



Scientometric trends in reproductive health research on endangered species

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Citation: Kumar, K., Sandeep, T. & Rao, T.S.C. (2026). Scientometric Trends in Reproductive Health Research on Endangered Species. *Journal of Veterinary and Animal Sciences*, 57(1), 163-174
<https://doi.org/10.51966/jvas.2026.57.1.163-174>

Received: 06.12.2025

Accepted: 09.02.2026

Published: 31.03.2026

Abstract

Research on reproductive health for endangered species is important for the conservation of biodiversity and species survival in the face of habitat loss and climate change. A scientometric analysis using bibliometric tools for a period starting from 1993 outlined trends in publications, authorship and collaborations and the themes in the research field. The study found 180 articles listed in Pub Med, which represents a 9.96% annual growth and a 32.78% rate of co-authorship partners, indicating global collaboration and efforts on this topic. While the number of publications had grown steadily until 2010, the study noted a rise in publications from 2016 to 2024. Brown JL and Comizzoli P were the most prominent authors, while the USA, China and Australia were the three major countries conducting research in this field. PLOS ONE was the most prolific journal in terms of total articles published, with a major theme of “assisted reproductive technology.” A research trend analysis of publications from 2008 to 2024 indicates a research focus on wildlife conservation. Reliance upon citation metrics led to the suggestion of conducting similar studies in the future with multiple databases as a mechanism to strategically and more effectively collaborate on conservation efforts in the future.

Keywords: *Reproductive health, endangered species, scientometric analysis, conservation, advanced reproductive technologies, collaborative research.*

Reproductive health is an intrinsic element of conservation biology and poses risks to population viability. Conservation evidence for biodiversity is rapidly declining due in part to habitat loss and climate change; thus, addressing reproductive issues around reproduction is essential to the survival of species. The research produced on reproductive health and management in wild populations and for ex-situ programs has increased through improved reproductive technologies that include artificial insemination and cryopreservation. As things stand, advancements in reproduction for endangered taxa have been made in interdisciplinary research that combines molecular biology and ecological research. Regardless of the advancements in the field, gaps exist in our understanding of reproductive physiology specific to species and how an environmental event may have an effect on fertility. Hence, this study is intended to conduct a scientometric analysis of the literature in the area of reproductive health, identifying main players, thematic priorities and changes in the research landscape for reproductive health in at-risk taxa, as awareness of conservation needs changes.

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The body of literature surrounding biodiversity loss indicates a grave necessity for new and innovative conservation strategies for biodiversity and endangered species. The current study systematically maps research patterns in the reproductive health of endangered animals. For instance, Li, (2024) has indicated that 19.38% of all animal species assessed have been classified as endangered primarily due to human encroachment of habitats. Monecke, (2024) addressed the model of internal coincidence as it relates to declining populations of the European hamster from climate change and light pollution, proposing internal coincidence as a potential conservation strategy. Hildebrandt and Holtze, (2024) propose using more traditional methods with stem cells and advanced reproductive techniques as a strategy for the conservation of keystone species, thereby addressing reproductive complexities observed in mammalian species. Mastromonaco (2024) conveys some obstacles in CANDES (Conservation of Aquatic and Non-Aquatic Diversity in Eastern Canada) in obtaining reproductive technologies, but Saragusty et al., (2020) provide *in vitro* gametogenesis and inner cell mass transfer through cell-based biotechnologies that are advancing the field. Hildebrandt and Holtze (2024) also note the significance of banks of genetic resources for the preservation of biodiversity and biodiversity in which progeny of genetically diverse gametes were produced from postmortem gametes. Iskandar et al., (2024) discussed the conservation of mahseer fish in Asia, while Segaran et al., (2023) performed a bibliometric analysis of the seahorse literature, implementing some interdisciplinary topics. Simantiris (2024) summarizes the implications of climate change on sea turtles, ultimately calling for a comprehensive approach for conserving biodiversity. The objectives of the present study were to assess publication patterns and progress in reproductive health studies concerning endangered species, to ascertain the main contributors, associations and nations influencing the research landscape and to investigate emerging themes and their ramifications for future research and conservation methodologies.

Materials and methods

A scientometric analytical technique was adopted to understand general trends in published research associated with the reproductive health of threatened species over the years from 1993 to 2024. The literature encompassed various species like European Bison, Asian Elephants, White Rhinoceros, Tasmanian devils, Eastern Quolls, cheetahs, Staghorn Coral, African Clawed Frog, *Anguillicoloides Crassus*, European rabbits, Giant anteater, Atlantic Cod, European Badger and Asiatic lions. The aim was to analyze the PubMed database, an open-access and a reliable database indexing the biomedical literature, to provide an objective description of trends in research publications. To address this aim, publications meeting specific criteria were

identified during January to March 2025 using controlled vocabulary and Boolean operators—reproductive health and fertility, endangered species and threatened taxa. After the use of relevant filters, the first search produced 215 documents, which were subsequently filtered down to 180 relevant articles. The search string successfully retrieved literature on reproductive health in threatened species, which combined both biological and conservation information, but proved a broad enough dataset to cover the physiological, technological and ecological underpinnings of reproduction in threatened species. Data cleaning of the data set involved exporting to BibTeX Format using the Biblioshiny interface of R's Bibliometrix version 5.0 (Aria and Cuccurullo, 2017) to support the analysis of either discrepancies and duplicates or standardization of entries accounted for within the process. Duplicates were removed based on DOI, author and title matches. The dataset was restricted to 180 documents relating to reproductive health in threatened species, 1207 authors and 98 sources. Analysis was undertaken from a three-dimensional bibliometric approach using the performance indicators of annual publication, authorship, contribution by institution and journal productivity of 9.96% annual growth. Science mapping techniques were also used to display and illustrate relationships and structural characteristics of the research field, most notably patterns of collaboration and clusters of keywords. Two research styles are identified: fundamental reproductive biology from 1993 to 2019 and technology application from 2020 to 2024, which focuses on technologies such as *in vitro* fertilization and stem cell technology. The utilization of tools such as Biblioshiny

Table 1. Sample Size

Description	Results
Main Information	
Timespan (year)	1993:2024
Sources (Journals, Books, etc)	98
Documents	180
Annual Growth Rate %	9.96
Document Average Age	6.52
Average citations per doc*	0
References	0
Document contents	
Keywords Plus (ID)	788
Author's Keywords (DE)	788
AUTHORS	
Authors	1207
Authors of single-authored docs	8
Authors' Collaboration	
Single-authored docs	8
Co-Authors per Doc	7.69
International co-authorships %	32.78

* - citation data not available in PubMed export

permitted Descriptive, Network, Thematic and Trend Analysis. As previously noted, the approach used publicly available secondary data and conformed to academic integrity and transparency, meaning no ethical approval was required. Although there were limitations associated with relying on databases and other facets of the data, which may have contributed to bias, the limitations were mitigated through consecutive data cleansing and data standardization. The study presents a rigorous and systematic approach, producing interesting outcomes with scientific analysis and visual representations, clarifying the thematic trajectory of reproductive health research on endangered species over the past 30 years. This data is particularly useful to guide future research and policy discussions related to wildlife conservation.

