

FROM BIOACOUSTICS TO ARTIFICIAL INTELLIGENCE: A BIBLIOMETRIC STUDY OF STRESS AND WELFARE MONITORING IN POULTRY

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Abstract: In this study, the scientific literature regarding the acoustic monitoring of stress and welfare in poultry was examined from both bibliometric and thematic perspectives. Publications covering the period from 1987 to 2025 were retrieved from the Web of Science Core Collection database; only research articles and reviews in English were included in the evaluation. Bibliometric analyses were conducted using the Bibliometrix package and the Biblioshiny interface within the R environment. Annual scientific output, sources, authors, countries, citation structure, keyword co-occurrence networks, and thematic structure were analyzed. The findings revealed significant growth in the research field, particularly after 2020, with an annual scientific output growth rate of 8.47%. While "Poultry Science", "Applied Animal Behaviour Science", and "Animals" emerged as the most productive publication sources, keyword and thematic analyses highlighted concepts such as animal welfare, behaviour, poultry, broiler, bioacoustics, precision livestock farming, and machine learning. Notably, the inclusion of "poultry-machine learning" and "animal welfare-behaviour" clusters among the motor themes indicates an evolution in the field from classical bioacoustics approaches toward AI-supported, automated welfare monitoring systems. In conclusion, the study finds that research on acoustic monitoring in poultry is becoming increasingly interdisciplinary and that AI-based methods could play a pivotal role in the future development of objective, continuous, and non-invasive welfare assessment systems.

Keywords: Bioacoustics, Animal welfare, Poultry, Vocalization, Artificial intelligence, Bibliometrics

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1. Introduction

The reliable and continuous monitoring of animal welfare in poultry is becoming increasingly important in modern production systems, both in terms of ethical requirements and sustainable production. Traditional welfare assessments rely largely on methods requiring direct observation or intervention, such as behavioral observations, physiological measurements, and periodic clinical checks. In contrast, the development of precision livestock farming technologies has brought to the fore sensor-based approaches that enable the monitoring of animal health, behavior, and welfare status in a contactless, continuous, and real-time manner. Among these approaches, bioacoustics and acoustic monitoring are particularly notable for their ability to provide low-cost, non-invasive, and continuous data. It has long been emphasized that animal vocalizations can convey information regarding emotional, physiological, and individual characteristics, and that automated sound analysis can be utilized for large-scale monitoring of animal welfare (McLoughlin et al., 2019). More recent studies also demonstrate that bioacoustics methods hold

significant potential for monitoring various components of welfare, such as physiology, health, behavior, and affective states (Coutant et al., 2024).

Animal vocalizations can be viewed not only as means of communication but also as indicators of the biological and environmental conditions the animals are experiencing. Characteristics of vocalizations, such as frequency, duration, fundamental frequency, energy distribution, spectral structure, and call type, can be linked to stress, health status, behavior, and emotional valence. Research on farm animals indicates that vocal characteristics can be used to assess positive welfare states, not just negative ones. For instance, it has been reported that the duration and fundamental frequency of vocalizations associated with positive states can vary in certain species, and that specific call types in chickens can be linked to positive states (Laurijs et al., 2021). Therefore, using vocalizations in conjunction with other behavioral and physiological indicators is considered a promising approach for the non-invasive assessment of welfare under farm conditions.

The importance of sound-based assessments in poultry has become increasingly evident through studies



