Global trends, knowledge mapping and visualization of current research on climate change and their impact on plant-pollinators interaction

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Abstract

The mutualistic interactions between plants and pollinators is one of the most prestigious field of research in ecology, which give information on the biotic network architecture, coexistence, diversification, and ecosystem function. In this manuscript, our research intends to identify the published literature for research production, collaborations, hotspots, and trends in research addressing the influence of climate change on the relationship between plants and pollinators. The research and review papers on the interactions between plants and pollinators, and climate change published in the Scopus database were retrieved. The contribution of nations, journals, institutions, current trends, and keyword analysis were shown using VOSviewer and RStudio bibliometrix to produce a network map of author collaboration across nations. The Scopus database (2007 to 2023) yielded a total of 256 entries, of which 229 publications were examined after being excluded based on various criteria. As per our data analysis, "The Rocky Mountain Biological Laboratory" and "Journal of Ecology" were the most effective organization, and journal, respectively. The author with the most publications was "Laura A. Burkle" of "Montana State University". The "United States" is rated #1 among all nations in terms of the global production of literature on the effects of climate change on interactions between plant and pollinators. We determined four primary research subjects and new research areas for further study through the analysis of keywords. This study highlights current research on the effects of climate change on plant-pollinator relationships and is an early attempt to understand how these connections form and alter. The majority of recent research has been on the effects of drought on plants in these systems, which is a developing field of study that requires attention from academics for future research.

Introduction

Phenology, which is mostly related to climate, plant, and animal's life, is the study of cyclical and seasonal natural occurrences (Taylor and White, 2020). Climate change influences the phenology, local abundance and population dissemination of plants and pollinators (Hegland et al., 2009a). Numerous experts have gathered a wealth of data about how seasonal behavior in plants and animals is impacted by global change (Abrahms et al., 2023; Covert et al., 2023; Halupka et al., 2023; Harvey et al., 2023; Ozgül et al., 2023; Peñuelas and Filella, 2001; Root et al., 2005; Singh et al., 2023; Walther et al., 2001). The change in plant phenology affects not just the health of individual plants but also the living forms that depend on them. As a result of the cascade effects from the individual to the environment, phenological changes in plants can negatively affect demography (McKinney et al., 2012; Stucky et al., 2018; Wudu et al., 2023). Widespread phenological change additionally influence human prosperity through agriculture, tourism, and human wellbeing (García-Mozo, 2017; Liu et al., 2019; Minoli et al., 2019; Shen et al., 2022; Song, 2023). Ecological interactions are a crucial component in maintaining the diversity of life on Earth. Mutualistic interaction between species exists in every ecosystem, and plant-pollinator interactions are excellent examples of mutualism (Kawata and Takimoto, 2023; St-Onge et al., 2022). Approximately 85% of angiosperm plant species and 33% of the world's cultivated crops are pollinated by animals; insects
play the largest part in this ecological service (Burkle, Marlin and Knight, 2013b; Buxton et al., 2022; Potts et al., 2016).

Response diversity is a phenomenon where differences in phenological shift rates are seen across several species within the same group. Because of this, there are mismatches between interacting species when the phenological overlap between them decreases (Cook, Wolkovich and Parmesan, 2012; Primack et al., 2009). Despite the fact that precipitation also profoundly influences phenology by regulating soil moisture, it is thought that temperature is the primary factor causing the shift in phenoevets. Examples of such phenological mismatches may be found in a wide range of biological systems, mainly in temperate and arctic locations (Kudo and Ida, 2013; Post and Forchhammer, 2008; Yin et al., 2023). With the exception of a few isolated instances when plants and pollinators interact negatively, generalist plants and insect pollinators demonstrate generally similar rates of phenological progress in response to global warming because of their adaptable relationships (Bartomeus et al., 2011; Burkle, Marlin and Knight, 2013b; Ovaskainen et al., 2013). Because the plants that are the only source of food for herbivores in alpine locations are impacted by early or late flowering/phenology changes, it eventually affects how they forage. In many cases, herbivores seem to be adapting to climate change more quickly than their host plants, which has modified the selection pressure and created unusual ecological connections in their new environments (de Sassi and Tylianakis, 2012; Hamann et al., 2021; Lu et al., 2013). Few experiments showed that 17–50% of pollinators were observed to be affected due to disruption in food supply and temporal mismatch changing the pollinator's demography (Memmott et al., 2007a; Ren et al., 2020).

