Economic losses from illegal fishing and the development of an integrated fisheries surveillance model in Indonesia's provincial waters

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Abstract. Illegal fishing remains a significant challenge to the sustainable management of Indonesia's marine fisheries, particularly within the 12-nautical-mile provincial waters, where fisheries surveillance involves multiple institutions operating under a decentralized governance framework. This study aims to estimate direct production-related economic losses from illegal fishing and to develop an integrated, multi-level fisheries surveillance model for Indonesia's provincial waters. The study was conducted in four provinces within Fisheries Management Area (WPPNRI) 712: Banten, West Java, Central Java, and East Java—using a mixed-methods approach combining fishing-production analysis, field observations, structured and in-depth interviews, legal and institutional analysis, comparative gap analysis, and process mapping. Direct production-related economic losses were estimated using seasonal fishing-production data and government-established fish reference prices. The results identified the continued use of prohibited fishing gears, particularly arad in Serang, Cirebon, and Rembang, and *cantrang* in Lamongan. The aggregate direct production-related economic losses associated with these prohibited fishing practices were estimated at approximately USD 1.61 million in Serang, in Cirebon, USD 55.62 million in Rembang, and USD 15.87 million in Lamongan. These estimates represent the monetary value of fisheries production associated with the prohibited fishing practices examined and should not be interpreted as a comprehensive valuation of the broader ecological, social, or long-term economic impacts of illegal fishing. Based on the institutional analysis, this study proposes an integrated multi-level fisheries surveillance model comprising four interrelated components: (1) community-based monitoring and reporting involving fishers and community surveillance groups; (2) coordinated multi-agency surveillance involving provincial and national institutions according to their respective mandates; (3) structured reporting and institutional coordination; and (4) inter-regional cooperation across provincial jurisdictions. The proposed model integrates community-level monitoring with provincial and national surveillance functions to strengthen information flows, institutional coordination, and cross-jurisdictional cooperation. As the model represents a proposed institutional framework rather than an empirically validated intervention, further stakeholder validation, pilot implementation, and empirical evaluation are required to assess its operational feasibility and effectiveness.

Keywords: collaborative governance, direct production-related economic loss, fisheries surveillance, illegal fishing, integrated surveillance model, provincial waters.

Introduction. Illegal, Unreported, and Unregulated (IUU) fishing remains one of the most significant threats to global fisheries sustainability, undermining marine biodiversity, fish stock recovery, food security, and the livelihoods of coastal communities (Food and Agriculture Organization of the United Nations, 2001; Sumaila et al., 2006; Pramod et al., 2017; Long et al., 2020). Beyond ecological degradation, IUU fishing generates substantial economic losses by reducing government revenues, distorting seafood markets, weakening traceability systems, and compromising the integrity of fisheries governance (Lewis & Boyle, 2017; Longo et al., 2021). Recent studies further demonstrate that IUU fishing produces governance failures through inaccurate catch reporting, which biases stock

assessments, weakens fisheries statistics, and ultimately reduces the effectiveness of evidence-based fisheries management (Vince et al., 2021; Chau & Bunsiri, 2022; Simataa et al., 2025). Consequently, combating IUU fishing has become a global governance priority under the FAO International Plan of Action to Prevent, Deter and Eliminate IUU Fishing (IPOA-IUU), requiring not only stronger legal frameworks but also more effective institutional arrangements, monitoring systems, and regulatory enforcement mechanisms (Food and Agriculture Organization of the United Nations, 2001; Hutniczak et al., 2019; Long et al., 2020).

Previous studies have consistently shown that IUU fishing is closely associated with weak governance, limited Monitoring, Control and Surveillance (MCS) capacity, fragmented institutional coordination, and ineffective law enforcement (Vince et al., 2021; Gezelius & Hauck, 2024; He et al., 2024). Nevertheless, most empirical studies have primarily focused on transboundary fisheries, distant-water fishing fleets, and foreign fishing vessels operating within Exclusive Economic Zones (EEZs) or on the high seas (Agnew et al., 2009; Long et al., 2020; Okafor-Yarwood et al., 2022). Comparatively little attention has been given to IUU fishing conducted by domestic fishing vessels operating in coastal waters under subnational jurisdiction, despite evidence indicating that domestic licensing violations, unauthorized fishing operations, and non-compliance with fisheries regulations constitute a substantial proportion of fisheries offences in many developing countries (Sodik, 2009; Fujii et al., 2021; McWilliam, 2021). Small-scale fishing vessels are particularly difficult to monitor because of their dispersed operations, limited use of vessel monitoring technologies, and high mobility across coastal and archipelagic waters, resulting in lower detection probabilities and reduced deterrence against illegal fishing activities (Song et al., 2020; Fujii et al., 2021; Simataa et al., 2025). This gap suggests that strengthening fisheries surveillance in coastal waters requires governance approaches specifically designed for small-scale fisheries rather than relying solely on offshore enforcement strategies.