conducted on broilers and laying hens. Current research demonstrates that distinct types of vocalizations can be automatically identified and utilized to monitor welfare-related conditions. Soster et al. (2025a) developed a system based on a convolutional neural network to distinguish between four types of broiler vocalizations, such as distress calls, pleasure notes, short peeps, and warbles, achieving a balanced accuracy of 91.1%. The study relied on a dataset comprising over 2,000 labeled vocalization samples, and the results highlighted the potential of automated acoustic monitoring for assessing broiler welfare. Similarly, Lev-ron et al. (2025) classified the vocal responses of broilers to environmental stressors such as cold, heat, and wind using acoustic signal processing and a transformer-based artificial neural network, reporting that the developed approach achieved a mean average precision of 0.97. These findings indicate that vocalizations could serve as a potential digital welfare indicator for the early detection of environmental stress. Alongside classical acoustic techniques, such as Mel-frequency cepstral coefficients, spectral features, and spectrogram analyses, convolutional neural networks, long short-term memory networks, and attention-based models are increasingly being employed for the automated interpretation of poultry vocalizations. A comprehensive systematic review from 2025 demonstrated that artificial intelligence-assisted (AI-assisted) vocalization analysis in poultry is advancing rapidly, particularly in the monitoring of health, behavior, and welfare, with the majority of the examined studies published after 2020 (Manikandan and Neethirajan 2025a; 2025b). Furthermore, another recent systematic review reveals that automated acoustic analyses in broiler and laying hens are beginning to be linked to the "Five Domains" welfare framework.

However, the bulk of existing literature focuses on the performance of specific algorithms, particular vocalization types, or specific welfare indicators. There is a scarcity of bibliometric studies that provide a holistic overview of the field's scientific evolution over time, prominent research themes, collaborations between countries and authors, and, crucially, the transition from traditional bioacoustics approaches to AI-driven monitoring systems. Therefore, the aim of this study is to examine scientific literature on the acoustic monitoring of stress and welfare in poultry using bibliometric and thematic methods, and to elucidate publication trends, influential sources, collaboration structures, key research themes, and the field's conceptual shift from bioacoustics to artificial intelligence.

2. Material and Methods

In this study, the Web of Science Core Collection (WoSCC) database was used to evaluate the bibliometric structure of the scientific literature regarding the monitoring of stress and welfare in poultry using acoustic methods. Web of Science was selected because it provides the detailed bibliographic metadata—such as author, source, citation,

keyword, and institutional information—necessary for bibliometric analysis. The literature search was designed to encompass the concepts of poultry, vocalization/acoustic monitoring, and stress/welfare. The "Topic Search" query employed was defined as follows:

TS=(broiler* OR "broiler chicken" OR poultry) AND (vocalization* OR vocalisation* OR acoustic* OR sound*) AND (stress OR welfare)

Bibliometric analyses were conducted using the R statistical programming environment (R Core Team, 2026) and the RStudio (version 2026.09.0+174) integrated development environment (Posit Software, PBC). The "Bibliometrix" R package was utilized for processing bibliographic data, calculating performance indicators, and performing science mapping analyses. Bibliometrix is a comprehensive open-source tool developed for bibliometric data analysis and science mapping (Aria and Cuccurullo, 2017). Biblioshiny, which is the web-based user interface of the Bibliometrix package, was used to generate the visual outputs of the analyses (Aria and Cuccurullo, 2026; Aria et al., 2026). The process of identifying, screening, and ultimately including studies in the analysis is presented in accordance with the PRISMA 2020 reporting framework (Page et al., 2021). Through this interface, analyses were performed regarding annual scientific output, source and author performance, citation metrics, keyword co-occurrence networks, thematic maps, and other aspects of conceptual structure.

The search initially yielded 211 records. The PRISMA 2020 approach was utilized to ensure transparent reporting of the selection process, and the process was illustrated using a flow diagram adapted for bibliometric studies. PRISMA flow diagrams enable clear reporting of the movement of identified records through the screening, eligibility assessment, and final inclusion stages, as well as the number of excluded records (Figure 1).

In the first stage, since 2026 was an incomplete publication year, 19 records from that year were excluded to avoid introducing bias into the time-series and thematic trend analyses; this left 192 records covering the 1987–2025 period. Subsequently, only "research article" and "review article" types were included, while 11 records belonging to other document types were removed, reducing the total count to 181. In the final stage, only studies published in English were retained; 9 non-English records were eliminated, resulting in a final dataset of 172 publications for bibliometric analysis. Due to the interdisciplinary nature of the subject, no Web of Science subject category filter was applied, thereby preventing the exclusion of studies published in fields such as animal science, veterinary medicine, behavioral science, agricultural engineering, computer science, electronic engineering, and related disciplines.

