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Oversight beyond formal forums: Collaborative environmental governance of seaweed farming in a border district of Indonesia

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ABSTRACT

Seaweed farming in Nunukan, a border district in North Kalimantan, Indonesia, involves many actors and is covered by provincial and district regulations, yet its oversight remains largely ad hoc and reactive. This study examines to what extent principles of collaborative environmental governance (CEG) are realised in the oversight of seaweed farming, and why community institutions appear to perform oversight functions more consistently than formal ones. Drawing on 71 interviews with 62 informants in three coastal sub-districts, complemented by document analysis, we assess five dimensions: involvement of local actors, collaborative forums, social learning, mutual trust and knowledge co-production. We identify four main findings. First, the oversight system is largely pre-collaborative: non-governmental organisations and academics are absent as independent actors, and the representation of farmers and fishers declines as decision arenas become more formal. Second, formal forums with a legal basis rarely produce traceable outputs, whereas community arrangements without legal status produce rules that are generally followed, such as compensation for damage and timing rules between farmers and harvesters. Third, trust is asymmetric: 24 of 40 field actors expressed low or no trust in local government, while trust among farmers remains relatively intact and relations between sea users differ across sub-districts. Fourth, scientific baselines are largely missing and the ecological observations of field actors are not recorded, so the two types of knowledge are seldom combined. We suggest that oversight could be strengthened by institutionalising multi-actor forums, linking informal and formal institutions rather than replacing them, making zoning and aid decisions more transparent, and building shared monitoring.

INTRODUCTION

Indonesia is one of the world's largest producers of tropical seaweed, and seaweed farming provides important livelihoods for coastal communities (Langford et al., 2022; Steenbergen et al., 2017). Nunukan District, North Kalimantan, is a major production centre. In 2023, it recorded 4,770 fishery households, 13,050 ha of farming area, 764,264 tonnes of wet seaweed production, and approximately 14,310 people employed in the sector. Located along the Malaysian border, Nunukan has overlapping marine uses involving seaweed farmers, harvesters, capture fishers, and shipping operators. These competing uses create governance challenges involving environmental monitoring, spatial management, and conflict resolution.

Oversight of this shared maritime space requires coordination beyond a single government agency. Although authority over coastal waters primarily rests with the provincial government, the effects of seaweed farming extend to district, sub-district, and village levels. In this study, oversight refers to monitoring, rule-setting, enforcement, and

dispute resolution concerning farming practices and marine space. Collaborative environmental governance (CEG) offers a useful perspective because collaboration can strengthen decision-making legitimacy, social learning, and environmental outcomes (Bodin, 2017; Newig et al., 2018). However, collaboration can also generate transaction costs, power asymmetries, and free-riding (Bodin et al., 2016), while collaborative platforms may remain consultative without producing joint decisions (Ansell and Gash, 2018). Although collaborative networks can facilitate adaptation to ecological change (Bodin, 2017; Douglas et al., 2020), informal institutions in Indonesia have also been associated with clientelism and the informalisation of state institutions (Berenschot and van Klinken, 2018; Hidayat et al., 2025). Conversely, common-pool resource research shows that resource users can establish and enforce their own rules (Partelow, 2018).

Nunukan has a formal regulatory framework comprising North Kalimantan Provincial Regulation No. 4/2018 on coastal zoning, Governor Regulation No. 26/2024 on seaweed, and Nunukan Regent Regulation No. 28/2021 on seaweed farming. An integrated surveillance team has also been established through a governor's decree. Nevertheless, coordination remains largely ad hoc. Recurrent ice-ice disease has been treated as a natural problem without laboratory testing, farmers in South Nunukan rejected seed assistance because of quality concerns, and conflicts between farmers and fishers over drifting seaweed remain unresolved. These conditions raise questions about the capacity of existing institutions to translate formal regulations into effective collaborative oversight.

Research on CEG has predominantly examined forests, water resources, and capture fisheries, often in high-income countries. Less attention has been given to Indonesian mariculture, particularly in maritime border regions where formal, customary, and informal institutions interact. Marine spatial planning research also indicates that excluding resource users can undermine zoning legitimacy (Flannery et al., 2018). This study addresses this gap by examining how institutional relationships shape everyday oversight of seaweed farming.

Drawing on Bodin (2017), this study operationalises CEG through five analytical dimensions developed by synthesising relevant literature: local actor involvement, collaborative forums, social learning, mutual trust, and knowledge co-production. Local actor involvement concerns substantive stakeholder representation, recognising that differences in resources and power influence participation (Ansell and Gash, 2018). Collaborative forums are assessed through meeting regularity, substantive agendas, and documented outcomes (Ulibarri et al., 2020). Social learning concerns dialogue, collective reflection, knowledge exchange, and the diffusion of practices (Gerlak et al., 2018). Mutual trust concerns reciprocal confidence among government agencies, farmers, marine resource users, and decision-making processes, recognising its relationship with learning and collaboration (Siddiki et al., 2017). Knowledge co-production examines the integration of scientific evidence and local ecological knowledge, including scientific baselines, zoning, early warning, and shared data platforms (Wyborn et al., 2019).

Coordination across sectors and administrative scales serves as a cross-cutting analytical lens. The framework distinguishes three institutional bases: formal institutions, including government agencies, village governments, and community surveillance groups; customary institutions, represented by the adat council; and informal institutions, including area coordinators, harvester groups, and fishers' associations.