Indonesia provides a particularly relevant case for addressing this knowledge gap. As the world's largest archipelagic state, Indonesia has decentralized fisheries surveillance responsibilities through Law No. 23 of 2014, assigning provincial governments authority over marine waters extending up to 12 nautical miles from the coastline (Badan Pemeriksa Keuangan, 2014). This allocation of provincial jurisdiction, however, does not imply exclusive provincial authority over all fisheries enforcement functions. Fisheries surveillance within provincial waters operates within a broader national legal and institutional framework in which provincial management and surveillance responsibilities coexist with nationally regulated fisheries surveillance, maritime security functions, and criminal law enforcement undertaken by competent authorities in accordance with their respective mandates. Accordingly, the 12-nautical-mile boundary should be understood primarily as a division of governmental affairs in marine and fisheries resource management and surveillance rather than as an exclusive boundary of law-enforcement authority. Within this framework, provincial governments play an important role in fisheries surveillance within their jurisdiction, particularly in coastal waters where small-scale fisheries dominate.

However, the implementation of this mandate has been constrained by limited financial resources, shortages of fisheries inspectors, inadequate surveillance infrastructure, fragmented institutional coordination, and uneven MCS capacity across provinces. These limitations reduce surveillance effectiveness and create opportunities for illegal fishing activities that remain largely undetected. From the perspective of Institutional Governance Theory, these conditions represent institutional failures in generating effective governance systems, while Regulatory Enforcement Theory suggests that low detection probability and inconsistent enforcement weaken regulatory compliance and reduce deterrence effects (Gezelius & Hauck, 2011; OECD, 2018; Hutniczak et al., 2019; Vince et al., 2021; He et al., 2024).

Despite increasing international attention to IUU fishing, limited empirical research has examined how provincial governments can effectively strengthen fisheries surveillance within decentralized governance systems, particularly in coastal waters dominated by small-scale fisheries. Existing studies have largely emphasized national enforcement

policies or offshore surveillance, whereas institutional strategies at the provincial level remain poorly understood. The novelty of this study lies in integrating an estimation of direct economic losses associated with illegal fishing with institutional analysis and an integrated multi-level fisheries surveillance model specifically designed for decentralized provincial waters. This study addresses this gap by examining fisheries surveillance within Indonesia's 12-nautical-mile provincial waters in Fisheries Management Area (WPPNRI) 712, one of the country's most productive yet highly exploited fishing grounds. Specifically, this study evaluates the legal and institutional framework governing provincial fisheries surveillance, estimates the direct economic losses associated with illegal fishing based on seasonal fishing production and government-established fish reference prices, and develops an integrated multi-level fisheries surveillance model to strengthen provincial governance against IUU fishing. By linking institutional governance, regulatory enforcement, direct economic loss estimation, and fisheries surveillance within a decentralized management framework, this study contributes to the broader literature on fisheries governance while providing policy recommendations for strengthening provincial fisheries surveillance in archipelagic developing countries.

Material and Method

Study site and data sources. This study was conducted in the FMA/WPPNRI 712, covering the Java Sea and adjacent coastal waters, with a specific focus on fisheries surveillance within provincial waters extending up to 12 nautical miles. Four provinces representing the western, central, and eastern parts of WPPNRI 712 were selected as study areas: Banten, West Java, Central Java, and East Java. Field data were collected at four major fishing centers: Archipelagic Fishing Port/*Pelabuhan Perikanan Nusantara* (PPN) Karangantu in Serang (Banten), Fish Landing Base/*Pangalan Pendaratan Ikan* (PPI) Gebang Mekar in Cirebon (West Java), Coastal Fishing Port/*Pelabuhan Perikanan Pantai* (PPP) Tasik Agung in Rembang (Central Java), and PPN Brondong in Lamongan (East Java). These locations were purposively selected based on the presence of fishing activities involving prohibited fishing gear and the comparability of fishing-unit characteristics, including vessel characteristics, fishing gear, and fishing grounds.

Both primary and secondary data were used. Secondary data included fisheries surveillance records, fisheries law-enforcement reports, fisheries statistics, vessel inspection records, relevant legal and policy documents, and government expenditure records related to fisheries surveillance. These data were obtained from official government institutions, including the Ministry of Marine Affairs and Fisheries, Provincial Marine and Fisheries Offices, and other competent government institutions involved in fisheries surveillance and maritime law enforcement. Only official administrative records, published government statistics, and institutionally documented data were used as secondary sources. The data were cross-checked across available institutional records and relevant legal and policy documents before being used in the analysis.

Sampling strategy and respondent selection. A multi-stage non-probability sampling strategy combining purposive, accidental, and snowball sampling was employed according to the type of information required. For the analysis of fishing practices and direct production-related economic losses, fishing respondents were selected using accidental and snowball sampling because no comprehensive sampling frame was available for fishers using the prohibited fishing gears examined in this study. Initial respondents were identified during field activities conducted in the context of a government program addressing the transition from prohibited fishing gear to legally permitted fishing practices. Additional respondents were subsequently identified through referrals from previously interviewed fishers with relevant experience and knowledge.

A total of 110 fishing respondents were interviewed across four study locations: 25 respondents at PPN Karangantu, Serang (Banten); 30 respondents at PPI Gebang Mekar, Cirebon (West Java); 30 respondents at PPP Tasik Agung, Rembang (Central Java); and 25 respondents at PPN Brondong, Lamongan (East Java). The fishing units represented in the study used arad in Serang, Cirebon, and Rembang, and cantrang in Lamongan.

