

# Bibliometric Analysis on the Climate Change-Mediated Breeding Asynchrony in Birds

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## Abstract

AC & DC have equally conceived the idea and designed the methodology, contributed to the acquisition of data, analysis of data, and written the paper. AD has contributed to the literature review & interpretation of results.

This bibliometric study systematically analyses research trends on climate change and its effects on avifaunal reproductive phenology for a span of 40 years (1985 to 2024). Utilizing Google Scholar as the primary data source, a comprehensive search query encompassing terms like “climate change,” “hatching asynchrony,” “birds,” “breeding”, “phenology”, etc., was employed. Data was meticulously filtered, validated, and analysed using Paperpile, Microsoft Excel 2019, and VOSviewer version 1.6.20, with a specific classification for dietary/habitat specialists and climate change-prone habitats. The analysis reveals a significant increase in publications since the early 2000s, reflecting a growing scientific attention towards adaptive changes in reproductive strategies, particularly hatching asynchrony in birds, against environmental and climatic fluctuations. Coastal zones around the world have emerged as the most extensively studied bird habitats, followed by tropical and urban parts. Urban birds, insectivores, and cavity-nesting bird species have been recorded as the most frequently investigated groups. Furthermore, high-impact contributors such as Marcel E. Visser and Christiaan Both, and prominent journals including Ornithology and Nature Ecology & Evolution were identified through co-authorship, citation, and bibliographic coupling analyses. The current study traces valuable insights into the evolving scientific inquiry in this critical field, mapping its intellectual topography and highlighting significant contributions to date. Though confined within a single database source and a defined temporal scope, this study offers a foundational understanding for future research in breeding asynchrony phenomena.

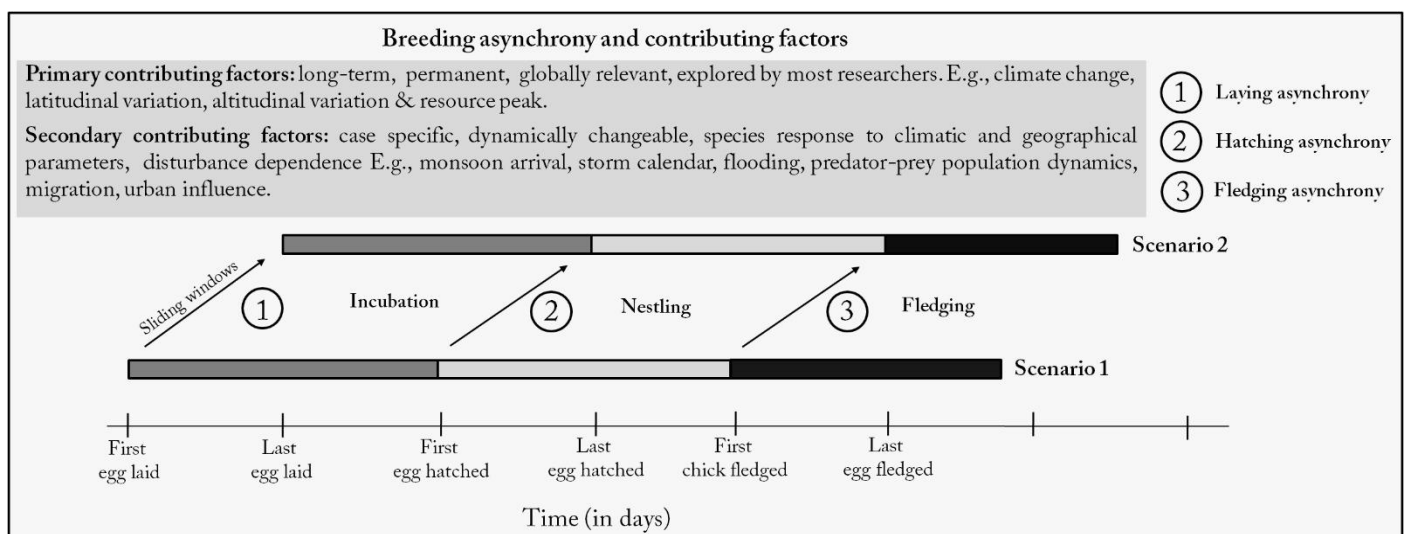
**Keywords:** climate change, bibliometric analysis, breeding asynchrony

## INTRODUCTION

Breeding asynchrony is widespread in avian broods, with its most prominent form manifesting as hatching asynchrony, with intervals between first and last nestlings ranging from hours to several days (Clark & Wilson, 1981; Magrath, 1990; Stoleson & Beissinger, 1995; Bizberg-Barraza et al., 2024). Hatching asynchrony is derived from laying interval, delays in the onset of incubation, and differential investment in successive eggs (Stoleson & Beissinger, 1997; Tomás, 2014; Votier et al., 2009). (Lack, 1954) suggested that hatching asynchrony helps to utilize resource peaks, manage food scarcity by creating a competitive hierarchy among nestlings, allowing the first-hatched to outcompete younger

siblings for food, potentially leading to selective starvation (facultative brood reduction hypothesis) (Figure 1). Other theories propose that hatching asynchrony reduces parental workload by minimizing sibling competition (the rivalry reduction hypothesis) or by spreading out nestlings' maximal food demand over time (the peak load reduction hypothesis)(Mock et al., 1997; Mock & Schwagmeyer, 1990). Alternatively, hatching asynchrony could result from a rush in incubation to hasten hatching and fledging, thereby decreasing both predation risks and exposure to food shortages as the breeding season concludes (hurry-up hypothesis)(Clark & Wilson, 1981; Magrath, 1990), or it may serve to preserve egg viability in warmer conditions (egg viability hypothesis)(Amundsen & Slagsvold, 1991; Stenning, 1996). Similarly, nutritional stress might prompt females to increase laying gaps, thus increasing hatching asynchrony, or conversely, decrease hatching asynchrony by delaying the onset of incubation as they spend more time foraging to accumulate energy reserves(Stoleson & Beissinger, 1995; Visser et al., 1998; Węgrzyn et al., 2023).

