The Development of Traceability Technology in The Fisheries Industry Supply Chain: A Systematic Literature Review

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Abstract. Traceability has become an essential component of the fisheries supply chain. It ensures food safety, verifies product legitimacy, and addresses customer concerns about product origin and authenticity. In fisheries traceability refers to the ability to track the source and movement of fishery products throughout the supply chain. The purpose of this study is to find out how the development of traceability in the fisheries supply chain today. This study uses documents in the form of scientific articles obtained from 3 reference sources namely Scopus, PubMed and WebofScience. The total articles obtained were 2655 which were then screened from the title, abstract to the suitability of the documents obtained with the objectives of this study which resulted in 40 selected articles. The traceability system in the fisheries supply chain has been very developed and also uses the latest technology to guarantee the seafood obtained by consumers, but there are still many obstacles such as dishonest fisheries industry players that make the system not run well. The development of digital technology utilizing IoT, QR codes, and e-DNA is required to integrate monitoring technology so that marine products presented to consumers can be guaranteed.

1 Introduction

Based on data released by the Food and Agriculture Organization (FAO), in 2020 global capture fisheries production amounted to 90.3 million tons. Of this amount of capture fisheries production, 49% came from seven countries: China, Indonesia, Peru, India, Russia, United States, Vietnam. The increase in capture fisheries production has consistently increased based on an increase in market or consumer demand. In 2021, according to the Organization for Economic Cooperation and Development (OECD), the global fish consumption rate is 180.07 million metric tons. This means that the increase in fish capture production only meets 50% of consumption needs (databox, 02-12-2021). Apart from the

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increase in consumption, advances in fishing technology on the high seas have also played a role. Modern fishing vessels on the high seas are equipped with navigation infrastructure or Global Positioing System (GPS), environmentally friendly fishing gear or nets, and adequate cold storage.

The technological advancements in fishing have both positive and negative impacts. On the one hand, technology can help increase efficiency and productivity, resulting in more fisheries production to meet the growing demand for food. On the other hand, uncontrolled use of technology can have negative impacts on the environment and the sustainability of fish resources. The risk mitigation efforts of technological advancement sometimes go unnoticed. Managing the positive and negative impacts of technological advancements in a sustainable manner is necessary to ensure the stability of the growth of the fishing industry. Despite many technological advances in fishing and processing, the industry still faces many challenges to the fishing industry. Overfishing has led to the depletion of fish stocks, causing significant economic setbacks for communities. In addition, illegal, unreported and unregulated (IUU) fishing exacerbates the problems in the fishing industry. These IUU activities result in overexploitation of fish resources, degradation of marine habitats and significant financial losses [1].

The lack of comprehensive monitoring and enforcement, inadequate traceability, and unsustainable practices contribute to these problems, creating a complex web of challenges that need to be addressed simultaneously to achieve sustainable fisheries supply chains. Responding to global demands and addressing these challenges, the implementation of traceability systems for fisheries products is a crucial strategic step. Traceability has become an essential component of the fisheries supply chain. It ensures food safety, verifies product legitimacy, and addresses customer concerns about product origin and authenticity. In fisheries traceability refers to the ability to track the source and movement of fishery products throughout the supply chain. Traceability involves meticulously documenting the product's journey from its starting point to its final destination [2]. The implementation of traceability systems in supply chains centers on two main activities that are closely interrelated, namely internal and external traceability. Internal traceability is the tracking and tracing of products or processes at a single stakeholder location, while external traceability occurs across the supply chain from upstream to downstream.

Conventional fisheries traceability systems face a variety of problems, including varying standards, mislabeling, and lack of transparency and accessibility of information. These issues are of particular concern to medium-scale fisheries, which often struggle to effectively monitor and manage their resources [3]. The lack of uniformity and oversight regarding the application of traceability standards further exacerbates the problem, with some standards not being globally accepted, leading to inefficiencies and misinterpretation of data [4]. This lack of uniformity and oversight can potentially lead to problems related to the difficulty of accurately identifying products and verifying their origin. In addition, the mixing of products in industrial processing facilities that have not implemented a comprehensive traceability system can obscure the origin of products, leading to a poor perception of food safety. Lack of transparency can undermine consumer confidence and complicate efforts to ensure the safety and authenticity of fishery products.

