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A Novel Scientometric Approach to Elucidated Giant Panda Frontier Research

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ABSTRACT. Giant panda conservation was one of the most successful in situ and ex situ conservation efforts in the world. The exclusivity herbivory evolution of *Ailuropoda melanolueca* from the Ursidae family sparks many interests in the dietetics research of said panda. Utilising data from 1079 Scopus and Web of Science-indexed journals from 1990 to 2020, this research conducted a depth scientometrics analysis for authors, countries and institutions conducting research closely related to giant pandas. Next, the study emphasises the burst analysis, cluster analysis and co-citation analysis to determine the top countries, research institutions, researchers and direction of research trends in *Ailuropoda melanolueca* research and its derivatives. The result shows from the exponential trend of research literature produced in the past 50 years that the Republic of China has dominated giant panda research, and second, in line is the United States of America. Based on overlay in trend analysis, there is substantial potential in economic-related research involving giant panda conservation.

Keywords: Citespace, Co-citation, Giant panda, Knowledge map, Scientometric

INTRODUCTION

Giant panda (*Ailuropoda melanolueca*) exclusivity herbivory evolution enables it to consume bamboo, and its derivative as a staple diet is a fascinating evolutionary trait that entices countless research. As a species that has a skeletal structure similar to a carnivore and is categorised as a *Ursidae* (caniforms), the evolution of giant panda from a diversified omnivore to a specialised herbivore dating back at least 5,000 years ago perplexed many researchers (Sheng et al., 2019). Some theories suggest the resemblance of caniforms in giant panda skeletal features resulted from the ancestorial diet of *Ursidae* linage (unconfirmed dates where researchers suggested the evolution occur during 2,000,000 years ago) and along the line of evolution. Giant pandas adapted towards surrounding resources and evolved from carnivores to omnivores and specialised herbivores in the last 5,000 years that were well

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suited to digest bamboo. In retrospect, there seems to be an inconsistent adaptation to plant diet as pandas bear a mix of herbivore and carnivore traits.

Panda herbivores have a modified ‘‘pseudo-thumb" for handling bamboo and a skull, jaw musculature, and dentition adapted for fibrous diets (Dierenfeld et al., 1982). Inclusion of depletion of T1R1 genetic that reduces umami receptor (Sponheimer et al., 2019) and specialise gut with microbe specialising in hemicellulose and cellulose digestion. By understanding the important issues, this research aims to illuminate the dynamics and connectivity between literature relating to the giant panda and its breakthrough in the dietetic domain, where all articles, authors and journals can help policymakers and researchers determine the present and future developments of the topics under consideration. The science community will use this information to identify: (i) academic tipping points in the giant panda population, diet speciality and genetic evolution, (ii) relations between various disciplines working on the problems, and (iii) knowledge development in giant panda research and *Ursadae* relation over time. (Chen, 2004, 2016; Chen et al., 2009; Chen and Leydesdorff, 2014).

Scientometrics is the study of a type of empirical output calculation. It has been extensively used in the fields of science assessment in a variety of research areas, including a report on the gut genomic content of giant pandas, DNA and cDNA research, the microbiome in giant pandas and to molecular evolution of Giant Panda over the past few million years (Guo et al., 2018). This paper shows how a scientometric analysis can detect the landscape of new subjects, as well as recent patterns and pivotal shifting points in the structure of the target domain (Chen, 2004, 2016; Chen et al., 2009; Chen and Leydesdorff, 2014). This approach was chosen because (i) massive bibliographic corpora are available (Web of Science and Scopus) (Bar-Ilan, 2008; Adriaanse and Rensleigh, 2013), (2) the availability of program packages for text mining and visualisation, such as CiteSpace (Chen, 2004, 2016; Chen et al., 2009; Chen and Leydesdorff, 2014). By reducing human bias, the visualised outcome of the scientometric evaluation will provide more thorough and reasoned research outcomes. (Chen, 2004, 2016; Chen et al., 2009; Chen and Leydesdorff, 2014).

Based on the author's knowledge, no attempt has been made to visualise the giant panda research and detect the domain frontiers. This study will fill the gap. The objective of this study is:

i. To map out the scientific contribution of giant panda research and determine the link of various disciplines focusing on it.

ii. To determine the most influential countries, journals, authors, and publications on giant panda research

The structure of this paper is as follows: after the introduction (Section 1), the methodology is presented and explained in Section 2. Section 3 conducts the scientometric analysis and discusses the important findings, hot research themes and evolution trends from the theme perspective. Section 4 summarises the conclusions and proposes suggestions for future research. Cite all references used according to APA style format.

METHODOLOGY

This study uses scientometric methods to analyse the worldwide scientific network for giant panda research. The scientometric method can examine the structure of a research area and the performance of countries, institutions, journals, and authors and identify the top research discipline (Hood and Wilson, 2001; Chen, 2006; Lin and Su, 2020).

Database Searches

The search in Web of Science was made using keywords (search code) commonly used to refer to giant panda. The Boolean "OR" was used to capture at least one of the specified terms used to describe giant panda. Web of Science searches the title of the manuscript, its abstract, keywords, author, and Keywords Plus as the search option when the field "TS" is checked (Bar-Ilan, 2008; Adriaanse and Rensleigh, 2013).

The search was restricted to articles published between 1970 and 2020. Publication types include only original research articles, while commentaries, short communications of findings, books and book chapters, protocol papers, theory/discussion papers and editorials were excluded. All research designs (quantitative, qualitative, and mixed-methods studies) are included. The search was conducted on April 09, 2021. The detailed retrieval strategy is shown in Figure 1.

Data Analysis

This work's visualisation and information graph research was done with CiteSpace tools. CiteSpace is a software program created by Chen (2004–2006) that provides a detailed set of tools for creating multiple bibliometric networks and performing multiple types of analysis. CiteSpace can create a variety of bibliometric networks (Chen, 2004; Chen and Leydesdorff, 2014). A 64-bit Windows CiteSpace V version 5.2.R 2.3.26.2018 were utilised in this study. The period for the time slicing was 1970 to 2020, with the parameter of the slicing variable timed as one (1). All term sources, including title, abstract, author keywords, and keywords plus, are chosen during text processing. In this analysis, three approaches were used: (i) Co-citation Analysis, in which two references are quoted together, such as when nation A cites nation B or when literature A cites literature B; and (ii) Burst Analysis, in which a burst is an abrupt increase in the frequencies [of citations] within a short time frame (Chen, 2004; Chen and Leydesdorff, 2014; Aryadoust and Ang, 2019) and (iii) Cluster Analysis, in which Text Co-citation tests is carried out in order to obtain a cluster of co-citing articles.