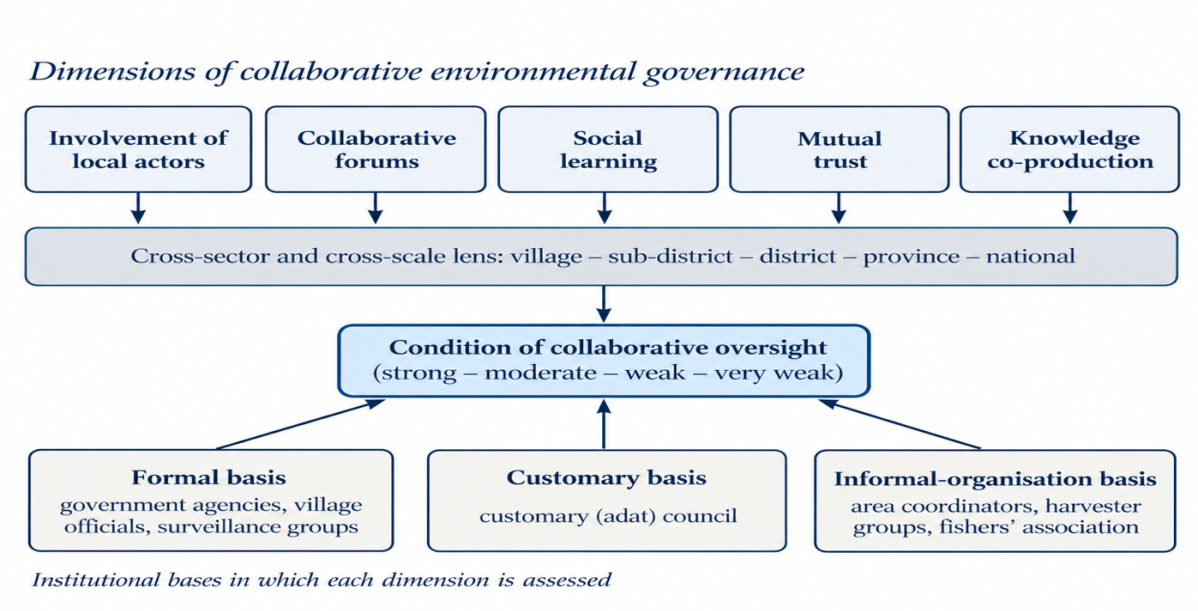


Figure 1. Analytical framework of collaborative environmental governance, integrating five dimensions, cross-scale coordination, and three institutional bases

This study addresses two research questions: (1) To what extent are CEG principles realised in the oversight of seaweed farming in Nunukan District? and (2) Why do community institutions perform oversight functions more visibly than formal institutions, and what explains differences between sub-districts? By addressing these questions, the study contributes to understanding how institutional relationships shape collaborative oversight in Indonesian mariculture and maritime border regions.

METHOD

This study was conducted in Nunukan District, North Kalimantan, a major seaweed production centre and maritime border region characterised by diverse governance actors and overlapping marine uses. Three coastal sub-districts—Sebatik Barat, Nunukan, and Nunukan Selatan—were selected to capture differences in community institutions, resource-user relationships, and conflict patterns. Fieldwork took place in January and February 2026. Table 1 summarises the characteristics of the three study areas.

Table 1. Characteristics of the selected sub-districts

Characteristic	West Sebatik	Nunukan	South Nunukan
Community institutions	Active surveillance group in Liang Bunyu, led by one person	At least eight informal organisations; *adat* council involved in Binusan	Limited institutional activity; farmers' association no longer meets
Farmer–harvester relations	Tense; harvesters suspected of taking drifting seaweed	Mutually beneficial; shared timing rule	Varied
Farmer–fisher relations	Latent conflict over drifting seaweed	Tension associated with farming expansion	Historical conflict between native and migrant fishers
Physical zoning markers	None	None	Boundary buoys in Mamolok

Source: Interview data, 2026

The study involved 62 informants selected from relevant stakeholder groups, including seaweed farmers, harvesters, capture fishers, village officials, sub-district heads, community

surveillance groups (*Pokmaswas*), the *adat* council, technical agencies, and the district parliament. Some informants were interviewed more than once, resulting in 71 interviews. Forty-six informants also participated in a survey involving 150 farmers, officials, and coastal residents conducted as part of the larger study; the survey findings are not reported in this article. Interviews were complemented by field observations and documentary evidence, including the decree establishing the integrated surveillance team, provincial coastal zoning regulations, and relevant governor and district regulations. Informants are anonymised and identified by their roles and locations.

Table 2. Distribution of interviews by informant category and location

Informant category	West Sebatik	Nunukan	South Nunukan	District/province	Total
Seaweed farmers	7	6	6	–	19
Harvesters	5	5	4	–	14
Capture fishers	4	4	5	–	13
Village officials	3	4	2	–	9
Technical agencies	–	–	–	9	9
Sub-district heads	1	1	1	–	3
Community surveillance groups (*Pokmaswas*)	1	1	–	–	2
Adat council	–	1	–	–	1
District parliament	–	–	–	1	1
Total interviews	**21**	**22**	**18**	**10**	**71**

Note: Technical agencies include district and provincial marine and fisheries offices, the environment office, transport office, investment and licensing office, provincial marine and fisheries surveillance unit, harbour master, navigation district, and police

Data were analysed abductively by combining theoretically informed indicators with patterns emerging from the field. The analysis examined five dimensions of collaborative environmental governance (CEG): local actor involvement, collaborative forums, social learning, mutual trust, and knowledge co-production. Each sub-indicator was assessed as strong, moderate, weak, or very weak, while the overall condition of each dimension was determined by the dominant rating of its sub-indicators. Frequencies refer to individuals rather than interviews, with informants counted once per code even when interviewed more than once. Reported proportions specify their respective denominators: most refer to 46 field actors, while the trust analysis covers the 40 field actors who expressed a clear view.

