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# RESEARCH RELATED TO FIREFLIES (COLEOPTERA: LAMPYRIDAE) AROUND THE WORLD OVER THE YEAR 2000 – 2021: AN OVERVIEW AND GUIDELINES

Muhammad Fakruhayat Ab Rashid , Azimah Abd Rahman* & Siti Masayu Rosliah Abdul Rashid

## ABSTRACT

Fireflies are groups of the Coleoptera order and the Lampyridae family. Fireflies are typically classified as nocturnal insects, however some are diurnal, and others have mixed nocturnal and diurnal characteristics. They are also known as luminescent insects due to their ability to emit light. Bibliometric analysis is a popular and rigorous method for discovering and analyzing enormous volumes of scientific data. Therefore, the objective of this study is to present overview and guidelines in studies related to firefly research worldwide from 2000 to 2021 using bibliometric analysis to provide researchers and scholars around the world an overview of results and trends in firefly research. A textual query on three databases; Scopus (289 papers), Web of Science (303 papers), and PubMed (541 papers) using the term "Fireflies Coleoptera Lampyridae" was performed on 30 August 2021 retrieving 1133 scholarly papers from 2000 to 2021 related to firefly studies for in-depth analysis. Bibliometric analysis were performed using Rstudio software version 4.1.1 and biblioshiniy for bibliometrix to visualize and analyze trends of firefly research. This bibliometric analysis was analyzed the annual scientific publication growth, the most productive authors, most frequent word has been using, most famous journal name, and which countries has highest collaboration with other country in firefly research. According to the findings of the analysis, there is significant inconsistency in global trends in annual scientific production, with the number of publications increasing and decreasing. In firefly research, according to the findings has show the most relevant authors is Fu X (Scopus), Fu XH (WoS), and Hosseinkhani S (PubMed). Moreover, the most relevant journals articles in fireflies studies is Zootaxa (Scopus & WoS), and Photochemical & Photobiological Sciences : Official Journal Of The European Photochemistry Association And The European Society For Photobiology (PubMed). Futhermore, the most frequently utilized keywords in fireflies study is lampyridae, firefly, bioluminescence, animals and fireflies. China and USA is the most highest collaboration among others countries in fireflies research. This research can help researchers or academics who are new to firefly research by providing information on which publications and authors to refer when performing firefly research.

**Keywords:** Bibliometric analysis, Fireflies, Coleoptera, Lampyridae, Rstudio

## INTRODUCTION

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***Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x***
***Theme: Human, Nature and Society***

Fireflies are a Lampyridae family of beetles that communicate with each other by flashing their lights to engage in complex male-female dialogue before mating (Borror et al., 1989; Foo & Dawood, 2015). Fireflies from the Lampyridae family are classified into 4 genera, namely *Pteroptyx, Luciola, Colopthia,* and *Lychnuris* (Nada & Kirton, 2004). Fireflies in Lampyridae family have around 2,200 species worldwide including nonluminous adults, flightless female fireflies, lightning bugs and their stunning bioluminescent displays make them one of the most fascinating insects on the world (Lewis et al. 2020; Martin et al., 2019; Lewis, 2016; Oba, Branham, & Fukatsu, 2011; Ohba, 2004). The fireflies are less active during the day and prefer to rest under the leaves of the berembang tree *(Sonneratia caseolaris)*. This could be influenced by environmental factors such as unfavourable weather for active firefly, which is not the case at night. Many firefly larvae live at the base of the berembang tree's root (Riza et al., 2017). Pteroptyx fireflies, which are native to Southeast Asia's coastal areas and riverbanks, display particularly spectacular synchronised flashing among these captivating beetles (McKenna and Farrell 2009). Pteroptyx species have been identified in Singapore, the Philippines, Thailand, Cambodia, Indonesia, New Guinea, Hong Kong, Sulawesi, and Malaysia (Jusoh et al., 2018; Sartsanga et al., 2018; Ballantyne & Lambkin 2001; Ballantyne & McLean 1970). 13 Pteroptyx species have been identified in Malaysia; 9 of these are found in Peninsular Malaysia, where they are primarily found in the *Sonneratia caseolaris* mangrove (Norela et al., 2017; Shahara et al., 2017; Norela et al., 2016).

Different parts of the mangrove vegetation will affect the fireflies life cycle. Adult fireflies commonly congregate at night on a display tree, where they look for mates by flashing their lights from two segments on the underside of their abdomen. Adult females lay their eggs in the damp soil of the river's tidal zone, where they hatch. The larvae of fireflies consume a range of soft-bodied food, including mangrove snails, earthworms and insects (Lloyd, 2008). They frequently moult their exoskeleton. When they are ready, they turn into pupae and emerge as adult fireflies (Nada et al., 2012; Jusoh et al., 2010). Female fireflies are always lay their eggs close to the food supply in order to ensure that the larvae have enough food (Ohba & Sim, 1994). Female fireflies lay their eggs on mossy or wet soil. The time it takes for an egg to grow into a larva is around 15-20 days. And the larvae will turn into pupae in 23 months. The pupae will mature into adult fireflies in 9-12 days. The process of changing fireflies from egg stage to adult stage takes roughly 6-7 months, whereas the lifespan of mature fireflies is only estimated to be 2-3 months (Ohba & Sim, 1994; Ballantyne & Menayah, 2002; Nada & Kirton, 2005). Fireflies may be found in a range of habitats, including ponds, streams, mangroves, marshes, and desert seeps, as well as grasslands and forests (Lloyd, 2002).

Firefly watching has become a lucrative industry in the world, particularly due to their abundance when they congregate around mangrove trees. Ecotourism has sprung up in areas where large numbers of fireflies congregate. For example the mangrove forest at Kg. Kuantan (Ballantyne & Menayah, 2000), Sungai Kinabatangan (Mahadimenakbar et al., 2004), Sungai Garama (Mahadimenakbar et al., 2007), Sungai Paitan (Chey, 2006). Fireflies are fascinating insects with stunning bioluminescent courting displays that have stormed onto the worldwide nature tourism stage. According to the World Tourism Organization (WTO), over 1.4 billion visitors travelled worldwide in 2018, contributing more than USD 1,451 billion to the global economy (WTO, 2019).

*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
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In a phenomenon known as entomotourism, a variety of insects have begun to attract the curiosity of nature lovers (Lemelin, 2013; Lemelin, Boileau, & Russell, 2019). Glow-worm caves, butterfly pavilions, insect museums, monarch butterfly overwintering sites, and Melipona stingless bee colonies all attract millions of tourists each year (Lemelin & Jaramillo-López, 2019; Samways, 2005).

Bibliometrics is defined as the measuring of texts and information. Bibliometric analysis is a popular method for discovering new information and connecting future society's needs to present research and technology. It is frequently used to examine relevant topics in technical, scientific, or social databases in a variety of contexts (Kumari et la., 2019). Bibliometric techniques are employed in academic and professional communities in ways that go beyond lists of scientific journals and citations. Instead, bibliometric analysis provide informative results for management applications and may anticipate future technology developments (Robinson et al., 2013).

The topic entomology of fireflies may be revealed by bibliometerics analysis research in the field. It can aid in the comprehension of fireflies development trends. Our findings will assist researchers and scholars in determining the present status of global fireflies using three databases: Scopus, Web of Science, and PubMed. This study using a software the latest version 4.1.1 of Rstudio. Researcher using Rstudio to open biblioshiny web-interface in order to do bibliometrics analysis of fireflies. The biblioshiny analysis function produces descriptive data from bibliographic data. The findings may be plotted using R's general function (plot). At 30 August 2021, there are no relatively studies on fireflies of bibliometrics analysis articles paper. Therefore, this article will present a bibliometric analysis of fireflies using three database from Scopus, Web of Science, and PubMed to determine the research questions with the greatest research output analysis:

i. What is the annual scientific publication growth in Fireflies?
ii. Which authors are the most productive authors in Fireflies?
iii. Which is most frequent word has been using in fireflies study?
iv. Which journal do scholars and researchers mostly publish their articles in fireflies study?
v. Which countries do collaborate regarding Fireflies with Malaysia?

