Internasional Journal of Integrative Sciences (IJIS)
Vol.5, No.4, 2026: 565-572

Strengthening Maritime Surveillance: the Utilization of Unmanned Aircraft from KRI Sigma Class to Prevent Illegal Fishing Activities in the Sulawesi Sea

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A R T I C L E I N F O

Keywords: Maritime Surveillance, Unmanned aircraft, KRI Class Sigma, Illegal Fishing, Sulawesi Sea

Received : 4 February 2026
Revised : 20 March 2026
Accepted: 21 April 2026

A B S T R A C T

The Sulawesi Sea is a strategically important maritime area for Indonesia, rich in fishery resources but vulnerable to illegal, unreported, and unregulated (IUU) fishing due to intense cross-border activities. This study explores the use of unmanned aerial vehicles (UAVs) operated from KRI Sigma Class vessels to enhance maritime surveillance and law enforcement. Using a qualitative descriptive approach, the research draws on Navy doctrines, policy documents, operational reports, academic literature, and field experiences. Findings indicate that integrating UAVs with KRI Sigma Class ships significantly extends surveillance range, improves early detection, and delivers real-time visual data to command systems. This enhances the speed and accuracy of decision-making while reducing fuel consumption, operational wear, and risks associated with traditional patrols. However, challenges remain, including limited UAV and sensor capabilities, harsh maritime environmental conditions, and the need for ongoing operator training and certification. The study concludes that a comprehensive strategy—covering platform standardization, improved communication interoperability, human resource development, and clearer operational regulations—is essential to maximize UAV effectiveness as a force multiplier against illegal fishing

INTRODUCTION

Indonesia's position as an archipelagic country makes national interests in the marine sector very prominent, both in the form of sovereignty enforcement, maintenance of marine security, and the protection of fish resources and coastal ecosystems. Within this framework, the Sulawesi Sea occupies an important position because it is also a border area with other countries, part of international shipping lanes, and fishing areas with high economic value. This combination of characteristics makes the Sulawesi Sea a space that is prone to illegal, unreported, and unregulated (IUU) fishing practices carried out by foreign and domestic vessels that do not comply with the provisions of fisheries licensing and management.

Various studies and empirical reports show that IUU fishing activities in the Sulawesi Sea cause significant economic losses, threaten the sustainability of fish stocks, and have the potential to cause cross-border friction that has an impact on the stability of maritime security in the region. On the other hand, illegal fishing perpetrators take advantage of the vast area of waters, limited sensor range, and coordination gaps between law enforcement agencies to avoid detection and prosecution. Adaptive operating patterns, including the use of relatively small vessels, rapid changes in fishing areas, and the tendency to operate at night, further complicate vessel patrol-based surveillance.

The Indonesian Navy, as the main component of the country's defense at sea, has direct responsibility for the enforcement of sovereignty and law enforcement in Indonesia's territorial waters. The KRI Sigma Class is one of the main elements that has been used in maritime security operations, including countermeasures against illegal fishing in the Sulawesi Sea. The ship has adequate combat capabilities and sensor systems, but still faces limitations in terms of observation range, operational durability, and the need to perform multiple tasks at once in a single assignment. In the context of a large area of operation and rapidly changing threat dynamics, conventional patrol patterns have the potential to leave surveillance loopholes that can be exploited by IUU fishing actors.

The development of defense technology, especially in the field of unmanned systems, opens up opportunities for the use of unmanned aerial vehicles (UAVs) as a leverage (force multiplier) for surface elements. In maritime operations, UAVs can be used to carry out reconnaissance, observation of large areas, and real-time data collection that can be integrated into the ship's command and control systems. The integration of UAVs with the KRI Sigma Class has the potential to change the geometry of surveillance by expanding the scope of surveillance beyond radar and visual line of sight, increasing maritime domain awareness, and accelerating the detection-identification-interception cycle of vessels suspected of illegal fishing.

Nevertheless, the use of UAVs in marine security operations is inseparable from challenges. The technical limitations of the rides, the influence of the weather, the need for supporting infrastructure, and the human resource aspect require careful planning and a clear conceptual framework. In addition, the use of UAVs for the purposes of fisheries law enforcement must also be in line with

Indonesia's national legal framework and international obligations, including related to the use of data and visual recordings as evidence.

