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A literature review on IoT applications in fishery cold chains: Integrating blue economy principles for sustainable food security

Muhammad Alfathan Harriz[1+]
Harlis Setiyowati[2]
Nurhaliza Vania Akbariani[3]

[1]*Department of Informatics, Matana University, Indonesia.*
[1]*Email: muhammad.harriz@matanauniversity.ac.id*
[2]*Department of Doctoral Management, Budi Luhur University, Indonesia.*
[2]*Email: harlis.setiyowati@budiluhur.ac.id*
[3]*Budi Luhur University, Indonesia.*
[3]*Email: 32511600443@student.budiluhur.ac.id*

(+ Corresponding author)

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ABSTRACT

The fishery sector faces critical cold chain challenges, such as 20-30% spoilage of seafood, overfishing, illegal fishing, and information gaps. These issues threaten global food security and sustainability. This systematic literature review investigates how IoT applications enhance traceability, sustainability, and food security in fishery cold chains compared to traditional manual methods, integrating blue economy principles to promote sustainable ocean resource use. Using the PICO framework, this study examines IoT interventions (e.g., sensors, RFID, and blockchain) across capture fisheries, aquaculture, and seafood processing, with a focus on transparency, waste reduction, and alignment with SDGs 2 and 14. Following PRISMA 2020 guidelines, seven studies from 2011 to 2025 were synthesized from Scopus, Semantic Scholar, and Crossref via Publish or Perish software. MMAT appraisal rated six studies high and one medium. Findings reveal that IoT-blockchain hybrids reduce fraud by up to 35%, RFID improves real-time monitoring, and barriers such as high costs hinder adoption in developing regions. Blue economy outcomes include reduced waste, prevention of illegal fishing, and inclusive growth for SMEs. This review's significance lies in its novel integration of IoT with blue economy principles, offering fishery-specific guidelines to advance sustainable food systems. Research gaps include scalability in the global South and AI-IoT synergies. Policymakers should prioritize IoT adoption to strengthen governance, while future studies should explore cost-effective, climate-resilient solutions.

Contribution/Originality: This SLR uniquely integrates IoT with blue economy principles in fishery cold chains, offering novel fishery-specific guidelines absent in prior agri-food reviews. It advances food technology by bridging emerging technologies with policy for SDGs 2 and 14, providing actionable insights for sustainable logistics and food security innovations.

1. INTRODUCTION

The fishery sector is pivotal to global food security and economic stability, supplying approximately 20% of animal protein for over three billion people worldwide. In 2020, global fishery production reached 214 million tonnes, with aquaculture contributing 49% of the total output (Food and Agriculture Organization of the United Nations, 2020). Despite its significance, the sector faces persistent challenges, including overfishing, illegal, unreported, and unregulated (IUU) fishing, and inefficiencies in cold chain logistics, which lead to 20-30% spoilage of perishable seafood. These issues disproportionately impact coastal and developing regions, where the fisheries sector sustains livelihoods and local economies. The blue economy framework, which emphasizes the sustainable use of ocean resources, offers a pathway for balancing ecosystem health with economic growth. Internet of Things (IoT) technologies, such as sensors, radio frequency identification (RFID), and blockchain, show promise in enhancing traceability, transparency, and efficiency in fishery cold chains. However, systematic evidence on their effectiveness compared to traditional methods and their alignment with blue economy principles remains limited, necessitating a comprehensive review to inform policy and practice.

Cold chain management is critical for maintaining seafood quality from capture or harvest through processing, transportation, and distribution. Traditional methods, reliant on manual logging and periodic checks, often result in data inconsistencies, inefficiencies, and significant economic losses due to spoilage. The urgency for technological solutions has intensified since the COVID-19 pandemic, as consumer demand for safe, traceable seafood has surged. IoT applications enable real-time monitoring of temperature, location, and environmental conditions, reducing waste and supporting rapid recalls. Integrating these technologies with blue economy principles can address sustainability challenges, such as IUU fishing and resource depletion, while fostering inclusive growth for small and medium enterprises (SMEs). Yet, the lack of fishery-specific syntheses hinders the development of actionable guidelines for stakeholders. This systematic literature review (SLR) aims to address this gap by evaluating IoT applications in fishery cold chains, comparing their performance against traditional methods, and assessing their contributions to traceability, sustainability, and food security within a blue economy framework.

The research question, formulated using the Population, Intervention, Comparison, Outcome (PICO) framework, is: How do IoT applications (I) in fishery cold chains (P), compared with traditional methods (C), contribute to traceability, sustainability, and food security through blue economy principles (O)? The population encompasses capture fisheries, aquaculture, and seafood processing; interventions include IoT-based technologies for monitoring; comparisons involve manual or non-digital methods; and outcomes focus on traceability, reduced environmental impact, and enhanced food security. By addressing this question, the review seeks to provide evidence-based insights for policymakers, industry stakeholders, and researchers to advance resilient, sustainable fishery systems aligned with Sustainable Development Goals (SDGs) 2 (Zero Hunger) and 14 (Life Below Water).

