

Same Rules, Different Relations: Sub-District Variation in the Relational Foundations of Collaborative Seaweed Aquaculture Governance in Nunukan, Indonesia

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HOW TO CITE:

Suhadi, Badu Ahmad, Muh. Akmal Ibrahim (2026). Same Rules, Different Relations: Sub-District Variation in the Relational Foundations of Collaborative Seaweed Aquaculture Governance in Nunukan, Indonesia. International Journal of Special Education, 41(15s), 1106-1121.

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ABSTRACT:

Collaborative environmental governance (CEG) treats social learning, mutual trust, and knowledge co-production as mutually reinforcing relational foundations of collective action. Whether these dimensions in fact move together where formal collaborative institutions are weak remains poorly evidenced, particularly in tropical small-scale aquaculture. This article examines the relational foundations of state supervision in one of Indonesia's largest seaweed-producing frontiers, Nunukan Regency on the Indonesia–Malaysia border, where 4,770 fishing households cultivate some 13,050 ha. Drawing on semi-structured interviews with 62 informants across three coastal sub-districts and four administrative tiers, supplemented by document review, we combine within-case comparison with systematic quantizing of coded responses. Three findings stand out. First, the three dimensions are decoupled rather than mutually reinforcing: trust among seaweed farmers remains robust, while collective learning and knowledge co-production are largely absent and 60% of field actors report low or no trust in local government. Second, actor category does not predict relational configuration. The same occupational triad — seaweed farmers, seaweed scavengers (pemukat), and capture fishers — produces economic symbiosis in one sub-district, latent conflict in a second, and native–settler antagonism in a third, under an identical formal framework. Local institutional density, not occupational identity, structures trust. Third, the technical regulations governing the sector are known to fewer than 2% of informants, a regulation-on-paper condition that forecloses evidence-based supervision. We argue that uniform, regency-wide collaborative interventions are therefore unlikely to succeed, and that institutional bridging with existing informal coordinators is a more plausible pathway than substituting them with formal structures.

Keywords: Collaborative Environmental Governance; Seaweed Aquaculture; Mutual Trust; Knowledge Co-Production; Coastal Supervision

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Introduction.

Seaweed farming is among the fastest-expanding branches of world aquaculture, and its production is heavily concentrated in Southeast Asia, where it is typically organised as a smallholder activity occupying nearshore common-pool space. Indonesia is one of the principal producing countries, and its seaweed frontiers have grown rapidly enough that the governance question has shifted from how to promote production to how to supervise it. Nunukan Regency, in North Kalimantan Province on the maritime border with Malaysia, illustrates the shift. In 2023 the regency recorded approximately 4,770 fishing households, some 13,050 ha under cultivation, and 764,264 tonnes of wet production, supporting an estimated 14,310 workers. Within roughly two decades a dispersed coastal livelihood has become a dense, spatially contested industry.

Supervision of this activity is not a self-contained administrative routine. Seaweed cultivation occupies sea space that is simultaneously a navigation lane, a capture-fishing ground, a conservation interest, and a customary domain. Authority over it is fragmented across the district fisheries and environment agencies, the provincial marine resources surveillance unit, the port authority, the navigation district office, and the marine police, with village and sub-district officials expected to mediate at the interface with communities. No single agency can supervise unilaterally. Supervision is therefore, in practice, a collaborative function — and its effectiveness depends on the quality of the relations among the actors who must jointly perform it (Rölfer et al., 2024; Wang, 2024).

Collaborative environmental governance (CEG) offers the most developed framework for analysing those relations. In Bodin, (2017) synthesis, collective action in social-ecological

systems rests on three relational foundations: social learning, understood as collective learning that exceeds the accumulation of individual knowledge; mutual trust among stakeholders; and knowledge co-production, the joint generation of knowledge combining formal science with local ecological knowledge. Adjacent frameworks converge on similar components. (Ansell & Gash, 2008) model collaboration as a sequence running from starting conditions through face-to-face dialogue, trust-building, and shared understanding to intermediate outcomes, while Emerson et al., (2012) identify principled engagement, shared motivation, and capacity for joint action as the core of collaborative dynamics. Across these accounts, the three relational dimensions are treated as mutually reinforcing: trust makes deliberation possible, deliberation generates shared understanding, and shared understanding sustains trust.

That assumption of mutual reinforcement is doing considerable analytical work, and it is rarely examined directly. Three gaps follow. First, the empirical base of CEG is skewed. Most studies address forests, watersheds, protected areas, or capture fisheries, and a disproportionate share are conducted in settings with dense, well-funded formal institutions. Aquaculture is under-represented, and supervision — as distinct from planning, licensing, or resource allocation — has rarely been analysed as a collaborative function in its own right.

