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Innovations in Technology and Data Systems to Strengthen Fisheries Management

Rifqi Fahrudin[1*], Royani[2], Asher Nuche[3], Elda Diah Safitri[4]
[1]Faculty of Information Systems, University of Catur Insan Cendekia, Indonesia
[2]Faculty of Health Sciences, University of Ichsan Satya, Tangerang, Indonesia
[3]Ijiis Incoporation, Canada
[4]State University of Jakarta, Indonesia
[1]rifqi.fahrudin@cic.ac.id, [2]royani@gmail.com, [2]ashernuche@ijiis.asia, [3]eldadiasafitri_1205619039@mhs.unj.ac.id
***Corresponding Author**

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ABSTRACT

Fisheries management faces critical pressures from overexploitation, climate change, and illegal, unreported, and unregulated (IUU) fishing. Conventional monitoring systems often rely on fragmented and delayed data, which significantly limit effective decision-making. **This study examine** how emerging digital technologies and advanced data systems enhance governance, transparency, and sustainability in the sector. A mixed-method approach was employed, combining a systematic literature review and a comparative case assessment of technology adoption. **The results demonstrate** that integrating Electronic Monitoring (EM) and Vessel Monitoring Systems (VMS) can expand monitoring coverage by up to 100% in industrial fleets compared to human observers, while reducing long-term operational costs. Digital reporting platforms (e-logbooks) were found to significantly reduce data transcription errors and shorten the feedback loop between data collection and regulatory action. Furthermore, Artificial Intelligence (AI)-assisted species identification improves the speed of processing catch data from EM footage. However, successful implementation depends on institutional readiness, regulatory alignment, and ensuring equitable digital access for small-scale fishers. **This research concludes** that while technology holds transformative potential, long-term effectiveness requires integrated governance frameworks and collaborative implementation strategies.

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1. INTRODUCTION

Fisheries play a critical role in global food security, livelihoods, and economic development, particularly in coastal and developing nations [1, 2]. The sector contributes significantly to employment, trade, and nutritional supply, supporting millions of people worldwide. However, fisheries resources are under increasing pressure due to overfishing, habitat degradation, climate change, and illegal, unreported, and unregulated (IUU) fishing [3, 4]. These challenges threaten the sustainability of marine ecosystems and undermine the long-term viability of fisheries-dependent communities [5]. Traditional fisheries management systems often rely on manual data collection, delayed reporting, and fragmented institutional coordination [6, 7]. Such limitations reduce the accuracy of stock assessments, weaken monitoring and enforcement efforts, and constrain timely policy

responses. The integration of Artificial Intelligence (AI) and machine learning into fisheries monitoring systems has revolutionized how data is analyzed, allowing for more precise catch estimations and illegal activity detection. [8]. As fisheries systems become more complex and dynamic, conventional management approaches are increasingly inadequate to address emerging risks [9].

Recent advancements in digital technology, remote sensing, artificial intelligence, big data analytics, and integrated information systems present transformative opportunities for fisheries governance [10, 11]. Tools such as satellite-based Vessel Monitoring Systems (VMS), Electronic Monitoring (EM), digital catch documentation, and interoperable data platforms enable real-time tracking, improved compliance monitoring, enhanced traceability, and evidence-based decision-making [12]. These innovations support adaptive management strategies and strengthen accountability across the fisheries value chain [13, 14].

Despite the growing adoption of technological solutions, significant challenges remain regarding institutional readiness, regulatory adaptation, financial investment, and equitable access particularly for small-scale fishers [15]. Technology alone does not guarantee improved governance outcomes without supportive policy frameworks and stakeholder engagement [13]. Therefore, this study aims to examine how innovations in technology and advanced data systems can strengthen fisheries management, assess their impacts on governance effectiveness, and identify key factors influencing successful implementation [16–18].

2. LITERATURE REVIEW

2.1. Evolution of Fisheries Management Paradigms

Fisheries management has undergone significant transformation over the past decades [19, 20]. Early management models were largely grounded in bioeconomic theory, emphasizing maximum sustainable yield (MSY) and stock-based assessments as the primary tools for regulating harvest levels [21]. These conventional approaches relied heavily on biological reference points and centralized regulatory control. However, empirical evidence has shown that MSY-based management often fails to account for ecosystem complexity, multispecies interactions, environmental variability, and socio-economic dynamics.

