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ARAŞTIRMA MAKALESİ RESEARCH PAPER

Comprehensive Analysis of Publications on the Use of Artificial Intelligence in Aquaculture Published in Web of Science

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Abstract: Aquaculture is gaining importance due to the increasing population and food demand. However, one of the biggest challenges in the sector is the need for innovative technologies. Artificial intelligence (AI) offers important solutions in environmental process management, early disease detection, water quality monitoring and optimizing feeding strategies. This study examines the evolution of AI in aquaculture by analyzing 202 publications in the Web of Science database between 1998 and 2024. Academic productivity has increased rapidly in recent years, reaching 64 articles in 2024. The most common document types are "*Articles*" (124) and "*Reviews*" (41), with research focused on environmental disciplines such as *Fisheries* (41) and *Marine Freshwater Biology* (29), as well as technical fields such as *Engineering Electrical Electronics* (26) and *Computer Science* (25). The leading journals are *Aquaculture* and *Computers and Electronics in Agriculture*. China (52) and the US (28) are the top contributors, with Li Daoliang (7 publications) being the most prolific author. Keyword analysis reveals central themes such as "*Aquaculture*" (66), "*Artificial Intelligence*" (61), and "*Machine Learning*" (36), while concepts such as "*Smart Fish Farming*" and "*Sustainability*" indicate a shift toward technology-driven green solutions. Citation networks reveal strong connections but some fragmentation. The findings suggest that AI is increasing its role in the industry, encouraging sustainability and collaboration.

Key words: Aquatic animal, bibliometric analysis, citations, smart fish farming, VoSviewer.

Web of Science'da Yayımlanan Su Ürünleri Yetiştiriciliğinde Yapay Zekanın Kullanımı Konusundaki Yayınların Kapsamlı Analizi

***Sorumlu yazar:**
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Öz: Su ürünleri yetiştiriciliği, artan nüfus ve gıda talebi nedeniyle önem kazanmaktadır. Ancak sektördeki en büyük zorluklardan biri, yenilikçi teknolojilere duyulan ihtiyaçtır. Yapay zeka (YZ), çevresel süreçlerin yönetimi, hastalıkların erken tespiti, su kalitesinin izlenmesi ve beslenme stratejilerinin optimize edilmesi gibi konularda önemli çözümler sunmaktadır. Bu çalışma, 1998-2024 yılları arasında Web of Science veri tabanındaki 202 yayını analiz ederek yapay zekanın su ürünleri yetiştiriciliğindeki evrimini incelemektedir. Son yıllarda akademik üretkenlik hızla artmış, 2024'te 64 makaleye ulaşmıştır. En yaygın belge türleri "*Makaleler*" (124) ve "*İncelemeler*" (41) olup, araştırmalar *Balıkçılık* (41) ve *Deniz Tatlı Su Biyolojisi* (29) gibi çevre disiplinlerinin yanı sıra *Mühendislik Elektrik Elektroniği* (26) ve *Bilgisayar Bilimi* (25) gibi teknik alanlarda yoğunlaşmıştır. *Aquaculture* ve *Computers and Electronics in Agriculture* en önde gelen dergilerdir. Çin (52) ve ABD (28) en fazla katkı sağlayan ülkeler olup, Li Daoliang (7 yayın) en üretken yazarlardandır. Anahtar kelime analizi, "*Su Ürünleri Yetiştiriciliği*" (66), "*Yapay Zeka*" (61) ve "*Makine Öğrenimi*" (36) gibi merkezi temaları ortaya koyarken, "*Akıllı Balık Çiftliği*" ve "*Sürdürülebilirlik*" gibi kavramlar teknoloji odaklı çevreci çözümlere yönelimi göstermektedir. Atıf ağları, güçlü bağlantılar olsa da bazı parçalanmaların sürdüğünü ortaya koymaktadır. Bulgular, yapay zekanın sektördeki rolünü artırarak sürdürülebilirlik ve iş birliğini teşvik ettiğini göstermektedir.

Anahtar kelimeler: Akıllı balık çiftçiliği, atıflar, bibliyometrik analiz, su hayvanları, VoSviewer.

INTRODUCTION

Aquaculture production has gained significant momentum on a global scale due to factors such as the rapidly increasing world population, the need for sustainable food sources, the spread of healthy eating habits, technological innovations and the decrease in natural aquaculture stocks. This increase is of vital importance for humanity due to the multidimensional benefits of aquaculture, such as contributing to food security with its high nutritional value, supporting economic activities, encouraging environmental sustainability and having a cultural value for many societies.

Aquaculture, the cultivation of aquatic organisms, is vital for global food security and an important source of protein (Boyd et al., 2022). As the global population increases, there is an urgent need for sustainable expansion in aquaculture. In 2022, global aquatic animal production reached 185 million tons, of which 94 million tons were derived from aquaculture activities. It is estimated that this increase in aquaculture production will continue in the coming years and will increase by 10% by 2032 and reach 205 million tons (FAO 2024).

