# NA-07 Ritual that governs ecology: the Bali water temples and the Tsembaga pig cycle

The permanent loss of industrial supply chains and the retreat of the centralized state present a fundamental challenge to human survival: the realignment of human governance with the biophysical realities of local ecosystems. Throughout the Holocene, human societies engineered complex adaptive systems to manage the extraction, distribution, and regeneration of natural resources without the computational apparatus or coercive monopoly of a modern state. This report examines the proposition that ritual hierarchies can serve as an ecological governance mechanism—a societal keystone function that regulates resource flows, calibrates human populations to carrying capacities, and mitigates tragedy-of-the-commons scenarios.
To determine which principles of self-governance hold across deep time, how they scale from the household to the bioregion, and how they succumb to capture by actors with dark-triad traits (narcissism, Machiavellianism, psychopathy), this analysis critically evaluates two foundational anthropological models of ritual-as-governance. The first is J. Stephen Lansing's study of the Balinese *subak* water temple network, a system that coordinated watershed-scale irrigation[1]. The second is Roy A. Rappaport's cybernetic analysis of the Tsembaga Maring pig cycle in New Guinea, a system that purportedly regulated land and warfare[3]. To ground these human systems in ecological theory, the report first assesses the biological metaphor of the keystone species and trophic cascades, focusing on the highly contested management of Yellowstone National Park, establishing a baseline for how centralized, single-variable governance models consistently fail to grasp complex system dynamics.

## The Ecological Metaphor: Governance as a Keystone Function

In 1969, zoologist Robert Paine introduced the concept of the "keystone species" based on his experimental removal of top predators (starfish) from a rocky intertidal food web in Mukkaw Bay, Washington[4]. Paine demonstrated that the removal of a single apex predator could trigger a trophic cascade, leading to the competitive exclusion of benthic species and a catastrophic collapse of biodiversity. This biological concept serves as a powerful metaphor for human ecological governance. When a governance mechanism correctly regulates the apex consumption patterns of a human population, it maintains the heterogeneity and productivity of the underlying ecosystem. When that governance is removed, degraded, or fundamentally misaligned, a socio-ecological trophic cascade occurs.

### The Yellowstone Wolf Controversy and the Illusion of Top-Down Control

The most prominent terrestrial application of Paine's keystone concept is the state-managed conservation model of Yellowstone National Park, specifically the reintroduction of gray wolves

(*Canis lupus*) in 1995. The standard narrative asserts that the eradication of wolves in the 1920s led to an overpopulation of elk (*Cervus canadensis*), which subsequently overbrowsed riparian vegetation such as aspen (*Populus tremuloides*), cottonwood, and willow (*Salix* spp.)[7]. This overbrowsing allegedly caused the loss of beaver populations, leading to stream channel incision and the degradation of aquatic habitats[9].

Following the reintroduction of wolves, researchers such as William Ripple and Robert Beschta documented what they claimed was one of the strongest trophic cascades ever recorded[11]. They argued that wolves initiated a "behaviorally mediated trophic cascade" (BMTC): the mere presence of wolves created a "landscape of fear," forcing elk to abandon vulnerable riparian zones, which allowed willows and aspens to recruit into tall, mature trees[7].

Rigorous empirical scrutiny has since dismantled the romanticized simplicity of this top-down control model, revealing it as a cautionary tale of misattributing complex ecological shifts to single-variable governance interventions. While the Northern Yellowstone elk herd dropped precipitously from a peak of 19,045 in January 1994 to 3,915 by 2013, wolves were only one factor among many[14]. The decline was heavily driven by human hunting—with 3,320 elk harvested in the winter of 1996–1997 alone—as well as severe winter weather, and expanding populations of grizzly bears and cougars that heavily preyed on elk calves[14]. Furthermore, wolf numbers on the Northern Range peaked at approximately 174 individuals across 13 to 14 packs in 2003, before declining to roughly 100 wolves, indicating that predator density itself was highly volatile[17].