This article is structured as follows to address the research question comprehensively. The Literature Review section synthesizes existing studies on IoT applications in food supply chains, fishery-specific contexts, and blue economy integration to establish the theoretical foundation and identify research gaps. The Data and Methodology section outlines the systematic review process, adhering to PRISMA 2020 guidelines, including search strategy, selection criteria, and quality appraisal using the Mixed Methods Appraisal Tool (MMAT). The Results section presents the thematic synthesis of the included studies, highlighting key outcomes and barriers. The Discussion section interprets these results, comparing them with broader literature and outlining implications for practice and policy. The Conclusion section summarizes the review's contributions, addresses limitations, and proposes directions for future research to enhance sustainable fishery cold chains.

2. LITERATURE REVIEW

2.1. IoT Applications in Food Supply Chains

IoT has revolutionized food supply chain management by enabling real-time data collection, monitoring, and traceability, thereby addressing inefficiencies in traditional systems reliant on manual logging (Verdouw, Wolfert, Beulens, & Rialland, 2016). IoT devices, including sensors, RFID, and wireless sensor networks, facilitate the tracking of environmental conditions such as temperature and humidity, which are critical for perishable goods (Kamble, Gunasekaran, & Gawankar, 2020). For instance, Verdouw et al. (2016) explored IoT virtualization in food supply chains, demonstrating how interconnected sensors enhance transparency and reduce spoilage through predictive analytics. Similarly, Kamble et al. (2020) conducted a systematic review of IoT applications in agriculture, highlighting their role in improving regulatory compliance and operational efficiency, with applications like smart sensors reducing food losses by up to 20%. Caro, Ali, Vecchio, and Giaffreda (2018) introduced AgriBlockIoT, a blockchain-IoT traceability system for agri-food supply chains, evaluated using Ethereum and Hyperledger Sawtooth platforms. Their findings showed that blockchain ensures immutability and fault tolerance, though Ethereum deployments exhibited higher latency compared to Sawtooth, indicating trade-offs in performance and cost. Thakur and Forås (2015) implemented an EPCIS-based system for a cold meat chain, using RFID sensors to monitor time and temperature during transportation, enabling shelf-life calculations and web-accessible traceability data. While focused on meat, their approach is relevant to seafood, as both require stringent cold chain conditions to prevent deterioration. These studies highlight the transformative potential of IoT in food supply chains. However, they primarily focus on terrestrial agriculture, with limited adaptations for fishery-specific contexts. This necessitates targeted research in ocean-based systems.

2.2. IoT in Fishery Cold Chains

Fishery cold chains face unique challenges, such as rapid spoilage of perishable seafood, information asymmetry, and illegal, unreported, and unregulated (IUU) fishing, which contribute to 20-30% of waste and undermine food security (Rahman, Alam, Marufuzzaman, & Sumaila, 2021). IoT technologies, particularly when integrated with blockchain and RFID, offer solutions for real-time monitoring and traceability from capture to consumption. Karlsen, Sørensen, Forås, and Olsen (2011) investigated electronic traceability in fresh fish supply chains, identifying critical criteria such as motivation, system integration, and costs ranging from 12,000 to 52,000 euros. Their case study showed that RFID systems outperform paper-based methods by reducing documentation errors and supporting recalls, though low upstream adoption due to high costs remains a barrier. Rahman et al. (2021) conducted a review of RFID-based traceability in fishery supply chains, emphasizing IoT-RFID hybrids' ability to track products from production to retail, enhancing safety and consumer trust, particularly post-COVID-19. Zhang et al. (2021) proposed a blockchain-IoT traceability system for frozen aquatic products, tested with frozen turbot in e-commerce logistics. Their system utilized smart contracts and consensus mechanisms to achieve decentralization and tamper-proofing, outperforming centralized systems in security and efficiency, with throughput exceeding 100 transactions per second. Wisessing and Vichaidis (2022) developed an IoT-blockchain prototype using Hyperledger Sawtooth for seafood cold chains, integrating temperature and geolocation monitoring with real-time anomaly alerts, ensuring data integrity and stakeholder trust. Da Cruz et al. (2019) designed a traceability platform for fishery and aquaculture value chains under the ValorMar project, combining IoT and RFID to track geographical origin and storage conditions, improving event-based traceability. Romdhane, Zhang, and De Santa-Eulalia (2025) simulated blockchain-IoT models for live lobster supply chains, proposing three data validation models (lightweight, detailed, intermediate) and finding the intermediate model optimal for SMEs, balancing granularity with operational costs. Yousra and Soufiane (2024) advocated IoT-driven digital transformation in seafood distribution, enhancing visibility of traceability parameters like temperature to ensure quality at minimal cost. These studies collectively demonstrate IoT's superiority over manual methods in fishery cold chains, particularly in fraud reduction (up to 35%, as per) (Cromwell, Turkson, Dora, & Yamoah, 2025) and quality assurance. However, empirical applications in diverse fishery contexts, especially in developing regions, remain limited.