Table 3. Operational indicators and assessment criteria for collaborative environmental governance

Dimension	Operational indicators	Weak condition	Strong condition
Local actor involvement	Actor composition, representation in decision-making, spatial variation	Nominal participation; absence of independent actors	Farmers, *adat* representatives, NGOs, and academics participate substantively and influence decisions
Collaborative forums	Meeting regularity, agendas, outputs	Ad hoc meetings, one-way information, undocumented outputs	Scheduled meetings, jointly determined agendas, documented follow-up

Social learning	Dialogue, collective reflection, knowledge exchange, diffusion of good practices	Critical events occur without reflection; training fails to reach field actors	Regular multi-actor evaluation and facilitated knowledge exchange
Mutual trust	Trust in government, among farmers, among marine users, and decision-making transparency	Low or absent trust; no transparency mechanisms	Trust among actors; published decisions and feedback mechanisms
Knowledge co-production	Scientific baselines, zoning, early warning, shared data platforms	Unavailable or inaccessible data; limited awareness of regulations	Open monitoring, participatory zoning, collaborative research

Source: Adapted from (Bodin, 2017; Gerlak et al., 2018; Siddiki et al., 2017; Wyborn et al., 2019)

RESULT AND DISCUSSION

The findings indicate that collaborative environmental governance (CEG) in seaweed farming oversight in Nunukan District remains weak across all five dimensions, although the institutional arrangements and challenges vary between sub-districts. Formal institutions possess regulatory authority but demonstrate limited follow-up, transparency, and knowledge integration. By contrast, customary and informal community institutions perform practical oversight functions, particularly mediation, compensation, and the enforcement of locally agreed rules. These findings suggest that the central governance problem is not the complete absence of institutions, but the weak connections between formal authority, community-based coordination, and scientific knowledge.

Local actor involvement and institutional representation

The oversight system remains largely pre-collaborative. Across 71 interviews, field actors, government representatives, and community surveillance groups and the *adat* council described arrangements dominated by government agencies, with no continuing involvement of NGOs or research institutions. A deputy chair of the district parliament called for university cooperation to support environmental management, indicating that such collaboration remains insufficiently established. Traders and exporters were also absent from oversight forums, limiting representation across the seaweed value chain.

Representation declines as decision-making becomes more formal. Field actors were not documented as participants in preparing the provincial coastal zoning plan (2018–2038), while the integrated surveillance team was dominated by law enforcement and technical agencies. Community surveillance groups participated mainly through a messaging group managed by provincial fisheries inspectors. At village and sub-district levels, participation was more substantial but uneven. A village head in Nunukan explained that zoning boundaries followed the locations where farmers had already installed foundations, while a senior farmer in Sebatik Barat stated that zoning was communicated only after it had been completed. These accounts indicate that consultation did not consistently translate into influence over decisions.

Table 4. Representation of actors across oversight decision arenas

Decision arena	Government	Farmers	Fishers	Surveillance groups	*Adat* council	NGOs	Academics
Provincial zoning plan (2018–2038)	Full	n.d.	n.d.	None	None	None	None

Integrated surveillance team	Full	None	None	Partial	None	None	None
Sub-district and village coordination	Full	Partial	Partial	Partial	Partial	None	None
User-conflict resolution	Partial	Full	Partial	Partial	Partial	None	None

Note: *Full = fully represented; Partial = represented in some meetings or through intermediaries; None = not represented; n.d. = not documented. Source: Interview data and documents, 2026*

Differences between sub-districts reinforce this pattern. Nunukan has at least eight informal organisations, and the *adat* council plays a substantive role in Binusan. In Sebatik Barat, the surveillance group in Liang Bunyu depends heavily on one individual, while community institutions are less developed in Nunukan Selatan, where the farmers' association no longer meets. The district environment office described collaborative governance as not yet established, while the fisheries office acknowledged limited community involvement in decision-making.

These findings are consistent with research showing that collaborative platforms may remain consultative rather than generate joint decisions (Ansell and Gash, 2018). They also support the argument that excluding resource users from marine spatial planning can undermine the legitimacy of zoning decisions (Flannery et al., 2018). In Nunukan, the limited involvement of independent actors and the declining representation of field actors in formal arenas leave information and decision-making power concentrated among government agencies. This imbalance provides an important explanation for the weak legitimacy and limited responsiveness of formal oversight.

Collaborative forums and the gap between formal authority and collective action

Seven forums were identified across provincial, district, sub-district, village, and community levels. Their institutional characteristics reveal a contrast between formal authority and practical effectiveness. Provincial forums have a legal basis but meet incidentally, while district and sub-district forums generally lack specific legal mandates and meet infrequently. Community forums are less formal but tend to produce more concrete and enforceable outcomes.

Table 5. Characteristics and outputs of seaweed farming oversight forums

Forum	Level and basis	Frequency	Main output	Follow-up
Integrated surveillance team	Province; governor's decree	Incidental	Patrols following complaints; action against destructive fishing	Partial
Parliamentary hearings with agencies	District; parliamentary rules	Annual	Oral and written recommendations	None
Fisheries inspector coordination	District; no specific basis	Incidental	Responsive field visits	Undocumented
Cross-sectoral discussions	Sub-district; no specific basis	1–2 times yearly	Outputs not documented	None

Village deliberation in Binusan	Village; customary practice	Incidental	Ban on farming in speedboat lanes; *adat* involvement	Partial
Internal surveillance group meetings	Community; group statutes	Daily, online	Reports to provincial inspectors	Partial
Informal coordinator meetings	Community; consensus	As needed	Compensation and harvesting-timing rules	Generally followed

Source: Interview data and documents, 2026

Formal meetings are uncommon and often lack systematic follow-up. A farmer in Liang Bunyu reported that forums occurred at most once a year, while the head of Sebatik Barat explained that meetings were generally organised in response to residents' requests for conflict resolution. Figure 2a shows that 27 of 46 field actors (58.7%) had not participated in an oversight forum during the previous three years. This included 8 of 19 farmers and 10 of 13 fishers. Of 14 forums reported by informants, the marine and fisheries office attended 12, whereas farmers were represented in only three.

