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Mapping ecological trends by keywords in the last 20 years

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Abstract:

Background. An effective bibliometric analysis based on the Science Citation Index (SCI) published by the Institute of Scientific Information (ISI) was carried out to identify the trend of ecological research between 1992 and 2016.

Methods. This study emphases on the high-frequency keywords and their relationships to reveal the hotspots and developing trends of ecological research fields .

Results. The result shows that the hotpots of ecology has changed a lot during the last 25 years, but some topics occupied an important position in ecological research consistently. Especially, “Biodiversity” and “Climate change” have been obtained more and more attention, so their ranks also have been changed greatly. As well as, we find that the relationship of the most frequently used keywords become more closely and complicated compared to before. Another interesting and amazing result shows that the keywords related to anthropogenic increased sharply. Finally, keywords analysis was an effective approach for mapping ecological research. We guess that anthropogenic keywords may be a potential guide for future research.

Introduction

Ecology is a recently emerging science and often described to be dynamic (Holling, 1998; Carmel et al., 2013). Ecology, a mainly descriptive and qualitative discipline before, is now becoming more quantitative and experimental (Wiens, 1992). Meanwhile, the definition of ecology has also changed (May, 1999) with the theoretical foundation becoming richer (Pielou, 1981; Cherrett et al., 1989) and the time and space scale going broader (Brown & Maurer, 1989; Wiens, 1989). Ecology is the study of the interrelationships between organisms and their environment, including the biotic and abiotic components (Begon et al., 2006) and addressing the full scale of life from tiny bacteria to processes that span the entire planet. It is vital for human beings because each individual species has an important role to play in the ecosystem with significant influence on the environment in which the mankind live.

With the development of the society, ecology nowadays is closely related to global environment changes and globalization issues, such as climate change, land use, pollution, and sustainable development. Almost every major ecosystem has been influenced by human activities (Thuiller et al., 2005). The geologists have recognized that this wholesale alternation of the Earth’s environment has rendered our current era as a new geological epoch – the Anthropogence (Zalasiewicz et al., 2008). Furthermore, advanced science and technologies are being frequently used in ecological research, such as remote sensing techniques (Cord et al., 2013; Crowther et al., 2015), lightweight unmanned aerial vehicle (UAV) (Anderson & Gaston, 2013), molecular methods (Griffiths & Dos Santos, 2012) and advanced model (Whittaker, 2014).

Biobliometric analysis is an important part of reference and research services capable of providing a series of visual and quantitative procedures to generalize the patterns and dynamics in scientific publications (Zhang et al., 2010). Therefore, this method has been used by more and more researchers in many disciplines of science and engineering . Conventional bibliometric methods, mainly focusing on the publication outputs (Allen et al., 2009), research institutes (Herbertz & Müller-Hill, 1995) and citation analysis (Ding et al., 2014), can hardly reveal the trends or future orientation of a research field. Luckily, the trends of keywords can solve this problem very well because keywords, which are considered as the basic elements to represent knowledge concepts, are commonly used to reveal the knowledge structure of research domains

(Yoon et al., 2010). High-frequency keywords are often used in the analysis of hotspots and developing trends of research fields (Su et al., 2014).

What are the research topics that dominate ecology study in this year and where the ecology study likely to head to in the next year? The answer can be figured out by looking at the most commonly used keywords in ecology papers published this year. Ecology is a very prolific field of research, with more than 360 active journals dedicated to the annual publication of several thousand research articles (data from the Web of Science). It is impossible for ecologists to read all the literatures published, which makes summarizing the papers extremely important because it can provide a good perspective or a potential research direction in the future. In this study, we perform a bibliometric analysis on the published ecological research with keywords in the period of 1992-2016, aiming at mapping the ecological research trends especially the changes of hotspots in different period. Furthermore, the findings from this study can help researchers to realize the breadth of ecological research, as well as providing an alternative demonstration of research advancements, which may serve as a potential guide for future research.