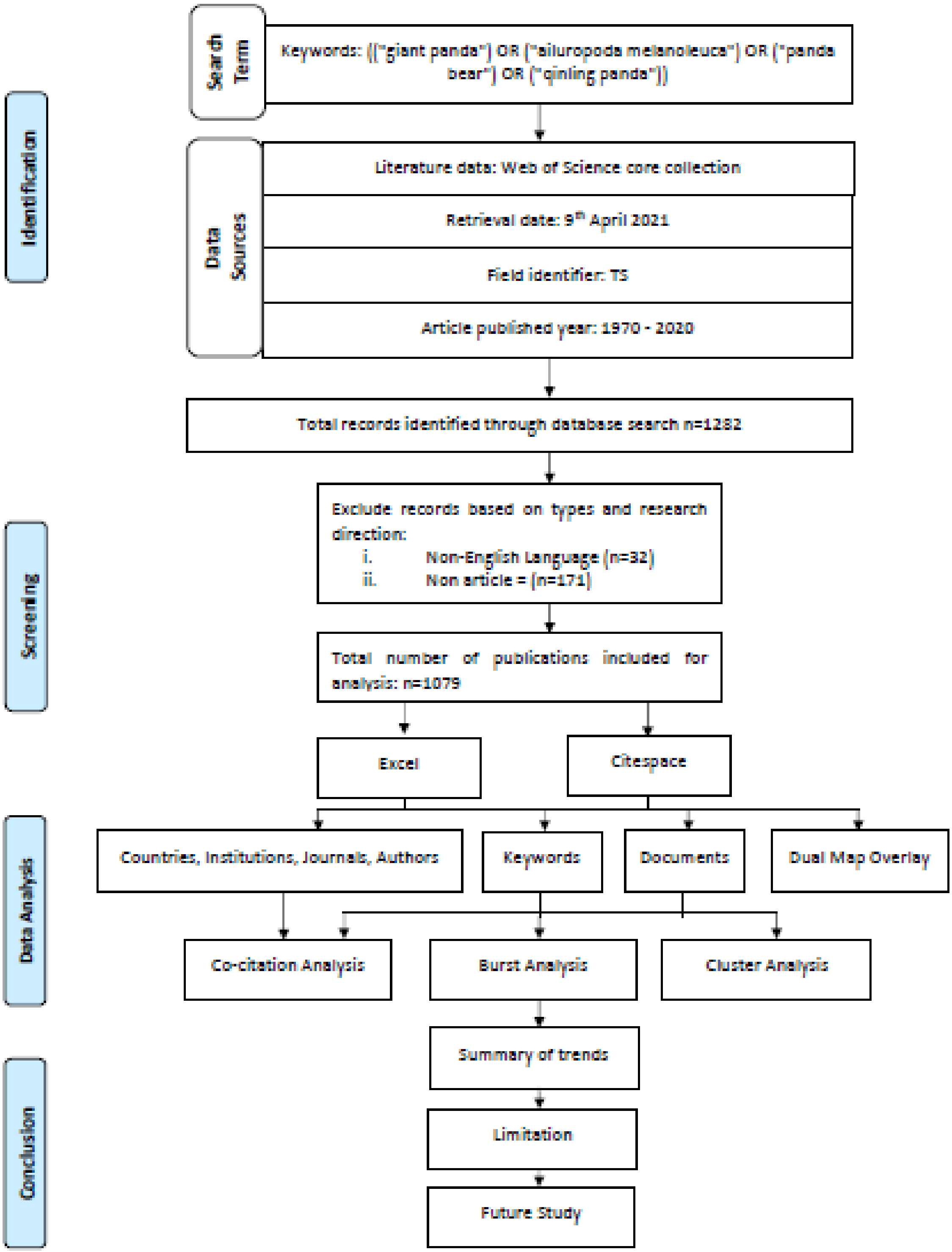

Figure 1. The framework of the study

This study used network analysis to examine the inter-domain specialisation to speciality patterns (dual-map overlay) that connect the giant panda investigation. The literature was divided into two main categories by the dual-map overlay: (1) referenced journals and (2) citing journals (i.e., the latter cited its references from the former). The frequency of these groups' relationships was physically depicted and calculated (Chen and Leydesdorff, 2014). CiteSpace's input data came from WOS, as previously stated. Threshold settings are necessary to allow article selection in order to create an individual network. Top N and Top N% are the two most commonly recommended strategies. In this analysis, the Top N per slice procedure was used, which picked the most cited items from each slice to form a network based on the user-determined input value and node sort. For this analysis, a value of 50 was selected, and various node forms were used, so the top 50 most cited items were shown and ranked accordingly. The "Time Slicing" is set to 1970-2020, and the "Years per Slice" is set to one year. The created network is also pruned, and the “Pruning” parameter is used.

For cluster recognition, a multidimensional clustering approach was used. The cluster mark was immediately extracted using the log-likelihood ratio (LLR). This approach was found to be the most efficient in terms of uniqueness and coverage. The thesis employs a timeline and cluster view of Document Co-citation Analyses to visualise the network's shape and structure. The timeline view comprises a series of vertical lines arranged from left to right to represent time zones in chronological order, which is from left to right. The DCA view cluster created colour-coded and automatically labelled spatial network representations in a landscape format.

Quality control and impact

The modularity Q index, the average silhouette metric betweenness centrality, and sigma were used to assess the quality and homogeneity of the study and observed clusters. The modularity Q index varies from 0 to 1, with higher indices showing more trustworthiness. The typical silhouette metric varies from -1 to 1, with higher values indicating greater homogeneity (Chen et al., 2009; Chen, Ibekwe-Sanjuan and Hou, 2010; Chen, 2014, 2016). Betweenness is a metric of the impact that indicates how close articles or papers are to one another. Since they link more publications or journals and, as a result, more knowledge and pathways flow through them, publications with a higher betweenness will have a greater impact on the network (Chen et al., 2009; Chen, Ibekwe-Sanjuan and Hou, 2010; Chen, 2014, 2016). Sigma is a collection of temporal metrics made up of betweenness, centrality and burstiness. It was calculated as $(\text{centrality} + 1)^{\text{burstness}}$. This metric (which ranges from 0 to 1) was created to classify and assess new ideas discussed in science journals, with the highest value indicating high-value analysis (Chen et al., 2009; Chen, Ibekwe-Sanjuan and Hou, 2010; Chen, 2014, 2016).

RESULTS AND DISCUSSION

This section shows results based on 1079 publications retrieved from 1970 to 2020 on giant panda research worldwide. Based on the research design of Figure 1, descriptive analysis is performed, and then the scientometric analysis result is shown to enhance the understanding of the topic study. Overall studies indicate that the total h-index number for literature in Giant Panda research is 62, where the total overall citation is 18,896 until Mac 2021 (total citation without self-citation and average citation per item = 12,886)

Evolution of Published Studies

This analysis focused on scientific publications between 1970 and 2020. During this period, 1079 articles were gathered. As shown in Figure 2, the number of published articles has increased each year in an exponential pattern. The greatest growth occurred in the last decade (2010 – 2020), when 67.65% of the papers were published in different fields.

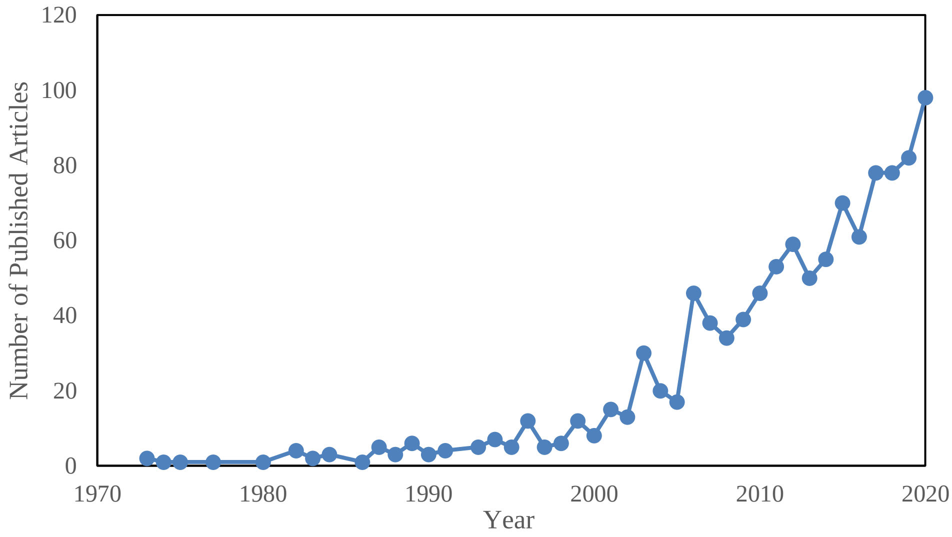

Figure 2. The trend of giant panda research between 1970 – 2020

Dual Map Overlay

Figure 3 is the dual-map overlay of giant panda research articles between 1970 to 2020. Dual-map overlay detects the most productive discipline for conducting giant panda research and the intellectual basis of this domain. The nodes on the left cite articles, which also determine the hotspot discipline for giant panda research between 1970 and 2020. Those nodes on the right are cited articles and disciplines, the foundation of giant panda research. The curve between two nodes indicates the relationship between citations, and the strength of the curves (after the weight of the z-score) is based on the number of citations (the thicker the line equals higher citations). The ovals in the map indicate a cluster of highly active citing and cited journals.