Second, and more consequentially for theory, the co-variation of the three dimensions is assumed rather than tested. If the dimensions in fact move together, then a single composite measure of collaborative capacity is defensible and interventions can be sequenced loosely. If they decouple — if trust can remain intact while learning and co-production collapse, or the reverse — then composite scores conceal more

than they reveal, and the sequencing of intervention becomes decisive. Settings where formal collaborative institutions are weak are precisely where decoupling is most likely and least studied.

Third, comparative CEG research overwhelmingly compares across jurisdictions (Bellanger et al., 2020; Chen et al., 2026; Li et al., 2026; Nijamdeen et al., 2025; Wang & Gong, 2022). Doing so confounds two explanations: differences in relational outcomes may reflect differences in the formal institutional framework, or differences in local social structure, and cross-jurisdictional designs cannot separate them. Holding the formal framework constant while varying the local relational context isolates the second effect, but such within-case designs remain uncommon.

This article addresses all three gaps through an embedded case study of seaweed aquaculture supervision in Nunukan. Because the three study sub-districts fall under one regency government, one provincial government, and one set of zoning and technical regulations, the formal framework is effectively held constant. We ask: (1) What is the condition of each of the three CEG dimensions in seaweed aquaculture supervision in Nunukan? (2) Do the three dimensions co-vary, or do they decouple? (3) Does actor category predict the configuration of trust among sea-space users, or does the local institutional context?

The contribution is threefold. Empirically, the article provides the first systematic account of the relational foundations of aquaculture supervision in an Indonesian border regency. Theoretically, it documents decoupling among CEG's three dimensions and shows that occupational category is a poor predictor of trust configuration relative to local institutional density. Practically, it explains why uniform, regency-wide collaborative interventions are likely to fail and identifies institutional bridging as the more plausible design response.

2. Analytical framework

(Bodin, 2017) formulation is the analytical spine of this study. Social learning refers to change in understanding that extends beyond the individual and becomes situated within wider social units through social interaction (Reed et al., 2010). It is not an automatic product of contact; it requires structures of facilitation and reflection. Mutual trust is the expectation, sustained through repeated and consistent interaction, that other parties will act as they represent they will — the condition that lowers the transaction costs of coordination and reduces exposure to opportunism. Knowledge co-production denotes the joint production of knowledge by scientists, officials, and resource users, in which formal science and local ecological knowledge are combined rather than ranked (Armitage et al., 2011; Jasanoff, 2004).

Three complementary bodies of work inform the interpretation. Adaptive co-management (Folke et al., 2005; Olsson et al., 2004) locates collective learning at the centre of adaptation under ecological uncertainty and directs attention to multi-level learning and institutional flexibility. Work on social capital distinguishes bonding ties within homogeneous groups from bridging ties across them (Pretty, 2003; Putnam, 2020), a distinction that proves essential here because the two forms diverge sharply. Polycentric governance theory (Carlisle & Gruby, 2019; Ostrom, 2010) supplies the design vocabulary for responding to within-jurisdiction variation, since it treats modular, context-sensitive units operating under a shared framework as a feature rather than a defect.

Each dimension was operationalised into four observable sub-indicators, developed inductively from a pilot round of interviews and then applied uniformly. For social learning: the existence and regularity of multi-actor dialogue forums; mechanisms of collective reflection on failure and success; exchange between scientific and local knowledge; and the diffusion of good practice among producers. For mutual trust: trust of field actors in government; trust among seaweed farmers; trust across the three categories of sea-space user; and the transparency of decision-

making. For knowledge co-production: availability of a scientific baseline; the zoning process as a collective knowledge product; integration of weather early warning and oceanographic data; and the existence of a shared platform for data and knowledge exchange. This twelve-cell matrix structured both the interview protocol and the coding frame.

Methods

Study site

Nunukan Regency lies at Indonesia's northern maritime border with the Malaysian states of Sabah and Sarawak. Three coastal sub-districts account for the bulk of seaweed cultivation and were selected as embedded units of analysis: Sebatik Barat, on the Indonesian half of Sebatik Island; Nunukan, the sub-district containing the regency seat and the busiest navigation lanes; and Nunukan Selatan, immediately to the south. The three share one regency administration, one provincial marine and fisheries authority, and one regulatory framework, but differ in settlement history, the density of community organisation, and the intensity of competition for sea space.

3.2. Research design

Table 1. Composition of informants by category and sub-district (62 informants; 71 interview records).

