Analysis of the Effectiveness of Radar and Drone Technology in Countering Maritime Security Threats: A Literature Review

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Abstract
Purpose: This study aims to analyze the effectiveness of the use of radar and drone technology in counteracting maritime security threats in Indonesia. The main focus is directed at the extent to which the two technologies can complement each other, the implementation obstacles faced, and strategic solutions to improve marine surveillance.

Methodology/approach: This study uses secondary data collected from various sources of literature, institutional regulations, and the results of previous studies relevant to law enforcement in Indonesian waters. The data is analyzed qualitatively and presented descriptively.

Results/findings: The main challenges of Indonesia's maritime security include the area of the sea that is difficult to reach, weak surveillance, and the development of various forms of threats such as smuggling and border violations. Radars and drones have great potential in detecting and monitoring illegal activities at sea. However, challenges such as limited reach, technical capabilities, human resources, and suboptimal integration between institutions are still the main obstacles. Therefore, it is necessary to modernize equipment, train personnel, and improve coordination between maritime institutions.

Conclusions: The study concludes that integrating radar and drone technologies significantly enhances Indonesia's maritime security. Radar ensures wide detection coverage, while drones provide real-time monitoring and flexibility. Yet, limited infrastructure and coordination reduce effectiveness. Strengthening technology, training, and interagency collaboration is essential to improve maritime defense efficiency and responsiveness.

Limitations: Lies in an approach that uses only secondary data, without the support of live interviews or field data. For this reason, follow-up studies are recommended to involve primary data from institutions such as the Indonesian Navy and Bakamla.

Contribution: Future research is also expected to explore other supporting technologies, such as surveillance satellites and AI, as well as examine regulatory and policy factors in more depth.

Keywords: *Drones, Maritime Security, Radar*

How to Cite: Sugiharto, B. (2025). Analysis of the Effectiveness of Radar and Drone Technology in Countering Maritime Security Threats: A Literature Review. *Jurnal Studi Ilmu Sosial dan Politik,* 5(2) 231-243.

1. Introduction

Indonesia is the world's largest archipelagic nation, possessing an extensive maritime territory of approximately 6.4 million square kilometers and comprising more than 17,000 islands. This vast maritime area serves as a source of natural wealth, such as fisheries and various other marine resources, and represents a strategic route for international trade. This unique geographical condition makes

maritime security critically important for safeguarding national sovereignty, supporting the welfare of coastal communities, and preserving marine resources. However, despite its enormous potential, Indonesia faces various challenges in securing its territorial waters from illegal fishing. The Indonesian Maritime Security Agency (Bakamla RI) reported in 2023 that maritime threats are highly diverse, ranging from illegal fishing, drug smuggling, human trafficking, and territorial violations by foreign vessels that infringe on Indonesia's sovereignty. These threats not only cause significant economic losses but also pose substantial risks to public safety and national security.

According to data from the Ministry of Marine Affairs and Fisheries, thousands of illegal fishing cases occurred in Indonesian waters in 2024. The economic losses from these activities are estimated to reach trillions of rupiah annually. Additionally, the Indonesian Directorate General of Customs and Excise reported in 2024 that most narcotics entering Indonesia are transported via sea routes, indicating that maritime zones have become major entry points for transnational criminal activities. These crimes require continuous and effective maritime surveillance and security measures. In this context, the Indonesian Navy (TNI AL) plays a central role as the frontline force responsible for maritime defence and security. However, monitoring such vast sea areas is not easy. Patrol vessels alone are insufficient to ensure maximum surveillance, especially given Indonesia's expansive maritime territory and its numerous hard-to-reach areas. Consequently, the TNI AL and related agencies have begun adopting advanced technologies to strengthen maritime security operations (Pramono & Safarini, 2022).

Radar systems and drones (unmanned aerial Vehicles/UAVs) have gained particular attention. Radar has long been a vital tool in maritime surveillance because of its capability to detect vessels and other objects within a certain radius in real time, even under poor weather conditions and at long distances (Wang & Li, 2023). Drones offer advantages in terms of direct visual monitoring, aerial imaging, and patrol capabilities in areas that are difficult for patrol vessels to reach. The use of drones in the maritime sector continues to develop, especially with the emergence of medium-altitude long-endurance (MALE) UAVs capable of extended flight durations and wide-area coverage (Rezeki, Rani, & Syahputra, 2023; Winkler, Butler, Attwood, Mann, & Potts, 2022). Radar enables the real-time detection and monitoring of vessels, whereas drones provide flexible situational awareness in remote or high-risk areas. A study by S. E. Putri and Hukul (2024) indicates that drones significantly enhance the effectiveness of detecting illegal activities at sea (Chairani & Adi Pradana, 2022).

However, the implementation of these technologies is challenging. One of the main issues is the limited communication infrastructure and regulatory frameworks that do not fully support drone operations in maritime zones (Qurani & Mulyono, 2025). Furthermore, the lack of integration between radar systems and drones reduces the overall effectiveness of the surveillance efforts. Rosyida, Sutanto, and Prakoso (2024) highlighted challenges such as limited drone battery endurance and flight regulations that restrict broader implementation. Nevertheless, the combined use of drones and radar offers a synergy that can significantly improve the effectiveness of maritime monitoring. Radar can detect suspicious vessels from afar, after which drones can be deployed to obtain real-time visual confirmation, enabling faster and more accurate decision-making (D. F. E. Putri, Prakoso, & Astaryadi, 2024). Despite these advantages, several obstacles remain, including technical issues, regulatory constraints, and limitations in human resources trained to operate advanced systems.

Another major challenge is the regulatory framework governing drone operations in Indonesian airspace, which still requires alignment to better support maritime security missions (Firaldi, Wibisono, Ngaliman, Indrayani, & Satriawan, 2023). In addition, poor data integration among radar systems, drones, and other surveillance platforms results in suboptimal monitoring (Setiawan, 2025). Equally important is the need to enhance the technical capacity of TNI AL personnel and other agencies to operate these advanced technologies, including data analysis and rapid response to detected threats. Beyond technological and personnel issues, overlapping jurisdiction among institutions operating in maritime areas is a significant challenge.