Materials and methods

Journal selection

The trend analysis is based on five core ecological journals, covering a time period of 25 years (1992-2016), excluding Ecology letters because it was established in 1998. To reduce the biases of consequence resulting from journal selection, all journals are comparative broad. Three of the selected five journals provide general ecological orientation: Ecology, Journal of Ecology and Ecology Letters. We also selected two applied ecological journals: Ecological Applications and Journal of Applied Ecology (Table S1).

Data source

Literature records (keywords) form 1992 to 2016 were derived from the Web of Science, an online academic citation index database provided by Thomson Reuters. This database is the most important and frequently used source for a broad review of scientific accomplishment in all field (Ugolini et al., 2015). First, we selected the target ecological journal and set the time interval (1992-2016). Second, we exported the full records from the Web of Science to text files, including title, author, keywords, abstract, organization, country and language. A total number of 64 text files were created, because the Web of Science limits each export to 500 records. From 1992 to

1995, the records of keywords were derived from JSTOR (Journal Storage). We searched title of paper, and then manually recorded the keywords, because the records of keywords in web of science were not complete before 1996. And then, we combine the text files into one for each journal. In every text files, "author keywords" were marked by "DE".

Data process

Due to the fact that some keywords have similar meaning but different spellings, the keywords in the original paper are not all exactly the same as they appear in the word clouds and co-occurrence networks. For example, phylogeograph, phylogeographic, phylogeographical are merged into phylogeography. Similarly, land-use, climate-change and bio-diversity are considered as land use, climate change and biodiversity, respectively.

The data from each txt file were extracted and analyzed with Bibexel (Persson et al., 2009), and the wordcloud was performed using 'wordcloud' package in R (version 3.1.1, R Development Core Team, 2016). Co-occurrence keywords networks were plotted for different period with Ucinet (Chung et al., 2013).

Results

Using the above mentioned searching strategy, totally 19493 publications were collected in 5 core journals during 1992-2016. There are only 374 publications in 1992. But it sharply increased to 916 in 2005, and then smoothly increased to 981 publications in 2016 (Fig.1). In general, the number of publications of each core journal also shows an increasing trend, in which Ecology ranked first with 7259 publications, accounting for 37.2% of total publications, followed by Ecological Applications (3879; 13.3%), Journal of Applied Ecology (3137; 16.1%), Journal of Ecology (2749; 14.1%) and Ecology Letters (2469; 12.7%) (Fig.1 and Table S1).

Ecology has changed greatly in the last 25 years, although some topics or themes consistently obtained more attention. For example, "Competition", "Conservation", "Biodiversity" and "Climate change" occupied an important position in ecological research, but their ranks have changed slightly besides "Climate change" in different time periods (Fig 2 & Table 1). The most frequently used keywords were "Competition" and "Herbivory" in 1992-1999, while "Biodiversity" and "Climate change" were the most used keywords in the last two periods, respectively (Fig.2). However, a consistent and evident trend in keyword use was emerged. Most generally, the diversity of keywords increased over

three study periods while the evenness decreased (Fig.2).

We selected top 20 keywords in ecology journals, finding that in terms of rank, the trend of the keywords related to anthropogenic increased sharply. For instance, the rank of “Invasive species” increased from 792 in 1992-1999 to 8 in 2010-2016. At the same time, some of others showed a dramatic decrease, such as the rank of “Succession”, which decreased from 15 in 1992-1999 to 46 in 2010-2016. The results of four selected keywords that are closely related to human activities, show that each increased dramatically during the past 25 years.

Discussion

Keyword analysis or trends of keywords used can offer information about research trends that concern researchers. However, few studies attempt to use this method to gather systematic data on ecological research. The growth of journal publications reflects various supply and demand as well as editorial policy changes. Nonetheless, it is worth recording the increase in the number of papers published in journals. Overall, these effects may result in a huge increase in volume and so I believe that it can promote a substantial growth in this period, especially in 1992 to 2005. However, the upward trend in the number of papers published is slowing down, which possibly because the content of papers is increasing through the online Supporting Information (Whittaker, 2014). As the development of ecological research, the diversity of keywords in our study increases over the three periods, but the evenness decreases. This suggests that although more aspects of ecology are being addressed, there are also an increase in the proportion of studies addressing some same core themes.