In recent years, the increasing world population and the need for sustainable food sources have brought about significant growth in aquaculture production. This growth has necessitated not only the efficient use of natural resources but also the integration of innovative technologies that will optimize production processes. Artificial intelligence (AI), in particular, draws attention with its versatile applications in the aquaculture sector, such as increasing production efficiency, reducing environmental impacts, improving stock management and improving quality control processes.

The term "Artificial Intelligence" was first introduced at the 1955 Dartmouth Conference, where John McCarthy proposed a study based on the hypothesis that " every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it" (Zha, 2020). Artificial intelligence, one of the main areas of computer science today, has penetrated into such diverse areas as education, healthcare, finance and manufacturing due to its ability to very quickly address problems that humans cannot solve. Today, AI technologies are widely used in areas such as increasing efficiency, improving decision support systems, and encouraging innovation, leading to a continuous expansion of AI's sectoral applications.

The first study on the use of AI and aquaculture, " *A fuzzy logic application to aquaculture environment control*" was written by Lea et al. (1998). Lee, (2000) in his article titled "*Process Control and Artificial Intelligence Software for Aquaculture*," reported that aquaculture farmers recognized that by controlling environmental conditions and system inputs (such as water, oxygen, temperature, feed rate, and stocking density), they could regulate the physiological rates of reared species and the final process outputs (such as ammonia, pH, and growth). Chen et al. (2003) reported how they developed a neural network model-based approach to more accurately predict nitrogen content in treated wastewater used in wastewater recycling and how the model was useful in evaluating the groundwater recharge process by increasing cost-effectiveness. In the following years, Carbajal and Sánchez (2008), Hernández et al. (2010) and Hernández et al. (2011) published articles on the use of artificial intelligence in shrimp farming.

Wangle et al. (2020) conducted a comprehensive review on the integration of machine learning and remote sensing for water quality monitoring, emphasizing the effectiveness of RS-based geospatial data and machine learning ML algorithms, particularly support vector machine regression and artificial neural networks, in accurately estimating water quality parameters and improving real-time decision-making in aquaculture.

Karimanzira and Rauschenbach (2021), investigated innovative solutions such as digitalization, advanced technologies and double water recirculation system (DRAPS) to overcome the stability, standardization and economic profitability problems of large-scale aquaponic systems and evaluated the potential to increase the efficiency and sustainability of these systems.

Zhao et al. (2021) reviewed the machine learning algorithms applied in smart fish aquaculture in the past five years, detailing their applications in areas such as fish biomass assessment, fish identification and classification, behaviour analysis, and water quality parameters prediction. Wang et al. (2021a) conducted a review examining the integration of AI in aquaculture, its applications to key challenges for the industry, existing commercial AI products, technical and financial barriers to AI use, and suggesting future research directions to increase efficiency and sustainability in aquaculture systems.

Vo et al. (2021) carried out an extensive review of smart aquaculture, evaluating 100 research articles from the last ten years to explore the methodologies, findings, and progress in machine learning applications within the field.

In order to reduce feed waste and water pollution in fish farming, Chiu et al. (2022a) developed an artificial intelligence objects (AIoT)-based precision feeding management system that automatically adjusts the feed amount by detecting fluctuations on the water surface and revealed that this system reduces aquaculture costs by optimizing the fish feeding process.

Lim et al. (2022) examined the microalgae biomass production process and evaluated the contributions of IoT and artificial intelligence integration to microalgae agriculture, and discussed the transition to smart microalgae agriculture, especially by addressing the stages of IoT hardware installation and process optimization with machine learning. Nguyen et al. (2022) compared the accuracies of multi-trait genomic prediction models (ssGBLUP), Bayesian (BayesCpi), random forest (RF) and multilayer perceptron (MLP) in a commercially important population of banana shrimp (*Fenneropenaeus merguiensis*), showing that machine and deep learning-based models provide higher prediction performance compared to the traditional ssGBLUP method and that the BayesCpi model in particular is more effective in large-scale genetic improvement programs.

Lu et al. (2022), emphasizing the importance of water quality in aquaculture, designed a low-cost and artificial intelligence-supported buoy system that measures parameters such as dissolved oxygen, salinity, water temperature and flow rate in real time and evaluated the effectiveness of this system in terms of wireless data transmission, short-term water quality predictions and cost-effectiveness.

Emphasizing the importance of water quality in fish farming, Guo et al. (2023) generated a dataset of 5203 images based on water colour and developed a deep transfer learning-based classification model, proposing an automatic water quality monitoring system that provides higher accuracy (99%) compared to traditional observational methods.

Bi et al. (2023) developed a new artificial intelligence-based method due to the labor-intensive process of manual control of buoys in mussel farms in New Zealand and provided automatic detection of buoys using image processing and a convolutional neural network (CNN) and reported that this proposed method performed better compared to other baseline methods.

Abdullah et al. (2024) reviewed various IoT applications in aquaculture, covering water quality monitoring, feeding strategies, and smart health monitoring, and highlighted the potential of IoT in aquaculture by focusing on sensor advancements, artificial intelligence (AI) integration, and increased productivity.