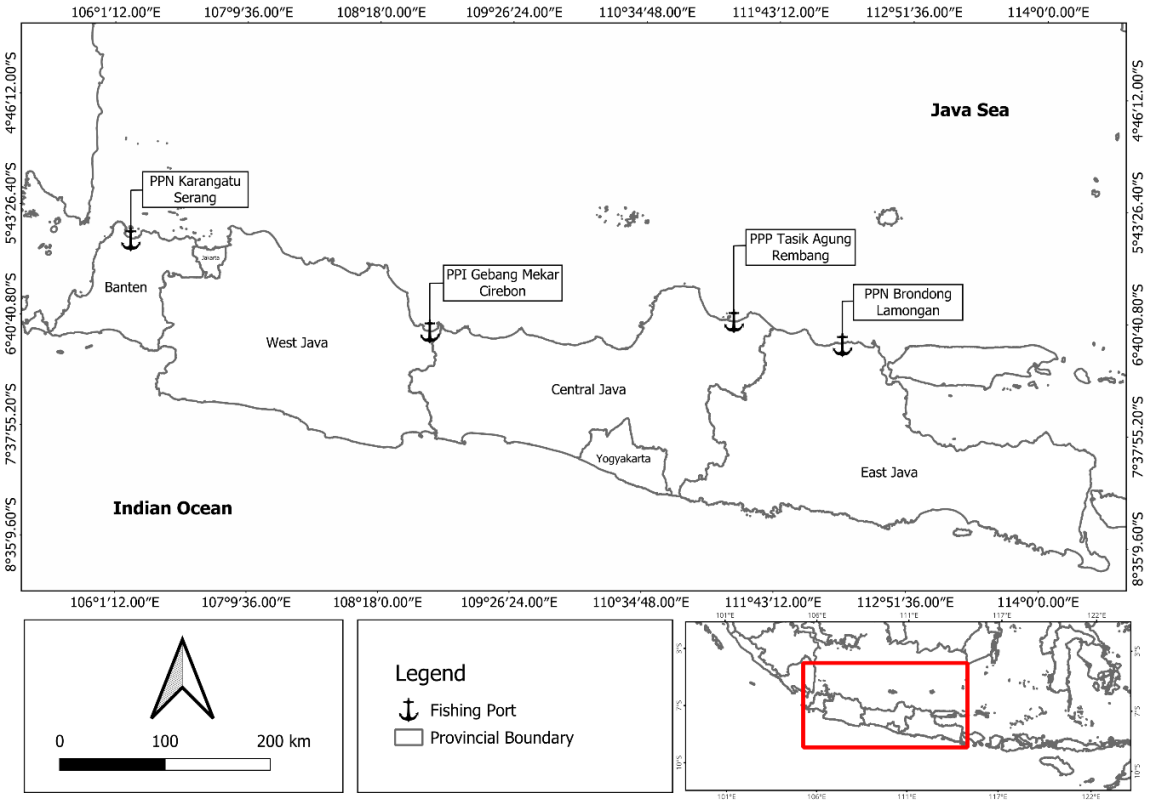


Figure 1. Location of the four fishing ports selected as study sites along the Northern Coast of Java, Indonesia.

Table 1

Distribution of fishing respondents and fishing units by study location

Respondent category	*Institution/location*	*Province*	*Number/description*
Fishing respondents	PPN Karangantu, Serang	Banten	25
	PPI Gebang Mekar, Cirebon	West Java	30
	PPP Tasik Agung, Rembang	Central Java	30
	PPN Brondong, Lamongan	East Java	25
Total			110
Provincial government informants	DKP Banten - Marine and Fisheries Resource Surveillance Division	Banten	Head of Division and/or 1 relevant staff member
	DKP West Java - Marine and Fisheries Resource Surveillance Division	West Java	Head of Division and/or 1 relevant staff member
	DKP Central Java - Marine and Fisheries Resource Surveillance Division	Central Java	Head of Division and/or 1 relevant staff member
	DKP East Java - Marine and Fisheries Resource Surveillance Division	East Java	Head of Division and/or 1 relevant staff member
Fisheries surveillance informants	PSDKP work unit associated with PPN Karangantu	Banten	Head of work unit and relevant staff
	PSDKP work unit associated with PPP Tasik Agung	Central Java	Head of work unit and relevant staff
	PSDKP work unit associated with PPN Brondong	East Java	Head of work unit and relevant staff
Port management informant	PPI Gebang Mekar	West Java	Head of fishing port

Note: DKP - Marine Affairs and Fisheries Office; PSDKP - Marine and Fisheries Resources Surveillance; PPN - Archipelagic Fishing Port; PPI - Fish Landing Base; PPP - Coastal Fishing Port.

Institutional informants were selected purposively based on their formal responsibilities and direct involvement in fisheries surveillance and fisheries management. At the provincial level, interviews were conducted with the Marine and Fisheries Offices (DKP) of Banten, West Java, Central Java, and East Java, specifically involving the head of the division responsible for marine and fisheries resource surveillance and/or one relevant staff member in each province. At the central-government field-unit level, interviews involved the heads of the relevant fisheries surveillance work units (PSDKP) together with relevant staff at PPN Karangantu, PPP Tasik Agung, and PPN Brondong. At PPI Gebang Mekar, where the same institutional arrangement was not represented in the field data collection, the institutional interview was conducted with the head of the fishing port. These institutional informants provided information on surveillance implementation, institutional responsibilities, human resources, surveillance facilities, operational constraints, inter-agency coordination, and fisheries law-enforcement practices.

