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Article

Current Status and Topics of Research on Smart Fishery in China: A Literature Review based on CNKI (2000−2022)

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Abstract: Recently, it has become important to find a way to combine modern information technology with the traditional fishery industry. For this, understanding the current situation of the smart fishery is important to promote its development. Promoting the transformation and upgrading of the traditional fishery industry can speed up the process of fishery modernization. Applying modern science and technology to the whole process of the fishery leads to the development of the fishery industry. Therefore, we tried to create a related knowledge map to present the status and important topics of China's smart fishery using the CNKI database from 2000 to 2022. CiteSpace software was used for the literature analysis, and Excel was used for statistical analysis and chart drawing of relevant data. The result shows the following. (1) Smart fishery is a new research field, and the number of related publications is on the rise. However, the total amount of literature is relatively small, and more research is needed. (2) Only a limited number of research groups and researchers have close cooperation, and most of them have little communication with each other. The map shows that "part of the network is concentrated, the whole point is scattered". (3) Major research topics are mainly focused on "aquaculture", "the Internet of Things", "marine fishery", "satellite remote sensing", "Internet" and "fishery production". (4) Future research topics and trends are likely to be in "modern fisheries", "big data", "aquatic products", "aquaculture", "marine ranching" and "recreational fisheries". Such a result provides a reference for decision-making and promoting the sustainable development of smart fisheries.

Keywords: Smart fishery, CiteSpace, Research status, Research hotspot, Fishery informatization

1. Introduction

Owing to modern information technologies such as the Internet of Things, big data, artificial intelligence, satellite remote sensing, and mobile Internet, the smart fishery is experiencing in-depth development, and the use of fishery information resources comprehensively improves productivity and operation and management efficiency in the fishery industry. It is important and effective to promote structural reform and accelerate the transformation and upgrading of the fishery industry [1,2]. The integration of fishery and the Internet of Things, the combination of fishery breeding technology, equipment technology, and information technology can promote the development of modern fishery to achieve higher productivity [3]. The development and application of big data technology in the fishery allow the integration of informatization and fishery production, sales, management, and scientific research [4]. Artificial intelligence technology in aquaculture has been applied in the fields of life information acquisition, growth regulation and decision, disease prediction and diagnosis, environmental perception and regulation, and underwater robots [5]. Satellite remote sensing technology provides necessary environmental information on fishery management and improves management efficiency, also creating a large benefit in the planning and management of mariculture [6]. Relying on Internet information technology and increasing production, the production and operation risks of modern fisheries are reduced. Through the integration of traditional fishery and the Internet and other modern information technologies, the innovation of the entire industrial chain is realized, which is critical for promoting the transformation and development of traditional fishery.

Promoting the digitalization of fishery and developing smart fishery are the key to realizing the modernization of fishery [7]. The National Digital Agriculture Rural Development Plan (2019−2025) proposed the development of "fishery intelligence" in "Accelerating the digital transformation of production and operation". Several Opinions on 'Accelerating the Green Development of Aquaculture Industry' topicd by 10 commissions of the Ministry of Agriculture and Rural Affairs also suggested "to promote

smart aquaculture, guide the deep integration of modern information technologies such as the Internet of Things, big data and artificial intelligence with aquaculture production, and carry out digital fishery demonstration". Smart fishery requires better production management with the development of fishery informatization. Accelerating the construction of smart fishery is conducive to promoting the structural reform of the fishery on the supply side. It also accelerates the transformation and upgrading of the fishery industry, which is important for China [8]. Smart fishery needs modern information and communication technology to integrate human wisdom and technology. This enables experienced people and intelligent technology to interact, bring out the best outcome, and promote a new way of fishery development and a new format of business. The best economic and social activities are also obtained with it. At the same time, more attention needs to be paid to the interaction between fish, fishermen, government, and enterprises with smart fishery, and consumers must understand the intelligent development of fishery [9]. Smart fishery helps integrates informatization throughout the entire process of the fishery, improves the organization and management of the fishery resource and overall production efficiency, and promotes the reform, transformation, and upgrading of the fishery.

