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# Blockchain-enabled traceability system for the sustainable seafood industry

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## Abstract

This study highlights both theoretical as well as practical contributions to improving traceability in supply chain management with special focus on the fish supply chain. As a theoretical contribution, it highlights how blockchain technology can contribute to improving supply chain transparency in various sectors by providing real-time visibility. Concerning practical contributions, this study adopted a case study approach in the Philippines to track and trace the fish supply chain from bait to plate. It deploys a project titled ‘Tracy’, a blockchain-based information technology artefact to support fishermen in the Philippines, who are facing numerous challenges in the seafood industry such as different standards and regulations, requirements for international exports, catch certification, etc. This study specifically contributes to developing a smartphone app through the Tracy project that allows fishermen to view the history of their fish captures and exchanges (such as the name of the fish species, weight, and length of the fish, date of capture, and vessel name). The update of transaction histories, the identity of the fishermen, and the amount of fish that has to be sold are additional updates also made possible by this app. This research study concludes with overall study outcomes and limitations with future research.

*Keywords:* Sustainable fishing, Supply chain transparency, Blockchain-based traceability, Traceability, Case study, The Philippines.

## 1. Introduction

Fishing is regarded as one of the most important food industries. For global environmental stability, a sustainable fishing strategy is essential. To ensure optimal circumstances for sustainable fisheries and a healthy ocean, all essential parties, including fishermen, must work together. Today's global fishing industries are facing several challenges throughout their supply chain. Some of the common challenges are the capture of fish, overfishing, degradation of the habitats of key species, fluctuating global fuel prices, climate change, etc. (Roy et al., 2023). In addition to supply chain issues, fishing industries are facing increasing competition for space, feed, and labor, as well as outbreaks of disease and the potential impacts of climate change (Afrianto et al., 2020; Howson, 2020). Such challenges threaten their sustainability. To maintain sustainability in the fishing industry, efforts are necessary to monitor and manage fish harvesting and its supply chain (Jose and Prasannavenkatesan, 2023).

According to Mai et al. (2010), the correct and appropriate implementation of traceability can lead to several advantages, including a decrease in the risks and costs associated with outbreaks of food-borne diseases (Hobbs, 2003), a decrease in the costs associated with product recalls (Agriculture & Canada, 2007), an increase in production efficiency (Moschini, 2007), and an increase in the sales of high-end products (Golan et al., 2004). In the case of the fishing industry, the deployment of traceability systems may help small-scale fisheries adhere to export regulations established by foreign markets like the European Union (EU) and the United States (US), and raise the price for the fish caught (Marttila et al., 2019).

The use of blockchain technology in the seafood business can assure a form of supply chain transparency and offers long-term sustainability (Tsolakis et al., 2021). Blockchain as a technology can revolutionize how businesses are conducted today. Within the fishing business, this technology has the potential to provide supply-chain transparency that contributes to stopping illegal acts, enhancing supply-chain coordination, increasing operational efficiency, improving sustainability performance, and detecting market trends (Marttila et al., 2019; Hastig, and Sodhi, 2020).

This study introduces and investigates an Information Technology (IT) artefact tool app called Tracey, a blockchain-based concept design intended to encourage small-scale fisheries in the Philippines to collect and exchange traceability data. Through the use of blockchain technology in the fishing business, such traceability and authenticity can be ensured, potentially assisting in the abolition of all forms of slavery. This study serves two purposes: to review and summarize the drawbacks and advantages of seafood traceability systems; and to provide Tracey, a novel concept solution that uses design science techniques to address first-mile traceability with small-scale fisheries. For this study, the following three research questions (RQs) were identified:

RQ 1: What kinds of difficulties are associated with seafood traceability, including fishing methods, that allow for maximum sustainable fishing?

RQ 2: How do blockchain and IoT-based traceability and transparency techniques create systems to identify and restrict unlawful fishing?

RQ 3: How can capacity be built 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 the basics of blockchain technology and how it can be applied to improve traceability in the fish supply chain. Various technical perspectives on the traceability of fish by blockchain are demonstrated in Section 3. The methodology of this study is highlighted in Section 4, while Section 5 describes the technological perspectives of blockchain on seafood traceability. This research study is discussed in Section 6, where mainly the three identified research questions are answered. The study is concluded in Section 7, along with the study's contributions and limitations.

## 2. Literature review

This study adopts a narrative literature review approach. This approach is widely used in literature review and helps researchers to establish a theoretical and methodological framework for a given topic. This narrative approach promotes a thorough and critical overview of previously published research on blockchain technology and potentially identifies current research gaps in the literature. In addition to research gaps, this approach also supports the formulation of meaningful research questions. The narrative literature review on blockchain technology shows that this technology is nowadays widely deployed in the field of supply chain and logistics management.

There are several benefits for an organization to deploy blockchain, which include decentralization, persistence, anonymity, and auditability. Nowadays, the application of blockchain spans a broad range of industries, including cryptocurrencies, financial services, risk management, the Internet of Things (IoT), and public and social services. This section performs an overall literature survey on the application of blockchain in various sectors, with special focus on supply chain and logistics management. The top three citation databases, namely Google Scholar, Scopus, and Web of Science (WoS) were used in this survey. The sorts of papers that were assessed were restricted to those that were published in peer-reviewed academic journals. The search terms for this investigation were “blockchain”, “supply chain” and “sustainability”. After discussion among the authors, the following additional supply chain-related search terms were determined: “fish supply chain”, “transparency”, and “traceability”. These query strings were used to choose every article that fit the theme. Although the word “blockchain” dates back to 2008, its initial applications were limited to the banking sector. The first scholarly journal paper on the integration of supply chains with blockchain was published in June 2017. Consequently, June 2017 to March 2023 was chosen as the search window's range.

### *2.1 Fundamentals of Blockchain and its adoption in supply chain management*

Blockchain technology is a distributed, decentralized, verifiable, and irreversible digital ledger that may be used to record nearly any type of transaction (Niranjanamurthy et al., 2019; Rajasekaran et al., 2022). It should ideally be a database that is accessible to everyone in the partners' network and can be updated. This technology opens up new possibilities for supply chains, including greater transparency (Gligor et al., 2022; Iranmanesh et al., 2023). In the world of logistics and supply chain management, blockchain technology is gaining traction. This technology has already received a lot of attention for its capacity to generate a trustworthy and transparent ledger of transaction data (Francisco and Swanson, 2018; Lee et al., 2018; Farooq et al., 2020; Ming et al., 2021). Supply chain managers are beginning to see the possibilities of this new technology as a result of its inherent potential for increasing transparency. There are several scenarios in which blockchain can be used to ensure supply chain transparency (Francisco and Swanson, 2018; Araballi and Devaki, 2023). Consumers in the seafood business, for example, frequently want assurances that the fish they buy and eat were not farmed using unlawful netting procedures or in protected waters (Adams et al., 2018). Consumers are concerned about the ethicality, sustainability, and legality of the food they consume and how it is produced.

To fulfil consumers' demands, blockchain technology can be a good solution, where this technology promises to dramatically change transaction methods by providing a transparent and immutable record for inspection. In recent days applications of blockchain are being implemented and developed within the finance sector (Harish et al., 2021; Hosen et al., 2023), the fashion industry (Chen, 2023), the cocoa industry (Bai et al., 2022), the agri-food industry (Menon and Jain, 2021), etc. From a customer point of view, transparency in the supply chain refers to information availability in a supply network (Agrawal et al., 2021; Iranmanesh et al., 2023).