In this study, 202 publications in the Web of Science database between 1998 and 2024 were analysed to evaluate the evolution, current trends and impacts of artificial intelligence in aquaculture and to suggest future research directions.

MATERIAL AND METHOD

The data were collected from WoS databases viz., Science Citation Index Expanded (SCI Expanded), Conference Proceedings Citation Index (CPCI-S), Emerging Sources Citation Index (ESCI), Book Citation Index-Science (BKCI-S) and Social Sciences Citation Index (SSCI) for the period between 1989-2024. Advance search was adopted and use the following keywords for searching and retrieving data "aquaculture" and "artificial intelligence".

The query path is; TS=("aquaculture" and "artificial intelligence"). The query link is: https://www.webofscience.com/wos/woscc/summary/4a2b833d-aefe-4b8c-a5f6-e0adb3e158ab-013bc4a758/times-cited-descending/1. Data on publications related to "aquaculture" and "artificial intelligence" include publication trends, publication types, contribution of countries, most productive authors, most cited publications, most publication titles, research fields, Web of Science Index and publication languages. 202 bibliographic records were retrieved and bibliographic records were analyzed and mapped using the VoSviewer version 1.6.20 and Microsoft Excel 2016.

RESULTS

Evolution in Publication Trends: This subsection focuses on the number of publications on aquaculture and AI, document types, and overall participation of authors, institutions, journals, and countries. The analysis shows that a total of 202 publications were published in the Web of Science from 1998 to December 31, 2024 (Figure 1).

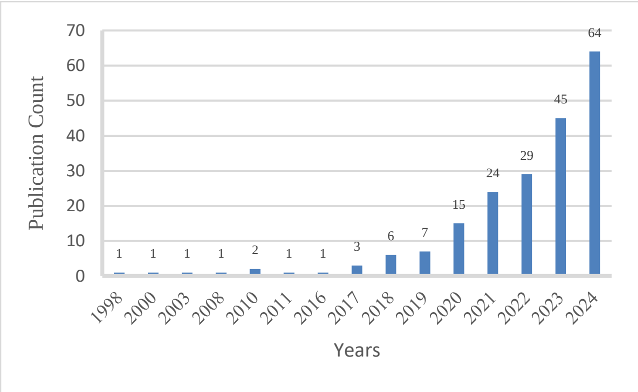

Figure 1. Number of publications on aquaculture and AI use recorded in WoS between 1998 and 2024.

The first publication on the use of Aİ and aquaculture, " *A fuzzy logic application to aquaculture environment control*" was written by Lea et al. (1998). The data in the Table 1 show that there has been a significant increase in the number of publications over the years, especially since 2020. While a limited number of publications were published between 1998 and 2019, this number increased rapidly after 2020 and reached 64 in 2024. This indicates a significant acceleration in academic productivity in recent years.

Publication types: When the distribution of publications on the use of aquaculture and AI between 1998 and 2024 is examined according to their types, among the document types, the most published ones are "*Article*" with 124 and "*Review*" with 41. These are followed by "*Proceedings Paper*" with 37, "*Early Access*" with 3, "*Book*

Chapter" with 2 and "*Editorial Material*" with one "*Data Paper*" each. This distribution shows that the research outputs largely consist of articles and compilation studies (Figure 2).

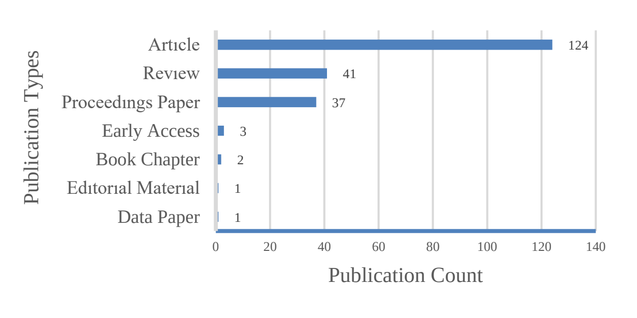

Figure 2. Distribution of publication types and their counts about on aquaculture and AI.

Research areas: The research findings show that technical disciplines such as Computer Science (57) and Engineering (55) have the highest density, while environmental fields such as Fisheries (41), Agriculture (29) and Marine Biology (29) hold an important place, with other fields exhibiting a lower but balanced distribution (Figure 3).

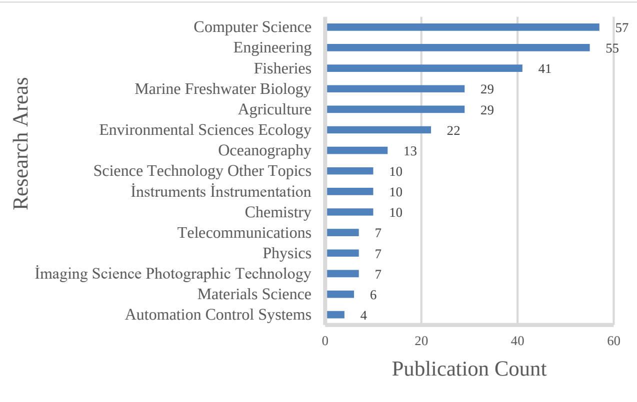

Figure 3. The 15 most published research areas and number of publications on aquaculture and AI.