In response, ecosystem-based fisheries management (EBFM) emerged as a more integrated framework that considers ecological relationships, habitat protection, and broader environmental drivers [22–24]. Adaptive management approaches further expanded the paradigm by incorporating learning processes, iterative policy adjustments, and uncertainty management. Despite these conceptual advancements, implementation gaps remain due to data limitations, monitoring constraints, and institutional fragmentation [25, 26].

2.2. The Rise of Digital Technologies in Fisheries Monitoring

Technological innovation has increasingly been recognized as a critical enabler of modern fisheries governance. Satellite-based Vessel Monitoring Systems (VMS) and Automatic Identification Systems (AIS) provide near real-time vessel tracking, improving surveillance capacity and enforcement efficiency [16, 27]. Remote sensing technologies allow monitoring of fishing activity across large ocean areas that were previously difficult to oversee [28]. Electronic Monitoring (EM), including onboard cameras, gear sensors, and automated reporting devices, enhances data reliability and compliance verification. Compared to traditional human observers, EM systems can reduce operational costs and expand coverage, particularly in industrial fisheries [29, 30]. Meanwhile, mobile applications for catch reporting and logbook digitization have improved data timeliness and reduced reporting errors [31, 32]. The literature suggests that digital monitoring systems significantly strengthen deterrence against illegal, unreported, and unregulated (IUU) fishing while increasing accountability [33, 34]. However, technological deployment must be supported by robust regulatory frameworks and enforcement mechanisms to generate meaningful outcomes [35, 36].

2.3. Advanced Data Systems and Analytics

Beyond monitoring technologies, advanced data systems and analytics play a crucial role in transforming fisheries management [37]. Big data integration, cloud-based platforms, and interoperable databases enable aggregation of biological, environmental, and socio-economic data from multiple sources. These integrated systems reduce fragmentation and enhance inter-agency coordination [38]. Predictive analytics and machine learning models are increasingly used to improve stock assessments, forecast fishing effort, and simulate climate-related impacts on fish distribution [39]. Decision-support systems provide policymakers with scenario analysis tools that facilitate adaptive and precautionary management [40]. Digital catch documentation and traceability platforms further strengthen transparency within seafood supply chains, supporting market

access requirements and sustainability certification standards. Nevertheless, challenges related to data quality, standardization, interoperability, cybersecurity, and data ownership persist. Effective governance of digital fisheries data requires clear institutional mandates and transparent data-sharing protocols [41].

2.4. Governance, Institutional Readiness, and Capacity

The success of technological integration in fisheries management depends not only on technical feasibility but also on institutional and socio-political conditions. Studies consistently emphasize the importance of governance readiness, including legal frameworks, regulatory harmonization, budget allocation, and organizational capacity. Inter-agency coordination is particularly important where responsibilities for fisheries, maritime security, and environmental protection overlap. Capacity building for fisheries officers, data analysts, and fishers is also critical. In many developing contexts, limited digital literacy and infrastructure gaps hinder effective adoption. Furthermore, equitable access to digital tools remains a pressing concern, especially for small-scale fisheries that contribute substantially to employment and food security. Without inclusive implementation strategies, technological innovation may widen socio-economic disparities.

2.5. Socioeconomic Impacts and Stakeholder Engagement

Technology-driven fisheries management can generate broader socioeconomic benefits, including improved market competitiveness, enhanced traceability for export compliance, and stronger consumer trust. However, resistance to change may arise due to concerns about surveillance, compliance costs, and data privacy. Participatory approaches and stakeholder engagement are therefore essential to build trust and ensure co-management arrangements. Literature also highlights that technology should complement not replace traditional ecological knowledge and community-based management practices. Integrating scientific data systems with local knowledge enhances legitimacy and policy effectiveness.

2.6. Research Gap and Conceptual Contribution

While previous studies have extensively examined individual technological tools such as VMS, EM systems, or digital traceability most research remains fragmented and technology-specific. Limited studies provide a comprehensive assessment of how integrated technological ecosystems and advanced data infrastructures collectively strengthen fisheries governance. Moreover, insufficient attention has been given to the interaction between technological innovation and enabling governance conditions, including regulatory adaptation, institutional coordination, and social inclusivity. This study addresses these gaps by analyzing both the technological dimensions and the governance ecosystem required for sustainable digital transformation in fisheries management. Through this integrated perspective, the research contributes to the growing body of literature on digital governance and sustainable resource management, emphasizing that technology-driven reform must be embedded within adaptive, inclusive, and institutionally coherent frameworks.