## *2.2 Application of Blockchain for sustainable development*

It is generally believed that science and technology (S&T) need to be more prominent in sustainable development, but there is little systematic research on how to set up organizations that can successfully use S&T for sustainability (Cash et al. 2003; Neumeyer, et al. 2020). Strategies for achieving sustainable development are increasingly understood to require the ability to mobilize and use S&T (Neumeyer and Santos, 2018; Li et al., 2023). For instance, emerging technology like blockchain provides high levels of sustainability and transformative power (Kewell et al., 2017). In recent decades there have been several initiatives to deploy blockchain to deliver social services (Lnes et al., 2017; Jovic et al., 2020; Tavares et al., 2021).

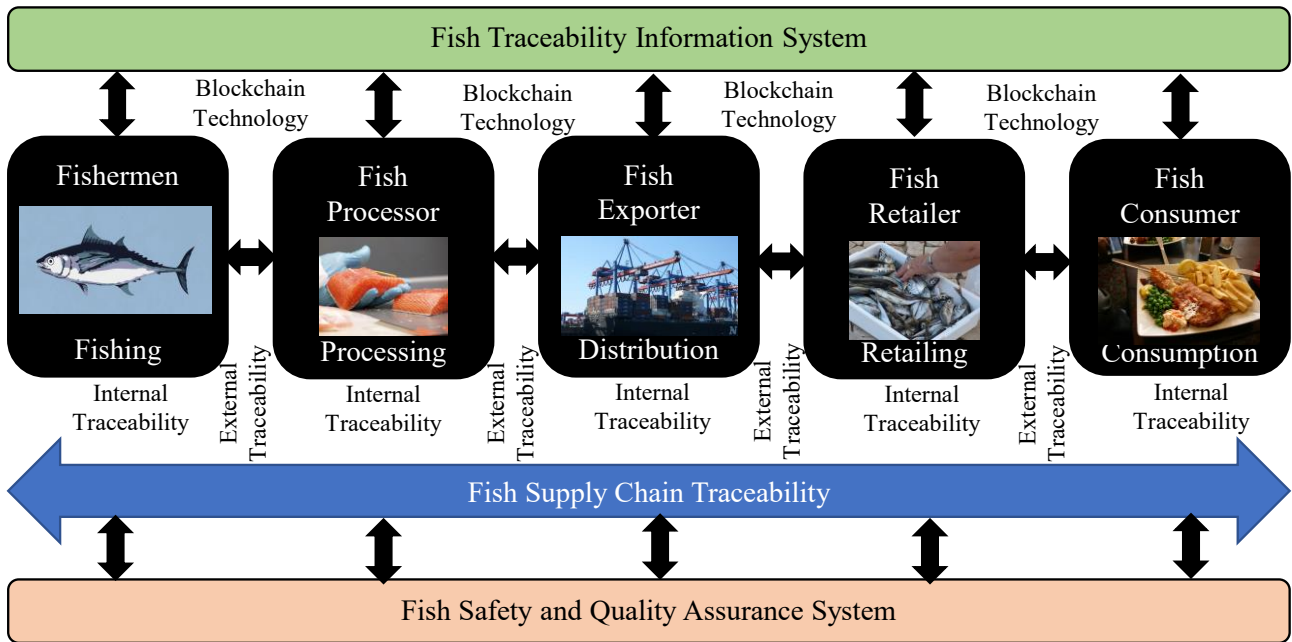
Devine et al. (2021) investigated how the coexistence of social and economic logic in social enterprises might foster trust and serve as accelerators for sustainable social businesses using blockchain. They also studied how blockchain might increase social venture sustainability and promote the fulfilment of social business as introduced by Yunus (2010). Research has been carried out on the role that blockchain technology can play in developing and maintaining more sustainable social businesses concerning financial and environmental sustainability which also further supports the development and utilization by social business practitioners and stakeholders (Chawla, 2020; Schinckus, 2020). In addition to social sustainability, blockchain is also widely deployed in supply chain sustainability, which ensures authentic and trustworthy transactions among supply chain stakeholders (Jović et al., 2020; Tsolakis et al. 2021).

## **3. Traceability of fish by blockchain: technical perspective**

### *3.1 Conceptual structure of a fish traceability system*

The implementation and application of food supply chain traceability are not supported by any broadly accepted conceptual framework or philosophy (Behnkea and Janssen, 2020). Additionally, there is a dearth of scientific research on the use of blockchain technology in supply chains in general, and on employing this technology for fish supply chain technology in particular. Islam and Cullen (2021) proposed a cohesive theoretical framework to improve the understanding and effective implementation of food traceability systems. This framework consisted of four consolidated principles: identification, data recording, data integration, and accessibility. Mantravadi and Srari (2023) present a framework for supply chain integration in urban food systems, with a focus on digital technology interventions and future research directions for the digitization of the food supply chain. Khan et al. (2022) present a public-private hybrid blockchain-based conceptual framework to address the traceability, transparency, and certification challenges associated with shrimp exporting from Bangladesh.

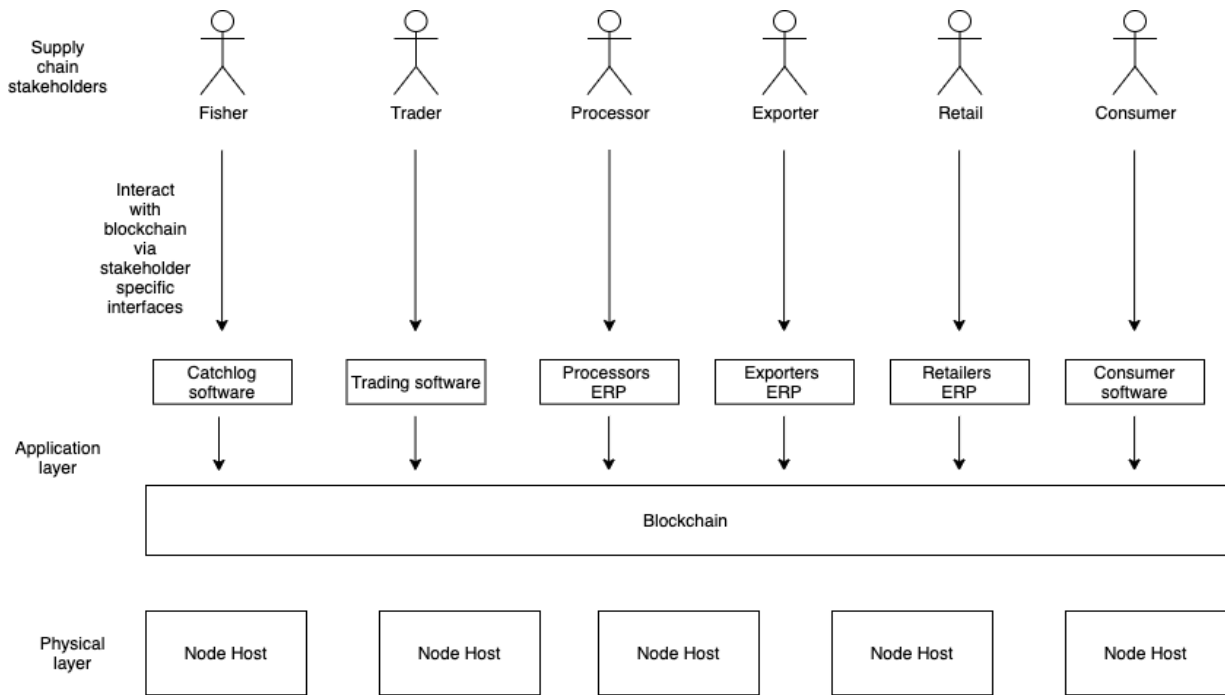
Based on the presented frameworks, this study took a practical approach in proposing a framework that contributes to seeking to comprehend the border conditions of the supply chain blockchain technology. This framework mainly describes how blockchain should be utilized for fish traceability. The various stakeholders in this framework consist of fishermen, fish processors, fish exporters, fish retailers, and fish consumers, as seen in Fig. 1.