The word cloud patterns revealed that “Competition”, “Biodiversity” and “Climate change” were most frequently used and comparatively stable in the three periods, which reflected that the importance and popularity in ecological research. One of the central problems in ecology is how the large number of species on Earth can coexist ,and what sets limits on diversity(Buttel et al., 2002), therefore, it is not surprising that “Competition” and “Biodiversity” are the most frequent keywords in different time period. In the past century, the global temperature and precipitation have changed spatially and temporally (IPCC, 2007), so it has attracted more attention by publics and ecologists because changes in climate have affected species distribution, population sizes and composition, as well as increasing the frequency of pest and disease outbreaks (Walker, 1999), and this partly explained why

175 “Climate change” and “Biodiversity” have become more and more closely
176 related. Another explanation is that climate change is a major driver to species
177 extinction, especially for species with small ranges (Pimm et al., 2014). Hoffmann et
178 al (2010) found that one quarter of the species assessed so far at risk of extinction
179 (Hoffmann et al., 2010), and the extinction rate is about 1000 times the background
180 rates of extinction (Barnosky et al., 2011). As well as, we found that some keywords
181 shown a decreased trend in three time period, such as “Succession” and
182 “population dynamics”. Three possible explanations for these decrease are (a)
183 some general keywords were replaced by more specific keywords, (b) some keywords
184 were fell out of mainstream of ecological research and (c) the communication tools
185 were changed, notably the internet, promoted international collaboration, and
186 normalization and standardization of research themes and vocabulary (Marriner et al.,
187 2010).
188
189 Interestingly, both word cloud and the rank of keyword frequency revealed that
190 keywords related to anthropogenic sharply increased, which may be a potential guide
191 for future research. Now, we had left the Holocene and had entered a new Epoch - the
192 Anthropocene, because of the global environment effects from increased population
193 and economic development (Zalasiewicz et al., 2008). To date, about half of the Earth’
194 s ice-free terrestrial ecosystems have converted into cropland and pasture, it would
195 result in the local loss of biodiversity (Pimm et al., 1995; Vitousek et al., 2008).
196 Furthermore, other anthropogenic changes include fire suppression, habitat
197 fragmentation, land use and climate warming, which likely affect many aspects of
198 ecosystem or our living environment (Barnosky et al., 2011). Many of these
199 alternations would lead to great changes in the biotic structure and composition of
200 ecological communities, either from the loss of species or from the introduction of
201 exotic species. Moreover, these changes may potentially affect ecosystem properties
202 (Hooper et al., 2005). Human-driven environmental changes may simultaneously
203 affect the biodiversity, productivity, and stability of Earth’ s ecosystems, but there is
204 no consensus on the causal relationships linking these variables (Hautier et al., 2015),
205 partly because of the more complicated nature in a new era compared with before.
206 There is a need to develop management and conservation applications from the
207 emerging areas of ecological research and it requires more collaboration among
208 ecologist, applied practitioners, industry, economists, and even social scientists.