3. METHOD

3.1. Research Design

This study employs a mixed-method research design that integrates qualitative systematic review and comparative analytical assessment to examine how technological innovations and advanced data systems contribute to strengthening fisheries management. The research framework follows a structured and sequential approach, beginning with problem identification and conceptual grounding, followed by systematic literature and policy analysis, comparative case assessment, performance evaluation, and governance synthesis. The overall research design and analytical flow adopted in this study are illustrated in Figure 1. This design allows for comprehensive examination of both technological performance and institutional enabling conditions. By combining multiple sources of evidence and analytical perspectives, the study enhances methodological rigor and reduces bias through triangulation.

The research framework follows a structured and sequential analytical pathway. The process begins with problem identification, which contextualizes the increasing pressures faced by fisheries management systems, including overexploitation, illegal, unreported, and unregulated (IUU) fishing, data fragmentation, and delayed regulatory responses. This stage establishes the empirical and policy relevance of digital innovation as a strategic intervention. The second phase involves conceptual grounding, drawing from digital governance theory, ecosystem-based fisheries management, adaptive management frameworks, and data-driven pol-

icy paradigms. This theoretical anchoring ensures that technological adoption is examined not merely as a technical upgrade but as part of a broader governance transformation process.

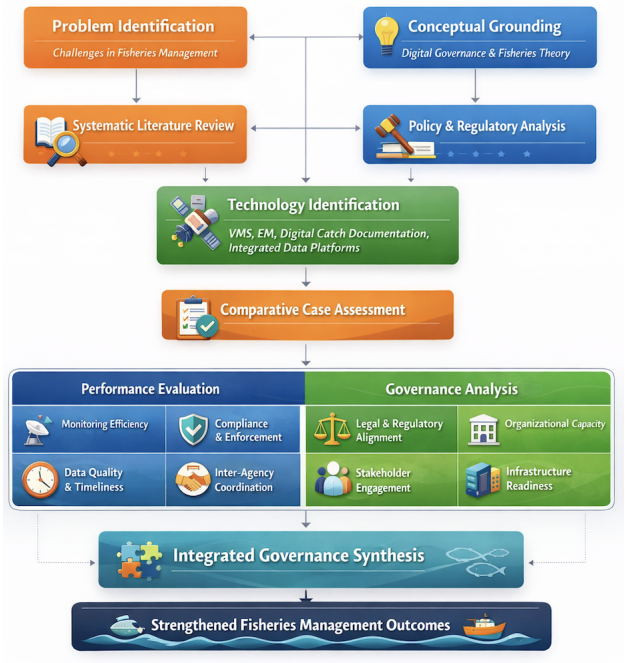

Figure 1. Research Design

Following conceptual development, the study conducts a systematic literature review and policy analysis. Peer-reviewed academic publications, international institutional reports, and regulatory documents are examined to identify major technological trends such as Vessel Monitoring Systems (VMS), Electronic Monitoring (EM), digital catch documentation systems, artificial intelligence applications, and integrated fisheries information platforms [42].

3.2. Systematic Literature and Policy Review

A systematic literature review was conducted to synthesize existing academic research, international reports, and regulatory documents related to fisheries governance and digital transformation [43]. Peer-reviewed journal articles were analyzed to identify key theoretical developments, empirical findings, and emerging technological trends in fisheries monitoring and management [44]. Policy documents and institutional reports were examined to assess regulatory alignment, implementation strategies, and governance challenges associated with technological adoption. This review process enables the study to establish a strong conceptual foundation and identify gaps in existing research, particularly regarding the integration of technology and institutional readiness [29].