Bibliographic records for the 172 finally included publications were exported from Web of Science in a format containing the "Full Record and Cited References." This format enables comprehensive bibliometric analyses,

as it encompasses publication years, authors, journals, institutions, countries, author keywords, Keywords Plus, citation data, and reference lists.

During the analysis process, the general bibliometric characteristics of the dataset were evaluated first. In this context, the total number of publications, annual scientific output, annual growth trends, number of sources, number of authors, co-authorship structure, and citation indicators were examined. Additionally, the most productive journals, most productive authors, countries with the highest publication output, and studies receiving the highest global citations were identified. During the analysis process, the general bibliometric characteristics of the dataset were evaluated first. In this context, the total

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To reveal the scientific collaboration structure of the field, co-authorship and international collaboration patterns at the country level were assessed. Bibliometrix/Biblioshiny enables the analysis of co-authorship networks at the author, institution, and country levels, alongside key indicators of scientific output performance.

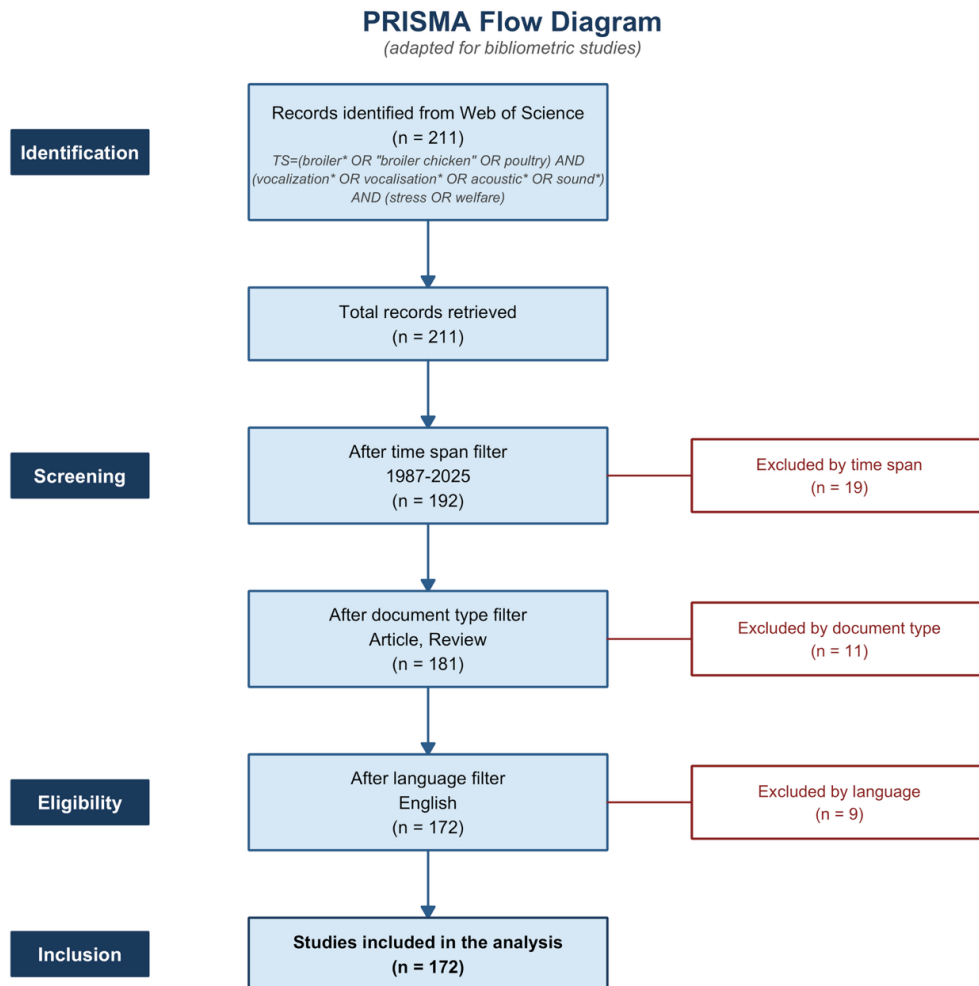


Figure 1. PRISMA flow diagram.