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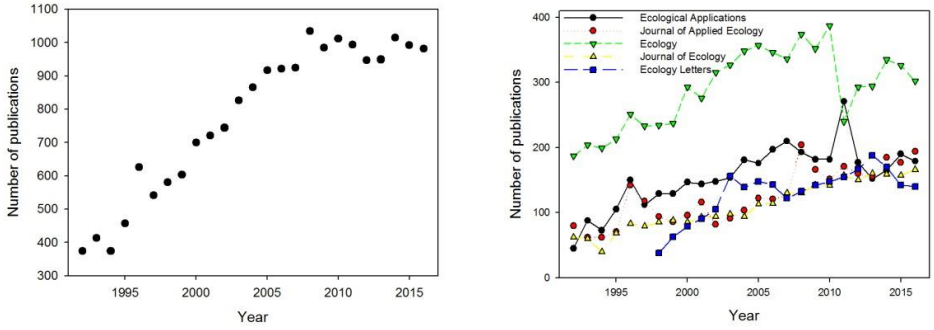
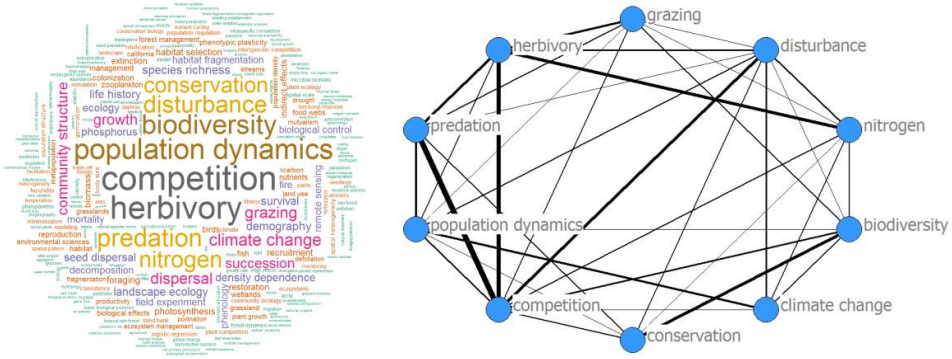
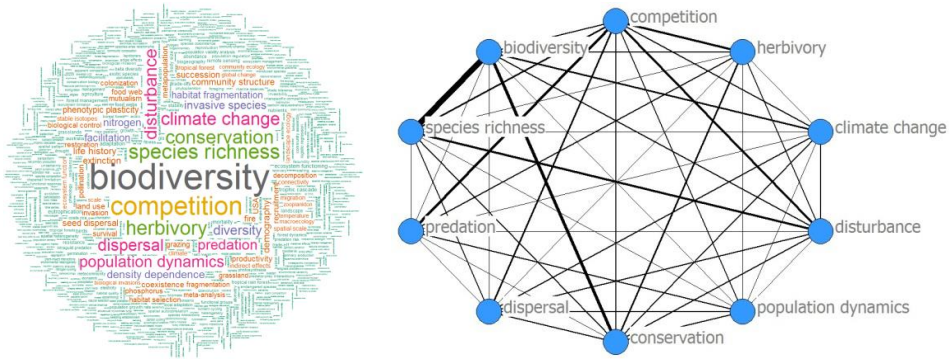


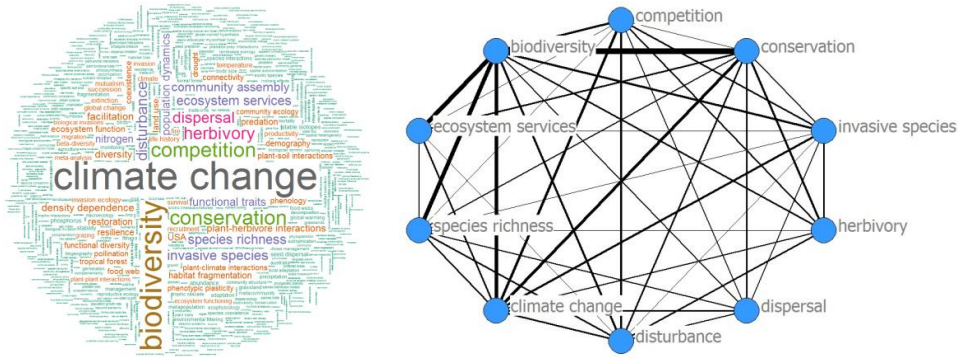
Fig.1 Temporal changes of number of papers in selected journals (left), and changes of all journals (right) in recent 25 years.



1992-1999



2000-2009



2010-2016

Fig.2 Keyword clouds of 5 selected ecology journals in recent 25 years (left column), and network maps of keyword co-occurrence networks (right column). Networks include a subset of the 10 most frequently occurring keywords. The density of the connecting lines represents the number of keyword co-occurrences.