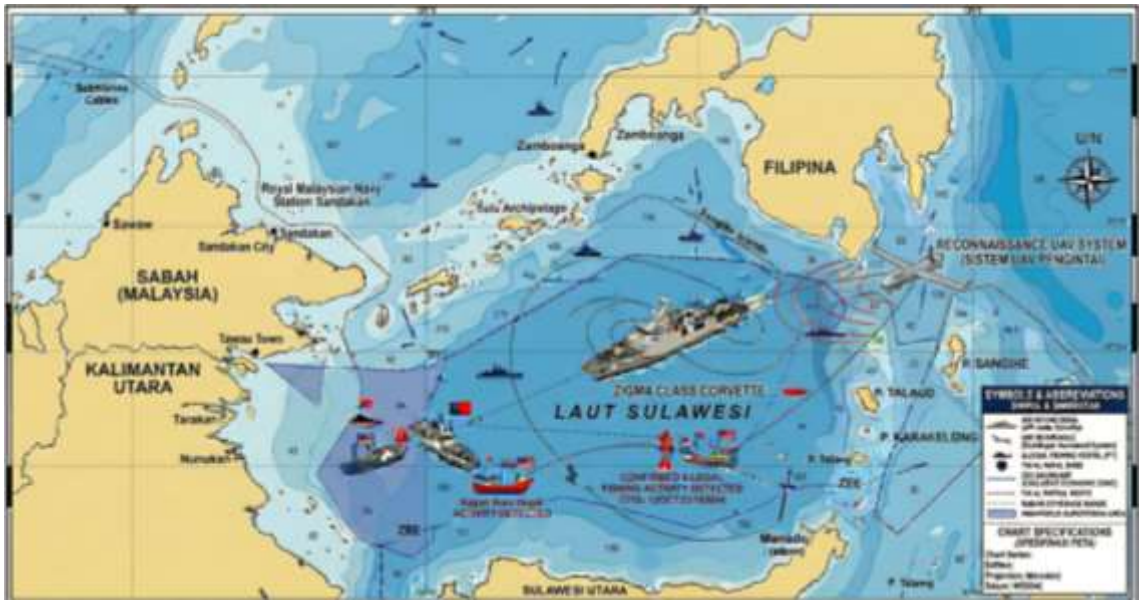

Figure 1. The Use of Unmanned Aircraft at KRI Klas Sigama to Prevent Illegal Fishing Activities in the Sulawesi Sea.
Source: Author's Processed Results, 2026

Departing from the above background, this article aims to formulate the conception of the use of UAVs operated from the KRI Sigma Class in the context of preventing illegal fishing activities in the Sulawesi Sea. In particular, this article analyzes the operational challenges of surveillance in the Sulawesi Sea, the added value provided by UAVs to the operation of the KRI Sigma Class, various technical and institutional limitations faced, as well as the need to develop operational concepts and supporting capabilities so that the use of UAVs can take place effectively and sustainably.

LITERATURE REVIEW

The issue of maritime surveillance and illegal fishing in Indonesia cannot be separated from the broader concept of sea power and maritime governance. highlights that Indonesia, as an archipelagic state, requires strong maritime control to safeguard sovereignty and marine resources. According to Marsetio (2024), sea power in the Indo-Pacific era emphasizes not only naval strength but also the integration of surveillance technologies to maintain maritime security. This aligns with Muhamad Ali (2021), who argues that naval capability development must support law enforcement and resource protection in national waters.

From a governance perspective, Dahuri (1996) emphasizes the importance of integrated coastal and marine resource management, where surveillance plays a key role in ensuring sustainability. Similarly, Djalal (1979) underlines the legal dimension of maritime boundaries and sovereignty, which becomes crucial in addressing cross-border illegal fishing activities. Buntoro (2012) further explains

that Indonesia's Archipelagic Sea Lanes (ALKI) create both opportunities and vulnerabilities, particularly in monitoring dense international maritime traffic.

Technological advancement, especially in unmanned systems, has become increasingly relevant in maritime operations. Prasetyo and Widodo (2020) demonstrate that unmanned aerial vehicles (UAVs) significantly enhance maritime domain awareness by extending surveillance range and enabling real-time monitoring. This is consistent with the concept of Network Centric Warfare proposed by Alberts et al. (1999), which highlights the strategic advantage of information superiority through integrated communication and sensor systems.

Methodologically, this study adopts a qualitative descriptive approach, following Sugiyono (2021), which allows for in-depth analysis of operational concepts, policies, and field experiences. Additional methodological support from Creswell (as cited in the article) reinforces the importance of thematic analysis in understanding complex defense and security issues.

Overall, existing literature indicates that strengthening maritime surveillance requires a combination of naval capability, legal frameworks, and advanced technology integration. However, gaps remain in the operationalization of UAV systems within naval platforms, particularly in addressing technical, environmental, and human resource challenges. This study contributes by bridging these gaps through a focused analysis of UAV utilization on KRI Sigma Class vessels in combating illegal fishing in the Sulawesi Sea.

