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Research Article

Marine Surveillance Technologies In Combating Illegal, Unreported, And Unregulated (IUU) Fishing: *A Systematic Literature Review*

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Abstract: *This study aims to systematically review the literature on Marine Surveillance Technologies in combating Illegal, Unreported, and Unregulated (IUU) fishing, mapping technological developments, effectiveness, and implementation challenges. The method used is a Systematic Literature Review (SLR) following PRISMA 2020 guidelines, with articles sourced from Science Direct, Web of Science, and Google Scholar from 2015–2025 using the keyword "Marine Surveillance Technology." From 135 identified records, 51 publications met the inclusion criteria. The analysis shows that technologies such as the Automatic Identification System (AIS), Vessel Monitoring System (VMS), and Visible Infrared Imaging Radiometer Suite (VIIRS) form the core of modern marine surveillance systems. The study reveals that effective surveillance depends not only on technological sophistication but also on institutional capacity, cross-sector data sharing, and collaborative governance, particularly in developing countries like Indonesia. Theoretically, Resource-Based View (RBV), Dynamic Capabilities, and Collaborative Governance are dominant frameworks. However, research gaps persist regarding the cost-effectiveness of high-tech solutions, contextual adaptation in developing nations, and standardized risk indicators. This study contributes a comprehensive synthesis for developing an adaptive, integrated, and sustainable fisheries surveillance system.*

Keywords*: Marine Surveillance Technology; IUU Fishing; AIS; VMS*

1. Introduction

Illegal, Unreported, and Unregulated (IUU) fishing has become one of the most critical global challenges in contemporary marine and fisheries resource management. Illegal fishing activities not only threaten marine ecosystem sustainability, but also contribute to declining fish stocks, biodiversity loss, economic instability in coastal communities, and global food insecurity. According to Long et al. (2020), IUU fishing has evolved into a transnational issue that requires stronger global maritime governance and technologically supported marine surveillance systems. Furthermore, Fujii et al. (2021) emphasized that weak monitoring, control, and surveillance (MCS) systems in many countries continue to hinder the effectiveness of efforts to combat illegal fishing activities. The expansion of the blue economy and increasing global demand for fisheries products have further intensified the exploitation of marine resources through illegal practices. Developing countries with extensive maritime territories often face limitations in patrol fleets, human resources, and maritime monitoring infrastructure, making them particularly vulnerable to IUU fishing activities (Long et al., 2020). Moreover, IUU fishing is increasingly associated with transnational crimes such as human trafficking, smuggling, labor exploitation, and money laundering within global fisheries supply chains (Fujii et al., 2021).

In this context, marine surveillance technologies have emerged as strategic instruments in supporting modern maritime monitoring systems. Conventional surveillance approaches relying on patrol vessels and manual observation are increasingly considered ineffective due to vast ocean coverage, high operational costs, and limited real-time detection capabilities. Consequently, many countries have begun adopting satellite-based monitoring systems and artificial intelligence technologies to enhance the effectiveness of maritime surveillance operations (Soldi et al., 2020). Recent technological advancements have introduced various modern maritime surveillance systems,

including Automatic Identification System (AIS), Vessel Monitoring System (VMS), Synthetic Aperture Radar (SAR), satellite imagery, unmanned aerial vehicles (UAVs), Internet of Things (IoT), big data analytics, and artificial intelligence (AI). These technologies enable faster, broader, and more accurate monitoring of fishing vessel activities compared to traditional surveillance methods. Galdelli et al. (2021) stated that the integration of AIS data and SAR imagery significantly improves the detection of suspicious fishing vessels, particularly in remote maritime areas.

Satellite-based technologies have experienced substantial growth in recent years. Kroodsma et al. (2022) explained that satellite radar systems are capable of identifying global longline fishing fleets and detecting vessel activities that were previously invisible to conventional surveillance systems. Their findings revealed that many illegal fishing vessels intentionally operate as "dark vessels" by disabling tracking signals to avoid maritime authorities. This condition indicates that AIS-based monitoring alone is insufficient to effectively combat IUU fishing activities. In addition to satellite technologies, the development of artificial intelligence and machine learning has become a major focus in global maritime surveillance systems. Soldi et al. (2020) argued that the integration of AI and data fusion techniques enables anomaly detection, predictive analytics, and vessel behavior analysis to be conducted automatically. AI technologies can identify suspicious vessel activities by analyzing sailing trajectories, fishing patterns, and behavioral characteristics within specific maritime zones. Furthermore, Mazzarella et al. (2021) demonstrated that deep learning models based on satellite imagery achieve high accuracy in detecting and classifying illegal fishing vessels.

