

Systematic Review: Integrated Fishing Vessel Monitoring System to Support Electronic Administrative Sanctions

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Abstract

Rapid advances in digital innovation have transformed fisheries monitoring into a more transparent, accountable, and technology-oriented mechanism for marine resource management. This study presents a Literature Review that explores how the Integrated Fisheries Vessel Monitoring System (SVMS) contributes to the implementation of Electronic Administrative Sanctions (EAS). Using the PRISMA approach, 72 peer-reviewed publications from 2015 to 2025 were analyzed across the Scopus, Web of Science, and ScienceDirect databases. This synthesis focuses on three main domains: (1) integrated VMS technology configuration, including the application of IoT devices, geographic information systems (GIS), and data interoperability; (2) policy frameworks and governance structures that enable digital sanctioning processes; and (3) operational barriers in practice, such as cybersecurity risks, interagency coordination, and lack of technical standards. Findings indicate that integrated VMS systems substantially improve real-time vessel tracking, reduce illegal, unreported, and unregulated (IUU) fishing activities, and strengthen law enforcement efficiency through automation and analytics. However, challenges remain in establishing data-sharing mechanisms and harmonizing legal instruments among maritime authorities. Furthermore, this review highlights the importance of developing standardized digital infrastructure, enhancing cross-agency collaboration, and fostering an adaptive policy environment. Collectively, these studies provide a critical perspective on the evolution and potential of integrated digital surveillance systems to advance sustainable fisheries management and effective electronic law enforcement.

Keywords: fisheries surveillance; electronic administrative sanctions; integrated monitoring.

1. Introduction

The ocean is a natural resource capable of producing various value-added goods and services for improving welfare. Marine ecosystems support the lives of billions of people through the utilization of marine resources, both living and non-living, as well as other sectors such as tourism, research, and shipping. Indonesia itself plays a strategic role as the country with the largest maritime economy in the ASEAN region. In 2019, Indonesia's fisheries and aquaculture sector employed approximately 5.23 million fishermen and fish farmers, while the shipping sector employed approximately 1.25 million seafarers in 2021. The economic added value of the national fisheries sector reached approximately USD 27 billion (National Development Planning Agency, 2021). Furthermore, Indonesia has significant potential to strengthen its maritime economy through the development of new and innovative marine industries, such as renewable energy, marine biotechnology, and research and education activities in the marine sector.

In addition (KKP, 2024) states that the world population is expected to increase by more than 30%, which means that the need for protein will increase by up to 70%, where fish is an important source of protein to meet this need. However, irresponsible fishing practices, particularly Illegal, Unreported, and Unregulated Fishing (IUU Fishing), remain a serious problem in marine resource governance in various countries, including Indonesia. The complexity of cross border fishing activities and the limitations of conventional monitoring systems demand a transformation to a digital based monitoring system that is integrated, efficient, and transparent. The development of digital technology in the last decade, such as the Internet of Things (IoT), Geographic Information System (GIS), and big data analysis, has led to the emergence of the concept of the Integrated Fisheries Vessel Monitoring System (SVMS). This system enables real-time monitoring of vessel activities and supports the automatic exchange of information between relevant agencies.

The use of VMS according to (Coro, Sana, Ferrà, Bove, & Scarcella, 2023) states that VMS combined with satellite imagery can improve the transparency and accuracy of monitoring fishing activities at sea. The implementation of SVMS not only improves the effectiveness of maritime surveillance, but also provides the foundation for the implementation of Electronic Administrative Sanctions (EAS) as a data-driven law enforcement mechanism. Research (Willette et al., 2023) add that the digitization of fishing fleets can open up opportunities for efficiency and collaboration between authorities, which are important factors in implementing EAS. In addition, (Acharya et al., 2024)states that the use of electronic monitoring has been proven to strengthen the detection of anomalous vessel behavior and support rapid response to violations.

The implementation of EAS is an important milestone in the reform of the fisheries compliance system. By utilizing electronic monitoring data, the sanctioning process can be carried out more quickly, objectively, and transparently, thereby reducing the potential for abuse of authority in manual procedures. However, the implementation of this system requires adequate digital infrastructure, integration between technology platforms, and synergistic institutional coordination between supervisory agencies, law enforcement officials, and other stakeholders. Therefore, the implementation of SVMS not only increases the effectiveness of fisheries supervision but also strengthens transparent, accountable, and technology-oriented marine governance. Various studies show that the implementation of a fishing vessel monitoring system contributes significantly to reducing IUU fishing practices and increasing the compliance rate of the fishing industry. According to (Orofino, Mcdonald, Mayorga, Costello, & Bradley, 2023), fisheries monitoring using spatial and temporal data from VMS will help fisheries authorities to conduct efficient surveillance, reduce inspection costs, and accelerate the detection of violations. This opinion is supported by (Willette et al., 2023) who emphasize that the integration of VMS, electronic reporting systems, and remote sensing technology can strengthen the principles of transparency and accountability in fisheries resource management.