The bibliometric information indicated in Table 1 for the years 1993 to 2024 captures the continued study of threatened species across 98 unique journals. The systematic review yielded 180 articles based on the predetermined criteria, getting a substantive dataset to examine in this study. The field is growing at an annual rate of approximately 9.96%. Therefore, there is a significant increase in published articles in this academic domain and a growing interest in the development of this area over some time. The field has 1,207 authors in place documenting this area of research, so there is collaboration within the profession. The study collection reflects a strong tendency for collaborating authors, as only 8 of the 180 chosen had one author. The collaborated research is reflected with 32.78% of the articles being internationally co-authored to show a global collaborative effort to research threatened species. The mean number of authors per publication is, in fact, 7.69 so there is the collaborated cooperation of

research. The collection also contained 788 distinctive terms to provide some coverage in terms of study scope and subject matter for this professional area. The lack of references in some publications is indicative of a limitation or due to an issue encountered acquiring the data; it can be expected and is typically included in any scientific pieces. Finally, the average age of the articles is approximately 6.5 years, confirming that this compilation has a modern perspective. The lack of reported citations for each document suggests a possible deficiency in the citation data of the dataset. The analysis reveals a growing global collaboration in the research of endangered species; nevertheless, it also indicates possible limitations in the reference and citation data gathered from PubMed.

Results and discussion

The study encompassed 14 endangered species. Fig 1 depicts the yearly output related to reproduction in endangered species, indicated as the number of papers published per year. The graph demonstrates a surge of scientific inquiry regarding reproduction in endangered species in the past 10 years. In the beginning there was a low level of publication output, indicating a low level of research in the field. Between 2010-2015 there was a small increase, indicating an increase in both interest and research in the field. After 2016, there was a dramatic increase in publication output, with the number of publications hitting its annual high, exceeding 15 papers yearly, indicating a clear global increase in interest and research in the area of conservation breeding (Comizzoli and Holt, 2019, Herrick, 2019, Mastromonaco and Songsasen, 2020). Post-2020, minimal chart changes suggest ongoing global impacts affecting reproductive challenges and biodiversity.

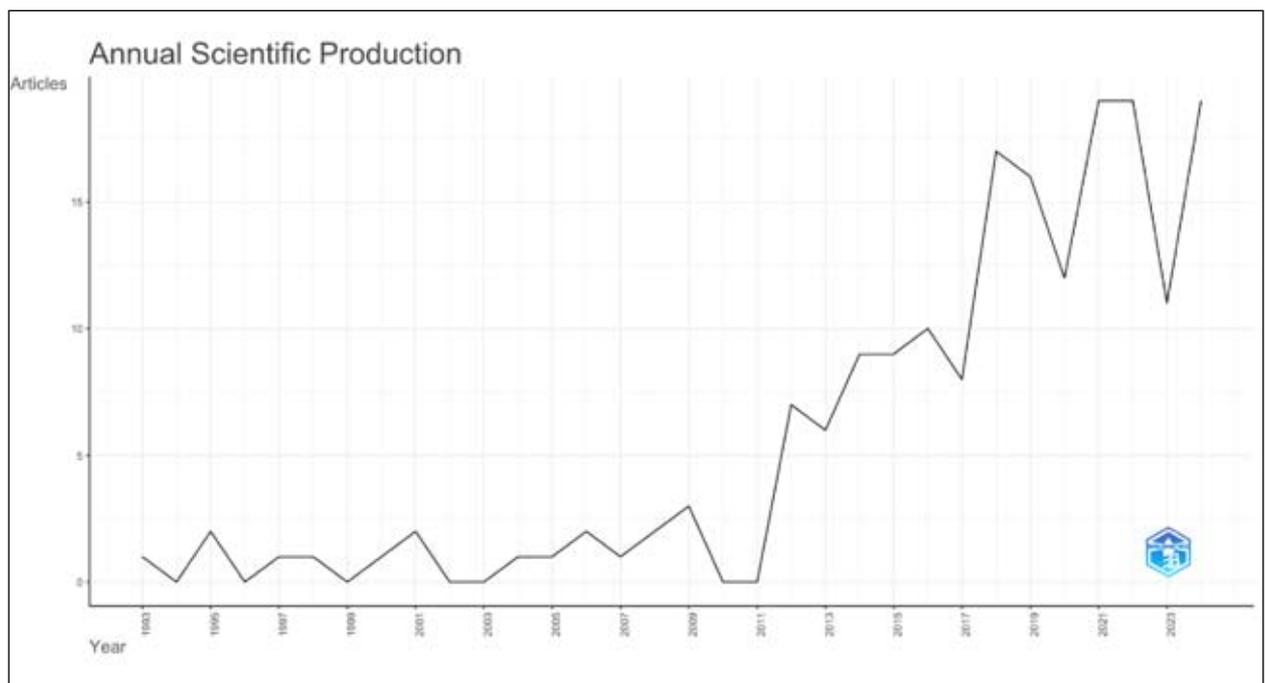


Fig 1. Annual Scientific Production

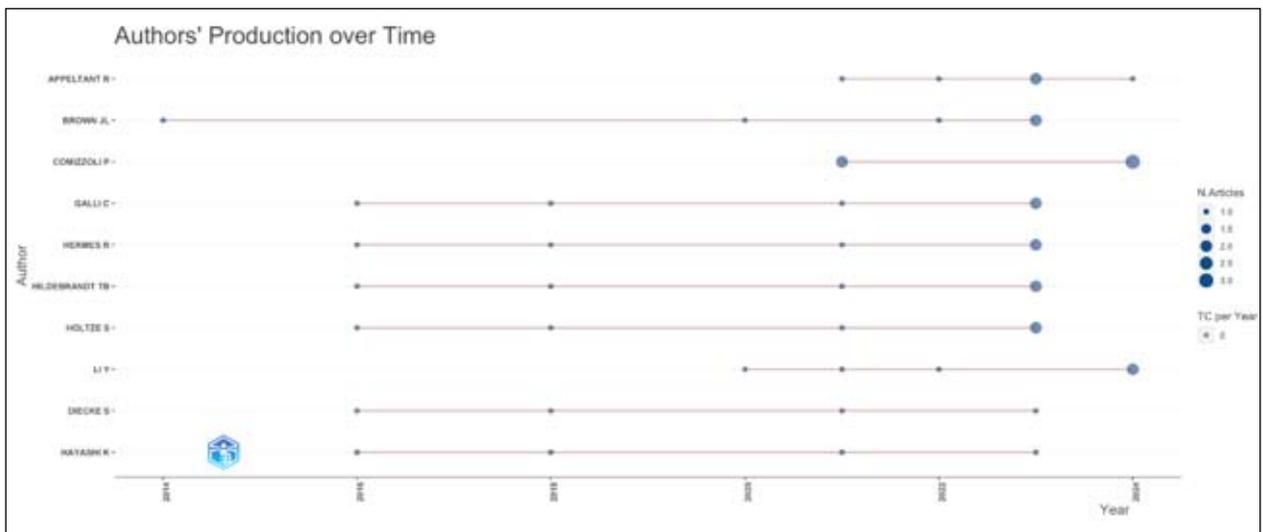


Fig. 2. Contributions of author by Year

Fig 2 shows key authors, notably Brown JL, contributing significantly to endangered species reproduction literature from 2014-2023. Comizzoli P has consistently included contributions aimed at the latest trending research. Noteworthy new contributing authors, Appellant R and Galli C, have limited but valuable contributions throughout some of the years, demonstrating a narrow area of focus or a specialization within the field. Hayashi K has sporadic contributions with a cluster of articles in the same few years, indicating scholarly contributions are generally limited in some years. Hildebrandt TB and Hermes R have similar contributions as each other in similar years, possibly contributing to research or collaboration on similar studies in this area. Authors of higher impact, Holtz E and Li Y, present with larger circles, demonstrate higher contributions to the scientific literature as evidenced by citation impact. This variation in contributions presents an updating and active movement towards new authors contributing to a developing research space. The line component illustrates the increased contributions from leading authors and the collaborative academic research space of the conservation effort in this area.