To resolve this issue, it is important to implement uniform traceability standards throughout the supply chain. Uniform traceability standards enable universally acceptable tracking and documentation of fishery products. This level of transparency ensures that every stage of the supply chain can be accounted for and verified. Standardized traceability protocols help maintain supply chain integrity and provide consumers with reliable information about the products they consume. The efforts to establish these uniform standards can be facilitated by international organizations such as GS1 and the International Electrotechnical Commission (IEC). GS1 and IEC are global organizations dedicated to

developing and maintaining standards for business communications, including product identification and tracking. GS1 standards, such as barcodes and RFID tags, enable accurate product tracking through every step of the supply chain. These technologies facilitate the capture and exchange of important data, such as origin, handling practices, and storage conditions [5], [6].The adoption of uniform standards and the use of technology not only increases transparency but also supports regulatory compliance and market access. Efficiently collecting and evaluating large amounts of data also helps discover patterns and trends that can be leveraged to improve fisheries management strategies and ensure compliance with sustainability guidelines. The use of technologies such as blockchain, GPS tracking, and Radio Frequency Identification (RFID) can significantly improve traceability. In particular, blockchain technology works very well to provide a record of the entire supply chain that is secure and cannot be altered by irresponsible parties. With an immutable transaction history, the system guarantees transparency and lowers the possibility of fraudulent activities. GPS tracking enables precise monitoring of fishing vessels and ensures that they comply with the law and adhere to established fishing methods [7], [8] Implementing and further developing traceability systems in the fisheries sector can foster collaboration and information exchange among stakeholders, thereby improving the overall efficiency and sustainability of the supply chain.

This paper will explain how the development of traceability to better understand the analysis of fisheries traceability system, this research conducted a literature review using Systematic Literature Review (SLR). This paper consists of four sections, namely section II discusses the systematic literature review as a research methodology, section III explains the results of the review as well as answers related to each research question, and section IV presents conclusions and suggestions for future studies. This systematic literature review discusses the development of fisheries traceability systems, technologies in fisheries traceability systems, and challenges in implementing current fisheries traceability systems.

2 Materials and Methods

This paper uses the SLR method to obtain targeted information with the PRISMA 2020 method [9], [10]. SLR was chosen for this study because it is capable of providing fairly robust results in identifying and selecting relevant studies with minimal bias [11]. As such, the SLR method ensures a comprehensive review of relevant studies and is therefore an important part of advancing knowledge on traceability in fisheries. This research uses Scopus, Pubmed and WoS as database sources. Then use mendley as a reference manager and use VoS Viewer and Biblioshiny to map the data.

2.1 Define Purpose SLR

The initial stage in this study is to determine the objectives of this research in the form of research questions. Determining research questions is the most important part of determining boundaries and gaining extensive knowledge related to traceability in the fishing industry. In this research we determine 4 main questions that become the direction and purpose of this research, namely:

QR1 : What is the development of research on Traceability in fisheries supply chains?
QR2 : What are the challenges of traceability in fisheries supply chain management?
QR3 : How has traceability evolved in the fishing industry?
QR4 : What role does digital transformation play in fisheries traceability?

After formulating the research question to be answered, we organized keywords relevant to the respective topic into a search protocol: 4 main keywords were used, which are: Fisheries, Traceability, Supply Chain Management, and Digitalization.

2.2 Inclusion/Exclusion Criteria Document

Some categories of papers to be used in this study were defined. This inclusion and exclusion was determined so that the research carried out answered the previous 4 main questions. The criteria for the scientific articles used must meet the following criteria:

- Studies published in English
- Peer-reviewed journal articles
- Study the subject specified in the research question by mentioning or referring to it in the title or abstract of the paper.
- Articles must be published after 2015 to be considered.
- The article database comes from 3 websites namely Scopus, PubMed and WebOfScience (WoS).

The exclusion criteria were:

- Papers not directly related to the fisheries supply chain
- Studies that did not focus on traceability or the technologies mentioned
- Non-English publications.

Next, we searched for articles with keywords relevant to the topic into the search protocol on three sources of scientific articles namely Scopus, PubMed and Web of Science (WoS). there are four main keywords used, namely: Fisheries, Traceability, Supply Chain Management and Digitalization which we then combine between these keywords so that articles with a combination of these keywords are used as a database in this article. the paper will only be used in the keyword section in combination with other keywords while for search results with one keyword is not used in this paper. The combination of keywords in this article can be seen in the following table:

Table 1. Keyword combination of Traceability in Supply Chain Fisheries.