The methodologies underpinning the strongest claims of the trophic cascade have also been exposed as severely flawed. Reassessments of Ripple et al.'s findings revealed that claims of a 1,500% increase in willow crown volume were mathematical artifacts[12]. The original researchers utilized a formula to calculate plant volume that relied heavily on plant height, and then ran a regression showing that height predicted volume, yielding an artificially high correlation ( $R^2 = 0.92$ ) that was a predictable consequence of how the data were generated[12].

When Matthew Kauffman et al. (2010) executed a landscape-level test of the BMTC hypothesis, they found no evidence that aspen were recovering in high-predation-risk areas[7]. The data demonstrated that irrespective of wolf presence, elk continued to browse heavily, and aspen recruitment was essentially non-existent outside of localized, physically protected anomalies[11].

The hydrology of the ecosystem presented a deeper, structural constraint: historical stream channel incision, caused by the localized extinction of beavers, had permanently lowered water tables by 1 to 2 meters[9]. Consequently, simply altering elk browsing behavior was biophysically insufficient to restore willow heights; the foundational physical infrastructure of the water table had to be restored first[9].

## Separating the Three Realities: State Conservation Governance

**What the managers said it did:** State and federal wildlife agencies posited that introducing a single apex predator would rebalance the ecosystem, framing the wolf as a silver bullet that would naturally restore the historical equilibrium of the park's vegetation and hydrology without requiring continuous, expensive human culling of ungulates[20].

**What the record shows it did:** The reintroduction added a highly effective predator to the landscape, contributing to a massive reduction in the elk population (a 60% decrease from 1994 to 2018)[16]. However, vegetation recovery remained highly patchy and was primarily correlated with areas that maintained high water tables or physical barriers to browsing, rather than mapping to a generalized "landscape of fear"[9].
**What modern scholarship infers:** Modern ecologists infer that ecosystems exist in alternative stable states. Removing a keystone species can push a system across a threshold (e.g., from beaver-meadow to incised-stream), but reintroducing that species decades later does not automatically reverse the state change if the underlying physical parameters (like hydrology) have fundamentally shifted[9]. The strongest case against the state-conservation model, led by critics like Kauffman and MacNulty, highlights that human governance models consistently fall victim to the romance of the primitive, assuming that restoring a single "natural" element will magically repair complex, multi-causal degradation[7].

## Scale Ledger: Centralized Ecological Management (The Yellowstone Model)

| Scale Rung | Operation & Viability | Reasons for Success, Failure, or Absence |
|---|---|---|
| **Household to Village (4 to 500)** | Never tried | Micro-communities lack the geographic territory and capital required to manage apex predators or enforce massive hunting quotas across ecosystems. |
| **Parish to Town (1,500 to 50,000)** | Failed | Local municipalities adjacent to the park routinely clash with centralized mandates, bearing the economic costs of livestock depredation without holding governance authority over the predators. |
| **Region/Bioregion (0.5 to 5 million)** | **Worked (Superficially)** | The Greater Yellowstone Ecosystem operates at this scale, managed by federal bureaucracies. It succeeds in maintaining a perimeter but fails at precise, |

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| | | adaptive, localized ecological tuning due to rigid policy mandates. |
| **Nation/Planet (50M to 8B)** | Failed | National legislation (e.g., the Endangered Species Act) applies binary, broad-brush protections that cannot adapt to the specific biophysical realities of hyper-local watersheds, leading to systemic friction. |

### Capture Test: Centralized Ecological Management

The centralized conservation model is highly susceptible to capture by dark-triad operators navigating bureaucratic structures. A Machiavellian actor within a state wildlife agency can capture this system by manipulating public sentiment and academic funding, prioritizing high-visibility, charismatic megafauna (wolves) to build personal political capital and secure institutional budgets, while ignoring the complex, unglamorous infrastructural work (e.g., restoring hydrology and beaver habitats)[9]. The historical record demonstrates this through the suppression of dissenting ecological data that contradicts the popular, easily fundable "trophic cascade" narrative[12]. The primary resistance feature of this system is the slow, grinding nature of the peer-review process and independent academic research, which eventually exposes statistical artifacts, though often decades after policy has been cemented.