Data collection procedures. Primary data were collected through field observations, structured interviews, and in-depth interviews conducted directly by the research team during field visits to the four study locations. Structured interviews with fishing respondents were used primarily to obtain information on fishing-unit characteristics, fishing gear, fishing operations, seasonal catch levels, fishing frequency, and other information required to estimate the direct production-related economic losses associated with illegal fishing. Catch information was collected for three fishing seasons—low, moderate, and peak seasons—to capture seasonal variation in fishing production. In-depth interviews with government officials, fisheries surveillance officers, port authorities, and other relevant institutional actors were used to obtain information on fisheries surveillance practices, institutional responsibilities, coordination mechanisms, surveillance capacity, and law-enforcement constraints.

Field observations were used to verify fishing-unit characteristics, fishing gear, fishing-port conditions, and operational aspects relevant to the study. Information obtained from interviews was cross-checked, where possible, against field observations, official fisheries statistics, surveillance records, vessel-related administrative records, and relevant government documents.

Ethical considerations. The field data collection was conducted as part of a government-supported program concerning the transition from prohibited fishing gear to legally permitted fishing practices, rather than as an investigation intended to identify or prosecute individual fishers for illegal activities. Accordingly, no formal research ethics approval was obtained for the field data collection. Nevertheless, ethical safeguards were applied during the interviews. Participation was voluntary, respondents were informed of the purpose of the study and the intended use of the information, and no personally identifiable information was recorded or reported in the manuscript. Interview responses were treated confidentially and analyzed in aggregate form. Information concerning prohibited fishing gear and related fishing practices was used solely for research and policy analysis and was not attributed to individual respondents. These measures were applied to minimize potential legal and social risks to participants.

Data analysis. Data analysis was conducted in two interrelated stages: (1) estimation of direct production-related economic losses associated with IUU fishing, and (2) development of an integrated fisheries surveillance model.

First, direct production-related economic losses associated with illegal fishing were estimated from fishing-production data obtained from fishing respondents. The raw data used for this analysis included the type of fishing gear, catch volume (kg), seasonal fishing production, and the applicable government-established fish reference prices. Seasonal production was differentiated into low, moderate, and peak fishing seasons to account for variation in catch levels throughout the fishing cycle. For each study location, the average catch production across the three fishing seasons was calculated and subsequently multiplied by the applicable government-established fish reference price to obtain the monetary value of production associated with the prohibited fishing practices examined in

the study. The analysis covered arad fishing units in Serang, Cirebon, and Rembang and cantrang fishing units in Lamongan.

In this study, this monetary estimate is operationally defined as a direct production-related economic loss associated with IUU fishing. It represents the estimated monetary value of fish production generated through the prohibited fishing practices examined in the study and does not constitute a comprehensive economic valuation of IUU fishing. Accordingly, the estimate does not include indirect or long-term economic effects such as resource depletion costs, ecosystem damage, future catch losses, lost government revenue, or broader social costs. The results were interpreted comparatively across fishing locations and fishing seasons to identify differences in the magnitude of direct production-related economic losses.

Second, the integrated fisheries surveillance model was developed using qualitative institutional analysis, comparative gap analysis, and process mapping**.** The raw data for this stage consisted of legal and institutional mandates, surveillance duties and functions, institutional arrangements, surveillance planning and capacity, operational surveillance mechanisms, surveillance objects and locations, operational support, field observations, and information obtained through interviews with provincial fisheries authorities, fisheries surveillance units, fishing-port authorities, and fishing respondents. These data were synthesized to identify regulatory and implementation gaps, institutional interactions, surveillance bottlenecks, and potential coordination mechanisms throughout the fishing-operation cycle.

The surveillance process was mapped across three operational stages: pre-departure surveillance, surveillance during fishing operations, and post-landing surveillance. Institutional roles and interactions among provincial Marine and Fisheries Offices, the Ministry of Marine Affairs and Fisheries and its fisheries surveillance units, fishing-port authorities, and other relevant enforcement institutions were subsequently mapped according to their respective mandates. The resulting institutional and process maps were used to formulate a proposed integrated multi-level fisheries surveillance model for provincial waters. Quantitative data were analyzed descriptively, while qualitative information was interpreted through content analysis and cross-source comparison to identify recurring institutional patterns, implementation gaps, and coordination requirements.

To account for seasonal variations in fishing production, the average catch was calculated based on three fishing seasons: the low season, moderate season, and peak season, as follows:

$$\bar{Q} = \frac{Q_{low} + Q_{moderate} + Q_{peak}}{3}$$

where:

- $\bar{Q}$ – average catch production across the three fishing seasons (kg);
- Q_{low} - catch production during the low fishing season (kg);
- $Q_{moderate}$ - catch production during the moderate fishing season (kg);
- Q_{peak} - catch production during the peak fishing season (kg).

The estimated direct production-related economic loss was subsequently calculated by multiplying the average catch production by the government-established fish reference price, using a formula adapted from Mahabror and Hidayat (2018).

$$DEL = \bar{Q} \times P_{ref}$$

where:

- DEL - estimated direct production-related economic loss (USD);
- $\bar{Q}$ - average catch production across the three fishing seasons (kg);
- P_{ref} - government-established fish reference price (USD kg^{-1}).