No	Keywords	Scopus	PubMed	WoS
1	Fisheries	141833	76068	392112
2	Traceability	34250	8853	24368
3	Supply Chain Management	53228	8116	97379
4	Digitalization	46117	739981	30011
5	1+4	50	483	55
6	1+2	362	129	596
7	1+3	184	104	586
8	1+3+4	3	5	7
9	1+2+4	-	3	1
10	1+2+3	22	1	62
11	1+2+3+4	-	-	2
TOTAL		621	725	1309
GRAND TOTAL		2655		

The total number of articles that were collected was 2655. Then selection is made based on predetermined criteria using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method by screening in stages. The screening includes the same article

(duplication), clarity of author, meets predetermined criteria and can be accessed openly using Mendeley.

2.3 Title and Abstract Examination

As required by the criteria, an initial screening was conducted based on the titles and abstracts of the identified journals. This step confirmed that only the most relevant studies were selected for detailed review. This stage further eliminated 2164 journals whose main focus was not related to the use of traceability technology in fisheries supply chains. This left only 63 papers that briefly aligned in title and abstract with the objectives of this study and were therefore carried forward to the next stage.

2.4 Checking Full Text and Finer Selection

The full text of the selected journals was carefully reviewed after prior filtration. This stage required a more thorough review to ensure that the study aligned with the review purpose and provided information on factors that support traceability in fisheries supply chains. After a thorough reading, 40 articles were found to be relevant to this study.

2.5 Analysis of Publication Trends

To understand the development of research in this area over time, we analyzed the distribution of articles by year of publication. The findings of the analysis are shown in Figure 1, which shows the distribution of articles by year of publication.

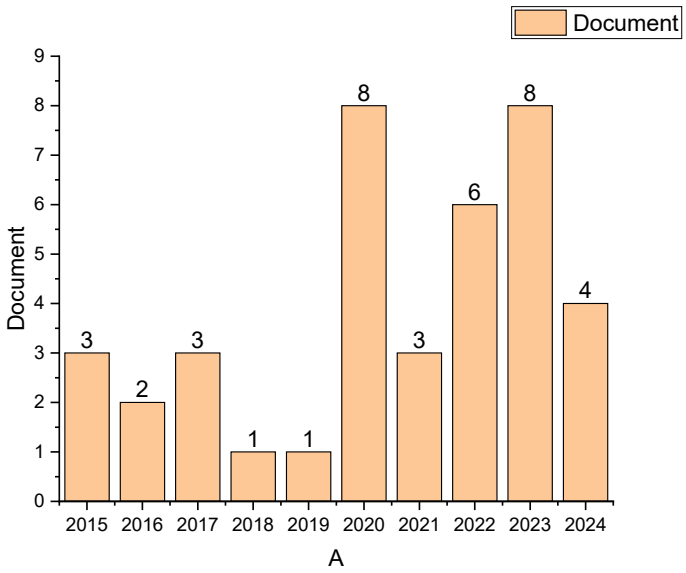

Fig. 1 Year distribution of study publications in this study.

Figure 2 shows the steps in this review as a whole can be seen in the following PRISMA diagram:

