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Global Study on Flying Foxes (Pteropus Livingstonii): A Bibliometric Analysis and Knowledge Mapping

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The aim of the study is to know the various aspects of research publications on flying foxes, including types of documents, annual scientific productivity, top contributing authors and their impact, authorship and collaboration pattern, top contributing countries and organizations, most important source publication, most cited papers, commonly used keywords in the area of flying foxes. Bibliometric methods were used to investigate these aspects of research publications on flying foxes. The bibliographic records of research output on flying foxes were downloaded from the Web of Science core collection. The results of the study revealed a consistent increase in the annual scientific productivity of flying foxes' literature. The last twenty years of the study (from 2001 to 2020) where most productive as 1,275 papers were published during this period, and 1,141 cited papers received the highest number of citations (n=32,054). Wang contributed the highest number of research publications (85) on flying foxes. He also emerged as the highly cited (4,315) author in the field. To the best of our knowledge, this seems to be the first comprehensive bibliometric study that productivity and citations, citation impact to present a holistic picture of the Flying Foxes (Pteropus livingstonii) literature.

Keywords: *Fruit bats, Bats, Flying foxes, Genus Pteropus, Megabats, Pteropus pselaphon, Scientometrics, Bibliometrics.*

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1 INTRODUCTION

Flying fox (Genus Pteropus) are some of the largest bat species found globally, and out of those, at least 60 known species are alive. The Pteropodidae comprises 186 currently recognized species commonly known as old-world Fruit bats or megabats (Almeida et al., 2011). Hodgkison et al. (2013) argued that, in the contemporary and ancient-world tropics, bat frugivory (Chiroptera) had evolved independently within the Phyllostomidae and Pteropodidae families, successively. To detect the location of fruits, bats rely on olfaction. However, the effects of bats are almost totally unknown on the evolution of the fruit scene. The evolution of fruit characteristics among fleshy fruited plants is a complicated biological evolution subject (Fischer & Chapman, 1993; Herrera, 1992; Jordano, 1995; Lomáscolo et al., 2008; Mack, 1993). Structures in different plant types can adapt paradigm, widely attributed to the selective dietary patterns of mutualism carnivores, which cause genetic changes via plant reproduction. This occurs in fruit, showing variations known as 'fertilization syndromes' that conform to each plant's hunting preferences clade of the significant groups of fruiting plant trees (Janson, 1983; Marshall, 1983). For example, physically oriented frugivores, like birds and normal mammals, are typically attracted to fruits that are visibly marked compared to the surrounding foliage (Martin Schaefer et al., 2007; Schmidt et al., 2004). It is also assumed that phylogenetic or some other random effect models affect fruit type difference. It also states that frugivores recognize the identification of various plants' fruits from symbols that they are pre-adapted to identify in a process called an evolutionary fitting (Janzen, 1985).

The belief that bats can cause disease in humans can make people more aware of communities that use bat products, potentially leading to temporary hunting or sale restrictions (Kamins et al., 2015). After all, it is important to prevent inappropriate thoughts that may harm these mammals' population, e.g., unauthorized slaughtering of fruit bats (Guyton & Brook, 2015). The lack of bats will also impact the environmental services provided by bats (Kunz et al., 2011) and could even raise the occurrence of pathogens and increase the spread of pathogens to humans (Amman et al., 2014). Relevant studies are concerned with physiological behavior, biogeographical analysis, and flying foxes' growth. There is no study focusing on the research publications of Pteropus livingstonii using Scientometrics indicators to the best of our insight. Therefore, it becomes important to conduct a scientific investigation in the area which is untouched to date. Hence, this study attempted to conduct a Scientometrics analysis on Pteropus livingstonii using the Web of Science database literature. In this topic, certain abbreviations are used for data analysis in different columns of the tables, i.e., TS= Topic search, WOSCC= Web of Science Core Collection, WOS= Web of Science, LCS=

Local Citation Score, GCS= Global Citation Score, TP = Total Publications, TC = Total Citations, TCP = Total Cited Papers, PY = Publication Year, PY_start= Publication Year Start, YoE= Year of Establishment, CY = Citation Years. research publications of Pteropus livingstonii using Scientometrics indicators to the best of our insight. Therefore, it becomes important to conduct a scientific investigation in the area which is untouched to date. Hence, this study attempted to conduct a Scientometrics analysis on Pteropus livingstonii using the Web of Science database literature. In this topic, certain abbreviations are used for data analysis in different columns of the tables, i.e., TS= Topic search, WOSCC= Web of Science Core Collection, WOS= Web of Science, LCS= Local Citation Score, GCS= Global Citation Score, TP = Total Publications, TC = Total Citations, TCP = Total Cited Papers, PY = Publication Year, PY_start= Publication Year Start, YoE= Year of Establishment, CY = Citation Years.