China is one of the large fishery production countries in the world. At present, China's fishery development looks perspective, but it is also facing severe challenges. For example, the development of quality improvement and efficiency enhancement is not achieved, the industrial structure is not well organized, and ecological protection is insufficient [10]. The practice and exploration of smart fishery in China have been started late and its development level is generally low. The integration of modern information technology, engineering control technology, and other technical means in the fishery is not yet mature, which is still an important bottleneck. In addition, we also face many problems such as a relatively weak foundation of the smart fishery, a lack of talents, and insufficient attention to the construction of the smart fishery. Therefore, it is important and urgent to find a way to speed up the construction of the smart fishery, use modern information technology, provide effective information support for the modernization of the fishery, and promote all-around development. At the same time, the development trend of the smart fishery in recent years it is not well-researched. Thus, we aimed to identify the research and development trends through a bibliometric analysis with Citespace to overcome the limitations of traditional qualitative literature analysis. As a result, the existing research results related to the smart fishery were summarized and presented in this article. The development trend, related research content, relevant topics, and other information on the smart fishery were also described to provide theoretical and empirical support for the modernization of the fishery.

2. Materials and Methods

This research is based on academic research articles in the CNKI database. The smart fishery was the keyword for retrieving relevant literature. In addition, articles with titles and abstracts including "Internet of Things", "big data", "artificial intelligence", "satellite remote sensing", "Internet" and "cloud computing", were searched. Considering that there were relatively few articles on smart fishery before 2000 in the CNKI database, the years 2000 to 2022 were selected in this study. After omitting repeated and invalid articles, 385 relevant articles were found and exported in Refworks format. The knowledge map was created based on the object of research to display the network structure, cross-relationship, and interactive evolution between knowledge groups. The development history, research content, and cutting-edge trends of the subject were revealed on the map [11]. CiteSpace software was used for the analysis to collect and screen the related literature. In the process, author cooperation network analysis, keyword co-occurrence network analysis, and related keyword clustering, and timeline and emerging word analysis were also carried out to obtain the corresponding knowledge map. Keyword co-occurrence was used to define the research topics [12]. After the map was created, Excel was used for statistical analysis and chart drawing.

3. Results

3.1. General Situation of Smart Fishery Research

The selected literature data were sorted and counted, and then Excel was used for the analysis. The trend in the number of articles on the smart fishery is shown in Fig. 1. The number had increased since 2013, but decreased sharply in 2019, but rebounded in 2021.
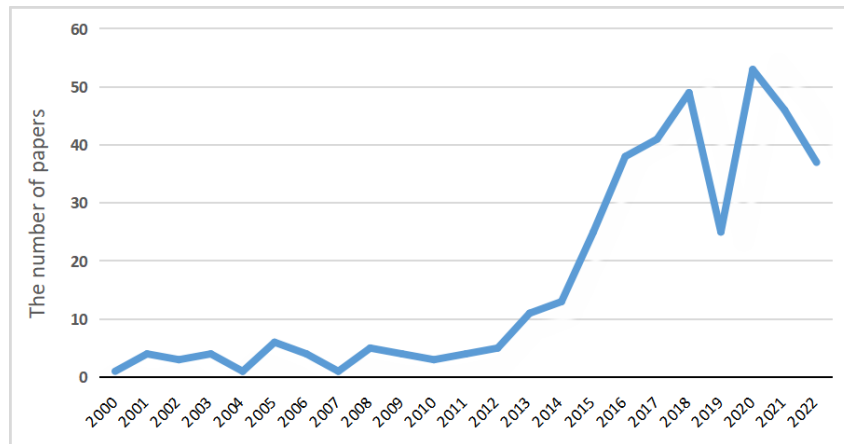
Fig. 1. Number of publications about the smart fishery in China from 2000 to 2022.