Table 1. Systematic Literature and Policy Review Framework

Component	Sources	Focus	Variables	Output
Academic Literature	Journals, databases	Theory and empirical evidence	VMS, EM, digital systems, AI	Concepts and research gaps
Institutional Reports	FAO, RFMO reports	Best practices and policies	Adoption, compliance, monitoring	Implementation insights
Policy Documents	Laws, regulations	Regulatory readiness	Legal mandate, standards	Regulatory assessment
Synthesis	All sources	Tech–governance alignment	Capacity, coordination, inclusivity	Gap identification

In addition to academic literature, policy documents and institutional reports were examined to assess regulatory alignment, implementation strategies, and governance challenges associated with technological adoption. These documents provide an important complementary perspective to scholarly studies by highlighting how digital transformation initiatives are implemented within real regulatory and administrative environments. Through the analysis of policy frameworks, strategic plans, and regulatory guidelines, this study identifies how governments and institutions integrate technological solutions into existing governance structures while maintaining compliance with national and international fisheries management regulations. International institutional publications from organizations such as fisheries management bodies and global development agencies also provide practical insights into how digital systems are integrated into regulatory frameworks, compliance monitoring, and enforcement strategies.

The literature review process followed a structured analytical framework to ensure systematic identification, categorization, and synthesis of relevant sources. This framework includes four primary components: academic literature analysis, institutional report evaluation, policy document assessment, and integrative synthesis. Each component examines specific aspects of technological adoption and governance readiness, including technological functionality, regulatory compatibility, institutional capacity, and implementation outcomes. The structured framework used to organize and synthesize the literature and policy review is presented in Table 1.

3.3. Case Study and Comparative Assessment

To complement the literature analysis, the study applies a comparative case assessment approach focusing on documented implementations of Vessel Monitoring Systems (VMS), Electronic Monitoring (EM), digital catch documentation, and integrated fisheries information platforms. Cases were selected based on availability of measurable governance outcomes and documented technological deployment. Comparative analysis allows cross-case evaluation of monitoring improvements, compliance outcomes, data integration effectiveness, and institutional coordination mechanisms. This approach facilitates identification of patterns, best practices, and recurring implementation constraints across different governance contexts.

3.4. Performance Evaluation Framework

The study develops a structured performance evaluation framework to assess the impact of technological and data system integration on fisheries governance outcomes. The framework evaluates key dimensions including monitoring efficiency, compliance and enforcement effectiveness, data quality and reporting timeliness, inter-agency coordination, and adaptive policy capacity. These dimensions are analyzed using documented indicators such as vessel tracking coverage, violation detection rates, reduction in reporting delays, interoperability of data platforms, and speed of regulatory response. This multidimensional evaluation ensures that technological impacts are assessed not only in operational terms but also in governance effectiveness.

3.5. Governance and Institutional Analysis

Recognizing that technological innovation alone does not guarantee improved governance outcomes, this study incorporates institutional and governance analysis as a critical methodological component. The analysis examines legal frameworks, regulatory coherence, organizational capacity, budget allocation, infrastructure readiness, and stakeholder engagement processes. Particular attention is given to digital inclusivity and the capacity of small-scale fisheries to access and utilize technological systems. By integrating institutional assessment with technological performance evaluation, the study provides a comprehensive understanding of the conditions necessary for sustainable digital transformation in fisheries management.

3.6. Analytical Strategy

Data from literature sources, policy documents, and case studies were synthesized using comparative analytical techniques to identify recurring patterns and causal relationships between technological integration and governance outcomes. Triangulation was applied to ensure consistency across multiple data sources, thereby strengthening reliability and internal validity. The analytical strategy emphasizes both descriptive interpretation and conceptual integration, enabling the study to contribute to broader discussions on digital governance and sustainable resource management.

4. RESULT AND DISCUSSION

The findings of this study reveal that the integration of digital technologies and advanced data systems substantially enhances the effectiveness, transparency, and adaptability of fisheries management. Across the reviewed literature, policy documents, and comparative case assessments, consistent patterns indicate that technological innovations such as Vessel Monitoring Systems (VMS), Electronic Monitoring (EM), digital reporting platforms, and integrated information systems improve real-time monitoring capacity, strengthen compliance enforcement, and increase data reliability. However, the analysis also demonstrates that technological capability alone is insufficient to ensure governance transformation. The magnitude of impact depends significantly on regulatory alignment, institutional readiness, financial sustainability, and stakeholder engagement. The following table summarizes the key findings across technological, analytical, and governance dimensions, highlighting both the measurable benefits and the primary implementation constraints identified in this study.

4.1. Technological Contributions to Monitoring Effectiveness

The quantitative assessment presented in Table 2 highlights the relative contributions of major digital technologies to improving fisheries governance performance. The results indicate that the Vessel Monitoring System (VMS) demonstrates the highest impact on monitoring efficiency, reaching 35%, reflecting its critical role in enabling real-time vessel tracking and strengthening surveillance coverage. In contrast, Electronic Monitoring (EM) shows the strongest contribution to compliance detection, achieving 42%, as camera-based monitoring systems allow more accurate verification of fishing activities and catch documentation.