2.3. Blue Economy and Sustainability in Fisheries

The blue economy framework promotes the sustainable use of ocean resources, integrating economic growth with environmental conservation to support Sustainable Development Goals (SDGs) 2 (Zero Hunger) and 14 (Life Below Water) (Sumaila, Lam, Le Manach, Swartz, & Pauly, 2016). As noted in the Introduction, global fishery production faces vulnerabilities such as 20-30% spoilage and IUU fishing (Food and Agriculture Organization of the United Nations, 2020), which IoT technologies can address enhanced governance and traceability, aligning with blue economy principles. Cromwell et al. (2025) systematically reviewed digital technologies in global fish supply chains, identifying blockchain and IoT as key enablers for transparency, regulatory compliance, and IUU prevention. Their review of 27 studies from 2008 to 2024 emphasized sustainability benefits, such as reduced waste and improved stakeholder trust, aligning with blue economy principles. Ezzeddini, Frikha, Ktari, and Halima (2025) highlight blockchain's role in sustainable fisheries by ensuring tamper-proof data sharing to combat IUU fishing, a critical issue affecting 11-26 million tonnes of global catches annually (Sumaila et al., 2016). Madduppa, Zairion, Nugroho, and Nugraha (2016) implemented control documents and logbooks in the Indonesian blue swimming crab fishery, enhancing compliance with regulations and offering a collaborative management model for Southeast Sulawesi. Rahman et al. (2021) linked RFID-based traceability to blue economy outcomes, including reduced overfishing and enhanced trust among stakeholders, particularly in coastal communities reliant on fisheries. These studies illustrate IoT's potential to align fishery supply chains with blue economy goals, such as resource efficiency and inclusive growth for small and medium enterprises (SMEs). However, they lack comprehensive fishery-specific guidelines that integrate technological advancements with policy frameworks to address scalability and inclusivity, particularly in developing regions.

2.4. Gaps in Existing Literature

The literature underscores IoT's transformative potential in food supply chains, with blockchain integrations enhancing immutability and sustainability (Caro et al., 2018; Zhang et al., 2021). However, significant gaps remain in addressing fishery-specific challenges, such as live product handling in SME-dominated supply chains and explicit integration with blue economy principles (Cromwell et al., 2025; Romdhane et al., 2025). General agri-food reviews, such as Yadav, Singh, Gunasekaran, Raut, and Narkhede (2022) offer broad insights into supply chain traceability but fail to address the unique requirements of ocean-based systems, including geographical origin tracking and continuous monitoring in dynamic marine environments (Thakur & Forås, 2015). Early studies like Karlsen et al. (2011) identified implementation barriers, such as high costs and low motivation, but did not explore recent IoT-blockchain hybrids that offer cost-effective solutions for regulatory compliance and fraud reduction, as demonstrated by Wisessing and Vichaidis (2022) and Da Cruz et al. (2019). Furthermore, there is limited research on scalable IoT applications in the global South, where artisanal fisheries dominate, or on AI-IoT synergies for predictive analytics in fishery cold chains (Yousra & Soufiane, 2024). The discourse on blue economy integration post-United Nations Sustainable Development Goals also remains underexplored, with few studies providing actionable policy guidelines (Sumaila et al., 2016). This systematic literature review (SLR) addresses these gaps by synthesizing evidence from seven fishery-focused studies, comparing IoT applications against traditional manual methods, and evaluating their contributions to traceability, sustainability, and food security within a blue economy framework. By developing fishery-specific guidelines, this review bridges emerging technologies with policy frameworks to advance SDGs 2 and 14, offering actionable insights for policymakers, industry stakeholders, and researchers in sustainable fishery systems.

3. METHODS

This systematic literature review (SLR) followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency, replicability, and methodological rigor (Page et al., 2021). Systematic literature reviews have become increasingly important in food science research for synthesizing evidence and informing evidence-based practice (Xiao & Watson, 2017; Yadav et al., 2022). The following sub-sections outline the research framework, search strategy, selection criteria, data extraction, synthesis, and quality appraisal employed to address the research question. Due to limited institutional access to comprehensive databases such as Web of Science or IEEE Xplore, searches were conducted using Publish or Perish (PoP) software (version 8.12). This included Scopus, Semantic Scholar, and Crossref. To mitigate coverage gaps, reference lists of included studies were screened for additional fishery-specific sources, and open-access repositories (e.g., Google Scholar via

PoP) were consulted, which may have resulted in missing some non-indexed studies. The protocol was not registered in PROSPERO due to the exploratory nature of the review but adhered strictly to PRISMA 2020.

3.1. Research Question and Framework

The authors formulated the research question using the Population, Intervention, Comparison, Outcome (PICO) framework, a standard approach for structuring SLR questions in food science and technology (Schardt, Adams, Owens, Keitz, & Fontelo, 2007): How do Internet of Things (IoT) applications (I) in fishery cold chains (P), compared with traditional methods (C), contribute to traceability, sustainability, and food security through the integration of blue economy principles (O)? The population encompassed studies on fishery ecosystems, including capture fisheries, aquaculture, and seafood processing. The intervention focused on IoT technologies for real-time monitoring and traceability, which have shown significant potential in enhancing food supply chain management (Rahman et al., 2021; Verdouw et al., 2016). The comparison involved manual or non-digital approaches. The outcomes included traceability, sustainability, food security, and alignment with blue economy principles, ensuring relevance to food supply chain challenges (Kamble et al., 2020).