The research on smart fishery started in the year 2000. There were few articles published in the initial period, and the annual number of articles was less than 10. Scholars in this period tried to study smart fishery in the context of information technology, but the research questions were relatively simple, and there were few researchers. Wang et al. [13] mentioned that many countries in the world established fishery-related information network systems. For example, on the FAO website, fishery statistics around the world can be queried, but there are little data on China's fishery statistics [13]. There was little research on the smart fishery in China, and attention was not paid to it yet. During 2013−2018, there was rapid growth in smart fishery research. Researchers paid more attention to this topic, and the number of articles reached a peak in 2018. Research topics and perspectives were expanded, including the scientific and technological innovation of the aquaculture industry. The emergence of the smart fishery affected aquaculture gradually. Research on the application of the innovative technology of the smart fishery platform emerged. Scholars began to pay attention to the need for innovation in the promotion of the scientific and technological achievements of the smart fishery. The research content of the smart fishery during 2019−2022 became gradually profound. The development status, application, and promotion of the smart fishery were analyzed, and the related problems were researched. The industrial view of "smart" convergence and the integrated development of the smart industry and modern fishery were researched to promote the level of modern fishery production, service, and management [8]. In addition, many articles made suggestions on how to promote the digitalization and intellectualization of China's fisheries. At the same time, the progress of smart fishery in aquaculture appeared as a key topic of concern.

3.2. Analysis of Authors

The authors with a high-yield and large influence were presented with their cooperative relationship. A node on the graph represents a researcher, and the size of the node represents the number of publications. The cooperation network of researchers is represented by the connections between nodes (Fig. 2).
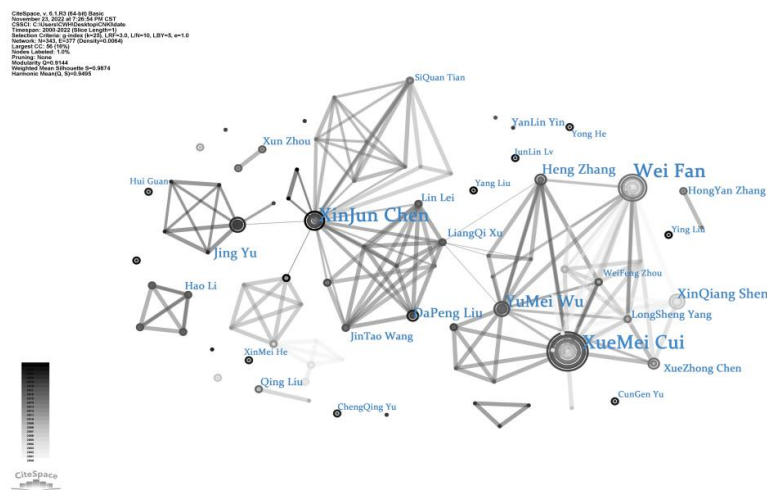
Fig. 2. Knowledge map of authors of smart fishery in China.

The statistics of the top 20 authors of published articles are shown in Table 1. The author with the most publications is Chen Xinjun, with 12 articles, followed by Cui Xuesen and Fan Wei with 10 articles. The authors with 4 or more publications included Wu Yumei, Yu Jing, Liu Dapeng, Zhang Heng, and Shen Xinqiang. In terms of the number of publications, there were few productive authors, and there is still a lot of room for research. The clustering analysis result shows two important research teams in this research field. The most notable research team of Cui Xuesen, Fan Wei, and Wu Yumei had the largest number of articles and cooperations. The other researcher was Chen Xinjun. He was connected to many clusters, and Chen Xinjun played a bridge role in communication and cooperation. These authors constituted the core group of smart fishery research. In addition, there were many authors in other independent nodes (Fig. 2).

Table 1. Top 20 authors in smart fisheries research

Number	Count	Author	Number	Count	Author
1	12	Xin-Jun Chen	11	3	Hong-Yan Zhang
2	10	Xue-Sen Cui	12	3	Liang-Qi Xu
3	10	Wei Fan	13	3	Hao Li
4	5	Yu-Mei Wu	14	3	Sheng-Long Yang
5	5	Jing Yu	15	3	Yan-Lin Yin
6	4	Da-Peng Liu	16	3	Jin-Tao Wang
7	4	Heng Zhang	17	3	Xue-Zhong Chen
8	4	Xin-Qiang Shen	18	3	Lin Lei
9	3	Qing Liu	19	2	Zi-Yuan Ding
10	3	Xun Zhou	20	2	Cheng-Qing Yu

