives on ecological research.

Founded in 1915, Ecological Society of America (ESA) is the largest ecological society with over 9000 members. Excelled in technology, ecologists in the US do well in quantitative analysis in both lab and field. Consequently, American ecology tends to "become to a marked degree an experimental science" (Shelford, 1917; Mitman, 2005). Shared the mission to publish and make broadly available the most significant results of ecological research, publications of ESA could well represent the development of ecology in the US (Turner, 2015; Reiners et al., 2017). Among various publications, the peer-reviewed journals (including *Ecology, Ecological Applications, Ecological Monographs, Frontiers in Ecology and the Environment* and *Ecosphere*) of ESA are all high-level professional academic journal of ecology, they have great influence on the ecological communities at the US and abroad.

On the other hand, Ecological Society of China (ESC) was established in 1979 as a national and non-profit academic organization. Affiliated to Chinese Association for Science and Technology, it is one of the most important social forces to promote ecological research and practices of China. In the relative short history of less than 40 years, ESC has developed to a society with more than 7800 members, 18 special committees and 5 working committees (http://english.rcees.cas.cn/sp/zgstxxh/). While sharing the common purpose to hold ecologists together and advance the academic activities of ecology, ESC had dedicated to advocate the national policy of ecological civilization construction. Actions are taken to response to global climate disruption and social injustice, and the current civilization would transit to a new form based on ecological principles. This is a synthetic reform of economy, education, politics and other various aspects concerning sustainable development. Local peer-reviewed journals reviewed by ESC include *Acta Ecologica Sinica*, *Chinese Journal of Ecology* and *Chinese Journal of Applied Ecology*. *Acta Ecologica Sinica* now has an English-language international version published by Elsevier, but the local version is still running as before. All these three journals adopted papers written in Chinese, which could well reflect the national ecological development of China. In 2017, these journals made the top 3 most cited journals of ecology according to Chinese S&T Journal Citation Reports (ISTIC 2018). They have great impacts in ecological communities in China, which make good source to explore the research features of Chinese ecologists.

The process of detecting and measuring the regional difference in perspectives of ecology could be complex and subtle. Thanks to the digital age, problems that hinder our exploration could now be addressed creatively. Large amount of data is made available online and could be downloaded freely, and the emergence and development of Automated Content Analysis (ACA) in the recent years have facilitated the use of advanced machine learning methods to deal with these data (Nunez Mir et al., 2016). In previous studies, co-word analysis had been used to explore the evolution of ecology, while text mining techniques were utilized to discover the patterns of ecological topics and scientific collaborations in Ecological Society of America in the past century (Neff and Corley, 2009; Kim et al., 2018). The application of bibliometrics in the ecological field could be enlightening and inspiring for making ecological reviews in a novel way, which may lead to new insights in the development of ecology. Though the languages of the two countries are different, consensus could be reached on ecological terms emerging in the chosen keywords, which make comparison possible. Bibliometric analysis was implemented on the keywords of the papers in order to explore (1) the potential different preference of journal publication in ecological societies from China and the US, (2) the ecological knowledge structure in these two countries, and (3) hotspots of ecological research in different time periods. We believed digging into ecological literature with the novel text mining methods could help understand the different insights on ecology between China and the US, which might provide more opportunities for us to learn from each other. Hopefully, our study could promote the communication and collaboration in ecological research across the two countries in the future.

2. Methods

2.1. Dataset

We used SCOPUS (https://www.scopus.com) to download information from ESA journals and used Web of Science (www.isiknowledge.com) and Wiley Online Library (https://esajournals.onlinelibrary.wiley.com/) to complete data coverage when information was missing from SCOPUS. For ESC journals, we used VIP ((http://www.cqvip.com/)) which covers all of the target journals' information since their first publications.

For both ESA and ESC journals, published year, journal name and author keywords were selected as features of interests within a time span of three decades, from 1988 to 2017. ESC journals' text information was stored in its original form of Chinese characters, and was translated to English for display purposes only. Duplicated records were merged into one single record. Word segmentation was implemented on the author keywords to get the tidy text format (Silge and Robinson, 2017), which facilitates further analysis. The final text corpus includes 15,706 articles from ESA journals and 28,756 articles from ESC journals. Notably, *Frontiers in Ecology and The Environment* would be excluded in the keyword-based analysis, because it did not require authors to provide author keywords for their articles, and the database contained missing values in keywords in ESA journals in early 1990s.

2.2. Comparison of ESA and ESC publication features

To compare publication features of ESA and ESC, paper volume, average keyword frequency and different diversity indexes were summarized from 1988 to 2017. Paper volume is the number of paper accepted by a specific journal or publication union from one country during a specified period of time, while average keyword frequency is defined as the number of keywords per paper.

