

From Ecological Restoration to Social–Ecological Resilience: Collaborative Governance Mechanisms among Multiple Stakeholders in Mangrove Conservation

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Abstract—Mangrove restoration is increasingly expected to support biodiversity, livelihoods, carbon management and coastal protection. Yet restoration interventions are often assessed as ecological projects rather than as arrangements through which actors allocate authority, knowledge, risks and benefits. This separation obscures why technically plausible interventions may not persist, adapt to disturbance or distribute gains fairly. This structured evidence synthesis addresses that gap by examining how collaborative governance mechanisms connect mangrove conservation and restoration to social–ecological resilience. A structured, purposive search across six thematic domains assembled 38 peer-reviewed sources published in 2021–2026. Records were screened and checked manually for duplicate titles and identifiers, then coded by hand for stakeholder categories, seven governance mechanisms and five resilience dimensions. Simple counts and a qualitative comparison of coded categories describe patterns in this purposive corpus. Adaptive monitoring and learning occurs in 14 records (36.8%) and nested cross-scale coordination in 10 (26.3%), while knowledge co-production occurs in four (10.5%). Manual comparison suggests that rights and tenure recognition is frequently discussed with equity and justice, while nested cross-scale coordination is frequently discussed with adaptive capacity. These are descriptive observations obtained from a manually coded literature corpus, not population estimates, statistical associations or causal effects; further quantitative analysis can be carried out in future research. The synthesis advances a mechanism-based framework in which participation, rights, knowledge, learning, finance, cross-scale coordination and accountable conflict resolution jointly create legitimacy, trust, learning, resource mobilization, compliance and institutional fit. It thereby shifts attention from planting outputs towards the governance capacities needed to sustain ecological function, livelihood security, equity, coastal-risk reduction and adaptive capacity.

Keywords—Mangrove conservation, collaborative governance, social – ecological resilience, ecological restoration, blue carbon

I. INTRODUCTION

A. Restoration is necessary but insufficient

Mangroves are routinely positioned at the intersection of restoration, climate mitigation, livelihood support and coastal-risk management. This positioning is justified by a diverse body of ecological, social and engineering evidence, but it also creates an analytical problem: a planted area, a carbon account, a co-management committee and a protective belt are not equivalent measures of durable social–ecological performance. A meta-analysis reports that restored mangroves outperform unvegetated tidal flats on aggregate ecosystem functions but remain below natural stands, with outcomes varying by restoration age, species and method [1]. Colombian restoration evidence highlights the importance of intervention technique [2], while a review identifies gaps in reporting pre-restoration conditions and social outcomes [3]. Southeast Asian research emphasizes site suitability [4], and species-specific analysis likewise places suitable species in suitable sites [5]. These findings matter because resilience requires not merely an initial intervention but the capacity to sustain, revise and legitimately govern it through environmental and institutional change.

A second gap concerns what is learned after implementation. Long-term evidence relates climate variability and hydrological rehabilitation to salinity, recruitment and cover trajectories [6]. Evidence from Mexico documents natural regeneration after interventions that changed hydrological conditions [7]. Recent remote-sensing work demonstrates that monitoring can distinguish restoration trajectories from later disturbance rather than representing a project as permanently successful or unsuccessful [8]. A review of restoration projects also found sparse reporting of socioeconomic outcomes and monitoring duration [3]. The issue is not simply more data. Data become useful for resilience only when affected actors can understand, contest and use them to alter decisions. The durability of hydrological responses likewise depends on

continuing stewardship, water governance and monitoring rather than on a one-time engineering act [7].

This manuscript therefore treats ecological restoration as an entry point into a wider governance problem. It does not ask whether collaboration, finance or monitoring individually cause ecological change. Instead, it synthesizes how the literature represents mechanisms through which multiple stakeholders may connect restoration and conservation interventions to capacities that support persistence, adaptation and fairer distribution under changing conditions. The aim is analytical and design-oriented: to clarify recurring governance mechanisms, their evidence concentrations, their boundary conditions and the research gaps that prevent stronger causal inference.

B. Operational concepts and analytical scope

In this study, social – ecological resilience is operationally defined as the capacity of an interconnected mangrove ecosystem and its associated institutions, livelihoods and infrastructure arrangements to maintain or recover key functions, adapt management in response to disturbance and, where necessary, reconfigure practices without displacing unacceptable ecological or social costs. This operational definition is deliberately broader than recovery of vegetation cover. It comprises five coded dimensions: ecological integrity, livelihood security, equity and justice, coastal-risk reduction and adaptive capacity. It follows coastal-governance scholarship that distinguishes persistence from adaptation and transformation, and that emphasizes system, target and transformative knowledge in iterative learning [9].

Collaborative governance is operationally defined as the institutionalized process through which government, local communities, Indigenous peoples, non-governmental organizations, researchers, private-sector actors, financiers and, where relevant, intergovernmental organizations exchange information, allocate or contest authority, make or influence decisions, and account for consequences across scales. This definition is stricter than the existence of meetings or formal membership. Collaboration is substantively present only when it changes the conditions under which priorities, rights, evidence, resources, coordination and disputes are handled. A global review identifies legitimacy, fairness and integration as central principles in mangrove conservation governance [10]; a nested-governance analysis emphasizes that mangrove commons cross ecological and institutional boundaries [11]. Together, these literatures make decision influence and cross-scale fit central to the operational meaning of collaboration.

The conceptual framework distinguishes intervention, mechanism, intermediate-capacity and outcome layers. Restoration and conservation interventions include protection, hydrological repair, assisted regeneration and blue-carbon projects. They operate through seven mechanisms: participatory agenda setting; rights and tenure recognition; knowledge co-production; adaptive monitoring and learning; transparent finance and benefit sharing; nested cross-scale coordination; and accountable conflict resolution. These mechanisms are expected to shape intermediate capacities—legitimacy, trust, collective learning, resource mobilization, compliance and institutional fit—that are relevant to the five resilience dimensions. Hazard regime, land-use pressure, state capacity, power asymmetry, market dependence, power asymmetry and market dependence are treated as moderators, not background noise. The framework is a conceptual synthesis of plausible pathways; it does not assert a universal causal sequence.

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Figure 1 depicts this mechanism-based architecture, including the distinction between mechanisms and outcomes that is often blurred when restoration is represented as an isolated ecological intervention.