METHODS

This study uses a descriptive qualitative approach aimed at formulating the conception of the use of ship-based UAVs in illegal fishing countermeasures. The main unit of analysis is the integration of UAV capabilities with the KRI Sigma Class operated in the Sulawesi Sea, seen from a doctrinal, technical, and operational perspective.

The research data is sourced from several categories. First, official documents of the Indonesian Navy, including doctrines, policies, and implementation instructions related to maritime security operations and the use of air elements. Second, national policies and regulations in the field of marine and fishery resource management, as well as law enforcement against IUU fishing. Third, the report on operations and the results of marine surveillance which contains information about illegal fishing incidents in the Sulawesi Sea. Fourth, academic literature that discusses the theory of sea power, the management of coastal and marine areas, and the use of unmanned systems in the context of maritime security. Fifth, field experience and research findings documented in the author's Taskap on the conception of UAV utilization in KRI Class Sigma.

Data processing is carried out through the stages of reduction, presentation, and drawing conclusions. In the reduction stage, the data is encoded and grouped into themes such as the operational effectiveness of UAVs, advantages over conventional patrols, technical and operational constraints, and the need for integration of maritime surveillance systems. Data that are not directly related to the focus of the research are set aside so that the analysis can be carried out in a

more targeted manner. The data presentation stage is carried out in the form of narrative descriptions and conceptual matrices that facilitate the identification of patterns, relationships, and tendencies of findings.

One of the analysis tools used is the SWOT matrix to map the internal strengths and weaknesses of the use of UAVs in the KRI Sigma Class, as well as opportunities and external threats in the Sulawesi Sea operating environment. Through this analysis, a comprehensive picture of the current position of capabilities and future development needs is prepared. The validity of the findings is supported through triangulation of sources, i.e. by comparing information from doctrinal documents, policies, operations reports, academic literature, and documented field experience.

RESULTS AND DISCUSSION

Operational Challenges in Countering Illegal Fishing in the Sulawesi Sea

The experience of operations in the Sulawesi Sea shows that illegal fishing perpetrators take advantage of the vast area of waters, the distance from the base, and the density of shipping activities to disguise their illegal fishing activities. The perpetrator's vessels often take advantage of areas that are relatively rarely reached by patrols, operate at certain hours, and change locations quickly to avoid detection. This condition demands the presence of a surveillance element that is able to provide wide coverage and more persistent monitoring than the surface patrol pattern alone.

The KRI Sigma Class, as the main element of the Indonesian Navy, has quite good radar sensor capabilities and command and control systems, but is still limited by sensor line of sight, fuel endurance, and personnel fatigue factors. In operations in the Sulawesi Sea, ships must divide their attention between surveillance duties, law enforcement, training and other duties that are assigned. This has the potential to create a surveillance gap that can be exploited by IUU fishing vessels, especially in areas that are far from the ship's position or are beyond the range of surface sensors.

Added Value of UAVs Based on KRI Sigma Class

The integration of UAVs into KRI Class Sigma operations changed the maritime surveillance pattern by adding vertical dimensions and expanding the scope of observations. UAVs equipped with electro-optical and infrared sensors can be placed at a certain altitude to search and track targets over a wider area than the ship's visual observation and radar capabilities. The resulting imagery and video can be sent in real-time to the ship's combat information center so that element commanders get a more complete and up to date picture of the situation.

The use of UAVs as a forward scout element allows KRI to prioritize maneuvers to contacts that have indications of violations, so that ship movements become more efficient. The ship does not need to physically comb through the entire sector; instead, UAVs are used to screen areas that need further inspection. This has an impact on fuel savings, reduced platform wear, and more effective utilization of operating time. In addition, the ability of UAVs

to visually record vessel activity provides important support for the evidentiary process in law enforcement against illegal fishing.

Technical, Organizational, and Legal Limitations

Behind these advantages, the use of UAVs is also faced with various limitations. From a technical perspective, flight endurance, sensor payload capacity, resistance to adverse weather conditions, and bandwidth limitations for data transmission affect the pattern of use of UAVs on the high seas. In conditions of strong winds, heavy rain, or high waves, UAV operations become riskier, and the quality of the data obtained may decrease.

From the organizational and human resource aspects, the successful use of UAVs is highly dependent on the availability of trained personnel as pilots, sensor operators, and data analysts. UAV operations are not only a matter of controlling vehicles, but also the ability to read tactical situations, interpret images, and relate findings to illegal fishing operating patterns. This requires structured education, training, and certification programs, as well as integrated exercises between UAV units and KRI elements to build interoperability and solid work patterns.