Diversity, by definition, is the condition of having or being composed of different elements. In ecology, richness, evenness and Shannon-Wiener index are common indicators to measure diversity of species in a community (Hill, 1973). Here we used these metrics to evaluate the diversity of keywords in different journals during different periods. For instance, the definition of keyword richness here is how many distinct keywords might occur in the journal (or publication union) across the time span of certain length. We calculated Shannon-Weiner index of keyword diversity based on the abundance of keywords in journals and publication year. We used the Shannon-Weiner index to calculate keyword evenness using the following formulas:

$$diversity = -\sum_{i=1}^{S}(p_i \times \ln p_i)$$

$$evenness = \frac{diversity}{\ln S}$$

where p_i is the proportion of keyword i and S is the number of distinct keyword (keyword richness). Here we used all three diversity indexes so as to get a more comprehensive view of how keyword abundance and distribution varied in the last three decades, while simply using Shannon-Wiener index to represent the overall diversity could be somewhat biased (Strong, 2016).

2.3. Construction of keyword co-occurrence network

We created a co-occurrence matrix using keywords in the ecological papers. Correlations among keywords from ecological papers were mapped on the co-occurrence network, based on whether these words were co-occurring in the same paper. If two keywords co-occur in one paper, an edge would be formed between the two keywords presented as nodes in the network. Specifically, the text of Chinese words were translated into English using Google Translate and checked up by manual inspection. Top 200 keyword pairs with largest occurrence rate in the time span were selected to build the final presented network. We created the networks in R version 3.5.1 (R Core Team, 2018) with packages 'igraph' (Csardi and Nepusz, 2006), 'ggraph' (Pedersen, 2017) and 'tidygraph' (Pedersen, 2018).

2.4. Detection of ecological research hotspots in different time periods

Usually, term frequency is used to quantify the popularity of the word, which is used to estimate the relative importance of ecological concepts (Kim et al., 2018). In our study, in addition to keyword frequency, we also used keyword degree in the co-occurrence keyword network to detect the hotspots of ecological research. It is obvious that keywords with large frequency are more likely to co-occur with other keywords, but this is not always the case, and the capability for a keyword to co-occur with more various keywords, we believe, might be a better indicator for detecting the common issues of the ecological society. For instance, "dispersal" and "nitrogen" both appeared 299 times in ESA journals during the past three decades, therefore based on keyword frequency we would say these two keywords were of equal importance. However, when we inspected their degree, "dispersal" co-occurred with 1638 distinct keywords while "nitrogen" had only 1575 connections to other keywords. In this case we would conclude that "dispersal" might have greater potential to be a common ecological topic than "nitrogen".

3. Results

3.1. Overview of ESA and ESC journal features

3.1.1. Paper volume

On average, ESC journals published 990 papers per year within the recent period of 30 years, nearly twice the number of ESA journals (Fig. 1A). Among Chinese journals, *Acta Ecological Sinica* accepted most articles each year, while *Ecology* took most articles across the American journals. *Ecological Monographs* adopted least papers every year, with the paper volume of 25.4.

The past three decades saw a sustainable growth in the paper volume in ecology journals (Fig. 2A), and in the first decade of the research time span, ESA journals published more papers than ESC journals per year. However, after 1998, the paper

