Article

A Decade of Vertebrate Palaeontology Research in the UK: Bibliometric and Topic Modelling Analysis

Haohan Wang [1,2], Daoming Han [1,2] and Zhaohui Pan [3,*]

1   Research Center of Natural History and Culture, Qujing Normal University, Qujing 655011, China;
    wanghh@eastern-himalaya.cn (H.W.); 2021164121@mail.qjnu.edu.cn (D.H.)
2   Key Laboratory of Yunnan Provincial Department of Education of the Deep-Time Evolution on Biodiversity
    from the Origin of the Pearl River, Qujing Normal University, Qujing 655011, China
3   Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences (CAS),
    Beijing 100044, China
*   Correspondence: panzhaohui@ivpp.ac.cn

Abstract: The study of vertebrate palaeontology in the United Kingdom holds a significant position in global research. This study conducts a comprehensive bibliometric analysis and topic modelling of UK vertebrate palaeontology from 2014 to 2023, utilizing data from the DeepBone database and Web of Science. A total of 2884 publications were analysed using bibliometric methods and Latent Dirichlet Allocation (LDA) to identify key research themes, institutional contributions, and international collaborations. The results reveal a significant increase in publication volume over the decade, peaking in 2021 with 374 papers. High-impact journals such as Nature and Science published approximately 6.60% of the total papers. The LDA analysis identified seven primary research themes, including morphology, palaeoanthropology, evolutionary biology, and geological periods. The Natural History Museum, University of Bristol, and University of Oxford emerged as major contributing institutions. Scientists from the United States were found to be the most frequent international collaborator. The average impact factor of the top journals in the field was 8.28 in 2024, highlighting the high quality of UK vertebrate palaeontology research. This study provides objective insights into the current state of vertebrate palaeontology in the UK, emphasizing its multidisciplinary nature, the importance of international cooperation in the field.

Keywords: vertebrate palaeontology; bibliometric analysis; Latent Dirichlet Allocation; UK

1. Introduction

Vertebrate palaeontology is essential for understanding the evolution of life and its co-evolution with the environment throughout geological history. Analysing current research trends provides crucial data for future studies. Advances in bibliometrics and big data science enable systematic and quantitative assessments of institutional contributions and collaborations, highlighting research frontiers [1,2]. Wang, Han et al. (2024) used bibliometric methods and Latent Dirichlet Allocation (LDA) to analyse collaboration networks and developments in vertebrate palaeontology over the past decade, enhancing our understanding of the field [3].

The United Kingdom has a notable history in vertebrate palaeontology. Charles Darwin's "On the Origin of Species" (1859) and Richard Owen's coining of the term "Dinosaur" in 1842 laid the foundational work [4,5]. However, the UK's contributions extend beyond these figures. William Buckland described the first scientifically named dinosaur, *Megalosaurus*, in 1824 [6], initiating systematic dinosaur studies. Mary Anning's discoveries of ichthyosaurs and plesiosaurs along the Jurassic Coast provided critical evidence for marine reptile research [7]. Additionally, the Old Red Sandstone formations in Scotland and Wales have yielded significant Devonian fish fossils which are crucial for understanding early vertebrate evolution [8,9]. Recently, institutions like the Natural

History Museum in London, the Oxford University Museum of Natural History, and the University of Bristol have made significant contributions [3]. The UK's fossil records span a wide range of geological periods, from the Devonian to the Cenozoic, offering invaluable resources for evolutionary studies.

This study examines UK-related vertebrate palaeontology research from 2014 to 2023 using the DeepBone database. It employs bibliometric methods to analyse international collaborations, and institutional contributions. By combining bibliometric analysis with LDA, this study identifies research hotspots in UK vertebrate palaeontology, offering insights into current and future research.

2. Materials and Methods

2.1. Data

The primary data for this study were obtained from the DeepBone big data platform as of 11 June 2024. The dataset includes 2884 publications involving UK institutions, published between 2014 and 2023. All publications were downloaded in PDF format and then converted to text format using the DeepBone platform's automated OCR process. Subsequently, the text files were manually verified and corrected to ensure consistency with the original PDFs for accurate Latent Dirichlet Allocation (LDA) analysis [10,11].

To enhance the dataset, titles of the 2884 publications were used to retrieve corresponding records from the Web of Science Core Collection (WOS). The bibliographic information, including full records and references, was exported in plain text format for bibliometric analysis [12]. This process yielded 2814 publications, representing 97.57% of the total dataset.

2.2. Methods

Annual publication data, including the proportion of publications in high-impact journals (Cell, Nature, Science–CNS) and the proportion of publications led by UK authors (either as first authors or corresponding authors), were statistically analysed using Origin Pro 2021 software (64-bit, version 9.8.0.200).

To identify research hotspots in UK vertebrate palaeontology over the past decade, spatial distribution maps were created using ArcGIS 10.2 software. The base map was sourced from the National Bureau of Surveying and Mapping Geographic Information (http://bzdt.ch.mnr.gov.cn/) and digitized at a scale of 1:41,000,000.

Bibliographic information from the WOS dataset was analysed using VOSviewer (version 1.6.20) to identify the top 30 countries collaborating with the UK and the top 30 contributing institutions in UK vertebrate palaeontology research. Advanced spatial visualization algorithms in VOSviewer were employed to construct international collaboration network, illustrating the collaborative links between the UK and its top 30 international partners, as well as the interconnections among the top 30 contributing institutions [13]. These networks were further optimised using Pajek software (version 5.16) [14]. The creation of national chord networks primarily used the gml file of the top 30 countries ranked by publication volume, exported from VOSviewer. This file was imported into Gephi 0.9.7 for organization and exported as csv format data. A Linux environment was deployed using Ubuntu 22.04.3 LTS. Finally, the open-source software charticulator (https://github.com/microsoft/charticulator) (accessed on 1 June 2024) from GitHub was used to create the chord network diagrams. The bibliographic data exported from WOS were imported into CiteSpace (version 6.2.2) to identify the top 10 journals by publication volume and the top 10 cited journals within the UK vertebrate palaeontology research domain [15–17]. The impact factors were sourced from the 2024 Journal Citation Reports published by Clarivate Analytics.