2 OBJECTIVES

The study's primary purpose is to conduct the Scientometrics analysis of the mentioned area using various Scientometrics indicators and statistical and visualization software. The following are the objectives of this study relating to research on "fruit bats" OR "flying foxes" OR "Pteropus pselaphon":

- To identify the types of the document in the area of flying foxes.
- To find out the annual scientific productivity in the area of flying foxes from 1932-2020.
- To identify the top contributing authors and their impact.
- To find out the trends of authorship and collaboration pattern on the topic of flying foxes.
- To recognize the top contributing countries and organizations.
- To classify the essential publication sources.
- To find out the most cited papers.
- To detect the most commonly used keywords in the area.

3 RESEARCH METHODOLOGY

A bibliometric analysis is performed in the study using the web of science citational database as it is quite challenging to conduct a mapping study by using various databases (Sweileh, 2020). Web of Science is a citational database, which consists of the Science Citation Index (SCI), Social Science Citation Index (SSCI), and Emerging Citation Index (ECI) maintained by Clarivate Analytics. Web of Science is the "precise and consistent indexing and abstracting database used by researchers worldwide and has extensive coverage"

with the slogan "The Discovery Starts Here" (Birkle et al., 2020; Khan et al., 2020; Tahira et al., 2013). Therefore, bibliographic data for the present study was downloaded from the Web of Science database due to comprehensive literature coverage.

31 SEARCH STRATEGY

The authors performed a comprehensive literature review on the topic to find out all possible keywords that could be used to create a search strategy that can extract the maximum number of relevant documents. To retrieve the most pertinent data confined to the research area, we used Topic search (TS) using "fruit bats," "flying foxes," and "Pteropus pselaphon" keywords.

32 SEARCH QUERY

The search query carried out relating to fruit bats" OR "flying foxes" OR "Pteropus pselaphon" entered as a limit followed by specific criteria to reduce unwanted documents in the searched topic. We observed the maximum records for downloading with the specific search strategy mentioned above without applying any filter for the time limit, country, or language. The searched data was downloaded on December 20, 2020, using the WOSCC category topic search (TS) with the following search query: ("fruit bats" OR "flying foxes" OR "Pteropus pselaphon")

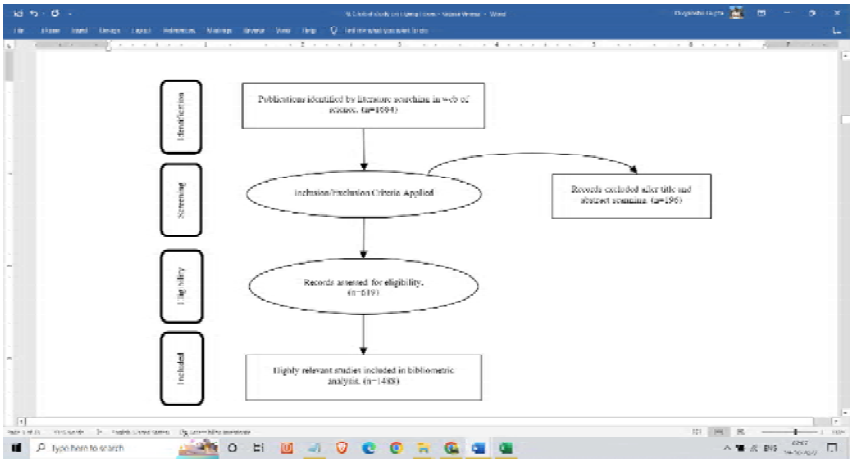

Figure I: Four-Phase Flow Diagram of Data Extraction and Filtration Process Flying Foxes (Pteropus Livingstonii) of Publications.