The degree of breeding asynchrony can be highly variable with respect to populations and/or environmental conditions(Gillette et al., 2021; Kontiainen et al., 2010; Martínez-Padilla & Viñuela, 2011; Potti, 1998; Stenning, 2008; Wiebe & Bortolotti, 1994). Breeding asynchrony increases as breeding seasons progress(Bowers et al., 2016; Callery et al., 2022; Mayor et al., 2017; Parejo et al., 2015),food availability decreases(Svensson & Nilsson, 1995; Wiebe & Bortolotti, 1994),and the air temperature rises(Ardia et al., 2006; Vátka et al., 2011; Vedder, 2012; Visser et al., 2009). Experimental manipulations of breeding asynchrony have suggested it can be costly, increasing the risk of unnecessary brood reduction(Viñuela, 1999; Wiebe & Bortolotti, 1994) and decreasing females' post-breeding survival(Slagsvold et al., 1995). However, some studies suggest that under poor food availability or late in the reproductive season, longer hatch intervals might allow parents to fledge more chicks(Wiebe & Bortolotti, 1994; Stenning, 2008) or fledge them in better condition(Slagsvold et al., 1995), or even enhance parents' future reproductive success by reducing the cost of reproduction(Clark & Wilson, 1981; Stoleson & Beissinger, 1995). It is well accepted that female birds optimize their net fitness gain by calibrating asynchrony to environmental signals. Nevertheless, the within-individual phenotypic plasticity underlying population-level relationships between breeding asynchrony and the environment remains poorly understood(Merilä & Hendry, 2014; Sauve et al., 2019; Viñuela, 1999).



**Figure 1: Phenomena Of Breeding Asynchrony And Contributing Factors**

Our study primarily focuses on generating collaboration networks and identifying research trends using the literature available on climate change-mediated breeding asynchrony in birds, and identifying the gaps that need to be addressed. This is crucial for understanding the research trends through the decades, as this will help in addressing gaps in conservation and ecology policies, as well as help researchers gain a comprehensive idea of how this topic has been studied through the decades.

## METHODOLOGY

### Data source and rationale of search

The first step in any bibliometric study is to determine the appropriate database to use for retrieving relevant information. In the current study, Google Scholar was relied upon to accomplish the objective of the study. Google Scholar is a multidisciplinary citation database, delivers an enormous search result in each field. In our study, the most comprehensive search results were provided by Google Scholar compared to other search databases. Google Scholar is a free database that includes content from other databases, such as Scopus and WOS. Furthermore, filtering and exporting data from Google Scholar to other analysis programs is easier to perform. Google Scholar allows for search using terms in titles or titles/abstracts or name of the journal or name of the author, or affiliation. The selection of GS over other popular bibliographic database managers like Scopus, Web of Science (WoS), etc. was made due to its consistent citation retrieving ability across various categories, languages, open access, and compatibility with downstream software, along with suitability in recent bibliometric and scientometric studies (Aguillo, 2012; Pereira & Mugnaini, 2023).

Research output (data) on a predetermined research query was retrieved from Google Scholar (Martín-Martín et al., 2021). These data retrieval sources were used for the bibliometric analysis specific to the research query. The search query was set as TS (Topic Search) = (keywords: climate change, hatching asynchrony, birds, habitats, ecology, phenology, egg laying, nesting, breeding) at the time of data filtering. The retrieved articles contained these keywords and their variants in their titles, keywords, and abstracts of main texts. A custom period of 40 years (1985 to 2024) was set, keeping parity with the literary onset of climate change research (Callaghan et al., 2020). The web searching was performed within one day to avoid any deviation caused by the continuous updates of the databases. Preliminary data was collected for analysis, and then the data was further filtered and sorted out based on publication type, content, and the DOI was validated. The publication type was restricted to “journal article,” “edited book,” or “book chapters”. The articles with all of the terms “climate change, hatching asynchrony, asynchrony, birds, habitats, ecology, phenology, egg laying, nesting, birds”, with at least one of the words “birds OR environment OR climate change OR hatching asynchrony”, anywhere in the article, returning the articles dated from 1985 to 2024 (search query:

climate+change+hatching+asynchrony+asynchrony+birds+habitats+ecology+phenology+egg+laying+nesting+birds+birds+OR+OR+OR+environment+OR+OR+OR+climate+OR+change+OR+OR+OR+hatching+OR+asynchrony&hl=en&as\_sdt=0,5&as\_ylo=1985&as\_yhi=2024,search date range= 1985-2024) were selected and retrieved (**Figure 2**). Publications in multiple languages (English, Spanish, German, among others) were considered to broaden the scope of the literature studied. To eliminate duplication produced from database screening, we used a web-based reference management tool called “Paperpile”.

### Data analysis

Relevant files were sourced from Google Scholar and then linked to Paperpile, where the information was manually reviewed and updated within the Paperpile library. After manual review, Paperpile’s built-

in duplicate-removal software was used to merge papers with multiple versions into a single file. Thereafter DOI of each publication was checked and validated for the same reason using the VOSviewer software. The data from the Paperpile library, combined with information from the Google Scholar database, was effectively exported to VOSviewer and Microsoft Excel for further analysis. For this process, we utilized Microsoft Excel 2019 and VOSviewer version 1.6.20.

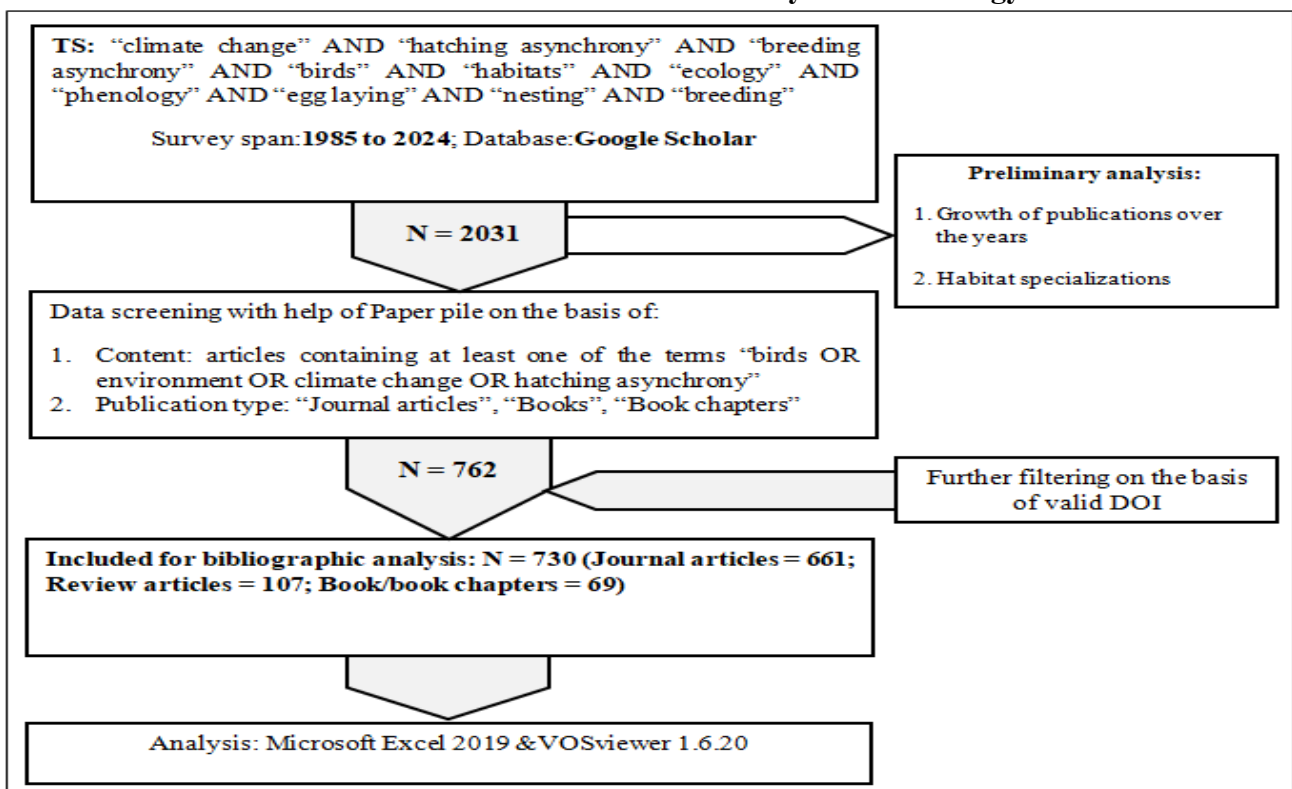
**Keyword sorting for research output on hatching asynchrony with ecological variables**

