

Social–Ecological Outcomes of Lake Management Policy Implementation: Evidence from Lake Tempe, Indonesia

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ABSTRACT

Lake management policy in developing countries increasingly couples large engineering interventions with commitments to community welfare, yet the ecological and social results of such policies are rarely assessed within a single analytical frame. This study examines the implementation of lake management policy at Lake Tempe, Wajo Regency, Indonesia, through four social–ecological dimensions: social ecology, community economy, culture and local wisdom, and social institutions. A qualitative descriptive design was applied in three lakeside sub-districts, combining in-depth interviews with eleven purposively selected informants from technical agencies, village government and lakeside households, participant observation, and document analysis, with data examined through reduction, display and verification. The findings show an asymmetric pattern of implementation. Dredging and river normalisation raised storage capacity and lowered flood peaks in treated reaches, but continuing sedimentation, untreated domestic and agricultural loads, and unmanaged aquatic weed growth confine ecological recovery to specific locations. Economically, gear restrictions and tighter control of floodplain land reduced fishing and farming returns while replacement assets and enterprise support did not arrive, leaving the tourism potential of the lake unconverted. Culturally, seasonal use rights inherited from long-standing local practice are increasingly read as private ownership, so routine enforcement escalates into disputes. Institutionally, mandates are dispersed across sectoral agencies with weak coordination, and decisions over water level are made without a shared forum, which concentrates costs on households that cannot influence them. The policy is therefore implemented as a technical programme rather than a social–ecological one, and its ecological gains remain reversible without corresponding investment in livelihoods, recognition of local rights and coordinated institutions.

Keywords: policy implementation; social–ecological systems; lake governance; community livelihoods; institutional coordination

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1. Introduction

Lakes occupy a disproportionate share of the world's freshwater services relative to their surface area, and they are simultaneously among the most rapidly degrading ecosystems in the tropics. Their shallow basins concentrate nutrients, sediment and pollutants delivered from entire catchments, so that pressures generated far upstream are expressed as visible losses of water quality, storage volume and fish productivity at the lake itself. A global appraisal of restoration practice shows that most interventions still target symptoms inside the water body while catchment drivers continue to operate, which explains why measurable recovery is frequently short-lived and spatially confined (Poikane et al., 2024). The same appraisal notes that projects reporting durable improvement almost always pair physical works with sustained changes in how surrounding communities use land and water, a combination that requires governance rather than engineering alone.

This governance requirement is sharply visible in Southeast Asia, where lakes sit inside dense agricultural landscapes and support large populations directly. Studies of tropical lakes facing recurrent aquatic weed invasion demonstrate that clearance campaigns produce only temporary open water when nutrient inflows, riparian encroachment and unregulated cultivation in the catchment remain unaddressed, so the same problem is managed repeatedly at rising cost (Henny et al., 2026). Comparable evidence from lake and reservoir restoration elsewhere indicates that interventions aimed at internal loading deliver limited returns unless external loading is reduced at the same time (Ali et al., 2023). What these findings share is a warning that the boundary of a lake problem is never the shoreline, and that policy drawn at the shoreline will underperform.

Indonesia has responded to lake degradation with a national programme that designates a set of critical lakes for priority handling. Since 2016 the central government has channelled substantial capital works into fifteen such lakes, and in 2020 six were reclassified as super-priority, including

Lake Tempe in South Sulawesi. The programme is dominated by dredging, river normalisation and control structures, financed and executed largely through the public works sector. This design reflects a defensible logic, since storage loss and flooding are the most immediately measurable harms, and it mirrors a wider pattern in which environmental commitments are absorbed into national development planning through capital projects rather than through changes in sectoral practice (Hazemba & Halog, 2021), but it also embeds an implicit assumption that restoring hydraulic function will translate into restored livelihoods. Whether that translation occurs is an empirical question, and it is the question this article addresses.

Lake Tempe is a suitable site for examining it. The lake covers approximately 13,000 hectares across three regencies, with about seventy per cent of its surface lying within Wajo Regency, and it functions simultaneously as a freshwater fishery, a seasonal agricultural floodplain, a raw water reserve and a flood retention basin for a catchment spanning six regencies. Its water level fluctuates strongly between seasons, and this fluctuation is not an anomaly but the organising rhythm of local production: households fish when the water is high and cultivate the exposed margins when it recedes. Any intervention that alters the timing or amplitude of that fluctuation therefore alters the household economy directly, which distinguishes lake policy here from policy in systems where the water body and the livelihood system are only loosely coupled. Where an aquatic resource carries this weight of local production, the distribution of benefits and burdens generated by its governance becomes a question of justice rather than of efficiency alone (Bennett et al., 2021).