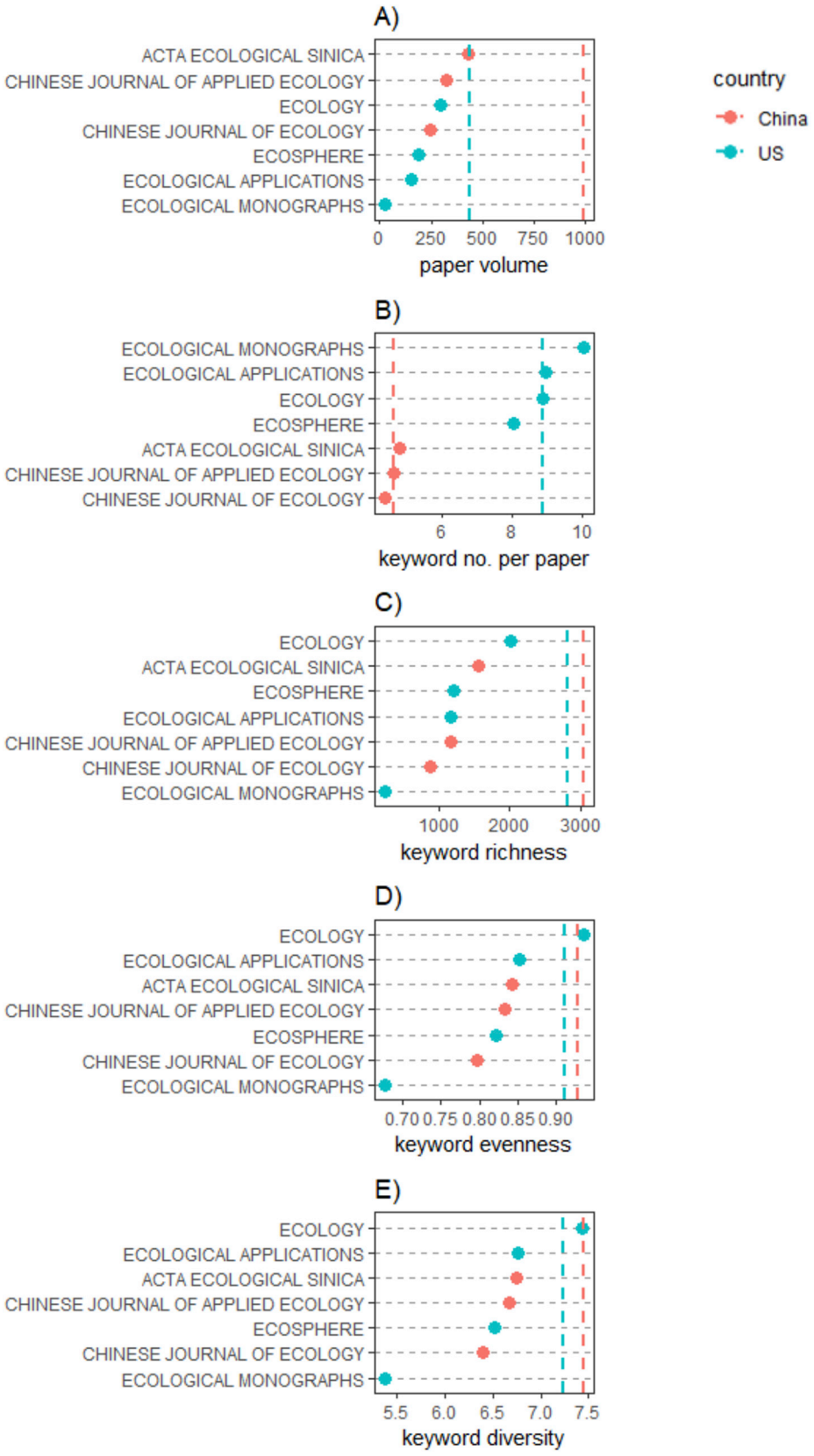

Fig. 1. Overview of ESA and ESC journal features by the temporal scale of three decades (1988–2017), depicted by paper volume, average keyword frequency, keyword richness, keyword evenness and keyword diversity. Dashed line represents the metric of all the investigated journals of ecological society in China and the US.