The resulting DEL represents the estimated monetary value of fish production associated with the prohibited fishing practices examined in this study and should not be interpreted as a comprehensive economic valuation of the broader ecological, social, or long-term economic impacts of illegal fishing.

Table 2

Analytical framework, raw data, data sources, and data processing procedures

Analysis	*Raw data collected*	*Source*	*Processing/interpretation*
Direct production-related economic loss	Fishing gear; catch volume (kg); production during low, moderate, and peak seasons; government-established fish reference price	110 fishing respondents; relevant government price reference	Average seasonal production × government reference price → monetary estimate
Integrated surveillance model	Institutional mandates; surveillance functions; coordination mechanisms; operational constraints; surveillance stages; institutional interactions	DKP; PSDKP; fishing ports; interviews; observations; institutional documents	Institutional analysis + gap analysis + process mapping → proposed integrated multi-level surveillance model

Note: DKP - Marine Affairs and Fisheries Office; PSDKP - Marine and Fisheries Resources Surveillance.

Results and Discussion

Characteristics of prohibited fishing gears and direct production-related economic losses. Field observations conducted by the research team across the four study areas identified the continued use of prohibited fishing gears, specifically arad in Serang, Cirebon, and Rembang, and cantrang in Lamongan. These fishing gears were therefore selected as the empirical focus of the illegal fishing analysis, which examined fishing practices involving prohibited gear rather than the broader categories of unreported and unregulated fishing. The continued operation of arad fishing gear is consistent with the findings of Indrawasih and Wahyono (2009), who documented its use in Cirebon and Rembang and identified economic dependence, enforcement limitations, and inadequate surveillance infrastructure as major challenges to implementing fishing gear restrictions. Similarly, Pane et al. (2023) documented the catch composition and fishing performance of arad in Cirebon waters. For Cantrang, Semedi, and Schneider (2021) demonstrated that regulatory restrictions along the northern coast of Java have been accompanied by complex interactions among fishing livelihoods, economic interests, and fisheries governance.

The estimated direct production-related economic losses associated with these prohibited fishing practices varied substantially across the four study areas (Table 3). The estimates were derived from fishing production during three seasonal periods: the peak fishing season (July-September), moderate fishing season (April-June and October-November), and low fishing season (December-March). Seasonal production values were calculated using catch-production data and the applicable government-established fish reference prices. The resulting values were subsequently aggregated according to the number of fishing units/fishers identified as operating the prohibited fishing gear at each study location. Differences in fishing production and catch composition have also been documented in Cirebon waters by Pane et al. (2023), supporting the importance of considering fishing characteristics when interpreting production-based economic estimates.

At PPN Karangantu, Serang, arad fishing generated estimated seasonal production values of USD 6,475.00 during the peak season, USD 3,535.00 during the moderate season, and USD 700.00 during the low season, resulting in an estimated value of USD 10,710.00 per fishing unit. With approximately 150 fishers/fishing units identified in the study, the aggregate estimated direct production-related economic loss amounted to approximately USD 1.61 million.

At PPI Gebang Mekar, Cirebon, the corresponding estimated values were USD 13,019.38 during the peak season, USD 8,288.13 during the moderate season, and USD 1,288.13 during the low season. The estimated value per fishing unit was therefore approximately USD 22,595.00. When applied to 584 identified arad fishers/fishing units, the aggregate estimated value reached approximately USD 13.20 million.

PPP Tasik Agung, Rembang, recorded the largest aggregate estimate among the four study areas. The estimated seasonal production values of arad fishing were USD 16,666.25 during the peak season, USD 9,832.50 during the moderate season, and USD

1,620.00 during the low season, producing an estimated value of approximately USD 8,118.75 per fishing unit. With 1,978 identified fishers/fishing units, the aggregate estimated direct production-related economic loss reached approximately USD 55.62 million. The magnitude of this estimate was primarily associated with the substantially larger number of fishing units operating the prohibited gear in this study area.

Table 3

Estimated direct production-related economic losses by study area and fishing gear

Study area	*Prohibited fishing gear*	*Peak season (USD)*	*Moderate season (USD)*	*Low season (USD)*	*Estimated value per fishing unit (USD)*
Serang	Arad	6,475.00	3,535.00	700.00	10,710.00
Cirebon	Arad	13,019.20	8,288.04	1,287.86	22,595.09
Rembang	Arad	16,666.00	9,832.50	1,620.20	28,118.70
Lamongan	Cantrang	25,927.50	20,632.50	10,127.50	56,687.50

Table 4

Estimated aggregate production-related economic values of prohibited fishing practices by study Area

Study area	*Estimated value per fishing unit (USD)*	*Identified fishers/ fishing units*	*Aggregate estimated value (USD)*
Serang	10,710.00	150	1,606,500.00
Cirebon	22,595.09	584	13,195,532.14
Rembang	28,118.70	1,978	55,618,788.60
Lamongan	56,687.50	280	15,872,500.00

In Lamongan, where Cantrang rather than arad was the prohibited fishing gear examined, the estimated seasonal production values were USD 25,927.50 during the peak season, USD 20,632.50 during the moderate season, and USD 10,127.50 during the low season. The resulting estimated value was approximately USD 56,687.50 per fishing unit, the highest unit-level estimate among the four study areas. However, because the identified population consisted of 280 fishers/fishing units, the aggregate estimated value was approximately USD 5.87 million, lower than the aggregate estimate for Rembang.