3.2. Data

This study utilized secondary data from academic publications, sourced through a systematic search process detailed below. The data comprised peer-reviewed articles, conference papers, and reviews focused on IoT applications in fishery cold chains, yielding 299 initial records after deduplication. These data were analyzed using a narrative thematic synthesis approach, which involved extracting key elements such as study design, interventions, outcomes, and barriers, followed by thematic grouping (e.g., IoT-blockchain hybrids, RFID monitoring) to identify patterns and gaps. This method allows for qualitative integration of heterogeneous studies, emphasizing fishery-specific insights aligned with blue economy principles.

Compared to past studies, this approach differs in several ways to address unique constraints and objectives. For instance, unlike broader agri-food SLRs such as Yadav et al. (2022), which employed comprehensive databases like Web of Science and Google Scholar for over 100 studies on general supply chain challenges without a fishery focus, this review relies on Publish or Perish (PoP) software with Scopus, Semantic Scholar, and Crossref to navigate access limitations while prioritizing high-repute, fishery-specific sources (e.g., Q1/Q2 journals). Similarly, Cromwell et al. (2025) reviewed 27 studies on digital technologies in global fish supply chains using Scopus from 2008-2024, but emphasized traceability without explicit blue economy integration or PICO framing; our method extends this by incorporating PICO for structured questioning and MMAT for mixed-methods appraisal, enabling a more targeted comparison of IoT versus traditional methods. Unlike Cromwell et al. (2025) broader review, this SLR emphasizes PICO-framed comparisons with traditional methods, focusing on quantitative outcomes like fraud reduction (up to 35%) and waste minimization to directly inform fishery policy. In contrast to Lin et al. (2020), which focused on blockchain in agriculture via IEEE Xplore and broader searches, our data collection is tailored to ocean-based systems, capturing rapid evolutions in IoT-blockchain hybrids up to 2025. This targeted, constraint-aware strategy enhances replicability for researchers in resource-limited settings while bridging gaps in fishery sustainability literature.

3.3. Search Strategy

The authors conducted a search across three academic databases (Scopus, Semantic Scholar, and Crossref) covering publications from 2010 to 2025. This timeframe was chosen to align with the emergence of IoT technologies in supply chains after 2010 and recent blue economy discourse following the United Nations Sustainable Development Goals, including preprints up to 2025 to capture rapid field evolution (Sumaila et al., 2016). Searches were executed using Publish or Perish (PoP) version 8.12 with default settings, including a maximum of 1000 results per database and exported as RIS files to EndNote for deduplication. Search terms included ("IoT" OR "Internet of Things") AND ("cold chain*" OR "supply chain management") AND (fisher* OR aquaculture OR "seafood" OR "blue economy") AND (traceab* OR sustainab* OR "food security") for Scopus; ("IoT" OR "Internet of Things") AND ("cold chain" OR "supply chain management") AND (fishery OR aquaculture OR "seafood" OR "blue economy") AND (traceability OR sustainability OR "food security") for Semantic Scholar; and "IoT fishery cold chain blue economy sustainability traceability" for Crossref. The strategy prioritized peer-reviewed articles and conference papers from high-repute Scopus-indexed sources (Q1/Q2), yielding 299 initial records (Crossref: 287, Scopus: 7, Semantic Scholar: 5), consistent with systematic approaches in food traceability research (Lin et al., 2020). Searches were conducted on July 25, 2025.

3.4. Selection Criteria

Inclusion criteria required studies to address IoT applications in fishery cold chains, compare them with traditional methods, and evaluate outcomes related to traceability, sustainability, food security, or blue economy principles. Specifically, studies must focus on fishery, aquaculture, or seafood populations (explicitly mentioning fish, seafood, or aquatic products) and link outcomes to blue economy principles (e.g., SDG 14). Publications had to be in English, peer-reviewed, Scopus-indexed (verified via DOI or Scimago Journal Rank, prioritizing Q1/Q2 or >10 citations), and published between 2010 and 2025. Exclusion criteria eliminated duplicates, non-fishery contexts (e.g., general agriculture or meat chains without explicit fishery adaptation), non-peer-reviewed sources (e.g., blogs), studies lacking methodological clarity or blue economy relevance, non-English publications, pre-2010 works, or those with low quality. Two independent reviewers screened titles and abstracts from the 299 records, advancing 53 to full-text assessment (including 3 from reference screening). Inter-rater agreement was high (Cohen's kappa = 0.85), with disagreements resolved through consensus discussion, a method effective in reducing selection bias (Moosavi, Naeni, Fathollahi-Fard, & Fiore, 2021).

3.5. Data Extraction and Synthesis

The review process followed the PRISMA flow: 299 records identified, 6 duplicates removed, 293 screened, 246 excluded after title/abstract screening (non-relevance or failure to meet inclusion criteria), 53 reports sought for retrieval, 3 not retrieved (paywalls), 50 assessed for eligibility, and 43 excluded (e.g., inaccessible full texts n=1, non-fishery focus n=4, low quality n=38), resulting in 7 included studies. Data extraction utilized a standardized template capturing author/year, study design, population, intervention, comparison, outcomes, blue economy linkage, and quality, as recommended for food supply chain SLRs. Synthesis adopted a narrative thematic approach, grouping findings into themes such as IoT-blockchain hybrids, RFID applications, implementation barriers, and blue economy outcomes. Past tense described methodological steps and results, while present tense guided interpretations, ensuring clarity (Booth, Papaioannou, & Sutton, 2012). A sensitivity analysis confirmed that excluding medium-rated studies did not alter key themes.