4 DATA SELECTION AND ANALYSIS

All documents published between 1932 to 2020 were considered for the study except editorial material and data paper. Total 1,684 documents were downloaded and analyzed. The authors also checked the records manually to

ensure that only relevant records were examined. Out of 1,684 records, 196 records did not pertain to the research topic. Therefore, 1,488 documents were considered for the analysis purpose. To confine the data to the study, we refined it by checking duplicates using Endnote Desktop X9.3.3. However, no replication of records was found during the duplication check. Data analysis was performed using various bibliographic data visualization tools like Biblioshiny (RStudio), VOS viewer, and Histcite, along with MS Excel.

41 RESULTS AND DISCUSSIONS

The analysis of 1,488 documents related to fruit bats" OR "flying fox" OR "Pteropus Pselaphon" revealed (see Table I) that these documents were published in 484 sources (Journals, Books, etc.) during the study period (1932-2020). Out of 1,488 documents, the majority of the Publications were in the form of research articles (88.58%, 1,318) followed by reviews (8.47%, 126) and proceedings papers (2.96%, 44). Four thousand eight hundred thirty-seven authors contributed to these publications with a total author appearance of 8,493. The analysis showed that authors writing on the topic had a collaboration index of 3.48 with 3.25 authors per document. The authors contributed only 8.47% (126) single-authored documents, demonstrating a high level of collaborative work in the field.

Table I: Main Information

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1932:2020
Sources (Journals, Books, etc.)	484
Documents	1,488
Average years from publication	9.75
Average citations per documents	26.44
Average citations per year per doc	2.667
References	40,588
DOCUMENT TYPES	
Article	1,318
Review	126
Proceedings Paper	44
DOCUMENT CONTENTS	
Keywords Plus (ID)	3,488
Author's Keywords (DE)	3,091
AUTHORS	
Authors	4,837
Author Appearances	8,493
Authors of single-authored documents	103
Authors of multi-authored documents	4,734
AUTHORS COLLABORATION	
Single-authored documents	126
Documents per Author	0.308
Authors per Document	3.25
Co-Authors per Documents	5.71
Collaboration Index	3.48

42 TYPES OF DOCUMENTS

Table II indicates that various types of documents on the Pteropus Pselaphon. It has been observed that, out of 1,488 documents, 1,318 documents (88.58%) were in the form of research articles, 126 documents (8.47%) in the form of reviews, and 44 documents (2.96%) were in the form of proceedings papers. Articles received the highest number of global citations (33,202), while reviews and proceedings papers received 5,824 and 310 global citations, respectively.

Table II: Documents Type

Document Type	Publications	Percent	LCS	GCS
Article	1,318	88.58	6,772	33,202
Review	126	8.47	795	5,824
Proceedings Paper	44	2.96	113	310
Total	**1,488**	**100**	**7,680**	**39,336**

Note: LCS= Local Citations, and GCS= Global Citations

43 ANNUAL SCIENTIFIC PRODUCTIVITY

The annual productivity and citations on flying foxes are shown in Figure II. In 1932, the first document on the research topic was published. There were no publications on the research topic for 37 years, from 1933 to 1969. The research publications and citations were split into six different time frames. The first-time frame consisted of 46 years (from 1932 to 1979), and the remaining 40 years were divided into five different time frames. The last time frame consisted of 20 years (from 2001 to 2020). The last twenty years of the study where most productive as 1,275 papers were published during this period, and 1,141 cited papers received 32,054 citations. A consistent increase was observed in the publications and citations on flying foxes. The most productive year was 2018 (115 publications), while the highest number of citations (3,332) were received in 2009. From 2009 onwards, a slight decrease in citations was observed in the study period, which can be attributed to the publications' citation life cycle.

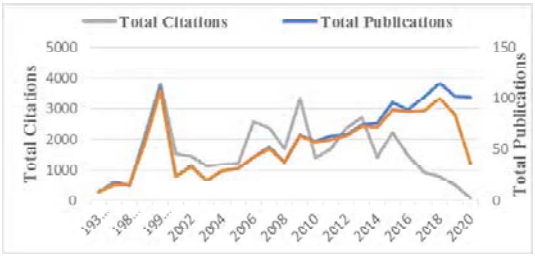

Figure II: Publication and Citation Trend of Literature on Flying Foxes From 1932 to 2020.