The bibliometric corpus retrieved from Google Scholar was further classified separately under (i) dietary/habitat specialists, and (ii) habitats prone to climate change, concurrently occurring with primary keywords - hatching/breeding asynchrony. The dietary/habitat specialists are divided into 5 categories: water and shorebirds, raptors, cavity-nesting birds, insectivore birds, urban birds, and others. Habitats prone to climate change are divided into 08 categories – alpine, tropics, coastal, urban, high altitudes/mountains, grasslands, islands, and others (*Table 1*). Numbers of articles were counted to identify the most surveyed/represented categories within the time frame.

**Table 1: Database size, Dietary/Habitat specialist bird groups, and Habitats prone to climate change, taken into consideration for this study**

Database size	Dietary/Habitat Specialists	Habitats prone to climate change
N= 2031	Waterbirds & shorebirds, raptors, cavity nesting birds, insectivore birds, urban birds, and others	alpine, tropics, coastal, urban, high altitudes/mountains, grasslands, islands, and others

**FIGURE 2: An overview of data analysis methodology**

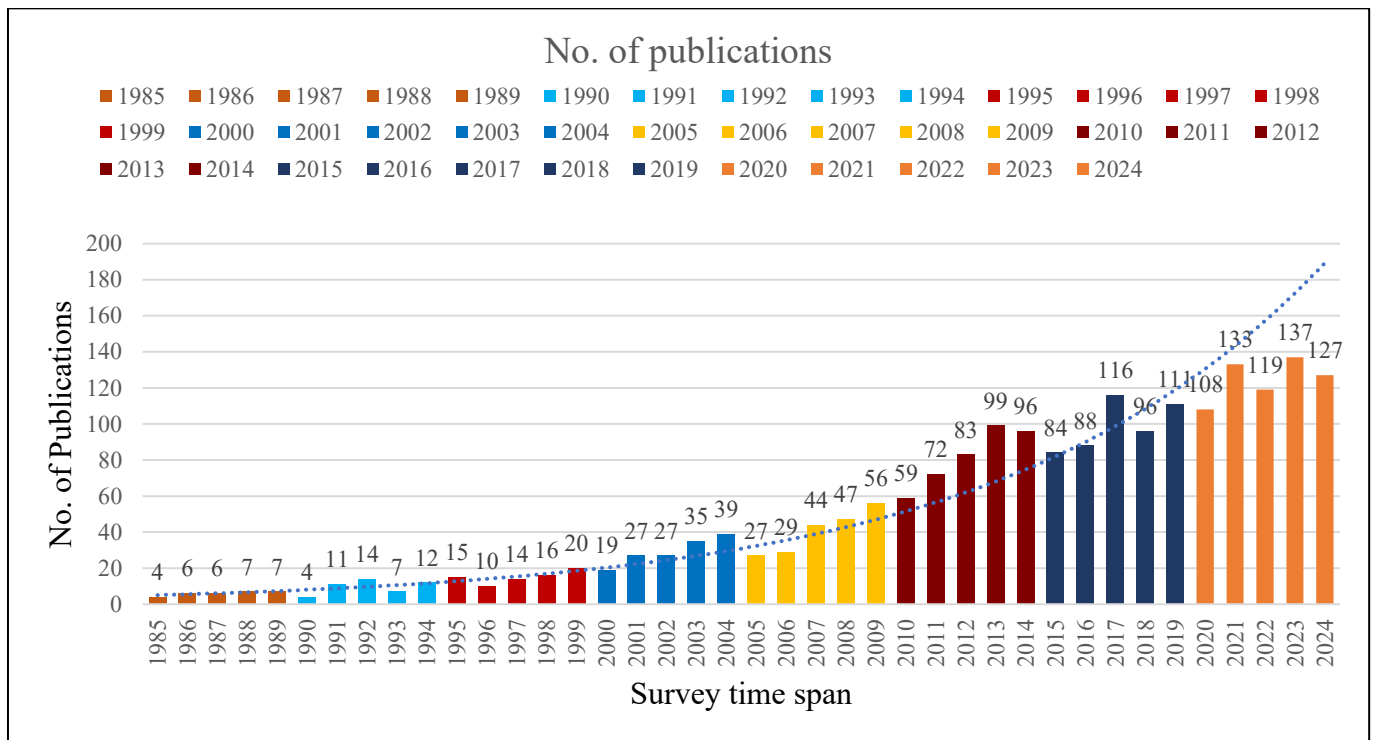


**RESULTS AND DATA ANALYSIS**

**Preliminary data analysis**

The search query returned 2031 documents, which were further analysed to determine the annual growth of publications, habitat specializations, and types of birds.

Growth of publications over the period 1985- 2024 revealed that the growth of publications was low in the 1990s, but it saw a steady increase in the 2000s (*Figure 3*). This could be due to the rising attention on climate change and its impacts that occurred in the 2000s. Following the pioneering work of (Parmesan & Yohe, 2003) which defines a diagnostic fingerprint of temporal and spatial ‘sign-switching’ responses uniquely predicted by twentieth-century climate trends and performs a suite of analyses to generate ‘very high confidence’ (as laid down by the IPCC) that climate change is already affecting living systems, and (Thomas et al., 2004), which predicted that based on mid-range climate-warming scenarios for 2050, 15–37% of species of regions and taxa sampled will be ‘committed to extinction’, we observe a steady increase in publications since 2007, after an initial decrease in the years 2005-2006. Post 2016, another rise in publications is observed, probably due to the remarkable review of Scheffers *et al.*, which analyses examples of observed impacts from meta-analyses and case studies that go beyond well-established shifts in species ranges and changes to phenology and population dynamics to include disruptions that scale from the gene to the ecosystem (Scheffers et al., 2016).



