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Katrina Xue-Lønmo

The blockchain-based DNA
tracing seafood supply chain :
a longitudinal case study

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Vitenskapelig høgskole i logistikk

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# The blockchain-based DNA tracing seafood supply chain: A Longitudinal Case Study

Author:
**Katrina Xue-Lønmo, Katrina.xue-lonmo@kristiania.no**
PhD Candidate, Behavior & Technology Lab, School of Economics, Innovation and Technology, Kristiania University College, 0152 Oslo, Norway

Group advisors
Professor Bjørn Jæger and Associate Professor Terje Andersen
Molde University College, Faculty of Logistics, Norway

PhD supervisor: Professor Asle Fagerstrøm, Kristiania University College, 0152 Oslo, Norway

Abstract

This study examines the integration of DNA tracing and blockchain technology in the seafood supply chain, highlighting its benefits for stakeholders. The seafood industry faces challenges like mislabelling, fraud, and unsustainable practices. DNA tracing provides reliable species verification, while blockchain ensures secure and transparent record-keeping. Combining these technologies is intended to improve traceability, enhance the efficiency of the seafood supply chain, support sustainable fishing, and build trust among stakeholders. Based on our longitudinal case study, data were collected through qualitative observations, interviews, and quantitative metrics to assess improvements in seafood supply chain traceability, operational efficiency, and stakeholder trust. The study results indicate that Blockchain-based DNA tracing technology innovates the supply chain, addressing the seafood industry's mislabelling, fraud, and unsustainability issues. Despite initial costs and technical challenges, the benefits are substantial. This study also identifies challenges and areas for future research. A blockchain-based DNA tracing seafood supply chain initial setup and maintenance can be costly and require significant technical expertise. The future research in blockchain-based DNA tracing seafood supply chain expertise and insights are invaluable. Researchers should explore ways to make these technologies more accessible and affordable for all stakeholders in the seafood supply chain. Future research should conduct practical applied research. Long-term studies are needed to assess the sustainable impacts of this technology integration in the supply chain.

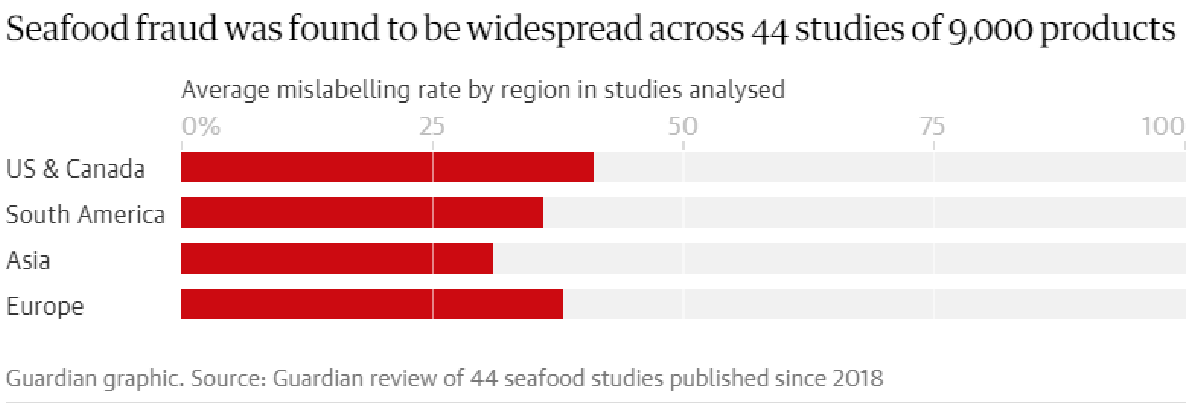
Keywords: DNA tracing; Blockchain; Seafood supply chain; Sustainability

Motivation:

Fish fraud has long been a significant global issue. Due to the highly international nature of seafood trade, which often involves complex and opaque supply chains, seafood is particularly susceptible to mislabelling. A considerable portion of the global catch is transported from fishing boats to large transshipment vessels for processing, a stage at which mislabelling is relatively easy and profitable.