The ecological pressures on the lake are cumulative rather than singular. Sediment delivered during the rainy season progressively reduces depth and storage, which shortens the interval before flooding recurs and simultaneously narrows the habitat available to fish. Nutrient-rich runoff from fertiliser and pesticide use in surrounding cultivation, combined with domestic wastewater discharged

without treatment, sustains conditions favourable to dense floating vegetation that shades the water column and depresses dissolved oxygen. Agricultural sources of this kind are difficult to regulate because they arise from the routine decisions of many smallholders rather than from identifiable point discharges, and evidence on farmer behaviour indicates that adoption of lower-input practices depends heavily on peer norms and on whether alternatives are economically survivable (Tran-Nam & Tiet, 2022). Upstream land cover in Sulawesi is itself shaped by the reach and effectiveness of forest and land management institutions, whose performance varies markedly across administrative units (Chervier et al., 2025).

The social pressures are equally cumulative. Regulation of the lake margin restricts activities that households have practised for generations, and the legal status of that margin as land held under use rights rather than ownership is imperfectly understood by those who occupy it. Restrictions on fishing gear impose replacement costs on households with little liquidity, while decisions about opening and closing the barrage distribute water in ways that favour fishing in one season and cultivation in another, so that the same operational decision benefits one group and penalises another. Where such distributive effects are decided without a forum in which affected groups can be heard, community engagement tends to be reduced to notification, and the professionalisation of engagement has been shown to be a precondition for turning affected populations into contributors rather than objects of water management (Puzyreva et al., 2022). Distributive effects of this kind are moreover not evenly borne, since exposure and the capacity to absorb loss differ systematically across social groups within the same hazard-prone area (Fekete & Rufat, 2023).

Existing scholarship on Lake Tempe has advanced along two largely separate tracks. One track examines the biophysical condition of the lake and the technical adequacy of interventions, and a second examines governance arrangements, typically by mapping stakeholder configurations or evaluating the presence of

required actors. Work in the first track establishes what is happening to the water but does not explain why households comply or resist; work in the second establishes who is formally involved but stops short of tracing how institutional arrangements are converted into ecological and economic outcomes on the ground, a limitation also identified in stakeholder network analyses of environmental planning more broadly (Mitincu et al., 2023). A related shortfall concerns knowledge, since the information that water sector actors require in order to act is rarely the information that technical assessment supplies (Adams et al., 2022). Neither track has treated the lake as a single system in which ecological condition, household income, cultural rules and institutional capacity are mutually constitutive. This is the gap the present study addresses.

Accordingly, this article analyses the implementation of lake management policy at Lake Tempe through the social-ecological systems framework (Berkes & Folke, 1998), complemented by the classical account of implementation as a function of communication, resources, disposition and bureaucratic structure (Edwards, 1980), and organised around four dimensions — social ecology, community economy, culture and local wisdom, and social institutions. It asks how the outcomes recorded in each dimension condition the outcomes recorded in the others. The contribution is threefold. Empirically, it provides an integrated account of a super-priority lake programme at the point of delivery rather than at the point of design. Analytically, it demonstrates that ecological gains achieved through capital works are held in place, or eroded, by social arrangements that the same policy does not fund. Practically, it identifies where the sequencing of instruments would need to change for recovery to become self-sustaining. Table 1 summarises the profile of the lake and the management programme examined here.

Table 1. Profile of Lake Tempe and the management programme under study

Parameter	Description
Lake surface area	Approximately 13,000 ha spanning Wajo, Soppeng and Sidenreng Rappang regencies
Share within Wajo Regency	Approximately 70 per cent of the lake surface
Hydrological catchment	Six regencies: Maros, Bone, Soppeng, Wajo, Sidenreng Rappang and Enrekang
Principal legal basis	Wajo Regency Regulation No. 14 of 2016 on Lake Tempe Management
National status	Designated among the six super-priority critical lakes in 2020
National allocation, critical lakes	IDR 850.39 billion for fifteen critical lakes since 2016
Dredged area within Wajo	242 ha
Dredged volume	2.87 million m ³
Additional storage capacity	7.23 million m ³
Raw water beneficiaries	Projected increase from 23,000 to 30,000 people
Designated development functions	Food crop and freshwater fisheries production, raw water reserve and irrigation, water-based and cultural tourism