Informant category	Sebatik Barat	Nunukan	Nunukan Selatan	District/Province	Total
Sub-district heads (camat)	1	1	1	—	3
Village and ward officials	3	4	2	—	9
Customary institution	—	1	—	—	1
Community surveillance group (Pokmaswas)	1	1	—	—	2
Seaweed farmers	7	6	6	—	19
Seaweed scavengers (pemukat)	5	5	4	—	14
Capture fishers	4	4	5	—	13
Technical agencies	—	—	—	9	9
Regional parliament, fisheries commission	—	—	—	1	1

The study uses a qualitative embedded single-case design (Yin, 2018). The case is seaweed aquaculture supervision in Nunukan Regency; the embedded units are the three sub-districts. This design was chosen deliberately to hold the formal institutional framework constant across units, so that variation in relational outcomes cannot be attributed to differences in statutory design, agency mandate, or budget authority. Within-case comparison across the three sub-districts is therefore the principal inferential strategy.

3.3. Sampling and informants

Informants were selected purposively and expanded by snowball referral until thematic saturation was reached within each actor category and sub-district. Sixty-two informants were interviewed, generating 71 interview records, since several informants were interviewed more than once for thematic depth. The composition was designed to permit three forms of triangulation: vertical, across administrative tiers from village to province; horizontal, across the three categories of field actor; and spatial, across the three sub-districts. Table 1 reports the distribution.

Informant category	Sebatik Barat	Nunukan	Nunukan Selatan	District/Province	Total
Total interview records	21	22	18	10	71

Note: the pemukat are operators who harvest drifting or detached seaweed from the water column and the seabed; they are a distinct occupational category from cultivators and from capture fishers, and their status is contested in some localities. Field actors (farmers, scavengers, fishers) total 46. Source: authors' interview data, 2026.

Among the 46 field actors, exposure ranged from newcomers with two to five years of involvement to operators with more than twenty years. Half had been active for more than ten years, which matters for the analysis of knowledge co-production because it establishes that the accumulated observational base within the community is substantial.

3.4. Data collection

Data were generated between 4th and 6th 2026 through four techniques. Semi-structured interviews followed a protocol organised in three blocks corresponding to the three CEG dimensions, with sub-district-specific probes. Participant observation covered coordination meetings, field visits, and routine interactions between producers and officials. Focus group discussions with multi-actor representation were held in Sebatik Barat and Nunukan Selatan to validate emerging interview findings and to surface collective rather than individual accounts. Document review covered the draft North Kalimantan Coastal Zone and Small Islands Zoning Plan 2014–2034, Governor Regulation 26/2024 on seaweed management, Nunukan Regent Regulation 28/2021 on technical guidelines for seaweed cultivation, agency planning documents, meeting minutes, aid distribution records, and local press coverage.

3.5. Analysis

Interview material was analysed following the interactive model of (Miles et al., 2020),

proceeding through data condensation, display, and conclusion drawing and verification. Coding moved from open coding of meaning units, through axial coding into the three dimensions and their twelve sub-indicators, to selective coding that built the cross-cutting interpretation. Coded responses were then quantitized: for indicators on which every field actor gave an assessable response, frequencies and proportions were computed and displayed (Sandelowski, 2000). Quantitizing is used here for transparency and traceability rather than for statistical inference; the denominators vary across tables because not all informants addressed every indicator, and each table states its own denominator explicitly. No significance testing is performed and no claim of statistical representativeness is made.

Trustworthiness was addressed through source and method triangulation, member checking with key informants from each actor category, and an audit trail comprising recordings, transcripts, coding memos, and document extracts. Divergent cases — notably the sub-district head whose account of forum activity was not corroborated at ward level — were retained and analysed rather than reconciled, since the divergence is itself a finding.

3.6. Ethics and limitations

Three limitations should be stated at the outset. The study covers three of Nunukan's coastal sub-districts and does not claim to represent the regency exhaustively. The design is cross-sectional, so claims about erosion of trust rest on informants' retrospective accounts rather than on repeated measurement. And because the analysis holds the formal framework constant by design, it cannot speak to the effect of statutory variation, which would require cross-jurisdictional comparison.

Results

Social learning

Formal multi-actor dialogue exists nominally but has not been institutionalised as a supervisory

mechanism. Table 2 reports the participation of field actors in formal supervisory forums over the preceding three years.

Table 2. Participation of field actors in formal supervisory dialogue forums, preceding three years.

Frequency of involvement	Farmers (n=19)	Scavengers (n=14)	Fishers (n=13)	All field actors (n=46)	%
Never involved	8	9	10	27	58.7
Once, less than annually	5	3	1	9	19.6
Approximately once a year	4	1	2	7	15.2
One to two times a year	1	1	0	2	4.3
Three or more times a year	1	0	0	1	2.2
Total	19	14	13	46	100.0

Source: authors' interview data, 2026.

Nearly three in five field actors had never taken part in a formal supervisory forum, the proportion rising to 76.9% among capture fishers, who are the actors most directly displaced by cultivation. A single informant out of 46 reported regular involvement. Where forums did convene, participation was reactive, triggered by acute conflict or an official visit, and no sub-district reported a scheduled cycle of meetings.