Figure 3 displays a network of international connections around the reproductive health of endangered species. The countries shown in dark blue i.e USA and Medium blue i.e Australia, have the highest number of publications or the most collaboration. The lines indicate connections by collaborators and the thickness of each line indicates more consistent/significant collaboration. The USA is a significant center for collaboration with links through many continents—Europe, Asia and Australia. Australia is an important connection due to the focus on conservation practices for endemic and endangered species in the region. Europe and Asia have many connections, indicating active collaboration of research within and between them. Overall, the map demonstrates that researchers around the world are presenting

connected work in the area of reproductive health for endangered species.

As illustrated in Figure 4, the dominant affiliations therein underpinning the institutions that contribute substantial papers in the realm of reproductive health for endangered species are visible. The foremost of these is the Chengdu Key Laboratory of Conservation Biology for Endangered Wildlife, having produced 24 papers focused on species conservation, in particular with China's vast biodiversity. The Smithsonian National Zoo and Conservation Biology Institute has also produced 23 papers, indicating robust contributions to the area of conservation science and reproductive biology for species conservation. Leading institutions with a significant number of publications included James Cook University and the Smithsonian Conservation Biology Institute, both with 22 publications; Washington State University with 18 publications; and the University of Oxford with 16 articles. Institutions having more specialized contributions were Chengdu Academy of Giant Panda, Cornell University, Department of Health Sciences and Technology, and the University of Queensland, which contributed 13 papers each; this indicates their involvement in the potentially multilayered approach to conservation and health. The affiliations represent a diverse selection of institutions from disparate geographical areas that have partnered in a worldwide collaborative effort in addressing the reproductive health issues for these endangered animals.

Fig 5 highlights the main contributions to reproductive health in threatened species as presented through their published articles. The primary contributors listed are Appellant R, Brown JL, Comizzoli P, Galli C, Hermes R, Hildebrandt TB, Holtz E, and Li Y, who each have contributed five publications. It is noted that leading experts complete specific aspects of the discipline, such as ART, gamete preservation and species-specific reproductive techniques that provide valuable perspectives

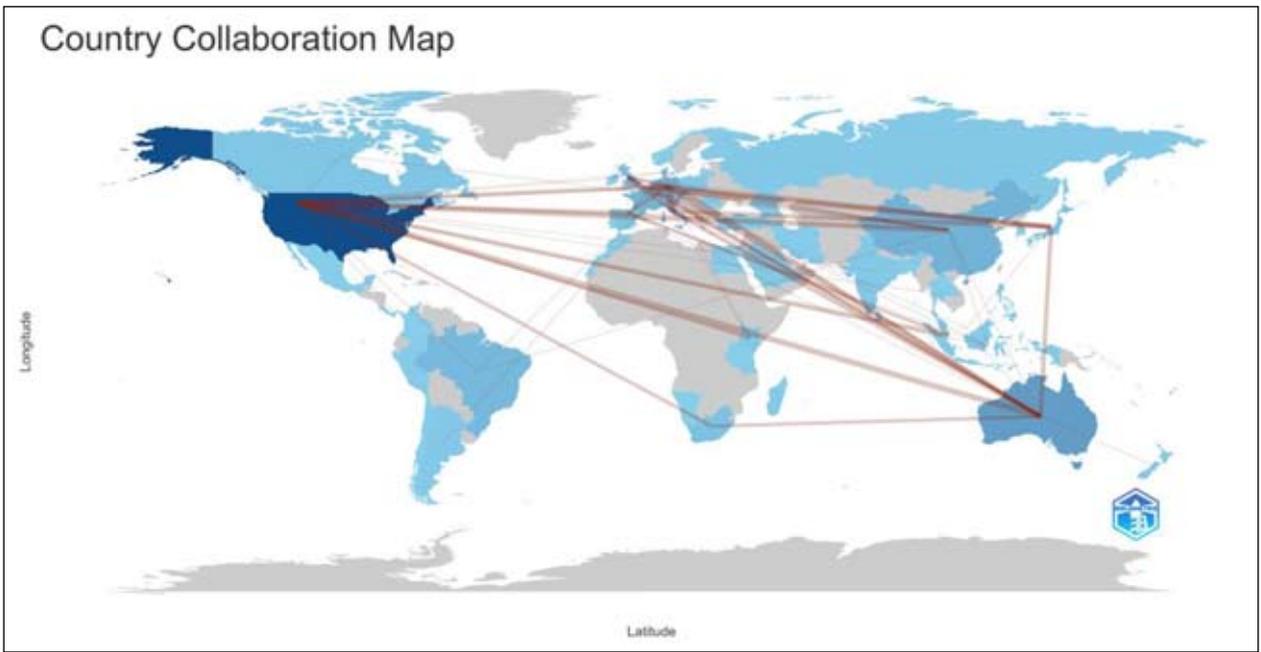


Fig 3. Country Collaboration Map

and methodologies. Other research contributors who have each published four articles are Diecke S and Hayashi K, which demonstrates evolving perspectives on the topic or complementary areas of study. Publications that are closely ranked: the number of publications denotes a collaborative research environment in which many authors will co-author articles in order to share skills or solutions. Combining these authors indicates contributions from multiple places, institutions, and areas of expertise, where everyone pushed forward knowledge regarding the reproductive health of threatened species.