Bibliometric analysis referred as quantitative and qualitative evaluation of the published literature in a particular research area by using mathematical and statistical tools. Bibliometric analysis is a useful technique for providing an overview of national and global contributions of the available literature in a specific field, and finding research gaps that may be addressed in future studies (Ellegaard and Wallin, 2015). Throughout recent years, various examinations have led bibliometric researches in different scholarly subjects (Belter, 2015; Semwal et al., 2023). Rather than comprehensive reviews, which endeavor to dissect a specific examination issue in few set of publications, bibliometric analysis give a total assessment of the writing in a specific region (Møller and Myles, 2016). This study intends to gain insight into the research trends on climate change impact on plant-pollinator interactions and provide references for future research by examining the worldwide correlations between the research trends and hotspots in this field. In addition, policymakers and funding organizations can decide where to allocate resources by obtaining information about current research trends and hotspots in the field.

Materials and methods

Data source and search strategy

Articles were retrieved from the Scopus database and assessed quantitatively and qualitatively as included in bibliometric analysis (Van Raan, 2014). The search was conducted in a single day, to remove
the errors due to additions in database. Scopus search was performed on 1st July 2023, using search strategy (TITLE-ABS-KEY ("plant-pollinator interactions") AND TITLE-ABS-KEY ("climate change") OR TITLE-ABS-KEY ("global change") OR TITLE-ABS-KEY ("global warming") as a result, total 256 published documents were retrieved. After extraction of data, extracted documents was further screened on the basis of different parameters (Fig. 1). Finally, a total of 229 research articles and reviews were included for bibliometric analysis.

Data analysis software packages

The retrieved data was downloaded in [.CVS] format and transferred to MS Excel for tabulation and further analysis. The data was also exported to VOSviewer version 1.6.19.0. (https://www.vosviewer.com) software and bibliometrix R-package (http://www.bibliometrix.org/) for mapping and visualization of the networks. Information such as global literature publication, most relevant authors, international collaborations, trend topics were obtained through bibliometrix R-package, and co-occurrence, co-authorship and co-citation networks was obtained by using VOSviewer (Aria and Cuccurullo, 2017; Mohammed and Li, 2023; Van Eck and Waltman, 2010).

Results

Annual Publication Trend

After screening 229 publications related to impact of climate change on plant-pollinator interactions (ICCPI) were included, out of which 199 were articles and 30 were reviews. Figure 2(A) shows the number of yearly publications on ICCPI from January 2007 to July 2023. Although the number of publications on this topic was consistently low over the first few years (2007–2011), Fig. 2(A) shows that from 2015 to 2022, there was a continuous growth in the volume of literature (14.31%), signaling the beginning of interest in this field of study. The literature output growth curve was exponential, and the equation used to fit the curve was $y = 0.9339e^{0.2343x}$, $R^2 = 0.6022$, predicting an increase in the number of publications on ICCPI in the next years.

Top 10 Journals and Institutions

A total of 229 documents were published in 103 well-known journals all across the world. Table 1 represents the top 10 leading journals, arranged according to number of publications. Approximately 36% of publications on ICCPI are attributed to the top 10 journals. “Journal of Ecology” published by British Ecological Society, Wiley-Blackwell, ranked first with 11 publications and 363 citations. “American Journal of Botany”, “Ecology and Global Change” with 10 published articles ranked second in this field followed by “Ecology Letters” with 8 publications. The impact factors of publishing journals range between 11.6 to 2.6 as per the Journal Citation Report 2023. The journal “Ecology Letters” has the maximum citation (n = 2181), followed by “Science” (n = 718) and “Ecology” (n = 695) (Table 1). The authors who took part in the study (ICCPI) represented 160 institutions, and Fig. 2(B) lists the institutions with the utmost number of published works.”Rocky Mountain Biological Laboratory” (n = 19), “CNRS
"Center National de la Recherche Scientifique" (n = 12), "University of Arizona" (n = 10), "University of Maryland" (n = 11), and "Montana State University" (n = 40) were the organizations that publish the most publications.