Indonesia has multiple agencies responsible for maritime security, such as TNI AL, Bakamla, the National Police, the Ministry of Marine Affairs and Fisheries, Customs, and the Ministry of Transportation. However, coordination among these institutions has yet to function optimally, leading to the duplication of duties, inefficient budgeting, and weakened responses to security incidents (Kadar, 2015). Furthermore, Aryani (2021) notes that the absence of an effective unified command center is a key factor in weak enforcement and monitoring efforts at sea. This slows down decision-making processes and creates inefficiencies in resource allocations. These conditions highlight the need for better integration of radar technology, drones, and command systems to accelerate information flow and inter-agency coordination.

Various studies also stress the importance of modernizing the Indonesian Navy's defense systems, particularly radar and drone technologies, to enable wider coverage and provide accurate real-time data (Batubara, Gultom, & Bura, 2020; Jamilah & Disemadi, 2020). With proper and integrated technologies, the TNI AL's capability to detect and counter maritime security threats can be significantly strengthened. This aligns with the Navy's modernization vision, which places technology as one of the main pillars of safeguarding Indonesia's maritime sovereignty. This study aims to analyze the effectiveness of radar and drone technologies in countering maritime security threats in Indonesia. This study focuses on examining how these technologies complement each other, identifying challenges in their implementation, and outlining potential solutions to enhance the effectiveness of maritime surveillance.

2. Literature Review
2.1 Radar
Radar, an acronym for Radio Detection and Ranging, is a technology used to detect, measure the distance, position, and movement of an object by utilizing electromagnetic waves. This technology plays a vital role in maritime operations, defense systems, and air and sea navigation. According to (Wen, Wei, & Lu, 2022), radar functions by transmitting electromagnetic waves into the surrounding environment. These waves are reflected when they strike an object, and the reflections are analyzed to determine the position, distance, and characteristics of the object. Through this mechanism, radar provides real-time situational awareness, even under low-visibility conditions, such as dense fog or nighttime operations.

This capability is crucial for maritime security, particularly for detecting foreign vessels, illegal activities, or other threats within Indonesian waters. Rangkuti, Pranata, and Ishak (2022) further emphasized that radar is no longer limited to detection alone but has evolved through integration with digital technologies, such as the Internet of Things (IoT). Through such integration, radar systems can operate automatically and become part of a broader and more intelligent monitoring system. This advancement enables radar to deliver faster and more accurate information for maritime surveillance, especially for institutions such as the Indonesian Navy (TNI AL) and the Indonesian Maritime Security Agency (Bakamla), which are responsible for safeguarding Indonesia's territorial waters.

Similarly, Petrovic et al. (2021) reiterated that radar technology has progressed toward automated and interconnected digital systems. The integration of radar with IoT-based platforms enhances its capability to operate within wider monitoring networks, thereby improving the real-time surveillance accuracy and efficiency of maritime security operations. Furthermore, Rina, Bungin, and Ilham (2023) highlight that radar is an essential navigational tool onboard ships. Its operation enables vessels to avoid collisions, identify their surrounding objects, and anticipate weather conditions. Under conditions such as darkness or fog, radar is the only instrument capable of providing reliable information on nearby objects. Consequently, proficiency in radar operation and proper maintenance are fundamental requirements for ship crews and maritime institutions.

In the development of modern defense technologies, radar has become a key component of detection and surveillance systems. Guo, Wang, and Guo (2024), explain that radar technology operates based on

the propagation of electromagnetic waves. Radar systems transmit radio waves that are reflected when they strike an object. The reflected waves were analyzed to determine crucial information, such as the position, distance, and speed of the object. In practice, radar is widely used in various fields, ranging from weather monitoring to search-and-rescue missions and in defense systems for early threat detection. Based on the perspectives of the aforementioned scholars, it can be concluded that radar is a fundamental technology that utilizes electromagnetic waves to detect and monitor objects in diverse environments. Beyond its applications in air and maritime defense, radar has expanded into nonmilitary sectors such as agriculture and disaster mitigation. These developments reflect the flexibility and importance of radar as a strategic decision-support tool, contributing to national security efforts and sustainable development initiatives.

2.2 Drone

Drones, also known as Unmanned Aerial Vehicles (UAVs), represent one of the most rapidly advancing technological innovations of the past few decades. Initially, drones were used primarily in the military sector for reconnaissance missions, allowing surveillance without deploying personnel in dangerous areas. However, over the past five years, drone applications have expanded across various sectors, including agriculture, logistics, geospatial mapping and maritime security. According to Sugiarto, Mulyani, and Nurdin (2020), a drone is an unmanned aircraft controlled remotely through an autopilot system or capable of flying autonomously by utilizing aerodynamic principles to lift its body into the air. The use of drone technology has grown significantly in Indonesia, particularly for capturing visual imagery such as aerial photographs and videos, not only for commercial purposes but also for border monitoring and maritime surveillance.

Raivi, Huda, Alam, and Moh (2023) ote that the term drone originates from the English word for a male bee; however, in technological contexts, it refers to an unmanned aircraft that can be controlled either partially or fully autonomously. This technology has evolved from a simple reconnaissance tool into a complex unmanned aerial system equipped with sensors and intelligent software that can make real-time decisions. In line with this, another study described drones, as components of UAV systems, as aircraft that do not require a pilot onboard because they are controlled externally. This capability makes drones strategic tools for various monitoring activities, especially in environments or conditions that pose risks to human operators (Hossain, 2022). From a more technical perspective, Xu et al. (2025) explained that drones are unmanned aircraft systems designed for industrial and commercial applications. Modern drone technologies are equipped with autonomous navigation features, mapping systems, high-resolution cameras, and real-time data transmission. Within the maritime security context, drones are particularly useful for monitoring illegal activities such as fishing, smuggling, and territorial violations in border areas.