Fig. 6 illustrates the data on the endangered species and reproductive health studies by different countries. The United States is the leader in personal and team publications, which means it is effective in area research and formation of partnerships. Australia and China are also significant contributors in publications. Europe showed participation by some countries that had good reputations and these include Germany, Poland, Spain, Belgium, and Italy, which further shows that the Europeans had partnerships and research activities. Similarly, India, South Africa, Switzerland and Turkey

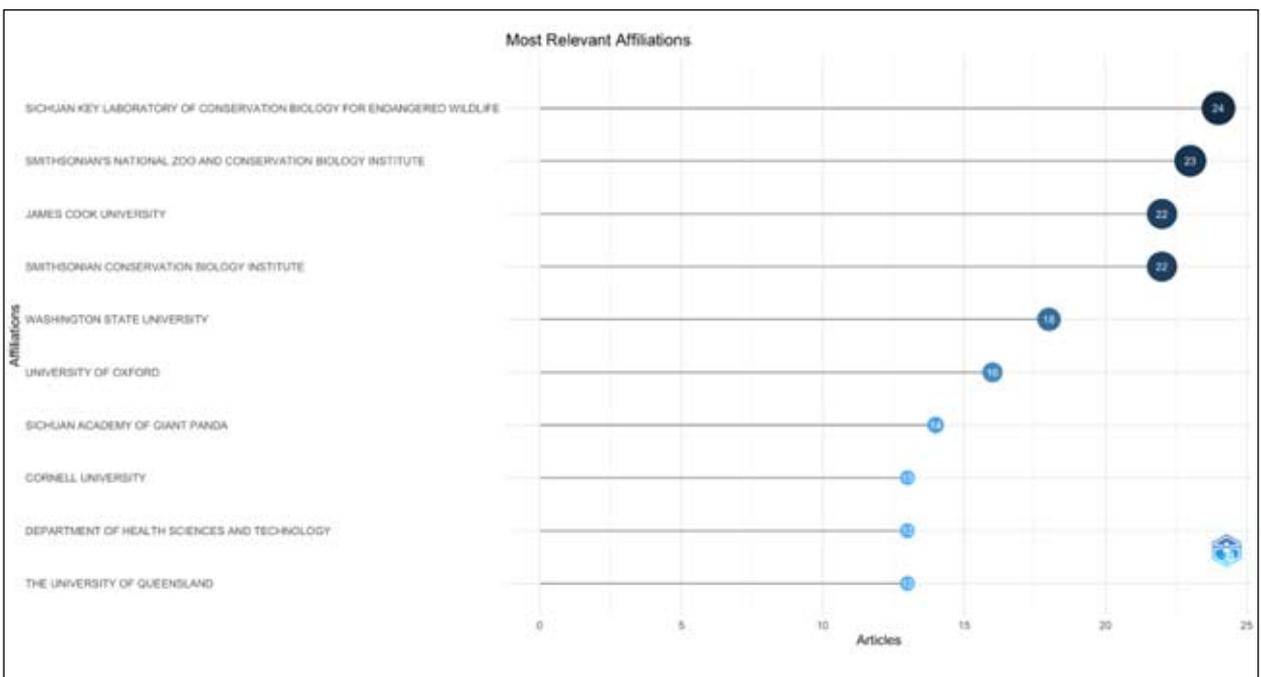


Fig 4. Most Relevant Affiliations

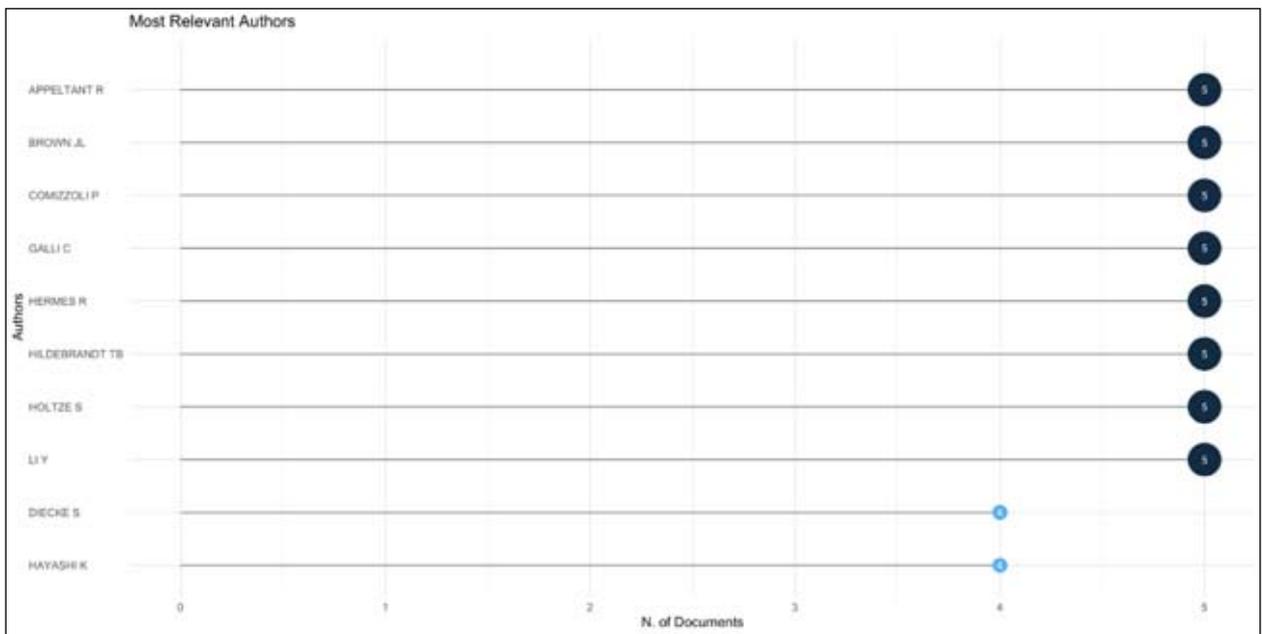


Fig 5. Most Relevant Authors

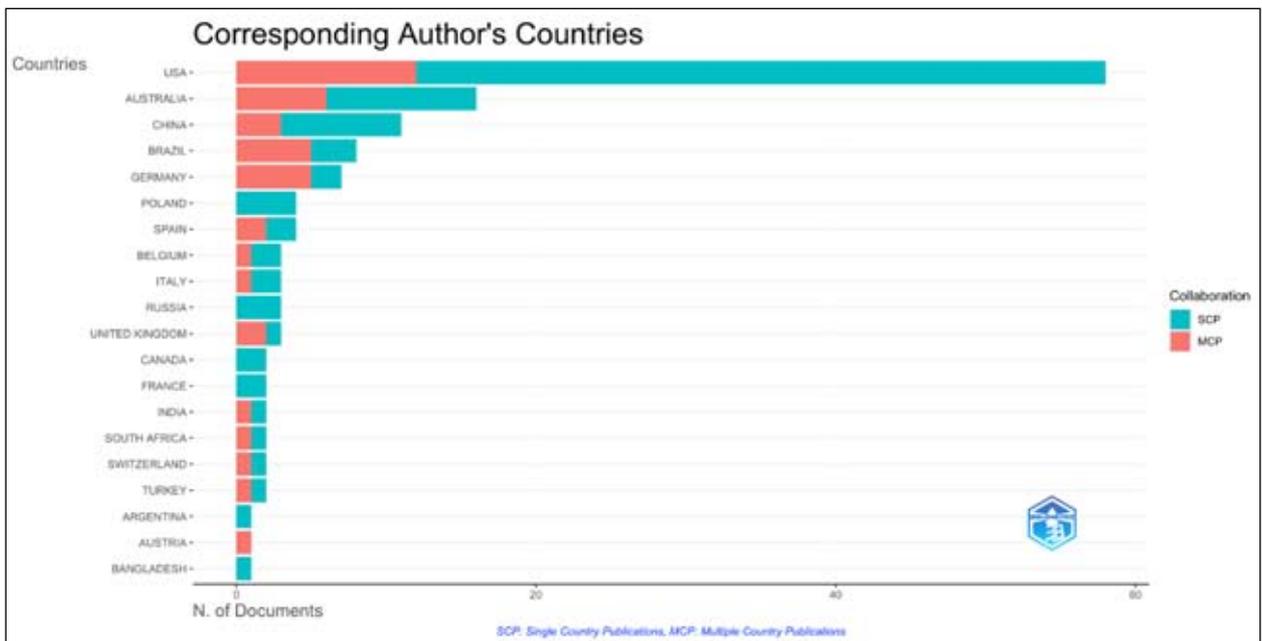


Fig 6. Country of Corresponding Authors

show a promising prospect of this general research field by having only one-country publications. The development of reproductive health among endangered species at the international level is exhibited by several various partnerships between countries. The contribution of other countries like Bangladesh and Austria is small, meaning that it has focused but very limited partnerships and research activities.