Overall, the aggregate estimates differed markedly among the four locations: Rembang recorded the highest value (USD 55.62 million), followed by Lamongan (USD 15.87 million), Cirebon (USD 13.20 million), and Serang (USD 1.61 million). These differences indicate that the magnitude of direct production-related economic losses associated with prohibited fishing practices is determined not only by the monetary value generated by individual fishing units but also by the number of fishing units operating the prohibited gear. Accordingly, Rembang generated the highest aggregate estimate despite Lamongan having the highest estimated value per individual fishing unit. These findings also highlight the economic dimension of fisheries compliance. Sumaila et al. (2006) demonstrated that economic incentives play an important role in illegal fishing decisions, particularly when the expected benefits of non-compliance exceed the anticipated costs of detection and sanctions. The substantial production-related values identified in this study therefore provide an economic rationale for strengthening fisheries surveillance, while the persistence of prohibited fishing practices should also be understood in relation to fishing livelihoods and the challenges of implementing gear restrictions, as documented by Indrawasih & Wahyono (2009) and Semedi & Schneider (2021).

Importantly, these estimates should be interpreted as direct production-related economic losses associated with the prohibited fishing practices examined in this study, rather than as a comprehensive economic valuation of illegal fishing. The calculations do not establish the counterfactual economic outcomes that would have occurred under legally compliant fishing practices. Furthermore, they exclude indirect and long-term consequences, including ecosystem degradation, resource depletion, future catch losses, foregone government revenue, and broader social costs. Sumaila et al. (2020) emphasized that illicit fishing-related trade can generate wider consequences for marine ecosystems

and human well-being. Accordingly, the present estimates should be interpreted as an indicator of the economic scale of the prohibited fishing activities under investigation, providing a basis for prioritizing surveillance interventions rather than a complete valuation of their economic, ecological, and social impacts.

Developing an integrated fisheries surveillance model for Provincial Waters. The institutional mapping undertaken in this study identified five principal agencies responsible for fisheries surveillance within Indonesia's provincial waters, namely the Provincial Marine and Fisheries Office (DKP), the Directorate General of Marine and Fisheries Resources Surveillance (PSDKP-MMAF), the Indonesian Navy (TNI AL), the Indonesian National Police (Polri), and the Indonesian Maritime Security Agency (Bakamla). Meanwhile, the Indonesian Navy, National Police, and Bakamla perform maritime security, surveillance, and law enforcement functions in accordance with their respective statutory mandates. These findings are consistent with Sodik (2009), who examined the legal framework governing fisheries MCS in Indonesia, and Maharbhakti et al. (2025), who identified the continuing challenges of implementing provincial fisheries surveillance authority. Although these institutional mandates are legally distinct and potentially complementary, the mapping results reveal intersections in operational functions, particularly regarding patrol activities, law enforcement coordination, and fisheries compliance monitoring within provincial waters (Table 4). Similar coordination challenges were identified by Sitorus & Said (2023), who emphasized the importance of institutional synergy in maritime patrol operations. Accordingly, the findings suggest that the central institutional challenge lies not simply in overlapping functions, but in the limited integration of operational responsibilities, information exchange, and surveillance resources among agencies.

The findings indicate that effective fisheries surveillance cannot rely solely on the authority of individual institutions but requires an integrated governance framework capable of combining the comparative advantages of each agency. Based on the institutional analysis and stakeholder assessment, this study proposes an integrated fisheries surveillance model specifically designed for Indonesia's provincial waters (Figure 1). The proposed model adopts a multi-layered surveillance mechanism beginning with community-based detection through fishers, fishers' organizations, and Community Surveillance Groups (Kelompok Masyarakat Pengawas/Pokmaswas), which function as the first line of surveillance. Their proximity to fishing activities enables rapid identification of illegal fishing practices, prohibited fishing gears, licensing violations, and spatial infringements. This approach is supported by Fujii et al. (2021), who emphasized cooperation with fishers and other stakeholders as an important strategy for strengthening MCS in coastal fisheries. Information collected at the community level is subsequently transmitted through an integrated reporting mechanism to the Fisheries Surveillance Task Force, where reports are registered, verified, and assessed before being referred to the appropriate agencies for further action. By connecting community-based reporting with institutional response mechanisms, the proposed model is expected to expand surveillance information coverage and reduce information gaps across geographically extensive coastal waters.