**Fig. 1.** Conceptual framework of fish traceability system (adapted from Aung and Chang, 2014).

The fish traceability information system presented in Fig 1 is adopted from Aung and Chang's (2014) conceptual framework. Fig 1 shows that in this fish traceability framework, multiple stakeholders partake in activities related to the fish product that flows through the stakeholders. Each stakeholder can have his or her information system that handles the storage and processing of traceability-related information.

It is noteworthy that Aung and Chang (2014) do not go into great detail about how each stakeholder's information systems work, but they do state that "a product traceability system requires the identification of all physical entities and locations from which the product originates, where it is processed, packaged, and stocked, including every agent in the supply chain" (Regattieri et al. 2007). Fig. 2 displays the use case diagram for a blockchain-based information flow system within supply chain stakeholders. Fig. 2 also visualizes on a high level what the use of blockchain in traceability systems could look like. Different stakeholders are interacting via different user or stakeholder-specific interfaces with information that everyone aggregates.



**Fig. 2.** Use case diagram of blockchain-based information flow system within fish supply chain stakeholders.

### 3.2 Technical features of blockchain that can support the tracing of fish from source to the consumer

Blockchain has several technical features that can support fish tracing from the source to the consumer. Technical features of blockchain that can be used for the traceability of seafood are smart contracts, distributed consensus, transaction verification, a platform for smart contracts, transferring value between peers, security, immutability, and uniqueness. Blockchain should contain smart contracts (application logic) that capture traceability information in a compliant standard such as GDST (Borit and Olsen, 2020). It can also contain a global or local ledger of unique identifiers for traceable resource units (TRUs) and information about transformations that the fish product goes through on its journey from bait to plate (Howson, 2020).

Smart contracts such as data/metadata storage and tokenization of assets are two of the most commonly used technical features of blockchain. Smart contracts are executable computer programs that are run on a blockchain. These contracts or programs comprise their code and their state. For example, in the Ethereum blockchain, a smart contract is a specific type of account that can have a balance and can send transactions in the blockchain network (Wesley et al., 2021). Users' accounts or wallets can interact with these smart contracts. Smart contracts are the basic building blocks of how traceability solutions could be built on decentralized ledgers. For example, decentralized data storage of key data elements related to a fish catch can be built based on smart contracts that store the state of the fish caught in a contract and that allow only certain people to access the information.

There is no single unified framework on how to utilize blockchain for seafood traceability, but there are multiple use cases where blockchain has been utilized (Howson, 2020). For instance, Aung and Chang (2014) provided a conceptual framework for food traceability systems, where various stakeholders in a food supply chain interact with each other through an information system. Hofherr et al. (2016) provided a seafood traceability framework based on a DNA analysis that integrates potential benefits and barriers from a regulatory perspective. Lewis and Boyle (2017) highlight the necessary tools and key initiatives to expand the role of traceability in seafood.

The application of blockchain technology is not sufficiently utilized, but is expanding to improve the traceability of seafood (Marttila, 2020). This study is necessary to know how blockchain can be

implemented for seafood traceability. To understand how blockchain should be utilized in the context of traceability, its potential benefits such as interoperability need to be looked into. The application of blockchain in seafood traceability is not a silver bullet solution. It has its weaknesses, e.g. decentralized systems in comparison to centralized systems, CAP (consistency, availability, partition tolerance) theorem of distributed systems vs blockchain vs centralized systems, and understanding the tradeoffs of technologies when choosing.

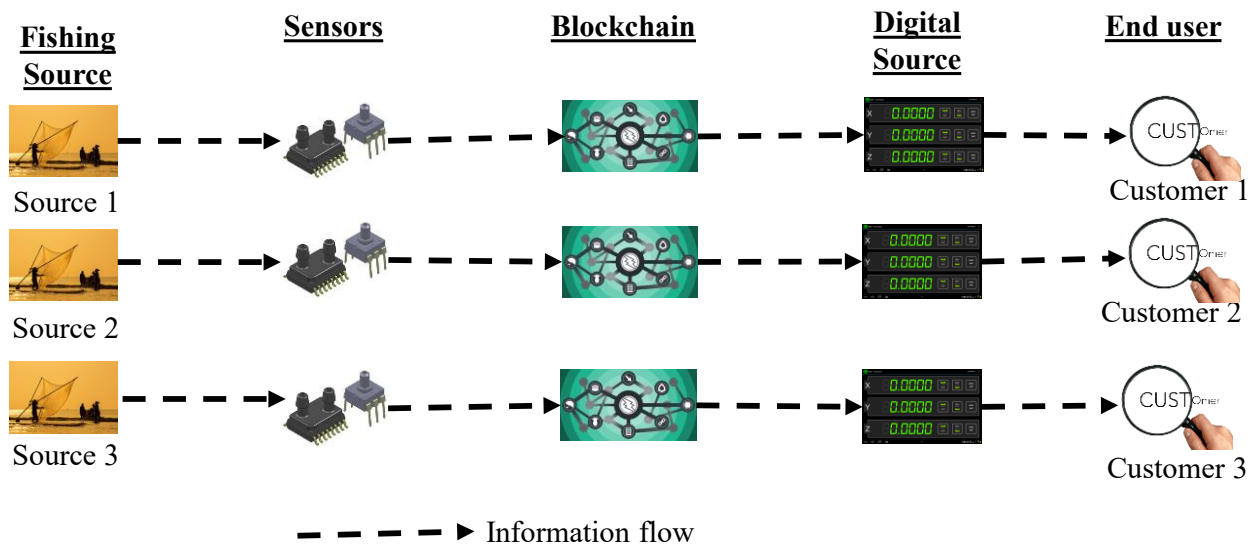


Fig. 3. Blockchain-enabled traceability solution within the fish supply chain.

Fig. 3 shows the blockchain-enabled fish supply chain solution. From Fig. 3, it can be seen that the necessary information flow starts from the fishing source up to the end-user (customer) via various sensors, a blockchain platform, and a digital source. The sensors collect all the required information via different technologies and tools (e.g. IoT, Wi-Fi). The collected information is authenticated and used for the necessary traceability by blockchain technology. Blockchain technology enables various transactions and keeps records within the supply network through smart contracts. The authenticated data is transferred to the digital source (e.g. cloud, mobile), from where the necessary update of the fish or fish product is received by the end-user (e.g. customer). The flow of necessary information is used to track the fish product from the source to the consumer with the necessary verification and authentication.

#### 4. Study methodology

A case study can be implemented with the main requirement being the necessity of thoroughly examining an event or phenomenon in its original setting (Crowe et al., 2011). The theory that underlies the case study was chosen to be interpretivism. Ritala et al. (2012) assert that under interpretivism, the researcher typically takes part in the investigation. A case study should not be viewed as a method in and of itself; instead, it is a design framework that can include a variety of techniques (Thomas). Stake (2005) concurred, saying that a case study is not a methodological decision, but rather a decision of what will be researched and how. One of the limitations of a case study is that it seeks to identify the possible researched case; it does not define populations or choose suitable samples (Sagadin 1991, p. 34). In the case study, it is preferable to choose analytical induction over representative sampling and statistical generalizations to a larger population.