Bibliometric analysis approaches are frequently utilised in information science for literature growth trend analysis and topic analysis (Koehler, 2001; Pan, Jian, & Liu, 2019; Tsay, 2011), computer science (Chen et al., 2018; Godoy, Zunino, & Mateos, 2015), medicine (Sohn et al., 2018; Tarazona-Alvarez et al., 2019), psychology (Dinić & Jevremov, 2021). This study can assist to orient researchers or academics who are new to fireflies research by showing information on which publications and authors to refer while conducting fireflies research. Firefly tourism can provide certain challenges, but it also has several advantages. Firefly tourism has the potential to generate economic advantages in the form of jobs and income at various levels, including local communities, states, countries, and regions. Firefly-watching is a once-in-a-lifetime event, maybe especially for city people who might not normally spend much time in nature.

Fireflies are frequently seen as attractive, and they create good childhood memories linked with previous rural lives in many cultures and lifestyles (Haugan, 2019; Lewis, 2016). Visitors frequently express transforming sensations of joy and even spiritual wonder in reaction to the luminous landscapes they experience at firefly areas (Schreiber, 2017; Lewis, 2016). Such firefly

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*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

experiences may have long-term and widespread positive impact, including enhanced mental health and wellbeing as well as more positive attitudes toward biodiversity protection (Buckley et al., 2019). In other words, these attractive insects serve as an enticing advertising for conserving invertebrate biodiversity and philanthropic conservation efforts.

Many cultures across the world have a long history of embracing the pleasures of watching fireflies (Figure 1). For generations in Japan, where fireflies are deeply ingrained in the culture, watching these insects has been a traditional midsummer pastime (Kawahara, 2007; Laurent & Ono, 1999; Lewis, 2016; Oba et al., 2011). Thousands of visitors boarded trains in Kyoto and Osaka in the early 1900s to travel to Uji, a town known for the spectacular displays put on by courting Genji fireflies *(Luciola cruciata)*. During peak season in June, firefly boats offered nightly excursions along the Ujiwara River, where tourists could dine while watching the spectacle (Allen & Wilson, 1992). Firefly tourism has been a popular leisure activity in Japan, Thailand, Korea, Taiwan, Malaysia, India, Mexico, and the United States in recent decades. Previously, information about firefly tourist attractions was spread by word of mouth, magazines, or newspaper articles; now, the internet has boosted these locations' increasing appeal by making webpages and photographs available on social media and travel blogs. Firefly photography, like other attractive experiences that are widely shared, has a major effect on visitors' choices of future trip locations (Boley et al., 2018).

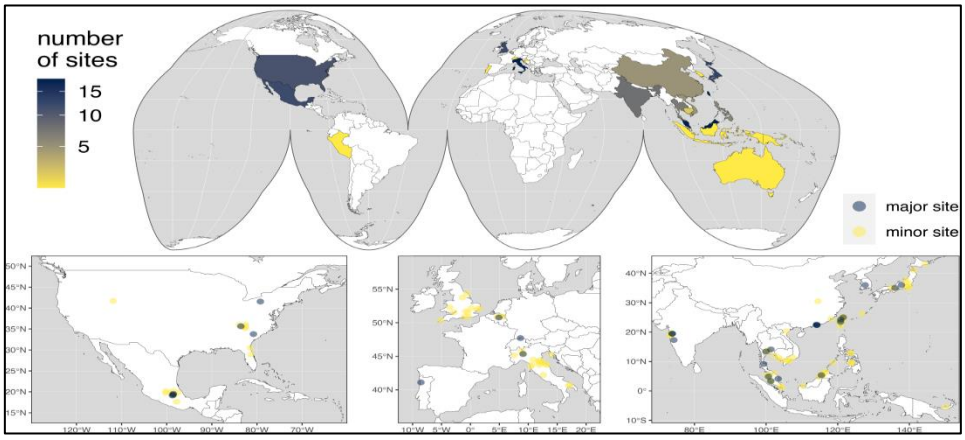


**Figure 1:** Firefly tourism sites around the world.
Source: (Lewis et al., 2021)

## METHODOLOGY

*Data source and Search strategy*

A comprehensive search was performed online using databases Scopus (www.scopus.com), Web of Science and PubMed (https://pubmed.ncbi.nlm.nih.gov/) on 30 August 2021. The search was conducted on a single day to avoid bias induced by daily database updates. In this retrospective

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*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

analysis, researcher selected articles on fireflies that were published between 2000 to 2021 and were indexed in Scopus and Dimensions. The search strategy used in the two databases was as follows:

Topic: "Fireflies Coleoptera Lampyridae".
Refined by: Document types in Scopus (THERE WAS NO RESTRICTION ON THE TYPE).
: Document types in Web of Science (THERE WAS NO RESTRICTION ON THE TYPE)
: Document types in PubMed (THERE WAS NO RESTRICTION ON THE TYPE)
Criteria : "titles, abstract and keywords *(topic area)*"
Year Published: 2000-2021.

Sample articles were downloaded in *CSV format (Scopus) and Text Document (WoS & PubMe) to include all important article information such as article title, author name, and affiliation, abstract, keywords, and references.and then processed using Rstudio software version 4.1.1 to make it easier in analyzing data. Data publication downloaded after refine result for Scopus is 289 articles, Web of Science is 303 articles, and PubMed is 541 articles. Furthermore, biblioshiny for bibliometrix is used to visualize and analyze trends in the form of bibliometric maps. Biblioshiny can generate and provides dataset such as main information, annual scientific production, average citation per year, and three-field plot. Futhermore, biblioshiny also can provides sources such as most relevant sources, most local cited sources, and so on (Figure 2).

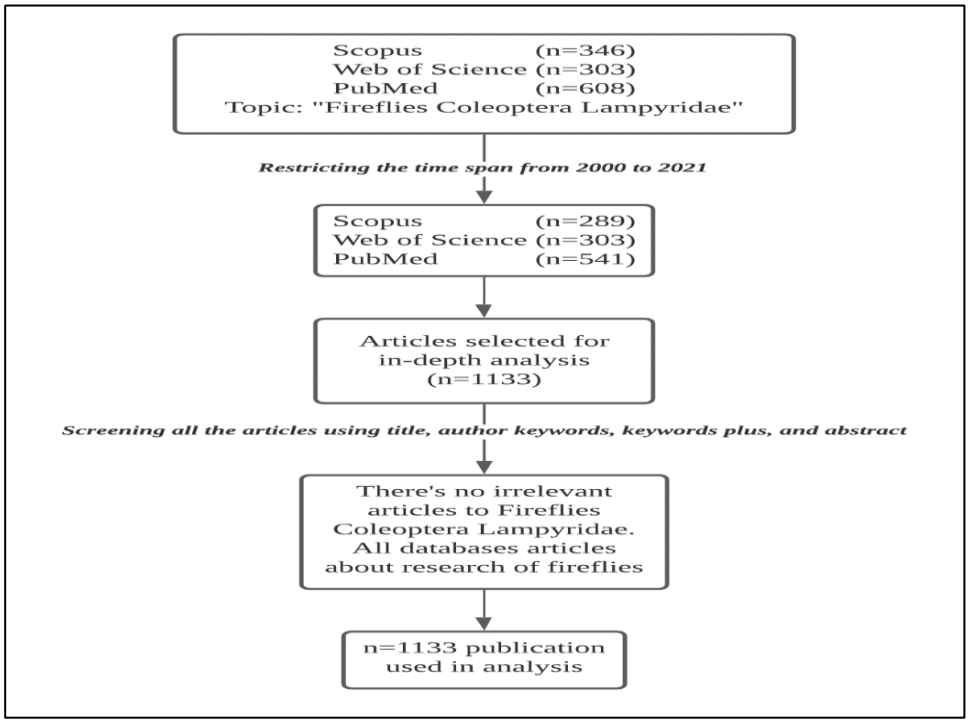


Figure 2: Flowchart for study selection

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Journal of Social Sciences and Humanities
*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

## Eligibility criteria and study selection

Only articles published between 2000 to 2021 with a focus on Fireflies Coleoptera Lampyridae. Moreover, there was no restriction on the type of articles that were included, language and study selection.

## Data Analysis

The latest version 4.1.1 of Rstudio was installed on Windows 8.1 by the researchers. Researchers open Rstudio and then in the console window researcher write >install.packages("bibliometrix") in order to install the bibliometrix. And then in the command prompt of Rstudio, researcher write > library(bibliometrix) to open biblioshiny web-interface. And after that, the researcher will open the biblioshiny web-interface and import the files that have been downloaded from databases of Scopus, WoS, and PubMed into biblioshiny app. A bibliometric analysis of fireflies using three database from Scopus, Web of Science, and PubMed has be done to get research output analysis of annual scientific production, most relevant authors, most relevant journals and journals growth, most frequent words and co-occurrence network, and collaboration among countries (Figure 3).