The advancement of these surveillance technologies reflects an ongoing transformation toward smart maritime governance supported by integrated digital ecosystems. Zhang et al. (2024) argued that smart maritime governance extends beyond technological implementation and emphasizes cross-platform data integration, interoperability, cybersecurity, and real-time decision-making systems. Thus, marine surveillance technologies are no longer merely monitoring tools, but have evolved into integrated maritime intelligence systems supporting sustainable marine resource governance. Despite these technological advancements, the implementation of marine surveillance technologies still faces multidimensional challenges. Taconet et al. (2021) explained that AIS-based fishing activity monitoring continues to encounter issues related to data gaps, signal spoofing, and incomplete vessel activity information across global maritime regions. Additionally, many developing countries experience difficulties in adopting advanced surveillance systems due to limited investment capacity, insufficient digital infrastructure, and weak institutional coordination (Fujii et al., 2021). Other emerging challenges include high infrastructure costs, cybersecurity risks, and limited international collaboration in maritime surveillance data sharing (Zhang et al., 2024).

Previous studies have investigated the role of surveillance technologies in combating IUU fishing. However, most existing studies focus on specific technologies separately, such as AIS monitoring, satellite detection, UAV surveillance, or AI-based vessel detection. For instance, Galdelli et al. (2021) primarily examined the integration of AIS and SAR imagery, while Kroodsma et al. (2022) focused on satellite radar applications for global vessel identification. Similarly, Soldi et al. (2020) concentrated on artificial intelligence and data fusion techniques in maritime surveillance systems. These fragmented approaches indicate that the current literature lacks a comprehensive synthesis of marine surveillance technologies within the broader context of combating IUU fishing. Moreover, systematic literature reviews integrating surveillance technologies, artificial intelligence, maritime governance, and the effectiveness of anti-IUU fishing strategies remain limited. Existing review studies have not comprehensively mapped the technological convergence among satellite surveillance, AI-driven

analytics, IoT maritime systems, and smart ocean governance within a unified analytical framework. Meanwhile, the development of maritime surveillance is increasingly moving toward integrated maritime surveillance ecosystems that combine multi-source surveillance data, predictive intelligence, and autonomous monitoring systems (Zhang et al., 2024).

Based on these conditions, an important research gap remains regarding the absence of a comprehensive systematic literature review that examines the development of marine surveillance technologies in combating IUU fishing from the perspectives of technological integration, smart maritime governance, and future surveillance ecosystems. Most previous studies primarily emphasize technical vessel detection aspects, while multidimensional analyses integrating technology, governance, and sustainability perspectives remain limited. Therefore, a systematic literature review is necessary to map research trends, technological developments, implementation challenges, and future directions of maritime monitoring systems supporting sustainable fisheries management. The novelty of this study lies in its attempt to systematically synthesize the development of marine surveillance technologies using a more integrative and multidisciplinary approach. This study not only identifies various surveillance technologies utilized in combating IUU fishing, but also analyzes technological convergence, artificial intelligence integration, data fusion systems, and smart maritime governance in developing integrated maritime surveillance ecosystems. Furthermore, this review maps implementation challenges, future research directions, and strategic implications for sustainable marine governance development in the future.

2. Literature Review

Illegal, Unreported, and Unregulated (IUU) Fishing

Illegal, Unreported, and Unregulated (IUU) fishing has become a multidimensional global issue affecting marine sustainability, economic stability, and international maritime governance. IUU fishing refers to fishing activities that violate national or international fisheries regulations, are not properly reported to authorities, or occur in areas lacking effective fisheries management frameworks. According to Pauly et al. (2021), IUU fishing significantly contributes to global fish stock depletion and undermines long-term marine ecosystem resilience. The increasing sophistication of illegal fishing operations has made traditional monitoring mechanisms insufficient to effectively address transnational maritime crimes.

The impacts of IUU fishing extend beyond ecological degradation. Sumaila et al. (2020) explained that IUU fishing generates substantial economic losses for coastal nations, particularly developing countries that depend heavily on fisheries resources for national income and food security. Furthermore, illegal fishing activities are increasingly associated with organized maritime crimes, including forced labor, human trafficking, and illegal supply chain operations. This situation demonstrates that IUU fishing should not only be viewed as an environmental issue but also as a governance, security, and socioeconomic challenge.