Fig 7 identifies the most important sources of publications related to the reproductive health of endangered species and classifies them based on the number of publications made. Two main journals were

used, including PLOS One and Theriogenology, with 10 articles each. Other source journals like Reproduction in Domestic Animals, Reproduction, Fertility and Development and Animals (MDPI) are other sources that are significant to carry out research related to reproduction. The physiology of conservation, the journal of wildlife disease, veterinary clinical pathology, and zoo biology were taken to be secondary publications, as each reported 5 total publications. Even journals like Advances in Experimental Medicine and Biology, though they do not generate many papers, can still be of use in studying since they might give pertinent insight/techniques regarding the process of conducting reproducible experiments. It

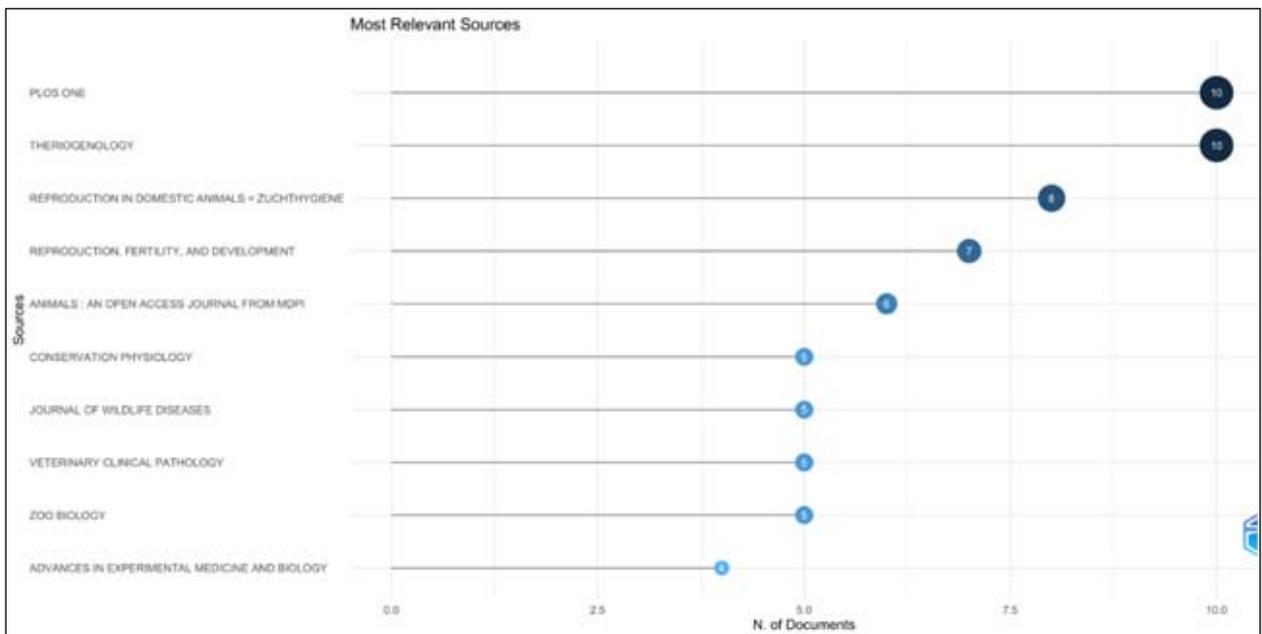


Fig 7. Most relevant sources

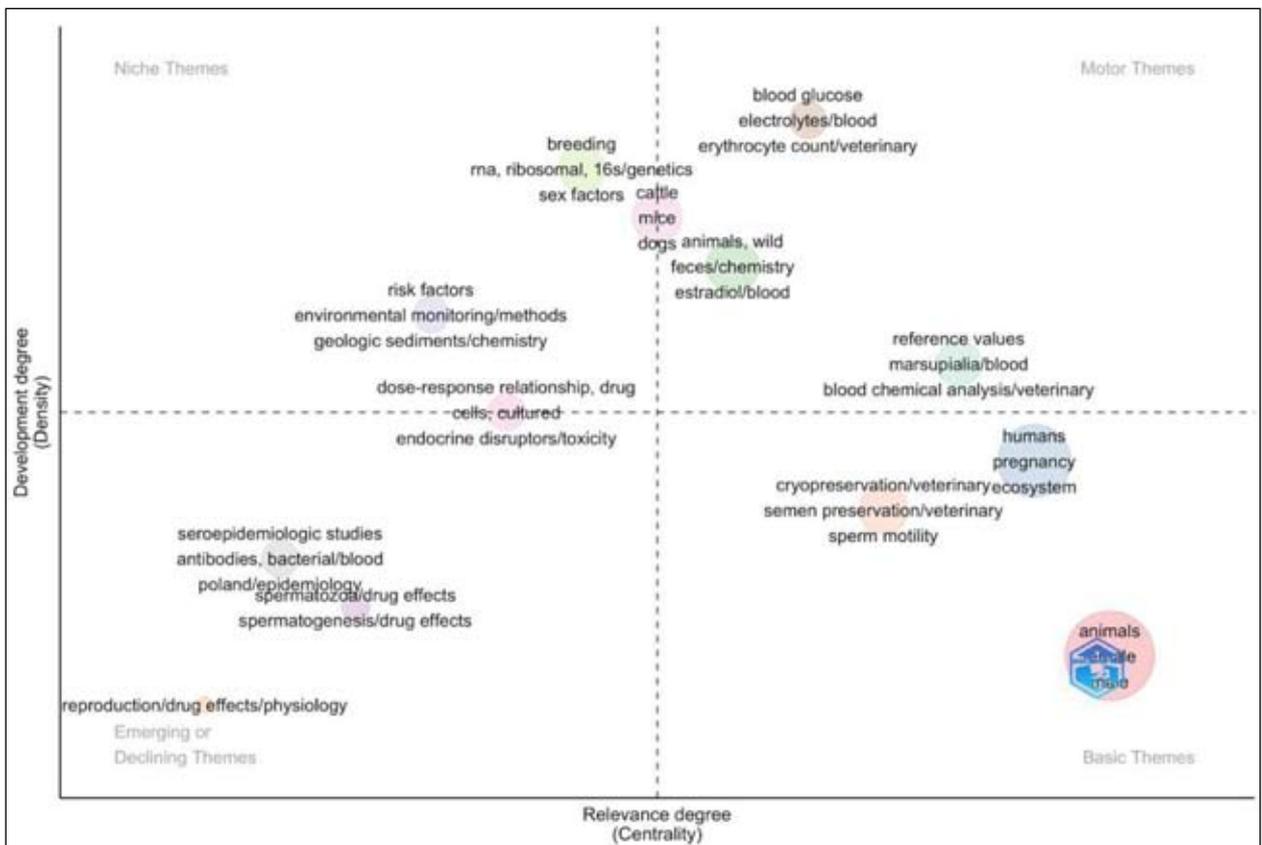


Fig 8. Niche Themes

indicates and implies an interdisciplinary vision of using conservation, veterinary medicine, experimental biology, and reproductive science, as the issues of reproductive health in endangered species are complex. Such distribution of publications indicates the value of both high-output, generalist journals and some specialty journals in regard to contributing to research of reproductive health in a conservation perspective.

Figure 8 illustrates the niche themes emerging from the co-word and thematic mapping of reproductive health research in endangered species. In addition to environmental exposure and drug-related effects, the analysis reveals specialized but conceptually dense themes related to captive breeding management, cryopreservation techniques, and hormonal monitoring. Captive breeding appears as a focused niche addressing controlled