Mechanism-based pathway to social-ecological resilience

Conceptual synthesis of interventions, governance functions, capacities and outcomes

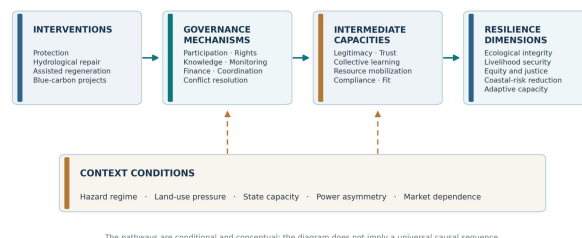


Fig. 1. Mechanism-based pathway from restoration and conservation interventions to social-ecological resilience, mediated by governance capacities and conditioned by context.

C. Research questions and contribution

The analysis addresses three questions. RQ1 asks which collaborative governance mechanisms connect mangrove restoration interventions to social – ecological resilience outcomes. RQ2 asks how stakeholder composition, power relations, tenure, knowledge, finance, monitoring and cross-scale coordination condition those mechanisms. RQ3 asks which mechanism configurations recur across contexts and what governance-design principles can be inferred without overstating causal certainty.

The contribution is threefold. First, the paper consolidates ecological, governance, justice, finance and risk-reduction evidence into a common mechanism vocabulary. Second, it makes manual coding decisions and descriptive counts transparent, allowing readers to distinguish evidence concentration from effect estimation. Third, it develops practical design principles that are explicitly conditional on authority, ecological setting, accountability and distributional safeguards. The study is not a field experiment, stakeholder survey, causal meta-analysis or representation of all mangrove scholarship. It is an original structured evidence synthesis and mechanism-based conceptual study.

II. LITERATURE REVIEW

A. Ecological restoration as a diagnosis-and-learning problem

Ecological restoration research provides the material basis for a resilience-oriented governance framework. The central lesson is not that planting lacks value, but that ecological outcomes depend on site – species fit, hydrological connectivity, landscape structure and sustained observation. The global meta-analysis by Su, Friess and Gasparatos compares restored mangroves with both unvegetated flats and natural stands, showing that restoration performance should be assessed against more than a single degraded baseline [1]. This supports a function-based orientation: an intervention can register a visible gain while

still leaving gaps in ecological function relative to a reference system.

Colombian evidence adds an implementation perspective. The reviewed record of restoration actions indicates that the type of restoration and the technique used shape observed success, with hydrological approaches represented among more highly successful cases than common sowing approaches [2]. A regional Southeast Asian review likewise finds that direct planting dominates the literature even though smaller, locally situated projects in suitable intertidal zones have a greater chance of success than large projects in unsuitable lower-intertidal settings [4]. These observations do not establish a simple hierarchy in which hydrological repair always replaces planting. They imply that agenda setting and site diagnosis must precede a preselected intervention, and that actors with local ecological knowledge, engineering authority and responsibility for later maintenance need a shared basis for deciding.

Long-term trajectory evidence reinforces the importance of feedback. In Ciénaga Grande de Santa Marta, climate variability, hydrological rehabilitation and freshwater flows were jointly associated with salinity, recruitment and cover trajectories [6]. The Mexican coastal-lagoon study similarly links hydrological modification to changed salinity conditions and subsequent natural regeneration [7]. Both studies support an adaptive interpretation of restoration: managers should be able to revisit water-management choices when monitoring reveals altered flows, salinity or recruitment. The relevant governance mechanism is not a generic commitment to adaptation; it is a decision rule that connects information to authorized revision.

Monitoring remains a critical weak link. A global assessment of indicator reporting found inconsistent baselines, sparse socioeconomic reporting and short monitoring windows across restoration case studies [3]. Sentinel-2-based monitoring in Indonesia illustrates that time series can identify both recovery and post-restoration disturbance [8]. This does not make remote sensing self-validating or socially neutral. It demonstrates the value of records that can reveal partial recovery and disruption, while governance determines who has access to the record, how uncertainty is communicated and whether a disturbance triggers corrective action. The restoration literature therefore supports a shift from output targets to jointly governed ecological diagnosis, function-based baselines and iterative learning.

B. Resilience and adaptive governance beyond project recovery

Resilience scholarship expands the time horizon and the unit of analysis. Coastal governance cannot assume that the desired endpoint is a stable system returned to a previous state. Rölfer, Celliers and Abson frame resilience through the navigation of stability and transformation, emphasizing iterative learning and exchange between scientific and local knowledge [9]. For mangroves, this perspective is important because climate variability, changing markets, institutional reform and altered coastal development can make both ecological reference conditions and social objectives contested.

Evidence on adaptive capacity adds a caution against treating institutional form as capacity. In Bali Barat, flexibility, learning and agency were considered important

program attributes but were reported as underperforming, while willingness to participate varied among stakeholder groups [12]. Australian coastal-governance research similarly finds that many innovations remain limited in scale and that stronger examples draw on knowledge, experience, networks and resource-mobilization capacity developed before crisis [13]. These studies suggest that capacity is distributed and unequal. A workshop or committee may create an organizational shell without providing the resources, authority or recognition needed to respond when conditions change.

The cross-scale problem is especially pronounced in mangrove systems. Walker and colleagues characterize mangroves as commons whose ecological connections span local, regional and wider governance levels, motivating a nested framework rather than an isolated project model [11]. The framework does not imply that centralization or decentralization is universally preferable. Rather, it asks whether rules at each level fit the scale of the problem, and whether authority and information can move across levels without erasing local rights or accountability. This is a basis for treating nested cross-scale coordination as a distinct mechanism rather than a synonym for participation.

Polycentric arrangements can create opportunities but also expose inequities. Comparative research in Ecuador finds that community justice under polycentric mangrove governance differed with cohesion, service equity, political division, external pressure and reliance on the state [14]. Thus, multiple centres of authority do not automatically ensure fair conflict resolution. They can enable local autonomy in one setting and reinforce fragmentation in another. The implication for resilience is conditional: institutional diversity needs accountable links, credible rights and mechanisms for resolving disputes when authority overlaps.