The methodology of this research is adopted as a case study approach within a case company, where the aim was to specify the traceability of the fish supply chain from the Philippines to Europe. The case study approach is adopted due to its advantage and usefulness in application when trying to

understand a topic, event, or phenomenon in depth and in the context of real-world experience (Starman, 2013). In this case study, one of the authors was a project team member with clear tasks regarding the project. As a result, the methodology was subjective, and a sizable portion of the data was gathered by observing events in the project. But to better comprehend the subject and the potential advantages of the initiative, a theoretical framework was developed.

Due to the nature of the study (individual implementation project in a country), a case study was the obvious choice as the main research method because action research was unfeasible due to its iterative nature and because the goal was to produce in-depth knowledge about a single country's problem without taking any trends or changes into account. The cooperation between the fishermen and the project workers was one of the study's key areas, and methodologies typical of observation and interviews were used. The study would be qualitative, using an inductive method because this case study only looks at the issues of an individual country, the Philippines. Since there was only a small number of personnel engaged, the study data was focused more on quality than quantity. Having a great amount of data would not have served the goal and been impractical to collect. This demonstrates the fundamental goal of this study, which is to develop information specific to one example rather than generalizations.

## **5. Blockchain-based fish traceability system: a case example**

### *5.1 Background of the study*

The purpose of this study is to present a case study in which blockchain technology is utilized to track fish from the source to the customer. This research study was carried out as part of the 'Tracy' project, in which blockchain was used to create an information system targeted at incentivizing fishermen in rural parts of the Philippines and to assure verified fish traceability and trade data. The Tracy project's goal was to design and develop an information system project for a Southeast Asian underdeveloped country.

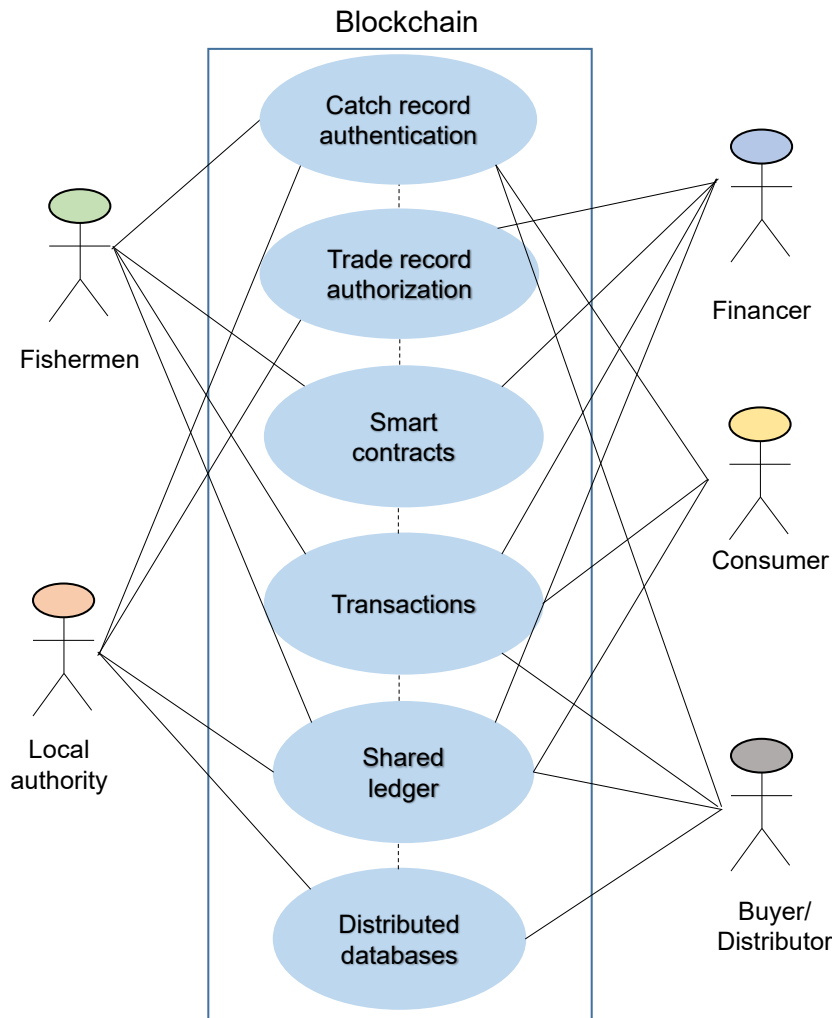
In the Philippines, the fishermen live in the coastal area, where they fish tuna as a livelihood. They face several challenges that affect the continuity and sustainability of the fisheries. Some of the challenges are the financial perspective that is related to exporting fish to the international market and abiding by various standard rules and regulations. When it comes to international exports, fishermen must also adhere to certain supply chain criteria such as fish product traceability, catch certification, and health and hygiene standards (CBI, 2019).

### *5.2 User requirements and data storage*

Through the Tracy project, the fish as catches are shared through a distributed ledger system using the Ethereum blockchain. The relevant data such as fish catch logs and trade data are collected through interview surveys and various existing databases as necessary to design and develop the information system project. These data are also necessary to estimate the log data related to predicting the use of fisheries resources. Although complete data is not always available, the interview survey compensates for the needs of data scarcity. The interview survey consisted of questionnaires, which were divided into three categories, namely traceability, technology, and borrowing. These interview questionnaires also help to find out the types of mobile devices the fishermen used, their income level, and the amount of money they eventually borrowed (Marttila et al., 2019).

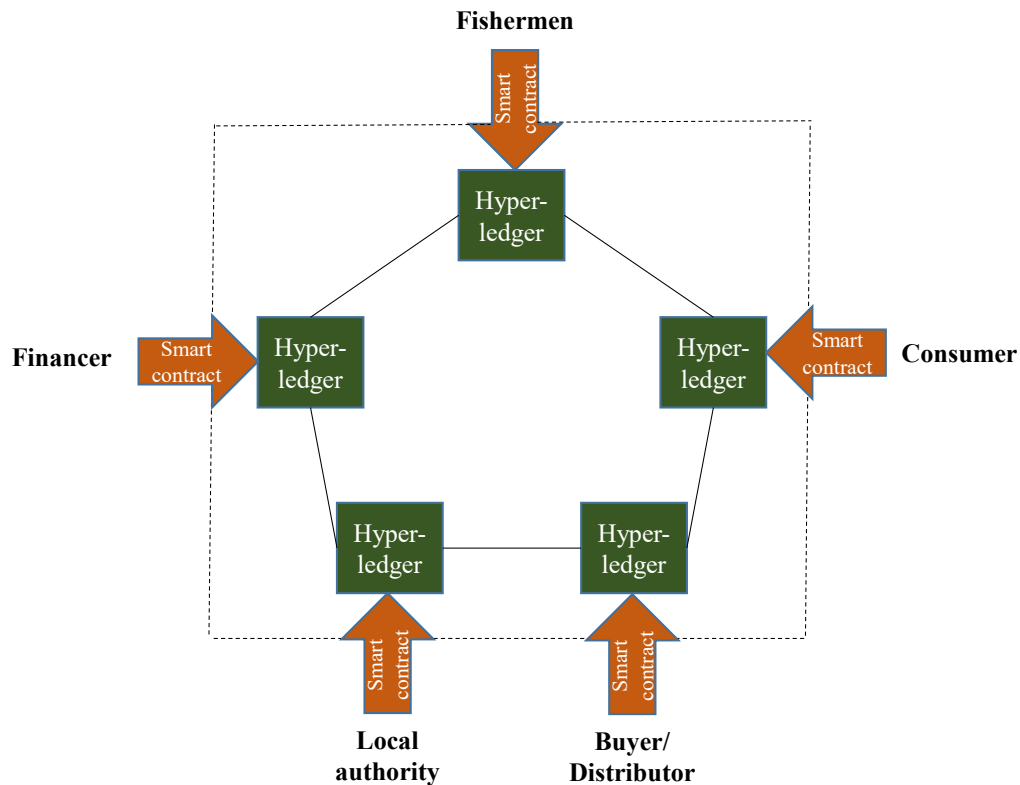
Tracy's IT artefact app use case diagram is shown in Fig. 4, which shows that there are five actors within the use case diagram, which are fishermen, local authorities, financiers, consumers, and buyers/distributors. Fig. 4 also shows that the blockchain-based fish traceability system consisted of phases such as catch record authentication, trade record authentication, smart contracts, transactions, shared ledger, and distributed databases, which are interconnected with each other in order to share