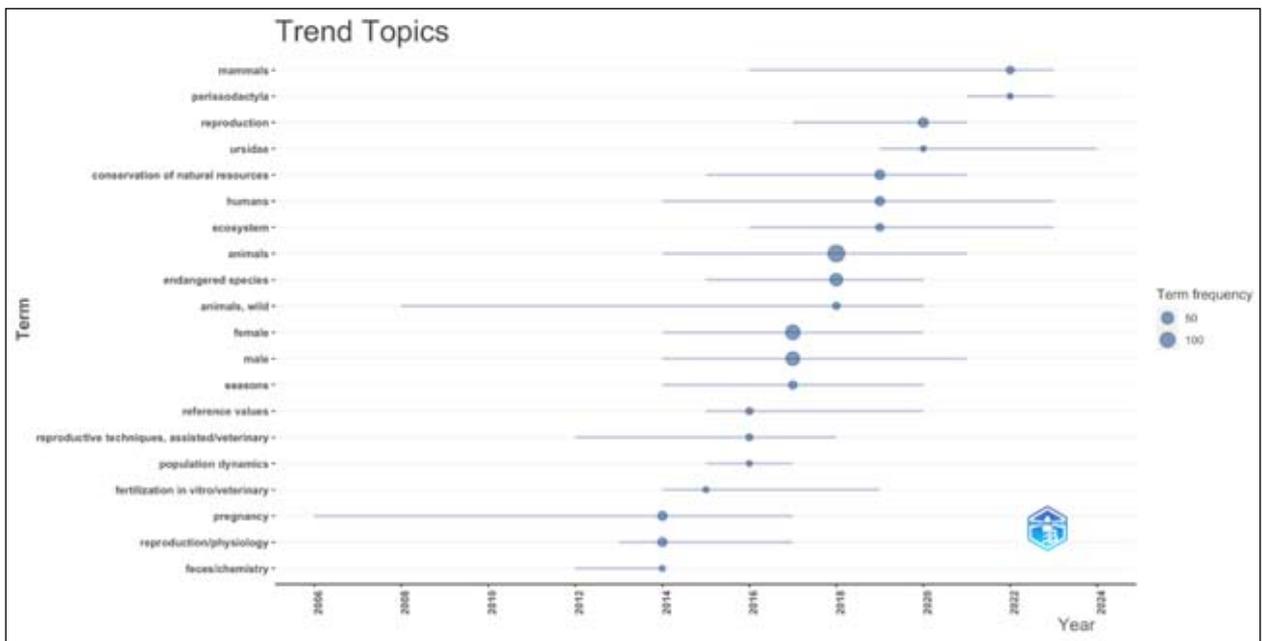


Fig 9. Trend Topics



Fig 10. Thematic Evaluation

reproduction in zoological and conservation facilities, often linked with assisted reproductive technologies. Cryopreservation-related keywords, including “gamete” and “embryo preservation,” form a technologically advanced but less central cluster, reflecting their specialized application in safeguarding genetic resources. Hormonal markers, such as reproductive hormones used for fertility assessment and estrus monitoring, emerge as a niche theme supporting both natural and assisted reproduction. These niche themes, while not yet dominant, play a critical role in enabling applied conservation strategies and indicate areas with strong potential for future research expansion.

The development of reproductive health research in endangered species from 2008 to 2024 is displayed in Fig 9. The search terms “wildlife conservation,”

“endangered species” and “reproductive technology” gained traction after 2010, which corresponds with the rise of global interest in biodiversity loss and advances in reproductive health science and reproductive technology. Assisted reproductive technologies (ARTs) were nursing important technologies for safeguarding the genetic diversity of endangered species. The figure outlines the taxonomic focus of research, as well as the effect of climate change and habitat loss on reproduction, thereby demonstrating a broader progression toward systems-based conservation that incorporates aspects of different sciences.

Figure 10 presents the thematic evolution of reproductive health research on endangered species from 1993 to 2024, highlighting a clear transition from foundational reproductive biology towards applied and