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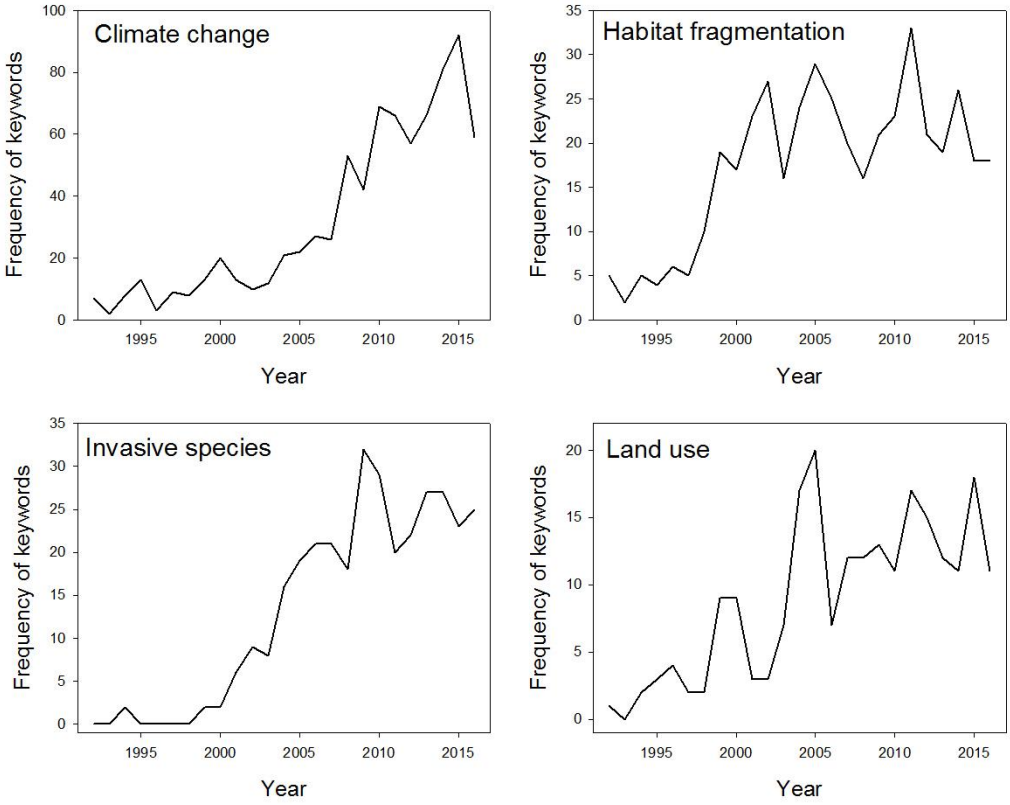

Fig.3 Temporal changes of hot keywords during 1992-2016

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Table1 The rank of top 20 keywords in ecology journals

keyword	1992-1999		2000-2009		2010-2016		Change in rank
	Frequency	Rank	Frequency	Rank	Frequency	Rank	
biodiversity	102	4	514	1	377	2	←
climate change	63	9	246	6	490	1	↑ (8)
competition	132	1	358	2	249	3	↓ (-2)
herbivory	123	2	278	4	208	5	↓ (-3)
conservation	83	8	261	5	247	4	↑ (4)
disturbance	91	6	241	7	180	7	←
species richness	45	16	281	3	160	9	←
dispersal	57	11	224	8	188	6	↑ (5)
population dynamics	110	3	218	9	128	15	↓ (-12)
fragmentation	56	12	218	9	158	10	←
predation	97	5	198	11	102	24	↓ (-19)
nitrogen	87	7	143	15	125	16	↓ (-9)
invasive species	4	792	152	13	173	8	↑ (684)
density dependence	42	20	148	14	120	17	←
facilitation	18	90	135	16	117	18	←
demography	45	16	122	18	93	30	↓ (-14)
life history	42	20	124	17	76	44	←
succession	52	15	111	23	74	46	↓ (-31)
restoration	30	39	93	37	106	22	↑ (17)
community structure	222	55	14	120	18	47	←

Note: ← mix, ↑ increase and ↓ decrease

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Table S1 Introduction of each ecological journals

Journal	Starting year	# of print/year	# of papers
Ecological Applications	1992	6	3879
Journal of Applied Ecology	1992	6	3137
Ecology	1992	12	7259
Journal of Ecology	1992	6	2749
Ecology Letters	1998	12	2469