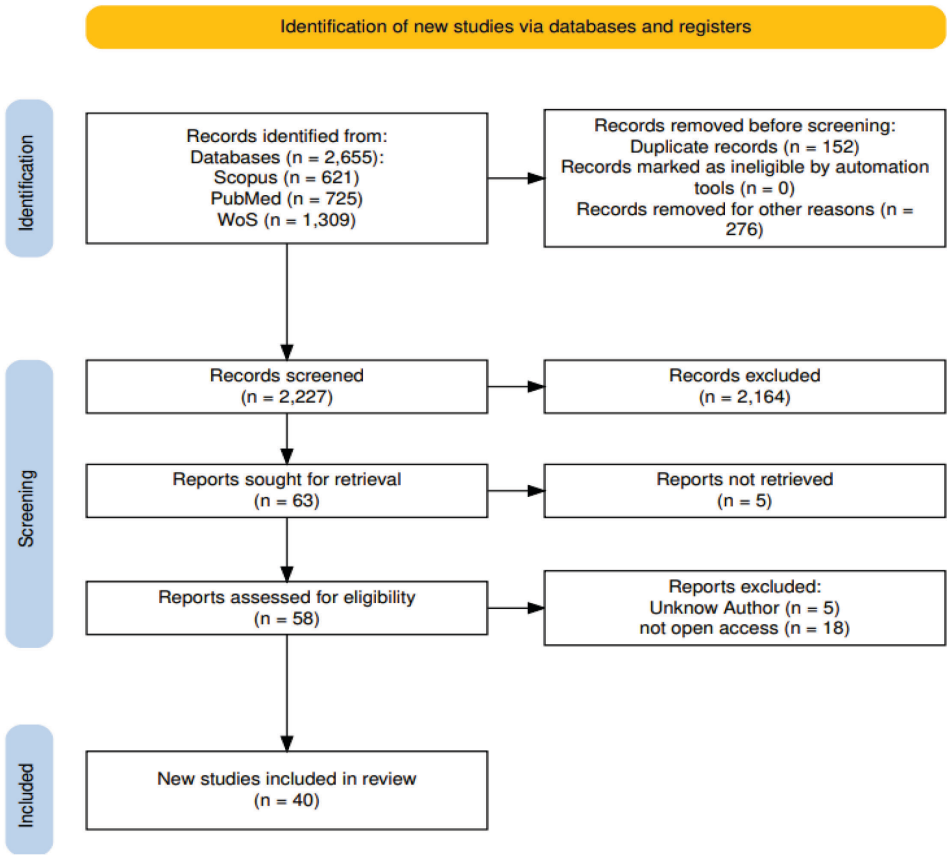

Fig.2. Diagram from PRISMA related to traceability in the fisheries supply chain.

3 Results and Discussion

3.1 Development of research or studies related to Traceability for fisheries supply chain

(QR1 What is the development of research on Traceability in fisheries supply chains?)

There has been a lot of research on traceability in the fisheries supply chain. It is recorded from the data base that there are 2655 documents that discuss traceability in the fisheries supply chain. The data was mapped with the help of Bibliometrix to find out which countries are very concerned about traceability in the world. In Fig.3, it can be seen that several countries such as Italy, China, USA, Spain and Indonesia are countries that have conducted a lot of research related to traceability in the fisheries supply chain.

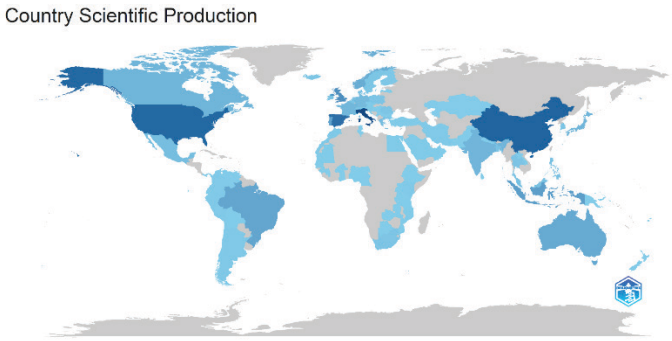

Fig.3. The distribution of research related to global fisheries supply chain traceability through Scopus, PubMed and WoS.

The picture above shows that the topic of traceability in fisheries supply chains is an interesting topic for developed countries in Indonesia. According to Olsen and Borit (2013), traceability in the fisheries supply chain is important for developed countries to ensure food safety, increase transparency and credibility, and improve the efficiency and productivity of the fishing industry. Therefore, the topic of fisheries traceability is an important study to be developed.

The development of the link between traceability and the fisheries supply chain was analyzed by bibliometric networking. In Fig.4, it can be seen that the study of traceability in the fisheries supply chain is starting to lead to a digital system, namely blockchain. Blockchain technology has numerous benefits for traceability in the fisheries supply chain. It offers a decentralized, transparent, and secure platform that maintains data integrity, accountability, and trust at all levels [13], [14]. Blockchain can also record transactions in an immutable ledger system, which enhances security, transparency, and traceability while lowering the risk of food theft and illegal fishing. Furthermore, this technology automates procedures, streamlines supply chain activities, and reduces costs by removing intermediaries, hence increasing efficiency and reliability [14].

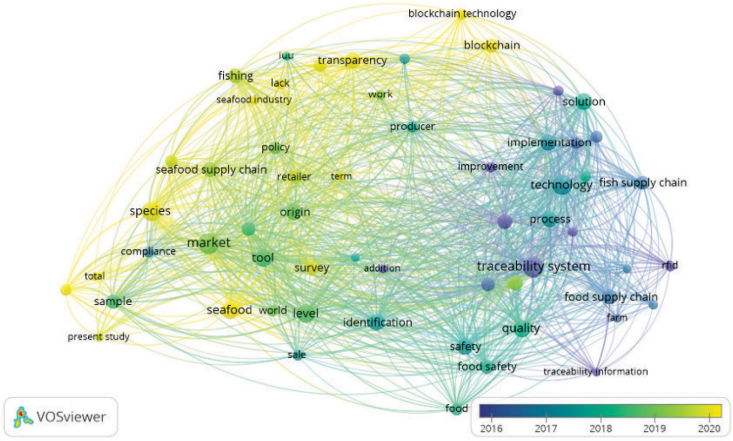

Fig.4. Bibliometric network of traceability on supply chain Fisheries

3.2 Challenges of Traceability for Fisheries Supply Chain

(QR2: What are the challenges of traceability in fisheries supply chain management?)

