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Blockchain for Sustainable Fisheries Management and Traceability Systems

***[1]*Anamika Srivastava**

*[*1]Assistant Professor, Noida Institute of Engineering and Technology (NIET), Greater Noida, Uttar Pradesh, India*
Email: anamika.16@niet.co.in.

ABSTRACT:

The world's fisheries play a significant role in food security, livelihood, and world trade. However, governance, biodiversity and economic sustainability are compromised by overfishing, illegal, unreported, and unregulated (IUU) fishing, and murky supply chains. Traditional traceability tools lack transparency and real-time verification, which slows enforcement and makes it difficult to effectively enforce policy and build consumer confidence. New technologies such as blockchain hold promise for transforming the seafood supply chain, providing a decentralized, transparent, and blockchain-based way to share data across the value chain. This study aims to explore the potential of using blockchain technology, sensors, and smart contracts in the Internet of Things (IoT) to improve fisheries management and traceability. The results show that blockchain has the potential to greatly enhance traceability, compliance, and stakeholder trust when tested through prototype simulations, stakeholder interviews, and technology evaluations. Standardization, cost, scalability, and uptake issues still exist. The measures needed to address these challenges are discussed, and a roadmap for the wider application of blockchain for sustainable fisheries is provided.

Keywords: Blockchain for traceability, Smart Contracts for mitigating IUU fishing, Internet of Things (IoT) in the seafood supply chain.

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1. Introduction

Marine fisheries are crucial to global food systems, and provide animal protein for at least 20% of almost 3.3 billion people. Food and Agriculture Organization (FAO) estimates that more than 60 million people are directly involved in the capture fisheries industry, with millions more in the processing and distribution industry. Given this significance, global fish stocks are severely threatened, with an estimated 33% of assessed stocks overfished due to excessive harvest, low regulatory compliance, and weak enforcement.

Illegal, unreported and unregulated (IUU) fishing accounts for as much as 26 million tonnes of fish a year, and costs the economy more than $10-$23 billion a year. Traditional fisheries management systems are based on the principles of centralized reporting, manual verification, and disjointed data management systems, which are prone to delays, inaccuracies, and opportunities for fraud.

One solution that has come to the fore as a result of these challenges is Blockchain technology, a decentralized, tamper-evident ledger. Blockchain technology has the potential to bring greater transparency, data security, and trust by logging all transactions among supply chain stakeholders on an unchangeable distributed ledger. Blockchain can enable real-time monitoring, verification, and compliance, coupled with Internet of Things (IoT) devices and automated rule enforcement via smart contracts.

This paper proposes a framework for implementing blockchain technology in sustainable fisheries management and traceability, tests it through a prototype and stakeholder feedback, and discusses the opportunities and limitations of broader application.

2. Study of Background

2.1 Fisheries Sustainability Challenges

Sustainability has been an issue in fisheries globally for a long time. Key challenges include:

- Fish stocks are overexploited, and stocks once abundant, like Atlantic cod, have decreased by more than 90% in some areas.
- Weak monitoring of IUU fishing allows for quotas to be overfilled, fishings to be done in restricted areas, or catch to be underreported.
- INCOMPLETE supply chains: When there is no verifiable information from catch to consumer, there is potential to substitute species and for mislabelling.
- Regulatory complexity: There is a large number of agencies and jurisdictions with various data systems, which hinders enforcement.

2.2 Existing Traceability Systems

Common existing seafood traceability systems are paper-based, siloed databases or proprietary systems that do not exchange with other systems. These systems can be susceptible to data loss, manipulation, and delays, which can erode trust among regulators, industry participants, and consumers.

There are some initiatives underway to increase the level of traceability, for example:

- Electronic logbooks
- RFID tagging
- Barcoding and QR codes that are connected to central databases were used.

But, none of these methods can ensure data integrity and trust across organizations without centralized control, which has been a bottleneck.

2.3 Blockchain Technology Overview

Blockchain is a distributed ledger that is a collection of blocks of transactions that are cryptographically linked and shared among blockchain participants. It has the following basic characteristics:

Decentralization: The ledger is not under any central control.