The literature data was preprocessed to ensure consistency and relevance. This involved several steps: non-alphabetic characters were removed, and all text was converted to lowercase. Common stop words from the NLTK library 3.9.1 and additional irrelevant terms specified in a supplementary CSV file were removed to focus on the meaningful content. This analysis was performed using Python 3.8.5. to uncover the underlying themes

within the literature data, we employed Latent Dirichlet Allocation (LDA), a robust method for topic modelling [10]. The preprocessed literature was transformed into a bag-of-words model using the Count Vectorizer technique. The data was then converted to a Gensim-compatible format, generating both a dictionary and a corpus, which mapped each word to a unique ID and represented each document as a bag-of-words, respectively. An LDA model was trained on the corpus, with the number of topics (num_topics) set to seven, reflecting an optimal balance between granularity and comprehensiveness. The model training involved 15 passes to ensure thorough learning, with a fixed random state for reproducibility. The LDA results were visualized using pyLDAvis 3.4.1 [18], which provided an interactive platform to explore the topics and their relationships. This visualization helped in interpreting the distribution of terms within each topic and the distances between different topics in a two-dimensional space.

3. Results

3.1. Annual Spatio-Temporal Distribution of Publications

From 2014 to 2023, a total of 2884 papers were published in vertebrate palaeontology from the United Kingdom, showing an overall increasing trend. This period can be divided into two phases: a rapid growth phase (2014–2021), where the number of publications increased steadily, peaking in 2021 with 374 papers, and a fluctuating decline phase (2022–2023), where the annual publication volume showed a fluctuating decline (Figure 1a). The proportion of publications in high-impact journals such as Cell, Nature, and Science (CNS) remained stable at approximately 6.60% (Figure 1b). The average proportion of papers led by UK authors (affiliated with UK institutions) in vertebrate palaeontology was about 59.21%, exhibiting a noticeable declining trend over the decade (Figure 1c).
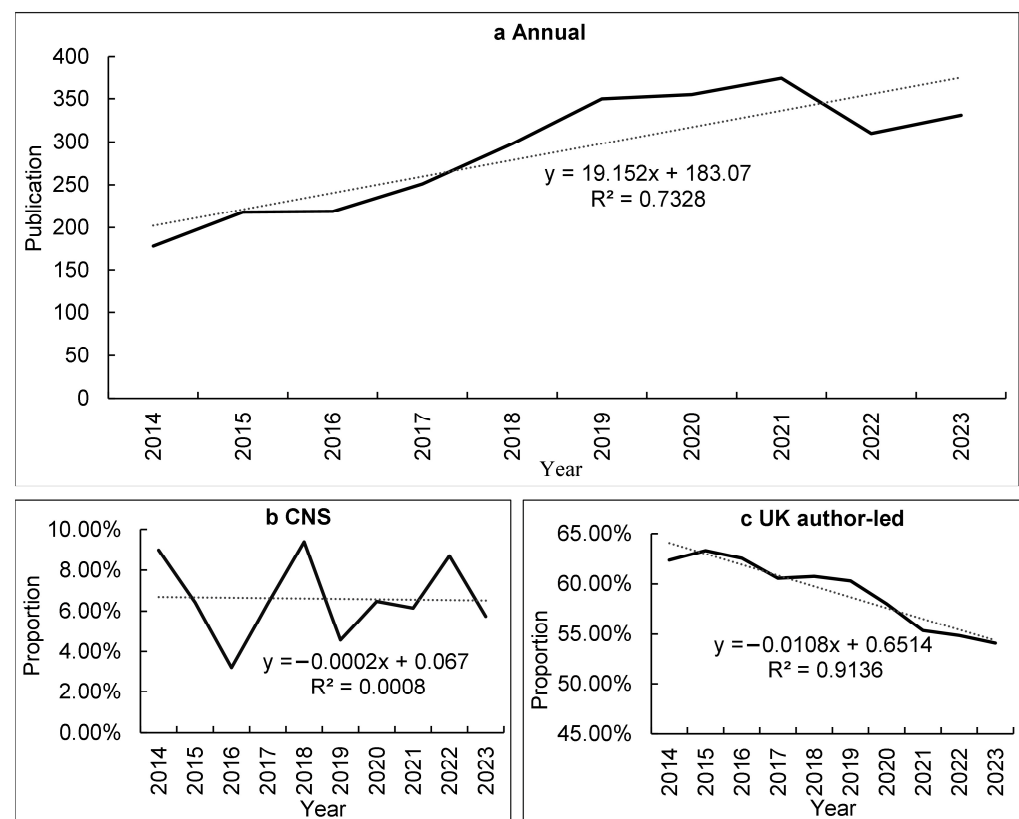

Figure 1. Annual publication trends in vertebrate palaeontology research from the United Kingdom, 2014–2023. (**a**) Total number of publications per year; (**b**) Percentage of papers published in CNS journals (Cell, Nature, Science); (**c**) Percentage of publications with UK researchers as lead authors. Black line for data points, dotted line for trend line.

An analysis of the main research disciplines based on WOS data revealed that UK vertebrate palaeontology research over the past decade spanned 29 disciplines. The primary disciplines included Multidisciplinary Sciences (899 papers, 31.95%), Paleontology (706 papers, 25.09%), and Evolutionary Biology (518 papers, 18.41%) (Table 1). This analysis focused on the actual research content rather than the journal's designated subject categories, as these classifications do not always align with the research topics.

Table 1. Top 10 research fields in UK vertebrate palaeontology publications, 2014–2023, based on Web of Science subject categories.