A study by Jahani, Khosravi, Kargar, Ong, and Arisian (2025) highlights that drones have become essential instruments in the logistics and supply chain sector, yet the same technology can be adapted for national security purposes. High maneuverability and access to difficult-to-reach areas are among the main advantages of drones over conventional surveillance methods. Additionally, Krystosik-Gromadzińska (2021) emphasized that drones function as flying robots that can be remotely controlled or operated autonomously using GPS-based navigation systems, sensors, and artificial intelligence-enabled software. In the context of maritime surveillance, these capabilities are highly effective for the rapid and accurate detection of the movement of foreign vessels. Recent research by Kemarau et al. (2024) also demonstrated that drones are no longer used solely for surveillance missions but have become crucial tools for spatial and visual data collection across various social and geospatial research fields. Drone usage in Indonesian waters can provide real-time data on changes in sea conditions, high waves, and early detection of security threats.

Based on the diverse scientific perspectives and findings above, it can be concluded that drones are unmanned aerial technologies with strategic functions in various sectors, including defense and maritime security. Future developments in drone technology are projected to become increasingly sophisticated through the integration of artificial intelligence (AI), rapid data processing, and cross-system communication capabilities. In the context of Indonesia's maritime defense—characterized by

vast territorial waters prone to violations—the systematic utilization of drones can serve as an effective solution to enhance the surveillance capacity, rapid response, and operational efficiency of the Indonesian Navy (TNI AL) in safeguarding national maritime sovereignty.

2.3 Maritime Security

Maritime security is a strategic aspect of maintaining the sovereignty and stability of a nation, particularly in archipelagic states such as Indonesia. This concept encompasses not only protection from physical threats in maritime areas but also economic, legal, environmental, and digital security dimensions. Over the past five years, scholars and researchers from within and outside Indonesia have offered comprehensive perspectives on the importance and scope of maritime security. According to Sugianto, Agussalim, and Armawi (2021), maritime security refers to a condition in which maritime zones remain safe and under control from various disruptions such as illegal fishing, drug smuggling, human trafficking, and other cross-border threats, especially in border areas such as the North Natuna Sea. They emphasize the importance of synergy between maritime defense and security agencies in protecting national maritime integrity and highlight the need for collaborative interagency strategies. This approach demonstrates that maritime security cannot be separated from the broader context of national, political, and military considerations.

Meanwhile, Wahyulianto (2022) explains that maritime security is not solely about physical protection but also involves building robust civil–military relations. In the Indonesian context, he underscores the critical roles of the Maritime Security Agency (Bakamla), Indonesian Navy (TNI AL), and other institutions in forming an efficient, coordinated, and free from overlapping authorities maritime security system (Afriyani, Indrayani, Indrawan, Wibisono, & Ngaliman, 2023). He stressed that weak coordination creates security gaps that can be exploited by illegal actors at sea. From a contemporary perspective, Alam et al. (2024) introduced a new dimension to maritime security studies—cybersecurity. In the era of digitalized defense and navigation systems, Indonesia's maritime infrastructure is highly vulnerable to cyberattacks. They highlight the need for robust data protection and secure communication networks for maritime defense to prevent intrusion by foreign actors and maritime terrorist groups. This shows that the concept of maritime security has evolved from traditional threats to encompass non-traditional forms of threats.

From policy and technological standpoints, Deanto and Marzaman (2024) explain that maritime security is closely tied to the effectiveness of national policies in adapting to advanced technologies. They argue that the use of digital technologies, such as radar, drones, and satellite-based maritime surveillance systems, can significantly enhance early detection capabilities. However, they also emphasize that the greatest challenge lies in developing regulatory frameworks that bridge the gap between technology and maritime security practitioners, preventing legal ambiguities during implementation. Internationally, Leary (2020) defines maritime security as a series of efforts and regulatory frameworks aimed at ensuring the safety of international navigation and preventing all forms of pollution and transnational maritime crimes.

This definition underscores the importance of international collaboration, especially for states with strategic maritime regions such as Indonesia, to promote sustainable maritime security. Based on these diverse perspectives, maritime security can be understood as a multidimensional concept encompassing the protection of maritime territories from all forms of threats, both traditional and modern. This requires an integrated approach that connects policy, technology, and cross-sectoral cooperation (Latunusa, Timuneno, & Fanggidae, 2023). As a maritime nation, Indonesia must develop an adaptive maritime defense ecosystem that combines military strength, law enforcement, advanced surveillance systems, and strong maritime diplomacy at both regional and global levels.

3. Research Methodology

This article is based on the use of secondary data obtained through systematic collection and analysis to generate relevant conclusions that meet the scientific standards. The primary method of secondary data collection involved gathering and reviewing information related to the duties and authorities of government institutions in conducting maritime activities. In addition, supplementary information on

law enforcement issues in Indonesian waters was collected from previous studies and scholarly writings. The analytical process was carried out qualitatively and presented descriptively to illustrate the data, processes, and analytical results that have academic value.

4. Results and Discussion

4.1 Current Issues Related to Maritime Policy in Indonesia

Indonesia's maritime security is a strategic issue that continues to evolve in response to the increasing complexity of threats within its national waters. Over the past five years, various studies have indicated that challenges to maritime security stem not only from traditional threats such as territorial violations and smuggling but also from transnational crimes, cyber threats, and weak inter-agency coordination. Maritime security refers to a condition in which maritime areas remain safe and controlled from various disturbances, such as illegal fishing, drug smuggling, human trafficking, and other cross-border threats, particularly in border regions such as the North Natuna Sea.

Scholars emphasize the importance of synergy between maritime defense and security agencies in safeguarding the integrity of national maritime territories and prioritizing collaborative strategies across institutions. This approach demonstrates that maritime security cannot be separated from the broader national political and military dimensions (Sugianto et al., 2021). Sajidin, Saputra, and Nofiasari (2023) highlight the increasing intensity of transnational crimes in Indonesia's maritime regions, especially in border areas. Their study proposes a strategic approach involving maritime diplomacy, intelligence cooperation, and strengthening legal systems and national maritime institutions. This approach is crucial, given Indonesia's position along international shipping lanes, which are vulnerable to cross-border threats.