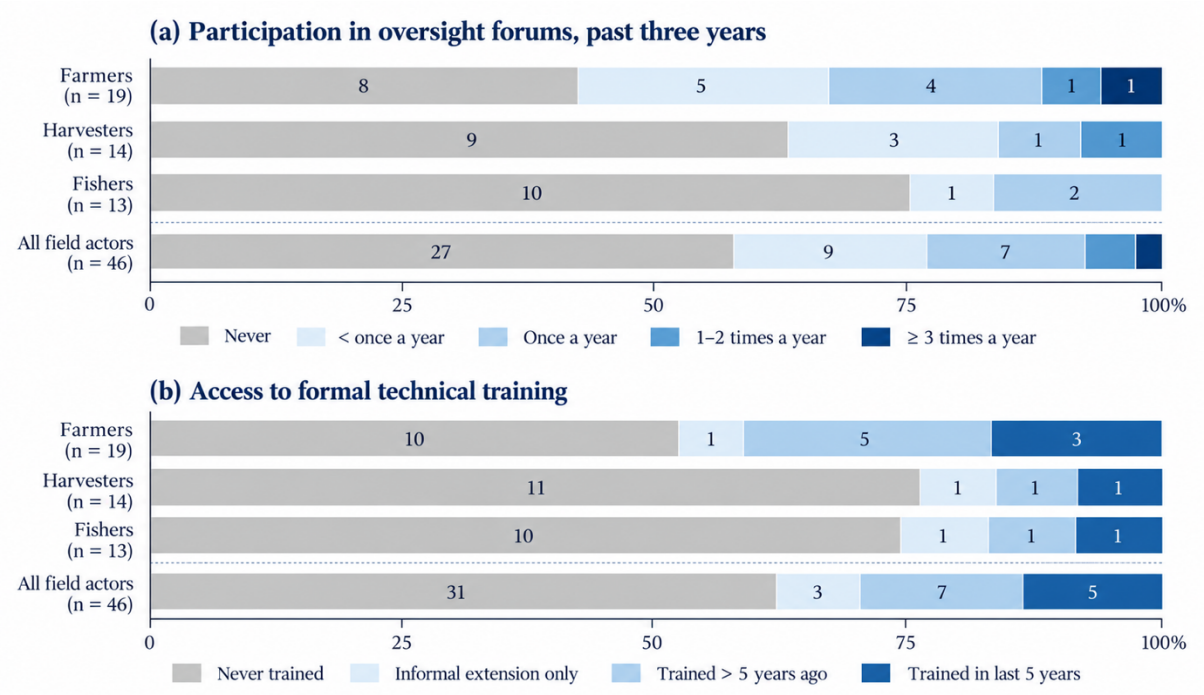


Figure 2. *Participation of field actors in oversight forums (a) and access to formal technical training (b), by actor category. Bar labels indicate counts, while bar lengths represent the proportion within each category.*
Source: Interview data, 2026

The limited influence of formal forums was also evident in their outputs. A senior farmer reported repeatedly submitting letters to the district parliament without obtaining a policy response. A provincial fisheries inspector similarly observed that information often remained with participants in coordination meetings or socialisation activities. Informants attributed these limitations to the absence of defined mandates, dedicated budgets, substantive deliberation, and follow-up mechanisms.

Community arrangements, in contrast, generated practical rules. Four harvesters in Tinabasan independently confirmed that compensation for damaged farming lines was determined jointly through their coordinator. Farmers and harvesters also followed a tide-based timing rule to separate harvesting from farming activities. In Binusan, village deliberation established a prohibition on farming in speedboat lanes and a referral procedure involving neighbourhood heads, the village security officer, and the *adat* council.

Communication patterns further illustrate this institutional contrast. Direct contact between coordinators accounted for 29 mentions, messaging groups for 27, and formal government forums for only 10 of 105 communication-channel mentions (9.5%).