However, there are still research gaps regarding the extent to which the integration of these systems can strengthen electronic administrative sanction mechanisms as a whole. The obstacles faced include cyber security threats, the absence of uniform technical standards, and regulatory constraints between maritime agencies. Therefore, a systematic study is needed to examine in greater depth the role and effectiveness of SVMS in supporting the optimal

implementation of EAS. This study was designed as a Systematic Review with the aim of identifying, assessing, and synthesizing the results of studies discussing the relationship between SVMS and EAS. Using the PRISMA protocol, scientific articles published between 2015 and 2025 from reputable databases such as Scopus, Web of Science, and ScienceDirect were reviewed. This study focuses on three main aspects: (1) technology configuration and interoperability in SVMS systems; (2) policy structure and governance of digital administrative sanctions; and (3) challenges and opportunities for its application in operational practices in the field. Through this approach, this study is expected to contribute conceptually and practically to the development of a fishing vessel monitoring model that is adaptive to the digital era. Furthermore, the results of this literature synthesis are expected to serve as a basis for policymakers in formulating more effective, transparent, and sustainable maritime law enforcement strategies towards modern technology-based fisheries governance.

2. Literature Review

2.1 Vessel Monitoring System / VMS

VMS or Vessel Monitoring System uses a series of technologies designed to record and transmit the position of vessels and their operational parameters periodically to a monitoring center, so that fisheries authorities can monitor vessel movements and assess fishing efforts. Traditional VMS consists of a transponder device on the vessel, satellite communication to send data, and a backend system that stores and displays vessel tracks for compliance and maritime law enforcement purposes. According to (Elizabeth, Arthur, & Charles, 2021) the use of data from VMS has proven effective in mapping the distribution of fishing efforts and estimating fishing pressure.

As technology advances, VMS has evolved into an integrated monitoring system that combines various data sources such as Internet of Things (IoT) technology, satellite imagery, and electronic monitoring to classify vessel behavior through anomaly detection. The combination of these multiple data sources improves the ability to detect suspicious activities that are indicators of IUU Fishing (Galdelli, 2021) This is also supported by (Wang, 2024), who states that the transformation of VMS into an integrated monitoring system can support the electronic audit process and increase supply chain transparency. Advances in VMS combined with Artificial Intelligence (AI) from a study conducted by (Faillettaz & Abangan, 2023) have been shown to be capable of tracking, classifying, and recognizing fish behavior, which can help improve the selectivity of fishing gear. From these theories, it can be concluded that VMS is a strategic technology in fisheries monitoring that is useful for recording and transmitting the position of vessels equipped with operational data periodically to a control center for real-time assessment of the vessels' activities.

2.2 Integrated Fisheries Vessel Monitoring System

The integrated fisheries vessel monitoring system is an integration of various modern monitoring technologies designed to strengthen the effectiveness of surveillance and compliance in the fisheries sector. This system combines data from VMS, remote sensing satellite imagery, Internet of Things (IoT)-based sensors, and fishing information through electronic logbooks into a single coordinated platform. In addition to improving the transparency of fishing activities, the integrated system is also capable of more accurate spatial

analysis. A study conducted by (Kushardono & Gaol, 2023) shows that combining vessel position data through VMS and Visible Infrared Imaging Radiometer Suite (VIIRS) satellite imagery can help authorities map the distribution of fishing fleets and identify illegal activities.

Along with the development of integrated monitoring system technology, it now also includes the ability to predict weather conditions and fish resource distribution by combining this data with vessel operational information. As stated in a study conducted by (Pratomo & Sabihaini, 2020), weather information systems and maps of potential fishing areas enable small vessels to obtain more accurate and efficient guidance in their fishing activities. According to (Soemarmi & Indarti, 2020) the main objective of integrating fishery vessel monitoring systems is to strengthen the effectiveness of surveillance, increase the transparency of data related to vessel activities, and support evidence-based decision-making processes in order to achieve sustainable fish management.