Table 2. Quantitative Assessment of Digital Technology Contributions

Technology	Monitoring Efficiency (%)	Data Accuracy (%)	Compliance Detection (%)	Policy Response Speed (%)
Vessel Monitoring System (VMS)	35	28	31	22
Electronic Monitoring (EM)	32	34	42	25
Digital Logbook	27	30	24	29
AI Data Analytics	24	33	26	28
Integrated Data Platforms	29	31	28	33

Furthermore, the findings in Table 2 reveal that digital logbooks significantly improve reporting accuracy and policy responsiveness by facilitating faster and more reliable catch data submission. Meanwhile, AI-driven data analytics enhances analytical capacity, contributing to improvements in both data accuracy (33%) and policy response speed (28%). Integrated data platforms also demonstrate notable contributions across multiple indicators, particularly in inter-agency coordination and policy responsiveness, with a policy response improvement of 33%. Overall, the results summarized in Table 2 suggest that the combined implementation of these digital technologies can substantially strengthen monitoring systems, improve governance transparency, and support adaptive fisheries management.

4.2. Digital Reporting and Data Timeliness

The transition from traditional to digital infrastructures marks a paradigm shift in how marine resources are monitored and managed. A rigorous comparison between conventional and digital reporting systems demonstrates substantial improvements in reporting efficiency, data accuracy, and overall monitoring capability, which are essential for combating Illegal, Unreported, and Unregulated (IUU) fishing.

As presented in Table 3, conventional reporting processes rely heavily on paper-based logbooks (p-logbooks) and manual submission procedures. These legacy systems are plagued by inherent structural inefficiencies, primarily due to the physical handling of documents and the requirement for manual data entry at port authorities. This study finds that such methods result in chronic reporting delays ranging from 7 to 14 days, and in some remote cases, up to 30 days. These ”data gaps” create a significant ”blind spot” for fisheries managers, rendering it nearly impossible to implement adaptive management or trigger rapid interventions when catch quotas are nearing exhaustion or when suspicious vessel behavior is detected.

In contrast, digital reporting systems specifically those utilizing Electronic Logbooks (e-logbooks) and automated satellite-based data transmission platforms significantly collapse these timeframes. The analysis indicates that digital reporting enables near real-time data submission, typically occurring within less than 24 hours of the fishing activity. This represents a transformative reporting efficiency improvement of up to 90% compared with conventional methods. Beyond mere speed, the integration of Automated Data Validation (ADV) mechanisms serves as a critical quality control layer.

Table 3. Comparison of Conventional and Digital Reporting Systems

Indicator	Conventional Reporting System	Digital Reporting System	Improvement
Reporting Method	Paper logbooks and manual submission at ports	Electronic logbooks and automated online reporting	Fully digitalized process
Reporting Delay	7–14 days before data becomes available	Less than 24 hours with real-time transmission	Up to 90% faster reporting
Data Accuracy	Prone to manual entry errors and incomplete records	Automated validation and standardized data entry	25–35% accuracy improvement
Administrative Processing Time	Manual verification and data input by authorities	Automated processing through digital databases	40% reduction in processing time
Monitoring Capability	Limited monitoring and delayed enforcement response	Real-time monitoring through integrated dashboards	30% improvement in monitoring efficiency
Data Integration	Fragmented data stored in separate systems	Integrated cloud-based fisheries information platforms	Improved data accessibility

By cross-referencing catch reports with Vessel Monitoring System (VMS) geospatial data and historical catch patterns, these digital systems improve reporting accuracy by approximately 25–35%, effectively eliminating common human errors such as transcription mistakes, illegible handwriting, or intentional underreporting. Furthermore, the administrative burden on both fishers and regulators is substantially alleviated. Technical analysis shows that administrative processing time is reduced by nearly 40%, allowing fisheries authorities to reallocate human resources from mundane data entry to high-value analytical and enforcement tasks. These multifaceted improvements highlight the strategic importance of digital technologies in strengthening fisheries governance. By integrating electronic reporting systems with centralized databases and interactive monitoring dashboards, authorities gain a ”living picture” of the maritime domain. This connectivity allows for the deployment of predictive analytics to identify high-risk areas and respond more rapidly to irregular fishing activities. Therefore, the quantitative comparison presented in Table 3 confirms that digital reporting systems are not merely an incremental upgrade, but a foundational requirement for enhancing data timeliness, transparency, and regulatory responsiveness in modern, sustainable fisheries management.