No.	Study Field	Frequency	Proportion
1	Multidisciplinary Sciences	899	31.17%
2	Paleontology	706	24.48%
3	Evolutionary Biology	518	17.96%
4	Biology	363	12.59%
5	Ecology	314	10.89%
6	Geosciences, Multidisciplinary	257	8.91%
7	Geology	190	6.59%
8	Anthropology	179	6.21%
9	Zoology	138	4.79%
10	Geography, Physical	130	4.51%

In the past decade, 370 publications from the UK in vertebrate palaeontology defined new taxonomic units, recording 318 new genera and 420 new species (excluding ichnospecies), four new subspecies, 39 new combinations, and two new names. The type specimens were distributed across 64 countries or regions. Greenland (6, 0.77%), the Cayman Islands (3, 0.38%), the Malvinas Islands (Falkland Islands) (1, 0.13%), and the Italy-Switzerland border (1, 0.13%) presented issues with indistinct national distinctions and were not included in this study (Figure 2). The country with the highest number of new taxonomic units defined was the United Kingdom, with 230 species (29.37%). China followed with 92 species (11.75%). The United States ranked third with 59 species (7.54%), followed by Morocco with 53 species (6.77%) and Australia with 30 species (3.83%).
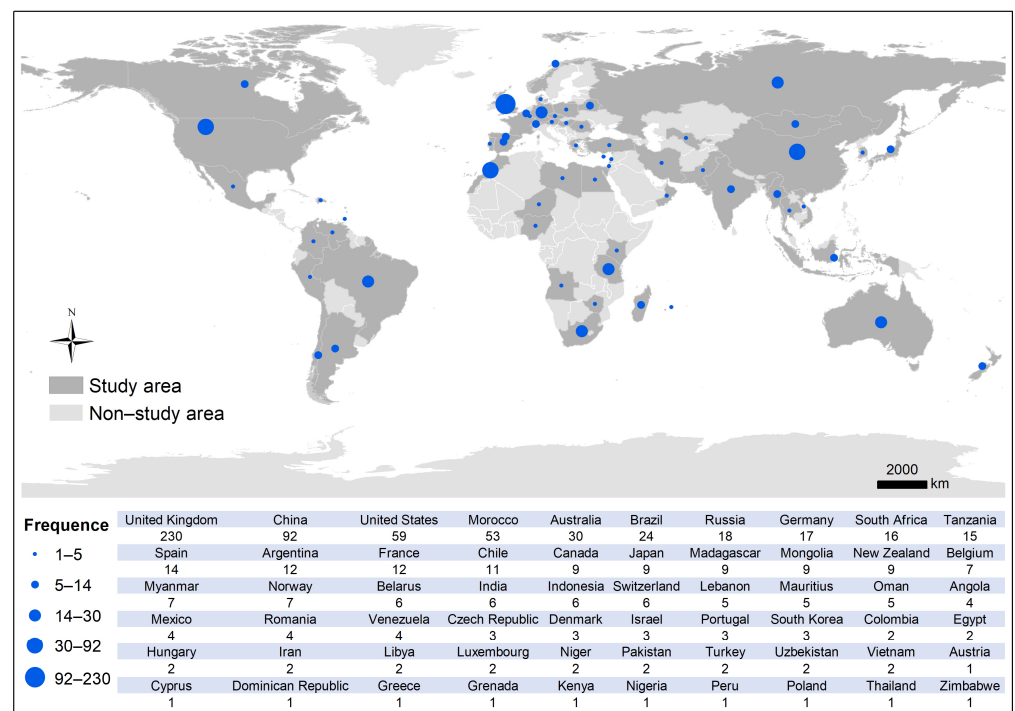

Frequence									
United Kingdom 230	China 92	United States 59	Morocco 53	Australia 30	Brazil 24	Russia 18	Germany 17	South Africa 16	Tanzania 15
Spain 14	Argentina 12	France 12	Chile 11	Canada 9	Japan 9	Madagascar 9	Mongolia 9	New Zealand 9	Belgium 7
Myanmar 7	Norway 7	Belarus 6	India 6	Indonesia 6	Switzerland 6	Lebanon 5	Mauritius 5	Oman 5	Angola 4
Mexico 4	Romania 4	Venezuela 4	Czech Republic 3	Denmark 3	Israel 3	Portugal 3	South Korea 3	Colombia 2	Egypt 2
Hungary 2	Iran 2	Libya 2	Luxembourg 2	Niger 2	Pakistan 2	Turkey 2	Uzbekistan 2	Vietnam 2	Austria 1
Cyprus 1	Dominican Republic 1	Greece 1	Grenada 1	Kenya 1	Nigeria 1	Peru 1	Poland 1	Thailand 1	Zimbabwe 1

Legend: 1–5, 5–14, 14–30, 30–92, 92–230

Figure 2. Global distribution of type localities for new vertebrate taxa described by UK-based researchers, 2014–2023.

3.2. Contributions of Countries and Institutions

Over the past decade, vertebrate palaeontology research in the United Kingdom has involved collaborations with 105 countries or regions. The most frequent collaborator was the United States, contributing to 1071 collaborative papers (38.06%). Other significant collaborators included Germany (676 papers, 24.02%), France (440 papers, 15.64%), Spain (373 papers, 13.26%), Australia (345 papers, 12.26%), China (329 papers, 11.69%), Canada (235 papers, 8.35%), South Africa (225 papers, 8.00%), Denmark (199 papers, 7.07%), and Italy (171 papers, 6.08%). Notably, collaborations between the UK, the United States, France, China, and Australia were particularly strong (Figure 3).
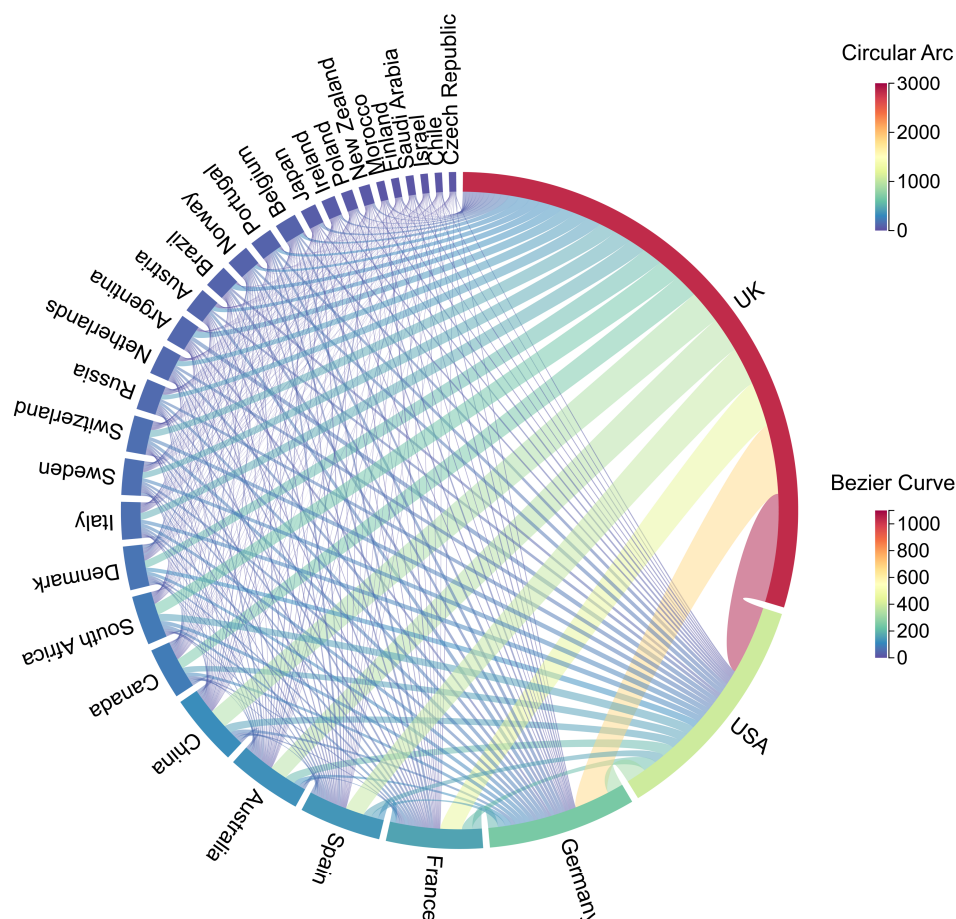
Figure 3. International collaboration network in UK vertebrate palaeontology, 2014–2023. Node size represents publication volume; line thickness represents collaboration frequency. Only top 30 contributing countries shown.