3.3. Research Topics

The keyword analysis was used to understand the research topic, core content, and the frequency of keywords, which indicate the degree of attention paid to relevant research [14]. Citespace was used to analyze the smart fishery, and the node type was selected as "keyword". The analysis was performed for the year 2000−2022 and for every year. Figure 3 shows the result. In the figure, the size of nodes is positively correlated with the frequency of keywords, and the lines represent the co-occurrence of different keywords. The large keyword nodes are observed for "aquaculture", "Internet of Things", "marine fishery", "satellite remote sensing", "fishery", "Internet" and "fishery production". "Aquaculture" is a keyword that shows that the smart fishery can be used for aquaculture and integrates traditional fishery with intelligent technology, aquaculture technology, equipment technology, and information technology with the automation of aquaculture production, information management, and intelligent decision-making. The intensive and large-scale aquaculture industry can be achieved in aquaculture for the sustainable development of modern fisheries [15]. Through the analysis of the aquaculture model, it was found that the great potential brought by the smart fishery, and the model was inevitable for its development [16]. The analysis result of the relevant literature of important nodes shows that the research focus of smart fishery is mainly to integrate aquaculture with modern science and technology and apply the Internet of Things, satellite remote sensing, and other modern technologies to the whole process of the fishery industry.
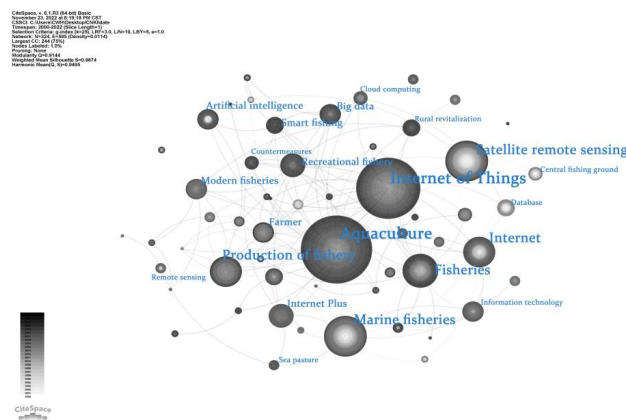

Fig. 3. Co-occurrence map of keywords in Chinese smart fishery research.

The ranking of the keyword frequency on fishery research is shown in Table 2. Aquaculture has the highest keyword frequency with a frequency of 50. The Internet of Things, fishery, fishery production, marine fishery, satellite remote sensing, the Internet, and modern fishery are ranked second to twentieth with a frequency of 40, 21, 19, 18, 14, 14, and 13, respectively. This shows that modern technologies such as the Internet of Things, satellite remote sensing, and the Internet play an important role in aquaculture, fishery production, and marine fishery. In addition, leisure fishery, Internet plus, big data, farmers, and artificial intelligence with a frequency of more than 10 are also important research topics in the smart fishery. The frequency of the keyword "rural revitalization" is only 7, indicating that the current research on smart fishery in rural areas is insufficient. However, this keyword is expected to be important for future smart fishery research.

Table 2. Top 20 keyword frequency in smart fishery research

Number	Frequency	keyword	Number	Frequency	keyword
1	50	Aquaculture	11	11	Big data
2	40	Internet of Things	12	11	Smart fishing
3	21	Fisheries	13	10	Farmer
4	19	Production of fishery	14	10	Artificial intelligence
5	18	Marine fisheries	15	7	Countermeasures
6	14	Satellite remote sensing	16	7	Information technology
7	14	Internet	17	7	Rural revitalization
8	13	Modern fisheries	18	7	Database
9	12	Recreational fishery	19	6	Cloud computing
10	12	Internet Plus	20	6	Sea pasture