## The Tsembaga Maring: Ritual Cybernetics and the Illusion of Homeostasis

In 1968, anthropologist Roy A. Rappaport published *Pigs for the Ancestors*, a study of the Tsembaga Maring, a group of approximately 200 horticulturalists living in the Bismarck Mountains of New Guinea[3]. Based on fieldwork conducted between 1962 and 1963, Rappaport applied cybernetics and systems theory to argue that the Tsembaga's ritual cycle—specifically the *kaiko* pig festival—functioned as a homeostatic thermostat regulating the biophysical parameters of their environment[3].

The Tsembaga relied on swidden (slash-and-burn) agriculture, primarily cultivating sweet potatoes and taro, while raising domestic pigs[23]. According to Rappaport's cybernetic model, the ritual cycle operated through a strict feedback loop. Following a period of warfare, the Tsembaga would plant a *rumbim* shrub, initiating a ritual truce with neighboring groups[25]. During this truce, the group focused on cultivating gardens and expanding their pig herds. Over a period of 10 to 20 years, the pig population would grow exponentially[3]. Eventually, the caloric

burden of feeding the pigs outstripped human carrying capacity. Pigs increasingly invaded and destroyed human gardens, and the labor burden, which fell almost exclusively on women who cultivated the sweet potatoes, became intolerable[3].

This biophysical stress triggered the uprooting of the *rumbim* and the initiation of the year-long *kaiko* festival[30]. The Tsembaga slaughtered the vast majority of their adult pigs, consuming massive quantities of pork and distributing the surplus to political allies[31]. The conclusion of the *kaiko* signaled the end of the truce. Rappaport argued that the sudden influx of high-quality protein prepared the warriors for combat, alleviating a systemic nitrogen imbalance right when physical exertion was most required[3]. Warfare ensued, adjusting the human population to the carrying capacity of the land via casualties and territorial displacement, until a new *rumbim* was planted, restarting the cycle[3].

## Separating the Three Realities: The Kaiko Cycle

**What the Tsembaga said it did:** The Maring stated that the ritual cycle was a sacred obligation to placate the spirits of ancestors killed in warfare, specifically the *kibe* (immortal spirits)[33]. By sacrificing the pigs, they honored their debt to the ancestors, ensured the continued fertility of the land, and secured supernatural support and martial efficacy for upcoming battles[3].

**What the record shows it did:** The historical and ethnographic record confirms that the Maring engaged in a cyclical pattern of peace, pig accumulation, mass slaughter, feasting with allies, and subsequent inter-tribal warfare[3]. The cycle reliably kept pig populations from permanently destroying the local horticulture by enforcing a hard reset on livestock numbers. Furthermore, the public nature of the *kaiko* dance served as a verifiable census of military strength; the number of men from ally groups who came to dance provided a direct, unforgeable metric of anticipated support in future fighting[32].

**What modern scholarship infers:** Rappaport inferred a mathematically elegant cybernetic system of ecological homeostasis, suggesting a continuous, self-regulating loop without central authority[3]. However, the strongest case against this functionalist model emerged from both nutritional and political anthropologists. Jonathan Friedman (1974), in his essay "Marxism, Structuralism, and Vulgar Materialism," dismantled the nutritional arguments, noting that human protein requirements did not align with a 10-to-20-year cycle of massive overconsumption[3]. Sweet potatoes, if consumed in high enough quantities, provided an adequate baseline of protein for survival; the *kaiko* was a feast of staggering, maladaptive excess, not a calculated nutritional baseline[3].

More devastatingly, the political critique spearheaded by Marilyn Strathern and Maurice Godelier (1991) highlighted the role of "Big Men" in Melanesian ethnography[38]. Big Men accumulate power not through hereditary rank, but through the aggressive manipulation of wealth (pigs) and debt[38]. Modern scholarship infers that the *kaiko* was not a mindless ecological thermostat; it was a highly contested political arena. Ambitious men intentionally forced the acceleration of pig production, ruthlessly exploiting the agricultural labor of women, to orchestrate massive feasts that humiliated rivals, demonstrated personal efficacy, and secured military alliances[38]. The ecological reset was merely a byproduct of political prestige-seeking.