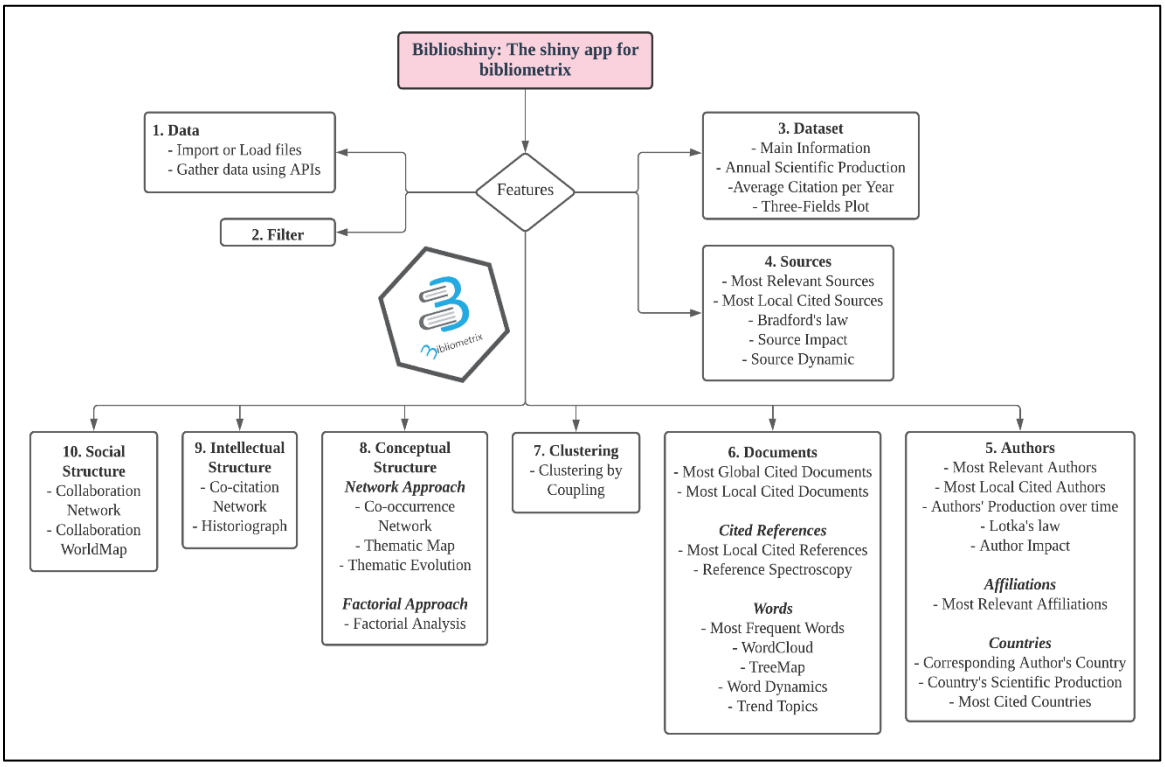


Figure 3: Features of Biblioshiny app for bibliometrix

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Journal of Social Sciences and Humanities

*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

## RESULT AND ANALYSIS

Using the search strategy has been mention above, researhcers retrieved 1133 databases of publication from three different indexed such as Scopus, WoS, and PubMed in relevant topic to "Fireflies Coleoptera Lampyridae" in the year 2000 until 2021.

### Annual Scientific Production

From 2000 to 2021, 1133 articles were published related to fireflies studies and indexed in Scopus (289 articles), Web of Science (303 articles), and PubMed (541 articles). In the time span between 2000 to 2021, the maximum of articles was published in Scopus indexed is in 2018 and 2019 (23 of 289), while the minimum of aticles was published in 2005 (5 of 289). In addition, from 2006 to 2021, there are significant inconsistency in global trends in annual scientific production, with the number of publications showed with increasing and decreasing. Annual scientific production in Web of Science showed the maximum of articles was published in 2021 (27 of 303), and the minimum of aticles was published in 2002 which is there is no publication recorded in that year. Moreover, the global trends of annual scientific production showed an obvious increase with the number of publications increasing steeply since 2017 (Figure 4). Futhermore, publication database of PubMed has showed the maximum annual scientific production of articles was published in 2014 (48 of 541), while the minimum of aticles was published in 2000 and 2002 (3 of 541). The global trends of annual scientific production showed an rapidly increase start from 2004. Moreover, for the annual growth rate has been recorded 6.38% (Scopus), 7.4% (WoS), and 9.95% (PubMed) that was shown in Table 1.

Table 1: Figure: Annual scientific publications from 2000 to 2021

| ***Year*** | **Scopus** | **WoS** | **PubMed** |
|---|---|---|---|
| *2000* | 6 | 6 | 3 |
| *2001* | 8 | 4 | 8 |
| *2002* | 5 | 0 | 3 |
| *2003* | 9 | 8 | 4 |
| *2004* | 10 | 12 | 16 |
| *2005* | 6 | 8 | 26 |
| *2006* | 14 | 16 | 20 |
| *2007* | 14 | 15 | 23 |
| *2008* | 11 | 9 | 27 |
| *2009* | 13 | 11 | 21 |
| *2010* | 15 | 16 | 26 |
| *2011* | 6 | 7 | 37 |
| *2012* | 13 | 14 | 32 |

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Journal of Social Sciences and Humanities
*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

| | | | |
|---|---|---|---|
| *2013* | 11 | 12 | 46 |
| *2014* | 15 | 16 | 48 |
| *2015* | 11 | 11 | 27 |
| *2016* | 14 | 17 | 24 |
| *2017* | 22 | 21 | 42 |
| *2018* | 18 | 20 | 31 |
| *2019* | 23 | 26 | 27 |
| *2020* | 23 | 27 | 28 |
| *2021* | 22 | 25 | 22 |

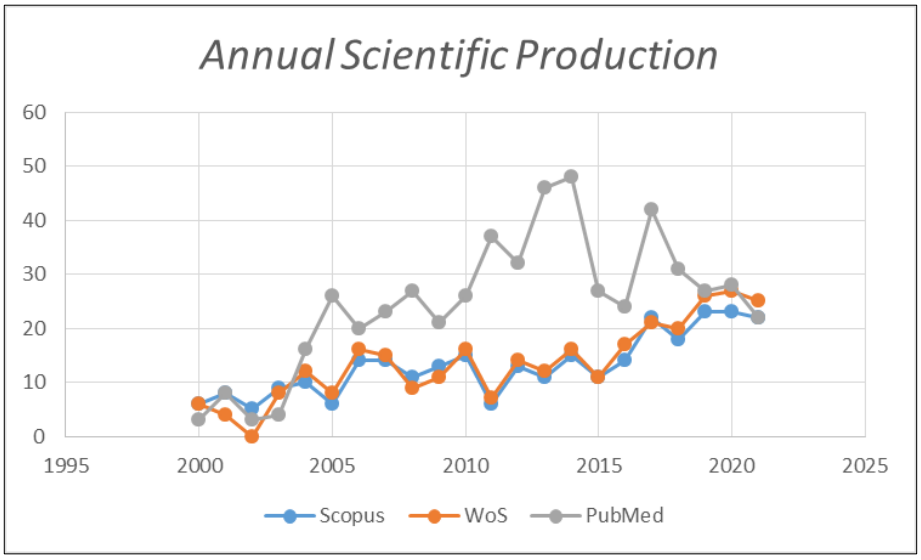


Figure 4: Annual scientific publications from 2000 to 2021.

## Most Relevant Authors

A total of 544 authors have been identified in the 289 articles published in Scopus journals. The top 10 authors are listed in (Table 2). The top 10 authors have contributed 147 (50.87%) of the papers. Author Fu X has the highest number of published papers (26, 9%), followed by Lewis SM has the second highest number of publication (21, 7.3%). The author at the ranked 10 is Barua AG that has published papers (8, 2.8%) in fireflies studies (Figure 5).