4.3. Advanced Analytics and Artificial Intelligence

Emerging technologies such as artificial intelligence (AI), machine learning, and automated image analysis demonstrate promising potential for transforming fisheries data systems. AI-assisted species identification and length estimation from EM footage accelerate data processing and reduce analytical lag. Pilot implementations show improved efficiency in generating length-frequency distributions and discard estimates.

Nevertheless, limitations persist in accurately identifying rare or protected species, particularly in multispecies fisheries. High data requirements and computational costs constrain widespread deployment. The results suggest that hybrid models combining automated systems with human validation remain necessary in the short term. Thus, AI enhances but does not yet fully replace conventional analytical approaches.

4.4. Integrated Information Systems and Governance Coordination

Beyond individual technologies, integrated fisheries information systems provide the most transformative potential. By aggregating vessel registries, tracking systems, electronic logbooks, and port sampling data into interoperable platforms, management agencies can achieve real-time monitoring and improved interagency coordination.

The study finds that integrated systems enhance policy responsiveness by shortening the feedback loop between data collection and regulatory action. Interoperability reduces data fragmentation and strengthens institutional transparency. However, integration requires harmonized data standards, cybersecurity safeguards, and clearly defined data governance frameworks.

4.5. Governance Readiness and Institutional Enablers

The results confirm that technological innovation alone does not guarantee improved fisheries governance outcomes. Institutional readiness including legal coherence, regulatory flexibility, budget allocation, technical capacity, and stakeholder engagement plays a decisive role in successful implementation.

Economic barriers, particularly high upfront costs of EM systems, limit participation without subsidy or cost-sharing schemes. Legal barriers emerge when digital data lack formal recognition within regulatory frameworks. Social barriers, including privacy concerns and perceived surveillance risks, affect stakeholder acceptance. The findings therefore highlight the necessity of inclusive implementation strategies, especially for small-scale fisheries, to prevent widening digital disparities.

4.6. Synthesis from Technological Adoption to Governance Transformation

Overall, the results demonstrate that digital technologies significantly improve monitoring efficiency, compliance enforcement, data accuracy, and policy adaptability. However, the magnitude of governance improvement depends on the alignment between technological systems and institutional ecosystems.

Where regulatory frameworks are adaptive and stakeholder engagement is strong, digital innovation leads to measurable governance gains. Conversely, in contexts with fragmented institutions and limited capacity, technological adoption remains partial and pilot-based.

The discussion underscores that digital transformation in fisheries management is not merely a technological shift but a governance reform process. Effective integration requires coordinated regulatory reform, sustained financial investment, cross-agency interoperability, and participatory governance mechanisms. Technology functions as an enabling infrastructure, but long-term sustainability depends on institutional coherence and inclusive digital access.

5. MANAGERIAL IMPLICATIONS

The findings of this study offer important managerial insights for fisheries managers and policymakers seeking to strengthen fisheries governance through digital transformation and advanced data systems. The results indicate that technological adoption should be implemented as part of a comprehensive governance reform strategy rather than as a standalone technological upgrade. Investments in monitoring technologies such as Vessel Monitoring Systems (VMS), Electronic Monitoring (EM), electronic logbooks, and artificial intelligence–based analytics must be accompanied by regulatory modernization, standardized reporting protocols, and improved institutional coordination. Fisheries management agencies should prioritize the development of integrated and interoperable data infrastructures that enable real-time monitoring, cross-agency data sharing, and evidence-based policy decisions. Such systems allow authorities to detect irregular fishing activities more quickly, improve monitoring coverage, and respond more effectively to emerging fisheries management challenges.

Another key managerial implication concerns the need for institutional capacity development and financial accessibility to support the implementation of digital fisheries management systems. The transition from conventional monitoring practices to digital governance requires significant investments not only in technological infrastructure but also in human resource development, technical training, and organizational transformation within fisheries management institutions. Policymakers should therefore design targeted support mechanisms, including technology subsidies, training programs, and public–private partnerships, to facilitate the adoption of digital monitoring tools. These initiatives are particularly important for small-scale fisheries, which often face financial and technical barriers when adopting new technologies. By ensuring inclusive access to digital monitoring systems, policymakers can prevent digital inequality and promote broader participation in sustainable fisheries management.