## Scale Ledger: The Tsembaga Pig Cycle

| Scale Rung | Operation & Viability | Reasons for Success, Failure, or Absence |
|---|---|---|
| **Household (4 to 10)** | Failed | Individual households could not independently defend territory, absorb the localized volatility of pig mortality, or host sufficient allies to deter aggression. |
| **Hamlet/Band (30 to 50)** | Sub-optimal | Too small to host a viable *kaiko* or project the necessary military force to maintain territorial boundaries against larger neighboring coalitions. |
| **Village (150 to 500)** | **Worked (Optimal)** | The Tsembaga (approx. 200 people) successfully used the cycle to manage land, labor, and diplomacy. The scale allowed face-to-face detection of free-riders during ritual divinations before battles[22]. |
| **Parish/District (1,500 to 5,000)** | Failed | The requirement for direct, interpersonal validation of alliances via dance and pork distribution degraded at larger scales. Kinship-based debt obligations cannot sustain logistics beyond this limit without a formal state apparatus. |
| **Town to Planet (15,000 to 8B)** | Never tried | The system fundamentally relied on localized, low-density swidden |

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| | | agriculture and vast tracts of uncultivated forest to absorb territorial shifts and buffer warfare[23]. |

### Capture Test: The Kaiko Cycle

The Tsembaga system is highly vulnerable to capture by individuals with dark-triad traits, specifically Machiavellianism and narcissism. A sociopathic operator steps into the role of a "Big Man" by aggressively manipulating the debt obligations of lesser men and orchestrating marriages to control female labor (essential for sweet potato cultivation and pig rearing)[29]. By aggressively pushing for the initiation of the *kaiko*, this operator converts the communal ecological stress of the pig population into personal political capital, forcing the community into a war-footing under their exclusive leadership[38]. The historical record of Melanesian Big Men demonstrates this exact pattern of calculated disequilibrium and unequal exchange[38].

However, the system possesses a profound, built-in resistance feature against permanent capture: power cannot be stored. Pigs die, and pork rots. Once the *kaiko* concludes and the pigs are slaughtered and eaten, the Big Man's material wealth is entirely liquidated[38]. Without a state apparatus, fiat currency, or a standing professional army, the ambitious operator is forced back to a material baseline and must rebuild his power from zero in the next decade-long cycle, preventing the establishment of permanent, hereditary autocracies.

## The Balinese Subak: Complex Adaptation and the Hydraulic State

While the Tsembaga model failed to scale beyond the village, the Balinese *subak* scaled to manage entire watersheds across a volcanic island supporting millions of people. Anthropologist J. Stephen Lansing's decades of research into the *subak* (water temple) system revealed how religious ritual governed the precise engineering of water flows and pest control in terraced wet-rice agriculture (*sawah*)[1].

Bali's topography consists of deep volcanic ravines, requiring farmers to construct complex weirs (*empelan*), tunnels (*aungan*), and canals (*telabah*) to deliver irrigation water to their fields[2]. The *subak* is a socio-religious association of farmers who share water from a single source[2]. Water division is physically instantiated by proportional dividers made of coconut logs, called *tektek*, which divide water into precise fractions based on the labor and land contributions of the members[44]. Lansing's field measurements demonstrated an extraordinary $r = 0.95$ correlation between the physical *tektek* allocations and the actual volumetric flow of water in liters per second[44].

The system operates strictly on the philosophy of *Tri Hita Karana*—the harmonious balance between the human world (*Pawongan*), the natural environment (*Palemahan*), and the divine (*Parahyangan*)[2]. The ecological genius of the *subak* lies in its management of a fundamental biophysical trade-off:

1. **Pest Control (Requires Synchronization):** Rice pests, such as the brown planthopper and rodents, proliferate exponentially if there is a continuous food supply. By synchronizing the planting, harvesting, and subsequent fallowing (flooding or burning) of contiguous rice fields over large areas, the *subak* starves pests by breaking their life cycles[1].
2. **Water Shortage (Requires Staggering):** If every farmer in a watershed plants simultaneously, the aggregate demand exceeds the river's base flow, and crops die of severe water stress[48].