2. RESEARCH METHOD

This study applied a qualitative descriptive design to trace how lake management policy is delivered and experienced at Lake Tempe, and was conducted in three sub-districts of Wajo Regency — Tempe, Maniangpajo and Tanasitolo — selected because they border the lake directly and function as the principal points of access to it. Eleven informants were selected purposively on the basis of their formal responsibility for, or direct dependence on, the lake: officials of the Regency Public Works and Spatial Planning Office, the Environment Office, the Fisheries Office and the Agriculture Office, a village head from the lakeside area, and resident fishing and farming households. Data were generated through in-depth interviews covering the design, financing and field execution of the policy and its

perceived consequences; through participant observation of dredging and rehabilitation activity, shoreline conditions and everyday interaction among resource users; and through analysis of management plans, policy evaluation reports and the regulatory instruments governing the lake. Analysis proceeded through data reduction, in which material was coded to the four social–ecological dimensions; data display, in which coded material was arranged into comparative matrices to expose consistencies and divergences across informant categories and observation sites; and verification, in which interpretations were checked against documentary evidence and against observation to establish convergence. Findings reported below are presented as analytical statements supported by this triangulated evidence base.

3. RESULTS AND DISCUSSION

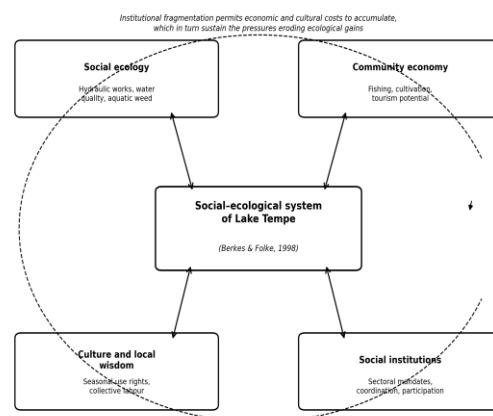


Figure 1. Conceptual framework linking the four social–ecological dimensions of lake management policy implementation at Lake Tempe. Source: elaborated by the authors, adapted from Berkes & Folke (1998).

3.1 Social Ecology

The hydraulic component of the policy has produced its intended effect where it has been applied. Dredging covering 242 hectares within Wajo removed some 2.87 million cubic metres of accumulated material and added roughly 7.23 million cubic metres of storage, sufficient in design terms to lift raw water provision from about twenty-three thousand to thirty thousand people. Normalisation of the feeder rivers has

attenuated flood peaks in the treated reaches by an order of thirty to forty per cent, a reduction visible in the extent of inundation of adjoining settlement and cultivation. These are real ecological outcomes: greater depth restores habitat volume for fish, and slower flood recession reduces the mechanical damage that repeated inundation inflicts on shoreline vegetation. The significant qualification is spatial. The works are concentrated at accessible points, so the improvement is a set of treated locations rather than a treated lake, and the untreated remainder continues to shallow at its prior rate.

This qualification matters because the process that created the deficit has not been interrupted. Sediment continues to enter the basin each rainy season from a catchment in which upland land cover has been progressively converted, and the rate of delivery is unaffected by works undertaken inside the lake. The result is a system in which storage is being added at one point and removed at another, so that the measurable gain from dredging begins to depreciate from the moment it is realised. The persistence of annual flooding despite normalisation is the clearest expression of this arithmetic: the intervention changed the hydraulic capacity of specific channels without changing the volume of water and sediment those channels are asked to carry, and rainfall variability has widened the range they must accommodate. Structural flood works of this kind are known to deliver protection unevenly across a floodplain population, so that residual exposure concentrates where infrastructure does not reach (Yuanita & Sagala, 2025), and evidence on community-level mitigation indicates that

engineered defences yield their fullest return only where household and neighbourhood measures are organised alongside them (Davlasheridze & Fan, 2025).