3.4. Co-occurrence of Keywords

Citespace's keyword clustering function was used to identify important topics and development trends [17]. Keyword clustering analysis was carried out to classify keywords according to their co-occurrences and group the keywords with high correlation and close relationships. Then, keywords with a high correlation degree were chosen to identify directional and representative knowledge subgroups [18]. Citespace was used to cluster the high-frequency keywords related to smart fishery research. The number of clusters was set to 10, and 10 cluster points related to high-frequency keywords related to the smart fishery were obtained (Fig. 4). The keywords included aquaculture, Internet of Things, Internet, Internet plus, satellite remote sensing, artificial intelligence, big data, modern fisheries, remote sensing, and pelagic fisheries. The largest cluster was for aquaculture, which indicates that this topic is the most popular research topic in the smart fishery. It was integrated with other research topics such as the Internet of Things, the Internet, artificial intelligence, big data, and other modern science, which can be applied to to aquaculture and modern fishery development.
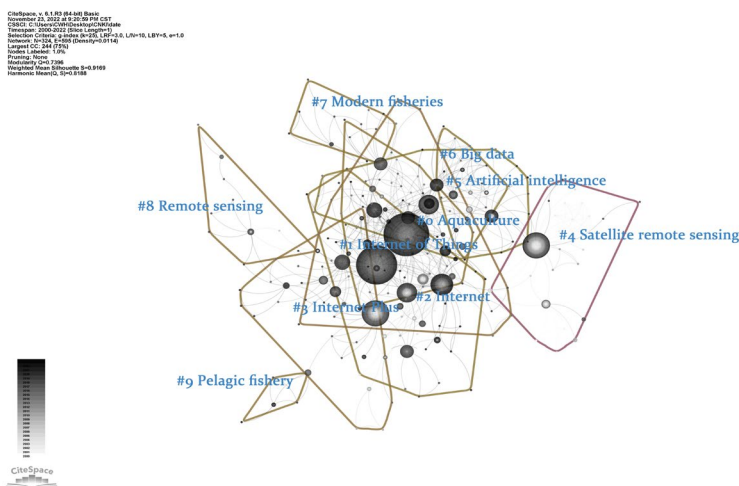

Fig. 4. Keyword clustering of Chinese smart fishery research.

3.5. Evolution of Research

Clustering analysis was carried out based on the keywords from the Citespace database in terms of time. As a result, 12 clusters were found (Fig. 5). Articles in the same cluster are distributed on the same horizontal line, and the length of the horizontal line in the same group indicates the approximate time of the cluster. In addition, the node size reflects the centrality of highly clustered literature. The larger the centrality, the larger the node. Emergent words refer to keywords that are used more frequently in a short period and are used to explain the development trend and change of research in this field in a certain period [19]. Figure 6 presents that in the relevant research of smart fishery from 2000 to 2022, there are top 14 keywords including satellite remote sensing, database, marine fishery, fishery, Internet, forecasting model, fishery production, farmers, modern fishery, aquaculture, aquatic products, big data, marine ranch, leisure fishery.
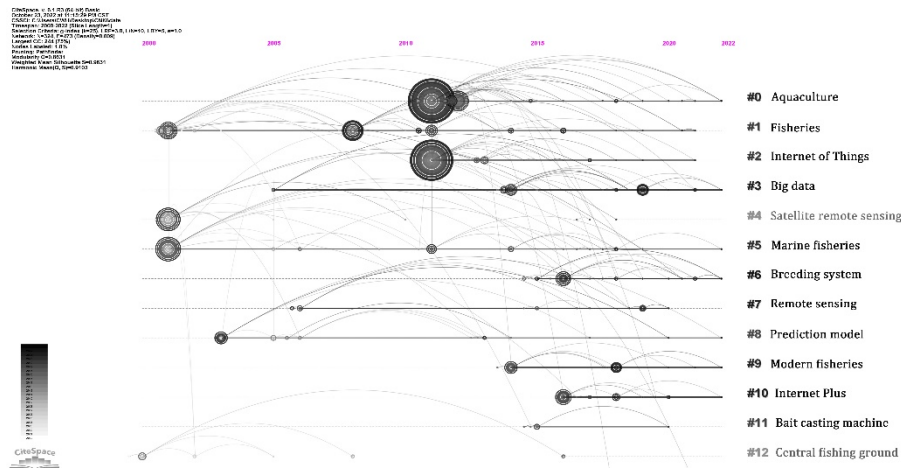
Fig. 5. Timeline map of Chinese smart fishery research.

Fig. 6. Keyword outburst map of smart fishery research in China.

The keyword timeline map (Fig. 5) and keyword outburst map (Fig. 6) imply the following stages in the research of the smart fishery in China.