During this period, 209 institutions each contributed to more than 10 publications in UK vertebrate palaeontology research. Authors affiliated with multiple institutions were counted separately in the analysis. The Natural History Museum ranked first, appearing in 642 papers (22.81% of all publications). The University of Bristol and the University of Oxford followed, with 472 (16.77%) and 456 (16.20%) papers, respectively. Other prominent institutions included University College London (350 papers, 12.44%), the University of Cambridge (289 papers, 10.27%), the University of Edinburgh (253 papers, 8.99%), the University of Birmingham (218 papers, 7.75%). Among international collaborating institutions, the Max Planck Institute (283 papers, 10.06%), the Chinese Academy of Sciences (211 papers, 7.50%), and the University of Copenhagen (174 papers, 6.18%) were the most prominent contributors (Figure 4a). Of the 209 contributing institutions, 43 (20.57%) were from the UK. Analysis of domestic collaboration networks revealed strong partnerships

between several UK institutions, particularly between the Natural History Museum and the University of Bristol/Oxford, the University of Edinburgh and National Museums Scotland, the University of Oxford and University of Cambridge, and the Natural History Museum and University College London (Figure 4b).
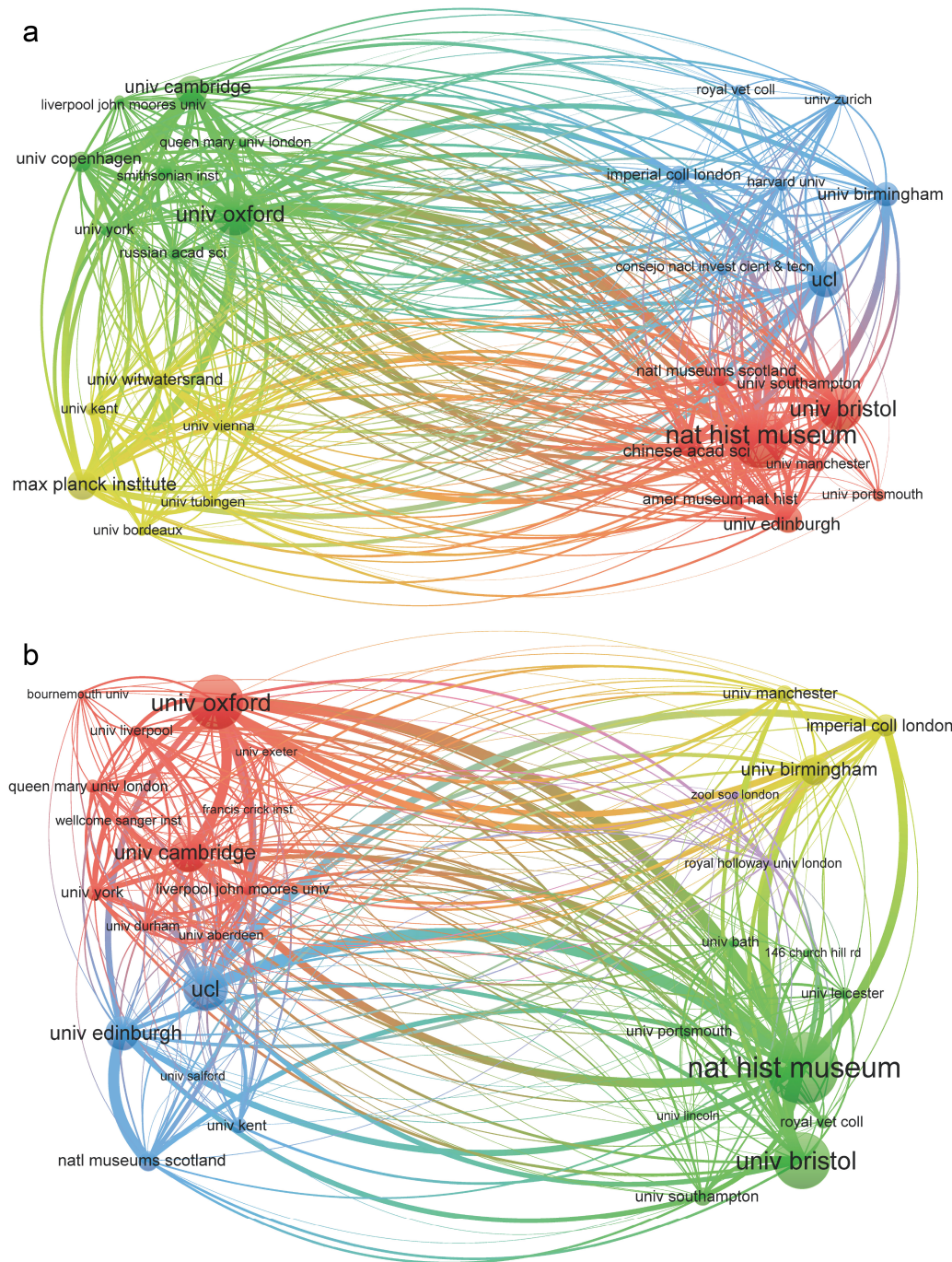

Figure 4. Institutional collaboration network in UK vertebrate palaeontology research, 2014–2023. (**a**) International collaborators network; (**b**) Domestic collaborators network among UK institutions. Node size represents publication volume; line thickness represents collaboration frequency. Only top 30 contributing institutions shown.

