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**Author(s):** Shamsuzzoha, Ahm; Marttila, Jarno; Kuusniemi, Heidi

**Title:** Blockchain and space data-based traceability for the sustainable seafood industry

**Year:** 2024

**Version:** Accepted manuscript

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### **Please cite the original version:**

Shamsuzzoha, A., Marttila, J., & Kuusniemi, H. (2024). Blockchain and space data-based traceability for the sustainable seafood industry. In Y. Dessouky, & A. Shamayleh (Eds.) *50th International Conference on Computers & Industrial Engineering (CIE50): Sustainable Digital Transformation*, 84-93. <https://www.proceedings.com/72579.html>



## BLOCKCHAIN AND SPACE DATA-BASED TRACEABILITY FOR THE SUSTAINABLE SEAFOOD INDUSTRY

AHM SHAMSUZZOHA<sup>1,3</sup>, JARNO MARTTILA<sup>2</sup>, HEIDI KUUSNIEMI<sup>3</sup>

<sup>1</sup>School of Technology and Innovations  
University of Vaasa, Vaasa, Finland  
[ahsh@uwasa.fi](mailto:ahsh@uwasa.fi)

<sup>2</sup>Streamr  
Zug, Zug, Switzerland  
[jarno.t.marttila@gmail.com](mailto:jarno.t.marttila@gmail.com)

<sup>3</sup>Digital Economy Research Platform  
University of Vaasa, Vaasa, Finland  
[heidi.kuusniemi@uwasa.fi](mailto:heidi.kuusniemi@uwasa.fi)

### ABSTRACT

Today's global fishing industries are facing several challenges such as capture fisheries, overfishing, degradation of key species' habitats, erratic global fuel prices, climate change, etc. Fishing industries face increasing competition for space, feed, and labour, as well as disease outbreaks and the potential impacts of climate change. Such challenges are threatening their sustainability. To maintain sustainability in the fishing industry, efforts are necessary to monitor and manage fish harvesting. This research study adopts blockchain technology and satellite-based space data to monitor and manage fishing for ensuring sustainability. The outcomes from this study help fishermen and consumers to ensure the traceability of fish from bait to plate. This research study is concluded with overall outcomes along with future research direction.

Keywords: Sustainable fishing, Supply chain, Blockchain technology, Space data, Transparency

### 1 INTRODUCTION

Fishing is considered one of the biggest food business chains. A sustainable fishing strategy is critical for global environmental stability. To maintain the capacity of the biosphere and its ocean there is a need to support and endorse the UN Sustainable Development Goals (SDGs), which are considered as a new framework for economic and social development. To achieve such goals, it is urged by all governments to fulfil the commitments as outlined in the SDGs and to encourage businesses to integrate them into their strategies [1]. To ensure the right conditions for sustainable fisheries and a healthy ocean, it is therefore important that all relevant stakeholders, including governments, industry, and communities are acting collaboratively.

The objective of this research study is therefore to ensure traceability in the total fish supply chain from origin to final destination. In that case, all fish in the supply chains will be traceable with the vessel information and trip dates, and this information will be disclosed upon request at the point of sale either on the packaging or via an online system [2]. Such traceability and authenticity can be ensured through the application of blockchain technology



in the fishing industry which might help to eliminate any form of slavery in this industry and can ensure the fish suppliers meet minimum social standards. These conceptual management practices are also recommended in the Universal Declaration of Human Rights and the International Labour Organization's Conventions and Recommendations. The overall objectives of this study can be summarized as follows:

- 1) To implement robust science-based management plans, including fishing strategies to maintain stocks at, or restore them at least to, levels that can produce maximum sustainable fishing.
- 2) To establish systems to identify and restrict illegal fishing through blockchain-based measures on traceability and transparency.
- 3) To build capacity to establish and manage information systems to account for domestic and international fishing fleets, landings, enforcement, and trade of fish products, in line with sustainability goals or practices.

The rest of the article is organized as follows: Section 2 outlines a literature review considering the fundamentals of blockchain, application of blockchain in various industrial sectors, advantages and disadvantages of blockchain, characteristics of blockchain, basics of blockchain, and how blockchain works. The section explores sustainable fishing and its impact on transparency. The technical perspective of blockchain-based fish traceability is discussed in Section 5, while the accompanying challenges of the global fish industry are explained in Section 5. The study is concluded in Section 6 by stating the study outcomes and future research direction.