***Publication titles*:** Figure 4. lists the top 15 publication titles with the most publications on aquaculture and AI. The journals with the most publications are *Aquaculture* and *Computers and Electronics in Agriculture*, each with 9 publications. Other important journals include *Sensors* (6), *Aquacultural Engineering*, *Fishes*, *Frontiers in Marine Science*, *Journal of Marine Science and Engineering*, and *Reviews in Aquaculture* (5 publications). Additionally, *Aquaculture İnternational, İEEE Access (Inst. Electrıcal Electronıcs Engıneers Inc.*), and *Scientific Reports* have 4 publications, while *Aquaculture Research*, *Applied Sciences Basel* and *Agriculture Basel* have 3 publications. These data provide an overview of the journals in which academic studies in the relevant field are concentrated.

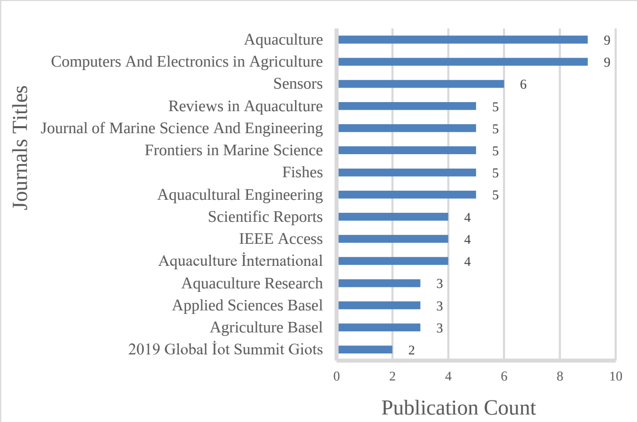

Figure 4. Top 15 journals titles and publication count in which studies on aquaculture and AI.

Countries' contribution

Analysis of the Web of Science database showed that the country with the most publications in the field of aquaculture and AI is the People's Republic of China (52 publications), followed by the USA (28 publications) and Taiwan (16 publications). Among other prominent countries on the list, Brazil comes in fourth place with 11 publications, followed by Australia 10 publications and İndia with 10 publications, respectively. Table 1 shows that Peoples R. China has taken an important leadership role in scientific publications covering aquaculture and artificial intelligence (Table 1).

Table 1. Ranking of countries with a minimum of two publications or more in the fields of aquaculture and artificial intelligence.

No	Countries	Publication Count	No	Countries	Publication Count
1	Peoples R China	52	23	Scotland	4
2	USA	28	24	South Africa	4
3	Taiwan	16	25	Tunisia	4
4	Brazil	11	26	Denmark	3
5	Australia	10	27	Egypt	3
6	İndia	10	28	Finland	3
7	England	9	29	İndonesia	3
8	Japan	9	30	İreland	3
9	Mexico	9	31	Poland	3
10	Spain	9	32	Thailand	3
11	South Korea	8	33	Türkiye	3
12	İtaly	7	34	Vietnam	3
13	Norway	7	35	Chile	2
14	France	6	36	İran	2
15	Malaysia	6	37	İraq	2
16	Philippines	5	38	Nepal	2
17	Qatar	5	39	Nigeria	2
18	Bangladesh	4	40	Palestine	2
19	Canada	4	41	Peru	2
20	Germany	4	42	Russia	2
21	Greece	4	43	Singapore	2
22	Saudi Arabia	4	44	Slovenia	2

Most productive authors: The top 15 most productive authors publishing on aquaculture and AI are shown in Figure 5. According to the data in the table, the researcher with the most publications in the field of aquaculture and artificial intelligence is Li Daoliang with 7 publications. He is followed by C. Cheng S., Chang Chin-

Chun and Ubina Naomi A.with 5 publications each. Ranjan Rakesh., Good Christopher., Hsun-Yu Lan., Tsukuda Scott and Sharrer Kata have 4 publications each. Among the other researchers, Sanchez-Fernandez Luis Pastor., Hamzaoui Mahdi., Xu Xianbao., Dupont Charlotte., and Li Juan and Wu Junfeng have contributed with 3 publications each. These data show the contributions of leading researchers who are actively working in the relevant field.

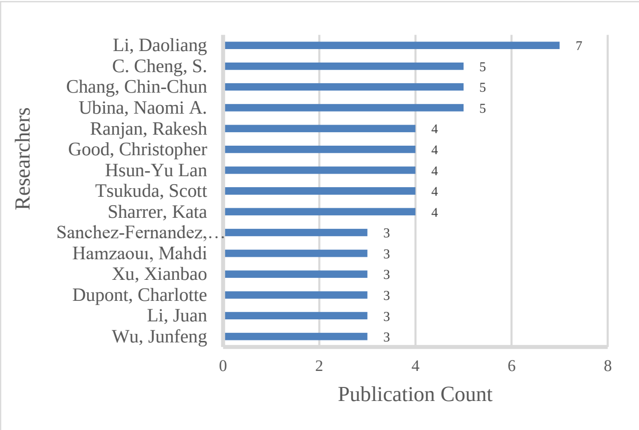

Figure 5. Top 15 most productive authors involved in aquaculture and AI.