In recent years, scholars have emphasized the need for stronger international cooperation and integrated maritime governance frameworks to combat IUU fishing effectively. Österblom et al. (2020) argued that fragmented institutional arrangements and weak enforcement coordination among maritime authorities continue to limit the effectiveness of anti-IUU fishing policies globally. Therefore, technological innovation and collaborative surveillance systems have become increasingly important in supporting maritime governance and fisheries sustainability.

Marine Surveillance Technologies

Marine surveillance technologies refer to various digital systems and technological infrastructures used to monitor, detect, track, and analyze maritime activities across ocean territories. The rapid development of maritime digitalization has transformed conventional marine surveillance into integrated technology-driven monitoring ecosystems. According to Greidanus et al. (2021), modern marine surveillance systems increasingly combine satellite remote sensing, radar technologies, vessel tracking systems, and artificial intelligence to improve maritime situational awareness.

One of the most widely adopted technologies in maritime monitoring is the Automatic Identification System (AIS). AIS enables vessel identification and trajectory monitoring through real-time transmission signals. However, AIS-based monitoring also faces several limitations, particularly regarding deliberate signal manipulation and vessel identity spoofing. Miller et al. (2022) found that many illegal fishing vessels intentionally disable AIS transponders to evade detection by maritime authorities. This phenomenon creates significant blind spots within maritime monitoring systems and complicates anti-IUU fishing operations.

To overcome these limitations, satellite-based technologies such as Synthetic Aperture Radar (SAR) and optical remote sensing have increasingly been integrated into maritime surveillance operations. Park et al. (2023) explained that SAR technologies are highly effective in detecting vessels regardless of weather conditions and nighttime visibility. Additionally, optical satellite imagery enables high-resolution observation of vessel movement patterns and fishing activities across remote ocean regions. The integration of satellite surveillance technologies with vessel tracking systems has significantly enhanced maritime domain awareness capabilities.

Another emerging technological development is the use of unmanned aerial vehicles (UAVs) and autonomous maritime drones. Riveiro et al. (2021) highlighted that UAV surveillance provides cost-efficient and flexible maritime monitoring capabilities, particularly in coastal and high-risk fisheries areas. UAVs allow authorities to conduct rapid-response surveillance operations while reducing dependence on expensive patrol vessels. Nevertheless, operational limitations such as battery capacity, weather sensitivity, and legal restrictions remain important challenges in UAV deployment.

Artificial Intelligence and Data Fusion in Maritime Surveillance

Artificial intelligence (AI) has emerged as a transformative technology in maritime surveillance systems. AI-based maritime monitoring systems utilize machine learning, deep learning, and predictive analytics to identify suspicious vessel behavior and detect potential illegal fishing activities. According to Raza et al. (2024), machine learning algorithms can analyze vessel trajectory patterns, speed anomalies, and behavioral deviations to identify vessels potentially engaged in illegal fishing activities.

Deep learning techniques have also demonstrated substantial improvements in vessel detection accuracy using satellite imagery. Xu et al. (2022) explained that convolutional neural networks (CNNs) can classify fishing vessels with high precision based on image recognition and spatial pattern analysis. AI-driven maritime surveillance systems are increasingly capable of processing large-scale maritime datasets in real time, thereby supporting faster and more accurate maritime decision-making processes.

In addition to AI technologies, data fusion techniques have become essential components of modern maritime surveillance systems. Data fusion refers to the integration of multiple surveillance data sources such as AIS, radar, satellite imagery, sonar systems, and meteorological data into unified monitoring platforms. Castelluccio et al. (2023) argued that multi-source data fusion significantly improves maritime anomaly detection and operational intelligence capabilities. The integration of

heterogeneous maritime datasets allows surveillance systems to generate more comprehensive situational awareness and reduce false detection rates.

However, AI implementation in maritime surveillance also raises several concerns related to algorithm transparency, data privacy, cybersecurity risks, and technological dependency. Chin et al. (2024) emphasized that the increasing reliance on AI-driven surveillance systems requires stronger digital governance frameworks and cybersecurity protections to prevent misuse, system manipulation, and unauthorized data access within maritime monitoring infrastructures.

Smart Maritime Governance and Sustainable Fisheries Management

The concept of smart maritime governance has emerged alongside the digital transformation of maritime surveillance systems. Smart maritime governance refers to the integration of digital technologies, data-driven decision-making, and collaborative governance mechanisms in managing maritime security and fisheries sustainability. According to Bueger et al. (2022), maritime governance is increasingly shifting toward interconnected surveillance ecosystems that combine technological innovation, institutional coordination, and international collaboration.