3.3. Key Publications and Highly Cited Journals

Over the last decade, UK vertebrate palaeontology research findings were published in 238 different journals or monographs. The top ten journals by publication volume are

listed in Table 2. Scientific Reports ranked first, with 134 articles, accounting for 4.76% of all publications. Nature and PeerJ both tied for second place, each with 109 articles (3.87%). Among the top ten journals, four are specialized and six are multidisciplinary. In 2023, the average impact factor of these journals was 8.28, with the highest impact factor being 50.5 and the lowest being 1.6. The average cited half-life was 9.81 years, with a maximum of 16.1 years and a minimum of 4.7 years. Seven of these journals are based in the UK, and three are from the US (Table 2).

Table 2. Top 10 journals by publication volume and co-citation frequency in UK vertebrate palaeontology research, 2014–2023. Impact factors (IF) are from 2023 Journal Citation Reports.

Rank	Journals	Countries	Frequency	IF (2023)	Cited Half-Life (Years)	Co-Cited Journal	Countries	Co-Citations	IF (2023)
1	Scientific Reports	UK	134	3.8	4.8	Nature	UK	8588	50.5
2	PeerJ	UK	109	2.3	4.7	Journal of Vertebrate Paleontology	USA	6716	1.6
3	Nature	UK	109	50.5	10.1	Science	USA	6112	44.7
4	Journal of Human Evolution	UK	108	3.1	13.6	PLOS ONE	USA	5619	2.9
5	Palaeontology	UK	107	2.5	16.1	Journal of Human Evolution	UK	5563	3.1
6	Proceedings of the Royal Society B-Biological Sciences	UK	98	3.8	11.1	Proceedings of the National Academy of Sciences of the United States of America	USA	5153	9.4
7	Journal of Vertebrate Paleontology	USA	96	1.6	13.9	Proceedings of the Royal Society B-Biological Sciences	UK	3519	3.8
8	PLOS ONE	USA	95	2.9	8.0	Zoological Journal of the Linnean Society	UK	3155	3.0
9	Proceedings of the National Academy of Sciences of the United States of America	USA	94	9.4	11.0	Palaeontology	UK	3102	2.5
10	Royal Society Open Science	UK	94	2.9	4.8	American Journal of Physical Anthropology	USA	3057	2.6

Nature is the most frequently cited journal in UK vertebrate palaeontology, with 8588 citations, followed by the Journal of Vertebrate Paleontology with 6716 citations and Science with 6112 citations. Among the top ten most-cited journals, six are specialized journals and four are multidisciplinary. In 2023, the average impact factor of these journals was 12.41, with the highest being 50.5 and the lowest being 1.6. Five of these journals are based in the UK, and five are from the US (Table 2).

The most frequently cited articles in UK vertebrate palaeontology over the past decade highlight the relevance and contribution of these works to the field. Among the top ten most-cited articles, five focus on phylogenetic tree construction, two on DNA sequencing methodologies, two on dinosaur research, and one on Paleontological Statistics. This distribution of research themes likely reflects the specific research interests and expertise of UK vertebrate paleontologists. These high-impact articles were published in journals with an average impact factor of 8.57 in 2023 (Table 3).

Table 3. Top 10 most co-cited articles in UK vertebrate palaeontology research, 2014–2023. Impact factors (IF) are from 2023 Journal Citation Reports.

Rank	Co-Cited References	Journal	Year	IF (2023)	Co-Citation
1	TNT, a Free Program for Phylogenetic Analysis	Cladistics	2008	3.9	231
2	The Early Evolution of Archosaurs: Relationships and the Origin of Major Clades	Bulletin of the American Museum of Natural History	2011	5.1	154
3	Phytools: An R Package for Phylogenetic Comparative Biology (and Other Things)	Methods in Ecology and Evolution	2012	6.3	152
4	TNT Version 1.5, Including a Full Implementation of Phylogenetic Morphometrics	Cladistics	2016	3.9	145
5	PAST: Paleontological Statistics Software Package for Education and Data Analysis	Palaeontologia Electronica	2001	1.7	141
6	Complete Mitochondrial Genome Sequence of a Middle Pleistocene Cave Bear Reconstructed from Ultrashort DNA Fragments	Proceedings of the National Academy of Sciences of the United States of America	2013	9.4	113
7	Paleotree: An R Package for Paleontological and Phylogenetic Analyses of Evolution	Methods in Ecology and Evolution	2012	6.3	111
8	APE: Analyses of Phylogenetics and Evolution in R language	Bioinformatics	2004	4.4	105
9	Illumina Sequencing Library Preparation for Highly Multiplexed Target Capture and Sequencing	Cold Spring Harbor Protocols	2010	-	102
10	Superiority, Competition, and Opportunism in the Evolutionary Radiation of Dinosaurs	Science	2008	44.7	90

3.4. Thematic Identification Through LDA Analysis

The Latent Dirichlet Allocation (LDA) model identified the following top-30 most salient terms in the field of UK vertebrate palaeontology research from 2014 to 2023: bone, teeth, tooth, phylogenetic, human, formation, fossil, distal, Cretaceous, Triassic, Pleistocene, surface, DNA, evolution, proximal, molecular, birds, crown, process, marine, tree, Jurassic, characters, vertebrae, ancient, cave, morphological, clade, species, and model (Figure 5). The LDA visualization also provides insight into the relationships between topics through a two-dimensional representation. In this visualization, topics are represented as circles, with their size indicating the relative prominence of each topic in the corpus. The distance between these circles reflects the similarity or dissimilarity of the topics. Closely positioned topics share more common terms and concepts, while those further apart are more distinct. For instance, Topic 1 (Morphology and Phylogenetic Analysis) and Topic 5 (Teeth and Bone Morphology) appear relatively close, indicating a strong thematic connection in fossil morphology studies at different scales. Conversely, Topic 2 (Palaeoanthropology and Molecular Anthropology) is positioned further from the others, suggesting its relative distinctiveness within the field of UK vertebrate palaeontology research.