## 2 LITERATURE REVIEW

Blockchain technology is a digital ledger, which is distributed, decentralized, verifiable, and irreversible and can be used to record transactions of almost anything of value. Ideally, it is a database that is shared with everyone within the partners' network and can be seen and updated [3]. This technology provides extended opportunities for supply chains, including high levels of transparency. Blockchain technology is getting increased interest in the field of logistics and supply chain management. This specific technology already received much attention for its capability to create a trusted and transparent ledger of transaction information [4]. From the inherent potential for elevating transparency, supply chain managers begin to recognize the possibilities of this new technology. Due to the increased rate of consumers' demands for supply chain transparency; this technology seems very much time available.

Traceability in the fishing industry is hindered when the information is incomplete or missing; however, the merits of traceability in the fishing industry are limited by the complexity of its supply network. For instance, a single-source producer of fish is less complex than a multinational conglomerate that aggregates the fish from several producers from several countries. The complexity of fishing supply chain networks is comprised of different actors (i.e., fish producers, suppliers, distributors, retailers, and end consumers) which consists of concealed elements and raises questions of effective and secure monitoring. In a significant development for global fisheries, blockchain technology is now being used to improve fish traceability which helps to stop illegal and unsustainable fishing practices in the fishing industry [5].

Blockchain mainly consisted of three properties namely, decentralization, transparency, and immutability [6]. In the case of decentralization, the information is not stored by one single entity but everyone owns the information in the network. If anyone needs information he/she

can directly access it without going through a third party. This kind of system has no core authority and every actor in the network can access information on any transactions or confirm new transactions. For transparency issues, blockchain supports the secured identity of any transactions [7]. The level of transparency provided by the blockchain has never existed before within a financial system. The context of immutability in blockchain means that once something has been entered into the blockchain, it cannot be tampered with. This immutability is much more valuable and important for financial institutes. This functionality is achieved by the blockchain through the cryptographic hash function. Table 1 highlights the basic advantages and disadvantages/barriers of blockchain in various industries based on the available literature review.

**Table 1: Display of advantages and disadvantages of using blockchain in various industries based on the available literature survey**

No.	Advantages	Disadvantages/barriers
1	Improve transparency (marketing, container ID, sensors) [8].	Technology can be costly to implement [9].
2	Ensure data integrity (temp., humidity, etc) [10].	Challenges of state-of-the-art technology (lack of knowledge) [6].
3	Helps to abide by legal issues [11].	Risks of Cyber-attacks [12].
4	Cost savings for all participants/stakeholders in the long run [13].	Lack of knowledge/understanding [14].
5	Transparency in the chain [3].	Privacy/business information sharing concerns [11].
6	Would be helpful/able to track the product life cycle [7].	Legal and Regulatory Uncertainties [15].
7	Achieving competitive advantage [16].	Resistance of some stakeholders to adopt [17].
8	Enhance organizational training [17].	Lack of early adopters [18].

## 2.1 Basics of blockchain technology

The basic principles of blockchain are displayed in Figure 1, where it is seen that each of the blocks is connected to the chain of blocks by a hash. A hash works like a fingerprint or signature, which identifies a block and all its content and it is always unique to a block. The hash of the previous block maintains the connection of one block to another block within the blockchain. Each of the blocks has its hash, which is passed to the adjacent block. The first block in the blockchain is known as the genesis block which connects to the next one by its hash and this hash is then passed to the second block in the chain and the 2nd block in the chain, passes its hash to the 3rd block in the chain, and so on. This connection makes the name blockchain, and more importantly, this secures the blockchain. In addition to a hash, each of the blocks contains information such as header, data/transaction, a hash of the previous block, timestamp, proof of work, Merkle tree, nonce, etc. All such critical information ensures the immutability of blockchain technology.

If anyone wanted to hack one of the blocks in the chain, it would change the hash of that block, which changes all the following blocks and become invalid, as he/she would no longer store the correct hash of the block that came before. However, the hashes alone cannot prevent the hacking of the block due to today's faster computing power of the computers. High-speed computers can recalculate all the hashes of the other blocks to make the blockchain valid again. In such a situation, blockchain uses different consensus mechanisms

such as proof-of-work with peer-to-peer distribution, which slows down the creation of new blocks. For instance, in the case of Bitcoins, it takes about 10 minutes to calculate the required proof-of-work and add a new block to the chain. In this way, it becomes super difficult and almost impossible to hack or tamper with any of the blocks in the blockchain, because it is required to recalculate the proof-of-work for all the following blocks. It is, therefore, noticed that the security of the Bitcoin blockchain is ensured by using both hashing and the proof-of-work mechanism.