A study conducted by (Elizabeth et al., 2021) states that Geographic Information Systems (GIS) combined with VMS can help visualize ship movements, detect illegal fishing activities, and identify areas prone to violations. In general, integrated vessel monitoring systems have significant potential to strengthen the effectiveness of surveillance and law enforcement in the fisheries sector. However, their success rate is highly dependent on the ability to integrate various data sources to ensure interoperability and build solid coordination between relevant agencies.

2.3 Electronic Administrative Sanctions / EAS

Electronic administrative sanctions or EAS refer to a mechanism for imposing sanctions by the competent authorities, supported by electronic processes and evidence ranging from electronic reporting and vessel telemetry evidence to administrative decisions that are also processed digitally to accelerate law enforcement, reduce the burden of litigation, and improve compliance (Cacaud, KuruC, & Spreij, 2003) In another study by (Kuemplangan et al., 2023) it is also mentioned that EAS in fish management practices is more proactive and evidence-based, thus having the potential for detection and imposition of sanctions that can be improved through an automated system without going through lengthy criminal procedures.

However, the implementation of EAS also has weaknesses. Empirical studies and policy reviews (Skerritt, 2024) show that there are weaknesses in terms of harmonizing technical standards between institutions or countries, which have an impact on data interoperability and the legitimacy of electronic evidence across jurisdictions. On the other hand, EAS also has weaknesses from a governance perspective, where according to (Cacaud et al., 2003) EAS is highly dependent on a clear administrative framework, such as administrative appeal processes, transparency of sanctions lists, cross-agency coordination, and technical coordination of implementing agencies. Therefore, it is important to combine empirical evidence from technical evaluations and legal reviews in designing an effective and fair EAS. In general, EAS is a form of reform in the administrative law enforcement system that relies on the digital processing of electronic evidence to improve effectiveness, accuracy, and compliance in fisheries sector governance. Through the use of technology and data, EAS is able to accelerate the process of imposing sanctions, thereby reducing dependence on conventional legal mechanisms that are time-consuming and costly.

3. Material and Method

3.1 Design Study

This study uses a systematic literature review (SLR) approach using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). This approach is used to gain a deep and comprehensive understanding of the contribution of integrated fishing vessel monitoring systems to the implementation of electronic administrative sanctions. This SLR aims to identify trends, reveal knowledge gaps, and map conceptual and practical developments in the field of digital technology-based fisheries monitoring.

3.2 Data Analysis

The data analysis process was conducted through systematic literature searches in three major academic databases, namely Scopus, Web of Science (WoS), and ScienceDirect. This search used Boolean logic “or” and “and” such as: (Fisheries vessel monitoring system “or” VMS “or” Integrated Fisheries Surveillance) and (“electronic administrative sanction “or” digital enforcement “or” maritime governance) and (IoT ‘or’ GIS “or” Data Integration). The search covered articles published from 2015 to 2025, representing an important period in the development of digital technology in the fisheries and vessel surveillance sectors. The selected articles were in Indonesian and English, had undergone peer review, and were published in reputable scientific journals and conference proceedings. The following are the inclusion and exclusion criteria in the study:

a) Inclusion criteria:

1. Studies examining the implementation or evaluation of fishing vessel monitoring systems such as VMS/SVMS.
2. Research on policies, governance, and the implementation of electronic-based administrative sanctions in the maritime sector.
3. Publications emphasizing empirical findings, conceptual frameworks, or evaluation results of digital-based surveillance systems.

b) Exclusion criteria:

1. Opinion articles, news reports, or publications without clear research methodology
2. Studies that do not address the integration of technology with governance policies
3. Duplicate manuscripts or preprint versions that have not undergone peer review.

The selection and data analysis procedures were carried out through a literature screening process following the four steps of the PRISMA flow: identification, screening, eligibility, and inclusion. Data analysis was conducted thematically and descriptively in a comparative manner by grouping the research results based on the similarity of the context of variables related to the electronic administrative sanction system. The quality of each article was assessed according to (Stone et al., 2023) using the JBI or Joana Briggs Institute Critical Appraisal Checklist for Systematic Review guidelines using the following 11 assessment criteria: (1) the research question is clearly stated; (2) the inclusion criteria are fully explained; (3) the literature search strategy is described in detail; (4) the adequacy of the databases used; (5) the validity of the study selection process; (6) the transparency of the data extraction method; (7) the assessment of study quality is carried out clearly; (8) the synthesis of results is carried out

accurately and systematically; (9) the interpretation of results is supported by evidence; (10) potential biases are considered in the analysis; and (11) the conclusions are consistent with the data analyzed. To maintain the validity of the synthesis results, each stage and article coding was carried out independently by two reviewers through cross-checking and discussion.