C. Participation, justice and the distribution of authority

The collaboration literature makes clear why attendance cannot serve as a proxy for governance quality. In Indonesia, overlapping authority claims and weak mangrove-specific regulation were associated with undermined institutional synergy [15]. Evidence from the Togo–Benin transboundary reserve associates co-management with reduced anthropogenic stressors while noting the need for sustained resources and engagement [16]. In Sri Lanka, social-network analysis identified mandated agencies as central but also documented communication barriers, low awareness and resource constraints; a bridging organization was proposed to widen inclusion and information diffusion [17]. These cases frame participation as a question of agenda access, information flow and decision influence, not simply the number of actors listed in a project.

Co-management evidence shows both potential and limits. In the Sundarbans, stakeholders reported learning and permit-access benefits but also restricted eligibility, weak meeting support and limited harvesting opportunities [18]. The Tanzania study relates livelihood perceptions to legitimacy, inclusion, respect and attention to local priorities [19]. A separate Sundarbans evaluation identifies persistent concerns regarding local voice, resource access, accounting and transparency [20]. The Togo–Benin record also identifies continuing needs for finance and regular engagement [16]. Taken together, these studies do not support the claim that co-management reliably produces any

one outcome. They show that co-management arrangements are interpreted through the accessibility of rules, benefits and accountability.

Rights and distribution are especially salient because conservation can change access to land, resources and work. Evidence from the Mekong Delta associates particular forms of devolved forestland management and payment arrangements with forest-cover outcomes, illustrating that the design of rights and incentives matters rather than the label of devolution alone [21]. In Malaysia, cash-flow mapping of a managed mangrove value chain indicates unequal capture of benefits between contractors and workers, prompting attention to labour safeguards [22]. These studies support an operational distinction between formal participation and enforceable claims to access, income and recognition.

Justice also includes who carries costs and whose knowledge is recognized. Kenyan blue-carbon participants stressed distributional justice and raised concerns that technical precision and efficiency narratives can reduce transparency and agency [23]. Research in Odisha identifies gendered social responsibilities and preferences as part of the burden associated with conservation-related changes in energy practices [24]. In the Mono Transboundary Biosphere Reserve, Indigenous and Local Knowledge is expressed through beliefs, taboos, customs, rituals and rules that support mangrove stewardship, while its continuity faces social and cultural pressures [25]. These sources justify treating recognition, benefit sharing and conflict resolution as core governance mechanisms. They are not optional additions to a completed ecological project; they condition whether cooperation is legitimate, intelligible and durable.

D. Finance, monitoring and hybrid coastal protection

Blue-carbon finance can mobilize resources, but it is not interchangeable with resilient governance. Global spatial modelling identifies that investibility is conditional on assumptions concerning additionality, carbon stocks, prices, buffers and financial viability [26]. Indonesia's blue-carbon policy analysis identifies the need to coordinate sectoral responsibility, policy and funding across institutions [27]. These sources indicate that capital enters a pre-existing field of tenure, regulation and ecological uncertainty. Its resilience relevance depends on whether financial decisions maintain rather than displace local agency and ecological integrity.

Monitoring, reporting and verification are central to that condition. Australian accounting research indicates that site-sensitive, elevation-stratified approaches can reduce overestimation relative to simpler regional estimates [28]. Global Mangrove Watch provides a basis for tracking extent change while cautioning against overinterpreting independent gain and loss estimates with wide uncertainty [29]. National-scale accounting research in China proposes annual recording of blue-carbon stocks for monitoring climate commitments [30]. Such methods can improve transparency, but they also create governance questions about the accessibility of measures, the treatment of uncertainty and the connection between national inventories and local rights holders.

The finance literature further points to institutional constraints. A review of global interest in blue carbon identifies verification burdens, small project scales and the possibility of double counting between commercial and national systems [31]. A later review of mangrove carbon-

market projects reports gaps between projects discussed in the literature and projects recorded in registries, and links stronger integrity to transparency, tenure protection, benefit sharing and accurate monitoring [32]. The evidence thus supports the conceptual proposition that finance is resilience-supporting only when its safeguards, benefit flows and claims are auditable and locally intelligible.

Finally, coastal-protection evidence cautions against treating mangroves as fail-safe infrastructure. Mangroves can attenuate waves and reduce direct wave impacts on hard defences, but performance is conditional on vegetation, width, health and spatial context [33]. Numerical work from the Pearl River Delta shows that patch configuration can create non-local effects, making cross-jurisdictional coordination relevant to the distribution of risk [34]. A global coastal-protection index shows why forest condition should be monitored alongside area [35]. Modelling for Bangladesh incorporates both mangrove growth and storm-related tree failure, underscoring residual risk and the case for hybrid design [36]. Reviews focused on Mauritius and Indonesia similarly emphasize baseline data, long-term monitoring, subnational representation and improved evaluation [37] [38]. Coastal-risk reduction is therefore best approached as a jointly governed, condition-based and adaptive hybrid-infrastructure problem.

III. RELATED WORK

A. What existing syntheses establish

This study responds by using a mechanism-based bridge rather than a pooled-effect design. Mechanisms are not treated as measured treatments with common outcomes across studies. They are coded as recurring governance functions that allow evidence with different methods to be compared at an appropriately cautious level. The analysis asks where the corpus places attention, which mechanisms and resilience dimensions are discussed together, and which stakeholder-mechanism links are visible in source texts. It does not estimate a governance effect size or rank interventions by causal effectiveness.

B. Why mechanisms provide a useful unit of synthesis

Mechanisms offer a middle level between broad normative principles and context-specific institutional arrangements. Participatory agenda setting concerns whether affected groups can shape priorities, problem definitions and criteria for action. Rights and tenure recognition concerns whether use, access, exclusion and benefit claims are clear, enforceable and legitimate. Knowledge co-production concerns the organized combination of local, Indigenous, scientific and technical knowledge. Adaptive monitoring and learning concerns shared baselines, feedback, disclosure and authorized revision. Transparent finance and benefit sharing concerns traceable allocation, safeguards and intelligible distribution. Nested cross-scale coordination concerns alignment between ecological scales, administrative mandates and decision levels. Accountable conflict resolution concerns accessible grievance, downward accountability, dispute handling and review.

The distinction among these mechanisms is essential. A consultation process can be participatory without recognizing tenure. A remote-sensing dashboard can improve monitoring without enabling communities to challenge benefit allocation. A national blue-carbon strategy can coordinate ministries

without resolving disputes over access. A local conflict-resolution practice can be legitimate within a community while lacking a pathway to resolve cross-jurisdictional harm. Treating the seven mechanisms separately therefore avoids collapsing collaboration into a single index while still permitting integrative design. The seven constructs and coding focuses are summarized in Table I.