Traceability in the fisheries supply chain is a system that makes it possible to track the status and origin of a fisheries product through all stages of production, distribution, and marketing. This system can identify the production process and the origin of the material from the supplier to the final product by recording each stage, thus providing greater transparency and food safety. Traceability is a major part of the product supply chain and acts as a system to trace product history through documentation. According to Olsen and Borit (2013) traceability is the ability to access information throughout the production cycle by identifying a product through the records stored on the product.

Traceability in fisheries supply chains has several challenges, including the prevalence of fraudulent mislabeling of product origin, unsustainable fishing practices around the world, and the complexity of seafood supply chains. [15]. Studies emphasize the importance of effective traceability systems to combat fraud, ensure food safety, and promote sustainable fisheries management. [16].

Traceability in the fisheries supply chain is still a big challenge, the main challenge is the lack of good data collection so that the database is not so complete, which causes several deficiencies. According to Tinacci et al. (2023) The lack of deposited reference sequences for certain species and low resolution of target genes pose limitations to DNA barcoding techniques, emphasizing the need for continuous updates to reference databases for effective traceability. Meanwhile, the following Filonzi et al. (2023) Lack of specific databases dedicated to barcoding or fish species can complicate correct species attribution, leading to unreliable taxonomy and information. This is the initial problem of an incomplete data base, which makes it very difficult to see how traceability in the fisheries supply chain works.

The barriers faced in fisheries traceability systems also apply to sustainability issues. Sustainability constraints that occur in fisheries supply chain traceability are apparent due to issues such as fraud during labeling, unsustainable fisheries management, and the need for improved regulatory frameworks. [4]. This has highlighted the critical importance of judiciously applying traceability technologies to address the challenges of managing sustainable fisheries and combating illegal fishing activities, especially in low-income countries and small-scale fisheries. [19].

3.3 The Evolution in Global Fisheries Traceability Standards

(QR 3 : How has traceability evolved in the fishing industry?)

The evolution of global fisheries traceability standards has seen significant changes in terms of scope, technology, geographic focus, and sustainability. In previous standards, the extent of traceability coverage was largely limited by geography. Existing recordkeeping documents showed that monitoring activities only reached the capture stage and there was little to no monitoring at later stages. The lack of a comprehensive perspective and limited information at several stages of the supply chain limited the focus of traceability campaigns and hindered a thorough understanding of the entire process [20]. This fragmented approach makes it difficult to accurately trace fishery products, leading to inefficiencies in the system and potentially increasing vulnerability to fraud or food safety issues [21]. Meanwhile, the use of technology is not yet available to all supply chain actors.

The collection of data and information using manual procedures such as paper-based records is prone to human error as well as loss and destruction of documents. These limitations prevent the achievement of a consistent and reliable traceability system [15].

Traceability standards are closely linked to various sustainability factors, including sustainable environmental and social practices. Historically, sustainability has not been considered much during the traceability process. The main focus of traceability has been on documentation of catch and ensuring regulatory compliance. This view, of course, ignores factors such as ecological impacts and overfishing. The absence of sustainability results in depletion of marine stocks and damage to ecosystems, posing a significant threat to the long-term potential of global fisheries.While the latest traceability standards are much broader and global in scope. They require the collection of complete information from capture to processing to distribution to the consumer. A thorough traceability process ensures that data is collected and rigorously confirmed at every stage, resulting in a transparent system that creates strong consumer trust in the fishing industry [22]. In addition, any issues such as contamination or mislabeling can be quickly tracked and identified, providing protection for consumers and businesses. In general, the evolution of traceability systems can be seen in the following Table 2:

Table 2. Comparison of previous and current standards

Attribute	Previous Standard	Current Standard
Scope	Focused on a specific region and data only focused on arrests	Global implementation and information from across the complete supply chain
Technologies	Manual and technology-based methods are not integrated throughout the supply chain	Using digital traceability for faster and secure data collection
Geographical Emphasis	Standard not yet universally recognized	Focusing on compatibility, information collected using divergent standards can be integrated.
Sustainability	Lack of consideration of sustainability factors beyond capture documentation	Sustainability becoming a core component of traceability standards, implementation of comprehensive sustainability certification