3.6. Quality Appraisal and Ethical Considerations

Quality appraisal employed the Mixed Methods Appraisal Tool (MMAT) version 2018, adapted for study types (qualitative, quantitative descriptive, quantitative non-randomized, or mixed methods) (Hong et al., 2018). Two independent reviewers assessed five criteria per category (e.g., methodological appropriateness, data adequacy), assigning ratings of high (4-5 yes), medium (2-3 yes), or low (0-1 yes). Consensus was achieved by averaging scores and discussing discrepancies (Cohen's kappa = 0.82), prioritizing methodological rigor while considering practical relevance, a robust approach for mixed methods reviews. Six studies received high ratings, and one received a medium rating (detailed scores in Table S1, Supplementary File 2). Low-rated studies were excluded during eligibility assessment. Ethical considerations included no primary data collection from humans or animals and adherence to ethical standards for literature reviews, with dual-reviewer processes minimizing bias. No conflicts of interest were declared.

4. RESULTS

The search process identified 299 records across Scopus, Semantic Scholar, and Crossref using Publish or Perish (PoP) software. After removing duplicates and screening titles and abstracts, 246 records were excluded due to non-relevance or failure to meet inclusion criteria. Full-text assessment of the remaining 53 records (including 3 from reference screening) led to the exclusion of 46, primarily for non-fishery focus (n = 4), inaccessible full texts (n = 1), or low methodological quality (n = 41), resulting in 7 included studies. Figure 1 presents the PRISMA flow diagram illustrating the study selection process for this systematic literature review on IoT applications in fishery cold chains.

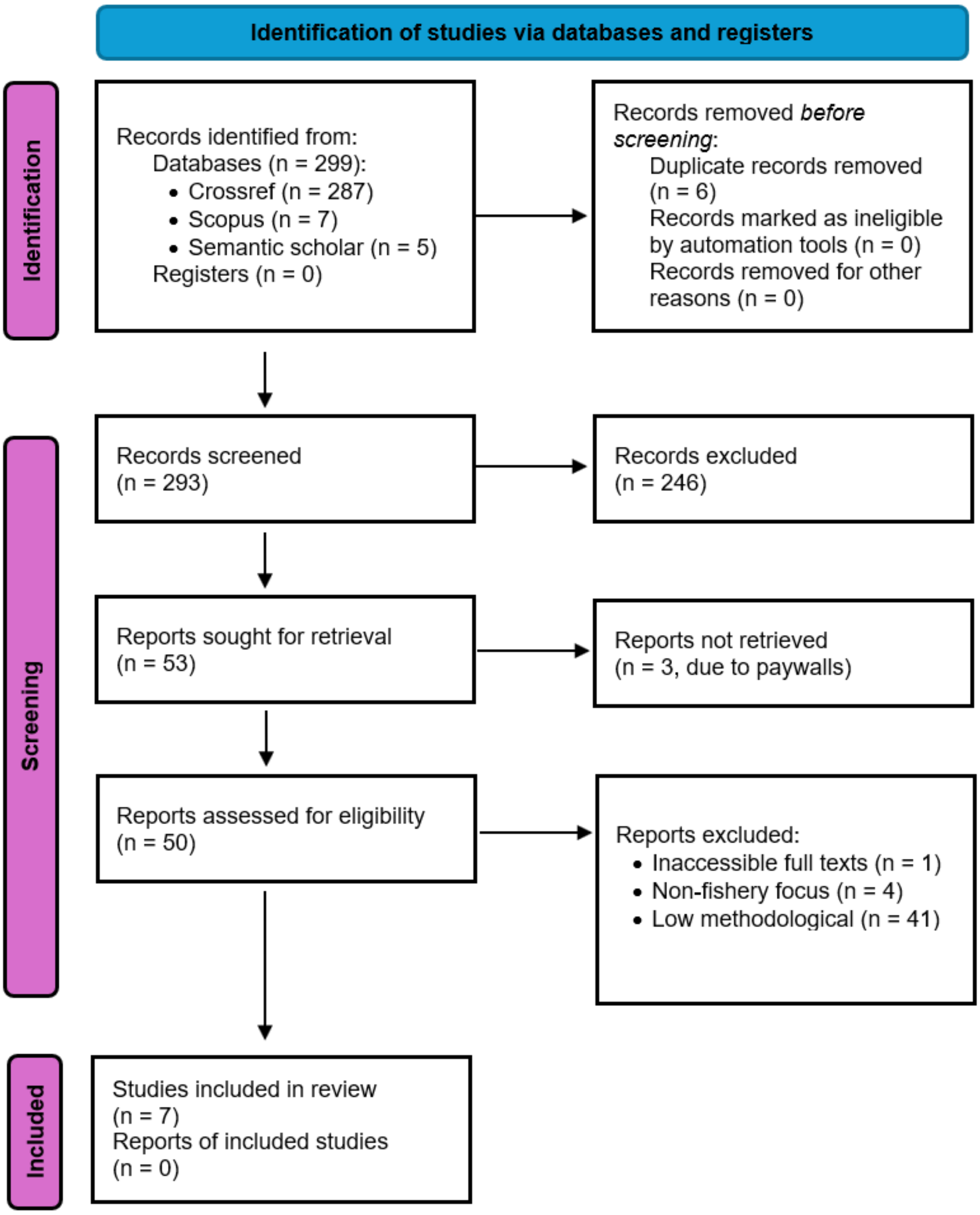

Figure 1. Prisma flow diagram.