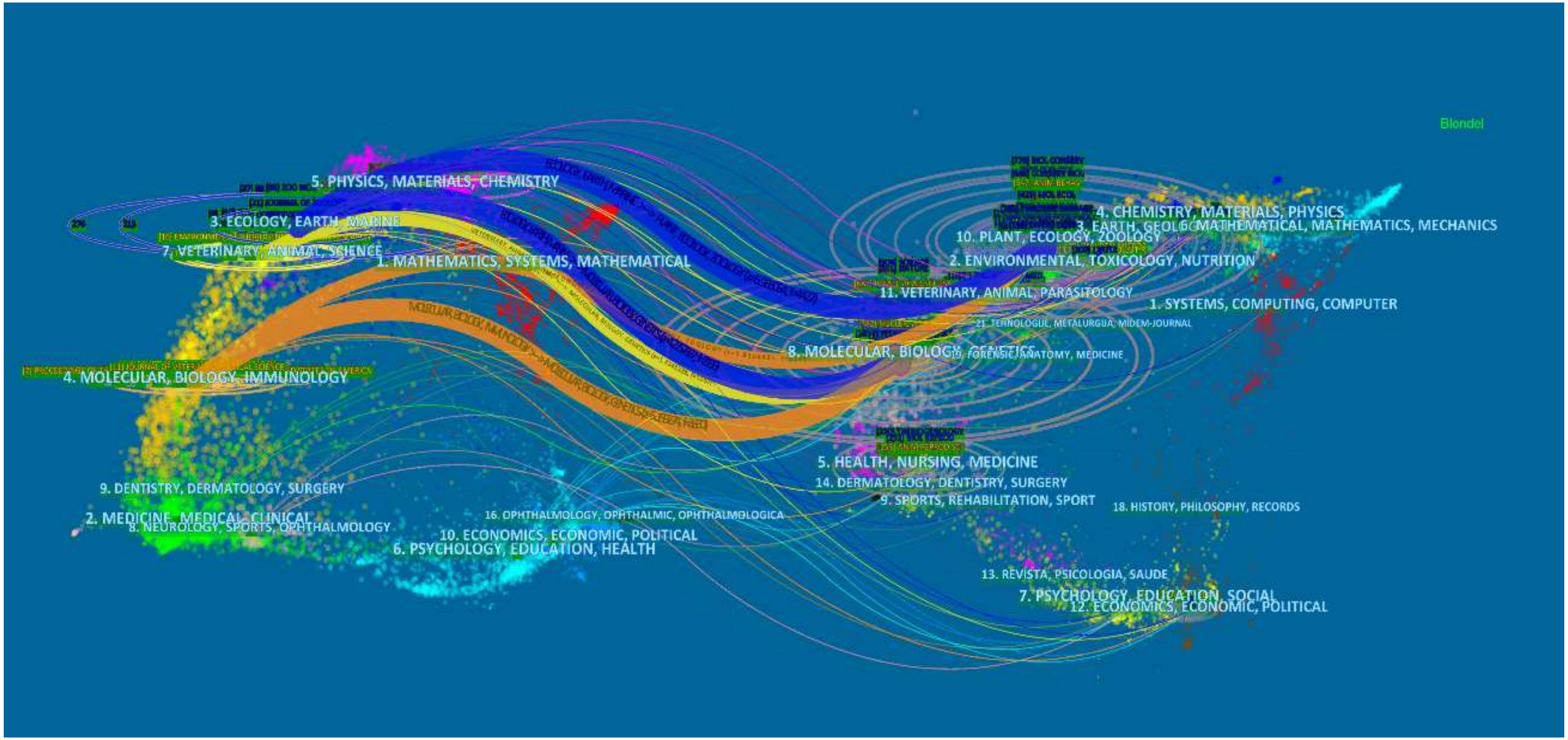

Figure 3. Dual-map Overlay on giant panda research

The results show that “Ecology, Earth, Marine”, “Veterinary, Animal, Science” and “Molecular, Biology, Immunology” is the discipline that has the most publications on giant panda research. Publications in “Ecology, Earth, Marine” mostly cited from two types of discipline: (i)” Plant, Ecology, Zoology” and (ii) “Molecular, Biology, Genetics”. These two disciplines can be considered the intellectual basis for research focus on “Ecology, Earth, Marine” with a z-score of 6.9 and 4.2, respectively. The discipline of “Veterinary, Animal, Science” cited their article mostly from “Molecular, Biology, Genetics” disciplines (z-score=1.7). While publications from “Molecular, Biology, Immunology” cited from “Plant, Ecology, Zoology” (z-score = 1.8) and “Molecular, Biology, Genetics” (z-score =5.1). Based on this result, the research areas for this topic are interdisciplinary, as many activities are shown in the map between each discipline and research cluster.

Countries' contribution and network

The top ten countries with the highest publication are listed in Table 1. 41 countries contribute to publishing in this domain, with China accounting for 73.03% of the total publications. China showed the greatest counts of publication and total citation, while the United States of America were the country with the highest h-index. This is followed by Japan, the United Kingdom, Spain, Germany, Canada and Australia, combining more than 100 papers.

Table 1. Top Ten Countries Distribution of Publications

Countries/Regions	TP	%	NCA	TC	TC/TP	TC/NCA	h-index
China	788	73.031	6963	12635	16.03	1.81	54
United States of America	413	38.276	6207	10714	25.94	1.73	55
Japan	50	4.634	610	781	15.62	1.28	17
England	49	4.541	1681	1826	37.27	1.09	21
Spain	31	2.873	462	552	17.81	1.19	14
Germany	29	2.688	537	545	18.79	1.01	12
Canada	27	2.502	1198	1267	46.93	1.06	13
Australia	24	2.224	266	274	11.42	1.03	10
Austria	19	1.761	1025	1061	55.84	1.04	12
France	17	1.576	492	538	31.65	1.09	11

Notes: TP = total number of publications; TC = total citations; NCA = Number of Cited Articles TC/TP = average citations per publication.

In order to obtain a more comprehensive analysis of countries' distribution and cooperation in the field of giant panda research, a network of co-author based on countries is shown in Figure 4. Each node represents a country, and the yellow line represents each country's cooperation. The nodes' size reflects the country's centrality score, and only country names with centrality scores more than 0.1 are shown in the figure.

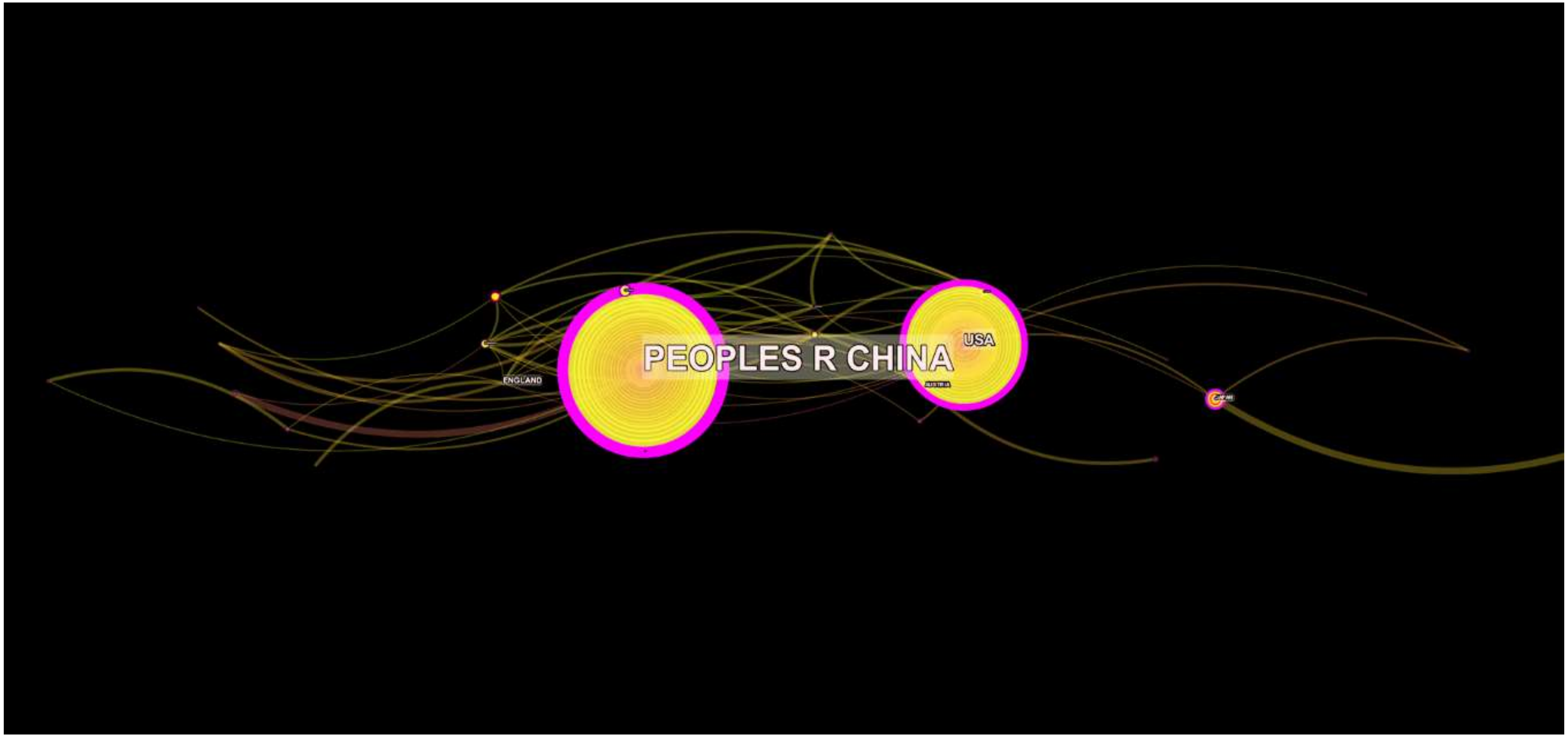

Figure 4. Network of countries co-citation

Table 1 and Figure 4 illustrate that China and the United States of America made the major portion of contributions, with China leading in terms of total publication and citation. China is shown to have the greatest influence among countries that focus their research on giant pandas. This is based on the centrality score of 0.96, while other countries' centrality score is below 0.5. In addition, as the country the giant panda exclusively originates from, China has been productive in empowering research and conservation efforts for *in-situ* and *ex-situ* panda enrichment. The dominant research on giant pandas from China is due to the facts that the giant panda habitat distribution is situated in China province and the efforts and priority taken by the Government of China for the conservation and habitation of giant pandas throughout the years (Xu et al., 2022). Therefore, it is within the expectation that the Republic of China has a tremendous advantage in contributing to panda-related research. The second country besides China that contributes tremendously to panda studies is the United States of America, while other countries are pale in contrast to these two countries. Hence, to improve the centrality score and gain high citations, this research area should improve the quality of the paper and strengthen cooperation with other countries.

Institution contribution and network

The top 10 institutions were ranked by the number of total articles. Research in this area has seen a contribution from 998 organisations worldwide. Among the top 10 institutions, 8 were from China, and two were from the United States of America, as stated in Table 2. Leading institution Chinese Academy of Sciences with 239 articles and h-index: 45.