3. Results

The final dataset, obtained from the Web of Science Core Collection and analyzed using Biblioshiny, comprises 171 documents published between 1987 and 2025 (Figure 2). These publications appeared in a total of 70 different sources and were authored by 666 individuals. The fact that only 11 of the studies were single authored indicates that the research field is characterized by a high degree of collaboration. The average number of authors per

document was found to be 4.68, while the international co-authorship rate stood at 23.98%. The dataset contains a total of 544 author keywords and 7,225 bibliographic records. The average age of the documents was calculated as 9.64 years, with an average of 34.13 citations per document. An average annual growth rate of 8.47% in scientific output demonstrates a long-term increase in research interest regarding the sound-based monitoring of stress and welfare in poultry.

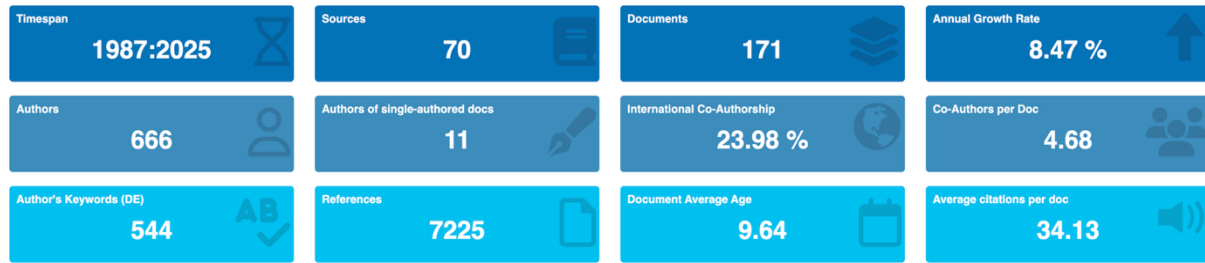


Figure 2. Main information.

An examination of annual scientific production reveals that the field initially had a very limited volume of publications (Figure 3). While the number of annual publications remained largely confined to a few studies from the late 1980s through the early 2000s, the first significant increase was observed between 2008 and 2010. Nevertheless, the primary acceleration occurred

after 2020. Output reached approximately 16 publications in 2022; following a temporary dip in 2023, it rose to 20 publications in 2024 and approximately 22 in 2025, marking the highest level recorded in the dataset. This pattern suggests that the field has expanded in recent years from classical animal behavior and welfare studies toward sensor-based and automated monitoring systems.