Water quality has followed a different and less favourable trajectory. Domestic wastewater from lakeside settlement enters the lake without treatment, and nutrient-bearing runoff from surrounding cultivation carries fertiliser and pesticide residues into the same receiving water. The combination sustains conditions in which floating vegetation regenerates faster than it is removed, and clearance campaigns therefore recover open water only until the next growth cycle. Dissolved oxygen depletion beneath dense mats and reduced light penetration together constrain fish recruitment, which links water quality directly to the productivity of the fishery and hence to household income. Rehabilitation activity has begun and is visible, but it operates at the scale of episodes rather than as a continuous management regime, and the absence of a system for harvesting and using cleared biomass means that removal has no economic engine behind it. The difficulty is compounded by the fact that internal loading from enriched sediment continues to release nutrients after external inputs are reduced, so water quality responds to intervention with a lag that discourages sustained investment (Ali et al., 2023), and by the absence of an agreed set of indicators against which restoration progress could be assessed and defended (Michael-Bitton et al., 2025). Table 2 sets out the correspondence between instruments applied and outcomes recorded.

Table 2. Policy instruments and recorded ecological outcomes at Lake Tempe

Policy instrument	Intended ecological function	Recorded outcome	Pressure that persists
Lake bed dredging (242 ha)	Restore depth and storage volume	Storage increased by 7.23 million m ³ at treated locations	Catchment sediment delivery continues; gains depreciate
River normalisation	Attenuate flood peaks	Flood reduction of about 30–40 per cent in treated reaches	Annual flooding persists; rainfall variability widens peaks
Environmental rehabilitation programme	Improve water quality	Programme initiated; localised recovery of open water	Untreated domestic and agricultural loads maintain enrichment

Fishing gear restriction	Reduce damage to habitat and stock	Reduced use of destructive gear where monitored	Uneven compliance; limited monitoring capacity
Aquatic weed clearance	Restore open water and light penetration	Episodic clearance with short-lived effect	Rapid regrowth; no sustained harvesting or utilisation system
Barrage operation	Regulate water level and discharge	Water level managed within operational limits	Operating decisions taken without a shared user forum

Read against the social–ecological systems framework (Berkes & Folke, 1998), these results describe a system in which the ecological subsystem has been treated as a technical object while the social processes that generate its condition have been left in place. The framework holds that ecosystems and the human systems that use them constitute a single interacting entity, so that intervention on one side without corresponding adjustment on the other produces gains that the untouched side steadily reverses; the evidence at Lake Tempe conforms closely to this expectation, since every ecological improvement recorded here is being consumed by a driver located in the surrounding social system rather than in the water body. Restoration that begins in the lake and stops at the shoreline is, on this reading, a maintenance expense rather than a recovery strategy, because it repairs an outcome while leaving its cause funded. Lake management at Tempe should therefore reallocate a defined share of the programme budget from in-lake works to catchment-level control of sediment and nutrient delivery, coupled to a permanent rather than episodic aquatic weed removal regime; comparable tropical lake experience demonstrates that recurrent weed invasion and water quality decline persist indefinitely where clearance is undertaken without simultaneous management of catchment loading and riparian land use (Henny et al., 2026).

3.2 Community Economy

The household economy around Lake Tempe is organised around the seasonal movement of water rather than around a single occupation. When the lake is high, income is generated by fishing; when it recedes, the exposed margin is cultivated, and many households move between the two within a single year. This alternation is not a diversification strategy adopted by choice

but the structure of production itself, and it means that household income is a direct function of two variables the policy now controls: the timing and amplitude of water level, and the legality of the techniques and locations used to exploit it. The economic consequences of the policy are therefore not incidental side effects of an environmental programme; they are the primary channel through which the policy is experienced. Governance of an aquatic economy of this kind therefore operates simultaneously on ecological condition and on the terms under which value is captured, and the two cannot be separated in evaluation (van Noort et al., 2025).

Restrictions on fishing gear illustrate the point. The ecological case for prohibiting certain gear is sound, and its introduction coincided with a reduction in visibly destructive practice. The economic consequence, however, fell entirely on the fishing household, which was required to replace a productive asset without transitional support. For households operating close to subsistence, the capital needed for compliant gear is not available from savings, and the immediate effect of the rule was therefore reduced effort and reduced catch rather than substituted effort at equivalent volume. Declining returns were reported alongside continued acceptance that the underlying objective was legitimate, which indicates a compliance problem generated by financing rather than by attitude, and which is precisely the situation that transitional support instruments exist to resolve. Studies of fishing communities undergoing induced technological or occupational transition report the same pattern, in which the willingness to shift practice is present but the capital and the intermediary support required to complete the shift are not (Cleaver et al., 2024).