Through an agent-based model (ABM) developed with James N. Kremer in 1993, Lansing demonstrated how the ritual calendar solves this optimization problem[41]. The ABM mapped 172 subaks and 12 dams along the Oos and Petanu rivers, modeling 49 distinct cropping plans over 12-month periods, factoring in pest diffusion rates and rainfall variability[42]. The simulation revealed that if coordination occurs only at the micro-level of individual subaks, pests destroy the harvest[42]. Conversely, if coordination occurs across the entire watershed simultaneously, water stress destroys the harvest. Optimal yield is achieved through a nested hierarchy of water temples[42]. Subaks coordinate their schedules via rituals at intermediate temples, creating an emergent mosaic of staggered planting blocks large enough to disrupt pest life-cycles, but small enough to avoid exhausting river flows[48].

The necessity of this system was catastrophically proven in the 1970s during the "Green Revolution." The Indonesian government, backed by foreign agronomists, mandated that Balinese farmers plant high-yielding hybrid rice varieties continuously, supported by chemical fertilizers and pesticides[1]. The state viewed the temple calendars (the *tika*) as irrelevant religious superstition[1]. The result was an ecological collapse. Continuous cropping provided a perpetual food source for pests, leading to devastating outbreaks of the brown planthopper. Simultaneously, the abandonment of coordinated schedules led to chaotic water shortages[1]. The system only recovered when the government ceded scheduling authority back to the water temples[1].

## Separating the Three Realities: The Subak System

**What the Balinese said it did:** The farmers believe irrigation water is a direct, sacred gift from Dewi Danu, the Goddess of the Crater Lake[2]. The *subak* must perform rituals and offer taxes (*soewinih*) to the nested hierarchy of temples to ensure the continued blessing, fertility, and flow of holy water[44]. Failure to do so invites divine retribution in the form of pests and drought.

**What the record shows it did:** The system successfully sustained high-yield, complex agriculture on steep volcanic slopes for over a millennium without degrading soil fertility[1]. It managed water distribution with mathematical precision, preventing upstream farmers from monopolizing flows and ensuring downstream survival through strict adherence to customary law (*awig-awig*)[2].

**What modern scholarship infers:** Lansing inferred that the *subak* is an emergent, self-organizing complex adaptive system[1]. The ritual nodes function as a distributed computing network, solving a highly complex optimization equation for water and pests entirely from the bottom up, without any centralized, coercive state control[41].

However, the strongest case against this pure bottom-up model comes from historian Henk Schulte Nordholt (1996) in *The Spell of Power*[50]. Schulte Nordholt argued that Lansing severely underestimated the role of the Balinese state, particularly the Mengwi dynasty (1650-1940)[51]. The royal courts actively managed large-scale irrigation through an official known as the *Sedahan Agung*. According to historical records like the *Kidung Nderet* manuscript, the *Sedahan Agung* was not merely a ritual coordinator, but a royal tax collector who gathered the *soewinih* (water tax) to fund the state apparatus and royal temples[50]. While small upstream dams could self-organize, Schulte Nordholt argued that the massive downstream infrastructure required dynastic capital, corvée labor, and the coercive threat of state violence[50]. Thus, the "perfect order" of the water temples was deeply entangled in the extraction of a hydraulic state.

## Scale Ledger: The Balinese Subak

| Scale Rung | Operation & Viability | Reasons for Success, Failure, or Absence |
|---|---|---|
| **Household (4 to 10)** | Subsumed | Individual households operated fields but held no independent water rights; compliance with the *awig-awig* (customary law) was absolute[2]. |
| **Hamlet (*Tempek*) (30 to 50)** | **Worked** | Natural divisions of fields (e.g., bounded by creeks) led by a *Kelian* (group head), managing local tertiary canals effectively[46]. |
| **Village (*Subak*) (150 to 500)** | **Worked (Optimal)** | The fundamental autonomous unit, headed by a *Pekaseh*. Managed one weir and primary canal, bound by strong socio-religious sanctions[43]. |
| **Parish (*Subak Gede*) (1,500 to 5k)** | **Worked** | A federation of subaks coordinating a mid-level watershed and regional water temple. Perfectly optimized the pest-to-water ratio[43]. |