Table 2. Top Ten Institution Distribution of Publications

Organisations	Country	TP	NCA	TC	TC/TP	TC/NCA	h-index
Chinese Academy of Sciences	China	239	4114	6747	28.23	1.64	45
China Conservation and Research Center for the Giant Panda	China	115	1563	1835	15.96	1.17	17
Chengdu Research Base of Giant Panda Breeding	China	110	1752	2159	19.63	1.23	19
Sichuan Agricultural University	China	89	640	817	9.18	1.28	15
Michigan State University	United State of America	72	1567	2856	39.67	1.82	30
China West Normal University	China	62	312	516	8.32	1.65	15
Sichuan University	China	57	1050	1155	20.26	1.10	13
Zoological Society of San Diego	United State of America	49	882	1458	29.76	1.65	23
Beijing Forestry University	China	47	316	386	8.21	1.22	9
University of the Chinese Academy of Sciences	China	45	550	667	14.82	1.21	14

Analysis of institution distribution and cooperation in giant panda research is shown in Figure 5. Each node represents an institution, and the yellow line represents the cooperation of each institution. The institution with centrality scores more than 0.1 is shown in the figure. Chinese Academy of Sciences has the highest centrality score, followed by the Chengdu Research Base of Giant Panda Breeding and China Conservation and Research Center for the Giant Panda. The centrality score is 0.41, 0.29 and 0.27, respectively. The results show that many of the institution (8 out of 10 institutions) is located in China, and another 2 are from the United States of America. Chinese Academy of Science contributes the highest total publication (239 articles) with a 45 h-index, while the second highest h-index is from Michigan State University (h-index = 30), followed by the Zoological Society of San Diego (h-index = 23). Even though China research institutes dominated the total publication, the total citation per publication indicates that the two institutions from the United States of America (Michigan State University and Zoological Society of San Diego) produced quite a reputable article that was accepted by scientific peers in the domain of Giant Panda Research as they dominated the second and third place in the ranking of total citation per document compared to another research institute.

Journal contribution and network

The articles were published in 400 journals. Table 3 shows the top ten most productive journals with h-index, Impact factor and publisher. The journals publishing the most paper are Forest Ecology and Management (n=60), Forest Policy and Economics (n=49) and Journal of Tropical Forest Science (n=37). Journals with high impact factors were Land Use Policy (IF=3.682), Forest Ecology and Management (IF=3.17) and Forest Policy and Economics (IF=3.139).

The journal co-citation results are shown in Figure 6. The journal with centrality scores of more than 1 is shown by name. A "central" journal acts as the mediating role of literature in the topic being studied. Conservation Biology (IF:6.099; Q1) is the most influential journal in giant panda research, with a score of 0.16. This is followed by Nature (IF: 46.488; Q1) and Journal of Mammalogy (IF: 2.27; Q1) with centrality scores of 0.14 and 0.12, respectively.

After analysing high-impact journals in the field, it was shown that most journals are included in the first and second quartiles of the Journal Citation Reports. Based on the Impact factor and centrality score, this topic has received attention from some of the best journals in forestry, economics and material sciences.

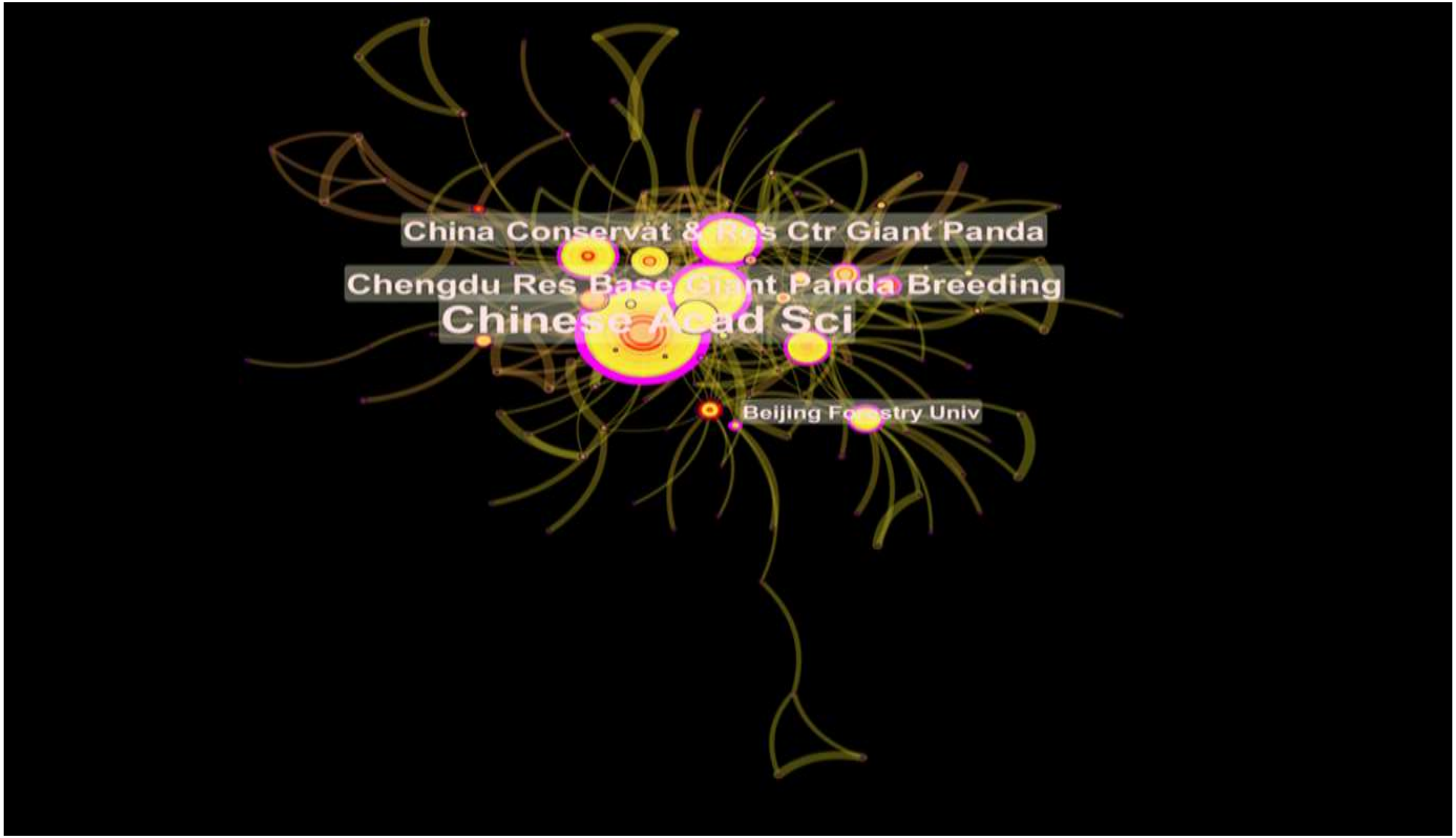

Figure 5. Network of institutions co-citation

Table 3. Top Ten Productive Journal

Source Titles	Records	%	NCA	TC	TC/P	TC/NCA	h-index	Impact Factor (5 years)	Publisher
Plos One	42	3.89	478	526	12.52	1.10	16	3.227	Public Library Science
Zoo Biology	38	3.52	443	676	17.79	1.53	17	1.245	Wiley-Liss
Biological Conservation	37	3.43	489	745	20.14	1.52	16	5.278	Elsevier Sci Ltd
Scientific Reports	27	2.50	225	248	9.19	1.10	8	4.576	Nature Publishing Group
Journal of Zoology	21	1.95	502	644	30.67	1.28	14	1.922	Wiley
Giant Pandas Biology Veterinary Medicine and Management	17	1.58	98	152	8.94	1.55	9	-	Cambridge
Chinese Science Bulletin	16	1.48	88	97	6.06	1.10	7	1.738	Science Press
Environmental Science and Pollution Research	16	1.48	89	111	6.94	1.25	7	3.306	Springer Heidelberg
Theriogenology	16	1.48	160	197	12.31	1.23	9	2.288	Elsevier Science Inc
Genetics and Molecular Research	14	1.30	27	31	2.21	1.15	3	0.912	Funpec-Editora