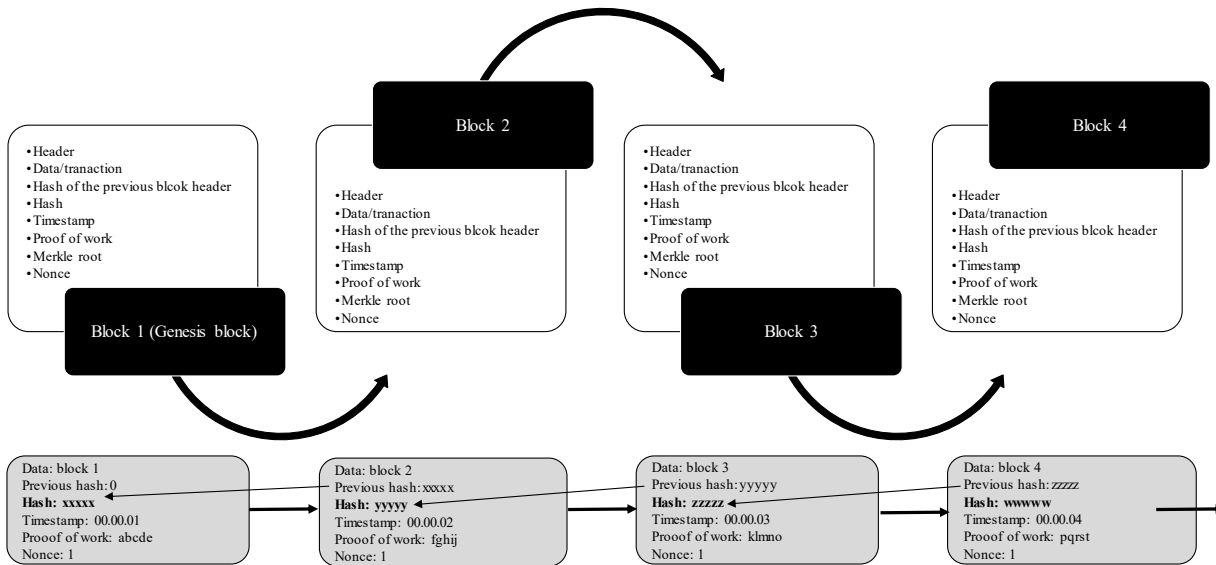


Figure 1: Display of basic principles of blockchain technology

## 2.2 How does blockchain work?

Blockchain is an innovative technology first coined by Satoshi Nakamoto [19]. Since then, it has evolved into something greater. In blockchain, any form of transaction flows a systematic way as displayed in Figure 2. From Figure 2, it is noticed that initially a request for a transaction is formulated which is eventually broadcast to a peer-to-peer (P2P) network. At the P2P network, the requested transaction is validated which is forwarded then to the next block. This verified transaction can be in the form of cryptocurrency, contracts, records, or other information. This verification process creates a new block and stores the existing unverified transactions within the blockchain. This new block is sent to everyone in the network and joins the existing blockchain in a permanent and unalterable format.

Each node in the network then verifies this new block and makes sure that it has not been tampered with. After the necessary verification process, each node adds this new block to his/her blockchain. Similarly, all the nodes create a consensus among them and they agree about which blocks are valid and which ones are not. After necessary verification, the requested transaction is completed and a new transaction request arrives in the next block and the process is repeated accordingly. If a block is noticed as tampered somehow it is then rejected by the other nodes in the network. If anyone wishes to successfully mess up a block, it is necessary to tamper with all the blocks in the successive blocks on the chain, redo the proof-of-work for each block and take required control of the peer-to-peer network that is extremely difficult and almost impossible to do with. In that way, blockchain maintains its security and trust building.