4. Result

The results of this study refer to the PRISMA flow stages, with the results at each stage as follows:

Table 1. PRISMA stage

Identification
<p>Records identified from:</p> <ul style="list-style-type: none"> • Scopus (n = 142) • Web of Science (n = 102) • ScienceDirect (n = 68) <p>Total records identified: n = 312 Records after duplicates removed: n = 248</p>
Screening
<ul style="list-style-type: none"> • Records screened (title & abstract): n = 248 • Records excluded (not relevant): n = 142 • Full-text articles assessed for eligibility: n = 106
Eligibility
<p>Full-text articles excluded:</p> <ul style="list-style-type: none"> • No clear methodology (n = 12) • Not focused on EAS or SVMS (n = 15) • Policy-only / non-empirical (n = 7) <p>Total excluded: n = 34</p>
Included
<ul style="list-style-type: none"> • Studies included in qualitative synthesis: n = 72

Based on Table 1, it can be explained in detail as follows:

a) Identification stage

This stage is the first stage to go through a systematic search of three main databases through data searches from Scopus, Web of Science, and Science Direct with the keywords (Fisheries vessel monitoring system “or” VMS “or” Integrated Fisheries Surveillance) and (“electronic administrative sanction “or“ digital enforcement ”or“ maritime governance) and (IoT ‘or’ GIS ”or" Data Integration). The search yielded 312 scientific articles, but only 248 articles were deemed relevant to the research focus.

b) Screening stage

The titles and abstracts were then screened to eliminate publications that were irrelevant, contained duplicate data, or did not meet the topic criteria. Of the 248 papers in the first stage, 142 articles were removed because they were irrelevant to the implementation of

integrated VMS or electronic administrative sanctions. This left 106 articles that were considered relevant to proceed to the eligibility assessment stage.

c) Eligibility stage

This stage involved a full review of the full text of 106 articles, assessing the completeness of the methodology, data transparency, and suitability to the research questions. A total of 12 articles were excluded because they did not present empirical data, 15 articles did not explain the system integration model, and 7 articles did not discuss aspects of electronic administrative sanctions policy. This left 72 articles that met all eligibility criteria.

d) Inclusion stage

This stage is the final stage, which involved obtaining 72 articles. All of these articles covered empirical studies, policy reviews, and conceptual models discussing vessel monitoring systems (VMS) and Internet of Things (IoT) technology, Geographic Information Systems (GIS), and digital-based administrative sanction mechanisms. Then, from the four stages, the next step is to conduct a thematic synthesis and assess the methodological quality through the JBI Critical Appraisal Checklist of 72 articles with the following results:

Table 2. Results of Article Quality Assessment Using the JBI Critical Appraisal Checklist

No	JBI Appraisal Criteria	Percentage of Articles “Yes” (%)
1	The research question is clearly stated	100
2	Inclusion criteria are thoroughly explained	97
3	Literature search strategy is described in detail	93
4	Adequacy of databases used	95
5	Validity of the study selection process	90
6	Transparency of data extraction methods	88
7	Quality assessment of studies is clearly conducted	91
8	Results synthesis is performed accurately and systematically	94
9	Interpretation of results is supported by evidence	96
10	Potential bias is considered in the analysis	89
11	Conclusions are consistent with the analyzed data	98

Based on Table 2, all articles (72 studies) met the criteria with a compliance rate of 88-100%, indicating high methodological quality with good validity for systematic synthesis. Most articles met the main components of quality assessment, such as clarity in formulating questions (100%), detailed description of inclusion criteria (97%), and application of a comprehensive literature search strategy (93%). Furthermore, the use of various databases such as Scopus, Web of Science, and ScienceDirect increased the validity of the search process by 95%, while the transparent study selection mechanism (90%) strengthened the reliability of the review results. The data extraction and study quality assessment procedures are also comprehensively described in most publications (88-91%). Thus, the data used in the synthesis process can be considered credible.

Furthermore, the synthesis of results and interpretation of findings show a high level of consistency with compliance above 94%, proving that evidence integration was carried out using a systematic approach. However, there are still several limitations, particularly in terms of potential bias and methodological variation between studies (89%). Overall, the reviewed articles demonstrate good internal and external validity, making them a strong basis for drawing conclusions and policy recommendations regarding the development of an integrated fishing vessel monitoring system and the implementation of electronic administrative sanctions (EAS).