Table 2: Top 10 most relevant author in Fireflies (Scopus)

| ***Most Relevant Author in Fireflies Studies*** | | | |
|---|---|---|---|
| Authors | Articles | Articles Fractionalized | Percentage (%) |
| Fu X | 26 | 9.32 | 9 |

***Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x***
***Theme: Human, Nature and Society***

| | | | |
|---|---|---|---|
| Lewis SM | 21 | 7.48 | 7.3 |
| Viviani VR | 20 | 7.53 | 6.9 |
| Ballantyne LA | 16 | 6.99 | 5.5 |
| Branham MA | 13 | 5.77 | 4.5 |
| Ballantyne L | 12 | 3.75 | 4.2 |
| Mermudes JRM | 12 | 4.19 | 4.2 |
| Da Silveira LFL | 10 | 3.52 | 3.5 |
| Jeng M-L | 9 | 2.44 | 3.1 |
| Barua AG | 8 | 2.98 | 2.8 |

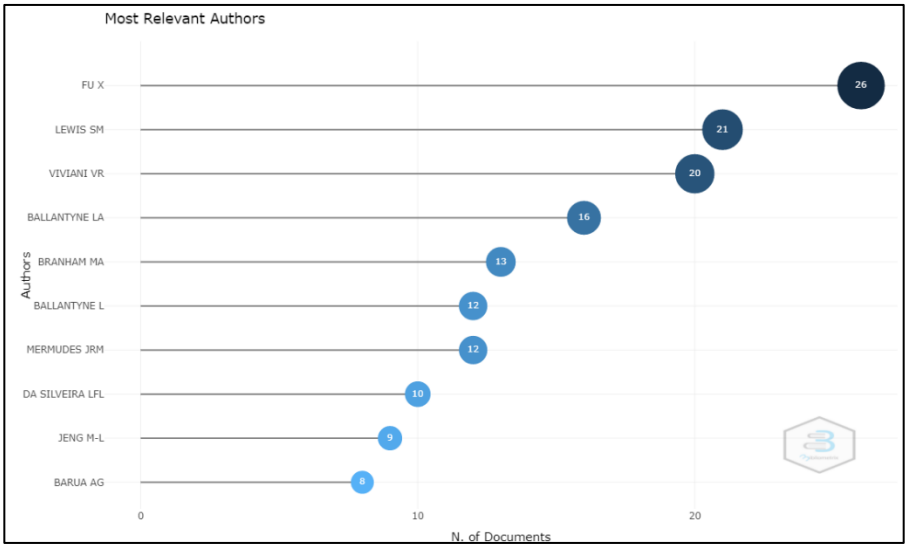


Figure 5: Top 10 most relevant authors in fireflies studies indexed by Scopus

A total of 561 authors have been identified in the 303 articles published in Web of Science journals related to fireflies research. The top 10 authors are listed in (Table 3). The top 10 authors have contributed 164 (54.13%) of the papers. Author Fu XH has the highest number of published papers (29, 9.6%), followed by Viviani VR has the second highest number of publication (22, 7.3%). The author at the ranked 10 is Oba Y that has published papers (11, 3.6%) in fireflies studies (Figure 6).

Table 3: Top 10 most relevant author in Fireflies (WoS)

| ***Most Relevant Author in Fireflies Studies*** | | | |
|---|---|---|---|
| Authors | Articles | Articles Fractionalized | Percentage (%) |
| Fu XH | 29 | 10.27 | 9.6 |
| Viviani VR | 22 | 7.63 | 7.3 |
| Lewis SM | 19 | 6.35 | 6.3 |
| Branham MA | 16 | 7.43 | 5.3 |

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Journal of Social Sciences and Humanities
*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

| | | | |
|---|---|---|---|
| Mermudes JRM | 15 | 4.78 | 5 |
| Ballantyne LA | 14 | 5.99 | 4.6 |
| Da Silveira LFL | 14 | 4.41 | 4.6 |
| Ballantyne L | 12 | 3.75 | 4 |
| Barua AG | 12 | 4.68 | 4 |
| Oba Y | 11 | 3.10 | 3.6 |

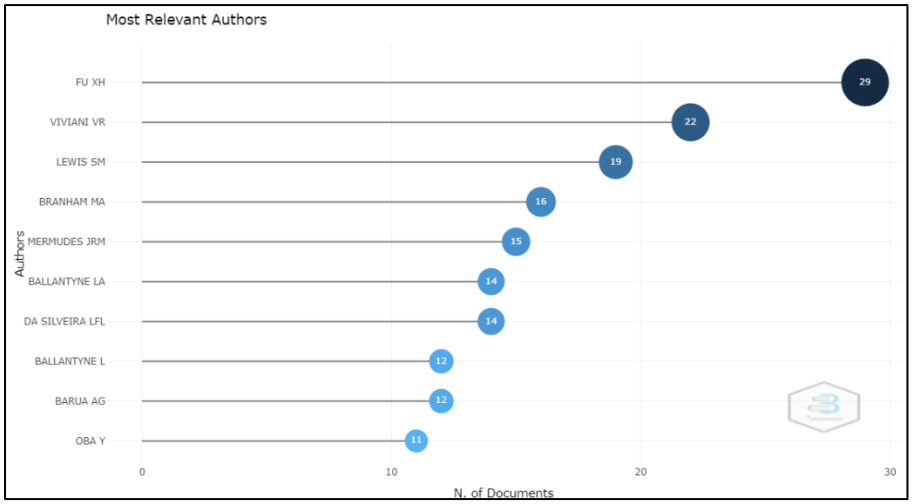


Figure 6: Top 10 most relevant authors in fireflies studies indexed by Web of Science

A total of 1,574 authors have been identified in the 541 articles published in PubMed journals related to fireflies research. The top 10 authors are listed in (Table 4). The top 10 authors have contributed 159 (29.40%) of the papers. Author Hosseinkhani S has the highest number of published papers (31, 5.7%), followed by Viviani VR has the second highest number of publication (24, 4.4%). The third highest author contributed published papers in the area of fireflies is Branchini BR and Oba Y (15, 2.8%) respectively. Moreover, the author at the ranked 10 is Ugarova NN that has published papers (11, 2%) in fireflies studies (Figure 7).

Table 4: Top 10 most relevant author in Fireflies (PubMed)

| ***Most Relevant Author in Fireflies Studies*** | | | |
|---|---|---|---|
| Authors | Articles | Articles Fractionalized | Percentage (%) |
| Hosseinkhani S | 31 | 9.25 | 5.7 |
| Viviani VR | 24 | 7.12 | 4.4 |
| Branchini BR | 15 | 2.67 | 2.8 |
| Oba Y | 15 | 4.23 | 2.8 |
| Esteves Da Silva JC | 14 | 6.04 | 2.6 |
| Ohmiya Y | 14 | 2.93 | 2.6 |

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Journal of Social Sciences and Humanities

*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

| | | | |
|---|---|---|---|
| Southworth Tl | 13 | 2.32 | 2.4 |
| Lewis SM | 12 | 3.74 | 2.2 |
| Ugarova NN | 11 | 5.50 | 2 |
| Fontaine DM | 10 | 1.46 | 1.8 |

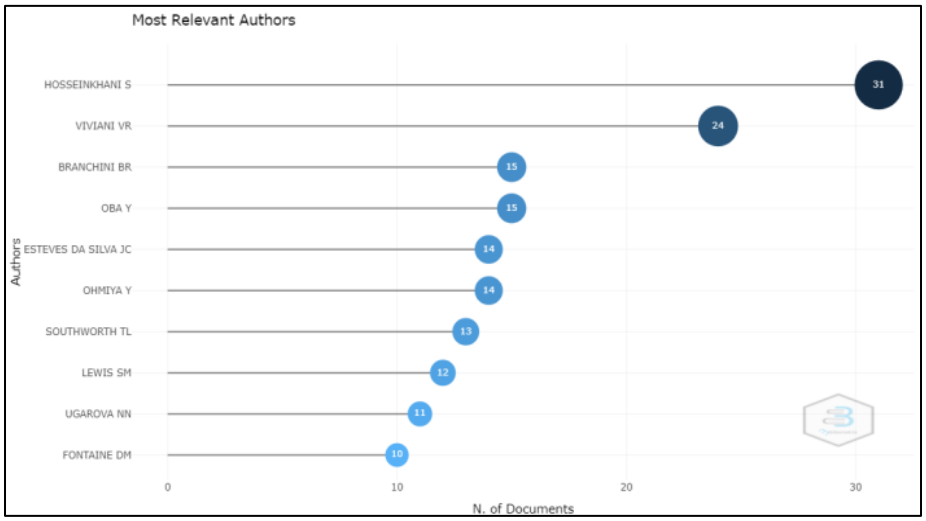


Figure 7: Top 10 most relevant authors in fireflies studies indexed by PubMed

## Most Relevant Journals and Journals growth (Sources)

In the 289 publications relevant to firefly study published in the Scopus database, 129 journals were recognised. The top ten journals are listed in (Table 5). There have been 36 articles published in Zootaxa journals, indicating the highest number of articles in firefly studies. The journal Coleopterists Bulletin is placed second, with 15 articles published. Journal of Mitochondrial Dna Part B: Resources has the third highest ranking in most relevant journal articles in firefly research, with 10 papers published in that journal. Furthermore, the tenth ranking goes to the Canadian journal Entomologist, which published 4 papers (Figure 8).