Reported forum composition was institutionally inclusive but socially thin. Fisheries agencies were named in 85.7% of the fourteen forums informants could recall, sub-district officials in 64.3%, and ward or village heads in 57.1%, while direct producer representatives were named in only 21.4%. Participation by producers was thus representational, mediated through coordinators or group heads, rather than broad. Formal inclusivity did not translate into substantive deliberation, consistent with Ansell & Gash, (2008) observation that collaborative forums may stall at consultation without reaching deliberation.

A vertical contradiction is visible in the accounts. In Nunukan sub-district the camat described an active forum, yet only one of three ward heads reported being involved and the majority of field actors reported no involvement at all. The same pattern, at lower intensity, appears in Sebatik Barat and Nunukan Selatan. Four structural obstacles were named consistently: the absence of any formal instrument constituting a collaborative forum, which leaves official participation discretionary; the absence of dedicated operating funds outside each agency's existing budget lines; a persistent top-down framing in which forums are designed to disseminate policy rather than to decide jointly; and the absence of any follow-up mechanism, so that agreements reached in a forum are not consistently executed.

Mechanisms of collective reflection are weaker still. Written performance indicators for supervision were absent at sub-district and village level and only partial at district agencies; periodic evaluation, where it occurred at all, was incidental

or annual and reported internally. Across seven recurrent critical events identified between 2020 and 2025 — repeated outbreaks of ice-ice disease, damage to cultivation frames by ferry anchors, distribution of seed stock perceived as unusable, accumulation of plastic waste in the water column, mangrove cutting for stakes, contraction of fishing grounds, and thirteen sites where cultivation overlaps navigation lanes — two were followed by an incidental formal investigation and none by multi-actor reflection. In the case of ice-ice, the recorded response of the technical authority was to classify the outbreak as a natural phenomenon, without laboratory sampling to identify pathogenic causes or changes in water quality.

Reflection does occur, but locally and in isolation. A community surveillance group in Nunukan sub-district operates an internal reporting channel to the provincial surveillance unit by instant messaging, with graduated warnings to those breaching cultivation zones. A farmer group in Mangkabat convenes informal meetings to review each planting season. The Tidung customary institution in Binusan village articulates a comparatively sophisticated conceptual scheme for monitoring water condition, clarity, and current, although its actual practice remains limited. None of these local reflections is connected to regency policy. Instructively, a formally constituted seaweed farmers' association in Nunukan Selatan ceased meeting after its inauguration — an instance of organisational form without operational substance that recurs in the discussion below.

Exchange between scientific and local knowledge is similarly constrained. Two-thirds of field actors (31 of 46, 67.4%) had never attended formal training in cultivation technique, biosecurity, or environmental monitoring, and only 10.9% had

done so in the preceding five years. Informants further described training as clustered in an earlier political administration and sharply reduced thereafter, indicating that capacity-building has not been institutionalised beyond the electoral cycle. Integration in the opposite direction is weaker again: among field actors, 50% of organisationally active farmers reported that their local knowledge had been taken into account in zoning decisions, against 11.1% of unaffiliated farmers, 7.1% of scavengers, and none of the capture fishers. Two of the active farmers qualified their answer, noting that consideration was formal while political considerations governed the outcome. Knowledge exchange thus runs through an exclusive channel available to those who already hold social capital.

Diffusion of good practice occurs, but entirely outside state facilitation. The channels informants named most often were informal: gatherings at the drying grounds during harvest (13 mentions), direct contact between area coordinators (11), instant messaging groups (8), and reciprocal seed exchange between localities such as Bambang and Tanjung Cantik (4), which allows genetic diversification and risk-sharing when a variety loses vigour. Extension officers were named seven times and formal agency training four times. Three standard administrative instruments — inter-area study visits, documentation of good practice in official publications, and annual recognition of outstanding producers — were not identified anywhere in the regency.

4.2. Mutual trust

Trust of field actors in local government is low and clearly skewed toward the negative pole. Table 3 reports the distribution across sub-districts.

Table 3. Trust of field actors in the commitments and policies of local government, by sub-district (n = 40 informants giving an explicit assessment).

Level of trust	Sebatik Barat	Nunukan	Nunukan Selatan	Total	%
High trust	1	1	0	2	5.0

Level of trust	Sebatik Barat	Nunukan	Nunukan Selatan	Total	%
Conditional trust	0	5	3	8	20.0
Moderate or neutral	1	3	2	6	15.0
Low trust or sceptical	5	3	5	13	32.5
No trust	5	2	4	11	27.5
Total	12	14	14	40	100.0

Source: authors' interview data, 2026.