The tighter control of floodplain land produced a parallel effect on the agricultural side. Households that had cultivated the recession margin found their access narrowed, and adjustment required either reduced planted area or relocation of activity, both of which lowered output. Water level regulation compounded the distributional problem: an operating decision that maintains a higher level supports fishing while shortening the cultivation window, and a decision to draw down does the reverse, so the same instrument allocates income between two groups that live in the same villages. Against these losses, the tourism function assigned to the lake in the policy design remains largely unconverted, since no organised local enterprise, product or visitor

management arrangement has been established through which environmental improvement could be translated into household revenue. Readiness of this kind is a measurable precondition rather than an automatic consequence of amenity improvement (Aslam et al., 2022), resident support for tourism development depends on whether benefits are perceived to reach the host population (Woosnam et al., 2024), and community enterprise models offer a route through which restoration and local income generation reinforce one another rather than compete (Price et al., 2025). Table 3 summarises the effects recorded across livelihood groups.

Table 3. Recorded economic effects of policy implementation by livelihood group

Livelihood group	Principal dependence on the lake	Recorded effect of the policy	Support required but not provided
Fishing households	Capture fishery during high water	Reduced catch and income following gear restriction	Compliant replacement gear; transitional income support
Floodplain cultivators	Recession agriculture on the exposed margin	Reduced planted area and output after access was tightened	Alternative plots; extension for adapted cropping
Mixed fishing–farming households	Seasonal alternation between both activities	Losses in both seasons; narrowed adjustment options	Sequenced support covering the full annual cycle
Prospective tourism actors	Landscape, cultural and open-water amenity	Improved amenity at treated sites not converted to revenue	Enterprise organisation, product development, visitor management
Downstream water users	Raw water and irrigation supply	Improved availability where storage was restored	Extension of storage gains beyond treated locations

Interpreted through the social–ecological systems framework (Berkes & Folke, 1998), this pattern shows the economic subsystem absorbing the full adjustment cost of an ecological intervention, which the framework identifies as the condition under which local support for conservation erodes and the intervention itself becomes unsustainable. The framework treats the community economy not as a beneficiary of ecosystem recovery but as one of its determinants, since households whose income depends on immediate extraction cannot finance restraint out of future benefits they may not receive; at Lake Tempe the absence of compensating instruments has consequently converted a shared environmental objective into

a private cost, and the resulting economic pressure sustains the very extraction the policy seeks to limit. Policy at Lake Tempe should therefore attach a funded livelihood component to every restrictive instrument, providing compliant gear, transitional income support and organised community enterprise around lake-based tourism before restrictions take effect rather than after; evaluative evidence on community-based ecotourism confirms that environmental protection generates durable local support only when communities capture a defined and visible share of the revenue that protection creates (Tien et al., 2024).

3.3 Culture and Local Wisdom

Access to Lake Tempe has historically been organised through a body of local practice that treats the lake as a shared resource subject to seasonal use rather than as divisible property. The exposed margin is worked by the household that customarily works it, the fishing calendar follows the movement of water rather than an administrative schedule, and collective labour has long been mobilised for tasks that benefit the shoreline as a whole. This body of practice constitutes a functioning management system in its own right: it allocates access without registry, coordinates timing without instruction, and encodes ecological knowledge about when the lake can be used and when it should be left alone. Its formal expression in the legal framework is the recognition that land within the lake area is held under rights of use rather than rights of ownership.

The reproduction of this system is now weakening, and the clearest symptom is interpretive. Occupation sustained across generations is increasingly understood by occupants as ownership, so that administrative action to reorder or clear the margin is experienced not as regulation of a use right but as expropriation of property. The resulting disputes are frequent and are directed both between households competing for the same margin and between households and the agencies enforcing the rule. The underlying difficulty is that the customary system supplied the practice but not the documentation, and once the practice is

challenged there is no shared record against which competing claims can be settled, which converts an ordinary administrative act into a contest over legitimacy.