Digital traceability systems have been widely used in the fishing industry. Technologies such as cloud-based platforms and internet-connected systems enable real-time tracking and further verification of fishery products. For example, blockchain features information and transaction records that cannot be altered by irresponsible parties, supporting high integrity and security mechanisms [23]. Internet of Thing (IoT) systems allow devices to continuously monitor factors such as temperature and location, making it easier for companies to maintain the right environment during product storage and distribution. In general, all these cloud-based platforms ensure smooth data sharing and collaboration among stakeholders, helping to increase efficiency and transparency in the supply chain [13]. Modern traceability and tracking standards emphasize global compatibility and inclusiveness. Efforts have been made to ensure that information collected under different regional standards can be integrated throughout global supply chains. This Inclusive approach expands global cooperation and ensures that traceability participation is accessible, enabling small-scale fisheries as well as fisheries supply chain operations in developing countries.

By providing global traceability requirements for the same quality and safety standards, consumer confidence will increase and market access for fishery products around the world will expand [24]. Nowadays, sustainability has become a core element of traceability. This is reflected by the growing awareness of consumers to pay attention to the origin of the products they consume and to the condition of the ocean and fish stocks. The application of sustainability certifications such as the Marine Stewardship Council (MSC) and Aquaculture

Stewardship Council (ASC) in fishing and aquaculture standards demonstrates the responsibility of companies to ensure that fish are caught in accordance with regulations [2], [25]. A strong focus on sustainability helps safeguard marine resources for future generations, ensuring the continued availability of seafood and the health of marine ecosystems.

3.4 Digital Transformation Of Fisheries Traceability For Improved Transparency

(QR 4: What role does digital transformation play in fisheries traceability?)

The traceability system in the fisheries supply chain has undergone many developments. One of the most prominent developments today is the existence of a digital traceability system that utilizes digital technology to artificial intelligence. The development of traceability can be seen briefly in the following Table 3:

Table 3. Digital Transformation of Traceability in Supply Chain Fisheries

Description	Technology	Information Collected	Reference
Product Identification	*Quick Response Barcode*	Item number, batch number	[5]
	Radio Frequency Identification (RFID)	Product temperature, location	[5], [26]
Genetic Analysis and Safety Quality Measurement	DNA Barcoding	Genetic origin, evaluating product ingredients	[27]
	Molecular biology techniques	Product authentication and Geographical origin of products	[16]
	Infrared dan *magnetic resonance imaging*	Internal quality attributes	[28]
Environment monitoring	*Intelligent packaging gas analyzers* and *biosensors*	Temperature, relative humidity	[29]
Geospatial Technology	*Geographic Information Systems* (GIS), *Remote Sensing* (RS), dan *Global Positioning Systems* (GPS)	Specific location data on animals and their movements	[8], [30], [31]
Software Technology	*Blockchain*	Technology integration for full traceability system	[7], [13]

The digital transformation of fisheries traceability through technology is now starting to use technologies such as IoT, QR codes, and electronic monitoring. These technologies are bringing many revolutions to the seafood industry that seek to improve transparency and sustainability from capture to serving [32]–[34]. These technologies provide access to real-time monitoring of seafood from the point of capture to the consumer, providing assurance of authenticity, combating illegal fishing practices and promoting marine conservation [23], [24], [35]. Detailed information on a product's origin, processing, and distribution gives consumers the assurance to make informed purchasing decisions, bridging the gap between producers and buyers. In addition, the integration of traceability using blockchain technology and IoT, creating a guaranteed traceability system, maintains data integrity and privacy, which will reduce the deceitful practices of all stakeholders [26], [36]. Along with the development of the industry, the utilization of genomic techniques and eDNA analysis

promises to improve species identification and biodiversity monitoring, further contributing to sustainable fishing practices and conservation of marine ecosystems [37]–[39].

4 Conclusion

The development of traceability systems in the fisheries supply chain is currently very rapid. The use of digital technology has also been very much a research topic in the world. However, many obstacles are encountered such as the ineffective application of traceability systems due to dishonest and poorly applied data. This causes the existing traceability technology to be not optimal. The development of digital technology is currently trying to prevent this by utilizing IoT, QR codes, and e-DNA to integrated monitoring technology, so that marine products presented to consumers can be guaranteed.

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