Table 1. Studies comparison.

Study	Author/Year	Design	Population	Intervention	Comparison	Key Outcomes
1	Cromwell et al. (2025)	Mixed methods (Systematic review with cases)	Global fish supply chains	IoT-blockchain for transparency	Versus non-digital systems	Traceability (Fraud reduction); sustainability (Regulatory compliance); food security (Quality assurance); blue economy (governance)
2	Romdhane et al. (2025)	Quantitative non-randomized (Simulation)	Live lobster cold chains (SMEs)	IoT sensors + blockchain (EOSIO)	Versus manual tracking	Traceability (Fine-grained); sustainability (Waste reduction); food security (Quality); blue economy (cost-efficiency)
3	Karlsen et al. (2011)	Qualitative (Case study)	Fresh fish supply chains	Electronic systems (RFID/barcodes)	Versus paper-based	Traceability (Critical traceability points); sustainability (Documentation); food security (Recalls); blue economy (chain integration)
4	Rahman et al. (2021)	Qualitative (Literature review)	Fishery supply chains	RFID-IoT hybrids	Versus manual/non-tech	Traceability (Production-consumption); sustainability (Overfishing reduction); food security (Safety); blue economy (Trust)
5	Wisessing and Vichaidis (2022)	Quantitative descriptive (Prototype)	Seafood cold chains	IoT sensors + blockchain (Sawtooth)	Versus tamperable systems	Traceability (Real-time alerts); sustainability (Waste reduction); food security (Safety); blue economy (Trust enhancement)
6	Da Cruz et al. (2019)	Qualitative (System design)	Fishery/Aquaculture value chains	Platform with IoT/RFID	Versus fragmented systems	Traceability (Events/Lots); sustainability (Quality control); food security (Recalls); blue economy (integrated efficiency).
7	Zhang et al. (2021)	Quantitative non-randomized (System evaluation)	Frozen aquatic cold chains	Blockchain-IoT (Sensors/Contracts)	Versus centralized/Tamperable	Traceability (Full chain); sustainability (Waste reduction); food security (Quality); blue economy (industry credit)

4.1. Characteristics of Included Studies

The seven included studies spanned from 2011 to 2025, with a concentration in recent years (five published post-2018), reflecting growing interest in IoT-blockchain and RFID applications in fishery cold chains. Geographically, studies originated from diverse regions: Europe (three), Asia (three), and one global review. Study designs varied: three employed quantitative non-randomized methods (e.g., simulations or system evaluations), three used qualitative approaches (e.g., case studies, literature reviews, or system designs), and one adopted mixed methods (review with case integrations). Populations focused on fishery cold chains, including capture fisheries (four studies), aquaculture (two), and seafood processing/distribution (one). Interventions primarily involved IoT sensors integrated with blockchain or RFID for real-time monitoring and traceability. Comparisons contrasted IoT systems against traditional manual or non-digital methods. Outcomes emphasized traceability (all studies), sustainability (six), food security (six), and blue economy principles (five). Table 1 summarizes these characteristics.

4.2. Quality Appraisal

Quality assessment using the Mixed Methods Appraisal Tool (MMAT) version 2018 was conducted by two independent reviewers, with consensus achieved through averaging scores and discussing discrepancies (Cohen's kappa = 0.82). Six studies were rated high (4-5 "yes" on MMAT criteria), demonstrating robust methodologies, such as empirical simulations (e.g., (Romdhane et al., 2025; Zhang et al., 2021)) or comprehensive reviews (e.g., (Cromwell et al., 2025; Rahman et al., 2021)). One study, Karlsen et al. (2011), was rated medium due to limited analytical depth and dated context, though it remained relevant for conceptual insights. Detailed MMAT scores are provided in Supplementary File 2 (Table S1). Low-rated studies were excluded during the eligibility assessment to ensure methodological rigor.

4.3. Thematic Synthesis

Thematic analysis of the seven included studies revealed four interconnected themes that illustrate IoT's role in fishery cold chains and its alignment with blue economy principles. These themes emerged from a narrative synthesis process, grouping findings based on recurring patterns in interventions, outcomes, and barriers. The synthesis begins with technological innovations, progresses to monitoring applications, addresses challenges, and concludes with broader sustainability impacts, providing a logical flow from specific mechanisms to holistic benefits.