The first topic (22.8% of tokens, Figure 6) focuses on the anatomical features of fossil vertebrates, fossil studies from geological periods, and morphological and phylogenetic analyses. This includes studying anatomical structures such as vertebrae and skulls.

The second topic (22% of tokens, Figure 6) revolves around palaeoanthropology and molecular anthropology, involving DNA and genome analysis to study human evolution, as well as archaeology and ancient human site studies. This topic also addresses the distribu-

tion of populations and species by analysing archaeological sites and fossils to understand the geographical distribution and evolution of ancient humans and other species.

The third topic (17.3% of tokens, Figure 6) centres on evolutionary biology and morphology research, covering species evolution processes and mechanisms, morphological characteristics and their functional significance, comparative analysis of fossils and extant species, studies on diversity and population structure, and the evolution of the brain and nervous system.

The fourth topic (12.4% of tokens, Figure 6) concerns geological periods and stratigraphy research. It involves studying the formation and depositional characteristics of geological periods and strata, fossil and paleontological research, analyses of biodiversity and extinction events, and comparative studies of geological and stratigraphic records globally.

The fifth topic (9.4% of tokens, Figure 6) focuses on the morphology of teeth and bones, studies on fish and fins, morphological and phylogenetic analyses, and research on fossils and preservation states.

The sixth topic (9.2% of tokens, Figure 6) revolves around the anatomy of bones and muscles, flight and kinematics, morphological and phylogenetic analyses, and functional anatomy studies.

The seventh topic (6.8% of tokens, Figure 6) centres on fossil records and phylogenetic analyses, mammalian evolution research, phylogenetic methodology studies, and morphological and phylogenetic feature analyses. It particularly focuses on mammalian evolution during the Miocene and Eocene periods.
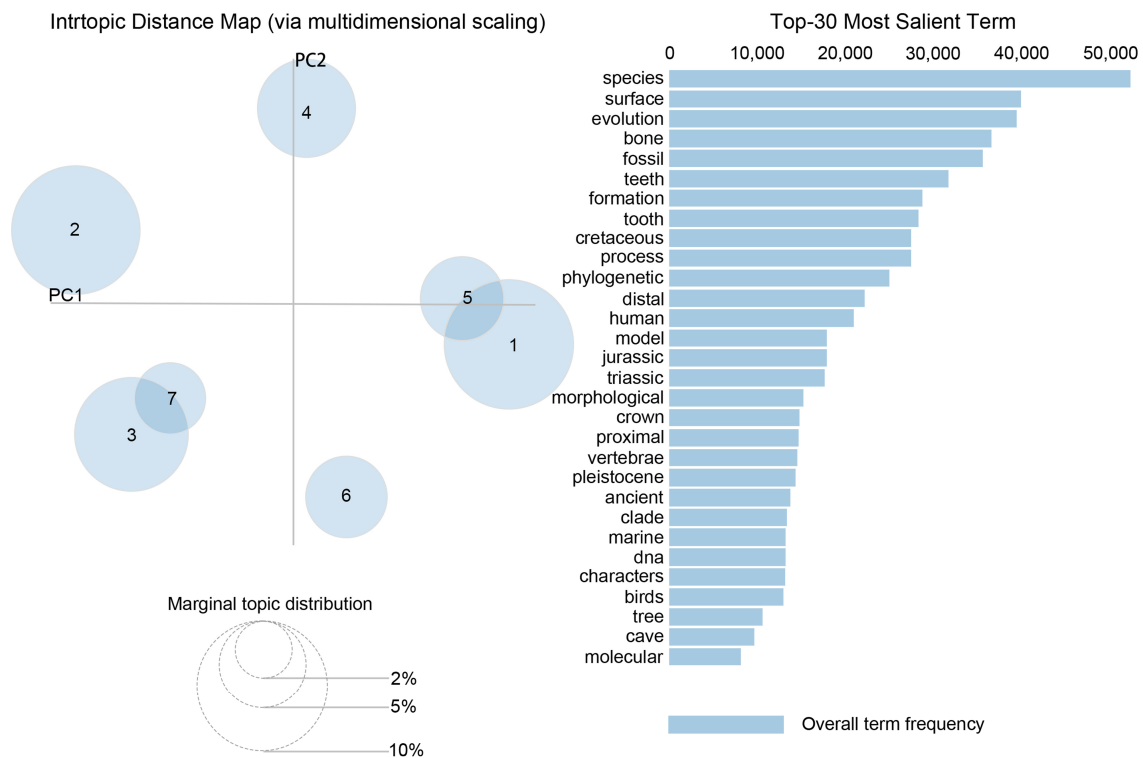

Figure 5. Topic modelling results for UK vertebrate palaeontology, 2014–2023. Intertopic distance map showing the seven main research themes identified through Latent Dirichlet Allocation (LDA) analysis.

Figure 6. Word clouds representing the seven main research themes in UK vertebrate palaeontology, 2014–2023, as identified by Latent Dirichlet Allocation (LDA) analysis. The size of each word corresponds to its frequency and relevance within the theme.

4. Discussion

4.1. Advancements and Challenges in UK Vertebrate Palaeontology

The observed annual increase in publication volume highlights the overall upward trend in UK vertebrate palaeontology, aligning with broader global academic research patterns [19]. The peak in 2022 for UK vertebrate palaeontology is consistent with global trends in the field [3]. This trend may be attributed to growing interest and participation of scholars, increased publication channels, intensified competition between publishers

and researchers [20], and continuous advancements in science and technology, expanding research fields, and significant discoveries [21]. Unlike many other fields, UK vertebrate palaeontology was not significantly impacted by the COVID-19 pandemic in 2019 [22], possibly due to two main factors: effective pandemic management policies and a substantial focus on data-based research. The latter, including computational analyses and literature reviews, could continue relatively uninterrupted during lockdown periods, providing UK researchers with an advantage in maintaining productivity.