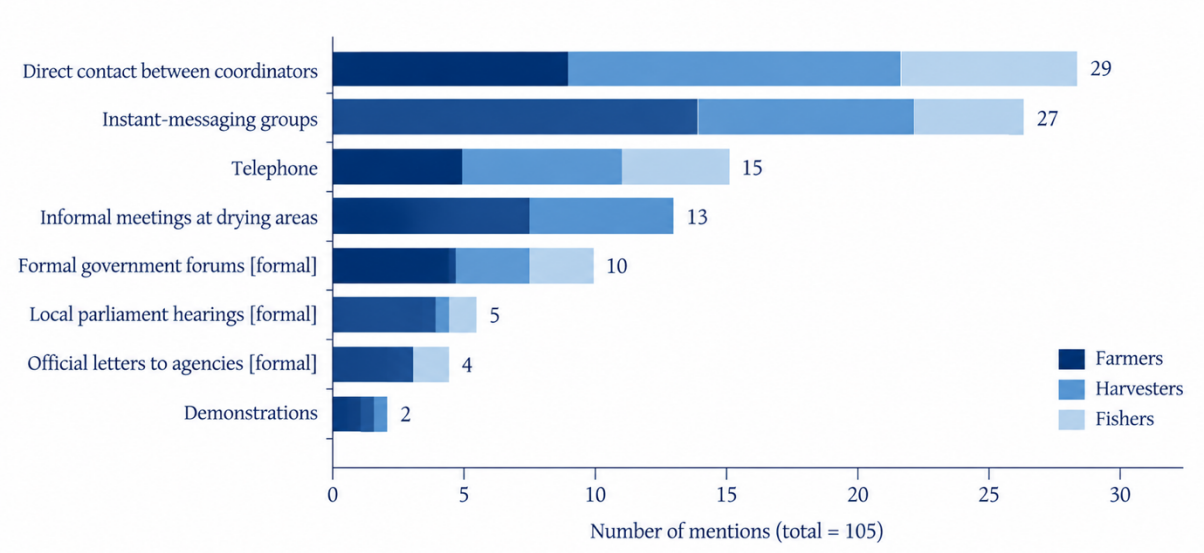


***Figure 3**. Communication channels used by field actors for oversight and learning. Counts represent mentions, and individual actors could report multiple channels*
Source: Interview data, 2026.

The findings demonstrate that formalisation alone does not ensure effective collaboration. Consistent with Bodin et al. (2016), collaborative arrangements require relationships that facilitate collective action rather than merely bringing actors together. In Nunukan, informal forums provide flexibility and immediate problem-solving capacity, whereas formal forums frequently lack implementation mechanisms. The policy challenge is therefore to connect these arrangements without undermining the community rules that already work.

Social learning and the limited integration of knowledge

Social learning is weak, particularly in collective reflection on governance failures. Among the agencies examined, only the provincial marine and fisheries surveillance unit used written performance indicators, while evaluation reports remained internal. None of the seven critical events identified between 2020 and 2026 was discussed through a multi-actor reflection forum.

Table 6. Institutional responses to critical events, 2020–2026

Critical event	Formal investigation	Multi-actor reflection	Corrective measure
Recurrent ice-ice disease	No	No	No
Seed distribution perceived as unsuitable	No	No	No

Shrinking fishing grounds	No	No	No
Plastic-bottle waste accumulation	No	No; occasional awareness raising	No
Mangrove cutting for farming stakes	No	No	Awareness raising
Ferry-anchor damage to farming lines in Liang Bunyu	Incidental	No	Partial
Thirteen locations overlapping shipping lanes	Partial	No	Partial

Source: Interview data and documents, 2026

Recurrent ice-ice disease was attributed to natural factors without laboratory testing, illustrating the absence of systematic investigation and collective learning. Community learning nevertheless occurred independently of government. A surveillance group in Nunukan applied staged warnings for zoning violations, while farmers in Mangkabat informally evaluated their farming seasons. In Nunukan Selatan, however, the farmers' association ceased operating shortly after its establishment. This contrast suggests that organisational structures require facilitation, operational resources, and sustained leadership to support learning.

Access to formal training was also limited. Of the 46 field actors, 31 (67.4%) had never attended formal training, while five (10.9%) had attended training during the previous five years.

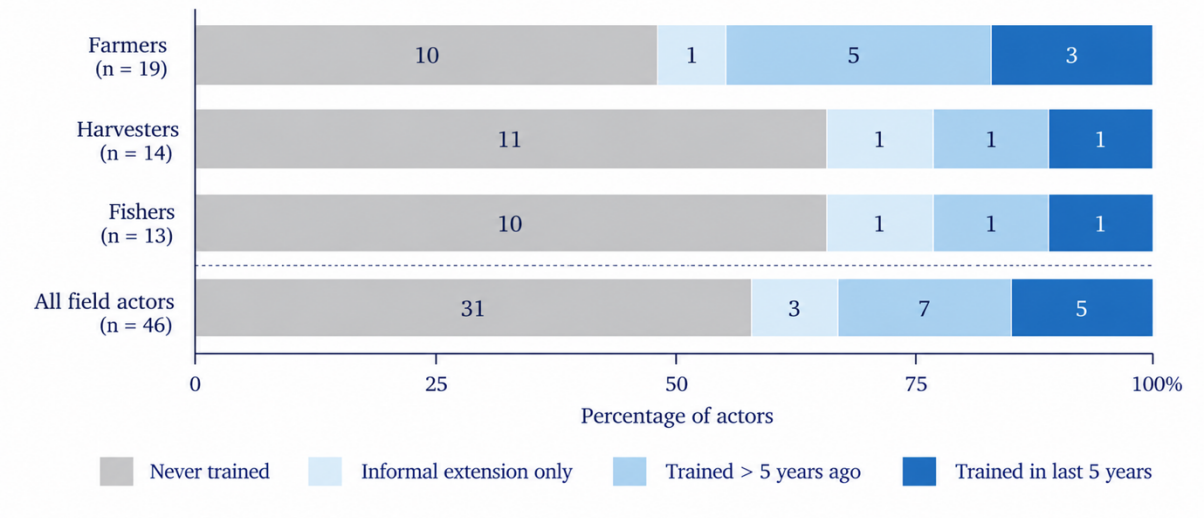


Figure 2(b). *Access to formal technical training among field actors by category*
Source: Interview data, 2026

Informants associated more frequent training with a previous district administration, suggesting that learning opportunities depended on changing political and administrative priorities. In the absence of regular training, knowledge circulated mainly through drying-area discussions, coordinator networks, messaging groups, and exchanges of seedlings between villages to reduce disease risks.