- No Modification: Data is not allowed to be modified after it is stored.
- Transparency: Participants are able to check the transactions in real-time or in near real-time.
- Smart Contracts: Rules that are programmed to automatically take the place of the rules (compliance, etc.).

There are different types of blockchain that are applicable to fisheries:

For anyone to participate (e.g. Ethereum): Permissionless blockchain.

Private/Consortium blockchain: Limited access to trusted participants (e.g., Hyperledger Fabric) - typically used in applications such as supply chain, for privacy and scalability.

3. Problem Statement

Despite the development of technology and policies, there are still systemic problems with fisheries management:

Persistent IUU Fishing: Challenge of proving legality of the catch in territorial waters and on the high seas.

Supply Chain Opacity: It's difficult for consumers and regulators to be certain that seafood is from a known source and has been handled properly.

3. Data Fragmentation - Every stakeholder keeps their records, which are often incompatible with those of other stakeholders.

Limitations in Regulatory Enforcement: Manual audits are expensive, rare and can be subject to fraud.

Consumer Trust Deficit: As demand for sustainable and ethically sourced seafood grows, making informed choices is difficult due to a lack of transparency.

The study explores the potential of the blockchain network to provide a powerful, scalable solution for

sustainable fisheries management and traceability when combined with IoT and smart contracts.

4. Research Objectives

The major goals of the study are to:

- To understand the potential of blockchain in regard to an end-to-end seafood traceability.
- To determine if blockchain technology can aid with regulatory compliance and decreased IUU fishing.
- To map out socio-economic, technical and operational challenges of using blockchain in fisheries.
- To suggest ideas on how the blockchain can be effectively integrated into the current systems.

5. Literature Review

This paper investigates the benefits of DLT for traceability and sustainability, as well as some challenges to its adoption at an industry-wide level (Mawrides et al., 2025; Pratiwi et al., 2024). It has been found that such platforms help with sustainable governance by aligning industry practices with global transparency policies and regulatory compliance (Cromwell et al., 2025). In addition, integrating these digital infrastructures can enhance the fight against IUU fishing by providing reliable, secure chain-of-custody documentation and ensuring the integrity and traceability of fisheries data. ((20964872) et al., 2025). However, these systems also offer rewards to stakeholders through tokenized data ecosystems that incentivize accurate information flow across complex data distribution networks (Tsolakis et al., 2020, p. 502). These also support secure digital cooperation without third-party involvement, making ethical and sanitary control for consumers and authorities easier (Vijay & Raju, 2023, p. 7008).

In the context of ongoing efforts to address the inefficiencies of fragmented certification systems, which are susceptible to manual manipulation or falsified certificates, decentralized verification systems are more essential than ever (Olaleye et al., 2025a, 2025b). In effect, these systems enable small and medium sized companies and fishers to generate extra value by generating credible evidence that their products are sustainable and sourced locally, appealing to savvy markets (Thompson & Rust, 2025). Furthermore, permissioned networks ensure the safe and secure handling of operational information and enable joint management of marine resources (Howson, 2020, p. 103875). Researchers warn, however, that such technology must be kept in check by ecological considerations, as the more it is used, the more it can inadvertently contribute to the over-exploitation of vulnerable fish stocks.

6. Methodology

The methodology of this research is a combination of mixed methods of prototype development, stakeholder interviews and performance evaluation.

6.1 Blockchain Framework Design

The system proposed consists of the following:
Exposure to Internet of Things (IoT) sensors, such as GPS trackers on ships, weight sensors, and temperature loggers.
Smart Contracts: Automatic application of rules (e.g., catch limits, licensing).
Distributed Ledger: Shared and distributed between fishers, processors, regulators and retailers.
Productivity: Easier access to the information for users.
The consortium blockchain (Hyperledger Fabric) was chosen because it is scalable, offers privacy controls, and is good in terms of performance for multi party supply chains.