A 2018 study revealed that nearly 70% of snapper samples across the UK were actually different species, comprising an astonishing 38 different types of fish, many of which are reef-dwelling species likely threatened by habitat degradation and overfishing. Furthermore, an analysis of 44 recent studies involving over 9,000 seafood samples from restaurants, stakeholders, and supermarkets in more than 30 countries found that 36% were mislabelled, highlighting the extensive scale of seafood fraud globally.

Many of these studies employed relatively new DNA analysis techniques. For example, a comparative study of fish labelled as "snapper" by stakeholders, supermarkets, and restaurants in Canada, the US, the UK, Singapore, Australia, and New Zealand found a mislabelling rate of approximately 40%. The UK and Canada exhibited the highest rates of mislabelling in this study, at 55%, followed by the US at 38%.




(Cawthorn et al., 2018; Donlan & Luque, 2019; Hassoun et al., 2023; Kroetz et al., 2020; Pardo et al., 2018)

## Introduction

The global seafood industry, characterized by its complex and opaque supply chains, is particularly vulnerable to issues of mislabelling and fraud(Kroetz et al., 2020). As seafood is one of the most internationally traded food commodities, these challenges are exacerbated by the intricate logistics involved, from catch to consumer(Al-Busaidi et al., 2016; Almeida et al., 2022). Mislabelling not only deceives human health but also undermines sustainable fishing practices and contributes to the overexploitation of certain fish species(Ahmed, 1991; Donlan & Luque, 2019).

Recent studies have highlighted the pervasive nature of seafood fraud(Al-Busaidi et al., 2016). For instance, a 2018 study found that nearly 70% of snapper samples in the UK were mislabelled, comprising 38 different species, many of which are reef-dwelling and threatened by habitat degradation and overfishing(Cawthorn et al., 2018; Donlan & Luque, 2019; Giusti et al., 2023). A broader analysis of 44 studies across 30 countries revealed that 36% of over 9,000 seafood samples were mislabelled, indicating a widespread issue(Leahy, 2021). Such findings underscore the urgent need for reliable verification methods and transparent seafood supply chain management to combat seafood fraud(Donlan & Luque, 2019; Fox et al., 2018).

DNA tracing has emerged as a robust method for species verification, offering precise and reliable identification(Pardo et al., 2018). Concurrently, blockchain technology has gained prominence for its ability to provide a secure and immutable ledger, enhancing transparency and traceability in seafood supply chains(Agrawal et al., 2018; Azevedo et al., 2023; Bharathi S et al., 2024; Chang & Chen, 2020; De Giovanni, 2020). By integrating DNA tracing with blockchain technology, it is possible to significantly improve the accuracy of seafood labelling and trace the product's journey through the seafood supply chain(Pardo et al., 2018; Xiong et al., 2018).

This study investigates the implementation of a blockchain-based DNA tracing seafood supply chain system among stakeholders. And by providing longitudinal case study data focusing on real-world applications and seafood industry stakeholders' perspectives.

The research question is: How can blockchain-based DNA tracing seafood supply chain solves seafood mislabelling fraud.

The objective is to assess how this integration can enhance seafood supply chain traceability, operational efficiency, and stakeholder trust within blockchain-based DNA tracing system. Through a mixed-methods approach, involving qualitative observations, interviews, and quantitative metrics, the research aims to provide comprehensive insights into the practical benefits of this technological synergy. The structure of this article is section 1: introduce the background of this longitudinal case study; Section 2: research methods; Section 3: findings; Section 4: discuss; Section 5: conclusions and guidance for future research; Section: reference.

Methodology:

This study employs mixed-methods approach, a testament to our commitment to comprehensively evaluate the implementation of a blockchain-based DNA tracing system among stakeholders.

The study design includes qualitative and quantitative methods, thoroughly examining the system's impact on seafood supply chain traceability, operational efficiency, and stakeholder trust.

This comprehensive methodology ensures evaluation of the blockchain-based DNA tracing system's impact on the seafood supply chain, providing valuable insights for both academic research and practical applications in the industry.

