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Research Article

A Systematic and Bibliometric Review of *Garra rufa* (Doctor Fish): Therapeutic Use, Research Landscape, and Knowledge Gaps (1993–2025)

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Abstract: This study presents a systematic and bibliometric analysis of *Garra rufa* (doctor fish) literature from 1993 to 2025, integrating PRISMA-guided review and science mapping via Bibliometrix. Covering 46 peer-reviewed publications, the findings reveal multidisciplinary interest in ecology, ichthyotherapy, aquaculture, and conservation. Key trends include increasing attention to zoonotic risks, biodiversity, and climate resilience. Despite biomedical promise, genetic and biosafety research remains limited. Türkiye and Iran dominate scholarly output, though international collaboration is sparse. This review provides a foundational reference for future research on *G. rufa*'s therapeutic applications, environmental challenges, and sustainable use.

Keywords: *Garra rufa*, Doctor fish, Ichthyotherapy, Bibliometric analysis

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1. INTRODUCTION

G. rufa, commonly referred to as “doctor fish,” is a freshwater cyprinid species endemic to the Middle East, inhabiting rivers, springs, and subterranean systems across Iran, Türkiye, Syria, Lebanon, and Jordan. It occupies ecologically diverse habitats characterized by broad temperature and elevation gradients, and exhibits notable morphological and physiological plasticity in response to local environmental conditions (Esmaeili et al., 2016; Shabani & Askari, 2013).

In recent decades, *G. rufa* has garnered increasing global attention due to its distinctive role in ichthyotherapy-an alternative treatment involving the use of live fish for managing dermatological conditions, particularly psoriasis. Clinical studies have demonstrated therapeutic benefits, including reductions of up to 71.7% in the Psoriasis Area Severity Index (PASI), prolonged remission periods, and high patient satisfaction with minimal adverse effects (Grassberger & Hoch, 2006; Zagad et al., 2020). This biomedical potential has positioned *G. rufa* at the core of a rapidly expanding wellness and medical tourism sector, with treatment centers operating in over 30 countries across Europe and Asia.

However, the intensifying global demand for *G. rufa* has placed mounting pressure on its wild populations. Anthropogenic threats—such as dam construction, unsustainable water extraction, agricultural runoff, urban pollution, overfishing, and the spread of invasive species—have resulted in significant habitat degradation and population declines (Abedi et al., 2011; Alp et al., 2018, 2020; Özcan & Altun, 2015; Patimar et al., 2010). Additionally, climate-induced stressors have been found to affect the species' morphological traits and physiological resilience (Şen Özdemir, 2023; Shirzad et al., 2022).

Beyond ecological impacts, ethical and biosafety concerns have emerged due to documented cases of zoonotic infections linked to fish spa treatments. Verner-Jeffreys et al. (2012) at the CDC reported that *G. rufa* may carry bacteria such as *Salmonella*, *Aeromonas*, and *Mycobacterium marinum.* These causes important health risks, especially for immunocompromised individuals such as poising. Subsequently, *Vibrio cholerae, Mycobacterium marinum* were isolated, and other fish-borne pathogens in doctor fish used for spa treatments by Volpe et al. (2019)

Despite its ecological, biomedical, and commercial relevance, substantial knowledge gaps remain. These include limited insights into the species’ genetic diversity, population structure, and adaptive capacity to environmental stress. The scarcity of genomic and transcriptomic studies restricts efforts to develop evidence-based conservation strategies, selective breeding programs, and sustainable aquaculture systems (Shabani et al., 2013; Shimada et al., 2025).

Based on these gaps, the present study offers a comprehensive systematic review and bibliometric analysis of *G. rufa* research spanning from 1993 to 2025. Employing the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework and the Bibliometrix R-package via the Biblioshiny interface, this study maps the evolution of scholarly discourse, identifies thematic trends, and highlights underexplored areas. The findings aim to support future research and policy-making in domains such as ecological conservation, sustainable aquaculture, and therapeutic innovation.

2. MATERIAL AND METHOD

2.1. Study Design and Methodological Framework

This study employed a dual-method design that integrates a systematic review—guided by the PRISMA 2020 guidelines (Page et al., 2021) and a bibliometric analysis using the Bibliometrix R-package (Aria & Cuccurullo, 2017) and its graphical interface, Biblioshiny. This combined methodology enabled both in-depth content synthesis and quantitative science mapping, offering a comprehensive perspective on the ecological, therapeutic, and biomedical research surrounding *G. rufa*.

2.2. Data Source and Search Strategy

The data for both methodological components were retrieved from the Web of Science Core Collection, which offers a consistent and curated citation structure suitable for bibliometric research (Mongeon & Paul-Hus, 2016). The search strategy was initiated using a single topic-based keyword: "*G. rufa*". No additional terms were included in the query, and no restrictions were placed on publication year or language at the initial stage. The initial dataset was downloaded in plain text format compatible with Bibliometrix.

2.3. Systematic Review Process

The systematic review adhered to the PRISMA 2020 statement to ensure methodological transparency and replicability. The literature screening followed a two-stage manual review:

- Title and abstract screening
- Full-text eligibility assessment

Inclusion Criteria

- Peer-reviewed articles or reviews.
- Direct relevance to *G. rufa* in ecological, therapeutic, biomedical, or aquaculture contexts.
- Sufficient methodological and contextual detail.

Exclusion Criteria

- Inaccessible full texts.
- Editorials, letters, or articles with marginal relevance.

All records were tracked and coded using a structured spreadsheet. A table was created to document the number of records identified, screened, excluded, and retained, including specific reasons for exclusion (see Table 1).

Table 1. PRISMA 2020-compliant flow diagram illustrating the multi-step identification, screening, eligibility, and inclusion process for articles selected for the systematic and bibliometric analysis of *G. rufa* research.

Identification	Records identified through database searching: *Web of Science Core Collection* **n = 82**	Records after applying document type filter (Article or Review): **n=3**
Screening	Records screened by title, abstract, and Web of Science categories: Applied categories: Fisheries, Marine/Freshwater Biology, Zoology, Dermatology, Ecology, etc. **n = 79**	Excluded due to category irrelevance or off-topic results: **n = 18**
Eligibility	Records further refined using Citation Topics (Meso level): Final refined set: **n = 61**	Additional exclusions based on Citation Topics refinement: **n = 15**
Included	Full-text articles assessed for eligibility **(n = 46)** All included in final analysis	

2.4. Bibliometric Analysis Workflow

Bibliometric analysis was conducted using RStudio version 4.3.2, the Bibliometrix package, and the Biblioshiny GUI. Data preparation involved cleaning and harmonizing author names, affiliations, and keywords to minimize redundancy and ensure analytical consistency (Zupic & Čater, 2014).