Table 5: Top 10 most relevant journals articles in fireflies studies (Scopus)

| ***Journals Name*** | |
|---|---|
| Sources | Articles |
| Zootaxa | 36 |
| Coleopterists Bulletin | 15 |
| Mitochondrial Dna Part B: Resources | 10 |
| Florida Entomologist | 9 |
| Insects | 7 |
| Molecular Phylogenetics And Evolution | 6 |

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Journal of Social Sciences and Humanities
*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

| | |
|---|---|
| Annales Zoologici | 5 |
| Luminescence | 5 |
| Photochemical And Photobiological Sciences | 5 |
| Canadian Entomologist | 4 |

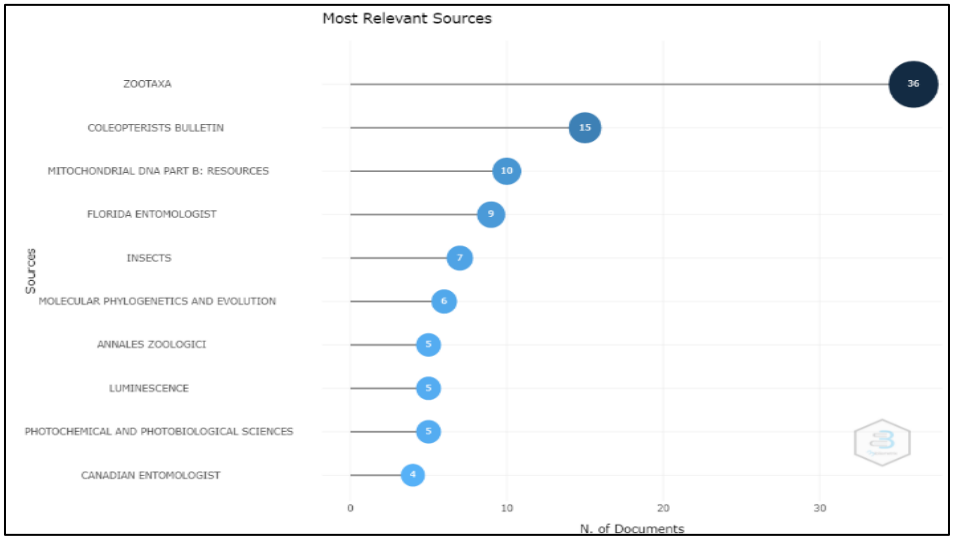


Figure 8: Top 10 most relevant journals articles and top 5 journals growth in fireflies studies (Scopus)

In the 303 publications relevant to fireflies study published in the Web of Science database, 127 journals were recognised. The top ten journals are listed in (Table 6). There have been 36 articles published in Zootaxa journals, indicating the highest number of articles in firefly studies. The journal Coleopterists Bulletin is placed second, with 17 articles published. Journal of Mitochondrial Dna Part B: Resources has the third highest ranking in most relevant journal articles in firefly research, with 11 papers published in that journal. Furthermore, the tenth ranking goes to the Luminescence journal, which published 5 papers (Figure 9).

Table 6: Top 10 most relevant journals articles in fireflies studies (WoS)

| ***Journals Name*** | |
|---|---|
| Sources | Articles |
| Zootaxa | 36 |
| Coleopterists Bulletin | 17 |
| Mitochondrial Dna Part B-Resources | 11 |
| Photochemical & Photobiological Sciences | 9 |
| Florida Entomologist | 8 |
| Molecular Phylogenetics And Evolution | 7 |

*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

| | |
|---|---|
| Integrative And Comparative Biology | 6 |
| Annales Zoologici | 5 |
| Insects | 5 |
| Luminescence | 5 |

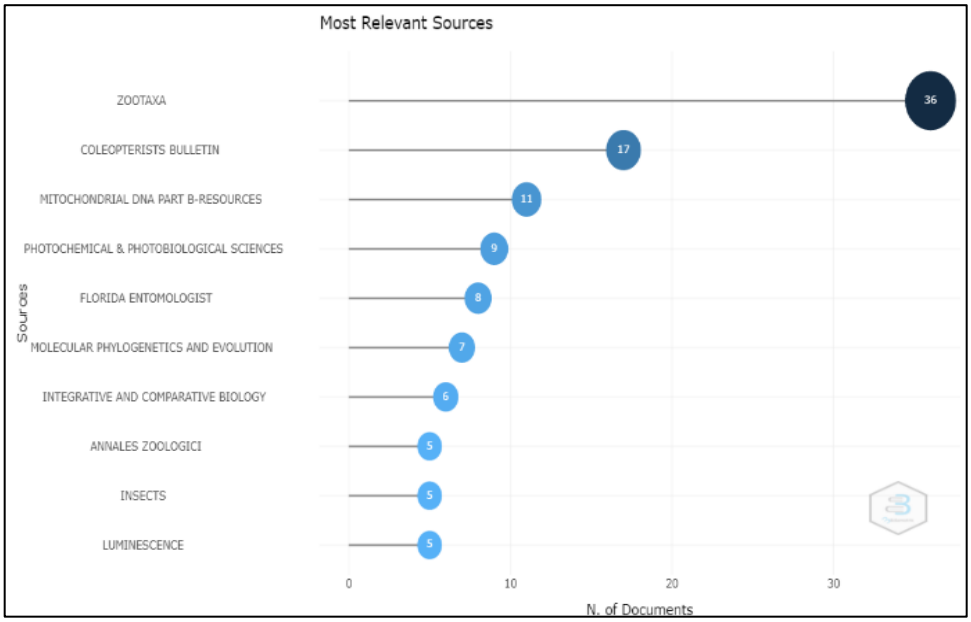


Figure 9: Top 10 most relevant journals articles and top 5 journals growth in fireflies studies (Web of Science)

In the 541 publications relevant to fireflies study published in the PubMed database, 210 journals were recognised. The top ten journals are listed in (Table 7). There have been 30 articles published in Photochemical and Photobiological Sciences journals, indicating the highest number of articles in firefly studies. The journal of Zootaxa is placed second highest, with 28 articles published. Journal Of The American Chemical Society has the third highest ranking in most relevant journal articles in firefly research, with 20 papers published in that journal. Furthermore, the tenth ranking goes to the Methods In Molecular Biology journal, which is published 11 papers (Figure 10).

Table 7: Top 10 most relevant journals articles in fireflies studies (PubMed)

| ***Journals Name*** | |
|---|---|
| Sources | Articles |
| Photochemical & Photobiological Sciences : Official Journal Of The European Photochemistry Association And The European Society For Photobiology | 30 |
| Zootaxa | 28 |
| Journal Of The American Chemical Society | 20 |
| Photochemistry And Photobiology | 19 |
| Plos One | 16 |

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Journal of Social Sciences and Humanities

*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

| | |
|---|---|
| Scientific Reports | 12 |
| The Journal Of Physical Chemistry. B | 12 |
| Analytical Biochemistry | 11 |
| Luminescence : The Journal Of Biological And Chemical Luminescence | 11 |
| Methods In Molecular Biology (Clifton N.J.) | 11 |