TABLE I. CORE CONSTRUCTS AND OPERATIONAL DEFINITIONS USED IN THE SYNTHESIS

Construct	Operational definition	Observable coding focus
Social–ecological resilience	Capacity to sustain, adapt or reconfigure linked ecological and social functions	Five resilience dimensions
Collaborative governance	Decision-relevant interaction and accountability among stakeholder groups	Actors, influence, links and review
Governance mechanism	Recurring institutional function that connects intervention to capacity	Seven controlled mechanism categories
Intermediate capacity	Enabling capacity between governance practice and resilience outcome	Legitimacy, trust, learning, mobilization, compliance, fit
Mechanism–resilience pairing	Joint discussion of a mechanism and resilience dimension within coded sources	Manual co-occurrence count and supporting source notes
Evidence concentration	Frequency or joint discussion in the purposive corpus	Descriptive corpus pattern only

Table I clarifies the analytical boundary. The resilience construct is intentionally multi-dimensional and does not presume that every source measures every dimension. Collaborative governance is likewise assessed through decision-relevant functions, not through an assumption that every stakeholder interaction is equitable. The mechanism labels are coding devices grounded in the corpus and used to organize interpretation; they do not imply that source studies used identical terminology.

C. Analytical positioning and propositions

The framework makes five conditional propositions for future empirical testing, rather than claims about established universal effects. First, procedural legitimacy should be more credible where participation grants affected groups decision influence rather than consultation-only access. Second, stewardship incentives should be stronger where tenure and benefit rights are clear and enforceable. Third, ecological correction should be more feasible where local knowledge, technical monitoring and management authority are connected. Fourth, long-horizon finance should be more compatible with resilience where safeguards, transparent allocation and legitimate benefit sharing accompany funding. Fifth, nested coordination should be more useful where it aligns ecological processes and institutional jurisdictions rather than multiplying unaccountable forums.

These propositions are consistent with evidence on legitimacy, integration, devolution, knowledge exchange, monitoring and finance [9] [10] [21] [23] [28] [31]. They should not be read as confirmed causal laws. A field study or comparative design would need repeated measures of governance practice and ecological, livelihood or risk

outcomes to test them. The present contribution is to specify the mechanisms and observable conditions such designs would need to examine.

IV. METHODOLOGY

A. Study design and evidence-search logic

This study used a structured and purposive evidence synthesis, not a PRISMA-complete systematic review, a statistical meta-analysis or a probability sample of mangrove research. The search window was 2021 – 2026. Six thematic search domains were used to ensure that the corpus did not reduce mangrove conservation to one disciplinary lens: T01 ecological restoration effectiveness and failure mechanisms; T02 social – ecological resilience and adaptive governance; T03 collaborative governance, co-management and stakeholder participation; T04 equity, tenure, local knowledge, gender and environmental justice; T05 blue-carbon finance, policy integration and monitoring; and T06 coastal-risk reduction and nature-based social – ecological resilience.

The search logic was purposive because the objective was coverage of mechanism-relevant evidence across these domains, not exhaustive retrieval of every publication that mentions mangroves. It combined global syntheses and geographically situated studies with different evidence forms, including empirical research, systematic evidence syntheses and narrative or conceptual reviews. Titles, abstracts and relevant full texts were examined manually against the stated criteria, and a simple source log recorded inclusion decisions. The resulting corpus should therefore be read as a traceable analytical collection, not as a census of all regions, actors or institutional pathways.

B. Eligibility, validation and de-duplication

Records were included when they fell within the time window, addressed mangrove conservation, restoration, governance, finance, monitoring or coastal risk in a way relevant to the conceptual pathway, and had a traceable peer-reviewed source record or stable source route. Records were excluded when their source could not be located, they repeated a title or identifier already included, fell outside the date window, or did not support a mechanism-relevant claim. These decisions were made by reading citation details and source texts individually before coding; a publication appearing under multiple themes was counted once.

For each retained source, bibliographic details were checked manually against the article or publisher record where available. Titles, years and identifiers were compared in a source log, and duplicate appearances were removed by direct inspection. The final set comprises 38 peer-reviewed publications. Bibliographic checking supports traceability; it does not rate methodological quality, establish comparability across designs or imply that all sources bear equal evidentiary weight. Table II summarizes the manual eligibility rules and coding fields.

TABLE II. ELIGIBILITY RULES AND CODED DATA FIELDS

Element	Included or recorded	Excluded or not inferred
Time window	Publications dated 2021–2026	Earlier or later records
Relevance	Mangrove restoration, governance, justice,	Generic coastal material without a mechanism link

Element	Included or recorded	Excluded or not inferred
	finance, monitoring or risk	
Source traceability	Peer-reviewed article or stable source record checked manually	Source record that could not be located
De-duplication	One publication after manual comparison of titles and identifiers	Repeated appearances across search themes
Bibliographic fields	ID, year, title, authors, venue, DOI, geography, evidence type	Invented metadata
Analytical fields	Claim, stakeholders, mechanisms, resilience dimensions	Unreported causal effects
Validation fields	Source details, claim note and manual coding rationale	Automated quality score or batch validation output

As summarized in Table II, the handwritten or spreadsheet-based coding fields preserve a source-specific supported claim while adding transparent synthesis categories. The unit of analysis was one publication, not one site, respondent group, intervention episode or independent field observation. This matters because publications can synthesize many cases, and because a frequency of coded sources cannot be converted into an incidence rate or used as a sample size for causal inference.

C. Coding framework and derived measures

The codebook specified eight stakeholder categories: Government, Local communities, Indigenous peoples, NGOs, Researchers, Private sector, Financiers and Intergovernmental organizations. It specified the seven governance mechanisms defined in Section 3 and five resilience dimensions. Each publication was read and coded manually against these categories, with a brief supporting note for each relevant claim. Coding described the focal evidence reported by each publication. It did not reanalyse original field data, extract unreported outcomes or treat text mentions as independent observations. A compact coding sheet records the categories assigned to each source.

Coding breadth was described by listing how many of the seven mechanisms, five resilience dimensions and eight stakeholder categories appeared in each publication. These simple tallies indicate the scope of a publication within this codebook. They do not measure intervention quality, diversity of real-world participants or strength of collaboration.