necessary information. The actors in the use case diagram are connected with the stages of the traceability system according to their characteristics and functionalities within the system. For instance, fishermen are connected to the catch record authentication, smart contracts, transactions, and shared ledgers to know the status of their fish catch. Similarly, all other stakeholders in the logistics chain are connected with the stages of the fish traceability system, depending on their information exchange needs, as visualized in Fig. 4.



**Fig. 4.** Tracy uses a case diagram of the blockchain-based fish traceability system.

In this information system, Hyperledger Fabric is used as a transparent and secure solution for the fish supply chain. The Hyperledger Fabric is selected due to the Hyperledger’s consensus algorithm that offers a much faster solution than major blockchain platforms. In addition, Hyperledger offers a private solution for a selected number of actors, which is also a major concern of fishery companies when deploying blockchain in their supply and logistics channels. Fig. 5 displays the proposed use case diagram of Hyperledger Fabric in the fish supply and logistics chain.



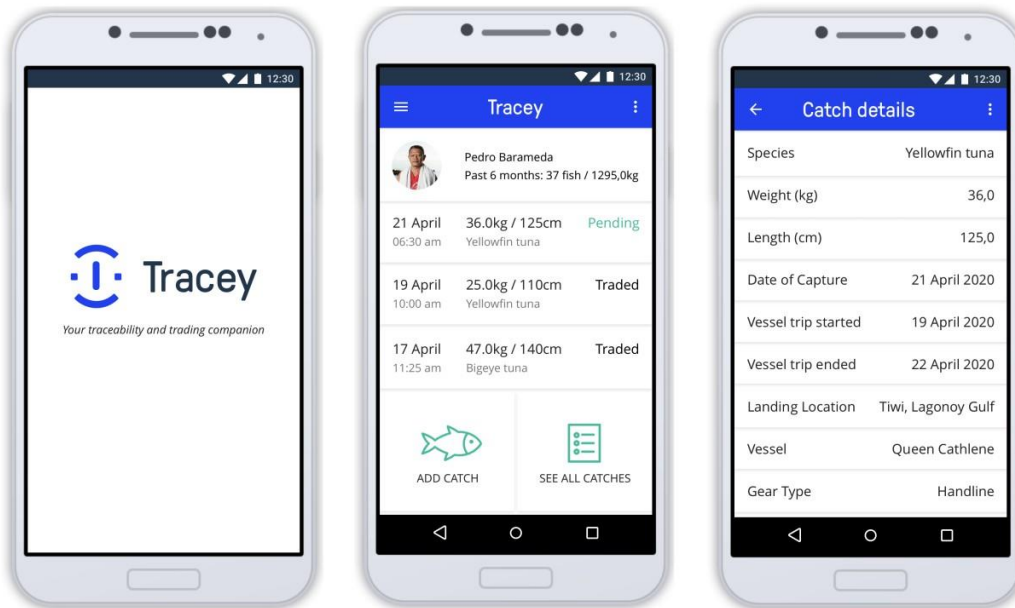
**Fig. 5.** Proposed use case diagram of Hyperledger Fabric in the fishery supply and logistics chain.

Fig. 5 shows that there are five types of actors in the proposed Hyperledger solution which can all have their Hyperledger nodes. Each of the nodes shares the same blockchain information, which is using a consensus algorithm to maintain the blockchain secured and verified. Fishermen, financers, local authorities, buyers/distributors, and consumers are utilizing the Hyperledger Fabric applications in different roles.

Fig. 5 also identifies that local authorities can offer digital end-user services (e.g. implementations), and authorize and manage users who can utilize the Hyperledger blockchain. In addition, the local authority can limit the utilization of the blockchain, for instance, of the fishermen. Therefore, limiting the visibility of the data in some cases is suggested. Financers (e.g. banks) and other financial institutions provide data in the blockchain and can obtain online information: for instance, how much fish is traded during a specific period of the year. This information provides useful content: for example, new ways to deal with controlling fishing.

### 5.3 Mobile-based solution approach

The most popular smartphone type in the rural Philippines, according to this case study, is the android phone. An android mobile-based application for fishermen and fish purchasers has been devised and developed based on this discovery. The basic interface for fishermen and fish buyers is the smartphone application shown in Fig. 6. Through this interface, they communicate with the Tracey backend. Utilizing this app, fishermen and fish buyers can register in either role. Depending on the functionalities, they are given different roles in the mobile app. In this app, the fishermen can record their catches. When the catch log is finished, it is transferred to Tracey's backend system, where the relevant data is saved in a centralized database and a decentralized ledger is created.



**Fig. 6.** Display of Tracey app for fishermen and fish buyers.

Fig. 6 depicts the created smartphone app, which will allow fishermen to view the history of their fish captures and exchanges (e.g. name of fish species, weight and length of the fish, date of capture, vessel name). The fishermen, together with the fish purchasers, can update a transaction history on Tracey’s application once the necessary amount of fish has been sold. The buyers then update the completed trades to ensure that the products match the information entered. The completed deals and accompanying traceability data are regarded as validated after the data exchange has been negotiated and accepted.

The Tracy Android application system interacts with a hosted back-end system that includes user administration, authorization, and authentication, as well as a relational database for traceability and trade data, data models, and Application Programming Interfaces (APIs). Command-line tools and APIs provide access to the user management and authentication system. Users will be able to control and authenticate their activities depending on their chosen roles, such as fisherman or purchaser, by utilizing the tools and APIs. The OAuth 2.0 protocol is used to authenticate and authorize users who want to utilize the APIs. Authenticated users can access the APIs to record and retrieve data on fish trading and traceability using the JavaScript Object Notation (JSON) format.

## 6. Discussion

In addition to reviewing and summarizing the benefits and disadvantages of seafood traceability systems, this study also offers Tracey a fresh concept solution that applies design science methods to first-mile traceability issues with small-scale fisheries. This study identifies three research questions, which are answered in this section.

The first research question, “What kinds of difficulties are associated with seafood traceability including fishing methods that allow for maximum sustainable fishing?” is answered by explaining several challenges as stated within the scope of this study. This study identifies export markets like the EU which require participants in the fish product supply chain to adhere to several regulations, including catch certification, health and hygiene standards, and product traceability (CBI, 2019). Although paper-based catch log documentations are still frequently utilized in the first stage of the supply chain, the traceability of fish products requires data from all stakeholders as the fish move through the chain from bait to plate. According to our findings, fishermen are generally eager to test

out gathering and sharing catch records and trade data, especially if they receive payment for doing so and the information is kept confidential from their peers or direct rivals (Marttila et al., 2019).