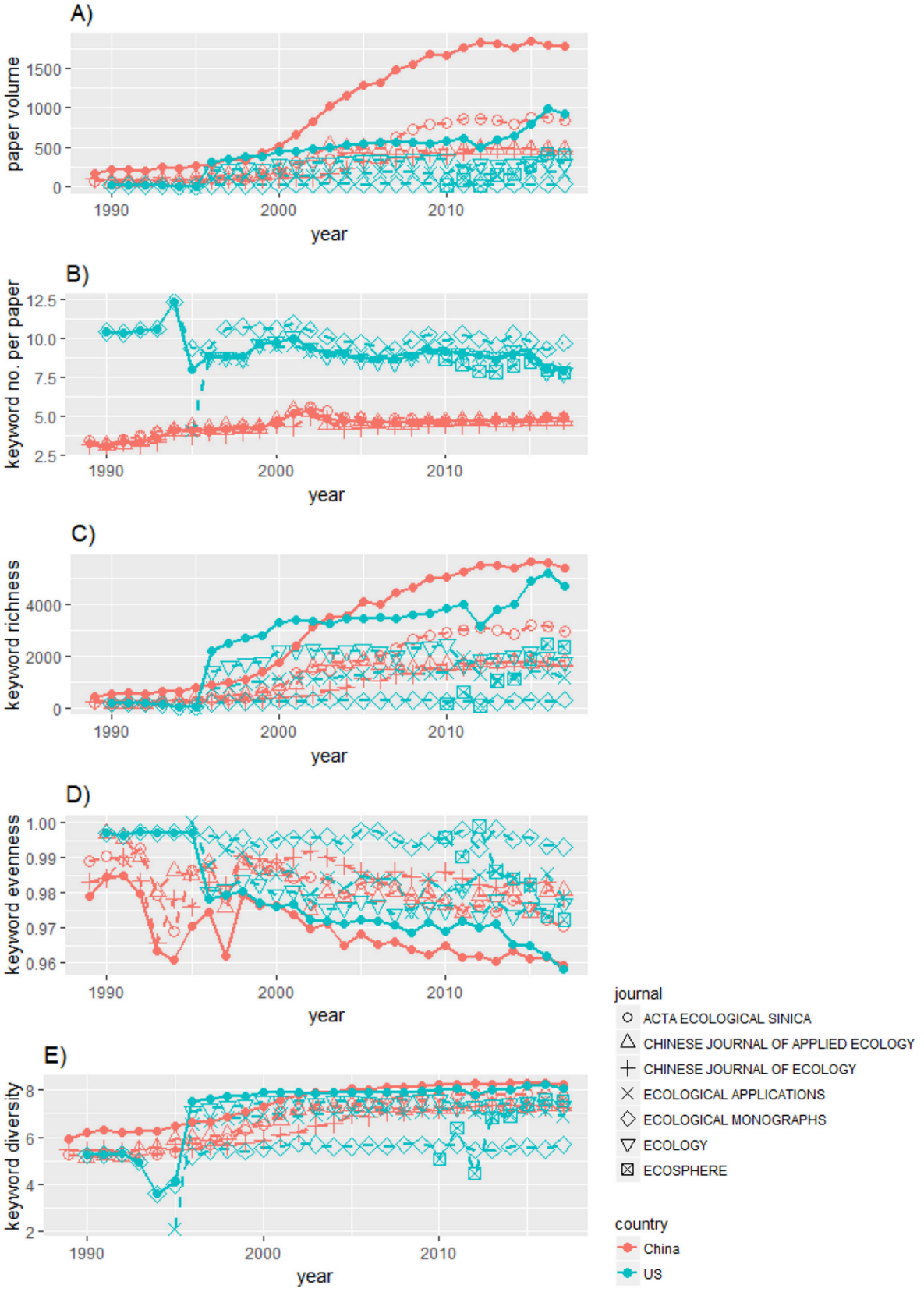

Fig. 2. Overview of ESA and ESC journal features at the time scale of year from 1988 to 2017, depicted by paper volume, average keyword frequency, keyword richness, keyword evenness and keyword diversity.

volume of ESC journals boosted rapidly and left ESA journals behind ever after, which was partly due to the dramatic jump of *Acta Ecological Sinica* paper quantity in 2000s.

3.1.2. Average keyword frequency

By average, there were 8.8 keywords in each paper from ESA journals, nearly double the ESC average keyword frequency per paper in the same period (Fig. 1B), and none of ESC journals had more average keyword frequency than any ESA journals. Among ESA journals, *Ecological Monograph* had the largest average keyword frequency (10 per paper). Through the 30 years, Chinese keyword number had climbed gradually and peaked at 2002, then dropped slightly in the following years, but kept an ascending trend in the early 2010s (Fig. 2B). On the other hand, while kept increasing in the late 1990s, there was a general trend of decline in average keyword frequency of ESA publications after 21st century, despite some fluctuations at late 2000s and early 2010s.

3.1.3. Keyword diversity

Grouped by the society, keyword richness, evenness and diversity were higher in ESC journals than ESA journals in general (Fig. 1C, D and E). Break down to journals, however, we found that *Ecology* had larger keyword diversity metrics than all the Chinese ecology journals, and came first as the most keyword-diversified journal among all ESA journals. Moreover, *Ecological Applications* from ESA publication ranked second in keyword evenness and diversity among all the selected journals (Fig. 1D and 1E). Nevertheless, keyword diversity indexes of *Ecological Monographs* came last of all journals, which might be due to the low paper volume they adopted each year (Fig. 1C, D and E).

Keywordrichness on the scale of country went consistently with keyword diversity (Fig. 1C). While both sharing an overall trend of rising, ESA journal keywords were more diversified before early 2000s, while China caught up and surpassed after late 2000s, but in recent years the gap between the two countries was closing gradually (Fig. 2C).

On the other hand, both publication unions shared a decreasing trend of the keyword evenness during the recent 30 year (Fig. 2D). ESA journals generally had higher keyword evenness than ESC journals, and since 2000 difference of keyword richness between ESA and ESC were widened, but this gap tended to close in the recent years.

3.2. Knowledge structure of Chinese and American ecological research

Through the keyword co-occurrence network (Fig. 3), the sophisticated relationships of keywords in ecological papers from two different countries was depicted in a comparably succinct form. Generally speaking, the knowledge structure of the US was more centralized in the last 30 years, while with the same amount of keyword pairs, keyword network in China was divided into two large components. In the US, some major research hot spot involved with biodiversity, competition, climate change, dispersal, disturbance, herbivory, nitrogen, population dynamics, predation, species richness. In the meanwhile, the Chinese ecological knowledge structure was relatively loose, however, considering the two largest clusters in the network, we could conclude that there were two main themes in Chinese ecological research. One was conservation biology surrounded by the concept of biodiversity and the reaches on community structure, the other was applied ecology focusing on agricultural production, which demanded large amounts of research on the relationship between yield and different environmental factors.

3.3. Most popular keywords in China and America during different time periods

America and China showed quite different features at the ecological hotspots in the 30 years' period (Table 1). Here we mainly used keyword degree to measure the popularity of a keyword. The most popular keyword in ESA publications was "climate change", emerged 661 times and co-occurred with 3388 unique keywords in the three decades. The keyword "competition" came second, followed by "biodiversity", "disturbance" and "herbivory". These are all abstract concepts in ecology. In the same list of China, the keywords might be related to the research contents. Among ESC publications, the most popular keyword was "biomass", which had been mentioned in 478 papers and co-occurred with 1301 distinct keywords from 1988 to 2017. Other than "biomass", the top 5 keywords also include "soil", "temperature", "growth" and "rice".

Divide the three decades into three period, we found that in the first two decades, "competition" and "herbivory" were the most popular keywords in the US (Table 2). But in the recent decade, "climate change" and "biodiversity" had gained more attention and leapt to be the top 2 in the list. In China, the transitions of popular keywords were more obvious (Table 3). In the first decade, the three most popular keywords were "ecology", "population" and "growth". The second decade had seen the top 3 keywords changed to "soil", "rice" and "biomass". And in the recent decade, "climate change" had come to the first place, followed by "biomass" and "yield".