In terms of law and regulations, the use of UAVs for fisheries law enforcement requires clarity in the regulatory framework, especially regarding the status of video and image recordings as evidence, data storage and security procedures, and coordination procedures with other law enforcement agencies. Without an adequate regulatory umbrella, the use of UAVs has the potential to raise juridical debates, although technically capable of providing very useful information in the field.

Conception of Utilization and Direction of Capability Development

Based on the above analysis, the conception of the use of UAVs from the KRI Sigma Class for the prevention of illegal fishing in the Sulawesi Sea needs to contain at least three main dimensions. First, at the tactical level, UAVs must be integrated in a layered surveillance design that incorporates ship sensors, UAV patrol patterns, and information from land-based maritime surveillance systems. UAV sortie planning needs to take into account priority areas, the movement patterns of the offending vessels, and weather factors so that the scope of supervision is optimal.

Second, at the operational level, it is necessary to develop a fixed procedure that explains the division of roles between the guard team at the platform, the combat information center, and the UAV crew team. This procedure must contain the criteria for launching the UAV, the tasks in the area of operation, the reporting pattern, and the relationship between the information obtained by the UAV and the decision to intercept, pursue, or coordinate with other elements. Thus, the information obtained by the UAV is truly an integral part of the decision-making cycle, not just an additional piece of data.

Third, at the capability development level, the use of UAVs requires standardization of platforms in accordance with the needs of marine operations, strengthening interoperable communication systems, and the availability of adequate logistics and maintenance support on board ships and at bases.

Investment in the aspect of human resources, through education, training, and certification, is no less important than the procurement of the vehicles themselves. Without personnel readiness and systemic support, UAVs will only be demonstrative capabilities, not capabilities that make a real and sustained contribution to operations.

This article shows that the integration of drones with the KRI Sigma Class offers a promising approach to strengthening countermeasures against illegal fishing in the Sulawesi Sea. Ship-operated UAVs are able to expand surveillance coverage, improve early detection capabilities, and provide real-time visual information that supports faster and more precise decision-making in law enforcement at sea. The utilization of UAVs also contributes to operational efficiency by reducing the need for physical patrols across sectors and directing KRI only to contacts that have indications of violations.

On the other hand, this article asserts that the success of the utilization of UAVs is determined not only by the availability of the platform but also by the clarity of the operating concept, the readiness of human resources, and adequate regulatory support. The technical limitations of the vehicle, the challenges of the operating environment, the need for operator training and certification, as well as the clarity of the legal framework for the use of UAV data as evidence, are aspects that must be seriously anticipated. Therefore, the development of the concept of UAV utilization in the KRI Sigma Class needs to be directed to full integration with the existing maritime surveillance system, strengthening communication interoperability, and sustainably fostering personnel.

If these three dimensions can be developed in an integrated manner, UAVs operated from the KRI Sigma Class have the potential to become a significant force multiplier in maintaining Indonesia's maritime sovereignty and security, especially in preventing and tackling illegal fishing in the Sulawesi Sea.

CONCLUSIONS AND RECOMMENDATIONS

This study demonstrates that the utilization of unmanned aerial vehicles (UAVs) operated from KRI Sigma Class vessels provides a significant enhancement to maritime surveillance and law enforcement efforts against illegal, unreported, and unregulated (IUU) fishing in the Sulawesi Sea. The integration of UAVs extends the surveillance range beyond conventional sensor limitations, improves early detection capabilities, and enables the delivery of real-time visual information to command and control systems. As a result, decision-making processes become faster, more accurate, and more efficient, while operational costs and risks associated with traditional patrol patterns are reduced.

However, the effectiveness of UAV deployment is not solely determined by technological availability. This study identifies several critical challenges, including technical limitations of UAV platforms and sensors, vulnerability to harsh maritime environmental conditions, and the need for well-trained and certified personnel. In addition, the absence of a comprehensive and clear regulatory framework regarding the operational use of UAVs and the legal status of collected data remains a significant constraint.

Therefore, this study concludes that a holistic and integrated approach is essential to maximize the potential of UAVs as a force multiplier. This includes the standardization of UAV platforms, strengthening communication interoperability, enhancing human resource capacity through continuous training and certification, and developing clear operational and legal frameworks. By addressing these aspects in a coordinated manner, UAVs operated from KRI Sigma Class vessels can play a crucial role in strengthening Indonesia's maritime security and effectively combating illegal fishing in the Sulawesi Sea.

FURTHER STUDY

This study still has limitations, so further research on Strengthening Maritime Surveillance: The Utilization of Unmanned Aircraft from KRI Sigma Class to Prevent Illegal Fishing is needed to refine this study and enhance the insights of readers and the authors.

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