The second research question “How do blockchain and IoT-based traceability and transparency techniques create systems to identify and restrict unlawful fishing?” is answered in Section 3, where a blockchain project titled ‘Tracey project’, is demonstrated with an IT artefact that uses blockchain technology to focus on the fishermen and the interface between the first two actors in the presented supply chain: catching fish from the sea, recording information about the catch, trading the fish catch, and recording the trade. The Tracey IT artefact was made up of three parts: a mobile app for recording trade and traceability data, a centralized backend system for storing user data, and a blockchain component for storing metadata. This IT artefact ensures traceability and transparency by identifying and restricting unlawful fishing.

The third research question “How 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?” is answered in Section 3.4, where, blockchain includes smart contracts to record traceability data following standards like GDST. Blockchain's smart contracts allow the storing of data and metadata and are the most widely utilized applications to keep records of the fish supply chain from bait to plate. Smart contracts save the state of the fish caught in a contract, permit only specific people to access the information, and contribute to a sustainable fish catch.

From a pragmatic viewpoint, this study adds value to fishermen in the Philippines by providing a methodology of how fish can be traced utilizing blockchain technology from the source to the customer. This study was carried out on a blockchain-based information system, which contributes to compensating Filipino rural fishermen and guaranteeing accurate fish trading and traceability data. The goal of this study was to assist Filipino fishermen who are struggling with several challenges that are affecting the longevity and sustainability of the tuna fishery. Additionally, the presented study analyzes the need to adhere to specific supply chain requirements for exporting fish to other countries, as well as the requirements for the traceability of fish products, catch certification, and health and hygiene standards for fishermen.

Moreover, the study also contributes to the well-being of consumers, who are much more concerned nowadays with the origin and authenticity of the fish they buy and eat. They are also concerned with seeking assurances that the fish they buy and eat was not grown in protected waters or with unlawful netting practices to ensure sustainable fishing in general. The developed smartphone app in this research study also allows fishermen to view the history of their fish catches and exchange valuable information such as the name of the fish species, weight, and length of the fish, date of capture, vessel name, distributor, etc. Furthermore, this smartphone app also supports additional information such as updates of transaction histories, the identity of the fishermen, and the amount of fish that has to be sold. It is therefore strongly believed that the presented study contributes substantially towards maintaining sustainable fishing globally in respecting our precious environment.

## **7. Conclusions and study limitations**

Global companies must track and trace their supply and logistics chain to improve productivity with higher trust. However, it is often difficult to ensure traceability in the supply and logistics chain due to accompanying challenges. This study aims to track the fish supply chain in big archipelago nations like the Philippines. One of the main problems that could cause a trustworthiness issue is the data quality and data integration of existing traceability systems. The Ministry of Marine Affairs and Fisheries in the Philippines has created procedures to regulate the traceability of fisheries products in recent years. Although centralized traceability systems may perform better and require less effort to

construct than decentralized ones, they have difficulties dealing with unscrupulous groups that attempt to alter the traceability chain because no consensus is rigidly maintained.

Utilizing blockchain technology can increase trustworthiness since it guarantees data immutability and allows for consensus among system participants because of its decentralized nature. In this study, we provide a decentralized traceability system that enables the fish supply chain to view the traceability chain and obtain aggregated information about fishery products. We used Hyperledger Fabric, which is well-known for its impressive identity management and its high performance relative to other blockchain technologies, to develop a decentralized fishing traceability system. Throughput and response times for practically all of the needed features were high in our system during performance tests. The method also decreased the likelihood of a single point of failure issue because each organization has several peers deployed.

Since the current traceability system is implemented in a centralized manner, one organization may change the traceability chain without the consent of other organizations, and altering the traceability chain may also be carried out by a single unreliable organization in the supply chain. Employing blockchain technology, which is known for its decentralized and immutability characteristics, is one potential answer to such data integrity challenges. As each node in the decentralized system maintains its traceability chain, any node that dares to change the chain without the consent of the majority of other nodes would prevent the change from taking effect. In this study, we develop and put into practice a prototype of a decentralized traceability system for fishery products within the framework of actual traceability management practices.

### *7.1 Study contributions*

The presented study contributes in both theoretical and practical ways. Concerning the theoretical perspective, this study contributes to the development of new knowledge related to blockchain technology, especially its application and importance in supply chain and logistics management. Various literature related to the application of blockchain in the supply chain is reviewed and analyzed. This survey shows that the speed at which customers are demanding supply chain transparency is increasing. From the perspective of the consumer, information accessibility in a supply network is referred to as transparency in the supply chain. The use of blockchain to ensure supply chain transparency is possible in a variety of situations, and this technology seems to be extremely readily available. From such potential applications, it is identified that supply chain managers are starting to grasp this new technology due to its ability to increase openness and its value. Additionally, from the theoretical perspective, it is also observed that supply chain traceability benefits transparency regarding the sources of fish and offers up-to-date information in the case of the seafood business. Due to blockchain technologies, the fishing industry gains from increased supply chain transparency which offers an immutable and distributed fish custody record component that is ideal for traceability applications and sustainability.

Concerning the practical perspective, the study contributes by presenting a case study of how fish can be tracked from the source to the consumer using blockchain technology. This research was conducted as a part of a project called 'Tracy', which is an initiative to employ blockchain technology to build an information system aimed at rewarding Filipino rural fishermen and ensuring accurate fish trading and traceability data. This project was intended to support fishermen in the Philippines who are dealing with several difficulties that have an impact on the longevity and sustainability of the tuna fishery. Additionally, the fishermen also face hurdles regarding the requirements to follow different standards and regulations as well as to abide by certain supply chain requirements for international exports, including traceability requirements for fish products, catch certification, and health and hygiene standards. Moreover, the fishermen also face additional challenges from consumers in the seafood industry, who typically seek reassurances that the fish they purchase and consume were not caught in protected waters or with illegal netting techniques. All such challenges are met through the

development of a smartphone app under the Tracy project that enables fishermen to view the history of their fish catches and exchanges (e.g., name of fish species, weight, and length of the fish, date of capture, vessel name). Furthermore, this app also contributes to updating additional information such as the required quantity of fish that has been sold, the fishermen's identities, and updates of transaction histories.

## 7.2 Study limitations

According to our findings, the fishermen are generally eager to test out gathering and sharing catch records and trade data, particularly if they receive payment for doing so and if the information is kept private from peers or their direct rivals. The connectivity of mobile phones, the accessibility of the internet in remote regions, the types of mobile phones in use, and the low educational levels of users are some of the technological obstacles to developing traceability solutions for fish tracking and tracing.

TX and Streamr are excited to design, develop, and test solutions employing blockchain technologies to answer the project's challenges as technology vendors. Technology companies face challenges when creating solutions from Europe to Southeast Asia due to the physical distance from end users as well as regional and demographic factors. More extensive survey studies should have been developed and carried out at fisheries improvement project (FIP) locations to improve the current status of fishing operations and to understand the end user's requirements and expectations.