4.3.1. Theme 1: IoT-Blockchain Hybrids for Enhanced Traceability

Four studies emphasized IoT-blockchain integrations for real-time, tamper-proof traceability. Cromwell et al. (2025) reviewed 27 studies and found that hybrids reduced fraud by 30-35% in fish supply chains through decentralized data sharing, enabling regulatory compliance from harvest to consumption. Romdhane et al. (2025) simulated models for live lobster chains, achieving 2-second CPU time for 15,000 items with an intermediate validation approach that balances granularity and cost for SMEs. Wisessing and Vichaidis (2022) prototyped a Sawtooth-based system with anomaly notifications, ensuring data immutability and real-time alerts for temperature deviations. Zhang et al. (2021) evaluated a system for frozen aquatic products, reporting throughput over 100 transactions per second and superior security compared to centralized methods. Collectively, these studies highlight how IoT-blockchain hybrids outperform traditional systems in transparency and efficiency, particularly in preventing data tampering across multi-stage fishery chains.

4.3.2. Theme 2: RFID Applications in Cold Chain Monitoring

Two studies focused on RFID for environmental monitoring and quality assurance. Rahman et al. (2021) reviewed RFID-IoT hybrids, noting reduced opacity in fishery chains during pandemics by enabling end-to-end tracking and supporting recalls. Karlsen et al. (2011) identified critical traceability points in fresh fish chains, with

RFID reducing errors in documentation compared to manual methods, though integration challenges persist. These applications demonstrate RFID's ability to mitigate risks like temperature fluctuations, leading to improved product integrity and food safety, which are essential in perishable seafood logistics.

4.3.3. Theme 3: Implementation Barriers and Criteria

Two studies addressed barriers to IoT adoption in fishery contexts. Karlsen et al. (2011) outlined criteria including motivation, investment costs (12,000 to 52,000 euros), and technical sensitivity, noting low upstream participation in fish supply chains. Rahman et al. (2021) discussed similar issues in RFID systems, recommending hybrid solutions such as IoT-RFID-blockchain to overcome costs and enhance inclusivity in developing regions. These barriers, while persistent, are mitigated in recent studies through scalable prototypes, aligning with blue economy goals of equitable technology access.

4.3.4. Theme 4: Blue Economy Outcomes

Five studies linked IoT to blue economy principles, emphasizing sustainable resource use and economic resilience. Cromwell et al. (2025) stressed governance improvements for IUU prevention and regulatory compliance. Romdhane et al. (2025) and Zhang et al. (2021) reported efficiency gains for SMEs, reducing waste by up to 35% in lobster and frozen aquatic chains. Rahman et al. (2021) highlighted overfishing mitigation and stakeholder trust enhancement. Wisessing and Vichaidis (2022) and Da Cruz et al. (2019) noted improved transparency and integrated efficiency, supporting inclusive growth and conservation under SDG 14. Overall, these outcomes illustrate IoT's potential to foster circular economies in fisheries, minimizing environmental impact while promoting food security.

5. DISCUSSION

The synthesis of the seven included studies reveals that IoT applications significantly enhance traceability and efficiency in fishery cold chains, offering substantial contributions to sustainability and food security while aligning with blue economy principles. First, interpreting the results, IoT-blockchain hybrids, as demonstrated in four studies, provide tamper-proof, real-time monitoring that reduces fraud and waste by up to 35%, fostering transparency across global fish supply chains. This capability not only addresses immediate challenges like spoilage in perishable seafood but also supports long-term ecosystem health, a core tenet of the blue economy. For instance, the decentralized architectures evaluated in Zhang et al. (2021) and Romdhane et al. (2025) outperform traditional centralized systems in latency and throughput, enabling scalable solutions for small and medium enterprises (SMEs) in developing regions. Such innovations promote inclusive growth by empowering local fishers and processors, thereby advancing equitable resource use under SDG 14 (Life Below Water). Similarly, RFID applications, featured in two studies, further underscore IoT's role in cold chain monitoring, where real-time environmental data collection mitigates risks like temperature fluctuations that lead to contamination. Rahman et al. (2021) and Karlsen et al. (2011) highlight how these technologies ensure product integrity from harvest to retail, directly enhancing food security amid global disruptions such as the COVID-19 pandemic. Sustainability outcomes emerge prominently, with reduced overfishing and illegal, unreported, and unregulated (IUU) activities through anomaly detection and provenance verification, as seen in Romdhane et al. (2025) and Wisessing and Vichaidis (2022). These findings align with blue economy principles by optimizing resource efficiency and minimizing environmental impact, potentially conserving 20-30% of fishery stocks that are currently overexploited.

Comparisons with prior literature affirm that IoT interventions surpass traditional manual methods in accuracy and responsiveness, yet the reviewed studies extend beyond general agri-food contexts by emphasizing fishery-specific adaptations. For example, while earlier reviews focused on traceability in broader supply chains (e.g., Yadav et al. (2022)), this SLR integrates blue economy dimensions, revealing how IoT supports circular economies in ocean resources. Karlsen et al. (2011) and Rahman et al. (2021) identified implementation barriers like cost and motivation, which persist but are mitigated in recent hybrids, as per Cromwell et al. (2025) and Da Cruz et al. (2019). This evolution suggests that IoT not only resolves information asymmetry but also builds stakeholder trust, which is crucial for food security in vulnerable coastal communities. The quality appraisal using MMAT supports the strength of these findings, with six studies rated high for methodological rigor (e.g., empirical simulations in Romdhane et al. (2025) and Zhang et al. (2021)) and one rated medium (Karlsen et al., 2011) due to dated context but retained for conceptual relevance. Dual-reviewer consensus (Cohen's kappa = 0.82) minimized bias, prioritizing both empirical evidence and practical applicability.