Notes: TP=total number of publications; IF=impact factor

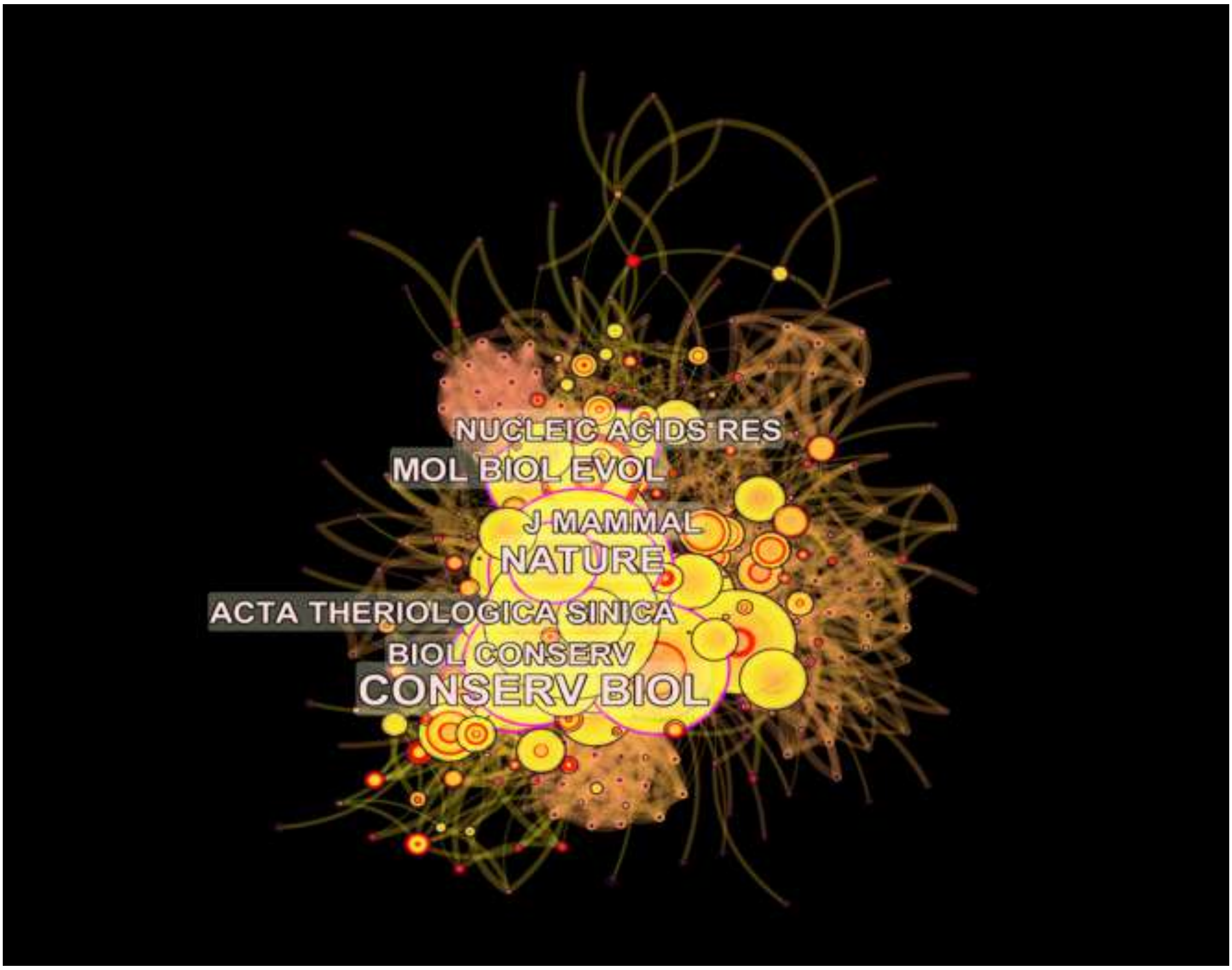

Figure 6. Network of journal co-citation

Author contribution and network

The 1079 articles published in this area involve 2967 authors. The top 10 most productive author is shown in Table 4. The author with the highest publication with the highest total citation and h-index is Zhang, H. with 122 publications (citation = 3391; h-index = 28), while the author with second highest citation and similar h-index with Zhang is Liu, J. (citation = 2349; h-index = 28).

Table 4. Top Ten Most Productive Authors

Authors	TP	NCA	TC	TC/P	TC/NCA	h-index
Hemin Zhang	122	2516	3391	27.80	1.35	28
Zhang Zihe	76	1495	1757	23.12	1.18	16
Desheng Li	74	1130	1286	17.38	1.14	15
Chengdong Wang	70	449	588	8.40	1.31	15
Fuwen Wei	64	1811	2618	40.91	1.45	27
Rong Hou	63	1100	1220	19.37	1.11	13
Ronald R. Swaisgood	55	764	1326	24.11	1.74	21
Jianguo Liu	53	1278	2349	44.32	1.84	28
Huang Yuan	52	1125	1269	24.40	1.13	15
Zejun Zhang	46	473	844	18.35	1.78	18

Figure 7 shows the author's co-citation network for giant panda research. The figure shows the author's name with centrality scores of more than 1. The higher the centrality score, the more influential the author is in the areas. The author with the highest centrality score (0.22) currently stands at the Chengdu Research Base of Giant Panda Breeding. He presently maintains 63 articles focusing on giant panda research and an h-index of 13. Huang Yuan of Beijing Forestry University followed. He has 52 articles on giant pandas in the Web of Science and an h-index of 15. Table 4 and Figure 5 shows that every author mentioned has significantly contributed to studying giant pandas. Generally, the more central an author is, the more recognition he/she will receive in this field of research.

Publication analysis and network

The top ten with the highest citation in the focus areas is shown in Table 5. The most cited paper was published in 2010 (Li et al., 2010). Li et al. (2010) used genomic research to interpolate the genetic markers of giant pandas, which contribute to the characteristics of the impact of giant panda diets. Li et al. (2010) found that there are protease, amylase, lipase, cellulase, lactase, invertase and maltase encoding digestive enzymes in the panda genome, which indicates that pandas may have all the necessary components of the carnivorous digestive system. The lack of homologues of digestive cellulase genes, including exoglucanase, endoglucanase and β-glucosidase, also indicates that the panda's bamboo diet is unlikely to be determined by its genetic makeup. It may depend more on its gut microbiome. This study also successfully determined that the giant pandas T1R2 and T1R3 are in a complete state, but T1R1 has become a pseudogene, resulting in the loss of the ability to detect umami. Umami is important for carnivorous or omnivorous behaviour, and taste is for carnivorous behaviour. Alternatively, omnivorous sex is very important.

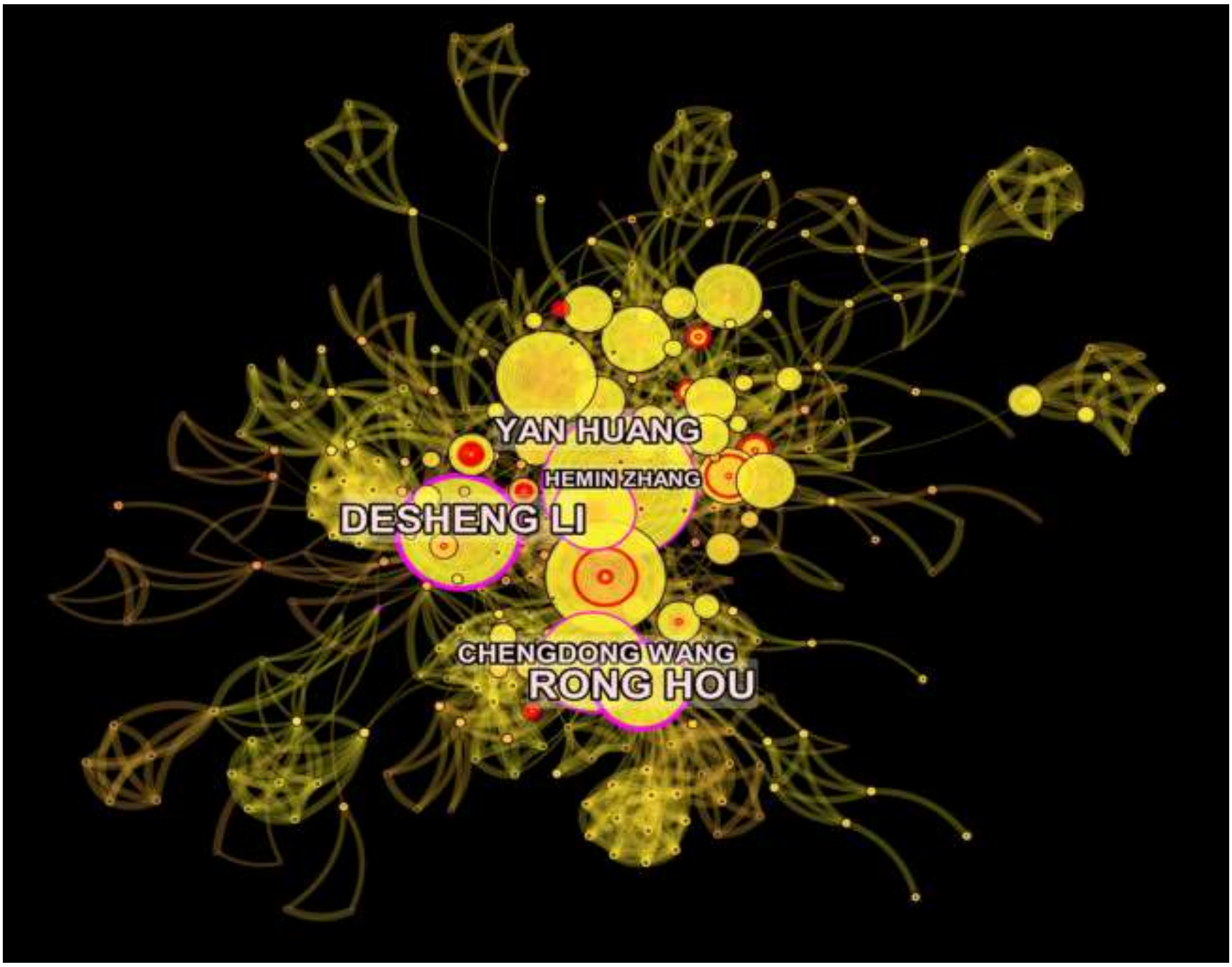

Figure 7. Network of author co-citation

The second most cited paper is the paper led by Liu et al. (2001). Liu et al. (2001) determined the spatial mapping of Wolong Nature Reserve from 1965 to 1997 to determine the degree of fragmentation of the nature reserve and its degree of suitability as a Giant Panda sanctuary. The research determined that the increased degree of fragmentation mainly resulted from increased housing areas developed by locals due to the population increase. As humans become the primary force of fragmentation (from land utilisation; to agricultural, housing and economic activities), Wolong Nature Reserved were not sustainably protected and posed threats to ex-situ Giant Panda conservation efforts. The third most cited paper is Zhu et al. (2011). Zhu et al. (2011) undertake large-scale analysis (5,636 near full-length gene segments) of 16S rRNA gene sequences to profile a large sample of microbial flora existing in the digestive system of giant pandas. The research managed to identify 85 bacterial operational taxonomic units (OTUs) where the majority of microbes were members of the Firmicutes (62 OTUs, 4,633 sequences, 83.8% of the total of 5,522 sequences) and Proteobacteria (12 OTUs, 871 sequences, 15.8% of the total sequences), with the remainder belonging to the phyla Actinobacteria, Bacteroidetes, Cyanobacteria, and Acidobacteria.