**FIGURE 3: Increment in the number of publications for 40 years (1985-2024), across 5-year ranges.**

**Table 2: Increment in the number of publications for 40 years (1985-2024)**

Publication year	No. of publications (%)
1985-89	30(1.48)
1990-94	48 (2.36)

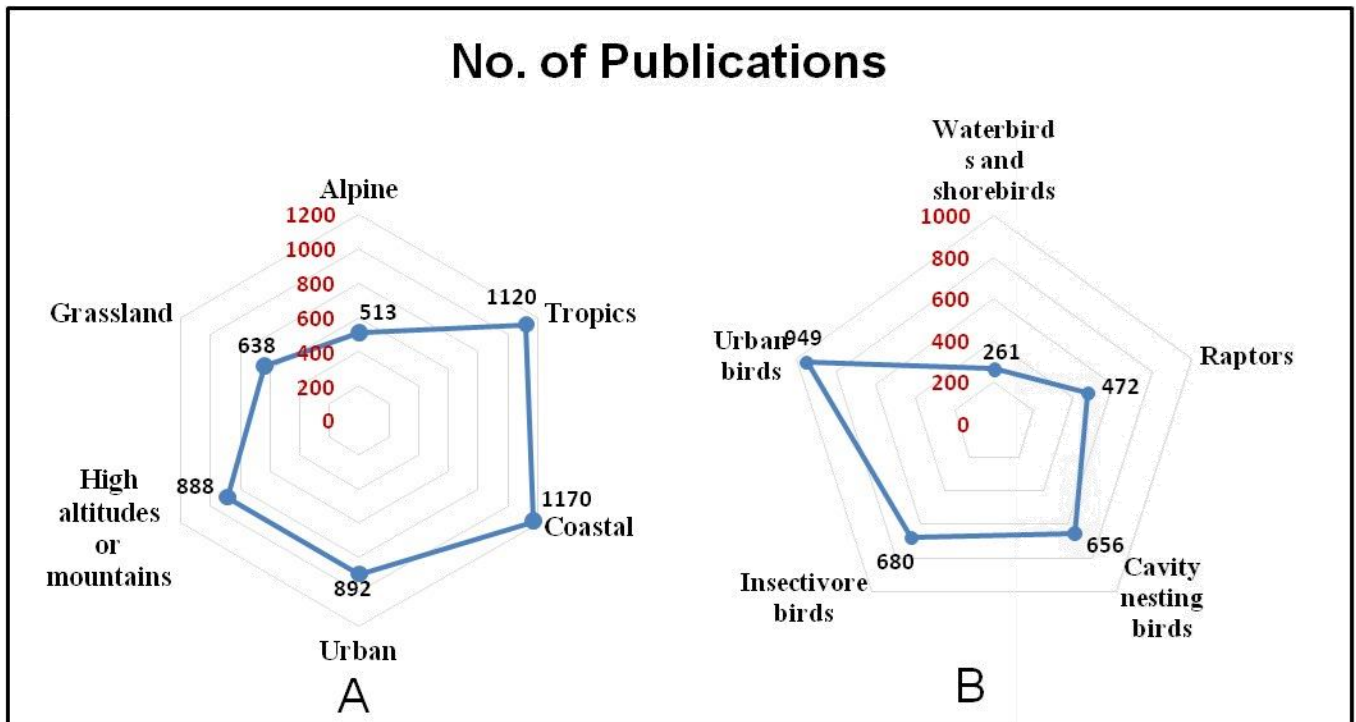
1995-99	75 (3.69)
2000-04	147 (7.24)
2005-09	203 (10)
2010-14	409 (20.14)
2015-19	495 (24.37)
2020-24	624 (30.72)

**Total publications 2031**

Further analysis of the results was done by including the terms in the search query itself, e.g., to retrieve no. of publications on alpine habitats, we included the term “alpine” in the pre-existing search query (TS: “climate change, hatching asynchrony, asynchrony, birds, habitats, ecology, phenology, egg laying, nesting, breeding”, time: 1985-2024) and noted the results down in a MS Excel worksheet. Using this method, publication data were retrieved for habitat types/categories and bird types/categories (Table 3) and graphically represented in MS Excel (*Figure 4A & B*).

**TABLE 3: Number of publications for respective habitat categories and respective bird categories**

Habitat prone to climate change	N	Dietary/habitat specialists	N
Alpine	513	Waterbirds & shorebirds	261
Tropics	1120	Raptors	472
Coastal	1170	Cavity nesting birds	656
Urban	892	Insectivore birds	680
High altitudes or mountains	888	Urban birds	949
Grassland	638		