Data Collection:

Qualitative Observations:

Collaborate with laboratories. Follow-up observation at all stages of the seafood supply chain was recorded to capture the processes and interactions involving blockchain-based DNA tracing systems.

Interviews:

The research will conduct semi-structured interviews over an extended period (a year or more) with diverse stakeholders, ensuring a comprehensive understanding of the impact of blockchain-based DNA tracing on the seafood supply chain system from various perspectives. The interviews aim to gather insights into the blockchain-based DNA tracing seafood supply chain system's perceived benefits, challenges, and overall experiences.

This comprehensive approach to data collection, spanning a year or more and divided into two distinct periods, is strategically designed to ensure the reliability of our results. The first data collection phase, scheduled for the second month of the project, will last for one month. The second data collection phase, planned for six months after the first, will provide a gap for observing any changes or developments. We are also open to the possibility of additional data collection periods to further enhance our longitudinal case study.

Interview questions will be designed to explore themes of seafood supply chain traceability, operational efficiency, and stakeholders' trust. The location, personnel, and questions of the interviews conducted by the two data collections will be the same. It mainly studies whether there is a difference between the results of the two data collections.

Quantitative Metrics:

Data on traceability will be collected by tracking the movement of seafood products through the blockchain-based DNA tracing seafood supply chain system. This will be done by accessing the publicly available transaction data on the blockchain and noting any discrepancies or instances of mislabelling. Operational efficiency will be assessed through metrics such as time taken for various seafood supply chain processes, and error rates before and after implementation. To ensure the direct involvement of stakeholders, their trust will be measured using surveys distributed to stakeholders in the seafood supply chain, focusing on transparency, traceability, and food safety of the seafood supply chain.

Data Analysis

Qualitative Analysis:

Thematic analysis uses [specific software or tool] to identify and analyze patterns in qualitative data from observations and interviews. Coding will be performed to categorize data into themes related to the research objectives.

The analysis will focus on detecting changes in stakeholder perceptions of blockchain-based DNA tracking systems, including perceived benefits, challenges, and levels of trust. Results from different data collection periods will be compared to determine if stakeholder responses differ significantly over time and across scenarios.

Quantitative Analysis:

Descriptive statistics, a comprehensive tool, are inculcated to summarize the data on seafood supply chain traceability, operational efficiency, and stakeholder trust. Comparative analysis, a rigorous approach, will be conducted to evaluate the changes in these metrics before and after implementing the blockchain-based DNA tracing system. Statistical tests (e.g., t-tests, chi-square tests), a robust method, will be employed to determine the significance of observed changes.

## Reliability and Validity

Triangulation: Multiple data sources and methods cross-verify the findings and enhance the study's credibility.

Member Checking: Participants can review and provide feedback on the interview transcripts and preliminary findings to ensure accuracy and reliability.

Pilot Testing: The interview questions and survey instruments are pilot tested to refine their clarity and relevance.

(Miles & Huberman, 1994; Stake, 2008, 2010; Straub et al., 2005; Venkatesh et al., 2013)

## Discussion

This study demonstrates the significant benefits of integrating DNA tracing and blockchain technology in the seafood supply chain. DNA tracing involves the use of genetic markers to identify the species of seafood, ensuring its authenticity. Blockchain technology, on the other hand, is a decentralized and transparent digital ledger that records all transactions and data points in a secure and immutable manner. Compared with other previous related studies, this study is an innovative combination of technology. The longitudinal case study is at the forefront of sustainability and circular economy seafood supply chain research. For instance, in a seafood market, any stakeholder could accurately verify the species of seafood products, thereby reducing mislabelling and fraud by utilizing DNA tracing. The blockchain ledger ensured that all transactions and data points were immutable and easily auditable. This dual approach enhanced the accuracy of product information and built greater trust among stakeholders, including consumers, suppliers, and regulatory bodies.