Table 5. Top Ten Highly Cited Publication

Title	Authors	Total Citations	Average per Year
The sequence and de novo assembly of the giant panda genome	(Li *et al.*, 2010)	713	59.42
Ecological degradation in protected areas: The case of Wolong Nature Reserve for giant pandas	(Liu *et al.*, 2001)	450	21.43
Evidence of cellulose metabolism by the giant panda gut microbiome	(Zhu *et al.*, 2011)	219	19.91
Exploring complexity in a human-environment system: An agent-based spatial model for multidisciplinary and multiscale integration	(An *et al.*, 2005)	177	10.41
Early Homo and associated artifacts from Asia	(Wanpo *et al.*, 1995)	173	6.41
Whole-genome sequencing of giant pandas provides insights into demographic history and local adaptation	(Zhao *et al.*, 2013)	158	17.56
A framework for evaluating the effects of human factors on wildlife habitat: the case of giant pandas	(Liu *et al.*, 1999)	142	6.17
Utilisation of bamboo by the giant panda	(Dierenfeld *et al.*, 1982)	139	3.48
'Nasty neighbours' rather than 'dear enemies' in a social carnivore	(Müller and Manser, 2007)	116	7.73
Mast flowering and semelparity in bamboos: The bamboo fire cycle hypothesis	(Keeley and Bond, 1999)	109	4.74

Cluster Network

The modularity Q index and the average silhouette metric for the Document Co-citation network were 0.718 and 0.8759, respectively, suggesting a high level of reliability and homogeneity for the network. A total of 10 co-citation clusters emerged from the analysis. Figure 8 presents the top 7 clusters in the data on a horizontal line with the cluster label appearing on the right side, and Figure 9 shows the network of the whole article. The cluster was numbered and ranked in size, starting with #0 as the largest. The circle shows the magnitude of the publication's influence, where a large circle equals a high citation for the publication. The red rings outside the circle indicated the burstiness of the articles. It shows where the articles start to "burst" and how big the "burst" strength is. The purple rings indicated the centrality of the articles, and high centrality articles indicated a strategic position and ability to bridge between different articles in the DCA networks. The yellow line in each line represents the lifetime of the cluster. The top ten articles with the highest citation are shown in Figure 9 highlights the most important piece of literature used as the basis for future research in the plethora domain of Giant Panda research.

Cluster labels were generated by text mining and keyword analysis algorithms in CiteSpace software. These clusters were given names according to four methods: (i) Latent Semantic Indexing (LSI), Term Frequency * Inverted Document Frequency (TF*IDF), log-likelihood ratio (LLR), and Mutual Information (MI). Based on a study by Chen et al. (2000), this paper reports the cluster based on the log-likelihood ratio (LLR) as the outputs of each method were not always sensical.

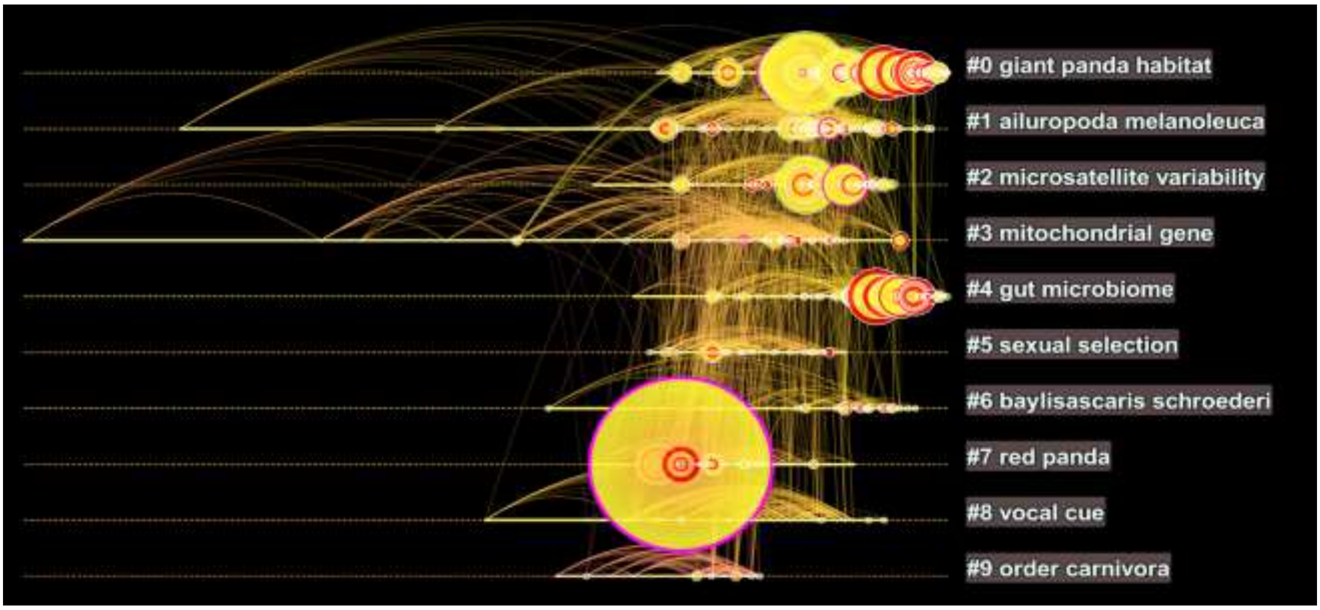

Figure 8. A timeline view of the Document Co-citation network

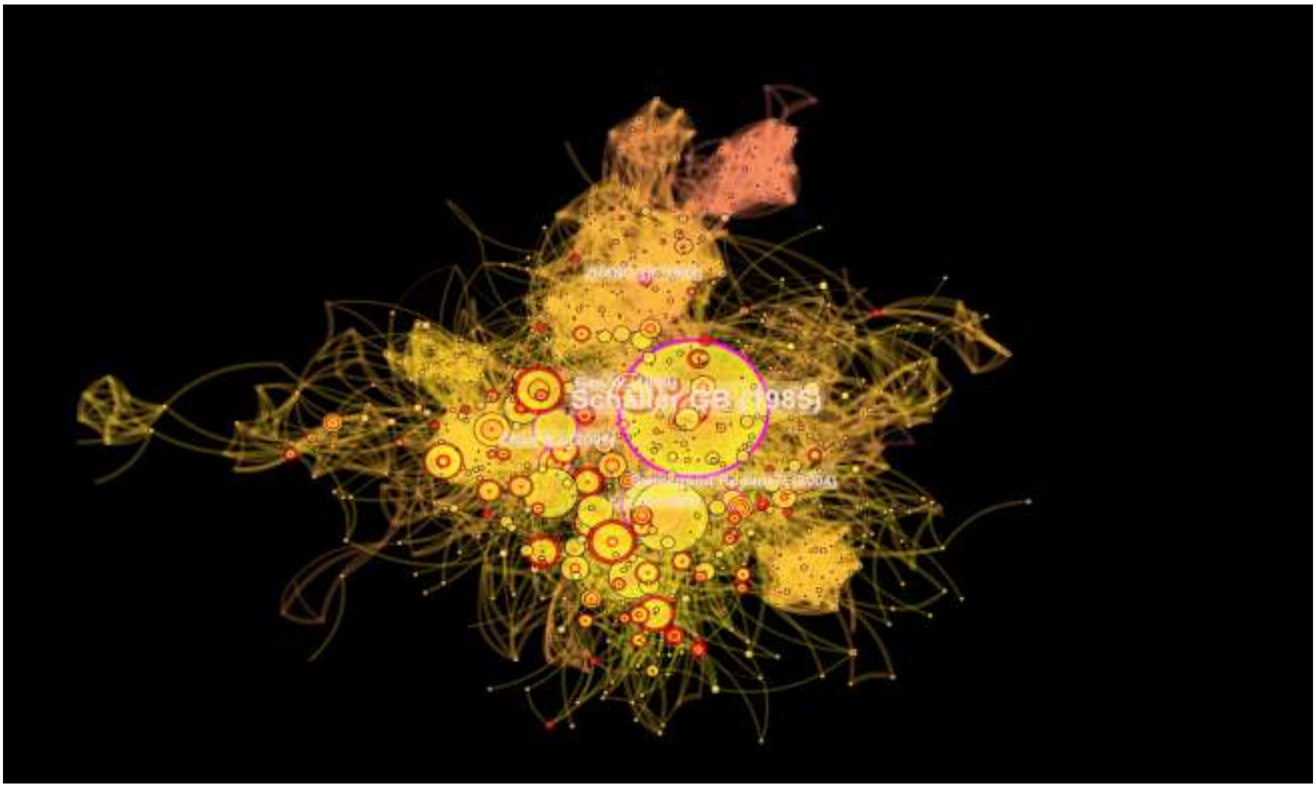

Figure 9. Cluster view of Document Co-citation Network (top 10 articles with the highest citation shown)

Table 6. Influential and Scientific Novelty Publication

Most influential publication (centrality > 1)		**Scientific Novelty Publication (sigma > 1)**	
Molecular censusing doubles giant panda population estimate in a key nature reserve.	(Zhan *et al.*, 2006)	Mitochondrial DNA sequence evolution in the Arctoidea	(Zhang and Ryder, 1993)
A framework for evaluating the effects of human factors on wildlife habitat: The case of giant pandas	(Liu *et al.*, 1999)	A molecular solution to the riddle of the giant panda's phylogeny	(O'Brien *et al.*, 1985)
Mitochondrial DNA sequence evolution in the Arctoidea	(Zhang and Ryder, 1993)	Giant Pandas in a Changing Landscape	(Loucks *et al.*, 2001)
Giant Pandas in a changing landscape	(Loucks *et al.*, 2001)		

Table 6 shows the most influential publication (publication with a centrality score of more than 1) and scientific novelty publication (publication with a sigma score of more than 1). There are 4 publications with a centrality score of more than 1 and 3 publications with a sigma score than 1. By sorting the cluster into sub-cluster #0 to #4, we could see the prominent articles that become baseline references of today's panda-related research in each subdomain. Therefore, we listed all summaries finding from each prominent article that was listed in each sub-cluster #0 to sub-cluster #4 in this section.