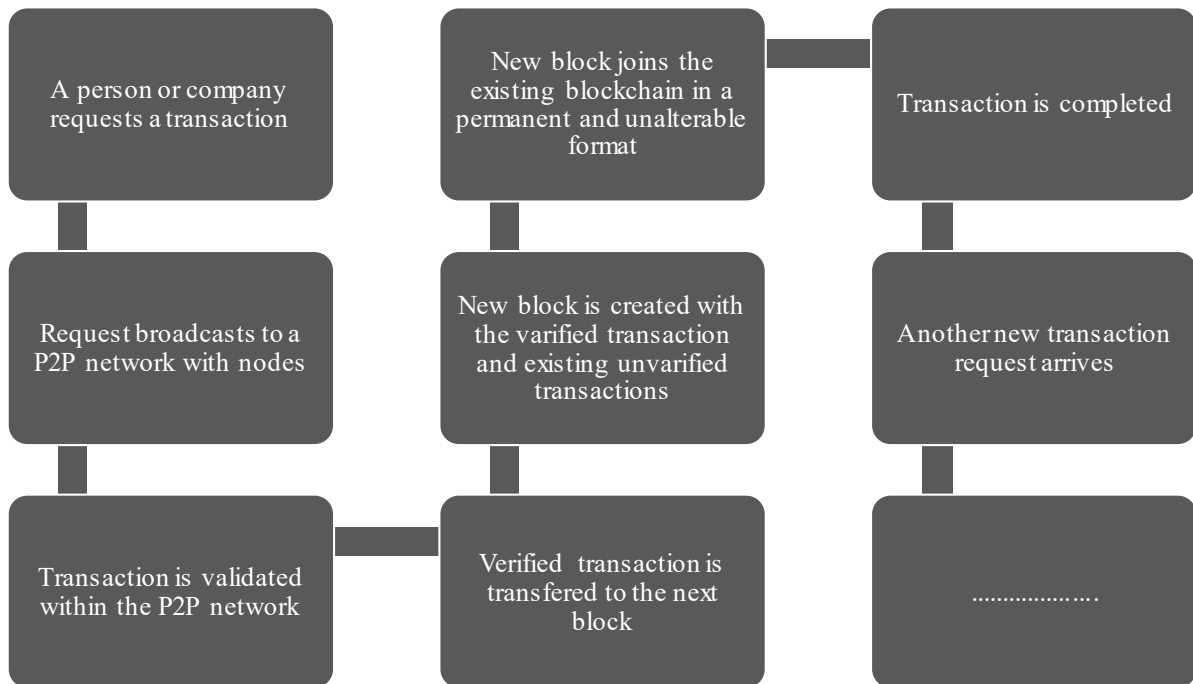


Figure 2: Basics of a transaction flow within the blockchain [20].

### 3 SUSTAINABLE FISHING: IMPACT OVER TRANSPARENCY

Sustainable fishing management is complex and multi-jurisdictional. To advance towards sustainability, it is necessary to improve oversight and transparency within the stakeholders such as fish traders, warehouse/distribution centres, wholesalers, government authorities (legal, rules and regulations, standardization board, food safety), and end customers (customer, restaurant owner). Such transparency provides valuable support to the entire fishing supply chain, starting from harvest through processing and delivery to the end consumer. Supply chain and transportation companies associated with the fish business get additional benefits from such real-time information visibility.

Several fish populations are subject to overfishing or are classified as overfished, which creates unbalance in the ecosystem. To remain productive and viable economically and ecologically, it is necessary to maintain balance fishing within fish species. Such balancing can be ensured through the management of transparency and oversight of fishing to entire fish populations. Transparency also promotes sustainable fishing by acting against illegal, unreported, and unregulated fishing and helps government and non-government organizations and consumers by eliminating or minimizing such illegal activities from the origin to the end.

It is believed that to ensure the availability of fish to the end customers, the entire fish supply chain should be legal, sustainable, and transparent. These requirements can be fulfilled through coordination among local governments, fisheries scientists, and local fishermen toward the realization of effective and sustainable fisheries management [21]. In addition, the implementation of government rules and regulations and monitoring of fishing efforts and catches can promote sustainable fishing. Effective traceability of fishing ascertains consumers to know where their fishes have come from and government organizations can be ensured that all aspects of fishing and processing are safe and free from human rights abuses and/or modern slavery. Such traceability will be a significant step in achieving this vision and may provide a road map for other relevant food industries and products.