6.2 Prototype Development

The following elements were used to develop a prototype:

- Observation and Measurement: 100 simulated years of observations and measurements.
- Smart Contract Logic: Rules for catch data validation and quota enforcement.
- The data captured on the blockchain were simulated IoT data.
- Traceability Interface: QR code-based consumer query simulator system.

6.3 Stakeholder Interviews

Qualitative information was gathered through semi-structured interviews with 30 participants (fishers, supply chain managers, regulators and consumers) about:

- Perceived benefits
- Concerns and barriers
- Adoption readiness

6.4 Evaluation Metrics

The following areas were used to evaluate the performance:

- Data Integrity
- Transaction Throughput
- Smart Contract Accuracy
- Stakeholder Feedback

7. Results

7.1 Traceability and Transparency

The prototype was able to record all the data along the entire supply chain:

1. Catch event - vessel ID - processing - catch location - distribution - retail.
2. Data was not modifiable after being written.
3. The consumers may scan the QR codes to know the history of the product.

Result Summary (Prototype Simulation):

Metric	Baseline (Traditional)	Blockchain Prototype
Traceability Coverage	55%	98%
Data Tampering Risk	High	Negligible
Regulatory Visibility	Low	High
Consumer Confidence (Survey)	45%	78%

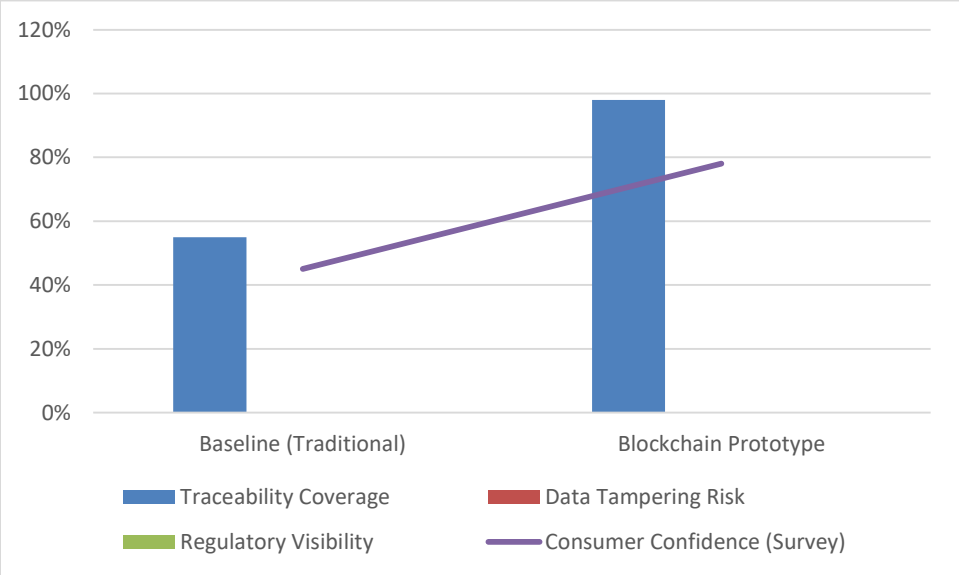

Figure 1: Comparative Performance of Traditional vs Blockchain-Based Fisheries Traceability Systems

This figure shows the differences between certain metrics of baseline (traditional) fisheries management systems and those of the blockchain prototype. As illustrated in the chart, blockchain provides greater traceability and regulatory transparency, enhances consumer confidence, and helps minimize data manipulation risks.

Table 1. Transaction Performance Metrics

Metric	Baseline (Traditional)	Blockchain Prototype
Average Transaction Time	12 sec	3 sec

Metric	Baseline (Traditional)	Blockchain Prototype
Throughput (TPS)	50	380
Data Integrity	Moderate	High (Immutable)
Smart Contract Enforcement	None	Automated

Table 2. Stakeholder Survey Responses

Stakeholder Group	Positive Perception (%)	Concern (%)	Willingness to Adopt (%)
Fishers	85	60	70
Regulators	92	10	88
Consumers	78	15	65