In contrast, Hartawan, Pramono, and Yudho (2021) examined the specific role of maritime intelligence in the Sunda Strait. Their research shows that the effectiveness of maritime intelligence contributes significantly to regional security and stability. Data analysis revealed that 89.51% of maritime security conditions were influenced by the activeness and accuracy of intelligence. This finding indicates that enhancing the quality of maritime intelligence is a strategic step in preventing maritime crime. Meanwhile, Praja (2024) focuses on the transformation of Indonesia's maritime policy during the digital era. This study emphasizes the importance of integrating information technology into national maritime security systems. However, it also notes serious challenges, such as limited digital infrastructure in border regions and the lack of professional personnel capable of operating modern devices. This research underscores that maritime security policies responsive to technological advancements must be accompanied by human resource development and adequate budget allocation.

Ali, Prakoso, and Sianturi (2021) discuss the necessity of a comprehensive and integrated maritime defense approach. They stress the need to build a synergistic maritime defense structure in which the Indonesian Navy (TNI AL), Bakamla, and other relevant agencies can operate with optimal coordination. This study emphasizes the importance of inter-agency communication in detecting threats, identifying vulnerabilities, and providing rapid responses to incidents at sea. A final relevant study by Arif and Yanto (2022) highlights the weak implementation of maritime safety and security policies, reflected in the persistently high number of ship accidents and maritime incidents in several regions of Indonesia.

The researchers argue that these issues stem not only from extreme weather conditions but also from inadequate supervision, noncompliance with safety standards, and low awareness among vessel operators regarding maritime regulations. They recommend a comprehensive review of maritime safety regulations and regular training for maritime transportation actors. As the world's largest archipelagic nation, Indonesia has more than 17,000 islands and a coastline of 108,000 km stretching from Sabang to Merauke. This geographical position makes Indonesia a strategic location for international maritime trade routes. However, this advantage also presents significant challenges in maintaining the national maritime security.

1. First Issue: Weak Surveillance and Early Detection Systems in Maritime Areas
    Indonesia's vast maritime territory has not yet been optimally monitored. Many areas remain vulnerable to smuggling, piracy, illegal fishing, and territorial violations by foreign vessels. According to Sajidin et al. (2023), more than 60% of Indonesia's maritime zones are not covered by adequate surveillance systems in terms of technology and personnel.

2. Second Issue: Weak Interagency Synergy Among Maritime Law Enforcement Bodies
    Numerous agencies possess authority at sea, including TNI AL, Bakamla, Polairud, the Ministry of Marine Affairs and Fisheries (KKP), and customs. However, overlapping mandates and limited coordination often result in delayed or ineffective responses to such threats.

3. Third Issue: Limited Technological Infrastructure in Border Regions
    Many coastal and border areas in Indonesia lack access to advanced technologies, such as maritime radar and data connectivity. Consequently, numerous illegal activities go undetected, particularly in regions such as Natuna, Papua waters, and North Maluku (Kristiyanti & Mahendro, 2025).

4. Fourth Issue: Low Human Resource Preparedness
    Many maritime law enforcement personnel are not adequately trained to operate advanced technologies, such as 3D radars, maritime drones, and AI-based surveillance systems. Consequently, sophisticated tools that are available often remain underutilized (Hartawan et al., 2021).

5. Fifth Issue: Cyber Threats to Maritime Technology Systems
    The use of digital technologies in radar and drone systems introduces new vulnerabilities to cyberattacks on these systems. Hacked surveillance systems can lead to stolen or sabotaged data. According to Deanto and Marzaman (2024), 40% of Indonesia's maritime security systems lack adequate cybersecurity protection.

4.2 Use of Drones in Maritime Security

In the past five years, the use of drones or Unmanned Aerial Vehicles (UAVs) has become an integral part of efforts to strengthen Indonesia's maritime security. Numerous studies published in SINTA-indexed journals indicate that this technology holds significant potential for supporting surveillance across vast and complex maritime areas. One study by Kurnianto, Guyana, and Widiarto (2024) highlighted the effectiveness of drones in detecting illegal fishing activities in Indonesian waters. Their research found that drones can enhance the detection of illegal vessels with high speed and accuracy, while also providing real-time data that supports law enforcement at sea. However, challenges such as limited battery endurance, flight regulations, and operational costs remain obstacles to their wider implementation. Zafirawan et al. (2024) discuss the role of drone technology in enhancing Indonesia's maritime defense. Their study showed that drones can be used for effective maritime surveillance, rapid responses to threats, search and rescue operations, and protection of maritime infrastructure.

In the context of tensions in the South China Sea, Permatasari, Risdhianto, and Almubaroq (2024) explored the potential of autonomous vehicles, including drones, as transformational solutions to improve maritime security. Their study emphasized how autonomous systems can optimize border surveillance, ensure continuous monitoring, and reduce operational risks for personnel. However, the implementation of drones in Indonesia faces several challenges. Kristiyanti and Mahendro (2025) noted that limitations in communication infrastructure affect the stability of connections and data transmission from drones to control centers. In addition, underdeveloped regulations hinder the utilization of drones for maritime security. Regulatory frameworks are required to ensure that drones are used safely and effectively.

To support maritime security operations, Hartanto, Sulistyo, and Adi (2022)merancang dan designed and developed solar-powered drones capable of conducting extended surveillance missions. These drones are engineered to support maritime security operations by utilizing solar energy, enabling continuous flight during daylight as long as sunlight remains available. Overall, these studies show that the use of drones in Indonesia's maritime security possesses great potential, but also faces challenges that require attention through technology development, supportive regulations, and enhanced human resource capacity. One of the main issues is the limited infrastructure and communication networks

across Indonesia's vast and dispersed maritime region. Many maritime areas lack stable data connectivity, making real-time data transmission from drones to command centers unreliable and difficult. Kristiyanti and Mahendro (2025) confirmed that weak communication infrastructure is a major barrier to maximizing drone utilization for maritime security.