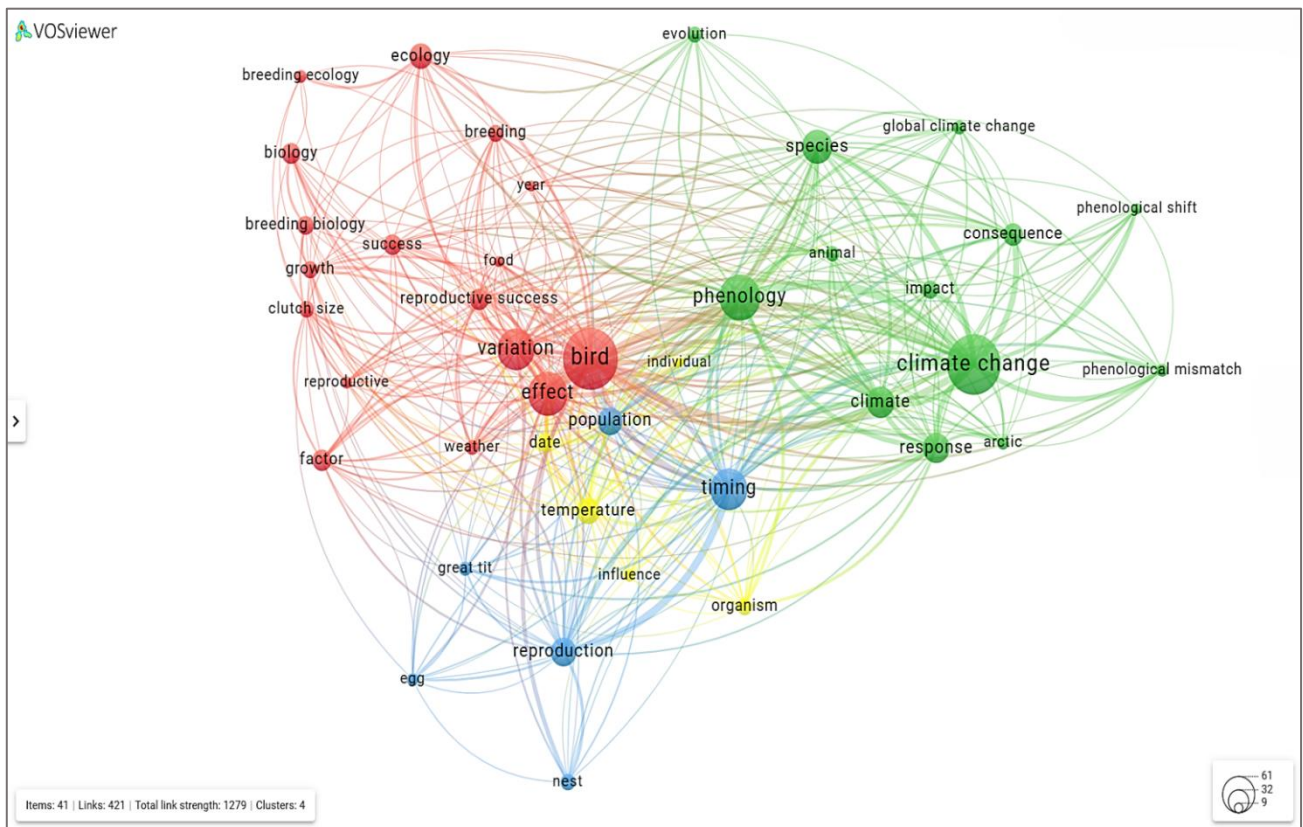
**Figure 4: Shows A Graphical Representation Of The Number Of Publications Against Respective (A) Habitat Categories And (B) Dietary/Habitat Specialists**

## Data analysis after Filtering

### Research themes

Mapping the most frequently used terms in the title/abstract fields of the retrieved literature, with a minimum occurrence of 10, gave 44 terms in total. For each of the 44 terms, a relevance score has been calculated based on their occurrences. Based on this score, the most relevant terms were selected. Excluding unrelated generic terms (i.e., study, abstract, review, research etc.), the rest 41 terms were distributed into clusters representing four main research themes (*Figure 5*):

1. **Cluster 1 (red)** includes 17 items: biology, bird, breeding, breeding biology, breeding ecology, clutch size, ecology, effect, factor, food, growth, reproductive, reproductive success, success, variation, weather, and year.
2. **Cluster 2 (green)** includes 13 items: animal, arctic, climate, climate change, consequence, evolution, global climate change, impact, phenological mismatch, phenological shift, phenology, response, and species.
3. **Cluster 3 (blue)** includes 6 items: egg, great tit, nest, population, reproduction, and timing.
4. **Cluster 4 (yellow)** includes 5 items: date, individual, influence, organism, and temperature.

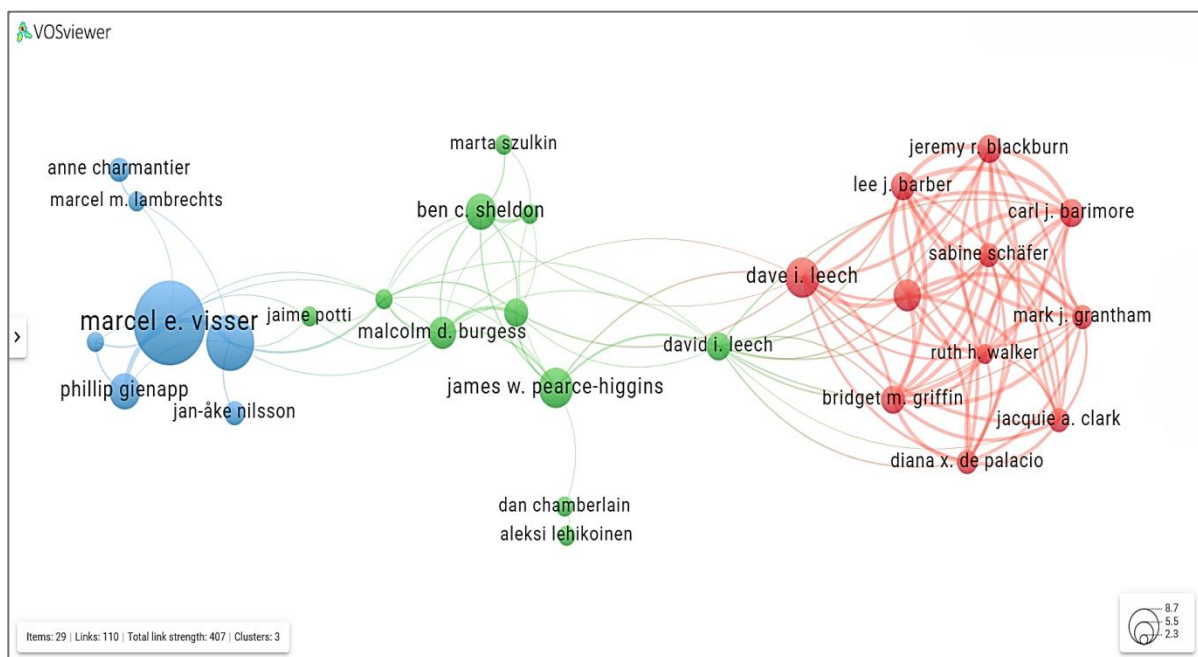


**Figure 5: Network Visualization Map (Created In Vosviewer) Of Terms In The Title/Abstract Fields Retrieved From The Filtered Literature, With A Minimum Occurrence Of 10 Terms Was Considered. The Map Shows Four Clusters Representing Four Distinct Research Themes. Nodes With Similar Colours Represent A Cluster Of Related Terms. The Map Shows 41 Items With 421 Links, Total Link Strength = 1279, And 4 Clusters.**