Most cited articles: According to WoS data; of the 202 articles published on aquaculture and AI, 42 articles were not cited at all, while 155 articles were cited between 1 and 158. The most cited publication was Yang et al. (2021a) with 158 citations, Zenger et al. (2019) came second with 145 citations, and Yang et al. (2021) came third with 125 citations. The data in the table show the differences in the ranking, number of citations and number of links of the documents. "Yang et al. (2021a)", which has the highest number of citations, has 158 citations and also attracts attention with 28 links. In second place is "Zenger et al. (2019)", which has 145 citations but zero links. In third place is "Yang et al. (2021b)" with 125 citations and 16 links (Table 2).

Table 2. Highly cited articles on aquaculture and AI in WoS.

Rank	Documents	Citations▼	Links
1	Yang et al. (2021a)	158	28
2	Zenger et al. (2019)	145	0
3	Yang et al. (2021b)	125	16
4	Lu et al. (2022)	114	0
5	Zhao et al. (2021)	111	3
6	Fernandes et al. (2020)	89	0
7	Wang et al. (2021a)	76	13
8	Chen et al. (2003)	60	1
9	Mustapha et al. (2021)	58	10
10	Gladju et al. (2022)	53	1
11	Wang et al. (2021b)	53	2
12	Lim et al. (2022)	49	0
13	Jin et al. (2021)	45	0
14	Lee (2000)	43	3
15	Chiu et al. (2022b)	42	1

Citation network of publications: The bibliographic citation network of publications in aquaculture and AI researches is shown in Figure 6. This figure created using WoSviewer, based on data from the Web of Science Database, assessed on January 5, 2025, presents a network analysis of bibliographic citation across 202 publications. Publications that received at least 1 citation were included in the visualization. Of the 202 documents, 156 meet the threshold. The largest set of connected documents consist of items. The network illustrates the relationships between documents, with the distance between nodes indicating their bibliographic relatedness and the node sizes representing the frequency of citation occurrences within each document.

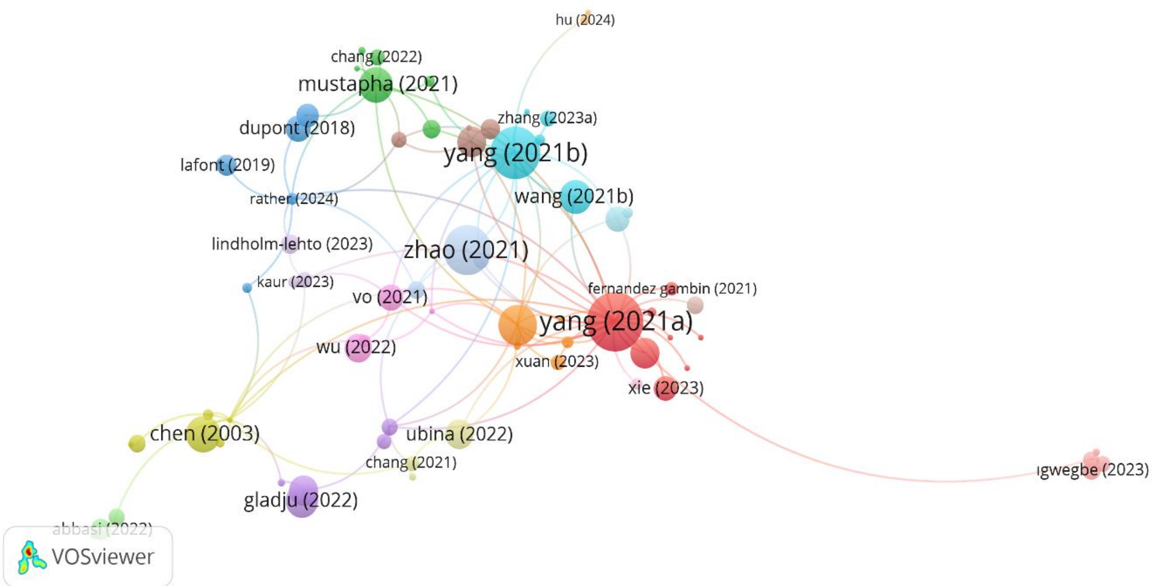

Figure 6. Citation network of publications featuring aquaculture and AI with at least 1 or more citations

Citation network of authors' total link strength: Table 3 and Figure 7, created using WoSviewer, presents a network analysis of the total link strength among 937 authors. Author with at least 1 publication were included in the visualization. The minimum number of citations for an author is calculated as 5. For each author, the total strength of citation connections to other authors was calculated and the authors with the largest total link strength were selected. It was calculated that some of the 432 authors in the network were not connected to each other and the largest connected item cluster consisted of 61.