Table 5

Authority of law enforcement agencies in fisheries surveillance

Institution	*Legal basis*	*Jurisdiction*	*Primary mandate*	*Scope of fisheries surveillance*	*Relevance to the 12-nautical-mile zone*
Indonesian National Police	Law No 2/ 2002	Throughout the territory of the Republic of Indonesia; at sea, including territorial waters (≤ 12 nautical miles)	Maintenance of public security and order, law enforcement, and criminal investigation	Enforcement against fisheries-related offenses, patrols in territorial waters, and investigation of IUU fishing offenses	Exercises law-enforcement authority within territorial waters up to 12 nautical miles
Indonesian Navy	Law No. 34 of 2004; Presidential Regulation No. 66 of 2019	Indonesia's maritime jurisdiction, including territorial waters, the EEZ, and continental shelf	National defense, law enforcement, and maritime security	Law enforcement against fisheries violations across maritime zones, including the EEZ	Exercises authority within the 12-nautical-mile zone as well as in maritime jurisdiction beyond 12 nautical miles
Indonesian Maritime Security Agency	Law No. 32 of 2014 on Maritime Affairs	Indonesian waters and maritime jurisdiction	Maritime security and safety patrols	Surveillance, prevention, and enforcement against violations of law at sea, including fisheries-related violations	Conducts integrated maritime patrols, including within the 12-nautical-mile zone
Directorate General of PSDKP, MMAF	Law No. 31 of 2004, as amended by Law No. 45 of 2009	Fisheries Management Areas of the Republic of Indonesia	Technical surveillance of marine and fisheries activities	Surveillance of fishing activities, aquaculture, distribution, quality, conservation, and fishing vessels	Exercises fisheries surveillance functions, including within the 12-nautical-mile zone
Provincial Marine and Fisheries Office (Provincial DKP)	Law No. 23 of 2014	Marine waters extending up to 12 nautical miles from the coastline	Management and surveillance of marine and fisheries resources under provincial authority	Licensing, marine spatial management, and surveillance of marine and fisheries resource utilization	Holds provincial fisheries management and surveillance responsibilities within waters extending up to 12 nautical miles

Note: PSDKP - Marine and Fisheries Resources Surveillance; MMAF - Ministry of Marine Affairs and Fisheries; EEZ - exclusive economic zone.

Following the reporting process, enforcement activities are conducted through a coordinated multi-agency approach involving PSDKP, the Indonesian Navy, Water Police, Indonesian Coast Guard, and Provincial Marine and Fisheries Offices according to their respective legal mandates and operational capacities. Rather than replacing existing institutional authorities, the proposed model establishes an operational coordination mechanism through a Fisheries Surveillance Task Force, with the Provincial DKP serving as its Secretariat and coordination hub. The Task Force facilitates surveillance planning, information exchange, independent and joint patrol coordination, and the referral of suspected violations to legally competent authorities. This arrangement is consistent with Sitorus & Said (2023), who highlighted the importance of collaboration among maritime security institutions in utilizing personnel, operational assets, and institutional capabilities. Similarly, Fujii et al. (2021) emphasized interagency coordination and information sharing as essential components of effective fisheries monitoring and surveillance. The proposed model, therefore, seeks to transform fisheries surveillance from a predominantly institution-centered approach into an integrated, system-based mechanism without consolidating or transferring the statutory authority of participating agencies.

An important feature of the proposed model is the establishment of a structured reporting and coordination mechanism under the leadership of the Provincial Marine and Fisheries Office. Surveillance outcomes generated by operational agencies are consolidated into periodic surveillance reports that are subsequently evaluated through the Fisheries Surveillance Forum. Rather than functioning solely as an administrative reporting platform, the forum serves as an institutional coordination mechanism through which participating agencies jointly evaluate surveillance performance, identify operational constraints, exchange intelligence, and formulate strategic priorities for subsequent surveillance activities. From the perspective of collaborative governance, Ansell & Gash (2008) emphasized the importance of institutional design, leadership, trust building, and shared understanding in sustaining collaboration among stakeholders. Emerson et al. (2012) further identified principled engagement, shared motivation, and capacity for joint action as central components of collaborative governance. Accordingly, the proposed reporting and evaluation mechanism is intended to strengthen institutional accountability, facilitate organizational learning, and support adaptive surveillance planning.

The proposed surveillance model also emphasizes horizontal collaboration among provincial governments through inter-regional cooperation. Considering that fishing activities frequently extend beyond administrative boundaries, surveillance strategies based solely on provincial jurisdictions are insufficient to address the highly mobile nature of fishing fleets operating within Fisheries Management Area 712 (Java Sea). Fujii et al. (2021) identified fragmented cooperation as a persistent challenge in fisheries monitoring and highlighted the importance of communication platforms and collaborative surveillance arrangements. Although their analysis primarily addressed cooperation among countries in the Asia-Pacific region, the underlying need for information exchange and coordinated monitoring is also relevant to cooperation among provinces within a shared fisheries management area. The proposed model therefore incorporates intergovernmental cooperation to facilitate information exchange, coordinate patrol planning, harmonize operational procedures where legally permissible, and identify shared surveillance priorities. Such cooperation is expected to reduce operational fragmentation while allowing each province and participating national institution to exercise its respective statutory responsibilities.

Overall, the integrated fisheries surveillance model developed in this study highlights that effective fisheries governance requires more than clearly defined institutional authority. It also depends on the ability of institutions to coordinate information, mobilize operational capacities, and respond collectively to surveillance needs. The proposed integration of community participation, multi-agency coordination, structured reporting, provincial leadership, and inter-regional cooperation is consistent with the collaborative governance framework developed by Ansell and Gash (2008) and Emerson et al. (2012), as well as the fisheries surveillance cooperation principles discussed by Fujii et al. (2021). The principal contribution of this study lies in translating these governance principles into an institutional and operational model specifically designed for

Indonesia's decentralized provincial waters. Unlike approaches that depend primarily on individual agency capabilities, the proposed model emphasizes process integration without consolidation of legal authority. Nevertheless, its effectiveness in improving surveillance coverage, operational responsiveness, resource utilization, and fisheries compliance requires further assessment through pilot implementation and performance evaluation. Strengthening institutional collaboration, therefore, represents a strategic pathway toward more coordinated fisheries surveillance and sustainable fisheries governance in WPPNRI 712.