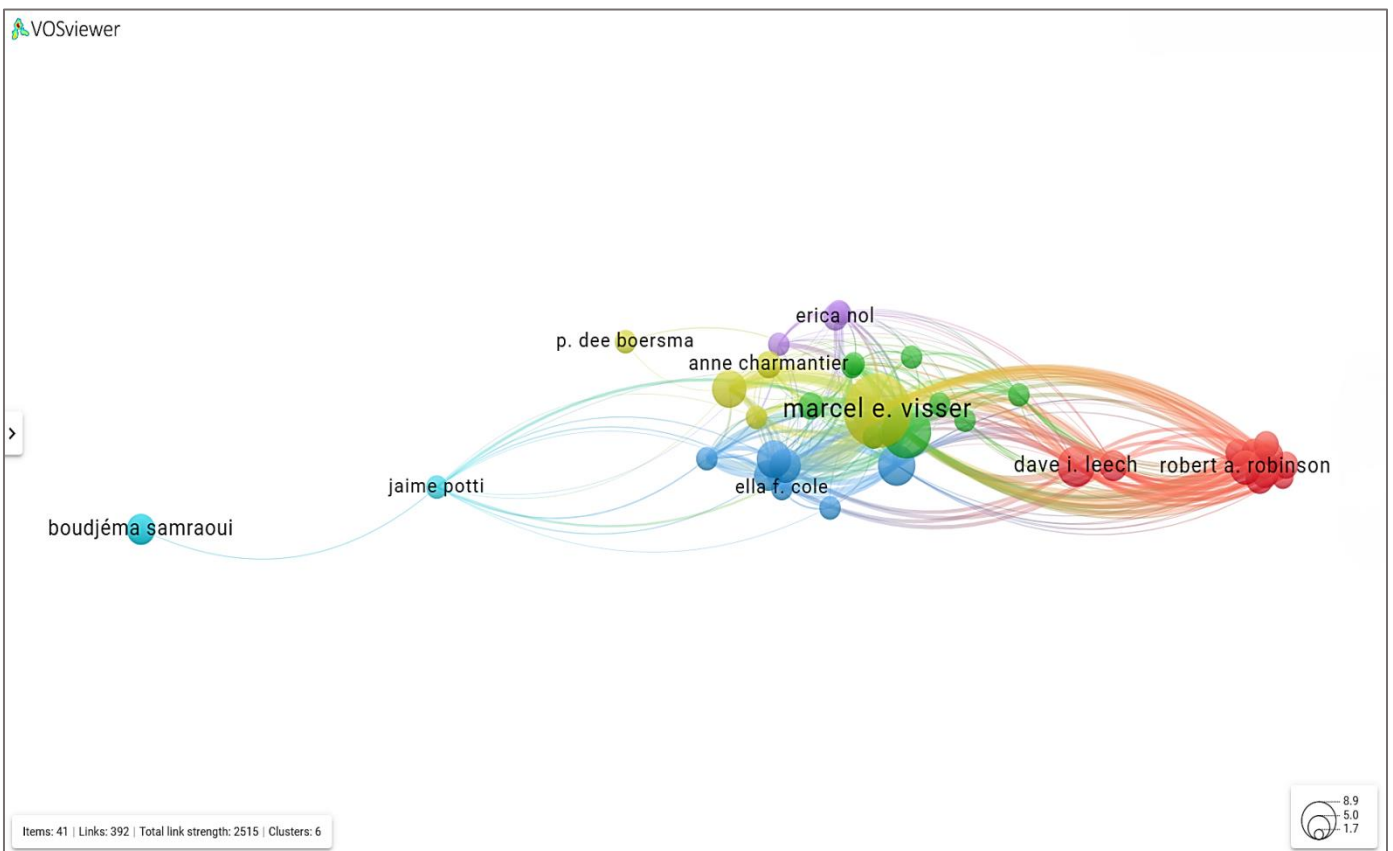
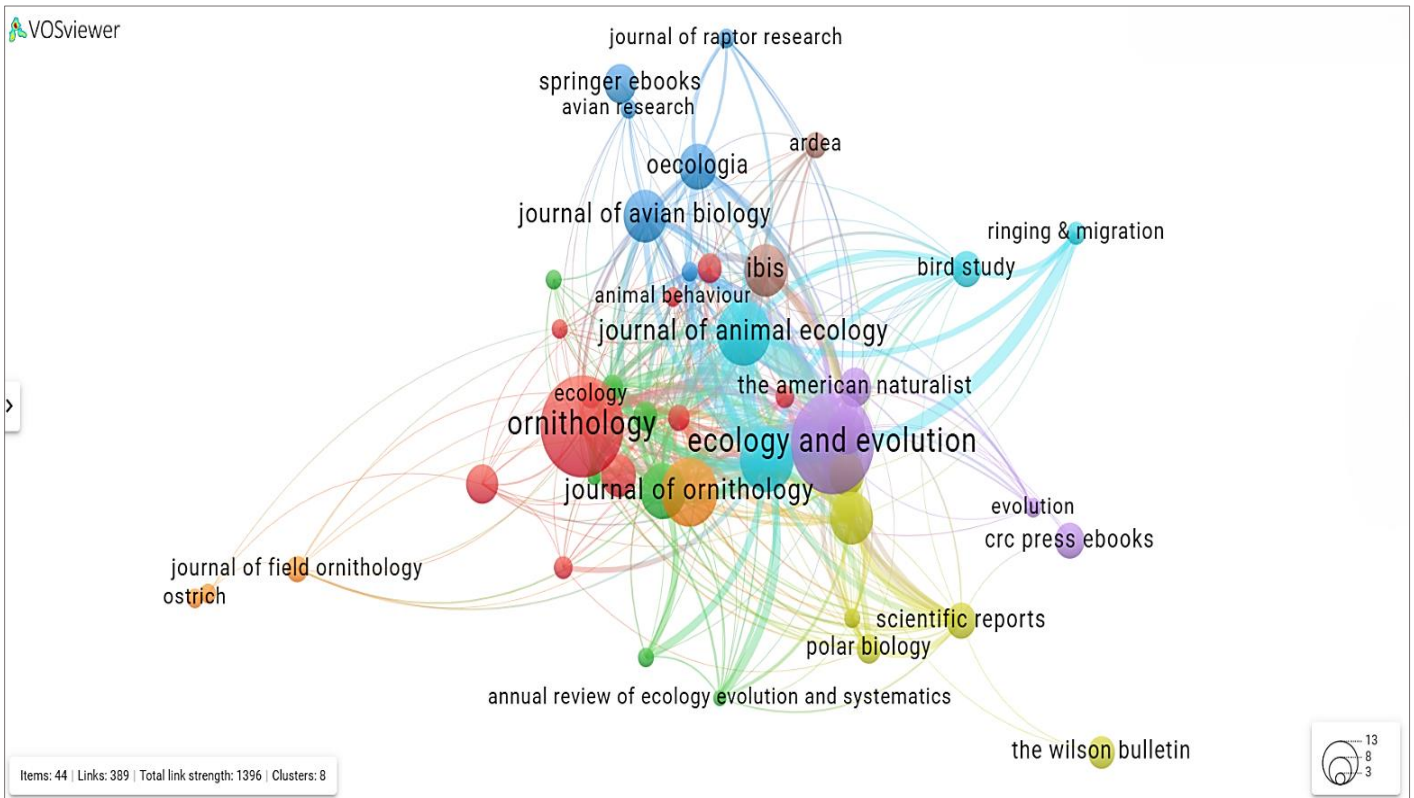
### Co-authorship analysis

Co-authorship analysis was done using retrieved data, with “Authors” as the unit of study. Considering the minimum number of documents an author has: 5 and the minimum number of citations an author has: 10, 43 of the 2241 authors meet the thresholds. Figure 10 shows details about the authors and the network visualisation map. Out of the 43 items, only the linkage map of 29 authors with the highest linkage density is shown (*Figure 6*).