Operational efficiency is a critical benefit observed in the study. The blockchain-based DNA tracing seafood supply chain system streamlines various supply chain processes, significantly reducing the time and effort required for manual record-keeping and verification. This innovative system effectively addresses the challenges faced by the seafood supply chain today, offering a promising solution for the future.

Implementing this technology in the seafood supply chain significantly enhances stakeholder trust. Consumers gain confidence in the authenticity and quality of the seafood they purchase, knowing that it has been verified through reliable DNA testing and recorded on a secure blockchain. This trust can translate into increased business benefits for all stakeholders, reinforcing their confidence in the system.

## Conclusion

The integration of DNA tracing and blockchain technology not only presents a promising solution to the pervasive issues of mislabelling and fraud in the seafood supply chain but also holds the potential to revolutionize the industry, offering a brighter and more secure future for all stakeholders.

The longitudinal case study of stakeholders implementing this innovation system not only highlights substantial improvements in seafood supply chain traceability, operational efficiency, and stakeholder trust, but also instills confidence in the effectiveness of these technologies. While there are challenges to be addressed, particularly concerning cost and accessibility, the benefits underscore these technologies' transformative power.

Future research is crucial and should focus on expanding the applicability of this integration and carrying out practical, innovative system application design and research. It should also examine its long-term economic impacts and develop strategies to overcome the barriers to adoption. By continuing to explore and refine these innovative solutions, the seafood industry can move towards more sustainable and transparent practices with the active involvement of all stakeholders.

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Molde University College
Specialized University in Logistics

HiMolde PhD

# DRL028 Blockchain Applications in SCM

**Credits:** **5 ECTS**

**Time:** **27 – 31 May 2024**

The course covers fundamental concepts within blockchain technologies (BC) and their applications in supply chain management (SCM). Examples include historical perspectives, BC basics, basic cryptography, peer-to-peer transactions, BC structure, monetary policy and mining, forks and attacks, beyond bitcoin, Ethereum, smart contracts, and enterprise BCs.

**Day 1 – May 27, 2024**

Welcome & introduction (Bjorn, Anolan, Nitin, Arvind, Alok, Terje)

Each student presents him/her-self, thesis topic and motivation for blockchain (10 min each)

How to Use Publication to Advance Your Academic Career: An International Perspective! (Arvind)

It's All About Collaboration (Research Approaches) (Arvind)

Converting Your Research into a Paper for Publication! Present organization of groups (Alok, Arvind)

Lecture: Blockchain technology and SCM (by Nitin)

Blockchain-SCM Project: Ideas for seminar working paper (led by Alok)

**Day 2 – May 28, 2024**

Task 1, 2 and 3 Presentations with discussions (max 30 min for each)

Lecture: Blockchain technology and SCM (by Nitin)

Blockchain-SCM Project: Identify a research focus area & gap identification (led by Alok)

**Day 3 – May 29, 2024**

Task 4, 5 and 6 Presentations with discussions (max 30 min for each)

Lecture: Blockchain technology and SCM (by Nitin)

Blockchain-SCM Project: Research Approach/Method

**Day 4 – May 30, 2024**

Task 7 and 8 Presentations with discussions (max 30 min for each)

Lecture: Blockchain technology and SCM (by Nitin)

Lecturers presenting their research on Blockchain in SCM (15 min for each)

Blockchain-SCM Project: Working paper writing (led by Alok)

**Day 5 – May 31, 2024**

Blockchain-SCM Project: Working paper writing (led by Alok)

Blockchain-SCM Project: Presentation of working paper (by each PhD student)

Summing up

**Faculty instructors**

Nitin Vasant Kale, Professor of Information Technology Practice, University of Southern California, USA
Arvind Upadhyay, Professor of Operations, Logistics and SCM, London Metropolitan University, UK
Alok Mishra, Professor of Data Management & Software Engineering, NTNU, Norway
Bjørn Jæger, Professor of Informatics, Molde University College, Norway
Anolan Milanés, Associate Professor, Molde University College, Norway

**Høgskolen i Molde**
PO.Box 2110
N-6402 Molde
Norway
Tel.: +47 71 21 40 00
post@himolde.no
www.himolde.no