Key Bibliometric Indicators:

- Annual scientific production
- Most relevant authors and institutions
- Source impact and citation metrics
- Co-authorship networks (authors, institutions, countries)
- Keyword co-occurrence and thematic evolution

Visualizations were generated using Biblioshiny's built-in tools, including strategic diagrams, conceptual structure mapping, and thematic evolution plots, to explore research clusters and shifting topical emphases.

2.5. Analytical Objectives

The combined methodology enabled the identification of:

- Research productivity trends and geographic distributions
- Influential authors, institutions, and journals
- Collaborative structures in *G. rufa* scholarship
- Thematic concentrations and knowledge gaps

By applying both PRISMA-guided filtering and quantitative bibliometric mapping, this study provides a robust and reproducible approach for evaluating the multidimensional research landscape surrounding *G. rufa*, including its ecological functions, therapeutic roles, and aquacultural potential (Cobo et al., 2011; Ellegaard & Wallin, 2015).

3. RESULTS

3.1. Overview

3.1.1. Descriptive Bibliometric Indicators

This study evaluates a total of 46 peer-reviewed publications on *G. rufa*, retrieved from the Web of Science Core Collection, spanning the years 1993 to 2025. The dataset encompasses 40 distinct sources, 159 unique authors, and 1,344 cited references, with an average of 3.74 co-authors per document, reflecting a collaborative scholarly environment. Only six documents were single-authored, while international co-authorship accounts for 19.57%, indicating limited but present cross-border collaboration. The average citation rate stands at 10.96 citations per document, and the mean document age is 10.3 years, suggesting a balanced accumulation of both foundational and recent studies (Figure 1).

A total of 162 unique author keywords were identified, demonstrating a diverse conceptual scope that intersects with fields such as aquaculture, dermatology, parasitology, and environmental science. These metrics collectively indicate that *G. rufa* research, though modest in volume, is multidisciplinary and thematically broad.

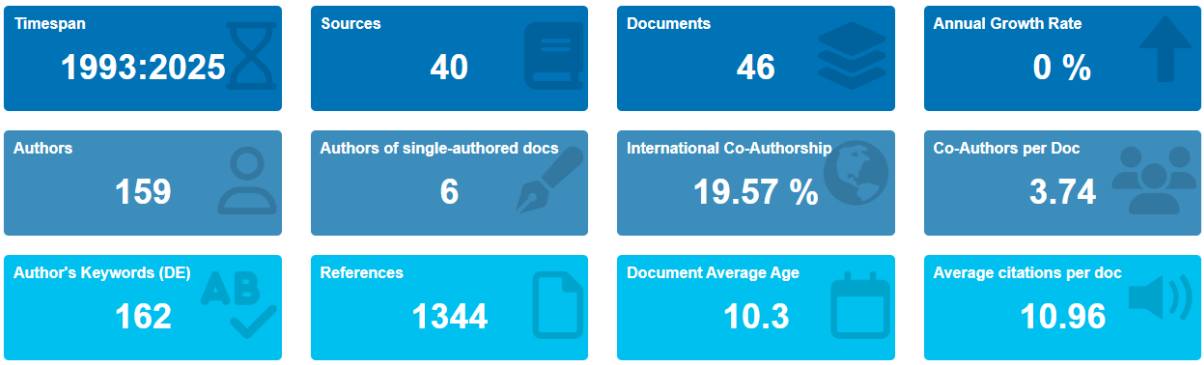

Figure 1. Descriptive bibliometric indicators of *G. rufa* research (1993–2025).

3.1.2. Annual Scientific Production

The temporal distribution of publications reveals a gradual and irregular growth pattern in *G. rufa* research output (Figure 2). From 1993 to 2005, the number of publications remained relatively low, fluctuating between zero and two articles per year. A noticeable increase began around 2010, with a pronounced peak in 2013, during which seven publications were recorded—the highest annual output observed.

This peak aligns with heightened global interest in ichthyotherapy, spa tourism, and fish-based dermatological treatments. However, after 2013, the volume declined, showing intermittent activity until 2025. The annual growth rate, calculated at 0%, confirms the stagnation in recent years. Nonetheless, the persistence of publications in 2021–2022 suggests continuing relevance across multiple domains, including ecology, aquaculture, and public health.

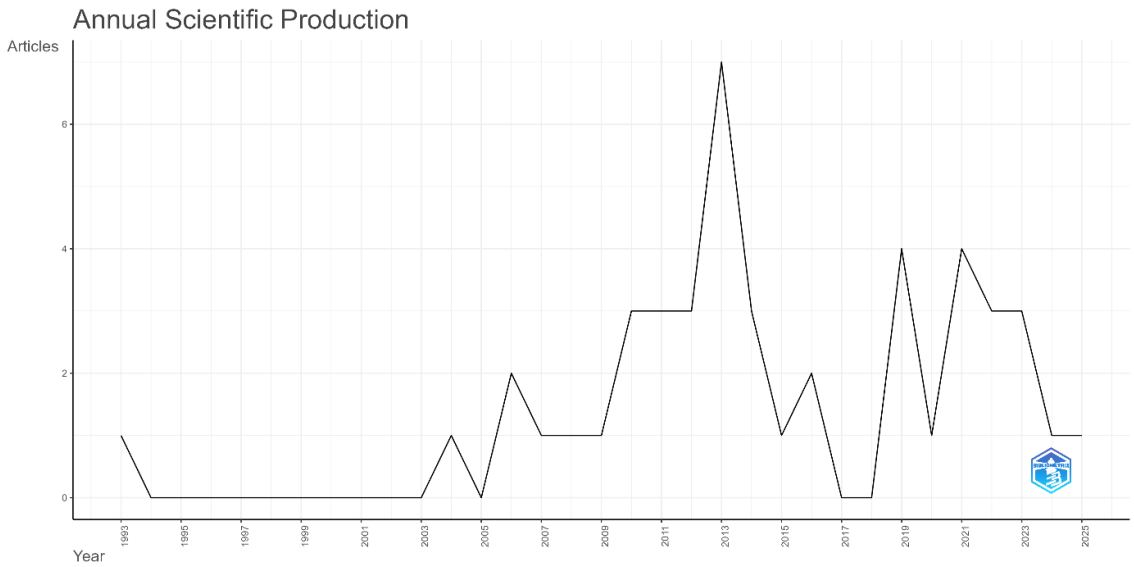

Figure 2. Annual scientific production trend for *G. rufa* publications (1993–2025).