In addition, the operational endurance of the drones remains a challenge. Most commercial drones can only operate for 30–90 min per flight, making them inefficient for monitoring large maritime zones. Hartanto et al. (2022) argue that solar-powered drones may serve as an alternative solution, but such technology is still in the development stage and has not been widely adopted by maritime security institutions such as the Indonesian Navy (TNI AL). From a regulatory perspective, the absence of a clear and structured legal framework for drone use in maritime security poses a serious issue. Many drone operations are still conducted without proper coordination among agencies, resulting in overlapping authority and inefficiencies in field decision-making. Zafirawan et al. (2024) emphasized the urgency of updating regulations and standard operating procedures (SOPs) for drone use in military and civilian operations to avoid procedural conflicts.

Another problem is the lack of specialized human resources trained in drone operation and data analysis for maritime applications. The Indonesian Navy and other maritime institutions still face personnel shortages with the technical expertise needed to operate, maintain, and analyze drone-generated data. Without intensive and continuous training, the optimal use of drones cannot be achieved, even if the technology is available to do so. Equally important is the issue of data and cybersecurity risks, where drone-collected data are vulnerable to hacking or sabotage if not protected with robust encryption and firewall systems. In this context, Permatasari et al. (2024) recommend strengthening information security systems for unmanned maritime operations to ensure that strategic data do not fall into the wrong hands.

4.3 Use of Radar in Maritime Security

Over the past five years, there has been a significant increase in attention to the effectiveness of radar technology in safeguarding Indonesia's maritime security. Radar has become one of the main instruments for the early detection and monitoring of illegal activities in maritime zones, especially considering Indonesia's vast territorial waters spanning more than 6.4 million kilometer ^{2}. One important study conducted by Dahsan, Anandari, Lestari, and Gultom (2024), xamined the effectiveness of coastal radar systems in the Malacca Strait region. Their findings indicate that radar has a high capability to detect small vessels that are not monitored by the Automatic Identification System (AIS), particularly illegal vessels that deliberately deactivate their signals to avoid detection. However, the study also showed that radar effectiveness is highly dependent on weather conditions, geographical features, and range limitations.

Furthermore, Batubara et al. (2020) discussed the role of radar in maritime surveillance operations conducted by the Indonesian Navy (TNI AL). They highlight how land-based radar, naval radar systems, and satellite-integrated radar continue to experience technical disturbances, particularly when detecting vessels under 10 GT. This study also emphasizes the importance of integrating radar with drones to achieve broader and more precise surveillance coverage. Meanwhile, Sitanggang, Farras, Shidqi, Al-Huda, and Salman (2024) report that in several strategic locations such as Natuna waters, radar systems operated by Bakamla and TNI AL are still not fully interconnected, resulting in monitoring data not being distributed in real time. This situation slows down the decision-making process when maritime law violations are detected. Another issue identified by Azzqy and Puspitasari (2020) is the low frequency of radar maintenance and hardware updates, which increases the vulnerability to system failures. In addition, the limited availability of technical human resources capable of operating radar systems has caused many radars in remote areas to function suboptimally. Their research proposed strengthening technical training programs and increasing maintenance budgets for radar systems.

Hidayat, Soemantri, and Poernomo (2019) note that radar installed on naval vessels offers advantages in mobility and flexibility; however, the limited number of patrol ships means that radar-based

monitoring cannot cover all high-risk areas. Although radar serves as the backbone of maritime surveillance systems, its utilization faces challenges related to technical aspects, system integration, and human resource readiness. Therefore, strengthening radar infrastructure, developing integrated interagency systems, and improving radar operator training are strategic solutions needed to enhance the effectiveness of national maritime security. Nonetheless, despite radar being a key technology for detecting vessel movements and illegal activities at sea, several issues continue to hinder its effective field implementation.

The first issue—the main problem faced in the use of maritime radar in Indonesia—is its limited range, particularly in remote archipelagic areas with a complex topography. Batubara et al. (2020) showed that coastal radar systems in the Malacca Strait are only effective up to a certain distance and are less optimal in detecting small vessels sailing far from the shoreline. Consequently, many illegal activities, such as illegal fishing, smuggling, and territorial violations, go unmonitored in real time. The second issue concerns radar systems operated by various institutions, such as the Indonesian Navy (TNI AL), Bakamla, the Ministry of Marine Affairs and Fisheries (KKP), and the Ministry of Transportation (Kemenhub), which are often not integrated into a unified data system. According to. Sitanggang et al. (2024), the lack of interoperability causes radar-generated information to be inaccessible for quick and effective use by other authorities. This leads to slow responses to maritime security violations, especially in high-risk areas such as the Natuna Sea and Indonesia's eastern maritime border.

Another significant problem is the shortage of trained technical personnel who are capable of operating and maintaining radar systems. Azzqy and Puspitasari (2020) found that many radar units in eastern Indonesia experience system failure due to the lack of technicians and availability of spare parts. Moreover, the radar systems currently in use are still dominated by conventional technology that cannot be integrated with modern systems such as automatic image recognition or artificial intelligence. Most radar systems in Indonesia are still land-based coastal radars, which means that their monitoring coverage is limited to coastlines and nearby waters. Hidayat et al. (2019), emphasize that the number of patrol vessels equipped with mobile radar systems remains very limited, resulting in insufficient surveillance across Indonesia's vast maritime zones. Foreign vessels engaging in illegal activities can easily evade detection by sailing beyond the monitoring ranges. Finally, funding issues serve as a major obstacle. Batubara et al. (2020) show that radar maintenance budgets remain low, leading to poor equipment conditions and delays in hardware and software updates. Without adequate financial support, radar systems will continue to experience declining performance and will not be able to detect maritime security threats optimally in the future.

4.4 Discussion
Several responses to the existing problems, according to the researchers and relevant perspectives, can be outlined as follows: Complexity of Maritime Security Issues in Indonesia, Maritime security in Indonesia is a highly complex issue, considering the country's strategic position as an archipelagic state located along one of the busiest shipping routes in the world. However, the vast maritime territory makes comprehensive surveillance difficult, resulting in frequent violations, such as illegal fishing, smuggling, and territorial incursions. These challenges are further exacerbated by the limited number of patrol fleets and uneven surveillance infrastructure, particularly in border regions and remote waters, Limitations of Radar Use in Detecting Threats, Radar technology has long been a mainstay in monitoring activities at sea. However, the radar systems currently used have limitations in terms of range, accuracy, and response speed. Many coastal and border areas are not optimally covered by the radar. In addition, radar technology used in several locations has not yet been systemically integrated, which means that the data produced cannot provide a comprehensive overview to support rapid decision-making.