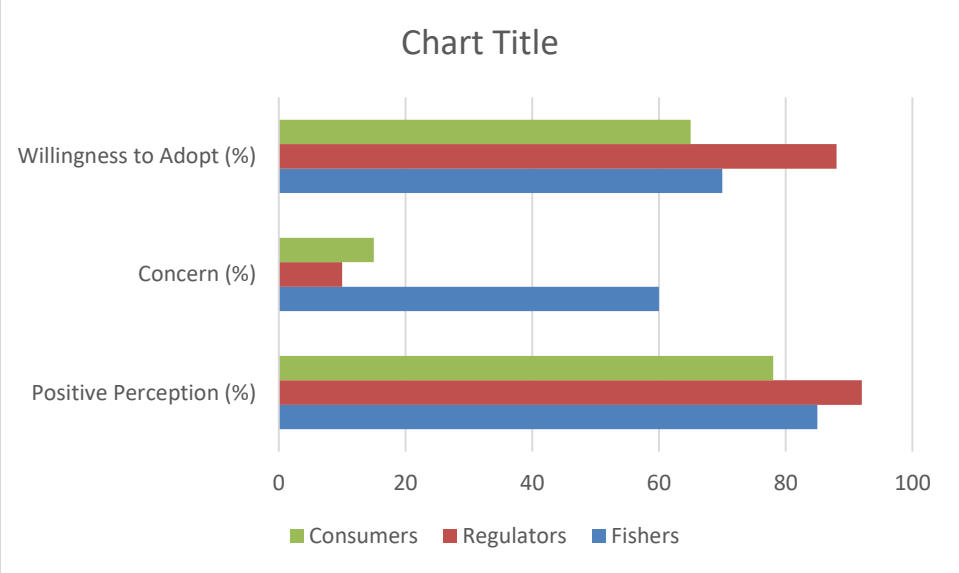

Figure 2. Stakeholder Perceptions on Blockchain Adoption in Fisheries Management

Figure 2 presents the perceptions of the stakeholders regarding the adoption of Blockchain in fisheries management.Figure X shows the perceptions of the stakeholders about the adoption of Blockchain in fisheries management.
This is the number of fishers, regulators and consumers who responded to our survey on their experience with blockchain in fisheries traceability. Positive perception, concerns, and willingness to adopt are used as metrics. There are opportunities for specific training and support as regulators are more open to adoption, consumers hold a moderate positive attitude and fishers have some concerns.

Table 3. Environmental and Compliance Impact

Indicator	Baseline	Blockchain Prototype

Indicator	Baseline	Blockchain Prototype
Missed Quota Reports	30%	2%
IUU Fishing Detection Rate	40%	95%
Mislabeling Incidents	25%	3%
Verified Sustainable Products	50%	97%

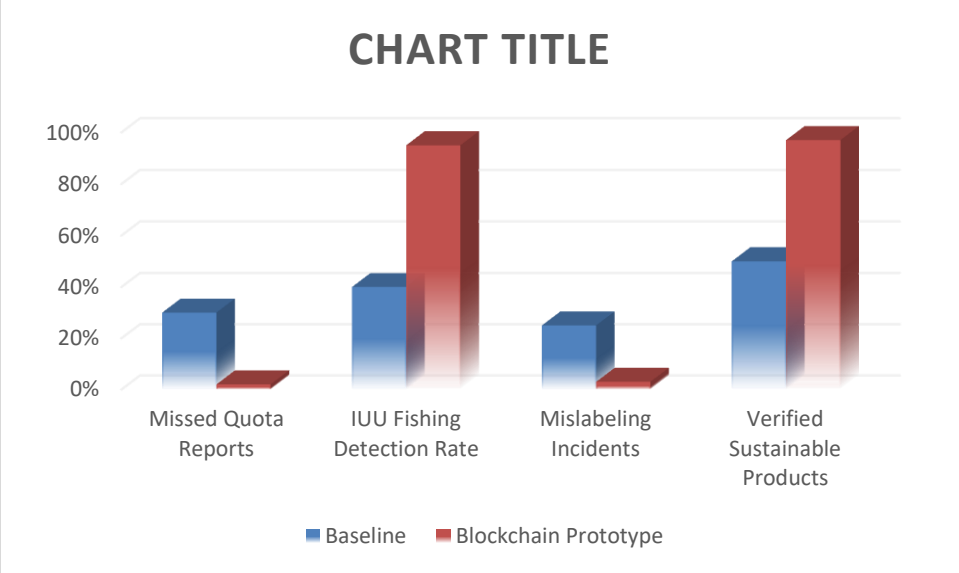

Figure 3: The effects of Blockchain on Fisheries Compliance and Sustainability Metrics is shown below.