3.1.3. Three-Field Plot: Interconnection of References, Authors, and Keywords

The intellectual and conceptual landscape of *G. rufa* research is illustrated in a three-field plot (Figure 3), which maps the interrelations among the most-cited references (CR), productive authors (AU), and recurring author keywords (KW). Key cited works such as Verner-Jeffreys (2012) and Grassberger and Hoch (2006) emphasize microbial infections and complementary therapies, reflecting dual concerns with fish pathology and therapeutic applications.

Leading contributors such as Aydın B., Golani D., and David L. are closely connected with core research themes like biodiversity, fish conservation, infection, and ichthyotherapy. The presence of keywords such as *"cyprinidae," "rainbow trout,"* and *"doctor fish"* alongside *"G. rufa"* highlights the taxonomic, therapeutic, and ecological dimensions of the field.

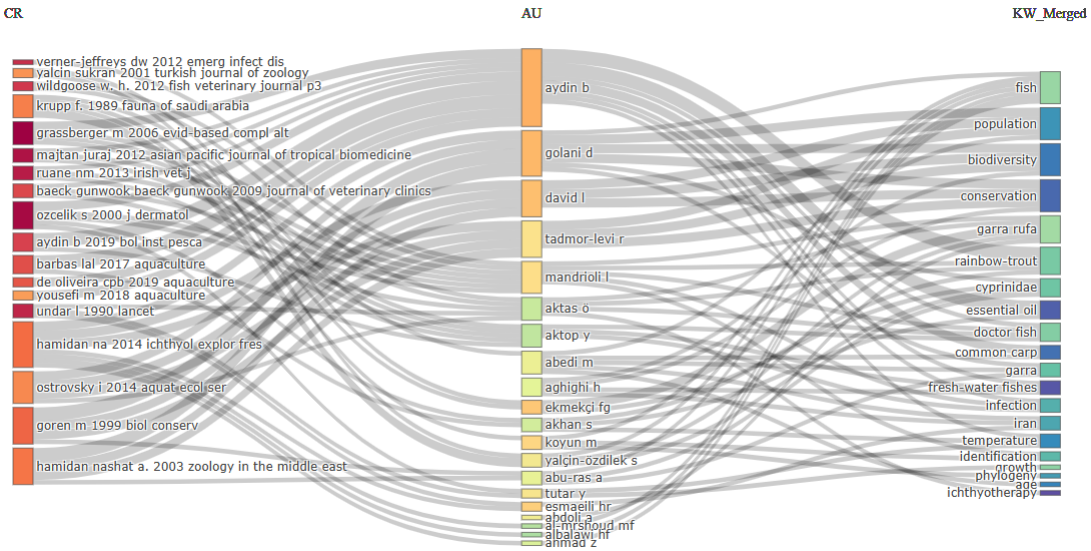

Figure 3. Three-field plot linking cited references (CR), authors (AU), and keywords (KW) in *G. rufa* literature.

3.2. Sources

This section examines the scholarly venues where *G. rufa* research has been most frequently published and cited. By analyzing both the number of publications and the volume of local citations, it is possible to identify the core journals that shape and reflect the knowledge base of this field.

3.2.1. Most Relevant Sources

The distribution of publications across journals reflects the multidisciplinary nature of *G. rufa* research, encompassing aquaculture, environmental science, veterinary medicine, and parasitology. The most relevant sources include *Aquaculture*, *Aquaculture Research*, *Fresenius Environmental Bulletin*, *Infection*, *Journal of Applied Ichthyology*, and *Turkish Journal of Fisheries and Aquatic Sciences*—each contributing two documents to the literature (Figure 4). This diversity of outlets underscores the broad academic interest in *G. rufa*, with studies spanning topics such as fish health, biodiversity, and ecological management.

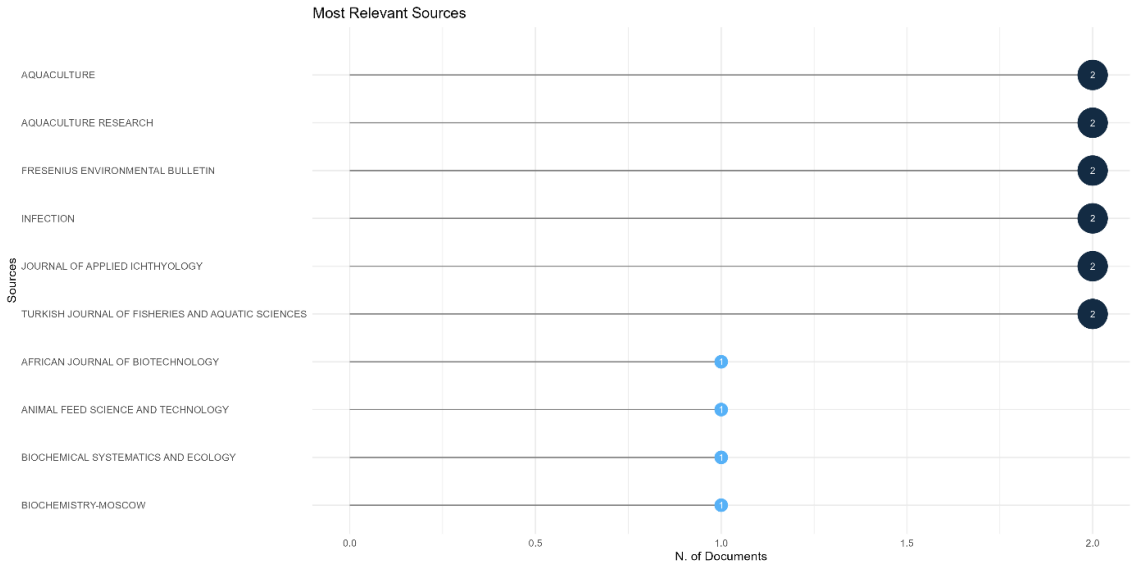

Figure 4. Most relevant sources in *G. rufa* research based on the number of published documents.

3.2.2. Most Local Cited Sources

A review of local citation counts reveals the foundational sources that have most significantly influenced subsequent research on *G. rufa*. The journal *Aquaculture* stands out with 83 local citations, followed by *Journal of Fish Biology* (n = 44), *Aquaculture Research* (n = 43), and *Journal of Applied Ichthyology* (n = 31) (Figure 5). These citation patterns suggest a strong reliance on aquaculture-focused journals, reinforcing the importance of fish farming practices, aquatic biology, and ichthyological methodologies in shaping the academic discourse on *G. rufa*.