44 TOP CONTRIBUTING AUTHORS AND THEIR IMPACT

The authors' productivity analysis shows that 4,837 authors contributed to the research on flying foxes. Table III describes the top ten authors contributing to the study of flying foxes and their productivity. The table shows that Wang L F (from the animal health laboratory, Australia) contributed the highest number of research papers (85). The total cited papers (TCP) were 80 out of 85, which received 3,736 citations with a citation impact of 43.95. Field H E (from the University of Queensland, Australia) contributed 81 research papers. His total cited papers were 77, which received 4,315 citations with a citation impact of 53.27. Field H E had the highest h_index (41) besides having the highest impact. It indicates that the most productive author in flying foxes research is not the most cited author. The top two authors were followed by Crameri G (TP=34) and Daszak P (TP=32) with TCP of 30 and 31. It is noteworthy that Kunz T H (from Boston University, United States) and Zhang S Y (from Shenyang Agricultural University, China) contributed 28 and 26 research papers. All their research papers were cited with the citation impact of 32.18 and 19.04, respectively.

Table III: Top Ten Contributing Authors and Their Impact

Author (n=4,837)	Affiliation	Country	TP	TCP	TC	C/P	C/CP	h_index
Wang L F	Animal Health Laboratory	Australia	85	80	3,736	43.95	46.70	35
Field H E	University of Queensland	Australia	81	77	4,315	53.27	56.04	41
Crameri G	Animal Health Laboratory	Australia	34	30	1,658	48.76	55.27	22
Daszak P	EcoHealth Alliance	USA	32	31	1,611	50.34	51.97	21
Kunz T H	Boston University	USA	28	28	901	32.18	32.18	21
Epstein J H	EcoHealth Alliance	USA	27	26	1,363	50.48	52.42	18
Zhang S Y	Shenyang Agricultural University	China	26	26	495	19.04	19.04	14
Hayman D T S	Massey University	New Zealand	24	23	1,122	46.75	48.78	17
Cunningham A A	Institute of Zoology, Regent's Park,	UK	23	22	965	41.96	43.86	14
Baker M L	Animal Health Laboratory	Australia	23	20	524	22.78	26.20	12

45 AUTHORSHIP AND COLLABORATION PATTERN

Figure III describes the authorship pattern of research on flying foxes. The number of collaborating authors was analyzed for each publication, ranging from a single author to twenty or more authors. As a single author, there were only 126 publications, which received 2,978 citations. Two authors published 200 publications and received 5,706 citations. The highest number of publications (242) were contributed by three authors, which also received the highest number of citations (5,949). Seven or more authors contributed 466 publications collectively. Overall, the authorship pattern showed that the majority

(more than 90%) of the publications on flying foxes research resulted from teamwork, which revealed that authors contributing to flying foxes research were more interested in collaborative research.

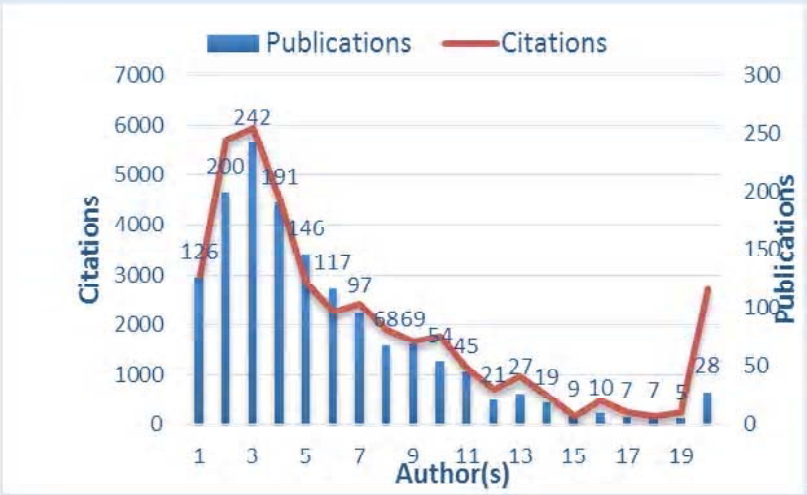

Figure III: Authorship and Citation Pattern of Flying Foxes Research (1 to 20 or More Authors)