Policy has not engaged this system as an asset. Socialisation activity has been conducted, and it has raised awareness among a section of the population, with waste disposal behaviour and participation in clean-up activity both improving where it has reached. The activity is nevertheless framed in the vocabulary of regulation rather than in the vocabulary of local practice, so that new rules are presented as external requirements rather than as extensions of obligations the community already recognises. The cultural functions assigned to the lake in the policy design, including cultural tourism, remain undeveloped, and the collective labour tradition that could have supplied a low-cost mechanism for continuous weed removal and shoreline maintenance has not been mobilised as part of the programme. Social capital of this type is a recognised asset in community-based development, functioning as the network through which collective effort is coordinated at low transaction cost (Vongvisitsin et al., 2024), and analyses of community-based ecotourism similarly find that locally embedded organisation, rather than external promotion, determines whether environmental assets are converted into community benefit (Hafezi et al., 2023). Table 4 sets out the alignment between local institutions and policy instruments.

Table 4. Alignment between local institutions and policy instruments

Local institution or practice	Function performed	Current status	Treatment within the policy
Customary seasonal use rights	Allocates access to the recession margin without registry	Increasingly interpreted as ownership; contested	Recognised in law as use rights but not documented at household level
Water-level norms shared among users	Coordinates fishing and cultivation across the season	Displaced by centralised barrage operation	Not incorporated into operating decisions
Collective labour tradition	Mobilises unpaid labour for shoreline tasks	Retained but unused by the programme	Not engaged as a delivery mechanism
Traditional gear and fishing calendar	Regulates effort in step with water level	Partly displaced by uniform gear rules	Superseded rather than adapted
Lake-based cultural practice and events	Sustains identity and potential visitor interest	Undeveloped	Designated as a development function but not operationalised

In the terms of the social–ecological systems framework (Berkes & Folke, 1998), what is being lost here is adaptive capacity rather than heritage. The framework treats accumulated local ecological knowledge and the customary rules that carry it as the memory of the system, the store of tested responses that allows a community to absorb disturbance without institutional collapse, and it holds that this memory degrades when formal regulation displaces rather than incorporates it. The evidence at Lake Tempe follows that trajectory precisely: the shift from a shared understanding of seasonal use to a contested assertion of individual ownership has removed the interpretive consensus that previously prevented allocation conflicts, and formal enforcement is now required to perform work that local rules once performed at no cost. Lake management should therefore document and formally recognise customary seasonal use rights within the regulatory framework, and route rehabilitation work through existing collective labour institutions rather than through contractors alone; comparative work on community-based resource management in Indonesia demonstrates that conservation objectives and local livelihood claims are reconciled most effectively where customary tenure is explicitly acknowledged in the governing arrangement rather than treated as an obstacle to it (Putraditama et al., 2021).

3.4 Social Institutions

Responsibility for Lake Tempe is distributed across a set of agencies whose mandates were designed for sectors rather than for a lake. The public works office holds the hydraulic works, the environment office holds water quality and rehabilitation, the fisheries office holds the stock and the gear rules, the agriculture office holds cultivation practice in the surrounding land, and the village government holds the interface with residents. The regency regulation of 2016 provides the legal foundation, and the lake itself sits within a catchment spanning six regencies, which places part of the causal chain beyond the jurisdiction of any single implementing authority.

The formal architecture is thus complete in the sense that every function has an owner, and incomplete in the sense that no owner holds the system. Longitudinal analysis of sectoral policy shows that such arrangements tend to drift towards disintegration rather than towards coordination unless an explicit cross-sectoral instrument is maintained (Fleckenstein, 2024).

The practical consequence is that instruments are delivered in parallel rather than in sequence. Dredging proceeds on an engineering timetable, rehabilitation on an environmental one, and gear regulation on a fisheries one, with the result that a household may face a new restriction before the programme that was meant to offset it has been designed. Capacity constraints reinforce the pattern: technical staffing for sediment and waste management is thin relative to the area to be covered, budget is allocated by sector rather than to the lake as an object of management, and monitoring after works are completed is limited, so the depreciation of gains described earlier is not systematically observed. Enforcement is correspondingly uneven, and rules that are announced but inconsistently applied lose authority among those expected to follow them. Weak and selective enforcement is a recognised failure point in Indonesian environmental regulation, where the gap between formal rule and applied practice erodes the legitimacy of the rule itself (Rohmy et al., 2024), and stakeholder assessments of public programme delivery consistently identify coordination and resource adequacy as the conditions on which success turns (Ngullie et al., 2021).