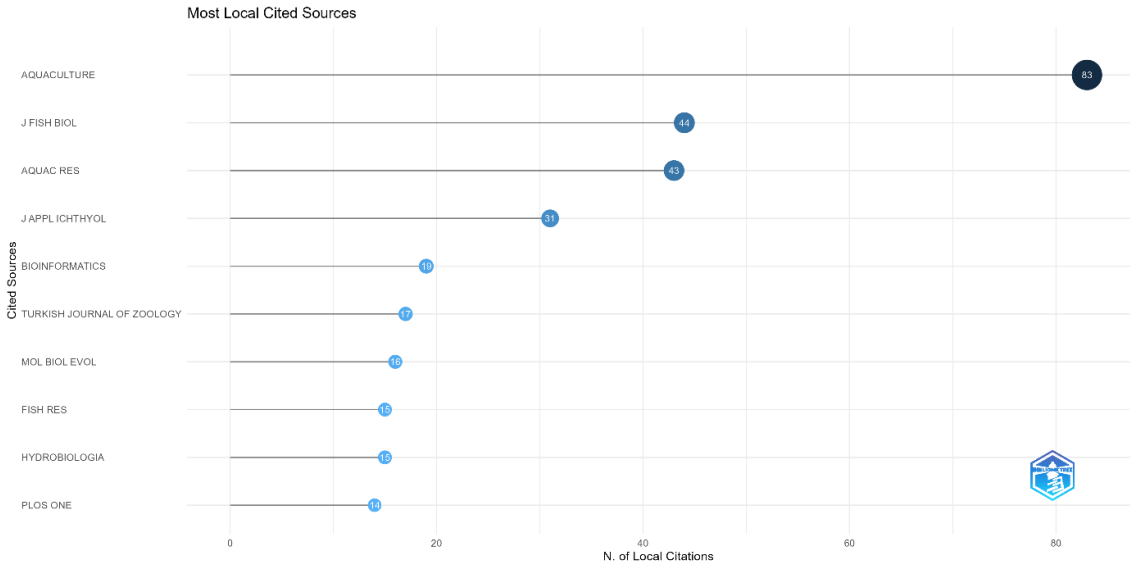

Figure 5. Most locally cited sources in the *G. rufa* literature.

3.3. Authors

3.3.1. Most Relevant Authors

The examination of the most prolific contributors to *G. rufa* research highlights a select group of authors who have published multiple documents within the domain. As illustrated in Figure 6, Aydın B emerges as the most productive author with four documents, followed by Golani D with three. Other notable contributors, including David L, Ekmekçi FG, Esmaeili HR, Koyun M, Mandrioli L, Tadmor-Levi R, Tutar Y, and Yalçın-Özdilek S, have each authored two documents. These researchers represent diverse specializations such as fish ecology, biodiversity, fish pathology, and ichthyotherapy, demonstrating the interdisciplinary character of *G. rufa* research.

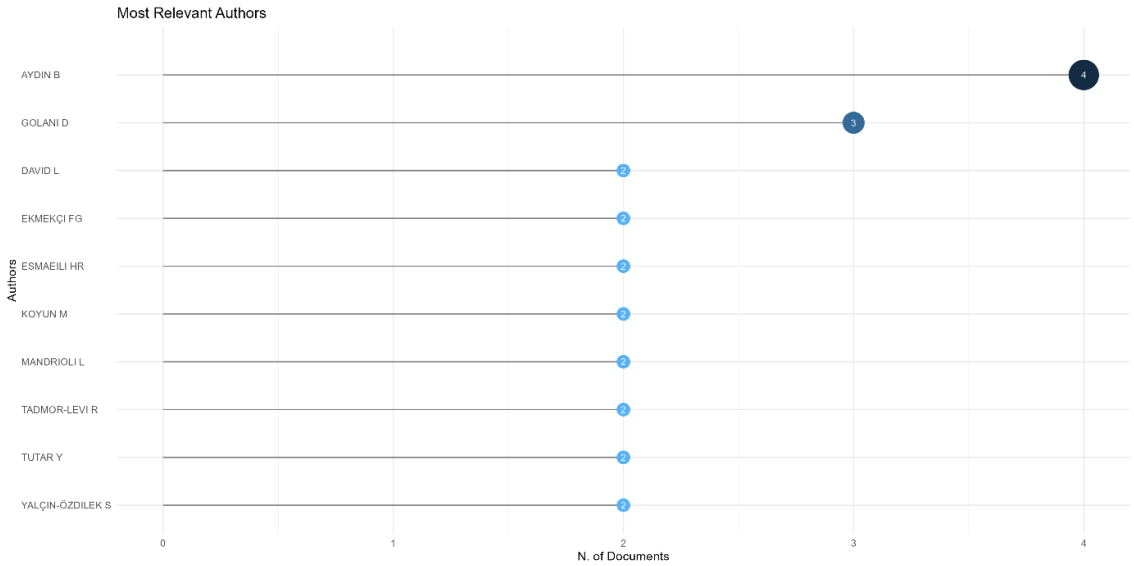

Figure 6. Most relevant authors based on the number of publications in the dataset.

3.3.2. Most Local Cited Authors

Citation analysis offers complementary insight into scholarly influence by identifying authors whose works have had significant impact within the dataset. As shown in Figure 7, Grassberger M and Hoch W are the most locally cited authors, each receiving 11 citations. They are followed by a cluster of scholars—including Collins EM, Geary M, Geoghegan F, Hickey C, Ruane NM, and Swords D—each cited six times locally. These individuals have made foundational contributions in areas such as fish health, parasite resistance, and environmental adaptations. Turkish researchers Aydın B and Akhan S also appear in the ranking with 5 and 4 citations respectively, indicating regional influence in the field.