Smart maritime governance emphasizes the importance of interoperability among surveillance systems, cross-border information sharing, and collaborative maritime enforcement mechanisms. Hassan et al. (2023) explained that sustainable fisheries management increasingly depends on integrated digital monitoring systems capable of supporting evidence-based maritime policies and adaptive governance strategies.

Furthermore, the integration of marine surveillance technologies within blue economy frameworks has become increasingly important in achieving sustainable development goals (SDGs), particularly SDG 14 concerning life below water. Smart surveillance systems support fisheries sustainability by improving compliance monitoring, reducing illegal fishing activities, and enhancing marine resource conservation. According to Voyer et al. (2021), digital maritime governance plays a strategic role in balancing economic utilization of marine resources with ecological sustainability objectives.

Despite these developments, challenges remain regarding technological inequality, institutional fragmentation, and uneven digital capacities among countries. Developing nations often struggle to adopt advanced surveillance technologies due to financial constraints and limited technological infrastructure. Consequently, the effectiveness of global anti-IUU fishing initiatives remains highly dependent on international cooperation, technology transfer, and capacity-building programs (Bueger et al., 2022).

3. RESEARCH METHOD

A Systematic Literature Review (SLR) approach was used to understand research developments on Marine Surveillance Technology in Combating IUU Fishing. SLR is a systematic, transparent, and replicable research method to identify, evaluate, and synthesize findings from previous research ((Tranfield et al., 2003).

Search Strategy

This Systematic Literature Review (SLR) on "Marine Surveillance Technology" was prepared based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 to ensure a transparent, replicable, and scientifically adequate systematic review (Haddaway et al., 2022). Journal articles were searched using Science Direct, Web of Science, and Google Scholar databases. The keywords used in the journal search were "Marine Surveillance Technology." The inclusion criteria for the selected journals were: a) English language journal articles published between 2015 and 2025; b) Research discussing Marine Surveillance Technology from all aspects; c) Articles selected based on their

relevance to the research title using quantitative and qualitative research methods; d) Articles selected based on their relevance to the research title and inclusion criteria.

Article Selection Process

This process was carried out according to the PRISMA 2020 guidelines, which consist of four main stages: Identification, Screening, Eligibility, and Inclusion. Figure 1 below shows the flow diagram of the PRISMA 2020 search method, as follows: At the identification stage, 135 articles were obtained from Science Direct, Web of Science, and Google Scholar search databases. The keyword used was "Marine Surveillance Technology". At the screening stage, there were 76 articles published between 2015 and 2025. At the eligibility stage, there were 68 articles relevant to the research title. At the inclusion stage, there were 51 research articles on Marine Surveillance Technology that met the inclusion criteria.