Table 1
Top 10 most productive journals.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Journals</th>
<th>IF*</th>
<th>Articles</th>
<th>Total Citations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Journal of Ecology</td>
<td>5.5</td>
<td>11</td>
<td>363</td>
</tr>
<tr>
<td>2.</td>
<td>American Journal of Botany</td>
<td>3</td>
<td>10</td>
<td>513</td>
</tr>
<tr>
<td>3.</td>
<td>Ecology</td>
<td>4.8</td>
<td>10</td>
<td>695</td>
</tr>
<tr>
<td>4.</td>
<td>Global Change Biology</td>
<td>11.6</td>
<td>10</td>
<td>422</td>
</tr>
<tr>
<td>5.</td>
<td>Ecology Letters</td>
<td>8.8</td>
<td>8</td>
<td>2181</td>
</tr>
<tr>
<td>6.</td>
<td>Proceedings of The Royal Society B: Biological Sciences</td>
<td>5.53</td>
<td>8</td>
<td>145</td>
</tr>
<tr>
<td>7.</td>
<td>Functional Ecology</td>
<td>5.2</td>
<td>7</td>
<td>234</td>
</tr>
<tr>
<td>8.</td>
<td>Oikos</td>
<td>3.4</td>
<td>7</td>
<td>578</td>
</tr>
<tr>
<td>9.</td>
<td>Ecology and Evolution</td>
<td>2.6</td>
<td>6</td>
<td>129</td>
</tr>
<tr>
<td>10.</td>
<td>Frontiers in Ecology and Evolution</td>
<td>3</td>
<td>6</td>
<td>15</td>
</tr>
</tbody>
</table>

(As per JCR report 2023)

Top countries and their cooperation

Co-authorship analysis of nations investigates collaboration among researchers, which can lead to improvements in the clarity and insight of a certain research topic (Tahamtan, Safipour Afshar and Ahamdazadeh, 2016). A total of 47 countries has contributed to research related to ICCPI. "The U.S.A" was the most productive country with maximum number of published documents (n = 85), followed by "Germany" (n = 41), "United Kingdom" (n = 21), "Canada" (n = 17) and "France" (n = 16). The output indicated that these countries have the maximum investment and funding for the research in this field resulting in strong research strength by the countries (Fig. 2 (C)). Figure 3(A) represents the international cooperation in publishing literature with the threshold of five documents per countries. The node size represents the number of articles and the thickness of connecting lines indicates the link strength. In the network visualization it is clearly observed that "U.S.A" has the maximum number of collaboration (n = 41) among the countries followed by "Germany" (n = 40) and "United Kingdom" (n = 22).

Top author and their co-citation analysis
A total of 751 authors were involved in ICCPI research, and the author who published the most publications \((n = 11)\) was “Laura A Burkle” from “Montana State University”, followed by “David W. Inouye” from “University of Maryland” \((n = 10)\), and “Rafferty NE” from “University of California” \((n = 9)\), etc (Table 2). Each of the top 10 most cited authors has received more than 5000 citations overall, with more than 25 citations per article on average. Co-citation is a method for determining how frequently two writers were cited together in other works. In this co-citation analysis, 135 authors out of 2190 had at least 35 citations, which served as the threshold. In Fig. 3(B), the line thickness represents the strength of the co-citations between authors, and the nodes represent the total number of citations. Four distinct groups were formed from the co-cited authors. The most often referenced authors are Inouye DW \((n = 331)\), Waser NM \((n = 288)\), Bascompte J \((n = 213)\), Potts SG \((n = 205)\), and Steffan-Dewenter I \((n = 192)\). The centrality of their nodes demonstrates the importance of their work in the field of ICCPI (Table 2).