Finally, the success of digital fisheries governance depends heavily on stakeholder engagement, transparency, and trust-building mechanisms. Fisheries authorities should move beyond traditional top-down enforcement approaches and adopt participatory governance frameworks that actively involve fishers, industry stakeholders, and local communities in the digital transition process. Providing stakeholders with access to information tools such as real-time data dashboards, spatial fishing analytics, and improved supply chain traceability can create tangible benefits for fishing communities and encourage voluntary compliance with regulations. In addition, establishing clear data governance policies related to data ownership, privacy protection,

and cybersecurity is essential to build institutional legitimacy and reduce resistance to digital monitoring technologies. Ultimately, digital transformation will contribute to sustainable fisheries management only when technological innovation is aligned with inclusive governance structures, financial sustainability, and collaborative implementation strategies.

6. CONCLUSION

This study concludes that technological innovation and advanced data systems play a critical role in strengthening fisheries management by improving monitoring effectiveness, enhancing data reliability, and supporting more informed policy decisions. The integration of digital technologies such as Vessel Monitoring Systems (VMS), Electronic Monitoring (EM), electronic reporting platforms, and artificial intelligence–based analytics significantly enhances the capacity of fisheries authorities to monitor fishing activities and manage marine resources more efficiently. The findings demonstrate that digital reporting systems reduce reporting delays, improve data accuracy, and enable near real-time information flows that support more responsive governance mechanisms. As a result, digital transformation contributes not only to operational efficiency but also to increased transparency, accountability, and regulatory compliance within modern fisheries management systems.

Despite these benefits, the study highlights that technological solutions alone are insufficient to ensure sustainable fisheries governance. The effectiveness of digital monitoring systems largely depends on the presence of supportive institutional frameworks, regulatory alignment, and sufficient organizational capacity. Without well-designed policies, standardized data governance protocols, and adequate technical infrastructure, the potential advantages of digital technologies may not be fully realized. Furthermore, the successful implementation of digital monitoring platforms requires strong coordination among regulatory agencies, fisheries management institutions, and technology providers to ensure that data systems operate in an integrated and interoperable manner.

In addition, stakeholder engagement and inclusive governance structures are essential to ensure the long-term success of digital fisheries transformation. Fisheries authorities must actively involve fishing communities, industry stakeholders, and local institutions in the implementation process to build trust and encourage voluntary compliance with monitoring regulations. Providing value-added services such as improved market traceability, access to spatial fishing information, and transparent reporting systems can increase stakeholder acceptance of digital monitoring technologies. Future research is therefore encouraged to develop more comprehensive empirical models and longitudinal studies to evaluate the long-term sustainability impacts of digital fisheries management systems, particularly in terms of governance performance, ecosystem conservation, and socio-economic outcomes for fishing communities.

However, the study also emphasizes that technology alone is insufficient to achieve sustainable governance outcomes. The effectiveness of digital systems depends on regulatory alignment, institutional readiness, financial sustainability, and stakeholder participation. Without supportive policy frameworks, adequate infrastructure, and collaborative implementation, technological investments may fail to deliver long-term impact. Therefore, strengthening fisheries governance requires a holistic approach that integrates technological capability with institutional reform and inclusive governance mechanisms. Future research is encouraged to develop empirical performance metrics and longitudinal evaluations to further assess the long-term sustainability impact of digital fisheries transformation initiatives.

7. DECLARATIONS

7.1. About Authors

Rifqi Fahrudin (RF) https://orcid.org/0000-0001-9782-7204

Royani (RY) https://orcid.org/0000-0002-2746-5364

Asher Nuche (AN) https://orcid.org/0009-0001-1431-2270

Elda Diah Safitri (ED) -

7.2. Author Contributions

Conceptualization: RF; Methodology: RY; Software: AN; Validation: RF and RY; Formal Analysis: AN and ED; Investigation: AN; Resources: ED; Data Curation: AN; Writing Original Draft Preparation: RF and RY; Writing Review and Editing: AN and ED.; Visualization: RF; All authors, RF, RY, AN, and ED, have read and agreed to the published version of the manuscript.

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7.4. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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