These patterns indicate that social learning is sustained locally but rarely institutionalised. As Gerlak et al. (2018) emphasise, learning requires more than interaction; it also involves reflection and the incorporation of experience into collective practice. In Nunukan, community actors exchange practical knowledge, but there is little systematic evaluation of failures or dissemination of successful practices across institutional boundaries.

The result is fragmented learning that does not consistently inform public policy or technical interventions.

Mutual trust and differentiated relationships among marine users

Trust is uneven across institutional relationships. Among the 40 field actors who expressed a clear view, 24 (60%) reported low or no trust in local government, while 10 (25%) expressed strong or conditional trust. Distrust was particularly pronounced in Sebatik Barat, where 10 of 12 informants reported low or no trust. Conditional trust, most frequently observed in Nunukan, referred to confidence in a policy provided that farmers themselves complied with its requirements.

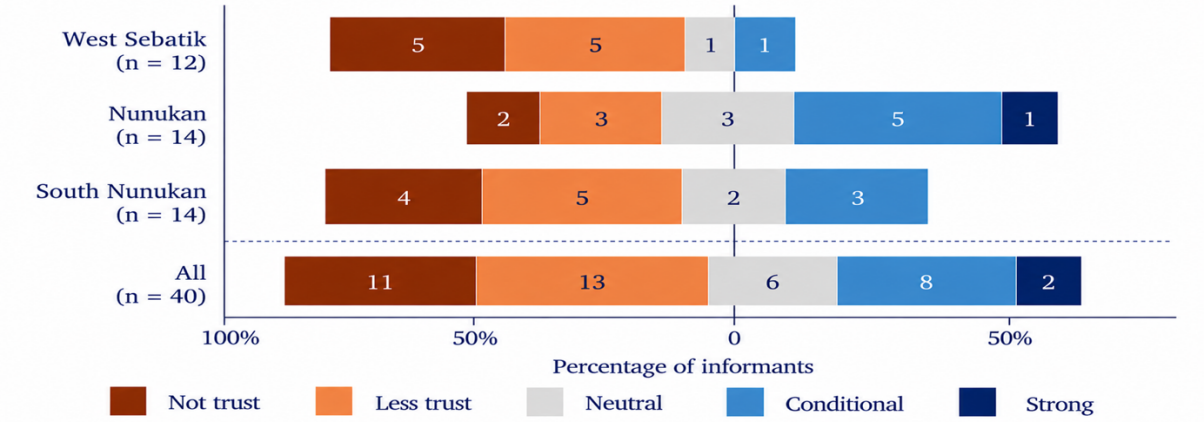


Figure 4. *Field actors' trust in local government by sub-district (a) and reported sources of eroded trust (b). Multiple responses were permitted for sources of distrust*
Source: Interview data, 2026

The most frequently cited source of eroded trust was the lack of transparency in zoning decisions (26 of 40 informants), followed by aid that did not reach ordinary farmers (21) and formal complaints that received no follow-up (19). Only one of nine village heads consistently received copies of new regulations. Five of eight transparency instruments examined were unavailable, including publication of draft policies, reporting on aid distribution, regular public hearings, feedback mechanisms, and water-quality monitoring reports. Zoning consultation, dissemination of regulations to villages, and awareness raising were only partially implemented.

Field actors consequently used alternative channels to express concerns, including social media criticism (five informants), parliamentary hearings (five), escalation through village security officers (three), and demonstrations (two).

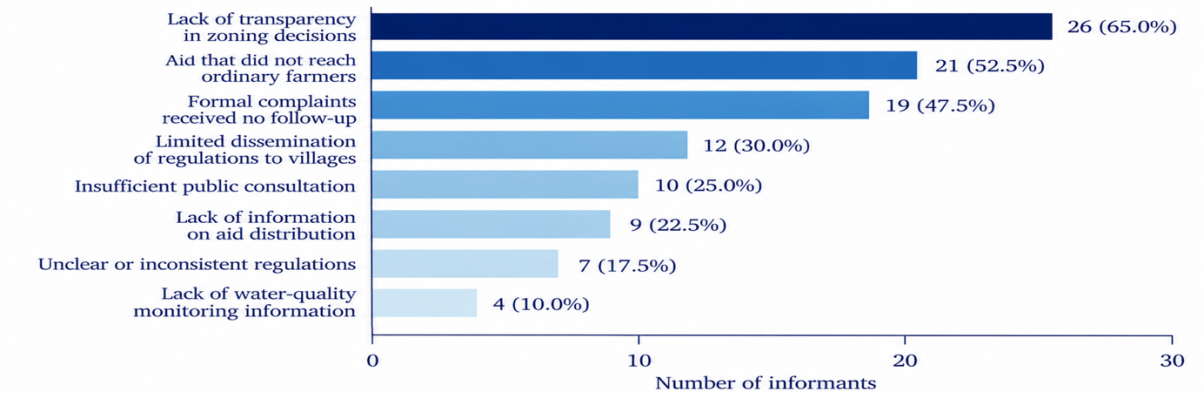


Figure 4(b). *Sources of eroded trust among field actors (n = 40). Multiple responses were permitted*
Source: Interview data, 2026

Trust among farmers was comparatively stronger, supported by coordinators, compensation arrangements, local deliberation, and reciprocal practices such as night-time guarding of farming areas in Liang Bunyu. However, relationships between farmers, harvesters, and fishers differed across sub-districts

Table 7. Relationships among users of marine space

Aspect	Sebatik Barat	Nunukan	Nunukan Selatan
Farmer–harvester relations	Tense; suspected taking of drifting seaweed	Mutually beneficial; all five interviewed harvesters considered farming expansion beneficial	Varied
Harvesting-timing rule	None identified	In place	None identified
Farmer–fisher relations	Latent conflict over drifting seaweed	Tension associated with farming expansion	Historical conflict between native and migrant fishers
Recognised mediators	Customary leaders and neighbourhood heads	Fishers' association chair and coordinators	Association chair and coordinators
Formal mediation forum	None identified	None identified	None identified

Source: Interview data, 2026

The differences suggest that cooperation depends not only on actor categories but also on conflict histories, institutional density, and individuals who perform multiple coordinating roles. The stronger community relationships in Nunukan coexist with limited trust in government, showing that trust is relational rather than uniform across the governance system. This is consistent with Siddiki et al. (2017), who highlight the close relationship between trust and collaborative governance processes.