### Table 2
Top 10 most productive author and their co-citation analysis.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Authors</th>
<th>Affiliation</th>
<th>Articles</th>
<th>Citations</th>
<th>Average citation per document</th>
<th>h-index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Burkle LA</td>
<td>Montana State University, United States</td>
<td>11</td>
<td>1341</td>
<td>121.90</td>
<td>26</td>
</tr>
<tr>
<td>2.</td>
<td>Inouye DW</td>
<td>University of Maryland, College Park, United States</td>
<td>10</td>
<td>530</td>
<td>53</td>
<td>49</td>
</tr>
<tr>
<td>3.</td>
<td>Rafferty NE</td>
<td>University of California, Riverside, United States</td>
<td>9</td>
<td>527</td>
<td>58.55</td>
<td>14</td>
</tr>
<tr>
<td>4.</td>
<td>Irwin RE</td>
<td>NC State University, United States</td>
<td>7</td>
<td>339</td>
<td>48.42</td>
<td>46</td>
</tr>
<tr>
<td>5.</td>
<td>Jacquemart A-L</td>
<td>Université Catholique de Louvain, Belgium</td>
<td>7</td>
<td>196</td>
<td>28</td>
<td>30</td>
</tr>
<tr>
<td>6.</td>
<td>Petanidou T</td>
<td>University of the Aegean, Greece</td>
<td>7</td>
<td>593</td>
<td>84.71</td>
<td>44</td>
</tr>
<tr>
<td>7.</td>
<td>Descamps C</td>
<td>Université Catholique de Louvain, Belgium</td>
<td>6</td>
<td>165</td>
<td>27.5</td>
<td>9</td>
</tr>
<tr>
<td>8.</td>
<td>Quinet M</td>
<td>Université Catholique-de Louvain, Belgium</td>
<td>6</td>
<td>165</td>
<td>27.5</td>
<td>28</td>
</tr>
<tr>
<td>9.</td>
<td>Forrest JRK</td>
<td>University of Ottawa, Canada</td>
<td>5</td>
<td>506</td>
<td>101.2</td>
<td>21</td>
</tr>
<tr>
<td>10.</td>
<td>Knight TM</td>
<td>Martin-Universität Halle-Wittenberg, Germany</td>
<td>5</td>
<td>766</td>
<td>153.2</td>
<td>45</td>
</tr>
</tbody>
</table>

(As per JCR report 2023)

**Keywords analysis**
Using the VOSviewer program, a co-occurrence of keywords map was made using a list of 820 author's keywords. Out of all the terms used by the authors, 58 fulfilled the minimal threshold frequency and were included in the keyword co-occurrence analysis. The threshold was set at greater than or equal to 3 occurrences in the articles. The size of each node in the network corresponds to the frequency of keywords. The keywords such as "climate-change" (n = 83), "pollination" (n = 53), "phenology" (n = 40) "plant-pollinator interactions" (n = 20), and "global change" (n = 16) occurred with maximum frequency. Overall, four distinct clusters were discovered, reflecting four distinct research trajectories. Cluster 1 (Red) comprises 33 keywords representing study based on disruption of plant-pollinators interactions due to global warming, includes keywords such as "climate change" "pollination", "phenology", "plant-pollinators interactions", "global change", "flowering phenology", and "pollinators". Cluster 2 (green) this cluster comprises 9 keywords such as "global warming", "temperature", "plant reproduction", "pollination services", "precipitation", and "Bombus" representing community level pollination network analysis. Cluster 3 (blue) contains 9 keywords representing research based on influence of abiotic stress such as droughts on the physiology and behaviour of plants and animals respectively, including keywords like "drought", "nectar", "plant–pollinators interaction", "pollen", "water stress", "abiotic stress", and "floral rewards". Cluster 4 (yellow) have total 7 keywords represents study primarily based on extend of phenological mismatch between plants and pollinators. This cluster consists keywords such as "phenological mismatch", "flowering", "biotic interactions", "competition", "ecological network", "fruit production", "phenological shift".

When examining the time-overlapping network analysis shown in Fig. 4, where the node colors are determined by the average time of each keyword's occurrence year, we noticed that earlier research focused more on "flowering phenology", "global change", "interactions between plants and pollinators", "flowering time", and "foraging behavior". Recent research has given more focus as science has progressed to ideas like "drought", "floral signals", "abiotic stress" and "floral rewards".