## References

- Abderahman, R. (2018). Blockchain Potential in Tilapia Supply Chain in Ghana. *Acta Technica Jaurinensis*, 11(2), 104-118. Available at SSRN: <https://ssrn.com/abstract=3319440>
- Abeyratne, S. A. & Monfared, R.P. (2016). Blockchain Ready Manufacturing Supply Chain Using Distributed Ledger. *International Journal of Research in Engineering and Technology* 5 (9): 1–10.
- Adams, R., Kewell, B. & Parry. G. (2018). Blockchain for Good? Digital Ledger Technology and Sustainable Development Goals. In *Handbook of Sustainability and Social Science Research*, 127–140. Cham: Springer.
- Afrianto, I.R.A.W.A.N., Djatna, T.A.U.F.I.K., Arkeman, Y.A.N.D.R.A., Hermadi, I.R.M.A.N., & Sitanggang, I.S. (2020). Block Chain Technology Architecture for Supply Chain Traceability of Fisheries Products in Indonesia: Future Challenge. *J. Eng. Sci. Technol*, 2020, 41-49.
- Agrawal, T.K., Kumar, V., Pal, R., Wang, L. & Chen, Y. (2021). Blockchain-based framework for supply chain traceability: A case example of textile and clothing industry. *Computers & Industrial Engineering*, 154, 107130.
- Andriesse, E., Kittitornkool, J., Saguin, K. & Kongkaew, C. (2021). Can fishing communities escape marginalisation? Comparing overfishing, environmental pressures and adaptation in Thailand and the Philip pines. *Asia Pacific Viewpoint*, 62(1), 72–85.
- Araballi, S., & Devaki, P. (2023). A Critical Review of Agri-Food Supply Management with Traceability and Transparency Using Blockchain Technology. *Intelligent Cyber Physical Systems and Internet of Things: ICoICI 2022*, 239-250.
- Atlam, H.F., Alenezi, A., Alassafi, M.O. & Wills, G. (2018). Blockchain with internet of things: Benefits, challenges, and future directions. *International Journal of Intelligent Systems and Applications*, 10(6), 40-48.
- Aung, M.M. & Chang, Y.S. (2014). Traceability in a food supply chain: Safety and quality perspectives. *Food Control*, 39, 172-184.

- Bai, C., Quayson, M., & Sarkis, J. (2022). Analysis of Blockchain's enablers for improving sustainable supply chain transparency in Africa cocoa industry. *Journal of Cleaner Production*, 358, 131896.
- Barnett, J., Begen, F., Howes, S., Regan, A., Mcconnon, A., Marcu, A., Rowntree, S. & Verbeke, W. (2016). Consumers' confidence, reflections and response strategies following the horsemeat
- Behnkea, K. & Janssen, M.F.W.H.A. (2020). Boundary conditions for traceability in food supply chains using blockchain technology. *International Journal of Information Management*, 52, 101979.
- Borit, M. & Olsen, P. (2020). Beyond regulatory compliance–Seafood traceability benefits and success cases. *FAO Fisheries and Aquaculture Circular*, FAO Publisher, Series no: 1197, Rome, Italy.
- Buterin, V. (2017). The meaning of decentralization. Available at: <https://medium.com/@VitalikButerin/the-meaning-of-decentralization-a0c92b76a274>.
- Casey, T.W., Krauss, A.D. & Turner, N. (2018). The one that got away: Lessons learned from the evaluation of a safety training intervention in the Australian prawn fishing industry. *Safety Science*, 108, 218-224.
- Cash, D.W., Clark, W.C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., Jäger, J. & Mitchell, R.B. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences*, 100(14), 8086–8091.
- CBI (2019). *Which requirements should your product comply with to be allowed on European markets?* Author. Retrieved from [2019-11-30], <https://www.cbi.eu/market-information/fish-seafood/buyer-requirements/>.
- Chawla, C. (2020). Trust in blockchains: algorithmic and organizational. *Journal of Business Venturing Insights*, 14, e00203.
- Chen, Y. (2023). How blockchain adoption affects supply chain sustainability in the fashion industry: a systematic review and case studies. *International Transactions in Operational Research*.
- Crowe, S., Cresswell, K., Robertson, A. Huby, G., Avery, A. & Sheikh, A. (2011). The case study approach. *BMC Medical Research Methodology*, 11, 100.
- Desai, P.S., Gowda, H.H. & Kasturirangan, K. (2000). Ocean research in India: perspective from space. *Current Science*, 78(3), 268-278.
- Devine, A., Jabbar, A., Kimmitt, J. & Apostolidis, C. (2021). Conceptualising a social business blockchain: The coexistence of social and economic logics. *Technological Forecasting and Social Change*, 172, 120997.
- FAO (2017). Food Traceability Guidance. *Food and Agriculture Organization of the United Nations*, Santiago, ISBN 978-92-5-109876-9.
- Francisco, K. & Swanson, D. (2018). The Supply Chain Has No Clothes: Technology Adoption of Blockchain for Supply Chain Transparency. *Logistics*, 2(1), <https://doi.org/10.3390/logistics2010002>.
- Gligor, D. M., Davis-Sramek, B., Tan, A., Vitale, A., Russo, I., Golgeci, I., & Wan, X. (2022). Utilizing blockchain technology for supply chain transparency: A resource orchestration perspective. *Journal of Business Logistics*, 43(1), 140-159.
- Greene, J. L. (2010). Animal identification and traceability: overview and issues. *Congressional Research Service*, available at: untitled (nationalaglawcenter.org).
- Haas, B., Fleming, A., Haward, M. *et al.* (2019). Big fishing: the role of the large-scale commercial fishing industry in achieving Sustainable Development Goal 14. *Reviews in Fish Biology and Fisheries*, 29, 161–175.
- Harish, A.R., Liu, X.L., Zhong, R.Y. & Huang, G.Q. (2021). Log-flock: A blockchain-enabled platform for digital asset valuation and risk assessment in E-commerce logistics financing. *Computers & Industrial Engineering*, 151, 107001.

- Hastig, G. M., & Sodhi, M. S. (2020). Blockchain for supply chain traceability: Business requirements and critical success factors. *Production and Operations Management*, 29(4), 935-954.
- Hobbs, J.E. (2003). Traceability in Meat Supply Chains. *CAFRI: Current Agriculture, Food and Resource*, 4, 36 – 49.
- Hofherr, J., Martinsohn, J., Cawthorn, D., Rasco, B. & Naum, A.M. (2016). Regulatory Frameworks for Seafood Authenticity and Traceability, in: Naum, A.M. and Robert H. Hanner, R.H. (Eds.), *Seafood Authenticity and Traceability*, Academic Press, 47-82.
- Hosen, M., Thaker, H. M. T., Subramaniam, V., Eaw, H. C., & Cham, T. H. (2023, February). Artificial Intelligence (AI), Blockchain, and Cryptocurrency in Finance: Current Scenario and Future Direction. In *Proceedings of the 2nd International Conference on Emerging Technologies and Intelligent Systems: ICETIS 2022 Volume 1* (pp. 322-332). Cham: Springer International Publishing.
- Howson, P. (2020). Building trust and equity in marine conservation and fisheries supply chain management with blockchain. *Marine Policy*, 115, 103873.
- Howson, P. (2020). Building trust and equity in marine conservation and fisheries supply chain management with blockchain. *Marine Policy*, 115, 103873.
- Iles, A. (2007). Making the seafood industry more sustainable: creating production chain transparency and accountability. *Journal of Cleaner Production*, 15(6), 577-589.
- Iranmanesh, M., Maroufkhani, P., Asadi, S., Ghobakhloo, M., Dwivedi, Y. K., & Tseng, M. L. (2023). Effects of supply chain transparency, alignment, adaptability, and agility on blockchain adoption in supply chain among SMEs. *Computers & industrial engineering*, 176, 108931.
- Islam, S. & Cullen, J. M. (2021). Food traceability: A generic theoretical framework. *Food Control*, 123, 107848.
- Jose, A. & Prasannavenkatesan, S. (2023). Traceability adoption in dry fish supply chain SMEs in India: exploring awareness, benefits, drivers and barriers. *Sādhanā*, 48(1), 19.
- Justice, A., Mensah, A.M., Sandyllove, A. & Jeffrey, A.D. (2020), The Law of Marine Fishing: Challenges and Coping Strategies for Sustainable Marine Fishing in Ghana. *Journal of Fisheries Science*, Vol. 2 No. 2, pp. 10 – 18.
- Jović, M., Tijan, E., Žgaljić, D. & Aksentijević, S. (2020). Improving maritime transport sustainability using blockchain-based information exchange. *Sustainability*, 12(21), 8866.
- Khan, M. A., Hossain, M. E., Shahaab, A. & Khan, I. (2022). ShrimpChain: A blockchain-based transparent and traceable framework to enhance the export potentiality of Bangladeshi shrimp. *Smart Agricultural Technology*, 2, 100041.
- Lewis, S.G. & Boyle, M. (2017). The Expanding Role of Traceability in Seafood: Tools and Key Initiatives. *Journal of Food Science*, 82(S1), A13-A21.
- Li, X., Wu, T., Zhang, H-J. & Yang, D-Y. (2023). National innovation systems and the achievement of sustainable development goals: Effect of knowledge-based dynamic capability. *Journal of Innovation & Knowledge*, 8(1), 100310.
- Lim, M.K., Li, Y., Wang, C. & Tseng, M-L- (2021). A literature review of blockchain technology applications in supply chains: A comprehensive analysis of themes, methodologies and industries. *Computers & Industrial Engineering*, 154, 107133.
- Mai, N., Bogason, G.G., Arason, S.S., Arnason, S.V. & Matthíasson, T.G. (2010). Benefits of traceability in fish supply chains – case studies. *British Food Journal*, 112(9), 976-1002.
- Mantravadi, S. & Srail, J. S. (2023). How Important are Digital Technologies for Urban Food Security? A Framework for Supply Chain Integration using IoT. *Procedia Computer Science*, 217, 1678-1687.
- Marttila, J. (2020). Seafood traceability systems: Case Tracey – your traceability and trade data companion. *Master of Science in Economics and Business Administration*, University of Vaasa, Finland.