46 TOP CONTRIBUTING COUNTRIES

Country-wise analysis disclosed that 88 countries contributed to research on flying foxes. In Table IV, the top ten contributing countries have been presented. The United States was the highest contributing country with 552 documents, while the total number of cited papers of the United States was 517. The United States affiliated publications obtained the highest number of citations (19,312) with a citation impact of 34.99 per paper, and a total cited paper impact of 37.35. Australia was in second place with 363 documents, and 11,873 citations with a citation impact of 32.71 per paper and a total cited paper impact of 34.82. The United Kingdom was in the third position with 150 documents and 4,344 citations with a citation impact of 28.96 and a total cited paper impact of 31.71. Though Malaysia contributed 64 documents and 59 papers were cited (2,944 citations), its total cited paper impact (49.90) was highest among all contributing countries. The result indicated that highly contributing countries did not have a high citation impact.

Table IV: Highest Productive Countries

Rank	Country (n=88)	Continent	TP	TCP	TC	C/P	C/CP
1	USA	North America	552	517	19,312	34.99	37.35
2	Australia	Australia	363	341	11,873	32.71	34.82
3	England	Europe	150	137	4,344	28.96	31.71
4	Germany	Europe	141	126	3,642	25.83	28.90
5	Peoples R China	Asia	99	92	2,085	21.06	22.66
6	France	Europe	73	69	2,554	34.99	37.01
7	Japan	Asia	72	64	873	12.13	13.64
8	Malaysia	Asia	64	59	2,944	46.00	49.90
9	South Africa	African	61	58	1,642	26.92	28.31
10	Canada	North America	58	54	1,512	26.07	28.00

47 TOP CONTRIBUTING ORGANIZATIONS

The analysis of contributing organizations on bats research has been presented in Table V. Total 1,665 organizations were contributed to the literature on the research topic. The top ten contributing organizations have been presented along with their publications, totally cited papers, total citations, citation impact, and total cited paper impact. University of Queensland (Australia) contributed the highest number of publications (79). Seventy-three papers from the University of Queensland were cited, which received 2,644 citations with a citation impact of 33.47. Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia, secured the second position for contributing 65 publications. Sixty papers of CSIRO were cited, which received 2,767 citations with a citation impact of 42.57. Centers for Disease Control and Prevention (United States) received the highest number of citations (4,086), citation impact (86.94), and total cited Paper impact (88.83). It showed that in bats research, the most contributing organization was not the most cited one.

Table V: Highest Productive Organizations

Organizations (n=1,665)	TP	TCP	TC	TC/TP	TC/TCP
University of Queensland, Australia	79	73	2,644	33.47	36.22
Commonwealth Scientific and Industrial Research Organisation, Australia	65	60	2,767	42.57	46.12
EcoHealth Alliance, USA	57	53	1,832	32.14	34.57
Centers for Disease Control and Prevention, USA	47	46	4,086	86.94	88.83
University of Florida, USA	42	39	1,049	24.98	26.90
Chinese Academy of Sciences, China	41	38	680	16.59	17.89
University of Cambridge, UK	35	34	1,359	38.83	39.97
University of Sydney, Australia	35	33	1,396	39.89	42.30
Ulm University, Germany	31	29	1,667	53.77	57.48
Zoological Society of London, UK	28	27	1,092	39.00	40.44

48 HIGHLY PRODUCTIVE SOURCES

The highly productive source analysis exhibited that 1,488 documents on flying foxes research were published in 484 different sources. All these documents were published in journals. The top 10 sources of publication have been presented in Table VI. The top four sources published 40 or more documents on bats, while the remaining source published less than 40 documents. The highest number of publications (88) were published by *PlosOne* with total cited papers = 87, total citations = 2,270, and citation impact = 25.80. *Acta Chiropterologica* followed it as the 2nd most preferred publication source, which published 42 documents with total cited papers = 37, total citations = 335, and citation impact = 7.98. Although *Emerging Infectious Diseases* published only 40 documents, all these documents were cited. The journal received the highest number of citations (3,029) with the highest citation impact (75.73) and impact factor (6.259) in the field. The sources included are quartile from one to four, and all sources have an impact factor. Most of the sources are published in the United States, two in the United Kingdom, one in Poland, and one in Switzerland.