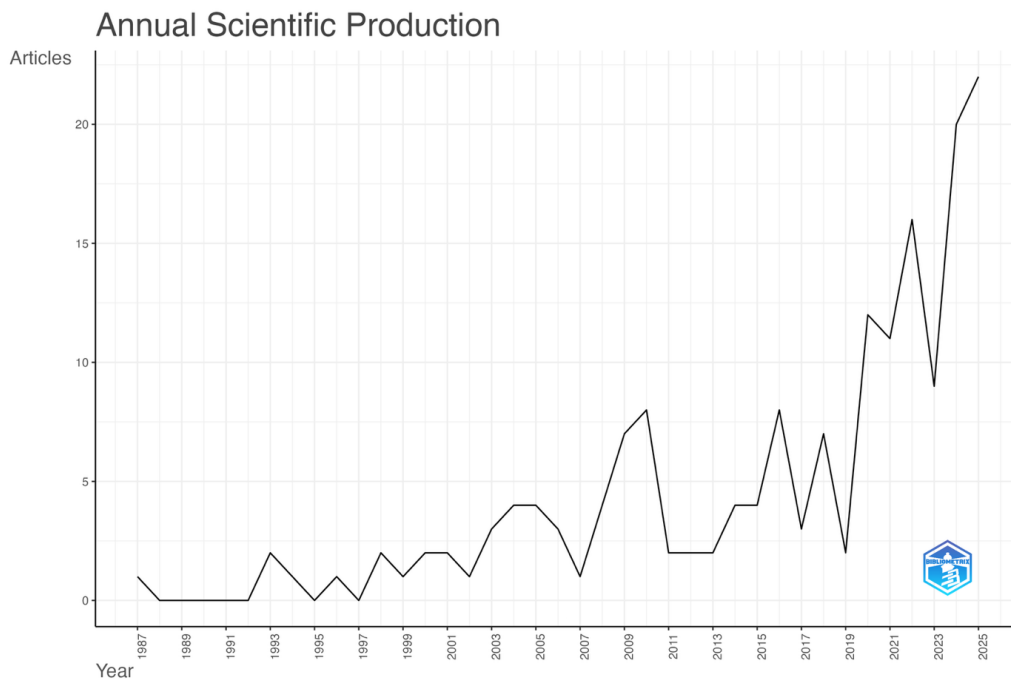


Figure 3. Annual scientific production on acoustic monitoring of stress and welfare in poultry between 1987 and 2025.

This acceleration is consistent with current literature. It is reported that acoustic monitoring in poultry has increasingly integrated with artificial intelligence, deep learning, and automated vocalization classification in recent years. For instance, the ability to classify different vocalization types in broiler chickens with a balanced accuracy of 91.1% using a convolutional neural network has demonstrated that acoustic data can be transformed into practical welfare monitoring systems (Soster et al., 2025a). Similarly, mean average precision values reaching 0.97 have been reported in the classification of broiler vocalizations associated with environmental stressors using artificial neural networks (Lev-Ron et al., 2025). Consequently, the increase in publications since 2020 reflects not only numerical growth but also a

methodological transformation in which acoustic data is integrated with AI-based decision support systems. An analysis of the sources indicates that the field is developing across journals covering both animal science/welfare and engineering-technology (Figure 4). "Poultry Science" holds the highest number of publications, ranking first with 21 documents. It is followed by "Applied Animal Behaviour Science" with 17 publications and "Animals" with 15. Other notable sources include "Computers and Electronics in Agriculture" (eight publications), "Animal" (seven), and "Frontiers in Veterinary Science" (six). Additionally, "British Poultry Science" and "Sensors" (five publications each), along with "Animal Welfare" and "Applied Sciences-Basel" (four publications each), are among the top ten sources.