Mechanism–resilience relationships were examined by reading the coding sheet and counting publications in which both categories appeared. The resulting cross-tabulation was used only to guide qualitative comparison of recurring and less visible pairings within this corpus.

A co-occurrence count describes joint visibility in the selected literature. It is not an effect size, a correlation of field outcomes or an indicator of real-world prevalence. Because the corpus was purposively assembled and source contexts differ, small differences between counts were not interpreted as precise rankings or statistical evidence.

D. Network and robustness procedures

Stakeholder–mechanism links were summarized by reviewing the coding sheet and noting which stakeholder

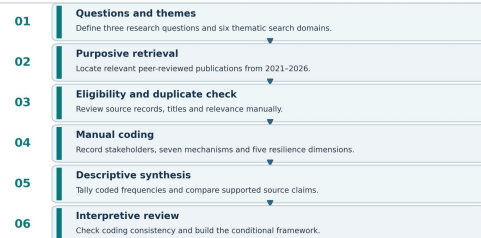
categories were discussed alongside each mechanism. A simple categorical map illustrates recurring links without computing network edges, weights or organizational centrality. These links describe coded publications rather than observed interactions among organizations.

A manual consistency review compared the source log with the coding sheet, checked category definitions against selected source passages and rechecked the arithmetic of the seven mechanism counts. The descriptive pattern was also read across the six thematic domains to note where a theme might shape visibility. This review is a check on interpretation within the selected corpus, not a rank-correlation or inferential sensitivity test; it cannot establish causal robustness or population-wide prevalence.

Figure 2 presents the workflow from question formulation through purposive retrieval, manual eligibility screening, coding, descriptive synthesis and interpretive review.

Structured evidence-synthesis workflow

A manually executable sequence for a purposive 38-source literature corpus



Output: a traceable source list, manual coding sheet, simple counts and conceptual propositions.

Fig. 2. Structured evidence-synthesis workflow from research questions to manual screening, coding, descriptive counts and interpretive review.

V. DATA

A. Corpus composition and provenance

The manually assembled corpus comprises 38 publications dated from 2021 to 2026. All 38 are peer-reviewed records. Twelve records are categorized as global or multi-region. By publication year, the corpus contains 6 records from 2021, 12 from 2022, 8 from 2023, 7 from 2024, 3 from 2025 and 2 from 2026. Twenty records, or 52.6% of the corpus, are from 2023–2026. These values describe the assembled evidence base rather than the temporal distribution of all mangrove research.

A manual source classification identifies 26 empirical peer-reviewed articles, 6 systematic evidence syntheses and 6 narrative or conceptual reviews. Geographic-scope categories include 12 global or multi-region records, 7 from Southeast Asia, 5 from South Asia, 4 from Latin America and the Caribbean, 3 from East Asia, 1 from Oceania, 1 from Africa and 5 other or unspecified records. The sources cover all six search domains, with several publications relevant to more than one theme. These counts are evidence concentrations within a purposive corpus; they are not estimates of the geographical or disciplinary prevalence of mangrove governance research. Table III presents the descriptive corpus profile.

TABLE III. CORPUS SUMMARY AND DESCRIPTIVE CODING PROFILE

Dimension	Category	Records or value
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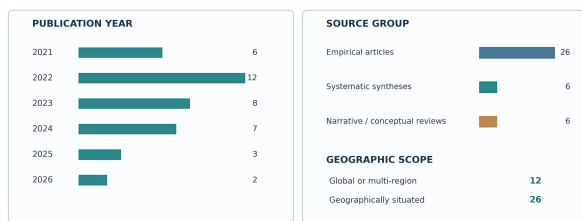
Dimension	Category	Records or value
Corpus size	Verified publications	38
Publication period	2021–2026	38
Verification	Peer-reviewed sources checked against source records	38
Evidence provenance	Peer reviewed; authoritative reports	38; 0
Source grouping	Empirical; systematic synthesis; narrative or conceptual review	26; 6; 6
Geographic scope	Global or multi-region	12
Recent material	Publications from 2023–2026	20 (52.6%)
Coding scope	Mechanisms, resilience dimensions and stakeholder categories	Recorded by manual category tallies; no normalized index

Table III reports the descriptive profile obtained by manually classifying the sources. The publications vary in the number of stakeholder, mechanism and resilience categories discussed. That is expected in a cross-disciplinary corpus, where many sources focus narrowly on a restoration technique, governance problem, finance arrangement or risk process. It should not be interpreted as evidence that real-world governance involves only a small number of actors or outcomes.

Figure 3 visualizes the same publication-year, evidence-type and geographic-scope profile. It provides context for the results that follow, especially the presence of global syntheses alongside geographically situated work.

Profile of the 38-publication purposive corpus

Manual classification of publication year, source group and geographic scope



Counts describe this selected evidence set and do not estimate the distribution of all mangrove research.

Fig. 3. Publication year, source-group and geographic-scope profile of the 38-record purposive corpus, based on manual.

B. Analytic dataset and interpretation boundary

The analytic material consists of a source list, a manually completed coding sheet and simple summaries of mechanism counts and recurring category pairings. Its unit is one publication, not a project, organization, community or hectare. Mechanism frequency therefore denotes coded records only.

The coding sheet records publication details, a short supported claim and the assigned stakeholder, mechanism and resilience categories. The mechanism summary gives the count and share of the 38-record corpus for each mechanism, together with prominent coded stakeholder and resilience categories. Pairings were inspected directly in the sheet and interpreted in the light of source texts. No bulk CSV or JSON export, network edge list, coefficient matrix or executable analysis package is required. No source-level estimates were pooled, and no statistical test was applied to

publications as though they constituted independent, randomly sampled experiments.

VI. RESULTS

A. Distribution of coded governance mechanisms

The descriptive coding identifies adaptive monitoring and learning as the most frequently coded mechanism, appearing in 14 of 38 records (36.8%). Nested cross-scale coordination appears in 10 records (26.3%). Transparent finance and benefit sharing and accountable conflict resolution each appear in 8 records (21.1%), participatory agenda setting in 7 (18.4%), rights and tenure recognition in 5 (13.2%), and knowledge co-production in 4 (10.5%). Adaptive capacity is the leading coded resilience dimension for participatory agenda setting, adaptive monitoring and learning, transparent finance and benefit sharing, nested cross-scale coordination and accountable conflict resolution; equity and justice leads for rights and tenure recognition, while ecological integrity leads for knowledge co-production. The leading stakeholder group is Government for participatory agenda setting, rights and tenure recognition, knowledge co-production, nested cross-scale coordination and accountable conflict resolution, and Financiers for adaptive monitoring and learning and transparent finance and benefit sharing. Table IV summarizes these mechanism frequencies and evidence functions.