Potential and Constraints in the Use of Drones, Drones have become a modern solution in maritime surveillance systems due to their ability to reach wide areas with high flexibility. In the context of

maritime security, drones can conduct aerial patrols, visual documentation, and reconnaissance in vulnerable areas. However, drone utilization also faces obstacles, such as limited flight endurance, extreme sea weather, and a shortage of trained human resources capable of operating them. Moreover, not all defence and maritime security institutions use drones systematically and sustainably. Lack of Integration in Surveillance Systems: One of the main issues in maritime security is weak coordination among institutions. Radar systems, drones, and satellite surveillance often operate independently, without proper data integration. This lack of system interoperability hampers the effectiveness of surveillance and rapid action implementation. Consequently, many potential threats cannot be immediately addressed because of delayed information flow or responses hindered by bureaucratic procedures.

Strategic Directions That Need Strengthening Given the various problems above, the researchers argue that Indonesia's maritime security strategy should be directed toward three main areas: modernization of surveillance technology, enhancement of personnel capacities, and integration of systems across institutions. Radar and drone technologies play crucial roles as monitoring tools; however, they must be supported by centralized information systems, rapid communication, and policies that encourage multisectoral collaboration. With a more coordinated approach, Indonesia will be able to strengthen its sovereignty and maritime security effectively and sustainably in the future.

5. Conclusion

Indonesia's maritime security challenges are highly complex owing to the vastness of its territorial waters, limited surveillance capabilities, and evolving threats. The use of radar and drone technologies holds significant potential for enhancing the effectiveness of maritime monitoring. However, both technologies still face technical constraints, limited coverage, human resource shortages, and a lack of inter-agency system integration. To optimize the functions of radar and drones in safeguarding maritime security, technological modernization, personnel training, and the strategic and sustainable integration of information systems and interagency coordination are essential.

5.1 Limitations and Future Research

This study had several limitations. First, the research relies heavily on secondary data obtained from literature sources and scientific journals published in the past five years, without incorporating field observations or direct interviews with the Indonesian Navy (TNI AL) or other relevant maritime institutions. This limits the depth of the analysis in capturing actual operational conditions in the field. Second, the primary focus is only on two technologies—radar and drones—whereas other technologies, such as surveillance satellites, Automatic Identification Systems (AIS), and underwater sensors, also play significant roles in maritime security. Thus, the approach used in this study does not encompass all relevant technological aspects. Third, the analysis does not fully address the policy dimensions, defense budget considerations, and technical regulations that influence the effectiveness of radar and drone utilization within the national maritime defense context.

Given these limitations, future studies should broaden their scope by collecting primary data directly from maritime security institutions such as TNI AL and Bakamla. Additionally, subsequent research should incorporate other technologies that support maritime surveillance, such as reconnaissance satellites and artificial intelligence (AI). Further analysis of regulatory factors, budgeting, and inter-agency coordination is necessary to better understand the structural barriers that influence the effectiveness of Indonesia's maritime security efforts. A case study approach focusing on high-risk regions, such as the North Natuna Sea, would provide a more contextual understanding of the implementation of technology in safeguarding national maritime sovereignty.

References

Afriyani, N., Indrayani, I., Indrawan, M. G., Wibisono, C., & Ngaliman, N. (2023). The influence of training, discipline, and innovation on the performance of members of the Regional National Crafts Council (Dekranasda) in Tanjungpinang City: A quantitative study. *Journal of*

Multidisciplinary Academic Business Studies, 1(1), 53-69. doi:https://doi.org/10.35912/jomabs.v1i1.1780

Ali, I. M., Prakoso, L. Y., & Sianturi, D. (2021). Strategi pertahanan laut dalam menghadapi ancaman keamanan maritim di wilayah laut Indonesia. *Jurnal Strategi Pertahanan Laut, 6*(2).

Arif, W., & Yanto, A. (2022). Konsep makna keamanan maritim. *Jurnal Maritim Indonesia (Indonesian Maritime Journal), 10*(3), 227-234. doi:https://doi.org/10.52307/jmi.v10i3.125

Aryani, C. (2021). Mendorong lahirnya RUU keamanan laut dalam penguatan sistem keamanan laut nasional. *Jurnal Pembangunan Hukum Indonesia, 3*(2), 155-173. doi:https://doi.org/10.14710/jphi.v3i2.155-173

Azzqy, A. A. R., & Puspitasari, A. (2020). Pengembangan Pulau Tarakan Sebagai Pangkalan Militer Udara Utama Di Wilayah Kalimantan Utara (Studi Kasus: Lanud Anang Busra-Tarakan, Kalimantan Utara). *Sebatik, 24*(2), 282-292. doi:https://doi.org/10.46984/sebatik.v24i2.1090

Batubara, F. D., Gultom, R. A., & Bura, R. O. (2020). Desain Konseptual Integrasi Sistem Drone/Uav Dan Sensor Radar Pasif Sebagai Fungsi Situasional Blank Spot Filler Sistem Radar Pertahanan Udara (Studi: Satuan Radar 211 Tanjung Kait). *Teknologi Penginderaan, 2*(1).

Chairani, R., & Adi Pradana, M. R. (2022). Pengembangan Karir Dan Motivasi Kerja Serta Implikasinya terhadap Kinerja Pegawai (Studi Kasus pada Dinas Tenaga Kerja dan Transmigrasi Kabupaten Way Kanan). *RELEVANSI: : Journal of Economics, Management and Business, 6*(2), 105-117. doi:https://doi.org/10.61401/relevansi.v6i2.71

Dahsan, S., Anandari, A. A., Lestari, A. A., & Gultom, R. (2024). Optimalisasi Penggunaan Radar Maritim untuk Pengawasan dan Deteksi Dini dalam Konteks Pertahanan Maritim. *Journal on Education, 6*(2), 13488-13499.