4. Discussion

Blocks in multinational cooperation in ecological studies could be various, including geographic and cultural barriers, dissimilarity in environment and socioeconomics, lack of economic agreements and difference in R&D investment, which would lead to different perspectives on the development of ecological disciplines (Livingston et al., 2016; Parreira et al., 2017). With vast territory, China and the US are both rich in ecological and environmental resources. However, as the largest

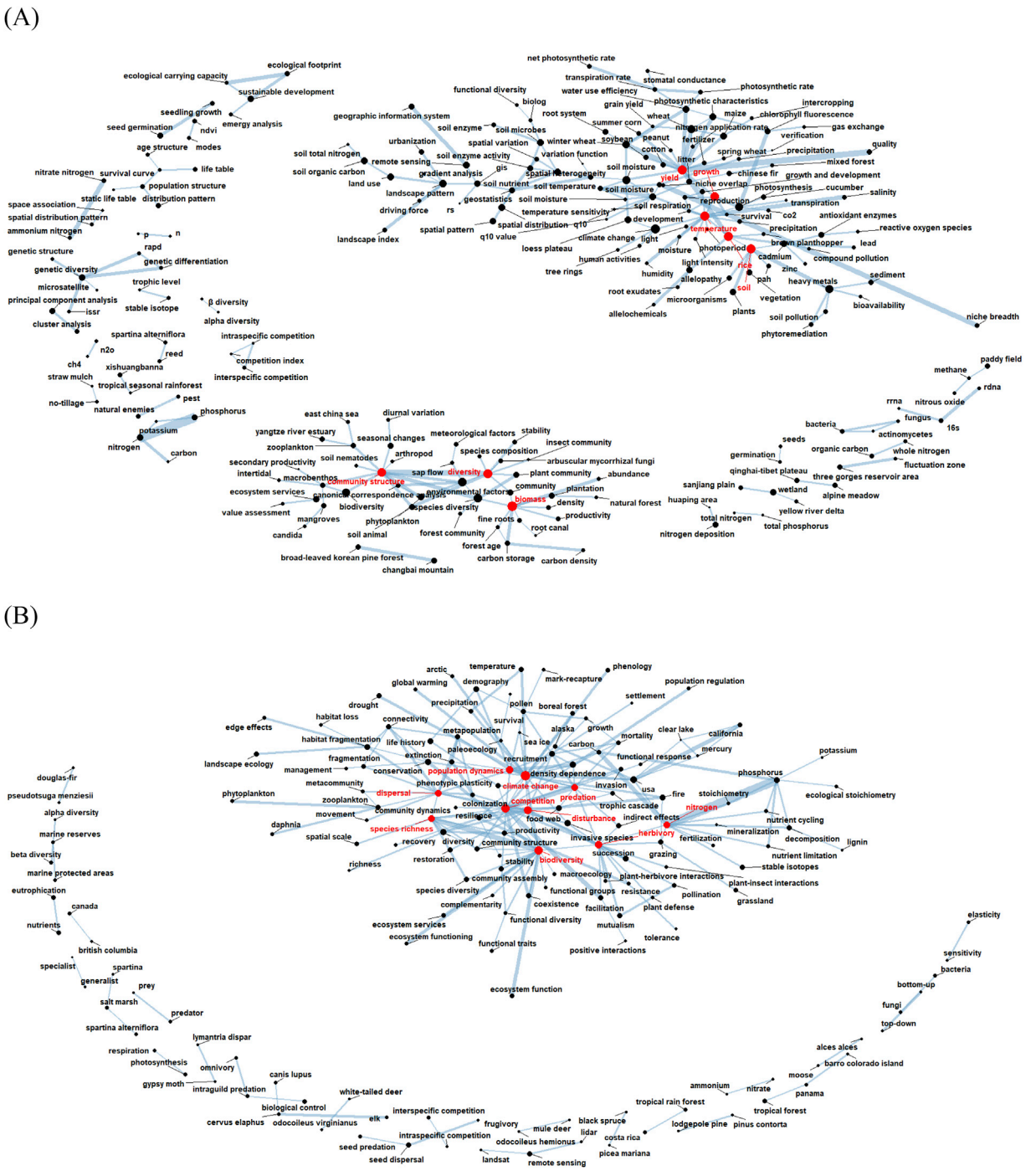

Fig. 3. Keyword co-occurrence network of ESC journals (A) and ESA journals (B). The width of edges was scaled by the co-occurrence number of keywords and the node size was proportional to the keyword frequency in the last 30 years. The text labels near the nodes are the keyword represented by the nodes, and the red nodes with red text labels are ecological hotspots during the three decades. We could find that network of ESA (B) is more centralized, while the ESC network (A) could be divided into two clusters (one on the top right and the other at the bottom). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

emerged economies and developed country in the world, the development of ecological disciplines in these two countries could be quite different. In addition, ESA has a much longer history than ESC. They are going through different stages of disciplinary development, and ecologists from these two countries might initiate their studies for different reasons based on their current stage of development. We took great interests in these differences in our study.

Table 1
Top 20 keywords in keyword co-occurrence network over 30 years (sorting by degree).