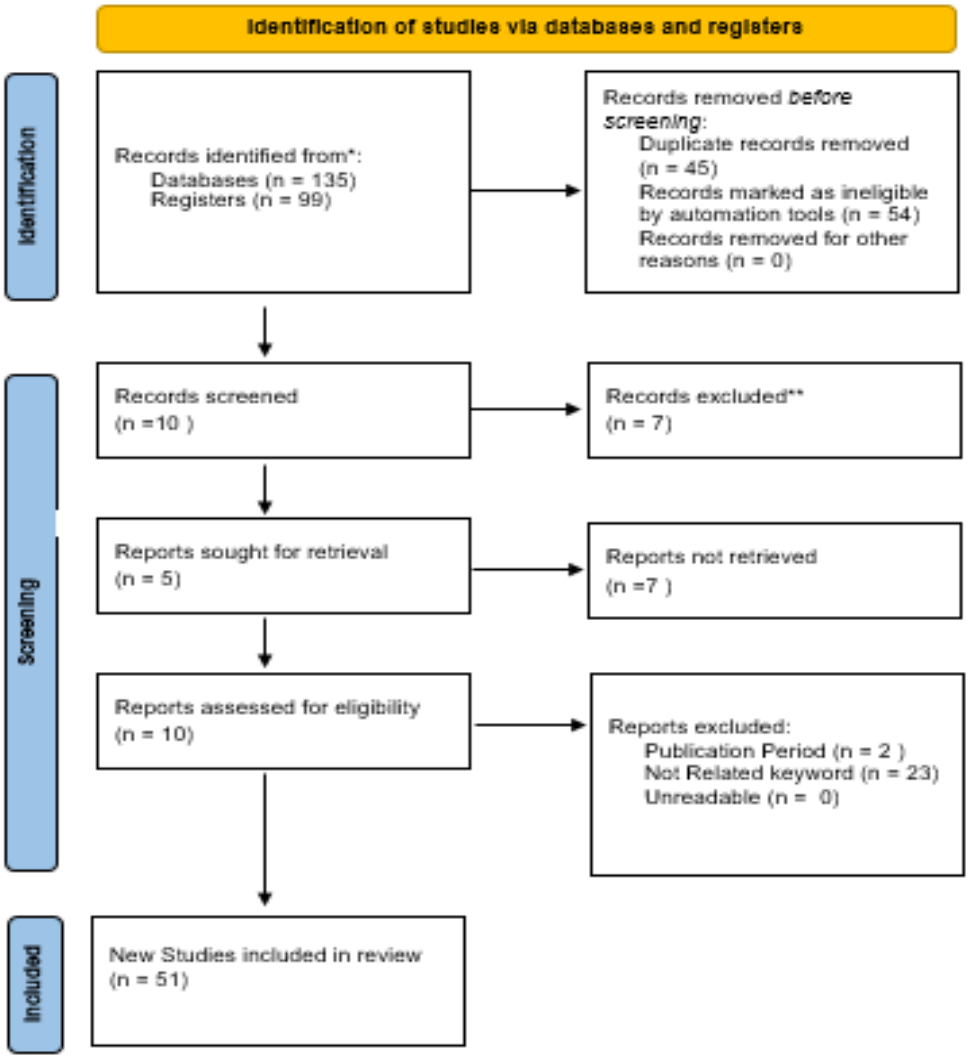

Figure 1. PRISMA (2020) flow diagram of the search method

4. RESULTS AND DISCUSSION

The data generated from this research were obtained from the analysis and summary of articles related to Marine Surveillance Technology, where the search using Science Direct, Web of Science, and Google Scholar based on four stages, namely identification, screening, eligibility, and inclusion, found 51 articles relevant to the research title and meeting the inclusion criteria, suitable for systematic review. The research results are categorized based on four characteristics, namely year of publication, journal index, research subject, and research findings on the topic of Marine Surveillance Technology. The data

obtained on Marine Surveillance Technology based on the research inclusion criteria are presented in Table 1 below.

Table 1. *Analysis Results*

Characteristic	Criteria	Frequency
Year	2015	2
	2016	7
	2017	6
	2018	12
	2019	7
	2020	8
	2021	1
	2022	4
	2023	3
	2024	0
	2025	1
Journal Index	Q1	25
	Q2	26
	Q3	0
	Q4	0
Country	United States (12 journals/23.5%), United Kingdom (10 journals/19.6%), Indonesia (6 journals/11.8%), China (4 journals/7.8%), Australia (3 journals/5.9%), Canada (3 journals/5.9%), Japan, South Korea, Thailand, and France, each contributing 2 journals.	

In this study, researchers used VOSviewer to build and visualize bibliometric networks. This network can include journals, researchers, or individual publications, and can be built based on citation, bibliographic coupling, co-citation, or co-author relationships (Sofyan et al., 2022).. The Overlay visualization explains novelty based on color, meaning the brighter the color, the higher the level of novelty (Merigó et al., 2024).

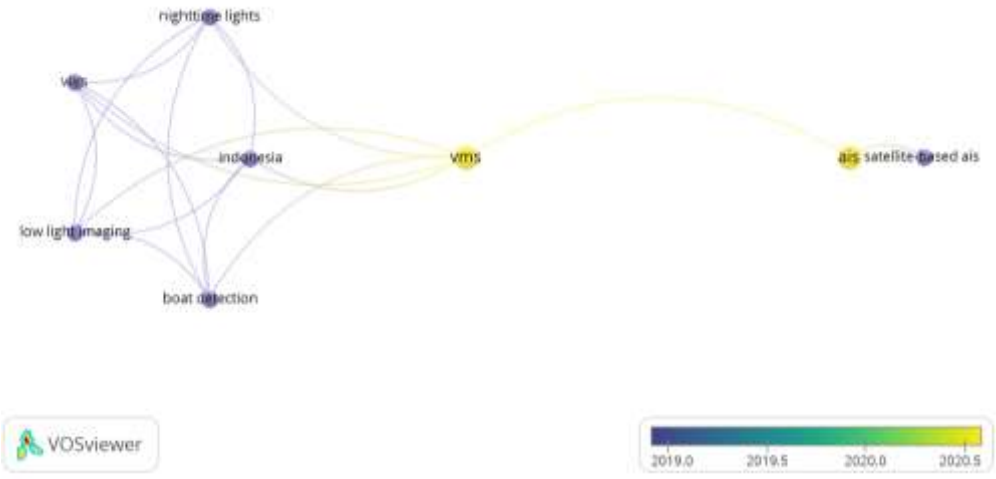

Figure 2. Mapping and Clustering of Research Articles Related to Marine Surveillance Technology