Sixty per cent of field actors fell into the low-trust or no-trust categories, against 25% expressing high or conditional trust. Spatial variation is pronounced: in Sebatik Barat, 10 of 12 informants were sceptical or distrustful, while Nunukan showed a flatter distribution dominated by a distinct pattern we term conditional trust. Informants in the latter category expressed trust in government policy on the express condition that they themselves remained compliant with their obligations — a calculative, contractual form of trust rather than the generalised confidence CEG presupposes.

Informants named the sources of erosion consistently. Absence of transparency in zoning decisions was cited by 65.0%, followed by aid distribution that fails to reach ordinary producers (52.5%), formal petitions that receive no follow-up (47.5%), regulatory dissemination that does not reach the field (45.0%), inconsistent enforcement of sanctions (40.0%), the absence of any solution to plastic waste (35.0%), programme dependence on the political cycle (32.5%), and a sense that native fishers have been displaced

(20.0%), the latter concentrated in Nunukan Selatan. The ranking is notable: the leading grievances concern the fairness and openness of process rather than the substance of outcomes.

Trust among seaweed farmers presents the opposite picture. Informal area coordinators operate in all three sub-districts and are recognised as authoritative for demarcation and first-instance dispute resolution. Informal compensation arrangements following damage to frames or lines were reported in every sub-district and are generally honoured without recourse to law. Conflict is settled by deliberation, escalating to state authorities only where deliberation fails. Sebatik Barat exhibits a rotating night-watch system in Liang Bunyu; Nunukan sub-district exhibits reciprocal seed exchange and tiered mediation; Nunukan Selatan is weakest, with a formally constituted association that has ceased to function.

The most theoretically consequential finding concerns trust among the three categories of sea-space user. Table 4 sets out the three configurations.

Table 4. Configurations of trust among sea-space users, by sub-district.

Relational aspect	Sebatik Barat	Nunukan	Nunukan Selatan
Farmer–scavenger relation	Tense, marked by suspicion	Positive economic symbiosis	Variable
Scavengers regard cultivation expansion as beneficial	No	Yes (5 of 5)	In part
Informal timing rules among scavengers	Absent	Present (guris to slack water)	Not identified

Relational aspect	Sebatik Barat	Nunukan	Nunukan Selatan
Farmer–capture fisher relation	Latent conflict over drifting stock	Tension over expansion	Historical native–settler conflict
Fishers report contraction of fishing grounds	In part	Yes	Yes, dominant
Formal multi-actor mediation forum	Absent	Absent	Absent
Recognised informal mediators	Customary and neighbourhood leaders	Fishers' association head; area coordinators	Association head; area coordinators
Density of informal institutions	Medium	High	Low
Trust in local government	Very low	Conditional	Variable

Source: authors' interview data, 2026

The same three occupational categories, under the same regulations, produce three qualitatively different relational configurations. In Sebatik Barat, scavengers are regarded by farmers as potential appropriators of drifting stock and as a hazard to frames. In Nunukan sub-district the identical pair is economically symbiotic: all five scavengers interviewed reported that the expansion of cultivation benefits their activity, and several advanced an ecological argument that their work removes seabed debris that would otherwise damage the cultivation substrate. Informal timing conventions regulate when scavenging may occur relative to the tidal cycle. In Nunukan Selatan the dominant axis is instead farmer against capture fisher, articulated through a native-versus-settler narrative with historical depth.

No formal multi-actor mediation forum exists in any sub-district. Mediation is performed by recognised informal figures — customary leaders, the head of the local fishers' association, coordinators of scavenging groups — and in Nunukan sub-district it operates as a tiered system running from area coordinator, to organisational head, to escalation to the navy or marine police. This tiered structure is a functioning supervisory arrangement that carries no formal status.

Transparency instruments are almost entirely absent. Of eight standard mechanisms examined — publication of draft policy before enactment, substantive public consultation on zoning, transmission of regulations to villages and wards, dissemination to communities, publication of aid distribution records, periodic public hearings, formal post-policy feedback, and reporting of water quality monitoring — none was fully available, and only consultation and dissemination were partially so. The vertical gap is striking: one of nine ward and village heads reported consistently receiving copies of regulations they were nonetheless expected to disseminate. Several requested a formal instrument specifying their supervisory role. In the absence of functioning formal channels, field actors have shifted to alternatives: criticism on social media (5 mentions), ad hoc parliamentary hearings (5), escalation through village-level military and police liaison officers (3), and demonstrations (2). The redirection of grievance away from administrative channels is itself a measure of vertical trust.

4.3. Knowledge co-production

No systematic scientific baseline exists for the sector. Of eight baseline components examined — periodic water quality data, salinity and pH, biodiversity mapping, oceanographic data,

mapping of cultivation density, disease incidence records, water pollution monitoring, and mangrove inventory — five were unavailable and three only partial, and public accessibility was absent or restricted to institutional internal use for all of them. Water sampling occurs incidentally, undertaken by students for theses, by ad hoc official delegations, or by visiting researchers, and the results do not enter any cumulative series. Ecological change reported by producers therefore cannot be correlated with measured data.