Deanto, M. A. R., & Marzaman, A. P. (2024). Transformasi Kebijakan Maritim dalam Era Digital: Peran Teknologi dalam Meningkatkan Efektivitas dan Keamanan Lautan di Indonesia. *Journal of International and Local Studies, 8*(1), 1-9. doi:https://doi.org/10.56326/jils.v8i1.3678

Firaldi, Y., Wibisono, C., Ngaliman, N., Indrayani, I., & Satriawan, B. (2023). The influence of leadership, discipline, and workload on employee performance through job satisfaction as an intervening variable in Regional Revenue Agency Riau Islands Province. *Journal of Multidisciplinary Academic Business Studies, 1*(1), 27-52. doi:https://doi.org/10.35912/jomabs.v1i1.1779

Guo, G., Wang, R., & Guo, L. (2024). Research on Radar Target Detection Based on the Electromagnetic Scattering Imaging Algorithm and the YOLO Network. *Remote Sensing, 16*(20), 3807. doi:https://doi.org/10.3390/rs16203807

Hartanto, E. T., Sulistyo, H., & Adi, A. P. (2022). Rancang Bangun Drone Solar Cell untuk Pengintaian dalam Mendukung Operasi Keamanan Laut. *Rekayasa, 15*(1), 8-14. doi:https://doi.org/10.21107/rekayasa.v15i1.14101

Hartawan, M. Z., Pramono, A., & Yudho, F. (2021). Peran Intelijen Maritim Terhadap Keamanan Laut di Selat Sunda. *Rekayasa, 14*(3), 389-392. doi:https://doi.org/10.21107/rekayasa.v14i3.11499

Hidayat, A. S., Soemantri, A. I., & Poernomo, H. (2019). Implementasi strategi pengendalian alur laut Kepulauan Indonesia (ALKI) II dalam mendukung ketahanan nasional. *Jurnal Ketahanan Nasional, 25*(3), 313-330. doi:http://dx.doi.org/10.22146/jkn.49528

Hossain, R. (2022). A short review of the drone technology. *International Journal of Mechatronics and Manufacturing Technology, 7*(2), 53-68.

Jahani, H., Khosravi, Y., Kargar, B., Ong, K.-L., & Arisian, S. (2025). Exploring the role of drones and UAVs in logistics and supply chain management: a novel text-based literature review. *International Journal of Production Research, 63*(5), 1873-1897. doi:https://doi.org/10.1080/00207543.2024.2373425

Jamilah, A., & Disemadi, H. S. (2020). Penegakan Hukum Illegal Fishing dalam Perspektif UNCLOS 1982. *Mulawarman Law Review, 5*(1), 29-46. doi:https://doi.org/10.30872/mulrev.v5i1.311

Kadar, A. (2015). Pengelolaan kemaritiman menuju Indonesia sebagai poros maritim dunia. *Jurnal Keamanan Nasional, 1*(3), 417-442. doi:https://doi.org/10.31599/jkn.v1i3.33

Kemarau, R. A., Sakawi, Z., Suab, S. A., Eboy, O. V., Wan Mohd Jaafar, W. S., Abdul Maulud, K. N., & Md Nor, N. N. F. (2024). Global perspectives on unmanned aerial vehicles technology in social sciences: applications, innovations, and future research directions. *Geocarto International, 39*(1), 2413547. doi:https://doi.org/10.1080/10106049.2024.2413547

Kristiyanti, M., & Mahendro, I. (2025). Pemanfaatan Teknologi Informasi Dalam Membangun Strategi Keamanan Maritim Di Indonesia. *Majalah Ilmiah Bahari Jogja, 23*(1), 1-10. doi:https://doi.org/10.33489/mibj.v23i1.387

Krystosik-Gromadzińska, A. (2021). The use of drones in the maritime sector–areas and benefits. *Zeszyty Naukowe Akademii Morskiej w Szczecinie*. doi:http://dx.doi.org/10.17402/473

Kurnianto, A., Guyana, D., & Widiarto, M. A. (2024). Fungsi Drone Kamikaze dalam Membantu TNI Angkatan Laut dalam Menghadapi Ancaman di Laut Guna Menjaga Pertahanan Negara Indonesia. *JIIP-Jurnal Ilmiah Ilmu Pendidikan, 7*(10), 11745-11750. doi:https://doi.org/10.54371/jiip.v7i10.6127

Latunusa, P. M., Timuneno, T., & Fanggidae, R. E. (2023). The effect of multiple role conflict and work stress on the performance of women nurses during the covid-19 with coping stress as intervening variables (Study at SoE Regional General Hospital). *Journal of Multidisciplinary Academic and Practice Studies, 1*(1), 29-43. doi:https://doi.org/10.35912/jomaps.v1i1.1462

Leary, D. (2020). 8. International Maritime Organization (IMO). *Yearbook of International Environmental Law, 31*(1), 305-306. doi:https://doi.org/10.1093/yiel/yvab057

Permatasari, H. I., Risdhianto, A., & Almubaroq, H. Z. (2024). Kendaraan Otonom Di Laut China Selatan: Masa Depan Keamanan Maritim Indonesia.

Petrovic, R., Simic, D., Cica, Z., Drajic, D., Nerandzic, M., & Nikolic, D. (2021). Iot oth maritime surveillance service over satellite network in equatorial environment: Analysis, design and deployment. *Electronics, 10*(17), 2070. doi:https://doi.org/10.3390/electronics10172070

Praja, A. S. I. (2024). Volume 12 Nomor 2 Juni 2024: Perkuatan Sistem Pertahanan Maritim Nusantara di Era Transformasi Digital. *Indonesian Maritime Journal, 12*(2), 54-63. doi:http://doi.org/10.52307/jmi.v912.167

Pramono, A., & Safarini, N. (2022). Pengaruh Pengembangan Karir dan Motivasi Kerja Terhadap Kinerja Pegawai pada Kantor Kecamatan Kota Agung Kabupaten Tanggamus. *RELEVANSI: : Journal of Economics, Management and Business, 6*(2), 82-93. doi:https://doi.org/10.61401/relevansi.v6i2.68

Putri, D. F. E., Prakoso, L. Y., & Astaryadi, E. S. (2024). Peran Teknologi Drone Dalam Meningkatkan Pertahanan Keamanan Laut Di Indonesia. *Jurnal Sains dan Teknologi ISTP, 22*(01).