Rank	US			China		
	Keyword	F	D	Keyword	F	D
1	climate change	661	3388	biomass	478	1301
2	competition	465	2558	soil	437	1148
3	biodiversity	460	2370	temperature	395	1085
4	disturbance	381	2186	growth	361	1050
5	herbivory	380	2172	rice	389	1039
6	population dynamics	325	1960	climate change	388	1017
7	predation	311	1886	diversity	387	959
8	species richness	310	1652	species diversity	355	946
9	dispersal	299	1638	environmental factors	352	930
10	nitrogen	299	1575	yield	402	922
11	invasive species	255	1548	biodiversity	323	913
12	density dependence	253	1526	community structure	375	893
13	conservation	235	1423	wheat	328	862
14	diversity	219	1224	photosynthesis	297	785
15	recruitment	187	1196	soil moisture	284	734
16	life history	173	1139	heavy metals	298	714
17	demography	173	1118	ecosystem	240	693
18	succession	170	1101	maize	228	637
19	fire	175	1044	landscape pattern	255	619
20	community structure	154	1043	spatial distribution	198	613

F: Frequency of keywords; D: Degree of keywords, measuring the quantity of distinct keywords that co-occurred with it in articles.

Table 2
Top 10 keywords in keyword co-occurrence network of ESA journals by decades in the last three decades (sorting by degree).

Rank	1988–1997			1998–2007			2008–2017		
	Keyword	F	D	Keyword	F	D	Keyword	F	D
1	competition	44	337	competition	195	1229	climate change	532	2810
2	herbivory	32	252	herbivory	173	1200	biodiversity	270	1493
3	nitrogen	31	225	predation	161	1072	competition	226	1377
4	disturbance	28	219	biodiversity	176	1060	disturbance	198	1249
5	population dynamics	31	219	disturbance	155	1023	invasive species	195	1210
6	predation	27	211	species richness	158	915	population dynamics	161	1095
7	succession	19	164	population dynamics	133	911	herbivory	175	1072
8	demography	20	154	dispersal	139	859	density dependence	133	901
9	life history	18	143	nitrogen	124	780	species richness	141	880
10	field experiment	16	143	climate change	111	731	predation	123	863

F: Frequency of keywords; D: Degree of keywords, measuring the quantity of distinct keywords that co-occurred with it in articles.

Table 3
Top 10 keywords in keyword co-occurrence network of ESC journals by decades in the last three decades (sorting by degree).

Rank	1988–1997			1998–2007			2008–2017		
	Keyword	F	D	Keyword	F	D	Keyword	F	D
1	ecology	119	281	soil	178	582	climate change	324	887
2	population	62	167	rice	168	530	biomass	305	858
3	growth	55	163	biomass	129	470	yield	305	719
4	soil	52	145	growth	112	420	environmental factors	262	704
5	temperature	47	126	wheat	124	400	temperature	228	680
6	rice	44	125	temperature	120	399	biodiversity	219	654
7	biomass	44	124	ecosystem	117	395	diversity	235	637
8	environment	36	107	species diversity	124	385	community structure	267	635
9	wheat	35	107	diversity	133	383	species diversity	218	621
10	community	35	101	photosynthesis	92	321	growth	194	595

F: Frequency of keywords; D: Degree of keywords, measuring the quantity of distinct keywords that co-occurred with it in articles.

4.1. Publishing preference

Our study showed that US ecology journals generally had more keywords than China (Fig. 1B), which implied that in average American ecological papers might contain more information than China. Therefore, American ecological papers might present more data and ideas. These publications potentially demand more effort to put in and lengthen the review

cycle, but the reward is paid with potentially greater impact in the field (Fox et al., 2016). It is broadly admitted that Chinese ecological journals had less impact than American ecological journals though they could hardly be compared by the same criteria.

Keywordrichness was a metric we created to measure the abundance of knowledge in different ecological publications over a period of time. With same amount of paper volume, the US definitely had higher keyword richness for overwhelmingly larger keyword number per paper (Fig. 4). Nevertheless, with more papers published in ESC journals, more and more distinct keywords were included and keyword richness in China could potentially surpassed the US in general.

Previous study had found that longer papers got more citations and therefore had more impact than shorter ones, and the restriction of manuscript length in some journals might be inappropriate (Fox et al., 2016). Our study suggested that variation of manuscript length might reveal the tradeoff between depth and breadth of ecological research. For instance, *Ecology*, suggested that more concise papers would be adopted in its publication, which would definitely decline its citation frequency per paper according to the past study (Leimu and Koricheva, 2005), actually kept the highest record of all keyword diversity indexes we tested among all the investigated ecological journals (Fig. 1C, D, E). Adopting more and more papers through these years (Fig. 2A), *Ecology* was more likely to publish larger quantity of influential works and embrace a great diversity of topics in ecology.