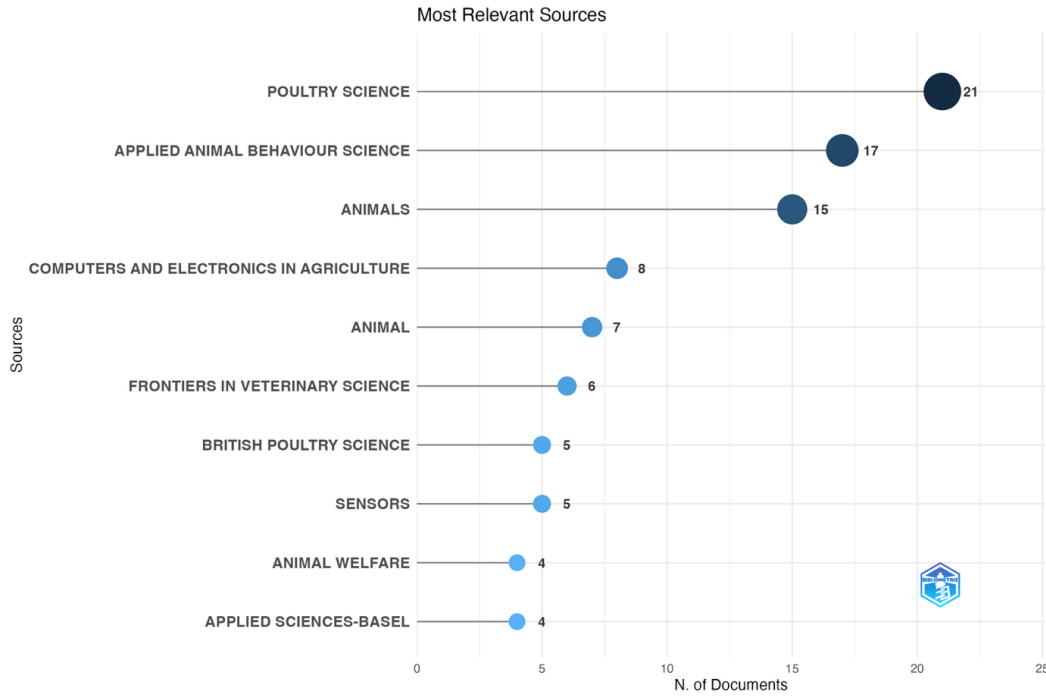


Figure 4. Most relevant sources, ranked by the number of publications in the analyzed dataset.

This distribution clearly demonstrates the interdisciplinary nature of the field. The prominence of welfare and behavior-focused journals, such as “Applied Animal Behaviour Science” and “Animal Welfare”, alongside species-specific journals like “Poultry Science” and “British Poultry Science” highlights the biological foundations of the literature. Conversely, the high ranking of technology-oriented sources such as “Computers and Electronics in Agriculture”, “Sensors”, and “Applied Sciences” indicates that acoustic welfare monitoring is increasingly integrating sensor technologies, signal processing, and artificial intelligence applications. Current literature also notes that the application of machine learning in poultry farming is expanding beyond the assessment of behavior, health, and welfare to include

sound- and image-based automated diagnostic systems (Naeem et al., 2025). Therefore, resource allocation can be considered a bibliometric indicator supporting the transition from “bioacoustics to artificial intelligence” mentioned in the study’s title.

The co-occurrence network based on author keywords demonstrates that the research field has evolved not around a single conceptual axis, but through multiple interconnected thematic clusters (Figure 5). The network reveals links between concepts related to welfare and behavior and those focused on poultry production, stress, acoustic/sound analysis, and technology. The fact that certain major nodes are connected to multiple clusters indicates that these terms serve as conceptual bridges within the research field.

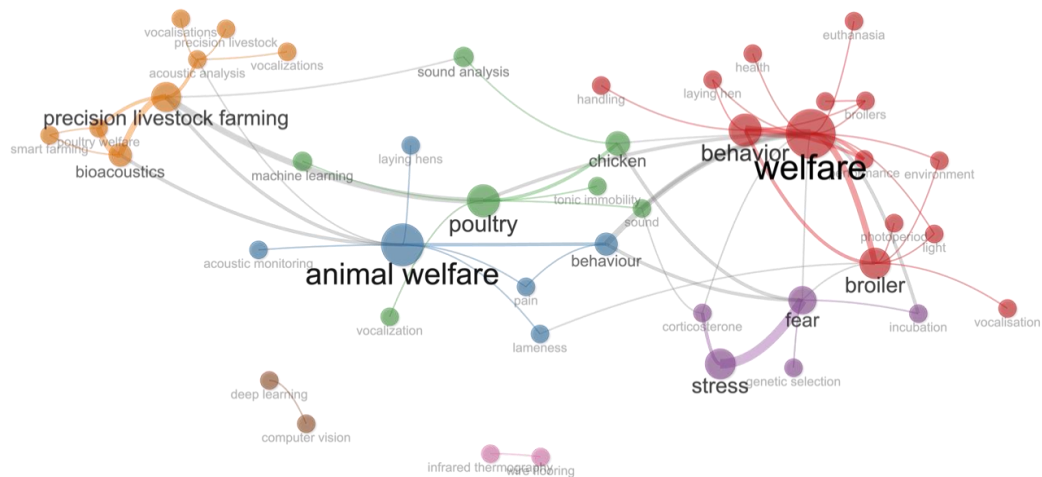


Figure 5. Keyword co-occurrence network illustrating the conceptual structure of research on acoustic monitoring of poultry stress and welfare.