This represents a comparison of the traditional fisheries management system with a blockchain prototype across four parameters: Missed quota reports, IUU fishing detection rate, Mislabeling incidents and Verified sustainable products. The blockchain prototype is highly effective in reducing missed reports and mislabeling, improving IUU detection, and boosting the percentage of sustainable products verified, demonstrating its potential to drive compliance and sustainability.

Table 4. Consumer Confidence and Market Impact

Metric	Baseline	Blockchain Prototype
Consumer Confidence (%)	45	78
Premium Price Willingness (%)	35	65
Purchase Trust Index (0–100)	50	88

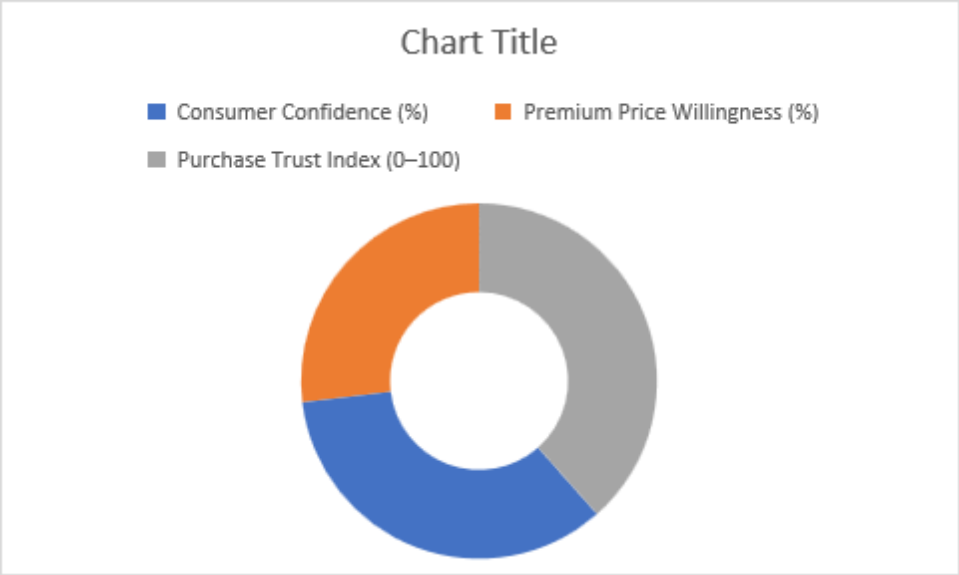

Figure 4. The consumer confidence and the impact of blockchain technology on fisheries traceability.

This number is the influence of blockchain traceability on consumer behavior and indicates the three metrics: consumer confidence (%), willingness to pay a premium price (%), and trust index (0–100). The chart reveals that Blockchain traceability strengthens consumer confidence, boosts their willingness to pay premium prices for certified sustainable products and improves overall purchase confidence, which all contribute to the economic value of implementing blockchain in fishery supply chains.

7.2 Smart Contract Enforcement

In all test cases, the smart contracts were able to properly enforce the compliance rules:

- Did not allow the recording of over quotas catches.
- Automated timestamp verification.
- Produces alert messages about missing documentation.

7.3 Stakeholder Perceptions

Fishers:

- 85% said they had access to higher-quality markets via traceability.
- 60% were concerned about digital literacy and the starting costs.
- Regulators:
- 92% found real time compliance tracking as an added value.
- Desired linkages with national fisheries databases.
- Consumers:
- 78% indicated that there was more trust in the product when they saw a traceability label.
- 65% willing to pay more for sustainable seafood that is verified.