The findings also qualify interpretations of informality in Indonesia. Research on informalisation of the state associates personal and clientelistic relations with the weakening of impersonal state institutions (Berenschot and van Klinken, 2018; Hidayat et al., 2025). In Nunukan, however, many informal arrangements operate horizontally among resource users and compensate for gaps in formal oversight. Their functions are closer to community-based self-organisation, in which resource users develop and enforce their own rules (Partelow, 2018). Nevertheless, these arrangements remain vulnerable to leadership changes and do not adequately address problems extending beyond local boundaries.

Knowledge co-production and the gap between regulation and practice

Knowledge co-production remains weak because scientific evidence and local ecological knowledge are rarely integrated into shared monitoring or decision-making. None of the eight scientific-baseline components examined was available through regular, publicly accessible monitoring. Water sampling occurred only occasionally, for example through student research or visiting teams, and results were not compiled into longitudinal datasets.

Table 8. Availability of scientific baseline data and awareness of regulations

Item	Status	Responsible actor	Public access
Regular water-quality monitoring	Not available	Provincial fisheries office	No

Salinity and pH	Incidental	University researchers	Internal
Biodiversity	Partial	National research agency and universities	Internal
Oceanographic data	Not integrated	Meteorological agency	Public application
Farming density	Not available	District fisheries office	No
Ice-ice outbreaks	Not available	Not identified	No
Coastal waste	Not available	District environment office	No
Mangrove inventory	Partial	District environment office	Internal
Provincial zoning plan, Regulation No. 4/2018	Known by 8 of 60 non-agency informants (13.3%)	Relevant government agencies	Limited awareness
Governor Regulation No. 26/2024 on seaweed	Known by 1 of 60 informants (1.7%)	Provincial government	Limited awareness
Regent Regulation No. 28/2021 on seaweed farming	Known by 1 of 60 informants (1.7%)	District government	Limited awareness

Note: *The 60 non-agency informants comprised 46 field actors, nine village heads, three sub-district heads, and two community surveillance group representatives. The only informant aware of the two seaweed regulations was a sub-district head*

Source: Interview data and documents, 2026

The limited awareness of regulations indicates that legal instruments have not been translated consistently into practical knowledge among resource users. The sub-district head familiar with the regulations identified misalignment between national, provincial, and district policies as a major problem. In practice, zoning boundaries often followed existing farming locations rather than guiding spatial allocation in advance. Physical demarcation was identified in only one of seven areas examined, where boundary buoys had been installed in Mamolok, Nunukan Selatan. In Binusan, village officials orally agreed to prohibit farming in speedboat lanes and near the jetty, drawing on local knowledge without a formal legal basis.

Field actors nevertheless possessed extensive ecological observations. Twenty-three of 46 field actors reported plastic-bottle waste accumulation, while others described declining harvests, shrinking fishing grounds, and recurrent disease.

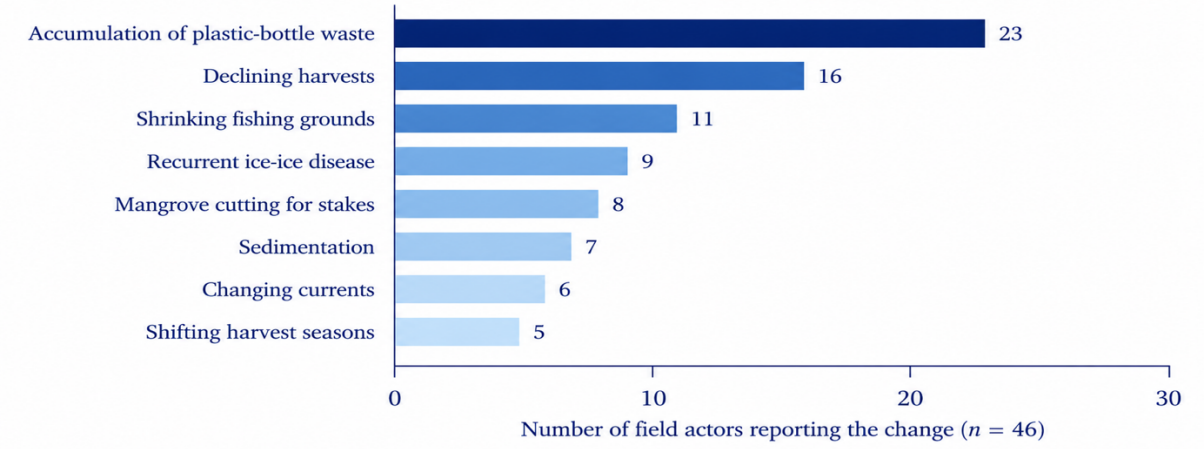


Figure 5. *Ecological changes reported by field actors (n = 46). Multiple responses were permitted*
Source: Interview data, 2026

Weather and oceanographic information rarely reached farmers through structured early-warning systems. Warnings were communicated orally by village offices, while some fishers relied on mobile weather applications and farmers exchanged information on tides and waves informally. No continuing joint research programme connected universities and communities. Surveillance groups reported to provincial authorities through messaging applications without systematic written reports. The *adat* council in Binusan proposed regular coordination, electronic reporting, and clearer responsibilities as elements of a shared platform, but lacked the resources to establish one.