Community observation, by contrast, is rich and convergent. Accumulation of plastic bottle waste was reported by 23 of 46 field actors and

triangulates across all three occupational categories; declining harvests (16 mentions), contraction of fishing grounds (11), rising frequency of ice-ice (9), mangrove cutting for stakes (8), localised shallowing (7), shifts in current patterns (6), and altered harvest seasons (5) follow. None of this observational capacity has been formalised into any official record.

The zoning process, which should be the paradigm case of collective knowledge production, instead exhibits acute asymmetry in regulatory awareness. Table 5 reports awareness of the three governing instruments across administrative tiers.

Table 5. Awareness of the governing regulatory instruments across administrative tiers (n = 60 informants).

Tier	Provincial zoning plan 2014–2034	Governor Regulation 26/2024	Regent Regulation 28/2021
Sub-district heads (n = 3)	1 of 3	1 of 3	1 of 3
Ward and village heads (n = 9)	2 of 9	0 of 9	0 of 9
Community surveillance groups (n = 2)	0 of 2	0 of 2	0 of 2
Field actors (n = 46)	5 of 46	0 of 46	0 of 46
Total aware	8 of 60	1 of 60	1 of 60
Percentage aware	13.3	1.7	1.7

Source: authors’ interview data, 2026.

Only 13.3% of informants were aware of the provincial zoning plan, and fewer than 2% of either the provincial regulation on seaweed management or the regency regulation setting technical guidelines for cultivation. Both sector-specific instruments were known to a single sub-district head and to no ward head, surveillance group officer, or producer. That same informant identified the underlying problem as a lack of synchronisation among central, provincial, and regency authorities in coastal management policy. Implementation reflects this. Informants described the zoning plan as half-applied, with boundaries in practice following wherever

producers had placed their frames rather than the reverse — an inversion of planning logic acknowledged explicitly by one ward head. Physical demarcation was absent throughout the study area apart from marker buoys placed by the provincial fisheries agency at Mamelok in Nunukan Selatan. Against this, one village secretary in Nunukan sub-district had issued an oral prohibition on cultivation in the fast-boat channel and near the jetty, an act of local institutional crafting that lacks legal footing but responds directly to observed conditions.

Weather early warning and oceanographic data are not connected to producers. No formal

channel transmits meteorological agency forecasts or ministry oceanographic data to cultivators; what exists is occasional verbal warning from village officials when bad weather appears imminent, without structured prediction of waves, currents, or salinity. In the absence of a public service, some capture fishers have installed commercial weather applications on their mobile telephones. Demand for oceanographic information is therefore demonstrable, and it is being met by consumer technology rather than by the agencies that hold the data.

Nor is there a shared platform. Sustained co-research between academics and producers was not identified; academic contact is sporadic and consists mainly of individual student fieldwork that is not returned to the community in usable

form. Community reporting to government runs through instant messaging from surveillance groups to the provincial agency, without written records that could enter a formal database. There is no routine inter-agency coordination meeting, no electronic reporting mechanism to the ministry, and no documentation of local knowledge. Notably, the customary institution in Binusan articulated precisely the platform that is missing — regular inter-agency coordination, electronic reporting, and clearly divided institutional roles — indicating that the conceptual capacity exists locally and that what is absent is institutional support to operationalise it.

4.4. Cross-dimensional synthesis

Table 6 summarises the condition of the three dimensions.

Table 6. Condition of the three CEG dimensions in seaweed aquaculture supervision, Nunukan Regency.

Dimension	Weakest sub-indicator	Principal empirical marker	Aggregate condition
Social learning	Collective reflection	None of 7 recurrent critical events followed by multi-actor reflection; 58.7% of field actors never in a forum; 67.4% never trained	Weak
Mutual trust	Decision transparency	60% low or no trust in government; 8 of 8 transparency instruments absent or partial; farmer-to-farmer trust intact; three distinct inter-user configurations	Asymmetric and decoupled
Knowledge co-production	Scientific baseline	Fewer than 2% aware of sector regulations; no cumulative water quality series; no co-research platform	Embryonic

Source: authors' interview and document data, 2026.

Three patterns cut across the dimensions. Informal institutions occupy the space that formal structures do not: at least six informal or semi-formal bodies were identified performing demarcation, mediation, and knowledge transfer functions, alongside the formal agencies. Spatial variation is substantial and does not follow administrative logic. And participation is unevenly distributed, with organisationally active producers bearing the costs of forum attendance, liaison, and self-policing while unaffiliated producers receive the collective benefits — a

distribution that is not sustainable without recognition or compensation.