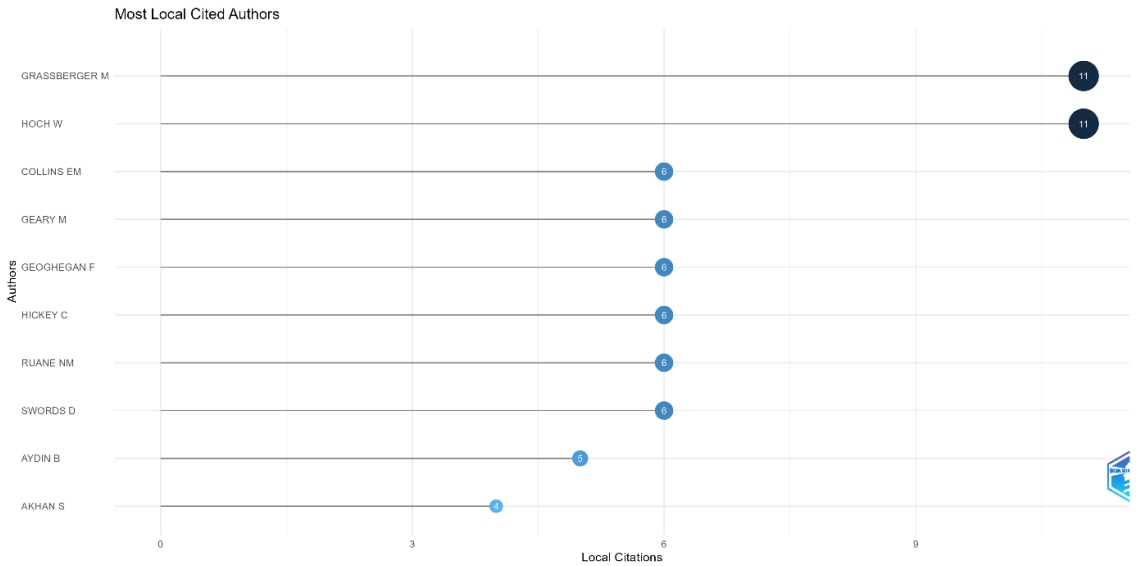

Figure 7. Most locally cited authors in *G. rufa* research.

3.4. Geographic and Institutional Contribution

3.4.1. Distribution of Corresponding Authors by Country

The distribution of corresponding authors reveals that Türkiye dominates the dataset in terms of national affiliation, followed by Iran, Israel, and Italy. While most contributions from Türkiye are single-country publications (SCP), Iran shows a more balanced mix with a considerable number of multiple-country publications (MCP), suggesting stronger international collaboration tendencies (Figure 8).

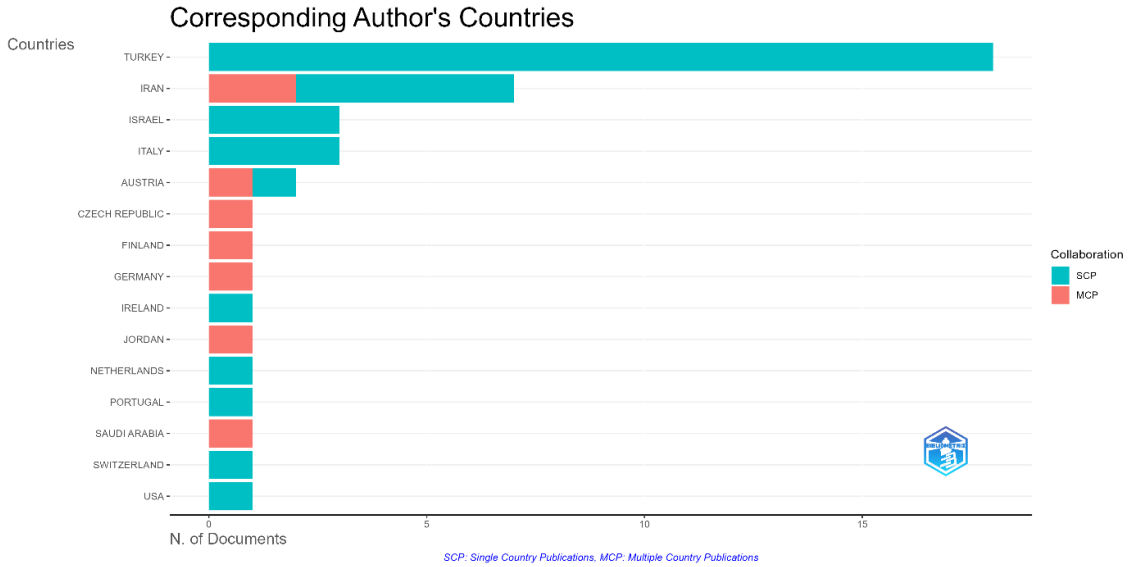

Figure 8. Corresponding author affiliations by country, distinguishing single-country (SCP) and multi-country (MCP) collaborations.

3.4.2. Most Cited Countries

Citation analysis underscores Türkiye's leading role, accounting for 190 citations, followed by Finland (100), and Iran (59). This trend suggests that research originating from these countries has received substantial scholarly attention. European countries such as Italy, Austria, and the Czech Republic also maintain a strong citation presence, reflecting their influential contributions within the research domain (Figure 9).

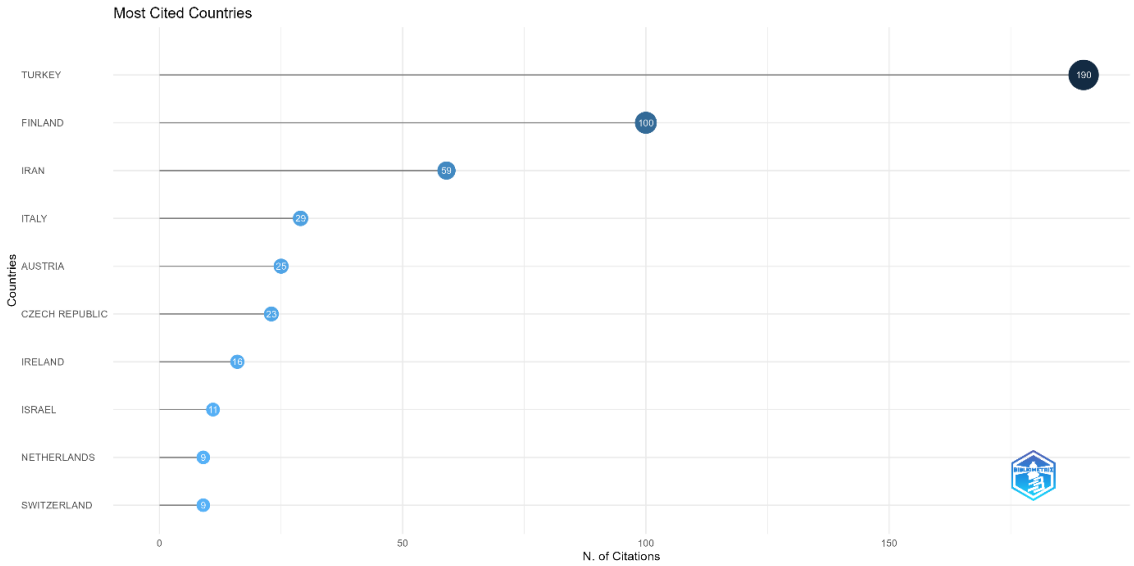

Figure 9. Most cited countries based on the total number of citations received in the dataset.