Table VI: Highly Productive Sources

Source (n=484)	Publisher/Country	TP	TCP	TC	TC/TP	TC/ TCP	IF	Q	h_index
PlosOne	Public Library Science, USA	88	87	2270	25.80	26.09	2.740	2	27
Acta Chiropterologica	Museum Inst Zoology Pas-Polish Acad Sciences, Poland	42	37	335	7.98	9.05	1.000	3	11
Emerging Infectious Diseases	Centers Disease Control Prevention, USA	40	40	3029	75.73	75.73	6.259	1	28
Biotropica	Wiley, USA	40	39	1060	26.50	27.18	2.090	2	20
Journal of Zoo and Wildlife Medicine	Amer Assoc Zoo Veterinarians, USA	35	27	231	6.60	8.56	0.494	4	9
Journal of Mammalogy	Oxford Univ Press, USA	28	28	641	22.89	22.89	1.891	1	14
Viruses-Basel	St Alban-Anlage, Switzerland	28	24	400	14.29	16.67	3.816	2	10
Scientific Reports	Nature Publishing Group, England	22	21	409	18.59	19.48	3.998	1	11
Journal of Zoology	Wiley, England	21	19	602	28.67	31.68	1.724	2	14
Journal of Virology	Amer Soc Microbiology, USA	21	20	585	27.86	29.25	4.501	1	14

48 HIGHLY CITED DOCUMENTS

Citations are a source for comparative analysis of publications to determine the status of research publications and researchers' performance in any research field. In any area of research, the number of citations obtained demonstrates the reputation of the research. Citation is an indicator, impact, and significance

of a specific scholarly study and a symbol of its recognition within the academic community (Ho, 2014; Ram, 2020). The ten most-cited documents on flying foxes have been presented in Table VII. The name of the first author, year of publication, and source of the publication is given in the table VII. Analysis showed that the research paper by Calisher et al. titled "Bats: Essential Reservoir Hosts of Emerging Viruses" was the most important research paper published in the *Clinical Microbiology Reviews* (DOI: 10.1128/CMR.00017-06). It received 756 citations at a rate of 50.40 per year. The article by Tong et al. titled "New World Bats Harbor Complex Influenza A Viruses" was the second most important research paper, which received 664 citations at the highest rate of 83 citations per year. It was published in *Plos Pathogens* (DOI: 10.1371/journal.pp.1003657). The article titled "A mechanism for slow release of biomagnified cyanobacterial neurotoxins and neurodegenerative disease in Guam" by Murch et al. was published in *Proceedings of the National Academy of Sciences* (DOI; 10.1073/pnas.0404926101) obtained 273 citations at the rate of 16.06 citations per year and ranked last in top ten most cited documents.

Table VII: Highly Cited Documents

Documents (n=1,488)	TC	CY	TC/PY
Calisher C H, 2006, Clin Microbiol Rev	756	15	50.40
Tong S X, 2013, Plos Pathog	664	8	83.00
Cox P A, 2003, P Natl Acad Sci Usa	390	18	21.67
Halpin K, 2000, J Gen Virol	385	21	18.33
Drexler J F, 2012, Nat Commun	351	9	39.00
Towner JS, 2009, Plos Pathog	323	12	26.92
Johara M Y, 2001, Emerg Infect Dis	300	20	15.00
Shanahan M, 2001, Biol Rev	298	20	14.90
Leroy E M, 2009, Vector-Borne Zoonot	274	12	22.83
Murch S J, 2004, P Natl Acad Sci Usa	273	17	16.06

410 CO-OCCURRENCE NETWORK OF AUTHORS' KEYWORDS

Keywords used by researchers in Flying foxes research reflected the outcomes and viewpoints of their research. Using the VOS viewer software, a Java-based tool, we visualized frequently used keywords in the study. A co-occurrence network of authors' keywords was created with a minimum of 15 occurrences. The important words used in the flying fox research are described in Figure 3, these keywords procedure five different clusters are represented by different colors. Based on the link strengths and occurrences, the bubbles, or clusters with lagger sizes represent the most commonly used keywords. The strength of the link between the nodes showed the number of research publications containing the keywords displayed. The keywords most often used were bats, fruit bats, Chiroptera, flying foxes, and Pteropus. These keywords are used by a large number of research publications on flying foxes.