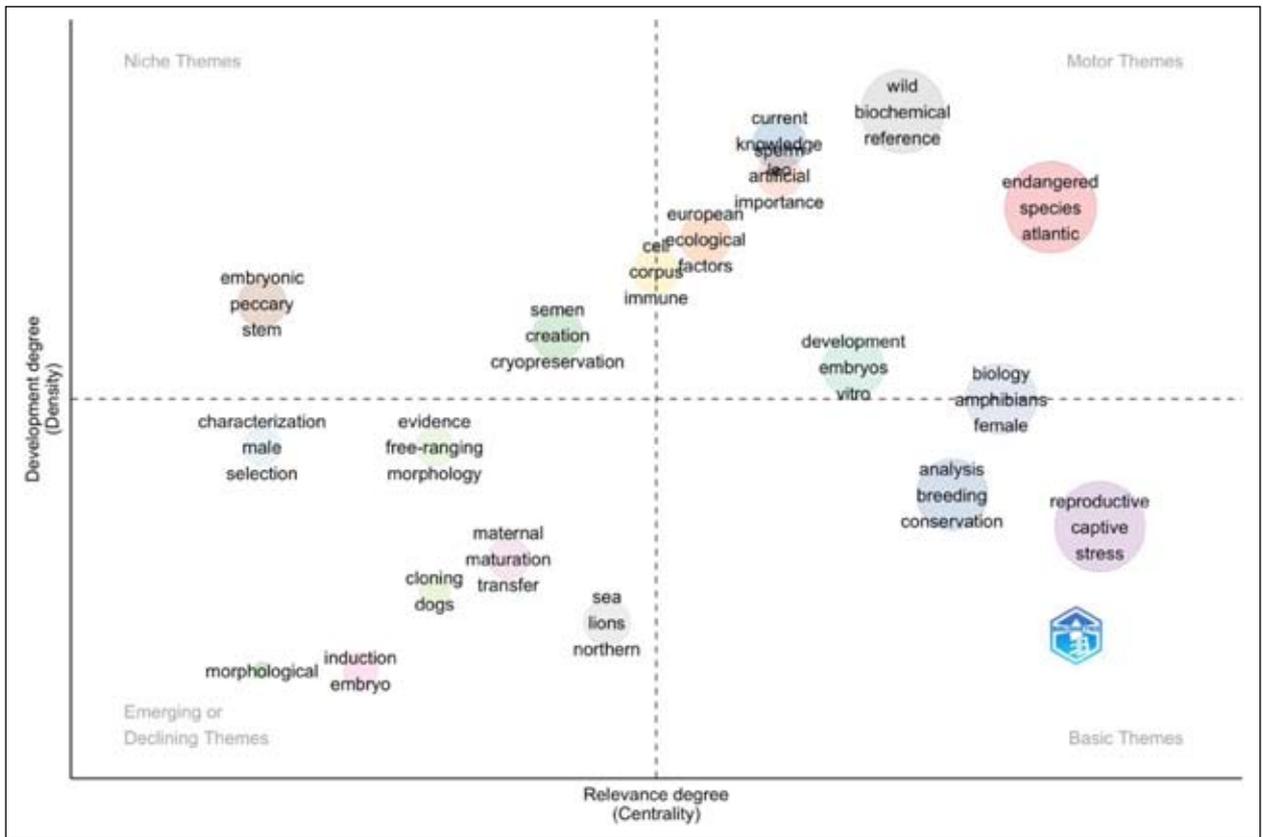


Fig 11. Emerging themes

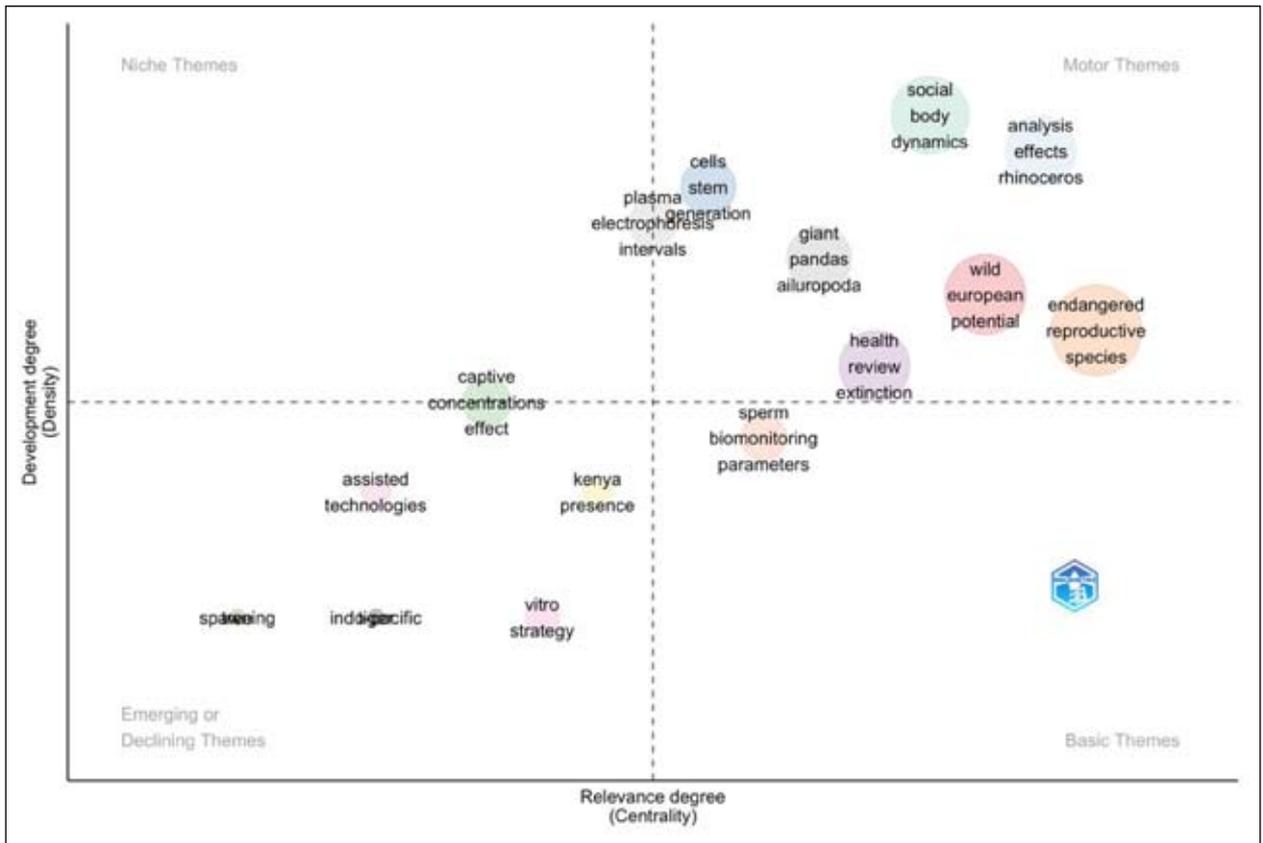


Fig 12. Thematic Map

technology-driven conservation strategies. Early research emphasized basic reproductive physiology and species-specific fertility assessments, whereas recent decades show a pronounced shift toward assisted reproductive technologies, captive breeding interventions and genetic conservation approaches. The increasing prominence of cryopreservation and genetic marker-based studies reflects growing efforts to preserve genetic diversity and mitigate reproductive bottlenecks in small or fragmented populations. Hormonal markers have also gained importance as essential tools for noninvasive reproductive monitoring and management in both wild and captive populations. Overall, the thematic evaluation demonstrates how reproductive health research has evolved into a multidisciplinary field integrating physiology, biotechnology, and conservation genetics to address the complex challenges faced by endangered species.

Figure 11 depicts emerging and developing themes in endangered species reproductive research based on thematic density and centrality. Assisted reproductive technologies represent a prominent emerging theme, indicating increasing research focus on artificial insemination, in vitro fertilization, and advanced embryo technologies for conservation purposes. Cryopreservation of gametes and embryos also appears as a rapidly developing theme, reflecting its growing importance in long-term genetic resource banking. Genetic markers, including studies related to genetic diversity, genome analysis, and molecular monitoring, emerge as an expanding research frontier supporting evidence-based conservation breeding programs. Hormonal markers form an emerging methodological theme, particularly in the

context of reproductive assessment and management in captive breeding programs. These emerging themes signal a strategic shift toward technology-enabled, precision-based reproductive conservation.