The positioning of concepts such as animal welfare, behavior, poultry, machine learning, broilers, stress, bioacoustics, and precision livestock farming on the thematic map further supports this network structure. This result suggests that acoustic monitoring studies are no longer focused solely on identifying vocalizations but have evolved into a broader research framework integrated with behavioral welfare indicators, precision livestock farming systems, and automated classification models. Indeed, current studies demonstrate that stress, behavior, and health status can be assessed non-invasively by utilizing acoustic features in conjunction with machine learning and deep learning models (Manikandan and Neethirajan, 2025b).

The thematic map categorizes clusters formed from the author's keywords into four regions based on centrality and density metrics (Figure 6). In the bibliometric approach, clusters with high centrality and high density values are interpreted as "motor themes"; those with low centrality and high density as "niche themes"; those with low centrality and low density as "emerging or declining themes"; and those with high centrality and low density as "basic themes."

In this context, there are two distinct clusters in the "Motor Theme" region. The first cluster is shaped around the terms animal welfare, behavior, and lameness. This indicates that research on animal welfare and behavior constitutes a fundamental axis of the field—one that is well-developed and strongly linked to other themes. The second motor theme centers on the axis of poultry, machine learning, and laying hens. The inclusion of "machine learning" as a motor theme is particularly significant; this finding demonstrates that AI-based analyses have evolved from a peripheral innovation into a central, advanced component of the current research landscape. This result aligns with the methodological shift—reported in a 2025 systematic review—from traditional MFCC- and spectrogram-based methods toward CNNs, LSTMs, attention mechanisms, and self-supervised audio models (Manikandan and Neethirajan, 2025a).

The presence of the "welfare-broiler-behavior" cluster within the "Basic Themes" region indicates that broiler welfare and behavior constitute one of the most fundamentals and interconnected conceptual backbones of the research field. The high centrality yet relatively low density of this cluster suggests that, while the topic is linked to numerous sub-fields of the literature, it continues to evolve internally around diverse methods

and indicators. This situation aligns with existing methodological gaps regarding standardized audio recording protocols, shared datasets, and models generalizable across species, ages, and environmental conditions. Current literature shows ongoing research into the automated detection of broiler vocalizations and the identification of new call clusters, demonstrating that this core theme is still actively expanding (Soster et al., 2025a; 2025b).

The cluster comprising precision livestock farming, bioacoustics, and poultry welfare is also situated near the core themes. This finding indicates that bioacoustics is increasingly being integrated into precision livestock farming systems, evolving from a purely laboratory-focused research topic into a technological application for real-time farm management. The non-invasive nature of acoustic monitoring and its capacity to generate continuous data can be considered key drivers of this transformation. Recent machine learning-based studies also treat sound signals as digital biomarkers that can be directly utilized for welfare assessment (Manikandan and Neethirajan, 2025b).

The "niche themes" region comprises the clusters of environmental enrichment-nutrition-cattle and disease-euthanasia. While these themes exhibit a high degree of internal development, they show more limited connections to the field's core conceptual structure. The emergence of the term "cattle" as a niche theme within a poultry-focused dataset may stem from the use of keywords in certain publications within the broader context of farm animal welfare or comparative animal welfare. Consequently, such terms should be regarded not as central components of the primary research axis, but rather as peripheral themes representing the field's connection to the wider animal welfare literature.

In light of all this information, the findings indicate that research on the acoustic monitoring of stress and welfare in poultry has progressed through three fundamental stages. In the first stage, studies focused primarily on behavior, stress, and the biological significance of vocalizations. In the second stage, approaches involving acoustic feature extraction, sound analysis, and precision livestock farming came to the forefront. In the current stage, machine learning, deep learning, and automated welfare classification have emerged as key driving themes in the field. This transformation demonstrates a strong parallel between bibliometric findings and the current experimental literature.