1. **Cluster 1 (red)** consists of 11 individuals: Bridget M. Griffin, Carl J. Barimore, Dave I. Leech, Diana X. De Palacio, Jacquie A. Clark, Jeremy R. Blackburn, Lee J. Barber, Mark J. Grantham, Robert A. Robinson, Ruth H. Walker, and Sabine Schäfer.
2. **Cluster 2 (green)** consists of 11 members: Albert B. Phillimore, Aleksi Lehikoinen, Ben C. Sheldon, Dan Chamberlain, David I. Leech, Ella F. Cole, Jaime Potti, James W. Pearce-Higgins, Jelmer M. Samplonius, Malcolm D. Burgess, and Marta Szulkin.
3. **Cluster 3 (blue)** is a smaller group with seven individuals, including Anne Charmantier, Christiaan Both, Francisco Pulido, Jan-Åke Nilsson, Marcel E. Visser, Marcel M. Lambrechts, and Phillip Gienapp.



**FIGURE 6: Network visualization map of co-authorship analysis in the filtered literature using “Authors” as the unit of analysis. The minimum occurrences of included terms were 10. The map shows four clusters representing four research themes. Nodes with similar colours represent a cluster of related terms. The map shows 29 items with 110 links, total link strength = 407, and 3 clusters.**



**FIGURE 7: Network visualization map of citation analysis in the filtered literature using “Authors” as the unit of analysis. The minimum occurrences of included terms were 10. The map shows four clusters representing four research themes. Nodes with similar colours represent a**

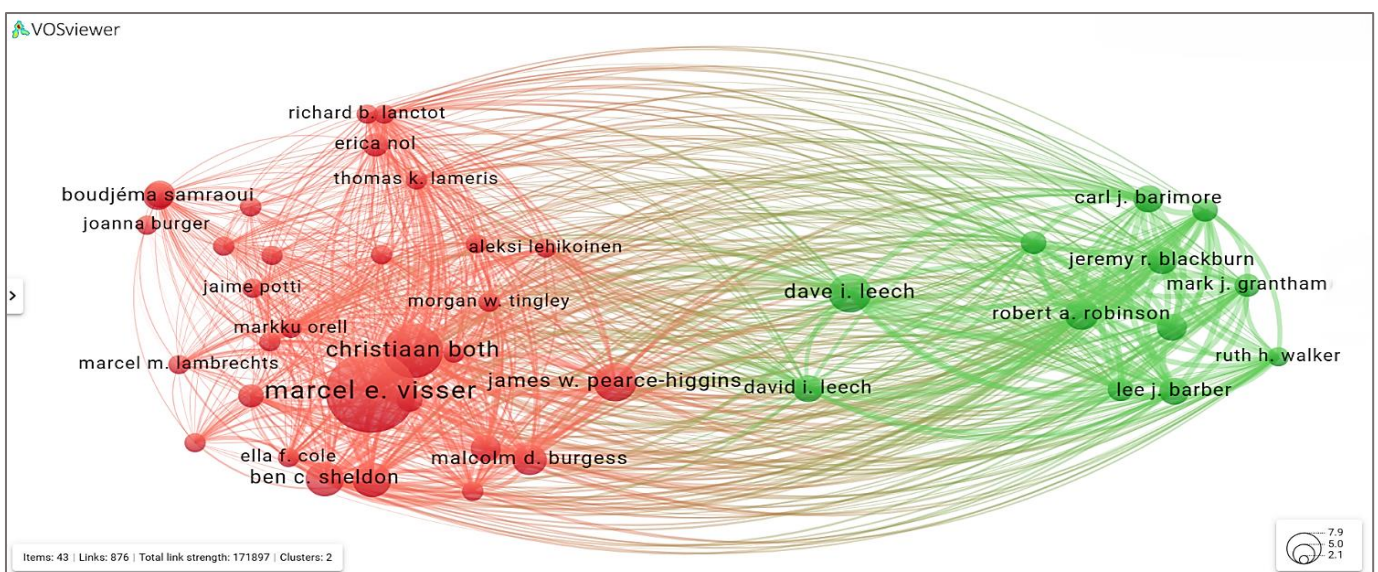
cluster of related terms. The map shows 41 items with 392 links, total link strength = 2515, and 6 clusters.

### Bibliographic coupling analysis

Bibliographic coupling analysis was done using retrieved data, with “Authors” as the unit of analysis. Considering the minimum number of documents of an author: 5 & the minimum number of citations of an author: 10, out of the 2241 authors, 43 meet the thresholds. **Figure 8** shows the details about the authors and the network visualisation map.

1. **Cluster 1 consists of 31 authors (red):** Albert B. Phillimore, Aleksi Lehikoinen, Anders Pape Møller, Anne Charmantier, Ben C. Sheldon, Boudjéma Samraoui, Christiaan Both, Dan Chamberlain, Ella F. Cole, Erica Nol, Farrah Samraoui, Francisco Pulido, Francisco Valera, Jaime Potti, James W. Pearce-Higgins, Jan-Åke Nilsson, Jelmer M. Samplonius, Joanna Burger, Malcolm D. Burgess, Marcel E. Visser, Marcel M. Lambrechts, Markku Orell, Marta Szulkin, Morgan W. Tingley, P. Dee Boersma, Phillip Gienapp, Richard B. Lanctot, Sarah T. Saalfield, Seppo Rytönen, Steven R. Beissinger, Thomas K. Lameris.
2. **Cluster 2 consists of 12 authors (green):** Bridget M. Griffin, Carl J. Barimore, Dave I. Leech, David I. Leech, Diana X. De Palacio, Jacque A. Clark, Jeremy R. Blackburn, Lee J. Barber, Mark J. Grantham, Robert A. Robinson, Ruth H. Walker, and Sabine Schäfer.