Putri, S. E., & Hukul, P. R. (2024). Analisis Pemanfaatan Drone Untuk Pemantauan Illegal Fishing Di Perairan. *Jurnal Perikanan dan Kelautan, 1*(1), 37-43. doi:https://doi.org/10.70134/peraut.v1i1.318

Qurani, H. R., & Mulyono, N. B. (2025). Improving customer satisfaction in service quality evaluation using the carter framework: A case study of SS Umrah and Travel in Indonesia. *Journal of Multidisciplinary Academic Business Studies, 2*(4), 257-268. doi:https://doi.org/10.35912/jomabs.v2i4.3526

Raivi, A. M., Huda, S. A., Alam, M. M., & Moh, S. (2023). Drone routing for drone-based delivery systems: A review of trajectory planning, charging, and security. *Sensors, 23*(3), 1463. doi:https://doi.org/10.3390/s23031463

Rangkuti, M. I., Pranata, A., & Ishak, I. (2022). Sistem Radar Untuk Monitoring Objek Sekitar Berbasis Internet Of Things (IOT). *Jurnal Sistem Komputer Triguna Dharma (JURSIK TGD), 1*(1), 10-17. doi:https://doi.org/10.53513/jursik.v1i1.4795

Rezeki, S. P., Rani, M., & Syahputra, I. (2023). Pelaksanaan Tanggung Jawab Nakhoda Kapal atas Kerusakan Kapal dalam Pengangkutan Penumpang Antar Wilayah Kabupaten Natuna di Pelabuhan Rakyat Midai. *Jurnal Studi Ilmu Sosial dan Politik, 3*(2), 81-87. doi:https://doi.org/10.35912/jasispol.v3i2.2338

Rina, H., Bungin, S. S., & Ilham, M. (2023). Analisis Pengoperasian Radar pada Kapal Saat Berlayar. *Hengkara Majaya, 4*(1), 93-97. doi:https://doi.org/10.61759/hmj.v4i1.66

Rosyida, E. D. I., Sutanto, R., & Prakoso, L. Y. (2024). EFEKTIFITAS DRONE DALAM MENGHADAPI PERANG HIBRIDA DI PERAIRAN INDONESIA. *NUSANTARA: Jurnal Ilmu Pengetahuan Sosial, 11*(9), 3822-3832. doi:https://doi.org/10.31604/jips.v11i9.2024.3822-3832

Sajidin, M., Saputra, I., & Nofiasari, W. (2023). Strategi Keamanan Maritim Indonesia Dalam Menghadapi Ancaman Kejahatan Transnasional Di Asia Tenggara. *Jurnal Lemhannas RI, 11*(3), 170-177. doi:https://doi.org/10.55960/jlri.v11i3.476

Setiawan, S. M. (2025). Pengaturan Penggunaan Drone di Indonesia dalam Perspektif Hukum Udara.

Sitanggang, A. S., Farras, A. M., Shidqi, F. A., Al-Huda, M. H., & Salman, D. (2024). Integrasi Sistem Navigasi Kapal dan Ais Untuk Navigasi Maritim Yang Lebih Aman dan Efisien. *Blantika: Multidisciplinary Journal, 2*(9). doi:https://doi.org/10.57096/blantika.v2i9.205

Sugianto, A., Agussalim, D., & Armawi, A. (2021). Penanganan Keamanan Maritim Perbatasan Wilayah Laut Dan Dampaknya Pada Aspek Pertahanan Keamanan. *Jurnal Lemhannas RI, 9*(2), 113-126. doi:https://doi.org/10.55960/jlri.v9i2.395

Sugiarto, B. S., Mulyani, A., & Nurdin, H. (2020). SISTEM INFORMASI PESAWAT TANPA AWAK (DRONE) BERBASIS APLIKASI ANDROID. *Journal of Information System, Informatics and Computing*(2), 9-16%V 14. doi:https://doi.org/10.52362/jisicom.v4i2.314

Wahyulianto, R. M. (2022). Strategi civil-military relations sebagai upaya penguatan keamanan maritim Indonesia. *JIIP-Jurnal Ilmiah Ilmu Pendidikan, 5*(9), 3416-3419. doi:https://doi.org/10.54371/jiip.v5i9.862

Wang, J., & Li, S. (2023). SALA-LSTM: a novel high-precision maritime radar target detection method based on deep learning. *Scientific reports, 13*(1), 12125. doi:https://doi.org/10.1038/s41598-023-39348-3

Wen, B., Wei, Y., & Lu, Z. (2022). Sea clutter suppression and target detection algorithm of marine radar image sequence based on spatio-temporal domain joint filtering. *Entropy, 24*(2), 250. doi:https://doi.org/10.3390/e24020250

Winkler, A. C., Butler, E. C., Attwood, C. G., Mann, B. Q., & Potts, W. M. (2022). The emergence of marine recreational drone fishing: Regional trends and emerging concerns. *Ambio, 51*(3), 638-651. doi:https://doi.org/10.1007/s13280-021-01578-y

Xu, K., Shi, H., Chen, H., Letu, H., Li, J., He, W., Zhang, X. (2025). Marine Unmanned Surface Vehicle Measurements of Solar Irradiance Under Typhoon Conditions. *Drones, 9*(6), 395. doi:https://doi.org/10.3390/drones9060395

Zafirawan, R. A., Prakoso, L. Y., Sukendro, A., Widodo, P., Saragih, H. J. R., & Suwarno, P. (2024). Diplomasi Keamanan Maritim Pada Pengawasan Terhadap Ancaman Keamanan Maritim Di Perairan Asean Untuk Mewujudkan Indonesia Emas 2045. *NUSANTARA: Jurnal Ilmu Pengetahuan Sosial, 11*(9), 3879-3885. doi:https://doi.org/10.31604/jips.v11i9.2024.3879-3885