TABLE IV. SEVEN GOVERNANCE MECHANISMS, EVIDENCE FUNCTIONS AND CODED FREQUENCIES

Mechanism	Evidence function in the framework	Records	Share of corpus	Prominent coded stakeholder group
Participatory agenda setting	Shapes priorities and decision access	7	18.4%	Government
Rights and tenure recognition	Clarifies enforceable access and stewardship claims	5	13.2%	Government
Knowledge co-production	Connects local, Indigenous, scientific and technical knowledge	4	10.5%	Government
Adaptive monitoring and learning	Links baselines, feedback and authorized adjustment	14	36.8%	Financiers
Transparent finance and benefit sharing	Makes resource allocation and safeguards traceable	8	21.1%	Financiers
Nested cross-scale coordination	Aligns ecological processes and institutional mandates	10	26.3%	Government
Accountable	Provides	8	21.1%	Government

Mechanism	Evidence function in the framework	Records	Share of corpus	Prominent coded stakeholder group
conflict resolution	review, grievance and dispute-handling routes			

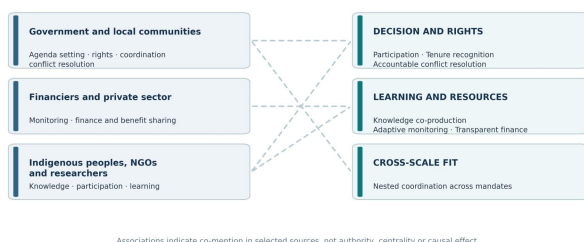
As shown in Table IV, the prevalence ordering is a map of attention within the purposive corpus. It does not indicate that transparent finance is more important than rights recognition in all settings, nor that a less frequently coded mechanism is less consequential for a particular restoration project. The low frequency of rights and tenure recognition instead identifies a coding concentration that should be interpreted alongside the literature's substantive emphasis on rights, incentives and justice.

B. Stakeholder–mechanism network

Manual review of the coding sheet shows that Government is discussed across all seven governance mechanisms. Financiers recur with adaptive monitoring and learning and with transparent finance and benefit sharing; Private sector actors are also visible in these discussions. Local communities are discussed with several mechanisms, including nested cross-scale coordination and accountable conflict resolution. Indigenous peoples, NGOs and Researchers are less frequently foregrounded in the selected sources, while Intergovernmental organizations are not prominent in the source-level mechanism coding. These are qualitative summaries of category visibility; they do not measure organizational power, actual participation or the intensity of collaboration.

Figure 4 maps these associations as an illustrative grouping of manually coded stakeholder and mechanism categories. The connecting lines indicate that a pairing was identified in the source texts, without representing edge weights, centrality, funding magnitude, decision authority or causal strength. The map helps identify which actors are visible alongside governance functions in this evidence set and where closer source-level or field analysis would be useful.

Stakeholders and governance mechanisms in the coded literature
Conceptual map of manually observed category pairings; lines have no calculated weights



Associations indicate co-mention in selected sources, not authority, centrality or causal effect.

Fig. 4. Conceptual map of stakeholder categories and governance mechanisms identified through manual coding; lines indicate reported associations within the selected literature, without network weights.

C. Mechanism–resilience evidence affinity

Manual comparison of coded mechanisms and resilience dimensions suggests that rights and tenure recognition is most often discussed with equity and justice and also with

livelihood security and adaptive capacity. Nested cross-scale coordination is particularly visible alongside adaptive capacity, with additional links to ecological integrity and coastal-risk reduction. Adaptive monitoring and learning appears with ecological integrity, adaptive capacity and coastal-risk reduction. These observations describe joint themes in the selected publications, without calculating normalized affinity coefficients or implying that an uncoded pairing is absent in practice.

Participatory agenda setting is discussed with adaptive capacity, ecological integrity, livelihood security and equity and justice. Knowledge co-production is most visible alongside ecological integrity and adaptive capacity. Transparent finance and benefit sharing is discussed with equity and justice, livelihood security, adaptive capacity and coastal-risk reduction. Accountable conflict resolution is discussed with adaptive capacity, livelihood security, equity and justice and ecological integrity. The relative prominence of these pairings depends on the purposive source selection and the wording of the manual codebook; further quantitative analysis can be carried out in future research using a broader, independently checked corpus.

Figure 5 presents a conceptual summary of these manually observed pairings alongside the descriptive mechanism frequencies. The grouped themes indicate where the selected literature places attention. They cannot show whether a mechanism produced a resilience outcome, whether its effect is positive or negative, or whether a less visible pairing represents a real-world absence rather than a gap in study design.

Mechanisms and resilience themes in the coded corpus
Frequency counts and qualitative pairings from manual coding; no normalized coefficients



These are patterns of visibility in a purposive corpus, not effect sizes or statistical associations.

Fig. 5. Conceptual summary of manually observed mechanism–resilience pairings and descriptive mechanism frequencies in the purposive corpus.

D. Sensitivity of the descriptive prevalence ranking

A manual recheck of the 38 source entries and the seven mechanism tallies retained the descriptive count pattern: 7 for participatory agenda setting, 5 for rights and tenure recognition, 4 for knowledge co-production, 14 for adaptive monitoring and learning, 8 for transparent finance and benefit sharing, 10 for nested cross-scale coordination, and 8 for accountable conflict resolution. Because the same publications underlie both readings, this consistency check provides no independent validation and no statistical estimate of ranking stability.

Reading the records by search theme shows that finance-oriented publications contribute appreciably to the visibility of transparent finance and benefit sharing, while restoration and risk-oriented publications emphasize other mechanisms. Several sources connect more than one theme, so assigning each record to a single domain would obscure those overlaps.

The thematic comparison was interpretive and did not involve repeated deletion of theme groups, rank correlations or a numerical robustness score.

These checks support a cautious description of the mechanism pattern within the constructed corpus. They do not identify a true population ranking, validate the coding categories across all mangrove literature or establish the importance of a mechanism in a local setting. Differences in thematic coverage motivate more extensive comparative and quantitative work rather than a claim of statistical robustness.