### 3.1 Application of Blockchain for sustainable fishing

Due to growing concern about consumer awareness and higher pressure from regulators, sustainable fishing has become an increased importance. Blockchain maintains immutable and tamperproof recordkeeping, which could prove to have a positive impact on sustainability. With such detailed recordkeeping, it is possible to authenticate that the captured fish or fish products are produced following ethical standards. This kind of certification is critical nowadays to ensure sustainable fishing. Often it is challenging and costly to authentic supply items from source to consumer. By adopting blockchain-based recordkeeping, end customers are given full access right to all their product information, which is stored on the blockchain through scannable QR codes, or similar solutions, on the product packaging [22]. Through such traceability, the consumers can know critical information regarding production processes, and the origin of fish [23]. Knowing the exact geographical location of the fishes can help the consumers to authenticate whether the captured fishes are met the expected standards.

With blockchain-based recordkeeping it is possible for the consumers to directly audit the books themselves, leading to easier decision-making when wanting to buy sustainable fishes. The decentralized and distributed structure of blockchain technology makes it possible to record-keeping and make the transaction records immutable, which means that no changes can be done to the records as soon as they are stored in the blockchain. This technology offers a shared book of records, where each of the actors in the network can access the provenance of a single fish. For instance, if a consumer wanted to buy a fish filet, he/she can scan a QR code on the package of the filet to view the production date and logistics processes of the fish before reaching the retailer's shelves [22]. This information visibility revolutionizes the supply chain of fish and brings many advantages to the flow of fishes from farmers to the end consumers. In addition, it highlights the role of blockchain in ensuring seafood safety and in rebuilding a trustful network of fish distribution between producers and customers [24].

### 3.2 Application of space data for sustainable fishing

The space data received from various satellites can be a useful source for monitoring and managing sustainable fishing. Experiences gained from global fishermen show that various information from the ocean such as water temperature, colour, wave size and direction, sea state, flotsam and jetsam, etc., has a direct influence on fishing strategies [25]. In such a perspective, satellite-based space data can be an important source for the identification and exploitation of potential fishing grounds to maximize fish catch. Therefore, various techniques and efforts have been made to retrieve environmental parameters, which are available through data collected from various space-borne sensors. Remote sensing satellites, which usually cover large spatial areas over marine sites have proven to be of substantial economic benefits [25]. Such kind of technology offers necessary data for harvesting and mapping valuable fisheries resources.

To identify potential fishing zones, it is necessary to know oceanic processes and various hydrological parameters such as sea surface temperature, ocean surface waves, wind, chlorophyll pigments, oceanic eddies, etc. Any variations of such processes and parameters directly affect the distribution, abundance, and availability of fish. The behavioural changes of such processes and parameters can be detected through satellite data. Although it is not always possible to collect all the data or information necessary to measure and assess the hydrological parameters and processes, fundamental data can be retrieved from the satellite sensors for locating marine fish. Integration of various thematic information received from satellite data with Geographic Information System (GIS) is significant in arriving at integrated coastal zone management practices. By measuring various environmental parameters such as

sea surface temperature, chlorophyll pigments, surface waves, etc., using space data, it is possible to identify potential fishing zones.

In addition to identifying the potential fishing zones, the space data can also be used to forecast fishing. In the absence of specific operational space data, efforts have been made to introduce operational satellites that accumulate necessary space data to be useful for ensuring sustainable fishing. Currently, fishing forecasting is mainly based on sea surface temperature, which is not sufficient for accurate forecasting. In addition to sea surface temperature, other ocean features such as atmospheric radiance data, variations of water constituents, atmospheric parameters (e.g. humidity, dew point, precipitation level, etc.), geophysical parameters (e.g. chlorophyll-a, suspended matter, yellow substance, and aerosol-optical thickness, etc), etc., are necessary to achieve integrated fishery forecasting. To provide such useful data, it is necessary to introduce satellites with new sensors to collect and optimize various ocean features for sustainable fishing.

#### 4 TRACEABILITY OF FISH BY BLOCKCHAIN: TECHNICAL PERSPECTIVE

##### 4.1 Conceptual Framework for a food traceability system

There's no single framework that describes how blockchain should be utilized for seafood traceability. Aung and Chang [26] have presented a conceptual framework for food traceability systems but this framework could be seen as a technology-agnostic framework from a traceability software perspective. In Figure 3, Aung and Chang's [26] conceptual framework is presented. On food traceability and seafood traceability, multiple stakeholders partake in activities related to the food product that flows through the stakeholders. Each stakeholder can have an information system that handles the storage and processing of traceability-related information. But if blockchain can be simplified as decentralized data storage, where does it fit into this conceptual framework?