3.4.3. Most Relevant Institutional Affiliations

The most prolific institutions include Cumhuriyet University with 8 articles, followed by Akdeniz University and The Hebrew University of Jerusalem with 6 articles each. Additional key contributors include Çanakkale Onsekiz Mart University, University of Bologna, and University of Eastern Finland, each contributing four publications. These findings highlight that Turkish institutions, in particular, play a pivotal role in shaping the research output on this topic (Figure 10).

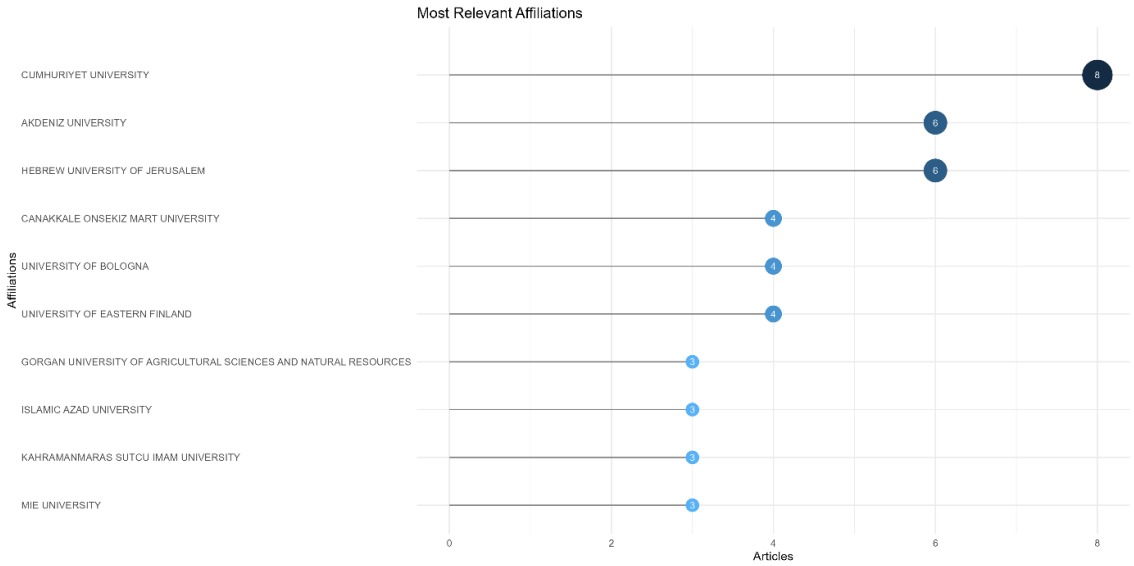

Figure 10. Most relevant affiliations based on the number of documents contributed by each institution.

3.5. Most Influential Documents

The identification of influential documents provides a deeper understanding of the intellectual foundations and impactful contributions in the research field of *G. rufa* and its applications. This analysis distinguishes between local and global influence based on citation metrics within the dataset and across the broader scholarly landscape.

3.5.1. Local Citations

Local citations indicate how often a document is cited within the specific dataset used in this bibliometric study. As presented in Figure 11, the most locally cited document is *Grassberger and Hoch (2006)*, which received 11 citations within the dataset. This work appears to have played a foundational role in shaping local discourse on the therapeutic use of *G. rufa*. It is followed by *Ruane (2013)* and *Aydın (2019)*, with 6 and 4 local citations, respectively. Several other studies—such as those by Yalçın-Özdilek (2006), Abedi (2011), and Gorshkova (2012)—each received three citations, indicating a relatively consistent pattern of mid-level influence in the local context.

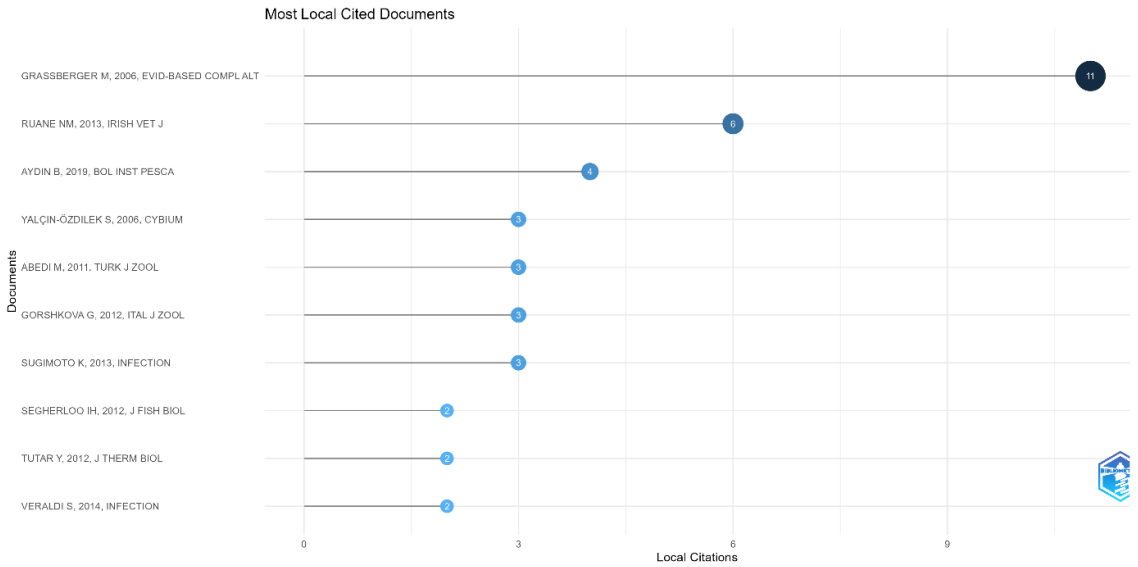

Figure 11. Most locally cited documents within the dataset.

3.5.2. Global Citations

Global citation analysis provides insight into the wider academic influence of key publications beyond the current dataset. As illustrated in Figure 12, *Oksala et al. (2014)* emerges as the most globally cited work, with 100 citations, indicating a high level of international recognition. It is followed by *Yanar (2019)* with 39 citations and *Grassberger and Hoch (2006)* with 25 citations—once again highlighting the consistent relevance of Grassberger and Hoch's work across both local and global contexts. Additional influential documents include *Civánová (2013)*, *Aydın (2021)*, and *Segherloo (2012)*, each contributing significantly to the global research dialogue surrounding fish-based therapy, aquatic biodiversity, and related methodologies.