- Marttila, J., Nousiainen, M., Sheppard, B., Malka, M., & Karjalainen, R. (2019). *Tracey* – Menon, S., & Jain, K. (2021). Blockchain technology for transparency in agri-food supply chain: Use cases, limitations, and future directions. *IEEE Transactions on Engineering Management*.
- Mondragon, A.E.C., Coronado, C.E. & Coronado, E.S. (2019). Investigating the Applicability of Distributed Ledger/Blockchain Technology in Manufacturing and Perishable Goods Supply Chains. *2019 IEEE 6th International Conference on Industrial Engineering and Applications (ICIEA)*, 728-732.
- Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System, <https://bitcoin.org/bitcoin.pdf>.
- Neumeyer, X., Ashton, W. S. & Dentchev, N. (2020). Addressing resource and waste management challenges imposed by COVID-19: An entrepreneurship perspective. *Resources, Conservation and Recycling*, 162, 105058.
- Neumeyer, X. & Santos, S. C. (2018). Sustainable business models, venture typologies, and entrepreneurial ecosystems: A social network perspective. *Journal of Cleaner Production*, 172, 4565–4579.
- Niranjanamurthy, M., Nithya, B. N., & Jagannatha, S. J. C. C. (2019). Analysis of Blockchain technology: pros, cons and SWOT. *Cluster Computing*, 22, 14743-14757.
- Olsen, P. & Borit, M. (2013). How to define traceability. *Trends in Food Science & Technology*, 29(2), 142-150.
- Rajasekaran, A. S., Azees, M., & Al-Turjman, F. (2022). A comprehensive survey on blockchain technology. *Sustainable Energy Technologies and Assessments*, 52, 102039.
- Ritala, P., Hurmelinna-Laukkanen, P. & Nätti, S. (2012). Coordination in innovation-generating business networks – the case of Finnish Mobile TV development. *Journal of Business & Industrial Marketing*, 27(4), 324-334.
- Roy, A. K., Yadav, B. M., & Joshi, S. A. (2023). Disruptive Technologies: Its Scope in Seafood Processing and Traceability of Fish Products. In *Advances in Fish Processing Technologies* (pp. 161-182). Apple Academic Press.
- Saberi, S., Kouhizadeh, M., Sarkis, J. & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, 57(7), 2117-2135.
- Sagadin, J. (1991). *Razprave iz pedagoške metodologije*. Ljubljana: Znanstveni inštitut Filozofske fakultete.
- Sahin, O. I., Saricaoglu, F. T., Dundar, A. N., & Dagdelen, A. F. (2023). Smart applications for fish and seafood packaging systems. In *Green Sustainable Process for Chemical and Environmental Engineering and Science* (pp. 211-227). Elsevier.
- Saitoh, S-I., Mugo, R., Radiarta, I.N., Asaga, S., Takahashi, F., Hirawake, T., Ishikawa, Y., Awaji, T., In, T. & Shima, S. (2011). Some operational uses of satellite remote sensing and marine GIS for sustainable fisheries and aquaculture. *ICES Journal of Marine Science*, 68(4), 687–695.
- Schinckus, C. (2020). The good, the bad and the ugly: An overview of the sustainability of blockchain technology, *Energy Research & Social Science*, 69, 101614.
- Starman, A.B. (2013). The case study as a type of qualitative research, *Journal of Contemporary Educational Studies*, 1, 28-43.
- Sterling, B. & Chiasson, M. (2014). Enhancing seafood traceability issues brief. *Global Food Traceability Center*, available at: [Enhancing-Seafood-Traceability-Issues-Brief.pdf](#) (researchgate.net).
- Tavares, E.C., Meirelles, F. de S., Tavares, E.C., Cunha, M.A. & Schunk, L.M. (2021). Blockchain in the Amazon: Creating public value and promoting sustainability. *Information Technology for Development*, 27(3), 579–598.
- Thomas, G. (2011). A Typology for the case study in social science following a review of definition, discourse and structure. *Qualitative Inquiry*, 17(6), 511–521.

- Thompson, B. S., & Rust, S. (2023). Blocking blockchain: Examining the social, cultural, and institutional factors causing innovation resistance to digital technology in seafood supply chains. *Technology in Society*, 102235.
- Thrane, M., Nielsen, E.H. & Christensen, P. (2009). Cleaner production in Danish fish processing – experiences, status and possible future strategies. *Journal of Cleaner Production*, 17(3), 380-390.
- Tsolakis, N., Niedenzu, D., Simonetto, M., Dora, M., & Kumar, M. (2021). Supply network design to address United Nations Sustainable Development Goals: A case study of blockchain implementation in Thai fish industry. *Journal of Business Research*, 131, 495–519.
- Wesley, P., Ziechmann, K., Richards, S., Awad, D., Enriken, W. & Cordell, R. (2021). Introduction to smart contracts, available at: <https://ethereum.org/en/developers/docs/smart-contracts/>.
- Yang, J., Owusu, V., Andriese, E. & Ablo, A. (2019). In-situ adaptation and coastal vulnerabilities in Ghana and Tanzania. *Journal of Environment and Development*, 28(3), 282–308.
- Yunus, M. (2010). *Building Social Business*. Public Affairs, New York, USA.
- Zhao, H., Liu, J., Zhao, P. & Chen, J. (2022). Will nuclear polluted seafood stop selling in the blockchain-enabled market? Lessons from government punishment and social cognition for retailer's selling. *Marine Pollution Bulletin*, 178, 113608.