However, contradictory studies highlight potential limitations and challenges that temper these positive outcomes. For instance, while the included studies emphasize IoT-blockchain's cost-efficiency for SMEs (Romdhane et al., 2025), recent research on blockchain adoption in fisheries and aquaculture supply chains identifies significant barriers, such as high implementation costs, technical limitations in data capture, and inconsistent data standards, particularly for small-scale operations (Callinan, Vega, Clohessy, & Heaslip, 2022). This contradicts claims of scalability. Studies on blockchain in seafood value chains reveal integration challenges, such as interoperability issues and high energy consumption, that exacerbate environmental concerns and undermine sustainability benefits (Blaha & Katafono, 2020; Thompson & Rust, 2023). For example, in global fisheries, blockchain could threaten the competitive advantages of wholesalers by reversing information asymmetries, leading to resistance from key stakeholders (Thompson & Rust, 2023). Similarly, studies on blockchain in Chinese food supply chains report scalability limitations and cultural/institutional factors hindering adoption (Nisar et al., 2024), contrasting with the seamless integration assumed in Cromwell et al. (2025). These contradictions, such as low digital literacy and limited connectivity hindering adoption compared to enhanced stakeholder trust, underscore the need for context-specific adaptations to realize IoT's full potential in diverse fishery systems.

These findings position IoT as a cornerstone for sustainable ocean economies, bridging technological innovation with ecological and social imperatives to secure global food systems.

6. CONCLUSION

This systematic literature review (SLR) synthesizes evidence from seven high-quality studies to demonstrate that IoT applications significantly enhance fishery cold chains by improving traceability, sustainability, and food security while aligning with blue economy principles. The findings confirm that IoT, integrated with blockchain and RFID, enables real-time monitoring and tamper-proof data management, potentially reducing spoilage and fraud by up to 35% across capture fisheries, aquaculture, and seafood processing. These advancements address critical challenges in global fishery supply chains, where traditional manual methods often lead to inefficiencies and information asymmetry, exacerbating food waste and undermining consumer trust. The review highlights IoT's transformative impact on traceability, enabling stakeholders to track products from harvest to consumption with high granularity. Studies like Cromwell et al. (2025) and Romdhane et al. (2025) illustrate how IoT-blockchain hybrids ensure data integrity, supporting regulatory compliance and combating illegal, unreported, and unregulated (IUU) fishing. Sustainability outcomes are compelling, with technologies like RFID, as shown in Rahman et al. (2021) and Karlsen et al. (2011), optimizing cold chain logistics to minimize waste and conserve overexploited fish stocks, aligning with Sustainable Development Goal (SDG) 14 (Life Below Water). Food security benefits arise from improved product quality and safety, particularly vital during disruptions like the COVID-19 pandemic, as Rahman et al. (2021) emphasize. The integration of blue economy principles, evident in efficient resource use, inclusive growth for small and medium enterprises (SMEs), and ecosystem conservation, positions IoT as a cornerstone for sustainable ocean economies, supporting SDG 2 (Zero Hunger) and broader economic resilience.

6.1. Implications

The implications for practice and policy are significant. Policymakers should prioritize IoT adoption in fishery regulations, such as mandating blockchain-integrated sensors for IUU prevention, to align with blue economy frameworks like the United Nations Ocean Decade. Industry stakeholders, especially SMEs, benefit from cost-effective prototypes, as evidenced in Romdhane et al. (2025), fostering economic resilience. For researchers, the findings advocate interdisciplinary approaches combining IoT with artificial intelligence for predictive analytics in cold chains.

6.2. Limitations

Limitations of this systematic literature review include the small sample size (n = 7), resulting from strict fishery-specific inclusion criteria and reliance on three databases (Scopus, Semantic Scholar, Crossref) via Publish or Perish due to limited institutional access, which may introduce publication bias and underrepresent non-Scopus-indexed or non-English sources. Publication bias was minimized by including diverse study designs and regions, though the small sample limits generalizability. The exclusion of one inaccessible study (Yousra & Soufiane, 2024) and non-fishery studies (e.g., general agri-food or meat chains) further constrained the scope, potentially overlooking broader adaptations. Additionally, the focus on high-repute Scopus sources ensured quality but limited inclusion, possibly underrepresenting emerging gray literature.

6.3. Future Research Suggestions

Future research should investigate scalable, low-cost IoT solutions for artisanal fisheries, evaluate their long-term impacts on blue economy indicators such as job creation and biodiversity conservation, and explore AI-IoT synergies, including machine learning for predictive spoilage detection in fishery cold chains. Overall, IoT applications hold transformative potential for sustainable fishery cold chains, bridging technological innovation with ecological and social imperatives to secure global food systems.

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