In the first stage from 2000 to 2005, important keywords were "satellite remote sensing", "Marine fishery", "fishery", and "forecast model". The relevant research in this stage included the following. Wang and Ge [19] researched the development of information technology and stated that people had higher requirements for information inquiry and access, and there was more

urgent requirements for online service of fishery statistical information. Fan et al. [5] summarized the application status and development of satellite remote sensing technology in marine fishery environment analysis and fishery research and introduced the remote sensing satellite platform for marine fishery applications and their characteristics. Cai [20] mentioned that with the rapid development, the Internet became an inevitable trend to apply for information management. However, it is difficult to apply the Internet to information management due to the characteristics of the marine fishery, such as wide area, multiple points, and scattered points. The early research in the smart fisheries was mostly focused on the application of satellite remote sensing in marine fisheries and fishery informatization. At this stage, fishery informatization had just started with many difficulties and unknown challenges.

In the second stage from 2005 to 2015, "aquaculture", "Internet of things", "Internet", and "database" were important keywords. The research activity in this stage was weak. The Internet of Things in China started to build a solid foundation for the intelligence, information, and automation of marine fishery [21]. The application of the Internet of Things in aquaculture helped improve the production technology of aquaculture, ensure the virtuous cycle of the aquaculture ecosystem, further improve the quality of aquatic products, cope with the rise of labor costs, and obtain better social, economic and ecological benefits [22]. The smart fishery was the sublimation of information fishery. To realize fishery intelligence and meet the needs of society, the construction of fishery informatization is required, and the development of fishery and social progress is necessary [23]. During this period, the research topics were mainly related to aquaculture, the application of the Internet of Things in fishery, and the establishment of the fishery database. The topics showed the coming of the information age, and it was urgent to strengthen the informatization and intelligence of fishery.

In the third stage from 2015 to 2022, the keywords such as "modern fishery", "farmers", "aquatic products", "Marine pasture", and "recreational fishery" appeared. The relevant research in this stage included accelerating the transformation of the fishery from fishing to farming, from offshore to offshore, from coastal to offshore, and from fishermen to recreational fishery practitioners [24]. Wang et al. [25] analyzed the basic mode and internal mechanism of "Internet +" embedded into the marine fishery industry chain and proposed the innovative path of an intelligent "Internet + Marine fishery" model to promote the sustainable and healthy development of Chinese marine fishery. The development of modern fishery effectively improved the living standards of farmers and promoted the upgrading of the industrial structure of the fishery. However, the contradiction between large-scale aquaculture operation and ecological environment improvement, and the low economic benefits of the aquaculture industry made it difficult to control industrial risks, and imperfect aquatic product quality assurance systems were serious obstacles to the sustainable development of modern fisheries [26]. Yang et al. used advanced information technology to develop intelligent equipment and realize precise, automatic, and intelligent aquaculture, which is of great significance in improving fishery production capacity and resource utilization rate [27]. In this period, the research focused on the sustainable development of modern fishery, the relationship between fishery production and management and ecological protection, modern fishery industry transformation with developed marine ranching, recreational fishery, and the application of modern science and technology in the whole fishery process. The relevant research on the smart fishery in China gradually became more in-depth, and many scholars proposed suggestions for development and new paths based on the research. It is still needed to continue to pay attention to developing smart fishery with many contradictions and problems to be solved.

4. Conclusions

In this study, the journal articles on smart fisheries in the CNKI database in the past 22 years were analyzed. The number of published articles on smart fishery increased in a fluctuant way from 2000 to 2022 and increased rapidly after 2013. Chen Xinjun, Cui Xuesen, and Fan Wei published more than 10 articles being the most prolific authors in this field. The cooperation team led by Cui Xuesen, Fan Wei, and Wu Yumei, and the research team represented by Chen Xinjun worked closely. However, most of the authors had less cooperation and communication, showing the characteristics of "regional concentration and overall dispersion". From the perspective of keywords in smart fishery, research focused on "aquaculture", "Internet of Things", "marine fisheries", "satellite remote sensing", "Internet", and "fishery production". The highest frequency and the largest cluster were found for aquaculture, which indicates that this topic was the most popular in the research on the smart fishery. The analysis result of keywords showed that future research trends are about "modern fishery", "big data", "aquatic products", "aquaculture", "marine ranching", and "leisure fishery". The national implementation of rural revitalization is an important topic to study how to rationalize fishery resources and realize the healthy and sustainable development of Chinese fishery. In the era of big data, the integration of fishery and related information technology is an essential trend in research. However, there are still not enough researchers related to the smart fishery, so scholars need to pay extensive attention to and conduct in-depth research.

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