Bibliometric mapping using VOSviewer for the period 2018-2024 revealed significant evolution in the research focus related to the application of marine surveillance technology in efforts to mitigate

Illegal, Unreported, and Unregulated (IUU) Fishing. In the initial phase (2018-2020), research dominance lay in the implementation of signal transmission-based vessel tracking systems, specifically Vessel Monitoring System (VMS) and Automatic Identification System (AIS), aimed at monitoring the position and operational behavior of fishing vessels in real-time. Over time, in the 2020-2024 period, the research trend shifted towards the integration of remote sensing technology and nighttime imaging, as reflected in the emergence of keyword nodes such as *Visible Infrared Imaging Radiometer Suite (VIIRS)*, *low light imaging*, and *boat detection*. The three main nodes VMS, AIS, and VIIRS form the central axis in the literature, interconnected conceptually and technically, and form the foundation for the development of the *Risk-Based Surveillance (RBS)* framework in the context of maritime surveillance.

The relationship between the VMS and AIS nodes forms a yellow cluster, representing a relatively new research group (2020-2022). This cluster reflects the integration of signal transmission-based data for vessel tracking and analysis of cross-border fishing activity patterns, with special emphasis on the use of *satellite-based AIS* to detect suspicious activities in the Exclusive Economic Zone (EEZ) and the development of early warning systems against IUU Fishing practices. On the other hand, the bluish-purple cluster combining the VIIRS, *nighttime lights*, and *boat detection* nodes depicts a research group oriented towards optical satellite imagery and low-light imaging. This cluster is very prominent in empirical studies in the Indonesia region, where VIIRS technology has proven effective in detecting vessels without signals (*dark vessels*) that do not emit AIS or VMS signals, especially during night operations in strategic areas such as the Arafura Sea and WPP NRI 718.

The Indonesia node emerged as an *intermediary node* that functions as a link between the signal-based cluster (VMS/AIS) and the image-based cluster (VIIRS *nighttime lights*). This position indicates that Indonesia serves as a primary empirical locus in Asia-Pacific regional research related to the application of a hybrid marine surveillance approach. Holistically, this bibliometric map indicates the global direction of research is increasingly moving towards multi-source data integration and spatio-temporal analysis to support risk-based fisheries surveillance. These findings substantially reinforce the previous *Systematic Literature Review (SLR)* results, which stated that the synergy of AIS, VMS, and VIIRS technologies, combined with national policies and institutional capacity, is a critical foundation in developing an adaptive and contextual RBS model for the Indonesian fisheries sector

Table 2. List of Most Cited References

No	Year	Author	Article	Citation
1	2018	Fournier, M., Casey Hilliard, R., Rezaee, S., & Pelot, R	Past, present, and future of the satellite-based automatic identification system: Areas of applications (2004–2016)	148
2	2016	Arias, A., & Pressey, R. L.	Combatting illegal, unreported, and unregulated fishing with information: a case of probable illegal fishing in the tropical Eastern Pacific	49
3	2021	Li, J., Cai, Y., Zhang, P., Zhang, Q., Jing, Z., Wu, Q., ... & Chen, Z	Satellite observation of a newly developed light-fishing “hotspot” in the open South China Sea	44

No	Year	Author	Article	Citation
4	2021	Fujii, I., Okochi, Y., & Kawamura, H	Promoting cooperation of monitoring, control, and surveillance of IUU fishing in the Asia-Pacific	37
5	2017	Leonardo, A., & Deeb, N.	Illegal, unreported and unregulated (IUU) Fishing in Indonesia: Problems and solutions	17

Based on a review of 51 articles published between 2015 and 2025, five main publications were found to have received the highest number of citations and become dominant references in Marine Surveillance Technology studies. These five articles represent the evolution and integration of marine surveillance technology. The article with the most significant impact is the research by (Fournier et al., 2018) entitled "Past, Present, and Future of the Satellite-Based Automatic Identification System: Areas of Applications (2004–2016)" which has been cited 148 times. This study is a fundamental reference in the development of AIS as the backbone of vessel activity monitoring technology. Its comprehensive review of the evolution of AIS from a mere navigation tool to an instrument for detecting illegal vessels affirms its position as a technical foundation in surveillance systems to combat IUU Fishing.