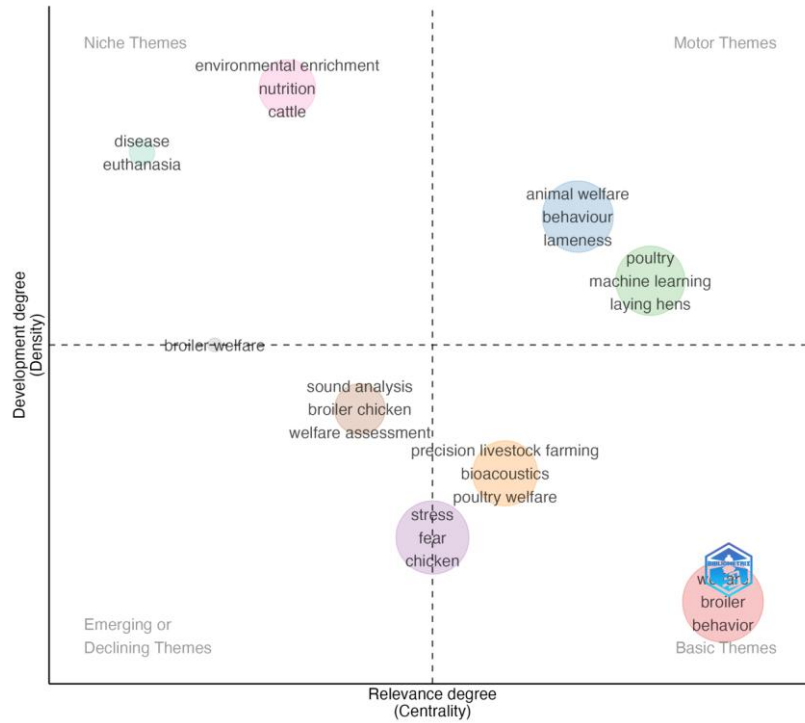


Figure 6. Thematic map based on author keywords.

Consequently, the existing bibliometric structure reveals that the field is not only expanding in terms of publication volume but is also undergoing a conceptual and methodological shift, moving from classical bioacoustics observations toward automated, real-time, AI-driven welfare monitoring systems. However, the low-density values of core themes and the positioning of certain stress/sound analysis clusters in the "emerging/declining" zone indicate that the field has not yet fully matured; issues such as data standardization, model validation under field conditions, explainable AI, and generalizability across different herd, breed, and age groups remain critical for future research. Systematic reviews identify field generalizability, data standardization, and the integration of next-generation AI architectures as key research priorities for the future (Manikandan and Neethirajan, 2025a).

4. Conclusion

This study presents the scientific evolution of literature regarding the acoustic monitoring of stress and welfare in poultry from 1987 to 2025, analyzing it from both bibliometric and thematic perspectives. The findings reveal that while the field maintained a limited publication volume for many years, it has demonstrated significant growth, particularly after 2020. The increase in annual scientific output indicates that acoustic monitoring technologies are gaining increasing importance in animal welfare research.

Analyses of sources and keywords demonstrate that the research field is not confined solely to animal behavior and welfare; rather, it possesses an interdisciplinary structure that integrates agricultural engineering, sensor

technologies, precision livestock farming, and artificial intelligence applications. The prominence of concepts such as "animal welfare," "behavior," "poultry," "broiler," "bioacoustics," "precision livestock farming," and "machine learning" suggests that the field is evolving from traditional bioacoustics approaches toward automated, data-driven monitoring systems.

The thematic map results, which position the "animal welfare-behavior" and "poultry-machine learning" clusters among the motor themes, indicate that AI-based approaches have transitioned from being secondary components to becoming core research axes within the field. Conversely, the placement of themes such as "sound analysis," "stress," and "welfare assessment" in the "emerging/declining" zone suggests not that these areas are losing importance, but rather that they are being reshaped by new technological approaches. Overall, the scientific evolution of stress and welfare monitoring in poultry shows a shift from behavioral observation and classical bioacoustic analysis toward sensor-based monitoring and AI-driven automated assessment systems. However, issues such as dataset standardization, model validation across diverse production conditions, generalizability in real-world farm environments, explainable AI, and multimodal sensor integration remain critical for future research. Therefore, integrating acoustic data with artificial intelligence holds significant potential for developing more objective, continuous, and non-invasive welfare monitoring systems for poultry.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	B.Ş.	CT
C	50	50
D	50	50
S	50	50
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50
FA	50	50

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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