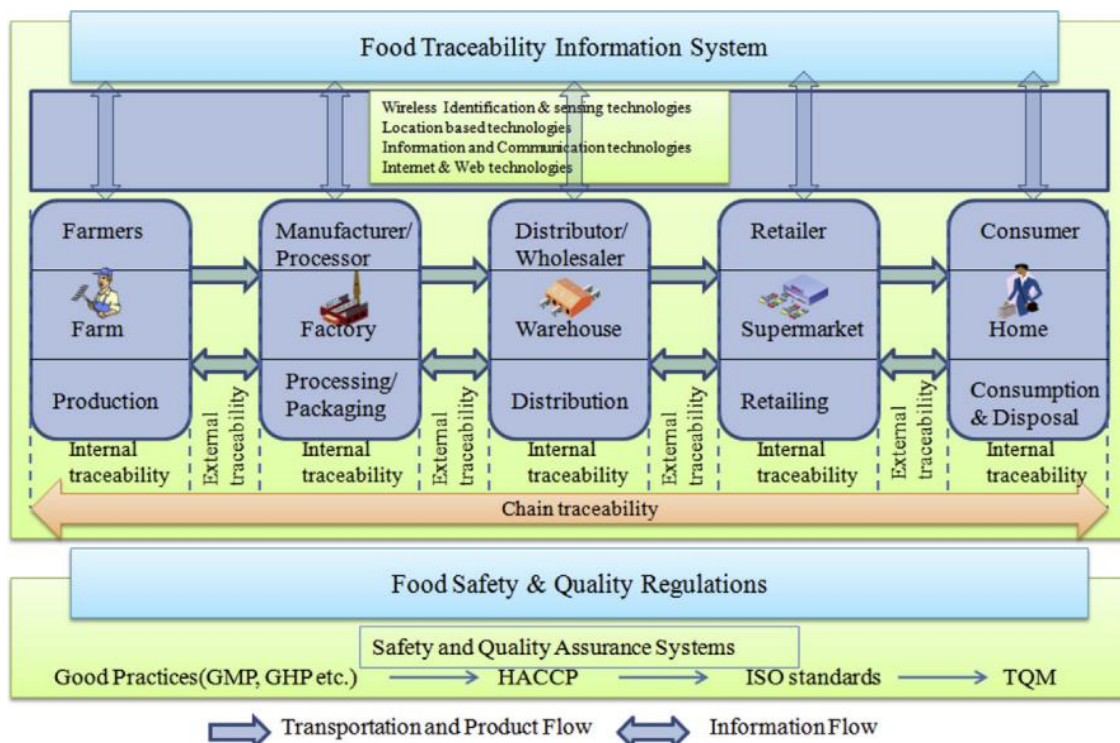


Figure 3: Conceptual framework of food traceability system [26]

Aung and Chang [26] do not go into detail on how the information systems work on each stakeholders' side but they note that "... a product traceability system requires the identification of all the physical entities and locations from which the product originates...where it is processed, packaged, and stocked, including every agent in the supply chain".

Figure 4 displays on a high level, what the use of blockchain in traceability could look like. From Figure 4, it is seen that different supply chain stakeholders are interacting with the blockchain platform via different user or stakeholder-specific interfaces (application layer) with information that everyone is aggregating. At the physical layer, the blockchain should contain smart contracts (application logic) that capture the traceability information in a compliant standard such as Global Dialogue on Seafood Traceability (GDST) [27]. According to Borit and Olsen [28], "Companies across the supply chain should consider adopting industry-wide use of the standards using globally unique identification of units as a significant step forward for electronic and interoperable seafood traceability". Blockchain could contain a global or local ledger of unique identifiers for traceable resource units (TRUs). It should also contain information about transformations that the fish product goes through on its journey from bait to plate.