The data in Table 3 and Figure 7 presents the metrics such as the number of publications, number of citations, nd total link strength of the authors. Song Zhang stands out with 270 citations and 135 link strength despite having only two publications. Daoliang Li is the author with the most documents with 7 publications and has a significant impact with 385 citations and 132 link strength. Authors such as Shuanglin Dong, Qinfeng Gao, Jintao Liu, Xinting Yang, and Chao Zhou stand out with high citations (158) and link strength (123) with a single publication. Xianbao Xu has high link strength (63) with 3 publications and 130 citations. Other authors with lower link strength metrics include Jincun Liu, Dean R. Jerry, David B. Jones, and Mehar S. Khatkar.

Table 3. Scientific performance and total link strength of the citations 15 most influential researchers publishing on aquaculture and AI.

	Author	Documents	Citations	Total link strength ▼
1	Zhang, Song	2	270	135
2	Li, Daoliang	7	385	132
3	Dong, Shuanglin	1	158	123
4	Gao, Qinfeng	1	158	123
5	Liu, Jintao	1	158	123
6	Yang, Xinting	1	158	123
7	Zhou, Chao	1	158	123
8	Xu, Xianbao	3	130	63
9	Liu, Jincun	2	149	17
10	Jerry, Dean R.	1	145	0
11	Jones, David B.	1	145	0
12	Khalilisamani, Nima	1	145	0
13	Khatkar, Mehar S.	1	145	0
14	Raadsma, Herman W.	1	145	0
15	Zenger, Kyall R.	1	145	0

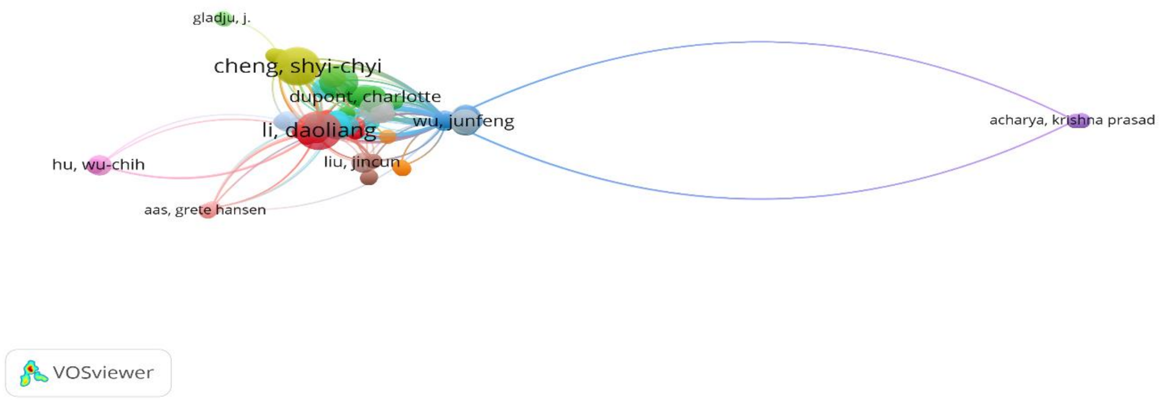

Figure 7. Citation network of authors' total link strength of publications in aquaculture and AI.

Analysis of the most used keywords: Table 4 and Figure 8 show the analysis results of 91 keywords used in articles written in the field of aquaculture and AI. When the 15 most frequently used keywords in Table 4 are examined, it is revealed that artificial intelligence and related technologies are increasingly used in the field of aquaculture. The data shows that the most frequently used keyword is "Aquaculture" (66 times, 156 connection strength). This is followed by advanced technologies such as "Artificial Intelligence" (61 times, 144 connection strength), "Machine Learning" (36 times, 96 connection strength) and "Deep Learning" (26 times, 68 connection strength). Applications such as "Computer Vision" (15 times, 42 connection strength) and "Internet of Things" (14 times, 40 connection strength) stand out especially in smart fish farming and precision aquaculture applications. In addition, environmental factors such as "Water Quality" (11 times, 34 connection strength) and "Sustainability" (7 times, 15 connection strength) play an important role in the development of aquaculture technologies. These findings show that a technology-oriented and environmentally aware transformation process is taking place in the aquaculture sector.

Table 4. The 15 most used keywords in articles published on aquaculture and AI.

	Keyword	Occurrences	Total Link Strength ▼
1	Aquaculture	66	156
2	Artificial İntelligence	61	144
3	Machine Learning	36	96
4	Deep Learning	26	68
5	Computer Vision	15	42
6	Internet Of Things	14	40
7	Water Quality	11	34
8	Artificial Intelligence	11	13
9	Precision Aquaculture	8	24
10	Fish	8	23
11	Sustainability	7	15
12	Convolutional Neural Networks	6	20
13	Iot	6	20
14	Smart Fish Farming	6	17
15	Object Detection	6	15

In Figure 8, keywords of scientific research conducted in the field of aquaculture and AI were analysed via VOSviewer. The findings show that the terms *Aquaculture* and *Machine Learning* are at the center of the research and have strong relationships with many other keywords. In addition to advanced artificial intelligence techniques such as *Deep Learning*, *Computer Vision* and *Object Detection*, technological approaches such as the *Internet of Things and Automation* are also frequently used in aquaculture applications. In the analysis, where environmental sustainability themes also draw attention, it is seen that keywords such as *Water Quality*, *Dissolved Oxygen* and *Sustainability* have an important place. In addition, when the time scale is examined, it is determined that the interest in *Smart Fish Farming* and *Environmental Monitoring* has increased in recent years.