**Top 15 most cited research articles**

Top 15 most cited articles with their journals, and total citations are listed in Table 3. Out of 15 top most cited research articles journal “Ecology Letters” published the maximum number of publications. Most of these articles (n = 9) were published after 2010. The most cited article was written by Memmott et al., published in “Ecology Letters” with 889 citations titled “Global warming and the disruption of plant-pollinator interactions”. The authors mimicked the effects of the phenological alterations that can be anticipated with a doubling of atmospheric CO₂ by using an empirical network of interactions between plants and pollinator species (Memmott et al., 2007b). The research article by Hageland et al., titled "How does climate warming affect plant-pollinator interactions?" was ranked second with 738 citations also published in journal “Ecology Letters”. The purpose of this review is to uncover the effects of temperature generated mismatches and their implications for pollination interactions.
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Title</th>
<th>Journal</th>
<th>Year of Publication</th>
<th>Total citations</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Global warming and the disruption of plant-pollinator interactions</td>
<td>Ecology Letters</td>
<td>2007</td>
<td>889</td>
<td>(Memmott et al., 2007b)</td>
</tr>
<tr>
<td>3.</td>
<td>Plant-pollinator interactions over 120 years: Loss of species, co-</td>
<td>Science</td>
<td>2013</td>
<td>718</td>
<td>(Burkle, Marlin and Knight, 2013a)</td>
</tr>
<tr>
<td></td>
<td>occurrence, and function</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Multiple stressors on biotic interactions: How climate change and</td>
<td>Biological Reviews</td>
<td>2010</td>
<td>263</td>
<td>(Schweiger et al., 2010)</td>
</tr>
<tr>
<td></td>
<td>alien species interact to affect pollination</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Artificial light at night as a new threat to pollination</td>
<td>Nature</td>
<td>2017</td>
<td>253</td>
<td>(Knop et al., 2017)</td>
</tr>
<tr>
<td></td>
<td>networks across time, space, and global change</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Early onset of spring increases the phenological mismatch between</td>
<td>Ecology</td>
<td>2013</td>
<td>222</td>
<td>(Kudo and Ida, 2013)</td>
</tr>
<tr>
<td></td>
<td>plants and pollinators</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>suggests that early flowering plants are favoured</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>An examination of synchrony between insect emergence and flowering</td>
<td>Ecological Monographs</td>
<td>2011</td>
<td>192</td>
<td>(Forrest, 2011)</td>
</tr>
<tr>
<td></td>
<td>in Rocky Mountain meadows</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pollinator interactions</td>
<td></td>
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</tr>
</tbody>
</table>

(As per JCR report 2023)
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Title</th>
<th>Journal</th>
<th>Year of Publication</th>
<th>Total citations</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.</td>
<td>Plant-pollinator interactions and phenological change: What can we</td>
<td>Oikos</td>
<td>2015</td>
<td>163</td>
<td>(Forrest, 2015)</td>
</tr>
<tr>
<td></td>
<td>learn about climate impacts from experiments and observations?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(As per JCR report 2023)

**Discussion**

This analysis was performed to identify the research hotspots and emerging trends in the field of climate change and their impact on the relationship between plants and pollinators. In this study, 229 articles from the Scopus database were subjected to a bibliometric analysis utilizing statistical tools like VOSviewer. Any study domain's publishing growth or fall is recognized as a trustworthy indicator of broad trends. In every study field, the quantity of publications is seen to be a reliable predictor of general trends (Peng et al., 2020). The ICCPI study had few annual publications prior to 2013, and after 2015, this number significantly rose. After 2015, the number of publications increased by around 12 each year. The total number of articles has increased consistently over time at an average rate of 14.31%, indicating a significant expansion of this field's study. The analysis of 229 articles was conducted that published from 2007 to 2023, which met the inclusion criteria. The total published literature covers 47 countries/regions and more than 64% of all papers on the impact of climate on plant pollination interactions are from the top three nations or regions, indicating a high concentration of publications in this field of study.

The research on ICCPI involved about 751 authors and 160 institutions, showing that scientists from throughout the world are interested in how climate change may affect relationships between plant pollinators. Four out of ten top institutions are solely in the United States, demonstrating that American academics are more concerned with how climate change may affect the mutualistic relationships between plants and pollinators in terms of total publications and citations. The United States also held the top spot, surpassing other nations. The USA was ranked #1st in terms of international collaboration, working with 25 other nations. The United States, Germany, and the United Kingdom participated in the majority of international partnerships. This was mainly made feasible by the fact that these nations were able to draw researchers and academics from all over the world and provide them access to funding for
their work as well as the necessary infrastructure to carry it out. The keyword analysis offered a distinct viewpoint on this field's growth and developments. By focusing on the articles, keyword analysis is used to investigate how difficulties related to an area of study relate to one another both now and in the future (Donthu et al., 2021).