These findings support the argument that knowledge co-production requires institutional connections between science, policy, and practice rather than the mere availability of knowledge (Wyborn et al., 2019). In Nunukan, scientific data are incomplete and inaccessible, while local observations are seldom documented or incorporated into official decisions. This disconnect is especially consequential for disease management, marine zoning, waste monitoring, and conflicts with shipping activities. It also reflects the broader mismatch between locally strong relationships and the wider administrative scales at which environmental and spatial decisions must be made (Bodin, 2017).

Comparative assessment and governance implications

The five dimensions reveal substantial variation between sub-districts. Nunukan has the densest informal networks and the strongest combination of formal, customary, and informal oversight, whereas Sebatik Barat depends heavily on a small number of community actors and exhibits pronounced distrust. Nunukan Selatan has weaker community organisation and unresolved historical tensions, despite the presence of boundary buoys in Mamolok.

Table 9. Comparative assessment of CEG dimensions across sub-districts

Dimension	West Sebatik	Nunukan	South Nunukan
Local actor involvement	Weak; surveillance depends on one person	Moderate; multiple informal organisations and *adat* involvement	Weak; limited community institutions
Collaborative forums	Weak; largely conflict-driven	Moderate; community forums and Binusan deliberation produce rules	Weak; no scheduled forum identified
Social learning	Weak; limited institutional support	Moderate; active informal knowledge exchange	Weak; farmers' association no longer operates
Mutual trust	Very weak; 10 of 12 informants reported low or no trust	Conditional; some farmer–harvester cooperation	Weak to varied; historical intergroup conflict
Knowledge co-production	Weak; limited shared monitoring	Weak; informal knowledge exchange without integrated data	Weak; boundary markers present only in Mamolok
Main functioning institutional basis	Informal, concentrated in Liang Bunyu	Formal, customary, and informal	Informal, with limited organisational capacity

Note: *Ratings are interpretive and based on the indicators in Table 3*
Source: Authors' synthesis of interview data and documents, 2026

Three implications follow from this comparison. First, multi-actor forums should be institutionalised through clear mandates, regular schedules, operational budgets, and documented follow-up. The Binusan deliberation offers a locally grounded example of

coordination between village authorities, customary leaders, and community actors. Second, existing community institutions should be connected to formal oversight rather than displaced by new organisational structures. Area coordinators, fishers' associations, harvester coordinators, the *adat* council, and farmers' groups could be recognised as partners while retaining the flexibility of locally enforced rules. The experience of the defunct farmers' association in Nunukan Selatan indicates that formal recognition without sustained leadership and operational support is insufficient.

Third, transparent decision-making and shared monitoring are essential for rebuilding trust and improving the use of evidence. Draft zoning decisions should be disclosed before adoption, aid distribution should be reported publicly, and regulations should be disseminated consistently to villages. Regular water-quality monitoring, structured early-warning communication, and collaborative research with universities could connect local observations to technical assessment. These measures should be adapted to local conditions: Sebatik Barat requires stronger trust and broader surveillance participation; Nunukan can connect its established informal networks to formal institutions; and Nunukan Selatan needs renewed community organisation and mediation capacity.

The findings should be interpreted in light of several limitations. Interview frequencies describe coded qualitative evidence and are not intended for statistical generalisation. Although a survey was conducted for the larger study, its results are not reported here. The analysis also covers only three sub-districts and includes limited representation from value-chain actors such as traders and exporters. Future research could compare Nunukan with other seaweed-producing regions and use social network analysis to examine the strength and structure of relationships between actors, building on the network perspective discussed by Bodin et al. (2016). Such comparisons would help establish whether the institutional patterns observed in Nunukan also occur in other mariculture settings.

Overall, collaborative oversight in Nunukan is constrained less by the absence of rules than by weak coordination between formal authority, community institutions, and scientific knowledge. Community arrangements demonstrate that practical collective action is possible, but their local reach and dependence on individual leaders limit their ability to address cross-scale environmental challenges. Strengthening collaborative environmental governance therefore requires connecting functioning community institutions to accountable, transparent, and evidence-based formal systems.

CONCLUSION

Oversight of seaweed farming in Nunukan does not fall short because of a lack of actors, regulations, or social capital, but because institutional connections remain weak. Much of the oversight takes place outside formal institutions: formal arrangements with official mandates perform poorly, while customary and informal institutions without state recognition carry out practical oversight. The five dimensions of collaborative environmental governance (CEG) remain weak not because collaboration is impossible, but because few institutional links connect community capacities with formal authority and scientific knowledge. These findings challenge the assumption that additional regulations and formal forums alone will strengthen oversight. As long as formal forums remain incidental, zoning decisions lack transparency, and local knowledge remains undocumented, oversight is likely to remain a top-down effort that fails to address underlying problems. Further research should examine how community institutions can be recognised and supported without undermining the flexibility that enables them to function effectively.

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AUTHOR CONTRIBUTIONS

ZAP: conceptualization, investigation, data collection, formal analysis, and writing–original draft preparation. DA: conceptualization, methodology, validation, supervision, and writing–review and editing. I: data analysis, interpretation of findings, and writing–review and editing. S: literature review, data curation, verification of sources, and writing–review and editing. All authors have read and approved the final version of the manuscript.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest related to the research, authorship, or publication of this manuscript.

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