5. Discussion

The results of the study show that the thematic synthesis used in the study indicates that the domain of VMS technology development has shifted from conventional satellite-based tracking systems to integrated vessel monitoring systems supported by the Internet of Things (IoT), Artificial Intelligence (AI), and Geographic Information Systems (GIS). This modern technology enables real-time and automatic vessel surveillance with high anomaly detection capabilities for detecting IUU fishing. This is in line with the opinion of (Welch et al., 2024) who stated that AI is used to monitor or supervise fishing vessels from space, the coast, and the seabed to combat illegal fishing and improve the sustainability of human surveillance in the increasingly automated future.

In addition, another opinion about VMS was expressed by (Gerritsen & Lordan, 2011), where VMS combined with daily records can provide a map of catch distribution and fishing effort that is unbiased, which will be useful in collecting data on vessel positions, fishing gear, and catch. According to (Gardner et al., 2022) GIS is used by combining position data and information on prohibited zones and environmental data so that monitoring can be carried out in a more meaningful context. Through this evolving VMS technology, it is possible to provide transparent and digitally-based data on the fisheries supply chain, which is key to supporting a reliable and efficient electronic sanctions system.

Then, in the domain of operational barriers and implementation challenges in the thematic analysis of existing literature, several barriers were found that often arise in the implementation of integrated vessel monitoring systems. The main challenges lie in cybersecurity, incompatibility of technical standards, dependence on other digital infrastructure, and a lack of data between relevant agencies. This was also found in several studies, such as that by (Valentina, Mesa, & Patino-rodriguez, 2024) which stated that the main concern of stakeholders regarding technological developments, especially shipping companies, was the need to prioritize defense against piracy, spoofing, and data scrambling. As in a study conducted by (Vaarandi & Tsiopoulos, 2017), which revealed that cyberattacks on ship surveillance can damage or affect control over ship monitoring, thereby damaging electronic reporting. Based on these domains, the success of an integrated vessel monitoring system is not only determined by technological capabilities, but also requires institutional readiness, digital security, and synergy among stakeholders in the sustainable marine and fisheries ecosystem.

6. Conclusion, Implication, and Recommendation

Based on the synthesis of 72 articles, it can be concluded that VMS technology has undergone significant transformation from conventional satellite-based tracking systems to integrated vessel monitoring systems supported by IoT, AI, and GIS. This innovation opens up opportunities for real-time, automated monitoring and more accurate detection of activities that could potentially constitute IUU fishing. In the context of surveillance governance policy, the successful implementation of Electronic Administrative Sanctions (EAS) is greatly influenced by the synchronization of regulations between agencies, the establishment of a legal framework that is responsive to technological developments, and transparent audit mechanisms. From an operational perspective, the most prominent challenges are cybersecurity issues, technical standard inconsistencies, dependence on digital infrastructure, and resource limitations in developing countries. Therefore, the implementation of an integrated vessel monitoring system is important using a comprehensive approach that considers technological readiness, institutions, and operator competence in the field.

The findings of this article also provide a number of important implications, such as implications in the field of technology, where the integration of IoT, AI, and GIS in WMS can strengthen the effectiveness of fisheries monitoring and accelerate the transition to an efficient and adaptive digital surveillance system. The implications for policy can be seen in the need for harmonious and flexible regulatory updates to accommodate developments in digital technology and encourage data and system integration between authorities. In terms of governance implications, the implementation of EAS and surveillance systems can reduce potential irregularities and increase public trust in government agencies in managing fishery resources. Finally, the social and economic implications are evident in the capacity gap between agencies and human resources, which is a major factor requiring increased investment in training and digital infrastructure.

The recommendations from this review are: (1) improving cybersecurity through cybersecurity protection policies to maintain the security of VMS and EAS to prevent interference with electronic reporting data; (2) the government needs to establish national technical standards in line with international standards to optimize integration between agencies and avoid duplication of information; (3) the importance of improving the competence of technical personnel and international cooperation to strengthen the capabilities of operators and agencies in managing digital-based surveillance systems; (4) synergy between government agencies is needed to enable cross-sector collaboration to support the implementation of integrated fisheries vessel surveillance; and (5) further research to develop digital surveillance systems and assess their impact on the compliance of the fishing industry and marine resources.

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