The UK holds a significant position in global vertebrate palaeontology, with around 7% of its research being published in top-tier journals such as Cell, Nature, and Science (CNS). This is further evidenced by the presence of Nature and PNAS among the top ten journals in publication volume over the past decade. The UK's rich fossil record, spanning from the Devonian to the Cenozoic, provides a wealth of material for groundbreaking research, contributing to its prominence in high-impact publications. However, there has been a noticeable decline in the proportion of papers where UK scholars are the first or corresponding authors. This could be attributed to the rapid advancement in science and increased competition in research, which necessitates more collaborative efforts to enhance the quality of research outputs [23]. The extensive collaborations are also a reflection of the global nature of modern scientific research, where complex questions often require interdisciplinary and international teams. For example, studies on the evolution of early vertebrates often involve collaborations between UK researchers and experts from other countries with relevant fossil records, such China. Analysis shows that the UK collaborates with 105 countries, reinforcing this conclusion. Notably, significant collaborative relationships exist with countries such as the United States, Germany, and France, which have strong paleontological research communities. Additionally, the wide distribution of type specimens defining new taxonomic units across 64 locations underscores the extensive fossil resource base for UK vertebrate palaeontology. This diversity of fossil sites not only within the UK but also globally indicates the expansive reach of UK researchers in accessing and studying a variety of paleontological resources. It also highlights the UK's role as a hub for international paleontological research, attracting researchers from around the world for collaborative projects, academic exchanges, and access to its world-class facilities and expertise. Future trends will likely see an increase in cross-border collaborative research. Such collaborations are essential for advancing the field, as they allow for sharing of expertise, resources, and access to diverse fossil records, ultimately leading to more comprehensive and impactful scientific discoveries. The increasing use of advanced technologies, particularly sophisticated analytical techniques, further necessitates international cooperation. These techniques, such as finite element analysis and geometric morphometrics, often require specialized expertise and well-established technical communities with accumulated knowledge.

4.2. Key Research Themes

The Latent Dirichlet Allocation (LDA) analysis of UK vertebrate palaeontology from 2014 to 2023 identified seven key research themes, highlighting the field's hotspots and trends. LDA offers several advantages over traditional bibliometric analysis methods that rely on keywords. It can automatically process the full text of documents, eliminating the bias or omissions associated with manually selected keywords. This is particularly relevant as some journals, such as the Journal of Vertebrate Paleontology, no longer require keywords from authors. LDA provides a more comprehensive coverage of topics by capturing all potential themes and concepts within the full text, revealing secondary themes and emerging research directions. Additionally, LDA has a significant advantage over abstract-only analysis by capturing the full depth and breadth of the research, ensuring that subtle but important themes within the complete document are identified and analysed. This approach avoids subjective bias that might occur in keyword selection and maintains dynamic adaptability by adjusting and updating the topic model as new literature emerges [24].

The dominant research theme is classical paleoecological and phylogenetic studies based on morphological analyses, comprising 22.8% of the scientific output (Topic 1). This indicates a strong focus on the anatomical features of fossil vertebrates and morphological and phylogenetic analyses to reconstruct ancient environments and understand evolutionary processes. The second major theme (22%, Topic 2) centres on palaeoanthropology and molecular anthropology. This includes studies on human evolution through DNA and genome analyses, as well as archaeological site investigations. This highlights the significant emphasis on human evolutionary research within UK vertebrate palaeontology. The third theme (17.3%, Topic 3) encompasses evolutionary biology and morphological research, addressing species evolution processes, morphological characteristics, and comparative analyses of fossils and extant species. This contributes to a deeper understanding of species evolution and environmental adaptation. Another significant theme involves geological periods and stratigraphy (12.4%, Topic 4), focusing on the formation and depositional characteristics of geological periods, fossil research, biodiversity and extinction event analyses, and global comparative studies of geological records. We observe overlaps among certain topics, which can be grouped for a more cohesive presentation. For instance, Topics 5 (9.4%) and 6 (9.2%) both address fossil remains from phylogenetic and morpho-functional perspectives. Topic 5 focuses on the morphology of teeth and bones, including studies on fish and fins, while Topic 6 revolves around the anatomy of bones and muscles, flight and kinematics, and functional anatomy studies. Combining these topics emphasizes comprehensive research on morphological and functional analyses of fossil remains, revealing skeletal and muscular structures and their roles in movement and adaptation. The seventh theme (6.8%, Topic 7) pertains to mammalian evolution during the Miocene and Eocene periods, involving fossil records, phylogenetic analyses, and morphological feature studies, further enriching the under-standing of mammalian evolutionary paths and diversity.

The LDA analysis highlights the multidisciplinary nature of UK vertebrate palaeontology, combining morphology, phylogenetics, molecular biology, stratigraphy, and paleoenvironmental studies. This integrative approach offers comprehensive insights into the evolutionary processes and environmental adaptations of ancient life forms, advancing our understanding of Earth's history.

5. Conclusions

This comprehensive analysis of UK vertebrate palaeontology research from 2014 to 2023 reveals a dynamic and evolving field characterized by increasing publication output, diverse research themes, and strong international collaborations. The identification of seven distinct research themes through LDA analysis highlights the multidisciplinary nature of the field, ranging from traditional morphological studies to cutting-edge molecular anthropology. The prominence of institutions like the Natural History Museum and leading universities underscores the UK's continued leadership in vertebrate palaeontology research. The study also reveals important trends, such as the increasing emphasis on collaborative research, particularly with international partners.

The findings demonstrate the UK's significant contribution to global vertebrate palaeontology, with a substantial proportion of research published in high-impact journals. The average impact factor of 8.28 for the top journals in the field underscores the quality and influence of UK research. However, the declining proportion of UK-led publications points to both challenges and opportunities, suggesting a shift towards more collaborative international research efforts. This trend, coupled with the diverse range of countries involved in collaborations, indicates the increasingly global nature of paleontological research and the UK's central role in fostering these international connections.