The article by (Arias & Pressey, 2016) entitled "Combatting Illegal, Unreported, and Unregulated Fishing with Information: A Case of Probable Illegal Fishing in the Tropical Eastern Pacific" obtained 49 citations. This research emphasizes the paradigm of information transparency and the use of surveillance data as a strategy for detecting IUU Fishing. This information-based approach inspired the development of models integrating AIS data and satellite imagery to improve the effectiveness of cross-jurisdictional maritime monitoring systems.

Research by (Li et al., 2021) entitled "Satellite Observation of a Newly Developed Light-Fishing Hotspot in the Open South China Sea" with 44 citations strengthens the role of satellite remote sensing in fisheries surveillance. This study utilizes optical satellite data to identify new fishing grounds and detect light-fishing activities through spatio-temporal analysis. These findings confirm the operational value of the Visible Infrared Imaging Radiometer Suite (VIIRS) as a complement to AIS in risk-based surveillance systems, especially for detecting vessel activities at night that do not emit AIS signals.

The aspect of regional collaboration was raised by (Fujii et al., 2021) in the article "Promoting Cooperation of Monitoring, Control, and Surveillance of IUU Fishing in the Asia-Pacific" with 37 citations. This study highlights the importance of institutional synergy and cross-border surveillance cooperation in the Asia-Pacific region. The contribution of this research lies in the development of collaborative surveillance strategies relevant to the context of fisheries surveillance in shared waters such as the Arafura Sea and the Indian Ocean.

From a national perspective, (Leonardo & Deeb, 2022) through the article "Illegal, Unreported, and Unregulated (IUU) Fishing in Indonesia: Problems and Solutions" with 17 citations provides a comprehensive analysis of the challenges and solutions for combating IUU Fishing in Indonesia. This study identifies root problems including weak institutional coordination, limited surveillance capacity, and the urgency of improving monitoring technology.

Overall, these five articles reflect the development of marine surveillance technology research from vessel transmission systems (AIS, VMS) towards the integration of satellite data (VIIRS) and big data-

based spatial analysis. The high citation pattern confirms that marine surveillance technology has become a main pillar in building an adaptive, collaborative, and data-based *Risk-Based Surveillance* (RBS) system. These findings strengthen the proposition that the integration between technological innovation, data transparency, and institutional coordination is a strategic direction in strengthening the fisheries surveillance system in Indonesia and the Asia-Pacific region.

Differences, Contradictions, and Debates in Research on Marine Surveillance Technology in Combating IUU Fishing

Research on marine surveillance technology in combating IUU fishing shows rapid development in the last decade, but is marked by significant differences in approach, contradictions in findings, and conceptual debates. Although various studies agree on the urgency of utilizing technology to address the complexity of IUU fishing, there is no consensus on the most optimal paradigm, effectiveness, and integration of technology. In general, debates arise from technical, policy, to implementation aspects.

From a technical perspective, the main difference lies in the effectiveness of AIS (Automatic Identification System)-based monitoring systems versus alternative technologies such as remote sensing satellites and radar. A study by (Fournier et al., 2018) affirms AIS as the backbone of modern surveillance systems, but research by (Welch et al., 2022) reveals that 75% of IUU vessels are not monitored by public AIS, creating a contradiction regarding the reliability of AIS as a single system. On the other hand, studies by (Hsu et al., 2019) and (Longépé et al., 2017) show that the integration of VIIRS and SAR data can detect dark vessels with high accuracy, but this technology is considered unaffordable for many developing countries. Debate also arises regarding AI-based approaches versus conventional methods. (Ewell et al., 2017) and (Chuaysi & Kiattisin, 2020) prove the superiority of machine learning in detecting illegal transshipment patterns (accuracy >97%), while studies by (Doumbouya et al., 2017) and (Dirhamsyah et al., 2022) emphasize that over-reliance on AI can ignore local context and result in false alarms in areas with limited data.

From the aspect of policy and governance, there is a polarization between top-down technology-based approaches and participatory bottom-up approaches. Research such as (Bundy et al., 2016) and (Bellmann et al., 2016) emphasizes the importance of global regulation and centralized risk-based surveillance systems. In addition, the debate regarding system interoperability is also prominent. (Fujii et al., 2021) calls for the harmonization of MCS (Monitoring, Control, and Surveillance) systems across countries.

At the methodological level, significant differences are seen in big data-based quantitative approaches versus contextual qualitative approaches. Most studies such as (Dunn et al., 2018) rely on global AIS big data analysis, but (Mackay et al., 2020), criticize this by showing that only 17% of IUU fishing literature is based on primary data, potentially ignoring human dimensions and organized crime. Inconsistency in measuring IUU risk variables also complicates comparison between studies. For example, research by (Richardson et al., 2018) uses environmental parameters (SST, chlorophyll) for risk modeling.