4.2. Difference in ecological hotspots

Based on the top 20 keywords with largest degree in each of the keyword co-occurrence network across the whole-time span (Table 1), it could be concluded that research of the ESA might have research priorities on population ecology and conservation biology, which supported by high degree of the keywords “population dynamics”, “competition”, “disturbance” and “invasive species”. Most of these keywords could be treated as ecological concepts (Reiners et al., 2017). Attempting to categorize these keywords referring to the previous study (Reiners et al., 2017), we found that while some researchers found most of ecological studies were still focusing on one species (Carmel et al., 2013), namely fell in the category of organismal ecology and population ecology, community ecology might have the potential to merge more topics into their study, including hotspot keywords of “biodiversity”, “species richness”, “invasive species”, “recruitment”, “succession” and “community structure”.

On the other hand, ESC communities focused more on agricultural ecology, where we could find three of the main crops in the top 20 list: rice, wheat and maize. More interestingly, the top 20 list of ESC journals contained large number of environmental factors that might affect the growth of plants. Only a few keywords emerged as concepts in the top 20 list in China, most of them appeared in a more specific form like “soil”, “rice”, etc. It could be inferred that China had devoted much effort into agricultural ecology, with intensely related hotspot keywords of “growth”, “yield”, “rice”, “soil” and “temperature” (Fig. 3A, Table 1). Actually, Chinese ecology might have a historical root in farming civilization and the development of Chinese ecology had never lost sight of agricultural production (Li, 2010, 2015).

Generally speaking, Chinese ecology could be divided into two large clusters, namely applied ecology and theoretical ecology, and topics in applied ecology might be more abundant (Fig. 3A), whereas in America theoretical ecology was regarded as the main issue to do research on (Fig. 3B). It seemed that in China, we usually had a practical problem first and thus might neglect the importance of theoretical studies, which led to insufficiency of basic ecological research (Li, 2010). On the contrary, while having solid theoretical foundation, American ecologists might still have to fight against the limitations of TEM-based (TEM, Theoretical Ecological Models) analysis so as to provide practical guide for decision-making in natural resource management and environmental policy (Donahauser, 2014).

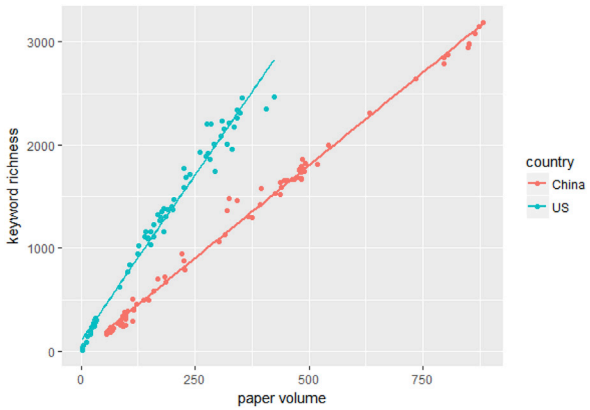

Fig. 4. The relationship between paper volume and keyword richness in ESA and ESC journals. Each point represents a year in the range from 1988 to 2017, and the line is based on the simple linear model. In general, with the same number of paper volume, the American ecological publications would hold larger keyword richness. But in some of the years, as the paper volume of Chinese journals increased, the keyword richness of ESC could surpass ESA (red points on the top right are higher than any points in blue). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

4.3. Potential issues for collaboration

Split the whole investigated period into three decades, we could find different trends of research interests between ESA and ESC communities (Tables 2 and 3). In ESA community, research priorities had not been changed much in the 30 years, but we could find that in 1998–2007 period "biodiversity" and "species richness" had gained more attention than before, and "climate change" had made the top 10, which boosted to the number one popular keyword connecting to the most various keywords in the latest 10 years. On the other hand, ESC community took great interests in applied ecology on agricultural production in the first two decades. However, more attention was paid to biodiversity, with its synonyms including "diversity" and "species diversity" in the recent decade. Notably, the keyword "climate change" had also got the first occupation in the ESC top 10 list in 2008–2017 period, which indicated that climate change had definitely became a crucial problem to address for both ecological societies from China and the US. Reasons behind this phenomenon might be the accelerated accumulation of ecological data and increased cooperation among ecologists. In addition, the involvement of diverse new technologies and approaches coming from different disciplines might also play a role in facilitating the research in climate change and biodiversity (Kim et al., 2018). The rising of these two topics was also supported by other study (Carmel et al., 2013), and we assume that climate change and biodiversity are global ecological topics which should gain attention from ecologists all over the world, and there is a great potential for researchers from different countries to join international programs on these two topics.

Though ecologists from both countries came to realize that climate change and biodiversity were of great importance in recent years, Chinese ecologists might get this awareness a bit later (Table 2, Table 3). Early in the period of 1998–2007, the US had already seen "biodiversity" and "climate change" in their top 10 keyword list, and they made the top 2 in the next decade. In China, however, we could not find "climate change" in the top 10 list from 1998 to 2007 (but it leapt to the first place in the next decade). Even "biodiversity" was not found, but scientists considered it as important and used "species diversity" and "diversity" a lot in their ecological articles. Only after the next decade from 2008 to 2017 had the keyword "biodiversity" widely used by Chinese ecologists in ESC journals. It is speculated that with the scientific research power, US is one of the countries that lead the trend of ecology. While with a shorter history in ecological development, China is learning fast and keeps its pace with the trend. Ecologists from different countries initiate the study of ecology at different places and times, but aim for the common goal to better the world with their knowledge. In the information era that facilitate the flow of knowledge, the globalization of ecological development might play an important role to unite ecologists worldwide and lead to larger and better research in the future.