This research provides valuable insights for policymakers, research institutions, and individual researchers in shaping future directions for UK vertebrate palaeontology. It suggests the need for continued support for both traditional and emerging research areas, fostering international collaborations, and promoting diversity in the field. Overall, this

study paints a picture of a thriving and evolving field, with the UK playing a pivotal role in advancing our understanding of vertebrate palaeontology on a global scale.

References

1. Kar, A.K.; Dwivedi, Y.K. Theory building with big data-driven research–Moving away from the "What" towards the "Why". *Int. J. Inform. Manag.* **2020**, *54*, 102205. [CrossRef]
2. Thomas, A.; Gupta, V. Tacit knowledge in organizations: Bibliometrics and a framework-based systematic review of antecedents, outcomes, theories, methods and future directions. *J. Knowl. Manag.* **2022**, *26*, 1014–1041. [CrossRef]
3. Wang, H.H.; Han, D.M.; Blom, H.; Dupret, V.; Pan, Z.H. Evolving trends in vertebrate palaeontology (2013–2022): A bibliometric analysis using DeepBone and Web of Science databases. *Hist. Biol.* **2024**, 1–14. [CrossRef]
4. Darwin, C. *On the Origin of Species*; John Murray: London, UK, 1859.
5. Owen, R. On Fossil Remains of Mammals found in China. *Q. J. Geol. Soc.* **1870**, *26*, 417–436. [CrossRef]
6. Buckland, W. Notice on the Megalosaurus or great fossil lizard of Stonesfield. *Trans. Geol. Soc.* **1824**, *1*, 390–396. [CrossRef]
7. Torrens, H. Mary Anning (1799–1847) of Lyme; 'the greatest fossilist the world ever knew'. *Br. J. Hist. Sci.* **1995**, *28*, 257–284. [CrossRef]
8. Janvier, P. *Early Vertebrates*; Clarendon Press: Oxford, UK, 1996.
9. Blieck, A.; Turner, S. Palaeozoic vertebrate biochronology and global marine/non-marine correlation. *CFS Cour. Forschungsinstitut Senckenberg* **2000**, *223*, 1–67.
10. Blei, D.M.; Ng, A.Y.; Jordan, M.I. Latent dirichlet allocation. *J. Mach. Learn. Res.* **2003**, *3*, 993–1022.
11. Jelodar, H.; Wang, Y.L.; Yuan, C.; Feng, X.; Jiang, X.H.; Li, Y.C.; Zhao, L. Latent Dirichlet allocation (LDA) and topic modeling: Models, applications, a survey. *Multimed. Tools. Appl.* **2019**, *78*, 15169–15211. [CrossRef]
12. Tang, J.Q.; Shen, Q.H.; Han, Y.Y.; Wu, Y.; He, X.F.; Li, D.W.; Huang, Y. Analysis of research status and trends on marine benthic dinoflagellate toxins: A bibliometric study based on web of science database and VOSviewer. *Environ. Res.* **2023**, *238*, 117179. [CrossRef] [PubMed]
13. Perianes-Rodriguez, A.; Waltman, L.; Van Eck, N.J. Constructing bibliometric networks: A comparison between full and fractional counting. *J. Informetr.* **2016**, *10*, 1178–1195. [CrossRef]
14. Palopak, Y.; Huang, S.J.; Ratnasari, W. Knowledge diffusion trajectories of agile software development research: A main path analysis. *Inform. Softw. Tech.* **2023**, *156*, 107131. [CrossRef]
15. Shen, Z.F.; Hu, J.T.; Wu, H.Y.; Chen, Z.S.; Wu, W.X.; Lin, J.Y.; Xu, Z.M.; Kong, J.Q.; Lin, T.X. Global research trends and foci of artificial intelligence-based tumor pathology: A scientometric study. *J. Transl. Med.* **2022**, *20*, 409. [CrossRef] [PubMed]
16. Chen, C. A Glimpse of the First Eight Months of the COVID-19 Literature on Microsoft Academic Graph. *Front. Res. Metr. Anal.* **2020**, *5*, 607286. [CrossRef] [PubMed]
17. Sabe, M.; Pillinger, T.; Kaiser, S.; Chen, C.; Taipale, H.; Tanskanen, A.; Tiihonen, J.; Leucht, S.; Correll, C.U.; Solmi, M. Half a century of research on antipsychotics and schizophrenia: A scientometric study of hotspots, nodes, bursts, and trends. *Neurosci. Biobehav. Rev.* **2022**, *136*, 104608. [CrossRef] [PubMed]

18. Sievert, C.; Shirley, K.E. LDAvis: A method for visualizing and interpreting topics. In Proceedings of the Workshop on Interactive Language Learning, Visualization, and Interfaces, Baltimore, MD, USA, 27 June 2014; Association for Computational Linguistics: Baltimore, MD, USA, 2014; pp. 63–70.
19. Fortunato, S.; Bergstrom, C.T.; Börner, K.; Evans, J.A.; Helbing, D.; Milojević, S.; Petersen, A.M.; Radicchi, F.; Sinatra, R.; Uzzi, B. Science of science. *Science* **2018**, *359*, eaao0185. [CrossRef] [PubMed]
20. Altbach, P.G.; De Wit, H. Too much academic research is being published. *Int. High. Educ.* **2019**, *96*, 2–3. [CrossRef]
21. Coccia, M. The evolution of scientific disciplines in applied sciences: Dynamics and empirical properties of experimental physics. *Scientometrics* **2020**, *124*, 451–487. [CrossRef]
22. Riccaboni, M.; Verginer, L. The impact of the COVID-19 pandemic on scientific research in the life sciences. *PLoS ONE* **2022**, *17*, e0263001. [CrossRef] [PubMed]
23. Armenteras, D. Guidelines for healthy global scientific collaborations. *Nat. Ecol. Evol.* **2021**, *5*, 1193–1194. [CrossRef] [PubMed]
24. Syed, S.; Spruit, M. Full-text or abstract? examining topic coherence scores using latent dirichlet allocation. In Proceedings of the 2017 IEEE International Conference on Data Science and Advanced Analytics (DSAA), Tokyo, Japan, 19–21 October 2017.