From our analysis, we observe an overwhelming representation and documentation of studies by authors primarily affiliated with institutes in North America and Europe, with the most notable countries being the US and the UK. Once again, we observe a lack of studies and authors affiliated with some of the most climate change-prone countries of the world, where species will most likely face the most severe effects of climate change in their phenology, but we observe a serious lack of studies/ representations from those areas themselves. The source of this issue may most likely be funding or resource issues, resulting in neglect of observations from some of the most vulnerable ecosystems of the Earth.



**FIGURE 9: Network visualization map of bibliographic coupling in the filtered literature using “Authors” as the unit of analysis. The minimum number of documents of an author was 5 & the minimum number of citations of an author was 10. Nodes with similar colours represent a cluster**

**of related terms. The map shows 43 items with 876 links, total link strength = 171897, and 2 clusters.**

## DISCUSSION

This bibliometric analysis examines research on climate change and its effects on avifauna from 1985 to 2024, revealing a notable increase in activity and a shift in themes within the field. Preliminary data analysis indicates a rise in publications, especially since the 2000s, which underscores a growing scientific interest in how birds refine their reproductive strategies, particularly in response to environmental changes and climate fluctuations. Different habitat categories were denoted using certain keywords, and these keywords were included in the search query to reveal the extent to which particular habitats have been studied for the influence of climate change. Results reveal that coastal habitats have been the most studied ones, followed by tropics, urban, high altitudes or mountains, grassland, and alpine habitats. Similar analysis for dietary/habitat specialists among bird groups reveals that urban birds have been the most studied, followed by insectivorous birds, cavity nesting birds, raptors, and lastly waterbirds & shorebirds.

Further analysis using the DOI of publications revealed details about research themes, co-authorship, citation, and bibliographic coupling. Upon mapping the terms in the title/abstract fields of documents in the retrieved literature, the main research themes or the most frequent terms were found to be - bird, climate change, variation, effect, phenology, reproduction, timing, reproductive success, population, impact, response, ecology. Co-authorship analysis with "Authors" as units of analysis revealed that the most notable authors who have worked in this field are Marcel E. Visser, Christiaan Both, Phillip Gienapp, Malcolm D. Burgess, James W. Pearce-Higgins, Albert B. Phillimore, Ben C. Sheldon, David I. Leech, Bridget M. Griffin, Robert A. Robinson, Dave I. Leech, and Lee J. Barber. Citation analysis with "Sources" as units of analysis revealed that the most notable journals with maximum number of publications were Ornithology, Ecology and Evolution, Journal of Animal Ecology, Journal of Ornithology, Global Change Biology, Frontiers in Ecology and Evolution, Proceedings of the royal society b biological sciences, Philosophical transactions of the Royal Society b biological sciences, Journal of Avian Biology, Ibis, Bird Study, Springer eBooks, and Oecologia. Citation analysis with "Authors" as units of analysis revealed that the most notable authors who have worked in this field are Marcel E. Visser, Christiaan Both, James W. Pearce-Higgins, Albert B. Phillimore, David I. Leech, Phillip Gienapp, Ben C. Sheldon, Robert A. Robinson, Malcolm D. Burgess, Carl J. Barimore, Bridget M. Griffin, and Lee J. Barber. Bibliographic coupling analysis done using retrieved data, with "Authors" as the unit of analysis revealed that the authors with the most linkage are Marcel E. Visser, Christiaan Both, James W. Pearce-Higgins, Albert B. Phillimore, David I. Leech, Phillip Gienapp, Ben C. Sheldon, Robert A. Robinson, Malcolm D. Burgess, Carl J. Barimore, Bridget M. Griffin, Phillip Gienapp and Lee J. Barber.

This study provides insight into how scientific interest has shaped the development of studies of climate change and its effects on birds. It observes the gradual growth and increased frequency of studies concerning birds and their behaviour, and also notes the noteworthy contributions to this field. However, there are certain limitations to this study. To begin, the reliability of the publications in this study was increased by limiting the data sources to the Google Scholar database, which may have resulted in a limited number of data sources. Finally, the time period for our analysis was selected from 1985 to 2024. However, with the research progress, publications are constantly increasing, so future research should

add new publications.

The exclusivity of the data retrieved from a single database (Google Scholar) may result in a small potential bias towards open access, English language, or high-profile publications. Restricting the types of literature analysed to published original research articles, review papers, and book chapters sometimes leads to the exclusion of gray literature in this study.

Though this single-database bibliometric analysis is potent for identifying research trends and thrust areas for future research, the integration of additional databases beyond Google Scholar and WOS, such as Scopus, Science Direct, and JSTOR, is still needed. Such could have offered sophisticated citation tracking, author profiles, journal metrics, and deep archival content, thus a better dataset for analysis. Thematic analysis on particular topics may be region-specific, such as coastal or arctic areas, or species or family-specific analysis, may help us visualise a bigger picture and design a better global action plan for species and habitat conservation.

## CONCLUSION

This bibliometric analysis comprehensively examined the evolving landscape of research concerning climate change and its multifaceted impacts on avifaunal reproductive phenology over a significant time span. One of the key findings is the pronounced surge in scholarly output, particularly since the early 2000s, which unequivocally signals a heightened scientific urgency and focus on avian responses to environmental and climatic shifts. The observed thematic progression, notably towards understanding avian reproductive strategies such as display of breeding or hatching asynchrony, underscores the field's maturation and its increasing granularity in addressing ecological challenges.

Our findings reveal a clear emphasis on coastal breeding habitats as the most extensively studied environments, followed by tropical, urban, high-altitude, grassland, and alpine regions. Concurrently, urban birds, insectivorous species, and cavity-nesting birds have garnered the most attention among dietary/habitat specialists. These trends highlight current research priorities and potentially indicate under-explored areas that warrant further investigation. The identification of core research themes—including 'bird,' 'climate change,' 'phenology,' 'reproduction,' and 'population impact'—provides a robust framework for understanding the field's intellectual structure.

Furthermore, the detailed co-authorship, citation, and bibliographic coupling analyses successfully delineated the most influential authors and prominent journals, such as *Ornithology* and *Global Change Biology*, that have been instrumental in shaping this domain. These insights offer a valuable roadmap for researchers seeking to identify key collaborators and publication venues. This study thus provides a critical overview of the scientific interest, developmental trajectory, and significant contributions within the climate change-avifauna nexus. While this analysis offers substantial insights, it is important to acknowledge limitations, including its reliance on a single database and a defined temporal scope. Future research would benefit from incorporating broader data sources and continuously updating the analysis to capture the dynamic and accelerating pace of publications in this field.

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