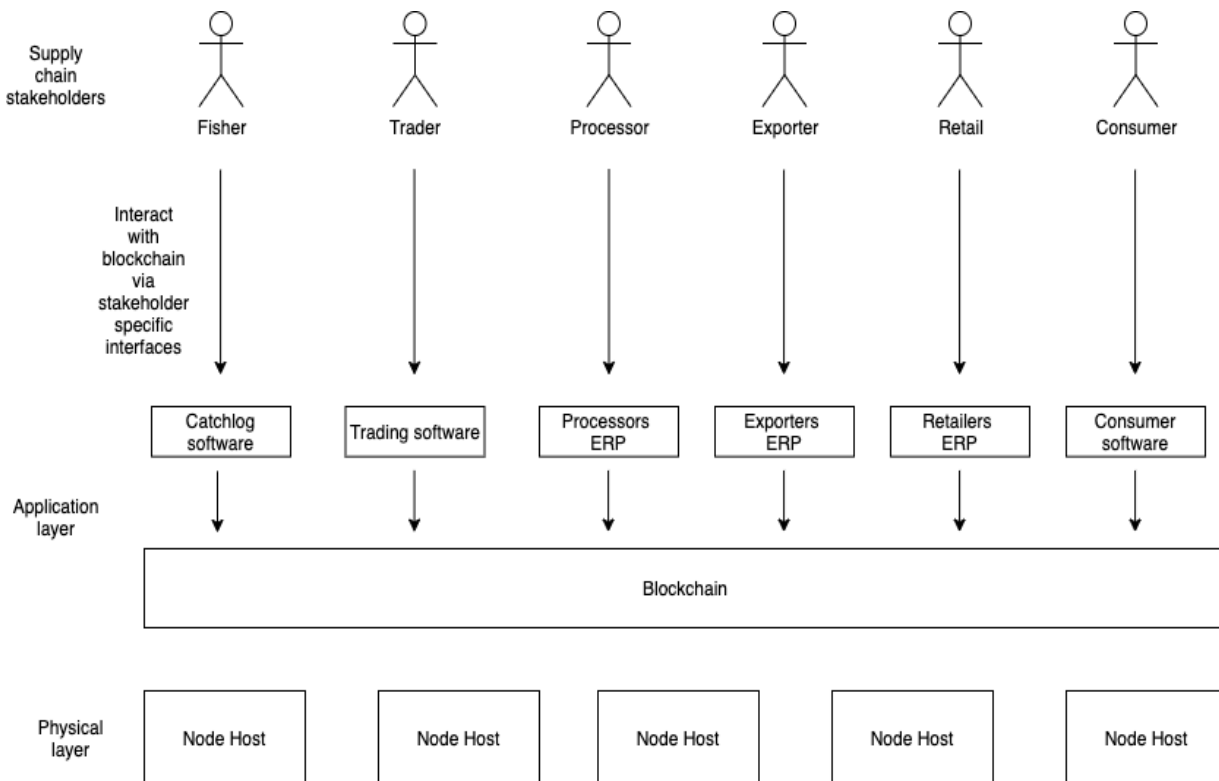


Figure 4: Blockchain-based generic seafood supply chain traceability system.

## 5 DISCUSSIONS AND CONCLUSIONS

In the seafood industry, especially in the fish industry, traceability is crucial to ensure the safety and quality of fish from farm to fork. However, it becomes difficult when supply chains, like those for seafood, are tangled and complicated. As a prized seafood product, fish focuses industry efforts on creating systems that can guarantee transparent and thorough traceability to enable safe, dependable, and sustainable practices [29, 30]. The main goal of this study was to do a literature review on blockchain utilization along the fish supply chain, comprehend

how it works generally, and identify any prospective applications. An actual blockchain application for fish traceability management is also a secondary objective.

It is expected that the use of blockchain technology will strengthen transparency and enable full traceability, thereby countering significant threats to licensing revenue and crew working conditions and safety, and broader impacts on the environment [5]. Blockchain technology is an option to improve traceability because it can automate transactions through the execution of smart contracts to manage the fishery supply chain operations effectively in a way that is decentralized, transparent, traceable, secure, private, and reliable [30]. This technology has the potential to provide a transparent, immutable, and decentralized traceability record, which can help solve issues with complicated and fragmented supply networks like the tuna supply chain. Additionally, the adoption of blockchain technology in fish supply chain management improves the speed and accuracy of transactions made by operators while facilitating consumers' access to nutritious seafood that is both sustainable and fulfils their current demands.

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