Figure 12 presents a comprehensive thematic map categorizing reproductive health research on endangered species into motor, niche, basic, and emerging themes. Motor themes are dominated by assisted reproductive technologies and captive breeding programs, underscoring their central role in contemporary conservation efforts. Basic themes include reproductive health, fertility, and species survival, which form the foundational knowledge base supporting applied research. Niche themes encompass hormonal markers and specialized reproductive monitoring techniques, reflecting their high internal development but limited connectivity across the broader research field. Emerging themes, notably cryopreservation and genetic marker-based conservation, highlight evolving research directions focused on preserving genetic diversity and enhancing reproductive success in threatened populations. Collectively, the thematic map illustrates an integrated and progressive research landscape in which traditional reproductive biology increasingly converges with biotechnology and conservation genetics to address endangered species survival.

The Three-Field Plot illustrated in Fig 13, created using the Bibliometrix package, provides a robust and detailed examination of the relationships between authors and keywords and between authors and countries producing publications on the reproductive health of

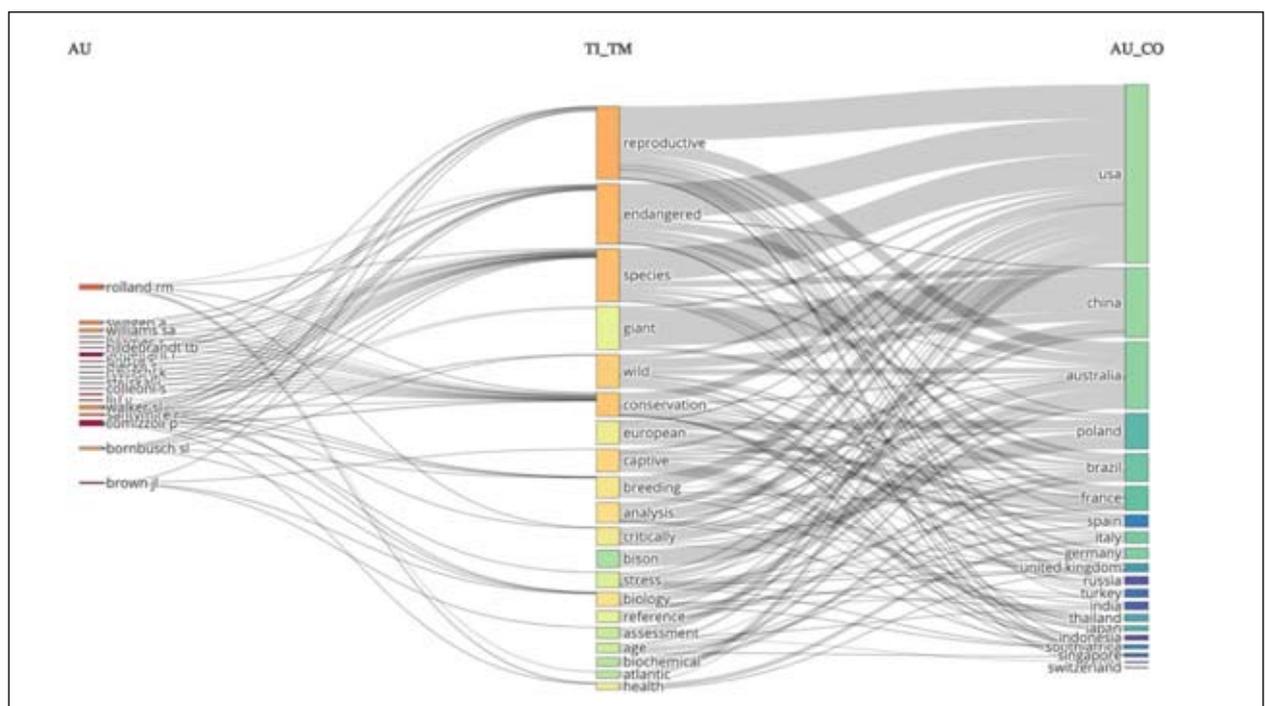


Fig 13. Three-Field Plot

threatened species. The authoring bodies include a wealth of academic and research talent, such as Rolland M., Sillen-Tullberg B. and Brown J. who are engaged in a variety of themes and topics that include authorship across multiple nations. The key topics that emerged include reproductive, endangered, species, conservation, captive, and wild. Some specific terms like Giant, Breeding and Stress Signal Research on species-specific issues, Captive Breeding programs under the auspices of zoos and aquariums, and Stressors on Reproduction. The USA is the most prolific participating country due to authorship representing a spectrum of topics and themes. Other active countries include China, Australia, Poland, France, Germany, and Italy, creating a palpable global effort. The plots also reveal the capacity for multiple authors to coalesce around a particular theme or topic and that authors are connected through their respective countries to produce the research prioritized by those countries, ecology, or conservation. The focus on criticality, biology, and stress also signals emerging interest in the biology of the species and the environmental and anthropogenic stressors. The relation of terms that are conservation-oriented, like assessment and breeding, also illustrates the desire to address the decline of populations with specific interventions.

Limitations of the study

1. The study relied exclusively on the PubMed database, which, while authoritative and widely used for biomedical literature, does not provide comprehensive citation-based impact indicators such as total citation counts, h-index values, field-weighted citation impact (FWCI), or Altmetric Attention Scores. As a result, the evaluation of research impact in this study is primarily descriptive rather than citation-driven.
2. PubMed's export format limits access to complete reference and citation metadata, which may affect the depth of citation-based comparisons.
3. Although the dataset captures a broad range of reproductive health research on endangered species, inclusion of additional databases such as Scopus or Web of Science in future studies would enable more robust impact assessment and cross-database validation. Despite these limitations, the study provides a reliable and systematic overview of publication trends, collaboration patterns, and thematic evolution in endangered species reproductive research.

Conclusion

The present scientometric analysis demonstrates a substantial and sustained growth in research focused on the reproductive health of endangered species, with an annual growth rate of 9.96%, reflecting increasing global recognition of reproduction as a critical component of conservation biology. The findings highlight strong

international collaboration and the pivotal role of leading institutions and researchers in advancing this interdisciplinary field. Keyword and thematic mapping reveal that assisted reproductive technologies and captive breeding programs have emerged as central motor themes, underscoring their importance in enhancing reproductive success and population sustainability in threatened taxa. In addition, the thematic analysis identifies cryopreservation as a rapidly developing research area, emphasizing its strategic role in long-term genetic resource preservation and ex situ conservation efforts. Hormonal markers and genetic markers emerge as specialized yet increasingly influential themes, supporting non-invasive reproductive monitoring, fertility assessment, and genetic diversity management within conservation breeding programs. The integration of hormonal and genetic tools with assisted reproductive technologies reflects a shift toward precision-based and evidence-driven conservation strategies.

Overall, the evolution of research themes indicates a transition from foundational reproductive biology toward technologically advanced and application-oriented conservation approaches. Despite this progress, the analysis also reveals the need for deeper integration of hormonal and genetic marker-based studies across species and ecosystems. Future scientometric and empirical research should expand these dimensions and incorporate multiple databases to capture a more comprehensive picture of global research activity. Strengthening these thematic areas will be essential for improving reproductive management practices and ensuring the long-term survival of endangered species in the face of escalating environmental and anthropogenic pressures.

Conflict of Interest

The author report No Conflicts of Interest.

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