Contradictions also arise in the evaluation of technology effectiveness in various geographical contexts. A study by (Oozeki et al., 2018) in Japan reported a 20% reduction in violations thanks to real-time VMS integration, while (Doumbouya et al., 2017) in West Africa highlights the failure of the MCS system due to funding and human resource limitations. These findings indicate that the success of surveillance technology is highly dependent on local infrastructure and capacity factors, so a "one-size-fits-all" approach cannot be applied. On the other hand, the debate regarding technology affordability versus sophistication continues. (He & Suuronen, 2018), propose intelligent systems based on IoT and

AI, while (Gremillet et al., 2015) and (Edyvane & Penny, 2017), recommend low-cost solutions such as seabird bio-indicators and "ghost nets" monitoring that are more applicable in remote areas.

Overall, research on IUU fishing surveillance technology from 2014 to 2024 faces paradigm fragmentation, methodological inconsistency, and contradictory findings across regions. An integrative approach that combines cutting-edge technology (such as AI and multi-source data fusion) with socio-economic considerations, institutional capacity, and community participation is needed to build a contextual and sustainable RBS system. Without reconciliation of these differences, maritime surveillance policies risk ignoring the multidimensional and cross-disciplinary root causes of IUU fishing.

5. CONCLUSION

The results of the Systematic Literature Review (SLR) on Marine Surveillance Technology in Combating IUU Fishing for the 2015-2025 period show that the technological approach has evolved from single monitoring systems towards complex multi-technology integration. This study reveals that key technologies such as Automatic Identification System (AIS), Vessel Monitoring System (VMS), and Visible Infrared Imaging Radiometer Suite (VIIRS) have formed the foundation of increasingly sophisticated risk-based surveillance (RBS) systems.

Thematically, research has evolved from a purely technical focus towards a holistic approach that combines technological, policy, and governance aspects. The main findings show that the effectiveness of surveillance technology is highly dependent on the implementation context, where factors of institutional capacity, infrastructure availability, and community participation become crucial determinants of success. The high citation pattern of fundamental works such as (Fournier et al., 2018) and (Arias & Pressey, 2016) confirms the importance of a strong theoretical foundation in the development of modern surveillance systems.

From a methodological perspective, the dominance of big data-based quantitative approaches and machine learning has contributed significantly to the detection of IUU fishing patterns, but there are still limitations in integrating socio-economic dimensions and local context. Differences in risk variable measurement and inconsistency in the operational definition of RBS systems pose challenges in comparing research results across regions.

Implications

This Systematic Literature Review study provides three main implications:

First, from a theoretical perspective, these findings reinforce the need for an integrated conceptual framework that combines technological innovation, institutional theory, and collaborative governance in understanding the effectiveness of marine surveillance systems. This multidisciplinary approach emphasizes that the success of combating IUU fishing depends not only on technological sophistication but also on policy harmonization and institutional capacity.

Second, from a practical perspective, the study results emphasize the importance of an adaptive technology deployment approach that considers the specific conditions of each region. The integration of high-cost technologies (such as SAR and AI) with low-cost solutions (such as community-based monitoring) has proven to be more sustainable in the context of developing countries with limited resources.

Third, from a policy perspective, governments need to develop regulatory frameworks that support system interoperability, cross-agency data sharing, and human resource capacity building. Surveillance policies must balance technocratic approaches with the socio-economic considerations of coastal communities.

Recommendations

Based on the analysis results, further research is recommended to:

a. Develop integrative models that combine multi-source data fusion (AIS, VMS, VIIRS, SAR) with spatio-temporal risk analysis to create more accurate early warning systems.
b. Apply mixed-methods approaches that blend big data analysis with in-depth qualitative research to understand the human and institutional dimensions in surveillance systems.
c. Expand studies to the context of developing countries with specific geographical characteristics and institutional capacities, so that research findings are more relevant and applicable.
d. Develop standardized Risk-Based Surveillance indicators that encompass technological, ecological, socio-economic, and institutional dimensions to improve consistency and comparability between studies.
e. Increase research on effective collaborative governance models for cross-border surveillance, considering geopolitical aspects and the national interests of each country.
f. By implementing these recommendations, it is hoped that the development of marine surveillance technology can contribute more significantly to comprehensive and sustainable IUU fishing eradication.

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