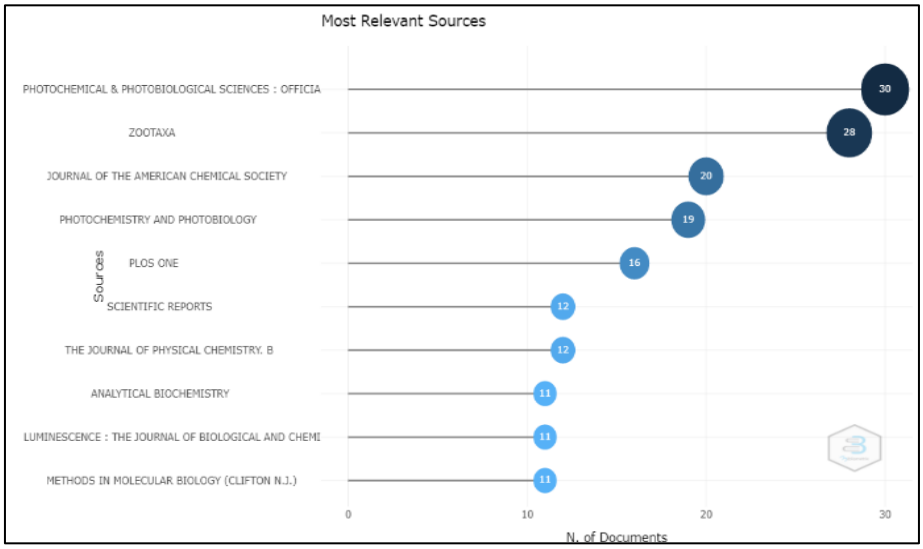


Figure 10: Top 10 most relevant journals articles and top 5 journals growth in fireflies studies (PubMed)

## Most Frequent Words and Co-occurrence Network on Fireflies Studies

Keywords in research are one of the most important variables in characterising a field of study and can reveal scientific trends. Keyword co-occurrence network measurement will provide a clear picture of the connections between a range of keywords via nodes. In the 289 publications relevant to fireflies study published in the Scopus database, 754 key words has been used in fireflies study by researcher all over the world. Table 8 reveals the most 20 frequently utilized keywords in fireflies study filter by author's keyword in Scopus database publication (Figure 11). The more frequently used key words in the fireflies literature are lampyridae has recorded 64 the number of occurrences, firefly (57 occurrences), bioluminescence (47 occurrences), fireflies (29 occurrences), coleoptera (23 occurrences), taxonomy (18 occurrences), mitochondrial genome (16 occurrences), luciferase (14 occurrences) and so on.

Table 8: The most top 20 frequently utilized keywords in fireflies study (Scopus)

| *The Most Frequently Utilized Keywords* | |
|---|---|
| Words | Occurrences |
| Lampyridae | 64 |
| Firefly | 57 |

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Journal of Social Sciences and Humanities
*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

| | |
|---|---|
| Bioluminescence | 47 |
| Fireflies | 29 |
| Coleoptera | 23 |
| Taxonomy | 18 |
| Mitochondrial Genome | 16 |
| Luciferase | 14 |
| Phylogeny | 14 |
| Morphology | 13 |
| New Species | 13 |
| Luciolinae | 11 |
| Neotropical | 11 |
| Sexual Selection | 11 |
| Elateridae | 8 |
| Lampyrinae | 8 |
| Phengodidae | 8 |
| Amydetinae | 7 |
| Elateroidea | 7 |
| Photinus | 7 |

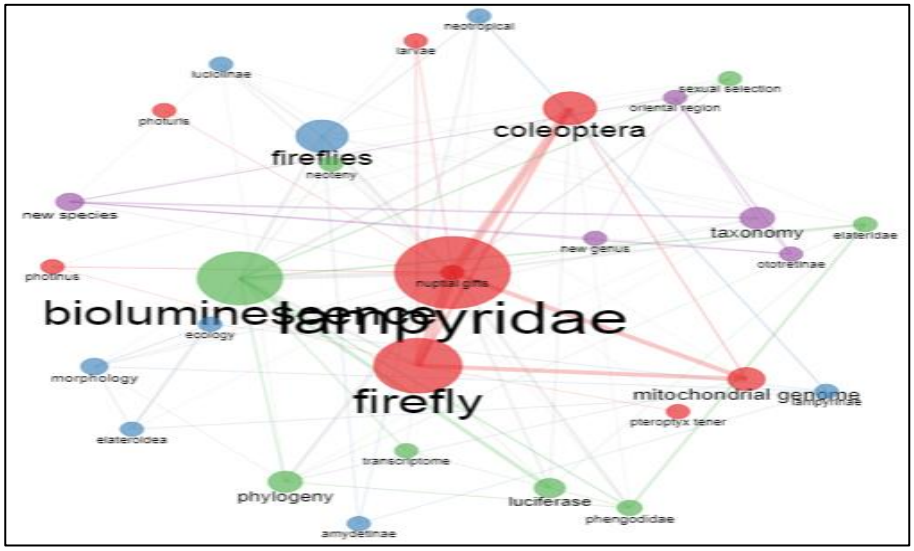


Figure 11: Visualization shows the density of the co-occurence network of the author's keywords in the area of fireflies research (Scopus)

755 key words were used by researchers all over the world in the 303 publications relevant to fireflies research published in the Web of Science database. Table 9 shows the top 20 most often used keywords in the fireflies study, filtered by author's keyword in the biblioshiny web-interface (Figure 12). The key words most frequently used in the firefly literature are lampyridae (69 occurrences), bioluminescence (55 occurrences), firefly (54 occurrences), fireflies (24

*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

occurrences), coleoptera (23 occurrences), mitochondrial genome (17 occurrences), taxonomy (17 occurrences), luciferase (15 occurrences), and so on.

Table 9: The most top 20 frequently utilized keywords in fireflies study (WoS)

| ***The Most Frequently Utilized Keywords*** | |
|---|---|
| Words | Occurrences |
| Lampyridae | 69 |
| Bioluminescence | 55 |
| Firefly | 54 |
| Fireflies | 24 |
| Coleoptera | 23 |
| Mitochondrial Genome | 17 |
| Taxonomy | 17 |
| Luciferase | 15 |
| Phylogeny | 15 |
| Morphology | 12 |
| New Species | 12 |
| Luciolinae | 10 |
| Neotropical | 10 |
| Sexual Selection | 10 |
| Elateridae | 9 |
| Lampyrinae | 9 |
| Lampyris Noctiluca | 9 |
| Elateroidea | 8 |
| Photuris | 8 |
| Amydetinae | 7 |

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Journal of Social Sciences and Humanities

*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

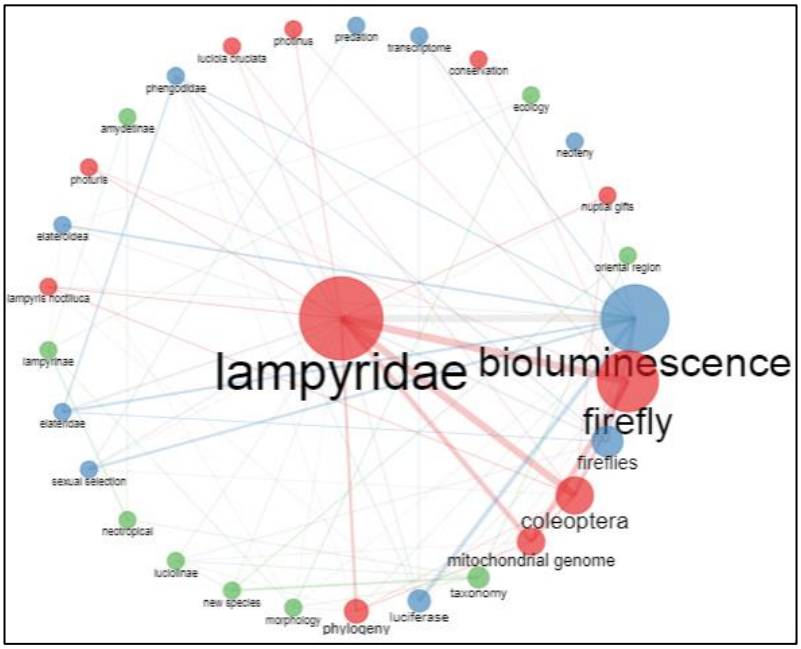


Figure 12: Visualization shows the density of the co-occurence network of the author's keywords in the fireflies study (WoS)

In the 541 papers relevant to firefly study published in the PubMed database, academics from all around the world has utilised 1,857 key words. Table 10 displays the top 20 most often used keywords in the firefly research filtered in the biblioshiny web-interface using the option by author's keyword (Figure 13). The key words most frequently used in the firefly literature are animals (508 occurrences), fireflies or enzymology (117 occurrences), fireflies (115 occurrences), luminescence (104 occurrences), luminescent measurements (82 occurrences), humans (78 occurrences), male (75 occurrences), kinetics (72 occurrences), and so on.