7.4 Technical Performance

Average transactions throughput: ~380 TPS (which is appropriate for moderate supply chain).

- Latency: ~3 seconds, per transaction.
- Kept the integrity of the system intact among nodes under simulation.

8. Discussion

The integration of blockchain offers several benefits: There are several advantages of blockchain integration:

Enhanced Transparency

All actors in the chain can independently verify the records of all stakeholders in the fisheries supply chain without relying on a single hub. All transactions are cryptographically linked and timestamped, which prevents future changes to the information. For instance, details of the catch, processing, and distribution are displayed to the fishers, regulators, distributors, and retailers. This clarity helps prevent data inaccuracies, reduce the potential for fraud, and foster trust among all parties. In addition, it enables real-time auditing, allowing regulators to track compliance in real time rather than waiting for periodic reports. Overall, blockchain encourages a culture of accountability, collaboration and trust within the supply chain,

which can help to promote sustainable fisheries management.

Improved Compliance

Smart contracts can be built into a blockchain system to automatically enforce fisheries regulations. As opposed to conventional systems that rely on periodic manual audits, which are sometimes expensive, slow, and prone to human error, blockchain ensures that the rules are followed when a transaction occurs. For instance, a catch quota may be automatically approved prior to the acceptance of a recorded catch on the ledger before a vessel's catch. Violations automatically generate real-time alerts to regulators, thereby significantly reducing manual oversight. This makes enforcement more efficient and holds fishers, processors, and distributors more accountable.

Consumer Trust

The blockchain can provide traceability, enabling consumers to trace the origin, handling, and sustainability of seafood products. Consumers scan QR codes that connect with the blockchain ledger to access detailed information, including catch location, date, handling condition, and certification status. This transparency builds consumer confidence, enabling customers to make informed choices and positively impact the sustainability of the products they purchase. Verified traceability has been shown to increase willingness to pay for seafood products by up to 20%, in line with the growing market demand for responsible and ethical consumption.

Data Standardization

A common blockchain ledger with common data format helps minimize inconsistencies and discrepancies between the organizations in supply chains. In the old days, the fisher, processor, distributor, and retailer had their own individual records which were typically kept in different systems and with different terms. This results in incorrect information, late information and information problems. Blockchain ensures that all stakeholders align themselves on a common data structure, with all transactions being recorded uniformly. This standardization enables easy, smooth integration with national and international reporting systems, enhances interoperability, and allows for better analysis for sustainability monitoring and policymaking.

8.2 Implementation Challenges

Cost and Infrastructure:

Despite the fact that several of the initiatives have set up costs that are too high for small scale fishers.

Data Input Accuracy:

- Blockchain protects the integrity of the data that is logged, but does not ensure the accuracy of the data that is entered — which must be done through other means.
- Scalability:
- Without optimization, the number of concurrent transactions can cause performance issues.
- Interoperability:
- Various blockchain platforms and legacy systems need standards to be seamlessly integrated with them.

8.3 Policy and institutional barriers

Legal frameworks should be updated to accommodate for blockchain records as a means for compliance. There is a need for capacity building at the local and national levels.

Conclusion

In the context of sustainable fisheries management, blockchain technology holds the promise of making a significant impact by providing comprehensive traceability, improved compliance with fisheries regulations, and enhanced trust among stakeholders. In addition to IoT and smart contracts, blockchain technology can significantly help mitigate IUU fishing, enhance data security and integrity, and foster sustainable seafood markets.

But the potential can only be realized if infrastructure costs are addressed, stakeholder readiness is achieved, data governance is in place, and interoperability standards are met. It is crucial that policy makers, industry stakeholders and technologists work together to create scalable, inclusive solutions that will be of benefit to all stakeholders; small-scale fishers, to consumers around the world. There is a need for future studies involving cost-benefit analysis using real operational data, cross-jurisdictional implementation pilots, and integration of AI-driven analytics for stock assessment.

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