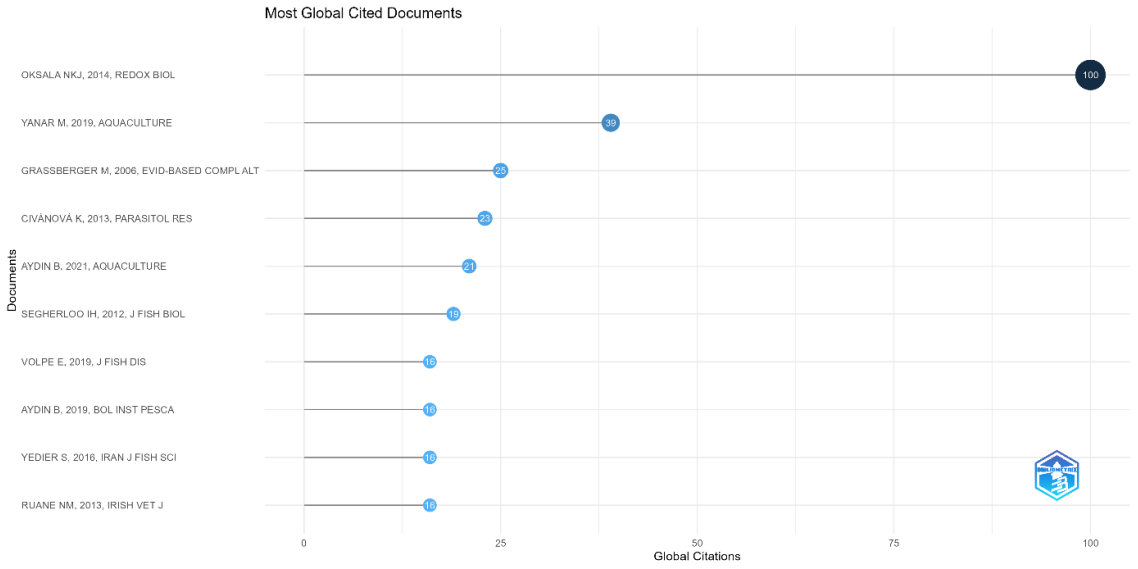

Figure 12. Most globally cited documents based on total citations.

3.5.3. Temporal Distribution of Cited References

To contextualize the impact of cited literature over time, **Figure 13** presents the Reference Publication Year Spectroscopy (RPYS). This visualization shows a notable increase in cited references beginning in the early 2000s, peaking around 2006–2015. This trend aligns with the growing global attention toward alternative therapeutic practices and biodiversity conservation in aquatic ecosystems. The black line in the figure denotes the number of cited references by year, while the red line represents deviations from the five-year median, highlighting periods of significant citation impact.

These findings underscore the centrality of a select group of documents in shaping the field, both within the focused scope of this dataset and the broader international academic discourse. The overlap between locally and globally cited documents—particularly in the case of *Grassberger and Hoch (2006)*—demonstrates how foundational studies can bridge specific research communities and the global scientific conversation.

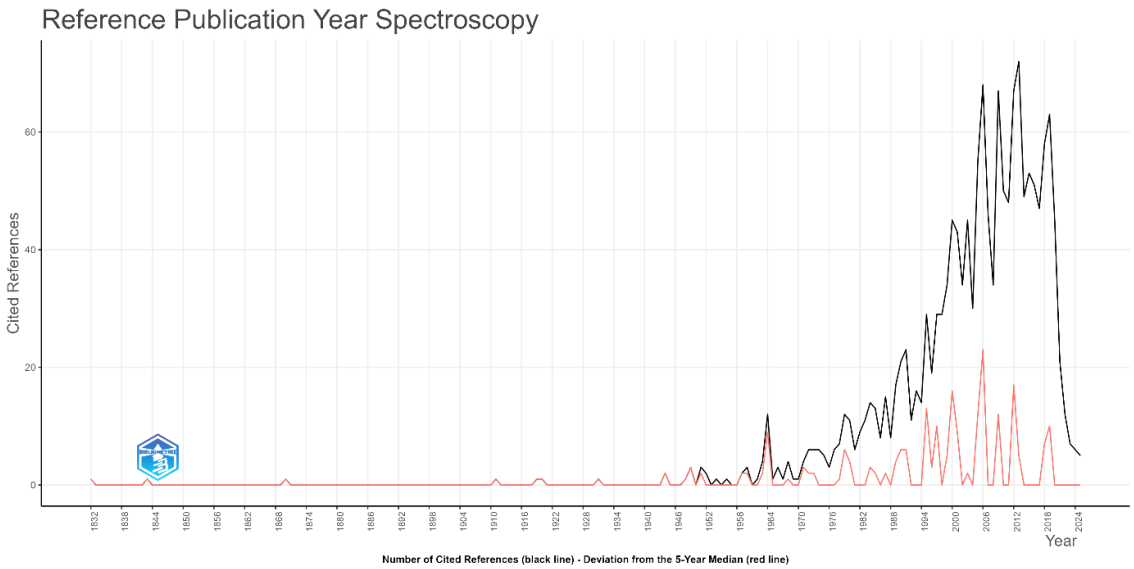

Figure 13. Reference Publication Year Spectroscopy (RPYS) indicating the temporal distribution of cited references.

3.6. Emerging and Trending Topics

Understanding the evolution of thematic focus areas over time offers valuable insights into the shifting priorities and knowledge gaps within the field. The analysis of trending keywords and term frequencies reveals how interest in specific aspects of *G. rufa* has developed, diversified, and intensified.

3.6.1. Keyword Frequency and Relevance

As presented in Figure 14, the most frequently used keywords across the dataset include "*G. rufa*" (n = 15), "fish" (n = 6), "growth" (n = 6), and "doctor fish" (n = 5). These terms reflect the core biological and commercial aspects of the species, particularly in relation to aquaculture and therapeutic applications. Additional recurring keywords such as “rainbow-trout”, “cyprinidae”, “infection”, and “identification” indicate a multidisciplinary interest spanning taxonomy, disease ecology, and aquaculture management.

Figure 14. Most relevant keywords by frequency of occurrence.