Table 10: The most top 20 frequently utilized keywords in fireflies study (PubMed)

| ***The Most Frequently Utilized Keywords*** | |
|---|---|
| Words | Occurrences |
| Animals | 508 |
| Fireflies/Enzymology | 117 |
| Fireflies | 115 |
| Luminescence | 104 |
| Luminescent Measurements | 82 |
| Humans | 78 |
| Male | 75 |
| Kinetics | 72 |
| Female | 62 |

e-Bangi Faculty of Social Sciences and Humanities Universiti Kebangsaan Malaysia
Journal of Social Sciences and Humanities

*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

| | |
|---|---|
| Models Molecular | 55 |
| Molecular Sequence Data | 55 |
| Phylogeny | 50 |
| Amino Acid Sequence | 49 |
| Hydrogen-Ion Concentration | 48 |
| Molecular Structure | 43 |
| Genes Reporter | 42 |
| Fireflies/Enzymology/Genetics | 40 |
| Light | 39 |
| Mice | 35 |
| Luciferases Firefly/Chemistry/Genetics/Metabolism | 33 |

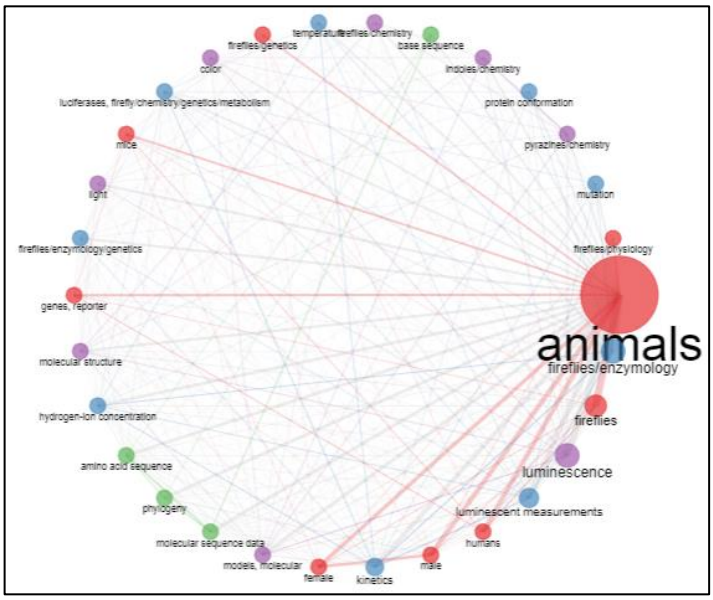


Figure 13: Visualization shows the density of the co-occurence network of the author's keywords in the fireflies study (PubMed)

## Collaboration among Countries in Fireflies Studies

In this part, we examine at collaboration trends and major patterns at the country levels. According to the findings of the researcher's analysis, there are 87 collaborations among countries in firefly research throughout the world in Scopus database (Figure 14). Table 11 lists the top 25 countries that collaborate the most on firefly research. The highest frequency of collaboration countries between the United States and China was 14 times. Furthermore, collaboration between China and Australia and Japan has occurred 11 and 10 times, respectively. A 4 frequency was recorded by Malaysia and Australia that has collaborate together. Moreover, collaboration between Australia

e-Bangi Faculty of Social Sciences and Humanities Universiti Kebangsaan Malaysia
Journal of Social Sciences and Humanities

*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

and Finland has also been recorded 2 frequency, placing at ranked 25th globally in terms of collaboration.

Table 11: Collaboration among countries in fireflies studies (Scopus)

| ***Collaboration among countries in fireflies studies*** | | |
|---|---|---|
| From | To | Frequency |
| Usa | China | 14 |
| China | Australia | 11 |
| China | Japan | 10 |
| Usa | Brazil | 7 |
| Usa | Japan | 6 |
| Australia | Singapore | 5 |
| Australia | Thailand | 5 |
| China | Finland | 5 |
| Usa | Australia | 5 |
| Australia | United Kingdom | 4 |
| China | Hong Kong | 4 |
| Japan | Finland | 4 |
| Malaysia | Australia | 4 |
| Usa | Belgium | 4 |
| Brazil | Canada | 3 |
| China | Panama | 3 |
| China | Thailand | 3 |
| China | United Kingdom | 3 |
| Czech Republic | United Kingdom | 3 |
| Japan | Korea | 3 |
| Japan | Panama | 3 |
| Usa | Canada | 3 |
| Usa | Portugal | 3 |
| Usa | Thailand | 3 |
| Australia | Finland | 2 |

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Journal of Social Sciences and Humanities
*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

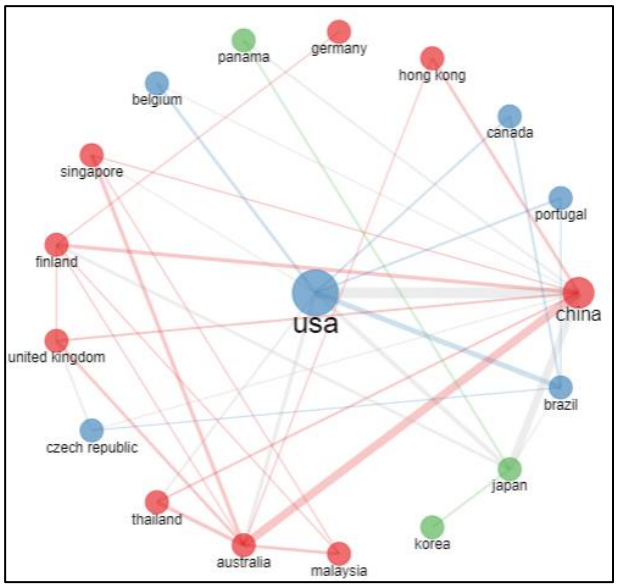


Figure 14: Collaboration network among countries around the world in the fireflies study (Scopus)

Furthermore, it is found in the Web of Science database. According to the researcher's findings, there are 99 collaborations among countries in the research of firefly study. The top 25 countries that collaborate the most on firefly research are shown in Table 12. The highest frequency of collaboration countries was 18 times between the United States and China. Furthermore, collaboration between country from China to Australia and Japan has occurred 11 and 10 times, respectively. The frequency of collaboration between Malaysia and Singapore has been reported at 4. Furthermore, collaboration between Japan and Panama has been recorded 3 times, putting the two countries in a tie for 25th place globally in terms of collaboration (Figure 15).

Table 12: Collaboration among countries in fireflies studies (WoS)

| ***Collaboration among countries in fireflies studies*** | | |
|---|---|---|
| From | To | Frequency |
| Usa | China | 18 |
| China | Australia | 11 |
| China | Japan | 10 |
| Usa | Japan | 9 |
| Usa | Brazil | 8 |
| China | Finland | 7 |
| Usa | Australia | 7 |
| Australia | Singapore | 6 |
| Australia | Malaysia | 5 |
| Australia | Thailand | 5 |
| China | Germany | 5 |
| Finland | Germany | 5 |
| Australia | United Kingdom | 4 |
| China | Thailand | 4 |

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Journal of Social Sciences and Humanities
*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

| | | |
|---|---|---|
| Czech Republic | United Kingdom | 4 |
| Japan | Finland | 4 |
| Malaysia | Singapore | 4 |
| Usa | Canada | 4 |
| Usa | Panama | 4 |
| Brazil | Canada | 3 |
| Brazil | Czech Republic | 3 |
| China | Panama | 3 |
| Japan | Germany | 3 |
| Japan | Korea | 3 |
| Japan | Panama | 3 |

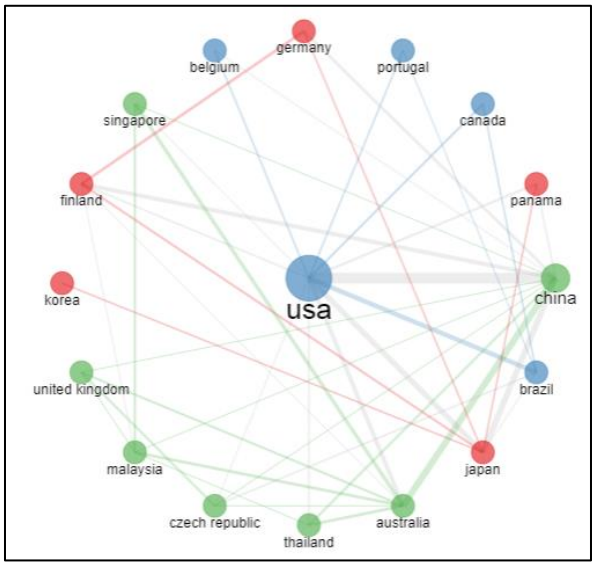


Figure 15: Collaboration network among countries around the world in the fireflies study (WoS)

Furthermore, it may be discovered in the PubMed database. According to the researcher's results, 44 countries are collaborating together on firefly research. Table 13 displays the top 25 countries in firefly research collaboration. The countries from the United States to China and Japan collaborated the most frequently, at a rate of 4 times. Furthermore, 3 times, countries from China to Australia collaborated together. There has been 1 recorded collaboration between countries from Australia to Malaysia. Furthermore, collaboration between the Czech Republic and Spain has been documented at 1 occasions, ranking the two countries at 25th place globally in terms of collaboration (Figure 16).