VII. DISCUSSION

A. *A shift from restoration outputs to governance capacities*

The synthesis supports a reframing of mangrove restoration from a bounded ecological activity to a continuing social – ecological governance process. Ecological evidence is clear that restoration performance is conditional on hydrology, site suitability, species, landscape context and time [1] [2] [4] [5] [6]. Yet these conditions are not selected and maintained in a social vacuum. They require collective diagnosis, authority to alter water or land-management decisions, resources for monitoring and channels through which those bearing costs can contest priorities. The framework therefore does not suggest that governance substitutes for ecological expertise. It suggests that ecological expertise is actionable only when embedded in institutions capable of learning, coordinating and accounting.

This interpretation answers RQ1. The seven mechanisms are not independent interventions. They form a linked set of governance functions. Participatory agenda setting can determine whether site selection and objectives reflect locally relevant risks and uses. Rights and tenure recognition can clarify who may steward, use or benefit from restored systems. Knowledge co-production can combine local observations with hydrological, spatial and remote-sensing information. Adaptive monitoring and learning can convert baselines and feedback into revised action. Transparent finance and benefit sharing can make resource flows and safeguards visible. Nested coordination can connect site-level practice to basin, municipal, national and transboundary decisions. Accountable conflict resolution can give disputes and grievances a route other than exit, coercion or opaque upward reporting.

B. *Participation must be decision-relevant and distribution-aware*

The first design implication is that participation should be evaluated by influence, not attendance. The literature documents barriers to communication, restrictive membership, weak meeting support and centralized accountability in co-management arrangements [17] [18] [20]. It also connects legitimacy and respect for community priorities to livelihood perceptions [19]. These findings make a practical distinction between consultation and agenda setting. Consultation may communicate a plan. Agenda setting allows affected actors to shape what counts as a problem, which outcomes matter, what evidence is credible and when a plan should be changed.

This distinction is particularly important where conservation introduces new restrictions or financial incentives. The Tanzanian and Bangladeshi cases show that access, support and accountability can be as decisive for

perceived legitimacy as the formal existence of a platform [18] [19] [20]. The Kenyan blue-carbon case indicates that technically precise benefit systems can nevertheless be experienced as opaque or disempowering [23]. Meaningful participation therefore requires public explanation of eligibility, benefit rules, monitoring results and the record of how local proposals altered decisions. It also requires attention to who can speak, travel, take time from paid or care work and safely contest a decision.

Gender and cultural recognition sharpen this requirement. Evidence from Odisha shows that conservation-related burdens are not distributed uniformly between women and men [24]. The Togo – Benin research shows that Indigenous and Local Knowledge is held and transmitted through specific cultural institutions and relationships, rather than existing as freely extractable information [25]. A collaborative process that invites “local knowledge” while ignoring these burdens and authorities can reproduce rather than correct inequality. The relevant design standard is not generic inclusion; it is the ability of differentiated rights holders and knowledge holders to exercise recognizable influence under conditions that do not impose hidden costs.

C. *Rights, knowledge and monitoring form a learning compact*

The second design implication is a shared diagnostic compact established before implementation. It should make explicit the ecological baseline—hydrological connectivity, elevation, salinity, sediment, site – species fit, reference condition and connectivity—alongside tenure, livelihood uses, local knowledge protocols and exposure to coastal hazard. This responds to evidence that ecological fit and reporting are often incomplete [3] [4] [5], and to the demonstrated importance of climate-aware hydrological management [6] [7]. It also provides a practical location for rights recognition: stakeholders can see what access, use and benefit claims are expected to change when an intervention begins.

Knowledge co-production is valuable here not because all forms of knowledge are interchangeable, but because each may reveal different aspects of a changing system. Remote sensing can track disturbance and recovery over time [8]. Site-sensitive carbon accounting can improve the credibility of estimates [28]. Local and Indigenous knowledge can identify customary rules, resource practices, seasonal conditions and culturally legitimate constraints [25]. The governance task is to define how these forms of knowledge are brought into a decision, how uncertainty is reported, who may request remeasurement and how disagreements are resolved. Without those rules, monitoring can become an upward-reporting requirement rather than a shared learning system.

Adaptive monitoring becomes more than a technical mechanism when it has a pre-agreed action pathway. An observation of salinity change, failure of natural recruitment, canopy decline, benefit exclusion or a new hazard should trigger review by actors with authority to revise the intervention. This approach aligns with resilience scholarship that stresses iterative learning [9] and with evidence that adaptive-capacity attributes can remain underperforming despite their recognized importance [12]. It also prevents the common tendency to treat monitoring as a terminal audit. A terminal audit records whether a project met an output; a

learning system asks what the observation means for the next decision.

D. Finance needs accountability, not only investibility

The third design implication concerns finance. Blue-carbon investment can help fund restoration, monitoring and stewardship, but finance is not a neutral external input. It is structured by additionality rules, transaction costs, registries, national accounting and market expectations [26] [31] [32]. The corpus includes finance as a recurring mechanism, and manual comparison shows that transparent finance and benefit sharing is commonly discussed alongside equity and justice. This descriptive observation may reflect the prominence of distributional and procedural concerns in finance discussions; it does not establish that financial mechanisms improve equity or justice.

A resilience-oriented finance arrangement should therefore be evaluated on at least four questions. First, are tenure and access claims sufficiently clear that local rights holders can understand what is being committed and for how long? Second, are benefit-sharing rules auditable, accessible and able to address unequal labour or opportunity costs? Third, does the finance cover baseline work, maintenance, community participation, monitoring and grievance response, rather than only initial planting or credit issuance? Fourth, are project-level claims reconciled with national reporting systems to reduce double counting and opacity? These questions draw directly on finance, labour, justice and monitoring evidence [22] [23] [27] [29] [30] [31] [32].

E. Cross-scale coordination and hybrid-risk governance

The fourth design implication is a nested decision architecture. Mangrove processes traverse property boundaries, tidal systems, catchments, coastal municipalities and national climate-accounting systems. The literature documents overlapping authority and weak sectoral synergy in Indonesia [15], the need for cross-scale governance of the mangrove commons [11], and the potential role of bridging organizations in linking marginalized actors to wider networks [17]. A nested architecture should therefore allocate decisions to the scale at which they can be made legitimately and effectively, while specifying how information and appeals travel across scales.