This section will look at studies that used molecular and genetic markers to investigate the phylogenetic relationships between giant and lesser pandas and other carnivores. O'Brien et al. (1985) constructed a consensus phylogeny of the giant and lesser pandas using four molecular and genetic markers. They discovered that the lesser panda diverged from New World procyonids at the same time they diverged from ursids, whereas the giant panda diverged from the ursid lineage later before modern bears radiated. They also discovered that after divergence from ursids, the giant panda underwent chromosomal reorganisation, resulting in drastic but limited chromosomal and anatomical morphological differences between them. They used the giant panda and bears to demonstrate the discordance between molecular and morphological (and chromosomal) evolutionary transitions in mammals.

Similarly, Zhang and Ryder (1993) sequenced the mitochondrial cytochrome b, 12S rRNA, and tRNA genes of four extant ursid species and compared them to four other species previously studied by them. In these gene regions, they looked at patterns of variation, substitution, insertion/deletion, transition/transversion ratios, and compensatory changes. They combined 12S rRNA and tRNA gene sequences into a single dataset because they followed a similar evolutionary model. They calculated the divergence times of various bear taxa using the cytochrome b gene clock and compared them to those using the 12S rRNA gene clock. They discovered that the cytochrome b gene clock corresponded to the fossil record, whereas the 12S rRNA gene clock suggested that artiodactyl rRNA genes evolved faster than arctoid rRNA genes. They suggested more sequence data and a closer outgroup to validate their findings.

These studies show how molecular and genetic markers can be used to reveal the evolutionary history and relationships of giant and lesser pandas and other carnivores.

In retrospect, the population, behaviour and biosphere of Giant Panda, Reid and Jinchu (1991) tracked the movements of two adult female pandas in a clear-cut area of Wolong Nature Reserve before and after bamboo flowering using radio collars. Adult females preferred habitats with continuous forest cover before flowering, while subadult pandas and one adult male used the clear-cut area all year. After the flowers bloomed, they discovered that the clear-cut area attracted more pandas, including two or three unidentified adults. They hypothesised that this was due to the greater availability and quality of bamboo in the clear-cut area and the decreased availability and preference for bamboo in other habitats following flowering. They also hypothesised that pandas chose bamboo culms based on their height and diameter in winter and were more concerned with the distribution of seasonally preferred bamboo culms and microtopography within patches than with patch conditions. They discovered that female pandas concentrated their activity in core areas on relatively level terrain and that net annual recruitment of bamboo was greater than annual culm loss to foraging pandas. They noted that the nature of adult male habitat selection was unknown and that feeding site selection based on slope, bamboo height, and diameter would have been important before flowering.

Furthermore, Via et al. (2010) used MODIS data and the Wide Dynamic Range Vegetation Index (WDRVI) to assess the giant panda habitat. They discovered that WDRVI contained more information for isolating giant panda habitats in spring because it could detect the presence of understory bamboo better than overstory canopy. They acknowledged that MODIS data had a relatively coarse spatial resolution, which may be insufficient for smaller scales or localised areas. They advocated creating new reserves or corridors to connect isolated habitat patches and nature reserves, particularly in the southernmost portion of the giant panda's geographic range, where habitat is scarce and isolated. They also proposed active habitat restoration in some areas and assessed these areas' suitability for giant panda reintroduction. They pointed out that these conservation strategies would benefit other endangered species that live in the same forest ecosystems as giant pandas. These studies demonstrate how radio-telemetry and remote sensing can be used to track giant pandas' movements and habitat selection across seasons and conditions.

The impact of human factors on giant panda habitat and population is another aspect of giant panda conservation. Liu et al. (1991) investigated the human influences on forest ecosystems and wildlife habitats. They identified factors such as population demography, household structure, needs and desires, wildlife conservation interpretations, and timber harvesting and fuel wood collection activities. They contended that these factors have an impact on the survival risk of threatened species by influencing abiotic and biotic factors as well as habitat quality. They proposed policies to reduce immigrant influx, encourage migration, and reduce resource consumption could aid in conserving wildlife habitats. They applied their model to the Wolong Nature Reserve, simulating the effects of various scenarios on human population size and giant panda habitat over 50 years. They discovered that increasing the household emigration rate and decreasing the birth rate could reduce the human population by 76%, while youth-only emigration could reduce it by 82%. They concluded these policies could help giant pandas avoid further habitat loss and fragmentation.

Liu et al. (2003) investigated how human population growth and household patterns affect biodiversity. They contended that household dynamics, such as wood consumption, have an impact on per capita consumption and biodiversity but are frequently overlooked by aggregate demographic statistics. They demonstrated that significant changes in the size and number of homes can significantly impact biodiversity. Loucks et al. (2001) assessed the status of China's wild giant panda populations and habitats. They estimated that only 1,100 wild giant pandas remained in 24 fragmented populations, most of which contained fewer than 50 individuals. They warned that extinction was possible for these populations due to habitat loss, fragmentation, inbreeding depression, and demographic unviability. They reported that while more than half of the remaining panda habitat was protected, China's protected areas failed to conserve it effectively. They emphasised the importance of habitat conservation outside the existing reserve system, particularly in the southernmost part of the giant panda's geographic range, where habitat was scarce and isolated. They proposed new reserves or corridors to connect habitat patches, nature reserves, and some areas of active habitat restoration. They also discussed how the logging ban would affect China's demand for forest products from other countries.

These studies emphasise the importance of considering human factors when conserving giant pandas, such as population size, household structure, resource consumption, and conservation attitudes. However, they pose some questions and challenges for future research and policymaking. How, for instance, can the trade-offs between human development and wildlife conservation be balanced? How can local communities become more involved and empowered in conservation efforts? How can conservation policies' efficacy and long-term viability be assessed and improved? How can the logging ban's socioeconomic and environmental consequences be mitigated? How can different stakeholders' cooperation and coordination be improved? These are some of the issues that must be addressed in order to ensure giant pandas and their habitats' long-term survival.

Cluster Characteristics

Table 7 presents the top 4 major clusters that emerged from DCA analysis. Each cluster represents a research topic in the research areas. The size of the cluster equals the number of publications it has. All 5 clusters have more than 90 publications, with cluster #0 having the highest number of publications (202 publications). The silhouette score for each cluster ranges from 0.806 to 0.919. This indicates a high homogeneity between publications in each cluster (silhouette score ranges from -1 to 1, with a score higher than 0 seen as homogenous). The publications were placed in each type of cluster because it was cited by a similar publication group, thus representing a co-citation relationship. The top three clusters are described below.

Table 7. Top 4 cluster

Cluster ID	Size	Silhouette	Mean year	Cluster Label
0	202	0.806	2007	Giant Panda Habitat
1	110	0.849	1998	Ailuropoda Melanoleuca
2	96	0.919	2002	Microsatellite Variability
3	92	0.891	1990	Mitochondrial Gene

Cluster #0: Giant Panda Habitat

Most influential publication in cluster #0 (centrality > 1)		**Scientific Novelty Publication in cluster #0 (sigma > 1)**	
A Framework for Evaluating the Effects of Human Factors on Wildlife Habitat: The Case of Giant Pandas	(Liu *et al.*, 1999) (centrality score = 0.11)	Giant Panda Selection Between *Bashania fangiana* Bamboo Habitats in Wolong Reserve, Sichuan, China	(Reid and Jinchu, 1991) (sigma score = 1.20)
-		Effects of household dynamics on resource consumption and biodiversity	(Liu *et al.*, 2003) (sigma score = 1.19)
		Range-wide analysis of wildlife habitat: Implications for conservation	(Viñ̃a *et al.*, 2010) (sigma score = 1.17)

- Cluster #0 contains 202 publications with a silhouette of 0.806 and a mean year of 2007.

Cluster #1: *Ailuropoda Melanoleuca*

Most influential publication in cluster #0 (centrality > 1)	**Scientific Novelty Publication in cluster #0 (sigma > 1)**	
-	Giant pandas discriminate individual differences in conspecific scent	(Swaisgood, Lindburg and Zhou, 1999) (sigma score = 1.36)
	Hormonal and behavioural relationships during estrus in the giant panda	(Lindburg, Czekala and Swaisgood, 2001) (sigma score = 1.30)
	Evaluation of behavioural factors influencing reproductive success and failure in captive giant pandas	(Zhang, Swaisgood and Zhang, 2004) (sigma score = 1.15)

- Cluster #1 contains 110 publications with a silhouette value of 0.849 and a mean year of 1998.