Four main investigation themes that may be grouped into different perception tactics and outcomes of shifts in the phenology of both plants and pollinators were identified in our review's keywords assessment. Cluster 1 may ultimately see a contemporaneous drop in the population abundance of both plants and pollinating animals due to the disruption and long-term impacts of global warming, such as the mismatch of phenological synchrony between plants and pollinators (Alzate-Marin et al., 2021; Handley and Tronstad, 2023; Villagomez et al., 2021; Zamora-Gutierrez et al., 2021; Zoller, Bennett andKnight, 2023). In cluster 2, researchers investigated pollination networks to see how their community might be affected by a disturbance (Doré, Fontaine and Thébault, 2021; Dupont et al., 2009; Elle, Elwell and Gielens, 2012; Minachilis et al., 2020; Pelayo et al., 2021; Santamaria et al., 2018; Xiao et al., 2017). Many researchers examined the effects of the climatic component "Drought" in cluster 3, where authors tried to gauge how plants would react to water stress (Aldridge et al., 2011; Chakraborty et al., 2022; Gambel and Holway, 2023; Hilário et al., 2023; Höfer et al., 2023; Thuma et al., 2023). Cluster 4 is made up of studies that look at the effects of phenological changes caused by climate conditions, including early or late blooming, poor seed set, and changes in the quantity and quality of nectar (Chakraborty et al., 2022; Hemberger, Rosenberger and Williams, 2023; Olsen et al., 2022; Plos et al., 2023; Rafferty, Diez and Bertelsen, 2020; Sutton et al., 2018).

**Conclusion**

In this bibliometric analysis, we evaluated the publications productivity and contributions of countries, authors, and journals. In terms of annual publications, research in the topic of ICCPI has generally shown tremendous growth. The maximum number of articles (n = 29) was published in 2022 and the USA ranked first in both global literature production (n = 85), and in international collaborations (n = 41). Cluster keyword co-occurrence network analysis identified a total of four distinct study fields; these research areas are connected as a result of the diverse impacts of climate change on the interactions between plants and pollinators. The studies related with drought is the new emerging research topic in this area. By providing the list of top publications, journals, and research hotspots, this study gives a brief overview of the research trends that has been done thus far and lays the groundwork for future researchers.

**Declarations**

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Ethics approval and consent to participate: Not applicable

Competing interests: The authors declared that they have no known conflict of interest related this manuscript. All the authors have critically reviewed and approved the final draft of the manuscript.

Author's contributions: Pooja Singh and Baby Gargi: Data curation, analysis, writing-original draft; Prabhakar Semwal: Conceptualization, Review and Edit, Project administration.

Funding: Not applicable

Availability of data and material: All data and material related this study has been included in this manuscript.

References


Biodiversity and Ecosystem Services on pollinators, pollination and food production.


tolerance is still susceptible to heat events predicted under future climate change. Ecol. Entomol. 43:
506–512.


throughout the United States. Ecological Applications 30: e02025.

and rainfall affect plant phenology and floral resource availability for pollinators. Front. ecol. evol.
11.

75. Van Eck, N. and L. Waltman. 2010. Software survey: VOSviewer, a computer program for bibliometric

76. Van Raan, A. 2014. Advances in bibliometric analysis: research performance assessment and

temperature and photoperiod on the seasonal timing of Western honey bee colonies and an early

Adapted Behaviour and Shifting Species Ranges;[proceedings of the International Conference”
Fingerprints" for Climate Change: Adapted Behaviour and Shifting Species Ranges, Held February

loss and its remedial measures using nature based conservation approach: a global perspective.
Biodiversity and Conservation: 1–21.

80. Xiao, Y., X. Li, Y. Cao, and W. Hu. 2017. A global change of specialization and generalization in

Experimental warming causes mismatches in alpine plant-microbe-fauna phenology. Nature
Communications 14: 2159.

82. Zamora-Gutierrez, V., A.N. Rivera-Villanueva, S. Martínez Balvanera, A. Castro-Castro, and J. Aguirre-


Figures
Figure 1

The flow diagram of process of literature search.
Figure 2

(A) Annual distribution of publications on impact of climate change on plant-pollinators interactions, (B) Top 10 most productive institutions, (C) Top 10 most productive countries with number of published documents.
Figure 3

(A) Network of collaborations between the countries, (B) Network visualization of co-cited authors, (C) Cluster network visualization of keywords.
Figure 4

Time-overlay network analysis of keywords.