At the site level, rights holders, community organizations, technical managers, women and marginalized groups, and knowledge holders need decision influence over diagnosis, access, restoration choices and benefit distribution. At landscape and basin levels, institutions responsible for water, land, fisheries, forestry, coastal engineering and development need procedures for resolving cross-boundary effects. At national and transboundary levels, climate reporting, funding and legal frameworks should not override local safeguards without accessible recourse. Polycentricity can be constructive when these links make authority visible and reviewable; it can be damaging when fragmented authority allows powerful actors to avoid accountability [14].

Coastal-risk reduction makes the need for coordination especially concrete. Mangroves can support wave attenuation and reduce direct impacts on hard defences, but their contribution is condition-dependent [33]. Patch design in the Pearl River Delta can affect risk beyond the immediate site [34]. Condition-based indices show that area alone is insufficient to track protective function [35], while engineering models demonstrate that vegetation failure under

extreme events and residual risk must be considered [36]. Hybrid design is consequently not a compromise between “green” and “grey” infrastructure; it is an institutional commitment to jointly assess condition, residual risk, maintenance responsibilities and the distribution of external effects. Mauritius and Indonesia evidence supports the associated importance of baselines, long-term monitoring, representation and evaluation [37] [38]. Table V translates these governance considerations into design principles and safeguards.

TABLE V. GOVERNANCE DESIGN PRINCIPLES AND BOUNDARY CONDITIONS

Design principle	Governance mechanism(s)	Boundary condition or safeguard
Establish a shared diagnostic compact	Knowledge; monitoring; participation	Ecological baselines and local protocols must be revisable
Give affected groups decision influence	Participatory agenda setting	Consultation alone is insufficient
Make rights and benefits auditable	Rights; finance; conflict resolution	Address labour, gender and access inequities
Connect monitoring to authorized action	Adaptive learning; coordination	Data access and uncertainty disclosure are required
Use bridging and nested institutions	Cross-scale coordination; participation	Avoid mandate overlap without accountability
Plan coastal protection as hybrid infrastructure	Monitoring; coordination; conflict resolution	Specify residual-risk and cross-jurisdictional trade-offs
Maintain accessible grievance and review routes	Accountable conflict resolution	Protect marginalized claimants and knowledge holders

Table V translates the mechanism framework into design principles without assuming that one institutional template fits all contexts. Each principle has a boundary condition because governance performance depends on power, tenure, ecological setting, state capacity and market dependence. A transparent registry cannot compensate for insecure land rights; a local committee cannot resolve basin-scale hydrological decisions without vertical links; and a wide mangrove belt cannot provide a fail-safe substitute for engineered protection under every storm scenario.

F. Evidence limits and research agenda

The principal limitation is an evidence-linkage gap. Governance studies frequently examine perceptions, institutional arrangements, networks, participation, justice or adaptive capacity. Biophysical studies frequently examine hydrology, regeneration, cover, carbon or coastal protection. Few sources measure governance processes and biophysical, livelihood or protective outcomes repeatedly within the same design. This means that the synthesis can identify plausible mechanisms and conditions, but it cannot attribute ecological change, risk reduction or livelihood outcomes to collaboration.

The purposive corpus also limits representativeness. It spans global syntheses and cases from several regions, but its evidence concentrations are shaped by the six search domains, publication accessibility and coding vocabulary. The 2026 records are recent, so their long-term uptake and replication cannot yet be assessed. Coding records rather than independent project observations prevents direct inference from counts. The controlled categories improve

transparency but necessarily simplify diverse institutional practices. The stakeholder map represents thematic co-mention, not real-world power or collaboration. The manual consistency review cannot establish causal robustness or transferability. Table VI summarizes the limitations and related research priorities.

TABLE VI. LIMITATIONS AND PRIORITY RESEARCH AGENDA

Limitation	Consequence for inference	Priority response
Purposive corpus	No population prevalence estimate	Transparent updates across regions and languages
Publication-level coding	No independent project sample	Link records to repeated site-level measures
Governance–biophysical separation	No causal attribution	Jointly measure authority, ecology, livelihoods and risk
Recent records	Limited long-term assessment	Follow projects beyond implementation and credit issuance
Controlled categories	Context may be compressed	Use comparative qualitative and mixed-method designs
Manual descriptive review	No statistical or causal robustness claim	Extend comparative and quantitative analysis in future work

The agenda in Table VI calls for designs that can observe mechanisms rather than presume them. Future studies could combine longitudinal indicators of hydrology, salinity, recruitment, canopy condition, connectivity, carbon and protective performance with repeated measures of representation, decision influence, tenure security, benefit distribution, funding reliability and grievance handling. Comparative work should examine how the same ecological intervention operates under different authority arrangements, including transboundary, Indigenous, gendered, urban, small-island and informal contexts. Such work would allow the conceptual propositions in this study to be tested while preserving the distinction between governance processes and outcomes.

VIII. CONCLUSION

Mangrove restoration can contribute to social – ecological resilience, but restoration alone is not the relevant unit of success. The decisive analytical question is how restoration and conservation interventions are governed across time, actors and scales. This structured evidence synthesis identifies seven mechanisms through which collaborative governance may connect intervention to resilience capacities: participatory agenda setting, rights and tenure recognition, knowledge co-production, adaptive monitoring and learning, transparent finance and benefit sharing, nested cross-scale coordination and accountable conflict resolution.

The corpus is most concentrated on adaptive monitoring and learning and nested cross-scale coordination, while leading coded resilience dimensions vary across mechanisms. These patterns should be read as descriptive observations from a manually coded purposive corpus, not causal estimates or real-world prevalence. A manual consistency

review supports the accuracy of the reported counts within the coding sheet, while leaving statistical and causal questions open. The framework's central implication is therefore conditional: durable mangrove outcomes are more plausibly supported where ecological diagnosis, legitimate authority, fair benefit distribution, accessible knowledge, adaptive feedback and cross-scale accountability are designed together.

For research, the priority is to measure governance arrangements and biophysical, livelihood and risk outcomes jointly over time. For governance design, the priority is to replace planting-centred delivery with a shared, revisable institutional pathway that can learn from disturbance, protect rights and negotiate residual risk. This is the transition from ecological restoration as a project output to social – ecological resilience as a continuing collective capacity.

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COMPETING INTERESTS

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