Table 13: Collaboration among countries in fireflies studies (PubMed)

| ***Collaboration among countries in fireflies studies*** | | |
|---|---|---|
| From | To | Frequency |
| Usa | China | 4 |
| Usa | Japan | 4 |

e-Bangi Faculty of Social Sciences and Humanities Universiti Kebangsaan Malaysia
Journal of Social Sciences and Humanities
*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

| | | |
|---|---|---|
| China | Australia | 3 |
| Usa | Italy | 3 |
| China | Finland | 2 |
| China | Japan | 2 |
| Japan | Brazil | 2 |
| Japan | United Kingdom | 2 |
| Thailand | Australia | 2 |
| Usa | United Kingdom | 2 |
| Australia | Finland | 1 |
| Australia | Malaysia | 1 |
| Australia | Singapore | 1 |
| Brazil | Belgium | 1 |
| Brazil | Czech Republic | 1 |
| China | Czech Republic | 1 |
| China | Hong Kong | 1 |
| China | Korea | 1 |
| China | Netherlands | 1 |
| China | Spain | 1 |
| China | Switzerland | 1 |
| China | Thailand | 1 |
| Czech Republic | Australia | 1 |
| Czech Republic | Slovenia | 1 |
| Czech Republic | Spain | 1 |

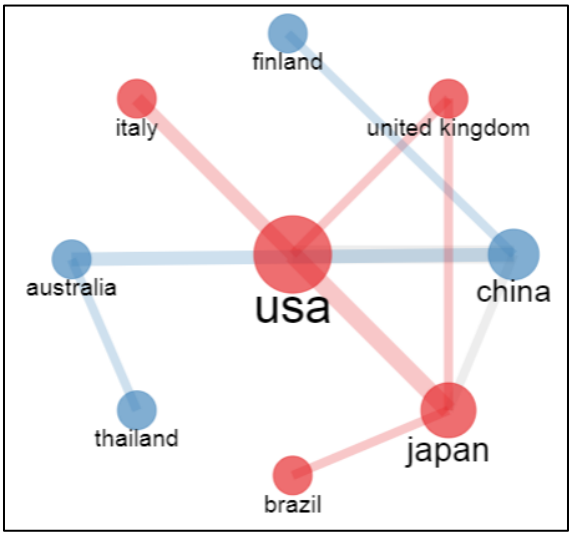


Figure 16: Collaboration network among countries around the world in the fireflies study (PubMed)

## DISCUSSION

Bibliometric analysis is part of research that statistically analyses scientific papers to identify citation links between publications and research trends in a certain field, and it's useful for comparing researcher contributions across countries (Şenel & Demir, 2018). A bibliometric

*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

analysis was carried out to evaluate global trends in firefly research, with an emphasis on particular themes within the field, during a period of time spanning from 2000 to 2021. To the best of our knowledge, this is the first study to perform bibliometric analysis on the global scientific body of research on fireflies via the Scopus, Web of Science Core Collection, and PubMed databases. Researcher used "Fireflies Coleoptera Lampyridae" as topics to find out the articles in Scopus, Web of Science and PubMed. The purpose of the reseacher is want to focus on firefly research around the world from 2000 to 2021, without no restriction on the type of articles. After screening, only 1133 articles remained for in-depth analysis. All 1133 articles retrieved from Scopus, Web of Science, and PubMed are related to firefly research.

The number of scientific publications is an intuitive indicator that may reflect the development of a discipline based on bibliometry (Sun et al., 2018). For example, a conspicuous change in the number of articles published annually could indicate that there is an important turning point in the area of research. In the present study, the researcher found that the number of publications is unstable, which means there are certain year is decreased and increased over the year 2000 until 2021 in firefly research. Particularly since 2004, indicating a period of rapid development in firefly research. There are some factors that encourage the development of the discipline, such as improving laboratory conditions and technology, increasing the number of researchers, and increasing support for forensic insect research through national policies (Sharma etal., 2018). The results of the analysis also show that the United States (USA) is the country with the highest number of scientific production and the most cited in three databases (Scopus, Web of Science, PubMed). This is not surprising, as the USA heads worldwide research in most fields (Hernández-Vásquez et al., 2018).

In firefly research, for the most relevant author is Fu X (Scopus), Fu XH (WoS), and Hosseinkhani S (PubMed). For the result analysis of most relevant journal is by Zootaxa with 36 articles in Scopus and Web of Science database, but in PubMed database the top journal in fireflies research is Photochemical & Photobiological Sciences : Official Journal Of The European Photochemistry Association And The European Society For Photobiology (30 articles). Futhermore, the most frequent word in firefly research is lampyridae, firefly, bioluminescence, fireflies, animals and so on in three different database. In Scopus database, USA has highest collaboration with others country like China (14 frequency), Brazil (7 frequency), Japan (6 frequency), Australia (5 frequency), (Belgium 4 frequency), Cadana (3 frequency), Portugal (3 frequency), and Thailand (3 frequency). Moreover, in web of Science USA has 7 collaboration among countries in fireflies study with top 25 country in the world.

The collaboration is USA with China (18 frequency), Japan (9 frequency), Brazil (8 frequency), Australia (7 frequency), Canada (4 frequency), and Panama (4 frequency). In PubMed database, China is the most highest collaboration with others country in firefly research. China has made 10 collaboration with others country in top 25 countries which is China with Australia (4 frequency), Finland (2 frequency), Japan (2 frequency), Czech Republic, Hong Kong, Korea, Netherlands, Spain, Switzerland, Thailand is 1 frequency respectively. To our knowledge, this is the first bibliometric analysis of firefly research using the Scopus, Web of Science, and PubMed databases, and it forms the basis knowledge and for future studies that, in turn, could support scholars or researchers around the world.

*Special Issue: Vol. 19. No.3 (2022). 123-150. ISSN: 1823-884x*
*Theme: Human, Nature and Society*

## CONCLUSION

This article presents a bibliometric analysis of fireflies research to determine the areas within which the annual scientific publication growth, the most productive authors, the most cited countries in fireflies study, most frequent word has been using, most famous journal name, and which countries has highest collaboration with other country in firefly research. The bibliometric analysis of 1133 fireflies research documents gathered from the Scopus, Web of Science (WOS), and PubMed databases in over the year from 2000 until 2021. This article attempts to configure and visualize the sharing of literature systematically in firefly research and analyze it through a bibliometric approach. The finding's of this study showed there is significant inconsistency in global trends in annual scientific production, with the number of publications increasing and decreasing over the year 2000 until 2021. Futhermore, the most relevant authors in this study is Fu X (Scopus), Fu XH (WoS), and Hosseinkhani S (PubMed). Moreover, the most relevant journals articles in fireflies studies is Zootaxa (Scopus & WoS), and Photochemical & Photobiological Sciences : Official Journal Of The European Photochemistry Association And The European Society For Photobiology in PubMed database. In addition, the most frequently utilized keywords in fireflies study is *lampyridae, firefly, bioluminescence, animals and fireflies*. The findings also showed China and USA is the most highest collaboration among others countries in fireflies research over the year 2000 until 2021. This bibliometric approach was used to identify key themes in fireflies research and is useful for determining novelty in conducting further research. Researchers want to fill in the research gaps in bibliometric analysis of fireflies in order to provide information in the form of an overview and guidelines because there are now relatively studies on fireflies in bibliometrics analysis articles papers until now.

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***Theme: Human, Nature and Society***

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