Conclusions. This study demonstrates substantial variation in the implementation of fisheries surveillance within Indonesia's 12-nautical-mile provincial waters in WPPNRI 712. Although the legal and institutional framework for fisheries surveillance is generally established across the four provinces, its implementation remains uneven, particularly in terms of budgetary support, surveillance facilities and infrastructure, maritime patrol capacity, and the availability of patrol vessels and other operational resources. These differences indicate that the formal allocation of surveillance responsibilities does not necessarily translate into equivalent operational capacity across provincial jurisdictions. Given the cross-boundary nature of fishing activities and vessel movements, strengthening fisheries surveillance therefore requires not only improvements in individual provincial capacity but also stronger coordination across jurisdictions and institutions.

The study also identified the continued use of prohibited fishing gears, particularly arad in Serang, Cirebon, and Rembang, and cantrang in Lamongan. Based on seasonal fishing production and government-established fish reference prices, the estimated direct production-related economic losses associated with these prohibited fishing practices varied substantially among the study locations. The aggregate estimated values were approximately USD 1.61 million in Serang, USD 13.20 million in Cirebon, USD 55.62 million in Rembang, and USD 15.87 million in Lamongan. These estimates demonstrate the substantial monetary value of fisheries production associated with prohibited fishing practices and highlight the economic importance of strengthening surveillance and regulatory compliance. However, these estimates represent direct production-related economic losses rather than a comprehensive valuation of the economic, ecological, and social consequences of illegal fishing.

Beyond the empirical assessment, this study proposes an integrated multi-level fisheries surveillance model for provincial waters. The model combines community-based monitoring and reporting through fishers and community surveillance groups, coordinated multi-agency surveillance, structured reporting, and institutional coordination involving provincial fisheries authorities and relevant national agencies, and inter-regional cooperation. The proposed framework is intended to address institutional fragmentation by improving information flows, clarifying coordination mechanisms, and connecting community-level monitoring with provincial and national surveillance functions.

The findings therefore underscore the importance of strengthening operational surveillance capacity alongside institutional coordination. Improvements in surveillance infrastructure and human resources, integrated reporting and information systems, community participation, inter-agency coordination, and inter-regional cooperation constitute important elements of a more integrated approach to fisheries surveillance within decentralized marine governance. The model developed in this study should, however, be regarded as a proposed institutional framework rather than an empirically validated intervention. Its operational feasibility and effectiveness require further stakeholder validation, field implementation, and evaluation.

Study Limitations. This study has several limitations that should be considered when interpreting its findings. First, fishing respondents were selected using non-probability sampling, combining accidental and snowball sampling. This approach was considered appropriate because fishers associated with prohibited fishing practices constitute a difficult-to-identify population; however, it limits the statistical representativeness of the sample and the extent to which the findings can be generalized to the broader fishing population.

Second, information concerning fishing activities and seasonal production was partly based on respondents' self-reported information. Because the study addresses legally sensitive fishing practices, the data may be affected by recall bias, reporting bias, or under-reporting. Accurate information on illegal fishing is inherently difficult to obtain because prohibited activities are not always formally recorded, and respondents may be reluctant to disclose information concerning non-compliant practices. Field observations and institutional information were used to support interpretation where available, but these procedures cannot completely eliminate potential reporting uncertainty.

Third, the estimates presented in this study should be interpreted specifically as direct production-related economic losses associated with the prohibited fishing practices examined, rather than as a comprehensive economic valuation of illegal fishing. The estimates were derived from seasonal fishing-production data and government-established fish reference prices and therefore remain sensitive to variation in reported production and reference prices. The analysis does not incorporate variable and fixed fishing costs, private profits, profit margins, fish-stock depletion, habitat degradation, future catch losses, foregone government revenue, or wider social and ecosystem costs. Consequently, the estimates should not be interpreted as representing the total social or economic costs of illegal fishing.

Fourth, the geographical coverage of the study was limited to four provinces within WPPNRI 712: Banten, West Java, Central Java, and East Java, with one principal study location selected in each province. The findings, therefore, reflect the institutional and fisheries characteristics of these study areas and should not be automatically generalized to other Indonesian fisheries management areas, provinces, or fishing communities with different ecological, socioeconomic, fleet, and governance characteristics.

Finally, the integrated multi-level fisheries surveillance model developed in this study was derived from legal and institutional analysis, field observations, stakeholder interviews, comparative gap analysis, and process mapping, but has not yet been experimentally implemented or empirically evaluated as an operational surveillance intervention. Consequently, the study does not claim that the proposed model has already demonstrated improvements in surveillance effectiveness, compliance, or reductions in illegal fishing. Future research should validate the model with relevant stakeholders, pilot its implementation in selected provincial waters, and evaluate its institutional feasibility, operational performance, costs, and effectiveness over time.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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