3.6.2. Temporal Evolution of Terms

To analyze how thematic focuses have changed over time, Figure 15 presents a trend topic timeline. Early research (pre-2010) predominantly concentrated on broad descriptors such as “fish”, “Türkiye”, and “pisces”. Between 2010 and 2017, studies began to emphasize “*G. rufa*”, “growth”, “population”, and “cyprinidae”, reflecting an increasing attention to biological characterization and species-specific studies. More recent years (2018–2023) saw the rise of topics such as “infection”, “conservation”, “biodiversity”, “temperature”, and “teleostei”, indicating a shift toward ecological resilience, climate sensitivity, and species preservation.

This progression highlights a growing complexity and ecological consciousness in *G. rufa* research. The expansion from basic taxonomy and aquaculture toward conservation biology, infection monitoring, and environmental stress analysis demonstrates the maturing nature of the field.

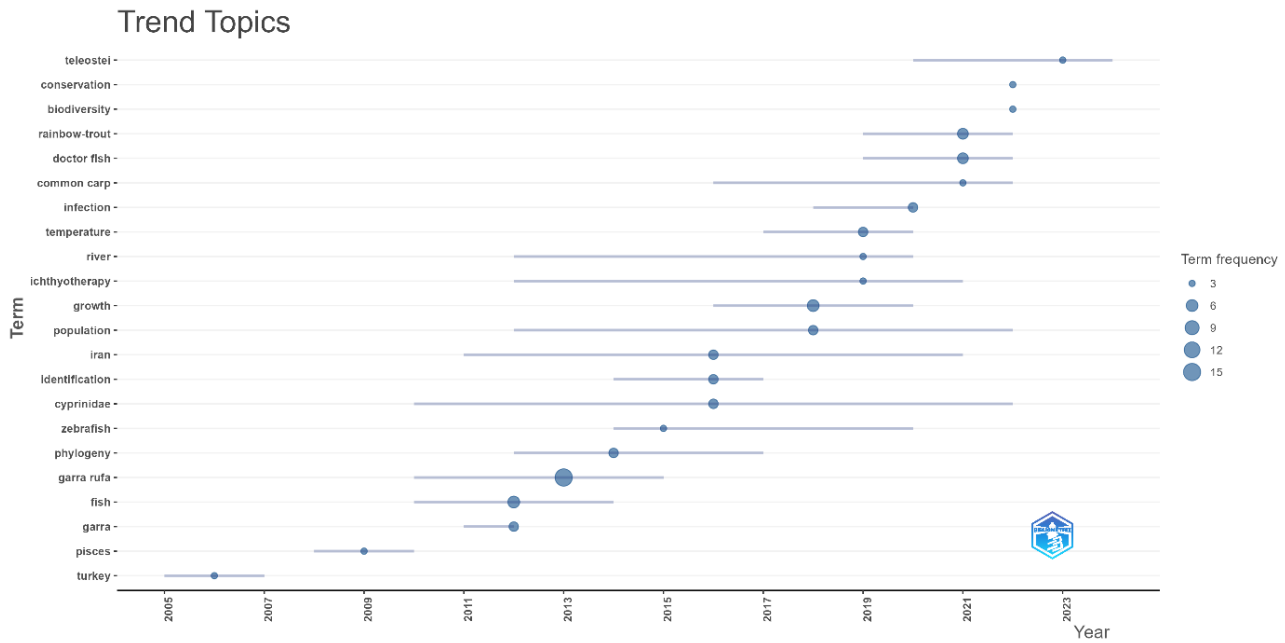

Figure 15. Trend topic analysis displaying the temporal distribution of emerging themes.

4. DISCUSSION

This study systematically reviewed and bibliometrically analyzed the literature on *G. rufa*, encompassing its biological, therapeutic, and environmental dimensions. The results reveal a research domain that, while modest in volume, is conceptually rich and multidisciplinary. The growing interest in *G. rufa* aligns with its unique role in ichthyotherapy and its commercial use in wellness tourism, as evidenced by the peak in scientific production during 2013—a period coinciding with heightened global attention to alternative therapies.

The bibliometric indicators identified key journals and authors that shape the field, with *Aquaculture* and *Aquaculture Research* emerging as both the most cited and most productive sources. Authors such as Grassberger and Hoch have had a foundational influence, particularly in research linking *G. rufa* to dermatological applications. The strong presence of Turkish institutions and researchers, such as Aydın B., reflects the species' endemic status and national relevance, both ecologically and economically.

Emerging themes, such as biodiversity conservation, climate resilience, and pathogen surveillance, indicate a transition from narrowly focused aquaculture studies to broader ecological and public health concerns. This evolution aligns with global scientific priorities regarding climate change adaptation and the One Health framework. However, the low number of international co-authorships and stagnating publication trends in recent years suggest a need for revitalized interdisciplinary collaboration and funding initiatives.

Furthermore, ethical issues surrounding spa-based fish therapy and biosafety concerns, including the transmission of zoonotic infections, remain underexplored in the literature. Addressing these dimensions requires integrating biomedical ethics, veterinary parasitology, and regulatory policy frameworks into future research efforts.

5. CONCLUSION

This review provides a comprehensive mapping of *G. rufa* scholarship from 1993 to 2025, highlighting its ecological, therapeutic, and economic significance. Although the literature is relatively limited in size, it exhibits thematic diversity and interdisciplinary potential. Key findings emphasize that:

- *G. rufa* research is primarily concentrated in Türkiye and Iran, with limited international collaboration.
- The species is most studied in the context of aquaculture and ichthyotherapy, with a growing emphasis on conservation biology and ecological resilience.
- Highly cited authors and institutions have played pivotal roles in shaping both local and global discourse.
- Ethical, genetic, and biosafety concerns remain underrepresented in current research.

To advance the field, future studies should prioritize genomic and transcriptomic research, develop standardized therapeutic protocols, and enhance cross-national cooperation. By addressing both scientific and policy-related gaps, the *G. rufa* research agenda can

better support sustainable aquaculture, biodiversity conservation, and safe biomedical applications.

Acknowledgments and Funding

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Compliance with Ethical Standards

Author's Contributions

NK: Conceptualization, Methodology, Data Curation, Analysis, Writing – Original Draft and Final Editing. The author read and approved the final manuscript.

Conflict of Interest

The author declares that there is no conflict of interest.

Statement on the Welfare of Animals

Ethical approval: For this type of study, formal consent is not required.

Statement of Human Rights

Ethical approval: For this type of study, formal consent is not required.

Data Availability Statements

The data that support the findings of this study are openly available in **Zenodo** at https://doi.org/10.5281/zenodo.15765170, reference number **15765170**.

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