Cluster #2: Microsatellite Variability

Most influential publication in cluster #0 (centrality > 1)		**Scientific Novelty Publication in cluster #0 (sigma > 1)**	
Molecular censusing doubles giant panda population estimate in a key nature reserve.	(Zhan *et al.*, 2006) (centrality score = 0.13)	Giant Pandas in a Changing Landscape	(Loucks *et al.*, 2001) (sigma score = 1.77)
Giant Pandas in a Changing Landscape	(Loucks *et al.*, 2001) (centrality score = 0.10)	Patterns of Genetic Diversity in Remaining Giant Panda Populations	(Lu *et al.*, 2001) (sigma score = 1.27)
		Genetic Viability and Population History of the Giant Panda, Putting an End to the ″Evolutionary Dead End″?	(Zhang *et al.*, 2007) (sigma score = 1.22)

- Cluster #2 has 96 publications and a silhouette value of 0.919.

Cluster #3: Mitochondrial Gene

Most influential publication in cluster #0 (centrality > 1)		**Scientific Novelty Publication in cluster #0 (sigma > 1)**	
Mitochondrial DNA sequence evolution in the Arctoidea	(Zhang and Ryder, 1993) (centrality score = 0.11)	Mitochondrial DNA sequence evolution in the Arctoidea	(Zhang and Ryder, 1993) (sigma score = 1.84)
		A molecular solution to the riddle of the giant panda's phylogeny	(O'Brien *et al.*, 1985) (sigma score = 1.80)
		A Phylogeny of the Bears (*Ursidae*) Inferred from Complete Sequences of Three Mitochondrial Genes	(Talbot and Shields, 1996) (sigma score = 1.17)

- Cluster #3 has 92 Publications and a silhouette value of 0.891

Document Burst

A burst analysis was performed to identify the most influential or landmark publications in the field of giant panda research. Table 8 presents the top ten publications with the strongest citation burst, with the duration of each burst depicted on the right columns. The result shows a pattern of new research topic emerging, where previous burst publication is slowly replaced by more current publications. In Table 8, Wei et al. (2015) indicate that habitat protection has been the vanguard of the Chinese government’s response to panda endangerment and has led to the creation of 67 protected areas. This finding points to the danger of a mismatch between data collected on one scale and policy 4 Giant Panda Ecology and Conservation decisions implemented on another (Guo et al., 2018). Most of these analyses did not address the implications of the panda’s history. Areas that currently contain panda habitat may no longer be suitable for the bamboo species present but should become suitable for bamboo species that previously existed at lower elevations and immure southerly latitudes. Bamboo species are the main food source for giant pandas, but they have been affected by human activities that have reduced and fragmented their habitats. Giant pandas used to live in a wider range of bamboo forests before humans encroached on their territories. The expansion of agriculture in China has been constrained by climatic factors, such as temperature and precipitation. Therefore, giant pandas have been able to survive only in higher altitudes where agriculture is less productive and human pressure is lower.

Climate change models predict that the agricultural value of land in the current panda habitat will increase (Tuanmu et al., 2013). For example, the increased elevational range of viticulture is predicted to affect the panda habitat. These observations point to an increased need for protection measures in low-elevation panda habitats in the future. Landscape ecology has had significant impacts on giant panda conservation policy and practice and has focused attention on the establishment of reserves in optimal locations, increasing connectivity between reserves through corridor establishment, and development of better management of anthropogenic threats and key ecological limiting factors within protected and unprotected areas (Wei et al., 2015).

Nie et al. (2015) research has led to speculation that giant pandas must also have low metabolic rates to achieve a daily energy balance. They report the first measurements of daily energy expenditure of captive and free-living giant pandas, measured using the Doubly labelled water (DLW) method. Nie validated these measurements using estimates of net energy assimilation and matched them with morphological, behavioural, physiological, and genetic data. It was estimated by comparing the Daily energy expenditure (DEE) by the DLW method to the net energy assimilation (NEA) estimated from individual measures of assimilation efficiency, multiplied by the daily faecal production, measured in three captive pandas almost daily for 11 months. Assimilation efficiency varied between 11.1 and 20.5%, comparable to previous estimates in captive pandas. Daily NEA varied over the year, being higher in the winter months. Consequently, there was a significant negative relationship between NEA and the average daily shade temperature.

Table 8. Top ten publications with the strongest citation burst

Title	References	Strength	Begin	End	1973 - 2020
Progress in the ecology and conservation of giant pandas	(Wei, Swaisgood, *et al.*, 2015)	15.96	2016	2020	
Climate-change impacts on understorey bamboo species and giant pandas in China's Qinling Mountains	(Tuanmu *et al.*, 2013)	15.25	2015	2020	
Exceptionally low daily energy expenditure in the bamboo-eating giant panda	(Nie *et al.*, 2015)	15.23	2016	2020	
Reassessing the conservation status of the giant panda using remote sensing	(Xu *et al.*, 2017)	13.21	2018	2020	
The Bamboo-Eating Giant Panda Harbors a Carnivore-Like Gut Microbiota, with Excessive Seasonal Variations	(Xue *et al.*, 2015)	11.99	2017	2020	
Giant Pandas Are Not an Evolutionary cul-de-sac: Evidence from Multidisciplinary Research	(Wei, Hu, *et al.*, 2015)	11.63	2015	2020	
Ecological scale and seasonal heterogeneity in the spatial behaviors of giant pandas	(Zhang *et al.*, 2014)	11.02	2015	2020	
Black and white and read all over: the past, present and future of giant panda genetics	(Wei *et al.*, 2012)	10.99	2015	2020	
Panda Downlisted but not Out of the Woods	(Swaisgood, Wang and Wei, 2018)	10.83	2018	2020	
Climate change threatens giant panda protection in the 21st century	(Li *et al.*, 2015)	10.48	2016	2020	

Table 9. Top ten keywords with the strongest citation burst

Keywords	Strength	Begin	End	1973 - 2020
giant panda	10.2	1993	2005	
overexpression	7.97	2009	2014	
Ailuropoda melanoleuca	7.88	2001	2008	
cloning	7.47	2008	2014	
pregnancy	7.19	2001	2009	
dna	7.08	2008	2011	
cdna cloning	5.8	2010	2014	
Ursidae	5.27	2004	2008	
expression	5.12	2012	2013	
panda *Ailuropoda melanoleuca*	4.87	1998	2012	

The keyword with the strongest citation burst is shown in Table 9. The keyword analysis was used to detect emerging trends and hotspot issues over the years. The burst reflects the emergence of keywords used in topic areas publication in a certain period of time. The green line is the timeline (between 1990-2019), while the red line is the burst period. The keyword Giant Panda highly burst from 1993 to 2005 (12 years) with the highest burst strength (10.2). The second keyword burst is overexpression (2009 to 2014, strength = 7.97), *Aliuropoda melanoleuca* (2001 to 2008, strength = 7.88), cloning (2001 to 2008, strength = 7.47), pregnancy (2001 to 2009, strength = 7.19), DNA (2008 to 2011, strength = 7.08), cDNA (2010 to 2014, strength = 5.8), Ursidae (2004 to 2008, strength = 5.27), expression (2012 to 2013, strength = 5.12) and panda Ailuropoda melanoleuca (1998 to 2012, strength = 4.87). The longest keyword burst is "panda *Ailuropoda melanoleuca*" that have 14 years burstiness span.

Overall Publication Trends

To sum up everything so far, based on research keywords, there has been significant movement from general research of pandas starting in 1993 towards more sophisticated research of genomics (DNA, cDNA, gene expression and cloning) towards more recent years. The early research focused on panda locality based on their distribution, in-situ and ex-situ conservation strategies and adaptation of giant pandas based on intra- and extraneous variables. However, as the panda conservation strategies evolved, the researcher's focus shifted towards understanding pandas on the genomic level.

CONCLUSION

This study only uses Web of Sciences (WOS) databases; other databases such as Scopus, PubMed and EmBase were not included, which might lead to publication bias. However, WOS is deemed better for investigating as its database is geared toward hard Science and social sciences and givens its wider databases and scope compared with other available datasets (Bar-Ilan, 2008; Adriaanse and Rensleigh, 2013). Future research could compare other sets of databases with WOS for mapping photovoice method research around the world. The other restriction is using CiteSpace software to mine the publication rather than being collected manually. The dataset might be subject to bias due to the chance of including irrelevant subjects. The decision to balance between stringent criteria and over-excluding certain studies is a challenge. Future research that aims for high precision can consider using more stringent keyword searches to reduce the likelihood of irrelevant studies. Finally, in this study's co-citation reviews, only the names of the primary (first) authors were included. Despite the fact that quoting publications did not have such a limitation, databases of referenced publications downloaded from WoS did not contain the names of other contributing authors. If these databases had more author names accessible, the co-citation review could produce different results. Despite these limitations, this study provides a comprehensive perspective on giant panda research publications between 1970 to 2020.

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AUTHOR CONTRIBUTIONS

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DATA AVAILABILITY

Not applicable

COMPETING INTEREST

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COMPLIANCE WITH ETHICAL STANDARDS

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SUPPLEMENTARY MATERIAL

Not applicable

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