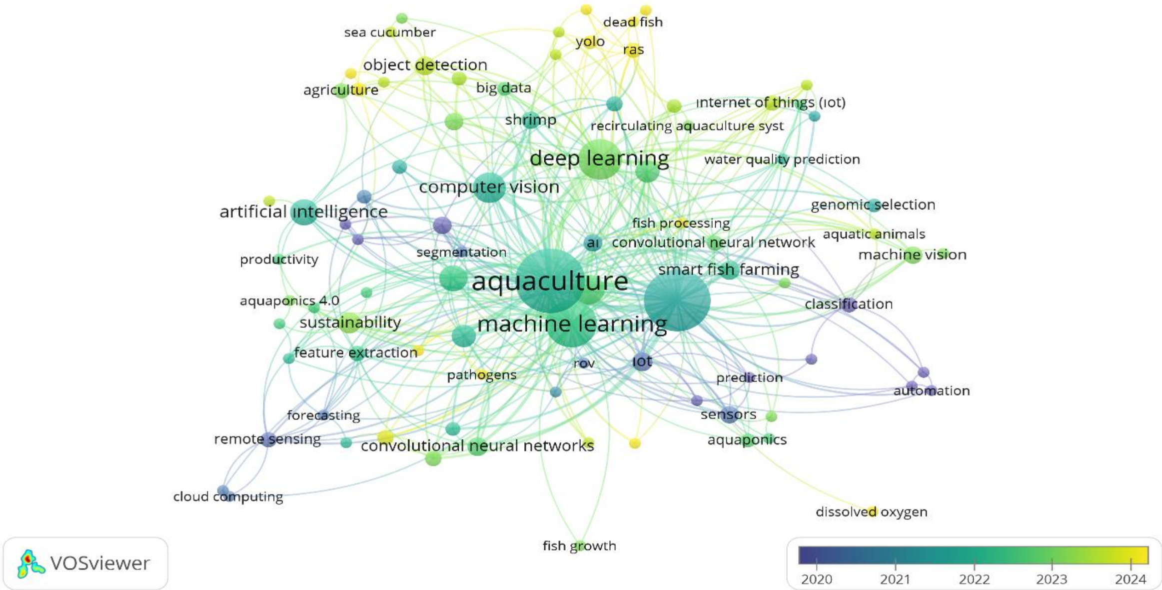

Figure 8. Analysis of keywords in articles published on aquaculture and AI.

DISCUSSION

The analysis of publication trends in aquaculture and artificial intelligence (AI) from 1998 to 2024 reveals a dynamic evolution in this interdisciplinary field. Between 1988 and 2019, research in the field of artificial intelligence and aquaculture initially focused on fuzzy logic and process control systems, but over time, it has become integrated with advanced technologies such as big data, signal processing, machine learning, and the internet of things (IoT) (Lea et al. 1998; Lee, 2000). In the early 2000s, the use of artificial intelligence software in aquaculture management increased, and after 2010, water quality monitoring systems and artificial intelligence-supported analyses came to the fore. During this period, information fusion, image processing, and IoT-based systems were used in areas such as disease detection, smart feeding, and real-time water monitoring, and processes for smart aquaculture were developed (Dupont et al. 2018).

The modest beginnings, marked by the pioneering work of Lea et al. (1998) on fuzzy logic for aquaculture environmental control, have translated into a significant increase in academic output after 2020, reaching 60 publications in 2024. This acceleration is in line with global advances in AI technologies such as machine learning (ML), deep learning (DL), and the Internet of Things (IoT), and reflects their increasing integration into agricultural and environmental sciences. The dominance of "Articles" (120) and "Reviews" (41) among publication types suggests a solid original research base supported by synthetic overviews, facilitating knowledge dissemination and consolidation in the field.

In the 2010s, advanced technologies such as information fusion, image processing, and IoT-based systems transformed the industry by offering innovative solutions such as disease detection, real-time monitoring, and smart feeding systems. In the 2020s, advanced AI techniques such as deep learning (DL) and computer vision (CV) have become widely used in areas such as fish behaviour analysis, biomass estimation, and remote monitoring of aquatic ecosystems (Hu et al., 2020; Chen et al., 2020). In particular, the integration of autonomous systems and underwater unmanned vehicles has made aquaculture processes more efficient and sustainable. These developments indicate a transition from approaches focused on the analysis of specific parameters in previous years to ecosystem-based, multi-data source solutions (Uz et al., 2020).