Participation is the weakest element of the institutional arrangement. Community involvement is largely confined to receiving information, and the decisions with the largest distributive consequences — principally the operation of the barrage — are taken without a forum in which fishing and cultivating households can present competing requirements and reach an accommodation. The absence of such a forum means that a technical decision arrives as an unexplained allocation, and

disagreement that could have been resolved in deliberation is instead expressed as friction between user groups and as distrust of the agencies. Community organisations capable of representing lakeside residents in a sustained way have not been strengthened, and no grievance channel exists through which contested land or water decisions can be tested. Evidence from

rural water programmes indicates that the functionality of publicly financed infrastructure over time is closely associated with the degree of substantive community contribution to its planning and upkeep (Al Djono & Daniel, 2022). Table 5 summarises actor mandates and observed performance gaps.

Table 5. Institutional actors, mandates and observed performance gaps

Actor	Formal mandate	Observed role in implementation	Performance gap
Public Works and Spatial Planning Office	Dredging, normalisation, barrage operation	Principal executing agency for capital works	Operating decisions taken without user consultation
Environment Office	Water quality and ecosystem rehabilitation	Episodic rehabilitation and awareness activity	No continuous monitoring or pollution control regime
Fisheries Office	Stock management and gear regulation	Introduced and enforced gear restrictions	Restrictions applied without transitional support
Agriculture Office	Cultivation practice in the surrounding area	Promotion of organic inputs and improved practice	Uptake limited; no link to lake water quality targets
Village government	Interface between residents and agencies	Communication and dispute handling at village level	No authority over decisions affecting residents
Lakeside community groups	Representation of resource users	Recipients of information	No forum, standing or grievance channel
Neighbouring regencies in the catchment	Land use and watershed management upstream	Not engaged in lake programme delivery	No cross-regency coordination instrument

The social–ecological systems framework (Berkes & Folke, 1998) places institutions at the centre of the explanation rather than at its margin, since it treats institutional arrangements as the layer through which ecological knowledge is converted into collective action and through which the costs and benefits of resource use are distributed among users. Where that layer is fragmented, the framework predicts exactly the configuration observed at Lake Tempe: technically competent interventions that fail to hold, because no institution is responsible for the interaction between them, and no forum exists in which the affected population can convert its knowledge and its objections into design changes. The fragmentation identified here is therefore not an administrative inconvenience but the mechanism that produces the ecological, economic and cultural results reported in the preceding sections.

Lake management at Tempe accordingly requires a single cross-sector and cross-regency coordinating body with a dedicated budget line and a standing user forum with formal standing in barrage operation and rehabilitation planning; evidence from collaborative ecosystem-based restoration confirms that durable outcomes depend on a permanent coordinating structure and sustained relationships among agencies and resource users rather than on the technical merit of individual interventions (Wondolleck & Yaffee, 2022).

4. Conclusion

Implementation of lake management policy at Lake Tempe has delivered asymmetric results across the four social–ecological dimensions examined. Hydraulic works restored storage and reduced flood peaks at the locations where they were applied, but continuing sediment delivery,

untreated domestic and agricultural discharge and unmanaged aquatic weed growth confine those gains to treated points and cause them to depreciate elsewhere. Economically, restrictions on gear and on floodplain access transferred the full adjustment cost to fishing and cultivating households, while the tourism function written into the policy design has not been converted into local revenue, so the policy currently subtracts income without adding it. Culturally, the shift from a shared understanding of seasonal use rights to a contested assertion of ownership has dismantled the interpretive consensus that previously allocated access without administrative cost, and the collective labour tradition that could have carried shoreline maintenance remains unused. Institutionally, mandates are distributed across sectoral agencies without a body responsible for the lake as a whole, monitoring after completion is limited, and the decisions with the largest distributive consequences are taken without a forum in which affected users have standing. These four results are not independent findings but a single causal sequence, in which institutional fragmentation permits economic and cultural costs to accumulate, and those costs in turn sustain the pressures that erode the ecological gains the

programme purchases. Durable recovery of Lake Tempe therefore depends less on the volume of material removed from the basin than on whether the surrounding social system is funded, recognised and coordinated to hold the improvement in place.

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Author Declaration

The authors declare that this manuscript is original work, has not been published previously, and is not under consideration for publication elsewhere. The authors declare no conflict of interest. All authors contributed to the conception, data collection, analysis, and writing of this manuscript and approved the final version for submission.

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