Discussion

Decoupling of the relational dimensions

The central theoretical finding is that CEG's three dimensions do not move together in Nunukan. Trust among seaweed farmers is robust and institutionally expressed through coordinators, compensation conventions, and deliberative settlement, yet social learning is weak and knowledge co-production embryonic.

Mutual trust in the vertical direction has eroded while horizontal trust has held. A composite index of collaborative capacity would report a uniformly low score and would conceal exactly the structure that matters for intervention design.

The distinction between bonding and bridging social capital clarifies the pattern (Pretty, 2003; Putnam, 2020). What survives in Nunukan is bonding capital: dense, repeated, face-to-face relations within occupationally and spatially homogeneous groups. What is absent is bridging capital linking those groups to one another and to the state. This is consistent with arguments that institutional trust and interpersonal trust follow distinct formative paths (Rothstein & Stolle, 2008), and it qualifies the CEG expectation that the dimensions reinforce one another. They may do so where bridging structures already exist; where they do not, bonding capital can persist indefinitely without generating collaborative capacity, and may even substitute for it in ways that reduce pressure for reform.

The practical corollary is that sequencing matters. If the dimensions were mutually reinforcing, intervening on any one would lift the others. Decoupling implies instead that strengthening farmer-level trust, the easiest and most frequently attempted intervention, will not by itself produce learning or co-production, because the constraint lies at the bridging interface rather than within communities.

Institutional density, not actor category, structures trust

The three configurations documented in Table 4 bear directly on how collaborative interventions are targeted. Programme design in coastal governance routinely proceeds from occupational category: farmers have these interests, fishers those, and conflict is predicted from the incompatibility of the two. The Nunukan evidence does not support this. The same triad yields symbiosis, latent conflict, and identity-based antagonism in three adjacent sub-districts governed by identical rules. What varies is the local institutional context: the presence and

authority of area coordinators, the existence of informal conventions such as the tidal timing rules among scavengers in Nunukan sub-district, the density of overlapping roles where individuals both cultivate and scavenge, settlement history, and the availability of a recognised mediator.

This is a place-based governance result (Berkes, 2009), and it has a specific design implication that follows from polycentric theory (Carlisle & Gruby, 2019; Ostrom, 2010). Where relational structure varies within a jurisdiction, a modular architecture is required: a common regency framework specifying rights, obligations, and escalation pathways, with sub-district units free to adopt the mechanisms suited to their own relational configuration. A uniform intervention risks worse than inefficiency. Imposing a formal mediation body in Nunukan sub-district, where a functioning tiered system already operates and where the farmer–scavenger relation is cooperative, could displace an arrangement that works; the same body might be indispensable in Nunukan Selatan, where the association has collapsed and the native–settler cleavage has no recognised mediator.

Because the design holds the formal framework constant, the inference is comparatively clean: the variation cannot be attributed to differences in statute, mandate, or budget authority, since these are shared. This is the methodological contribution of the within-case design, and it suggests that cross-jurisdictional CEG comparisons may systematically overstate the explanatory weight of institutional design relative to local social structure.

5.3. Regulation on paper and the limits of evidence-based supervision

That two sector-specific instruments are known to a single informant out of sixty is not a dissemination shortfall of the ordinary kind. It is a failure of policy diffusion severe enough to place the regulations outside the operative institutional environment altogether (Rogers, 2003). In Matlands, (1995) terms this approximates symbolic implementation: the policy exists formally, but with neither the

knowledge nor the resources at street level that would give it substantive effect. The consequence for supervision is direct. Supervision presupposes a known standard against which conduct is assessed; where neither the supervised nor the supervising ward officials know the standard, what occurs is not enforcement but ad hoc reaction.

The same condition forecloses evidence-based supervision from the knowledge side. Without a cumulative water quality series, the classification of recurrent ice-ice outbreaks as a natural phenomenon can be neither confirmed nor contested, and each outbreak is absorbed as loss rather than converted into learning. The gap is not one of information as such: the meteorological and hydrographic agencies hold the relevant data. It is an interface failure, in which technically available data are not consolidated or rendered in a form that field actors can use. That producers have resorted to commercial weather applications demonstrates both the demand and the tractability of the problem.

The obstacle is best characterised as the absence of knowledge brokers — individuals or bodies positioned to translate across the scientific, administrative, and producer communities (Cvitanić et al., 2015). Nunukan has neither a designated liaison researcher nor a standing platform. The consequence is two parallel knowledge worlds: an academic literature on the seaweed ecosystem that does not reach practice, and a substantial observational base among producers — evidenced by the convergent reporting of plastic accumulation, current shifts, and disease frequency — that does not reach policy. Approaches designed to connect diverse knowledge systems without subordinating one to the other (Tengö et al., 2014) offer a workable template, but they presuppose a broker function that does not currently exist.