5. Conclusion

Our study compared ecological research features in China and the US from 1988 to 2017 using publications from the national ecological societies. On the whole, ecological papers in the US contained more information than China, but with the increasing number of ecological paper volume, Chinese ecological research were able to cover an even broader range of topics. In China, the initiation of a research usually came from a practical problem, while in the US the starting point was usually an abstract theoretical question. Typically, agricultural ecology made up a large part in Chinese ecology, but in recent years, climate change and biodiversity became hot issues and ecologists from both countries had considered them as hotspots in ecological research. We hope that our work will improve comprehension of perspectives on ecology between China and the US so as to explore the possibilities of international cooperation in the future.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gecco.2018.e00509.

References

Carmel, Y., Kent, R., Bar-Massada, A., Blank, L., Liberzon, J., Nezer, O., Sapir, G., Federman, R., 2013. Trends in ecological research during the last three decades–a systematic review. PLoS One 8, e59813.
Csardi, G., Nepusz, T., 2006. The igraph software package for complex network research. InterJournal, Complex Syst. 1695, 1–9.
Donahauser, J., 2014. On how theoretical analyses in ecology can enable environmental problem-solving. Ethics Environ. 19, 91–116.
Edwards, P., 1995. Ecological progress to meet the challenge of environmental change. Trends Ecol. Evol. 10, 261.
Fox, C.W., Paine, C.E., Sauterey, B., 2016. Citations increase with manuscript length, author number, and references cited in ecology journals. Ecol. Evol. 6, 7717–7726.
Hill, M.O., 1973. Diversity and evenness: a unifying notation and its consequences. Ecology 54, 427–432.
Institute of Scientific and Technical Information of China, 2018. Chinese S&T journal citation reports. Nat. Sci. 145.
Kim, J.Y., Joo, G.J., Do, Y., 2018. Through 100 years of Ecological Society of America publications: development of ecological research topics and scientific collaborations. Ecosphere 9.
Leimu, R., Koricheva, J., 2005. What determines the citation frequency of ecological papers? Trends Ecol. Evol. 20, 28–32.
Li, W., 2010. Progresses and perspectives of ecological research in China. J. Res. Ecol. 1, 3–14.
Li, W., 2015. Contemporary Ecology Research in China. Springer Berlin Heidelberg.
Livingston, G., Waring, B., Pacheco, L.F., Buchori, D., Jiang, Y., Gilbert, L., Jha, S., 2016. Perspectives on the global disparity in ecological science. Bioscience 66, 147–155.
Mitman, G.A., 2005. The Evolution of American Ecology, 1890–2000. Johns Hopkins University Press.
Neff, M.W., Corley, E.A., 2009. 35 years and 160,000 articles: a bibliometric exploration of the evolution of ecology. Scientometrics 80, 657–682.

Nunez Mir, G.C., Iannone, B.V., Pijanowski, B.C., Kong, N., Fei, S., 2016. Automated content analysis: addressing the big literature challenge in ecology and evolution. Meth. Ecol. Evol. 7, 1262–1272.
Parreira, M.R., Machado, K.B., Logares, R., Diniz-Filho, J.A.F., Nabout, J.C., 2017. The roles of geographic distance and socioeconomic factors on international collaboration among ecologists. Scientometrics 113, 1539–1550.
Pedersen, T.L., 2017. Ggraph: an Implementation of Grammar of Graphics for Graphs and Networks. R Package Version 0.1 1.
Pedersen, T.L., 2018. Tidygraph: a Tidy API for Graph Manipulation. R Package Version 1.1.0.
R Core Team, 2018. R: a Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.
Reiners, W.A., Lockwood, J.A., Reiners, D.S., Prager, S.D., 2017. 100 years of ecology: what are our concepts and are they useful? Ecol. Monogr. 87, 260–277.
Shelford, V.E., 1917. The ideals and aims of the Ecological Society of America. Bull. Ecol. Soc. Am. 1, 1–8.
Silge, J., Robinson, D., 2017. Text Mining with R: a Tidy Approach. O'Reilly Media, Inc.
Strong, W.L., 2016. Biased richness and evenness relationships within Shannon–Wiener index values. Ecol. Indicat. 67, 703–713.
Thompson, J.N., Reichman, O.J., Morin, P.J., Polis, G.A., Power, M.E., Sterner, R.W., Couch, C.A., Gough, L., Holt, R., Hooper, D.U., 2001. Frontiers of Ecology: as ecological research enters a new era of collaboration, integration, and technological sophistication, four frontiers seem paramount for understanding how biological and physical processes interact over multiple spatial and temporal scales to shape the earth's biodiversity. Bioscience 51, 15–24.
Turner, M.G., 2015. Celebrating the past, embracing the future. Front. Ecol. Environ. 13, 291.