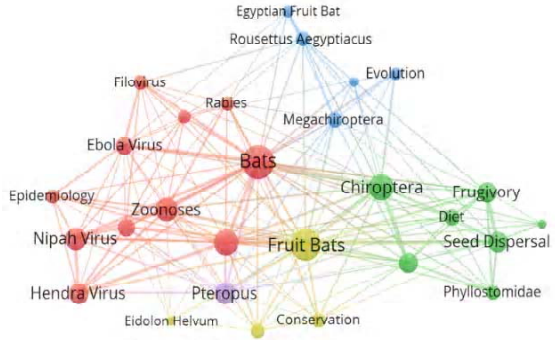

Figure IV: Co-Occurrence Network of Author Keywords (Minimum Number of Occurrences 15)

411 THREE-FACTOR ANALYSIS (KEYWORDS, ORGANIZATIONS, AND COUNTRIES)

A three-factor analysis of keywords (left), organizations (middle), and countries (right) was performed on flying foxes research (see Figure V). The thickness of the boxes shows the intensity factors. The figure indicates that the keywords bat, bats, fruit bat, fruit bats, Pteropus, Nipah virus, and Chiroptera have a strong link to Australia, United States, United Kingdom, Germany, and Japan. Out of the ten most important organizations researching flying foxes, four organizations (the University of Sydney, University of Queensland, Australian Centre for Disease Preparedness, and Centre for Disease Control and Prevention, USA) have a strong relationship with these keywords. Hokkaido University has strong connections with Japan, but as shown in the figure, it has weak links to the most frequently used keywords. Research on flying foxes from Australia is strongly linked to the University of Sydney and the University of Queensland, making links to most figure keywords.

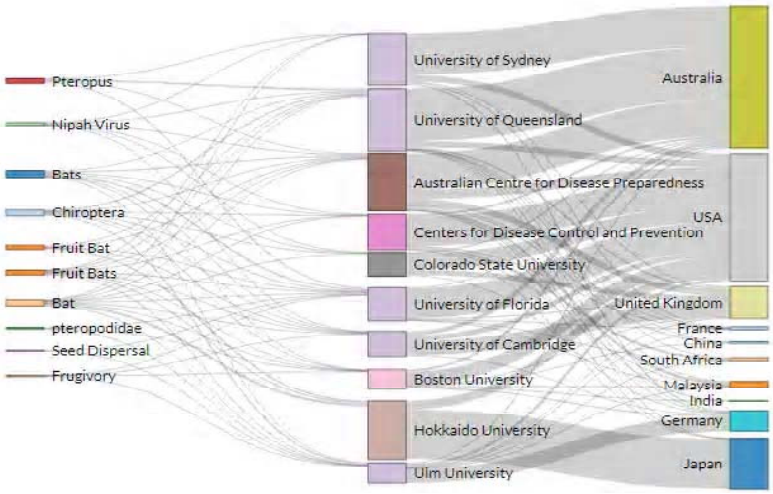

Figure V. Three-Factor Analysis of Keywords, Organizations, and Countries

412 COLLABORATING COUNTRIES

In figure VI, the table given inside the figure shows the collaboration patterns among the top contributing countries in flying foxes research. The data shows that the United States has more collaboration with other countries. The United States has collaborated with eight countries among the top collaborating countries. The highest research collaboration was found between the United States and Australia, followed by the United States and the United Kingdom, United States, and Germany. Australia was the other prominent country that produced the flying foxes research in collaboration with the United Kingdom and Singapore.

Figure VI: Country Collaboration Map (Top 10 Countries)

5 CONCLUSION

Based on this study findings, it can be understood that flying foxes research is published in various types of sources and a variety of output formats. We can conclude that research on flying foxes is getting the researchers' attention, which has resulted in a sharp increase in the research output. Research on flying foxes is mostly concentrated in developed countries, and contributing authors are inclined towards collaborative research. The study concluded that the accumulation of citations does not depend on the productivity of an author. It is recommended to replicate this study after ten years to observe future research trends in the field.

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