From substitution to institutional bridging

The informal arrangements documented here — area coordinators, compensation conventions, tiered mediation, the night-watch rotation,

reciprocal seed exchange — constitute a functioning order maintained without legal enforcement, of the kind Ellickson, (2017) described. Their existence reframes the policy problem. The deficit in Nunukan is not community capacity; on the evidence of the drying-ground exchanges, the customary institution's monitoring scheme, and the surveillance group's graduated warnings, community capacity is the more developed side of the relationship. The deficit is on the state side, in the failure to provide the recognition, resources, and technical capability that would convert local capacity into a supervisory system.

This diagnosis has an unattractive corollary that should be stated plainly. Where the state assigns supervisory responsibility to community bodies without transferring proportionate resources, the arrangement is not collaboration but the delegation of burden. The participation asymmetry documented in Section 4.4 — active producers bearing forum attendance, liaison, and self-policing costs while unaffiliated producers free-ride — is the observable form of this. Formalisation that adds obligations without adding support would deepen rather than relieve it.

The alternative is institutional bridging: recognising existing informal roles within the formal framework rather than substituting for them. Concretely, this means giving legal standing and defined function to area coordinators and recognised mediators, with the escalation pathway from coordinator to association head to state agency codified rather than improvised; constituting a supervisory forum by regency instrument with specified membership, meeting cycle, decision rules, and traceable follow-up obligations, since the collapse of the Nunukan Selatan association demonstrates that founding a body without operating resources and governance rules produces form without function; establishing transparency mechanisms directed at the leading grievances, namely publication of draft zoning before enactment, publication of aid distribution records, and a functioning feedback channel; and building the

evidentiary base through scheduled water quality monitoring with public reporting, a structured community reporting channel, and a designated broker role linking universities, agencies, and producers.

The transparency measures deserve emphasis because the ranking of grievances in Section 4.2 places procedural fairness ahead of outcomes. Trust in authority responds strongly to whether decision processes are perceived as consistent, unbiased, and open to those affected (Tyler, 2006, 2021). This is encouraging for policy, since procedural reform is within the regency's control in a way that production outcomes and disease incidence are not.

Limitations and further research

The findings are drawn from three sub-districts of one border regency and their transferability should be assessed against that. The cross-sectional design means that the erosion of vertical trust is reconstructed from informants' accounts rather than observed longitudinally, and the direction of the relationship between institutional density and trust configuration cannot be established from these data: dense informal institutions may generate cooperative relations, or cooperative relations may permit institutions to form. Panel data or process tracing across a longer period would be required to adjudicate. Three lines of further work follow. First, testing whether decoupling among CEG dimensions is general to weakly institutionalised settings or specific to this case. Second, comparative within-case designs in other Indonesian aquaculture frontiers, which would establish whether institutional density outperforms actor category as a predictor elsewhere. Third, evaluation of institutional bridging where it has been attempted, to determine whether formal recognition strengthens informal coordinators or erodes the legitimacy on which their authority rests.

5. Conclusion

The relational foundations of collaborative supervision in Nunukan are weak, but they are not uniformly weak, and the pattern of

unevenness is the finding. Social learning is constrained by the absence of institutionalised forums and of any mechanism of collective reflection: none of seven recurrent critical events over five years was followed by multi-actor review. Knowledge co-production is embryonic, with no cumulative scientific baseline and sector regulations known to fewer than 2% of informants. Trust, however, is asymmetric rather than absent: it has eroded sharply in the vertical direction, with 60% of field actors reporting low or no confidence in local government, while horizontal trust among producers remains intact and institutionally expressed.

Two results carry beyond the case. The three dimensions of collaborative environmental governance decouple: they are not a single latent capacity, and treating them as one obscures where intervention is needed. And occupational category is a weak predictor of relational configuration compared with local institutional density. The same triad of farmers, scavengers, and capture fishers produces economic symbiosis, latent conflict, and identity-based antagonism in three adjacent sub-districts operating under identical rules. Since the formal framework is constant by design, the variation must be attributed to local social structure.

For practice this implies that uniform, regency-wide collaborative programmes will fail in predictable ways, succeeding where the local configuration happens to match the design and displacing functioning arrangements elsewhere. A modular architecture is required: a common framework of rights, obligations, and escalation pathways, with mechanisms fitted to each locality. Within that architecture, the immediate priorities are procedural transparency, given that the leading grievances concern the fairness of process rather than the substance of outcomes; formal recognition of existing informal coordinators and mediators, coupled with resources rather than obligations alone; and the establishment of a broker function capable of connecting the substantial observational capacity already present among producers to the scientific

and administrative systems that currently ignore it.

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