Studies published in 2021 and 2022 have shown that AI, ML, IoT, and CV technologies are playing an increasing role in aquaculture (Zhao et al., 2021; Wu et al., 2022). Applications such as smart fish farms, water quality monitoring, and automatic feeding systems have provided higher accuracy and efficiency compared to traditional methods, while AIoT-based solutions have created new opportunities in monitoring environmental impacts (Chiu et al., 2022b). In 2023, more complex and integrated systems such as digital twin technologies, AI-assisted fish health monitoring, and water pollution analysis have come to the fore (Ubina et al., 2023; Igwegbe et al., 2023). This year stands out as a transition period in which technologies offer interactive and data-driven solutions compared to previous periods.

Studies from 2024 show that AI and ML techniques are becoming more widespread in aquaculture and their sectoral applicability is expanding (Cai et al., 2024; Alprol et al., 2024). While deep learning algorithms increase operational efficiency in areas such as fish counting, behavioural analysis, and disease diagnosis, AIoT solutions have provided optimized processes in precision feeding and water quality management. These technologies have significant potential for the future of aquaculture by reducing labour costs and supporting environmental sustainability.

The distribution of research areas highlights a synergy between technical disciplines (e.g., Computer Science, 57; Engineering, 53) and applied fields like Fisheries (41) and Marine Biology (29). This interdisciplinary nexus underscores AI's role as a transformative tool in addressing practical aquaculture challenges, such as water quality management, species monitoring, and precision farming. The concentration of publications in leading journals like *Aquaculture* and *Computers and Electronics in Agriculture* (9 each) reflects the field's maturation, with these outlets serving as key platforms for advancing both theoretical and applied insights. However, the diversity of journals, including *Sensors* and *Frontiers in Marine Science*, indicates a broadening scope, encompassing sensor-based technologies and marine ecosystem sustainability.

Geographically, the dominance of the People's Republic of China (52 publications) and the USA (28) points to significant investments in AI-driven aquaculture research, likely driven by economic stakes in seafood production and technological innovation. Emerging contributions from countries like Taiwan (16), Brazil (11), and India (10) suggest a globalizing trend, potentially fuelled by regional needs for sustainable aquaculture amid growing food security demands. This aligns with the prolific output of researchers like Li Daoliang (7 publications), whose work exemplifies leadership in integrating AI into aquaculture systems, and the high citation impact of authors like Zhang Song (270 citations), indicating influential contributions despite fewer publications.

Citation analyses further illuminate the field's intellectual structure. The most cited articles, such as Yang et al. (2021a) with 158 citations and Zenger et al. (2019) with 145, highlight seminal works that have shaped discourse, likely due to their innovative applications of AI in precision aquaculture and genetic prediction. The citation network (156 connected publications) and authors' link strength (e.g., Li Daoliang, 132) reveal a tightly knit research community with robust knowledge exchange, albeit with some fragmentation, as 432 authors formed a largest cluster of only 61. This suggests opportunities for greater collaboration to enhance connectivity and impact.

Keyword analysis reinforces the technological and ecological priorities driving this field. "Aquaculture" (66 occurrences) and "Artificial Intelligence" (61) anchor the research, while "Machine Learning" (36), "Deep Learning" (26), and "Computer Vision" (15) reflect the adoption of cutting-edge tools for applications like fish detection and behaviour analysis. The prominence of "Water Quality" (11) and "Sustainability" (7) underscores an environmental consciousness, aligning with global sustainability goals. The temporal shift toward "Smart Fish Farming" and "Environmental Monitoring" in recent years indicates a maturing focus on automation and real-time ecosystem management, consistent with broader trends in smart agriculture.

These findings demonstrate that AI in aquaculture has evolved from rudimentary applications in the late 1990s to a sophisticated, technology-driven field by 2024. The rapid post-2020 growth reflects not only technological advancements but also increasing recognition of AI's potential to enhance efficiency, reduce labour costs, and promote sustainable practices in aquaculture. However, challenges remain, including the need for broader adoption in less-represented regions and the integration of fragmented research efforts into cohesive frameworks. The reliance on technical disciplines also suggests a need for greater involvement of social and economic perspectives to address scalability and accessibility issues.

The integration of AI into aquaculture has reached a pivotal stage, characterized by significant academic productivity, interdisciplinary collaboration, and a focus on sustainability. The leadership of countries like China, the influence of key researchers, and the dominance of technology-oriented journals and keywords collectively signal a transformative trajectory. Future research should prioritize bridging regional disparities, enhancing cross-disciplinary collaboration, and addressing practical barriers to large-scale implementation. By doing so, AI can fully realize its potential to revolutionize aquaculture, contributing to global food security and environmental resilience in an increasingly digitalized world.

As a result, AI applications in aquaculture have evolved from simple systems to complex and integrated technologies in an evolutionary process that extends from the 1980s to the present. Today, the combination of deep learning, IoT, and autonomous systems is making the sector more efficient, sustainable, and digital. However, more research is needed on issues such as standardization, cost-effectiveness, and infrastructure requirements for the wide-scale applicability of these technologies. In the future, AI-supported aquaculture systems have a high potential to contribute to global food security and environmental sustainability goals. In this context, increasing academic and industrial collaboration stands out as a critical element that will accelerate the sectoral adaptation of the technology.

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