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| **Town/Watershed (15k to 50k)** | **Worked (with State aid)** | Overseen by the *Sedahan Agung*. While Lansing claimed this was purely ritual, history shows royal taxation and coercion were required to maintain infrastructure at this scale[43]. |
| **Region (Lake Batur) (1M+)** | **Worked (Ritually)** | The Supreme Water Temple (Pura Ulun Danu Batur) unified 250+ subaks spiritually, establishing cosmological legitimacy, though operational control remained decentralized[2]. |
| **Nation to Planet (50M to 8B)** | Failed | The system relies entirely on gravity-fed watersheds and continuous topological gradients. It cannot scale across non-contiguous zones or govern non-agricultural extraction. |

## Capture Test: The Subak System

The *subak* system exhibits a moderate to high vulnerability to capture at its upper administrative levels. The structure relies on the *Pekaseh* (subak head) and the *Sedahan Agung* (regional head)[43]. A narcissistic or Machiavellian ruler captures the *Sedahan Agung* position to convert water allocation into an extortion mechanism, threatening to cut off water flows or deny ritual sanctification unless exorbitant taxes are paid. The historical record confirms this capture: Balinese Kings (such as the Mengwi) historically captured the temple networks to extract the *soewinih* tax and mobilize corvée labor for royal wars[50]. Subsequently, the Dutch colonial administration (post-1908) formalized the *Sedahan Agung* as salaried colonial bureaucrats to legitimize taxation and resource control[50]. Most recently, following the 2012 UNESCO designation of the Jatiluwih terraces as a World Heritage site, the system has experienced modern capture by the global tourism industry. Dark-triad developers funnel profits to external investors, while local farmers endure the costs of preserving the "cultural landscape" under restrictive heritage regulations[53].

Despite these vulnerabilities, the system possesses unique resistance features dictated by physics and theology. The physics of gravity-fed water flow prevents total top-down autocracy. Downstream kings relied absolutely on upstream farmers to release water; if kings over-taxed or utilized excessive coercion, upstream farmers could simply ignore them, divert the water, or

destroy the fragile tunnels[44]. Furthermore, the *Tri Hita Karana* cosmology is deeply internalized by the populace; egregious violations of fairness trigger massive social excommunication, rendering a captured subak sociologically inoperable.

# Implementability after the Fall

For survivors attempting to reconstitute localized governance after the total collapse of industrial supply chains and digital grids, the ritual-ecological mechanisms analyzed above offer critical blueprints for managing carrying capacity and resource allocation.

**Minimum Viable Version:**

- **Household (4 to 10 people):** Implements the absolute integration of waste and caloric production. Analogous to the Tsembaga women raising pigs on sweet potato waste, the household relies on a cyclical nutrient loop, strictly capping livestock based on a fixed caloric ceiling, completely divorced from concepts of perpetual growth or market demand.
- **Village (300 people):** Implements a physical constraint analog of the Balinese *tektek* (proportional divider). Water, grain stores, or labor pools are divided by fixed, observable physical geometry, rendering the allocation immune to rhetorical manipulation by charismatic leaders. A cyclical ritual calendar is established to coordinate planting and harvesting, enforcing a hard, synchronous fallow period to break pest cycles without chemical pesticides.
- **District (3,000 people):** Implements the *Subak Gede* model. Representatives of ten constituent villages meet at a central, ritually sanctified location. They do not share a sovereign ruler; they share a cosmological calendar and a physical watershed boundary.

**What it needs to start:**

1. **A Shared Physical Constraint:** A gravity-fed water system, a limited forest perimeter, or a single keystone resource that forces interdependence.
2. **A Shared Calendar:** Without the internet or a global clock, time synchronization is paramount. A lunar-solar calendar (like the Balinese *tika*) tied to physical planetary movements must be adopted to sync agricultural actions across disparate groups.
3. **Physical Ledgers & Geometry:** While basic literacy is helpful for recording customary law (like the *awig-awig*), proportional distribution must rely on observable physical geometry (e.g., identically sized weir cuts) that any farmer can verify visually, eliminating the need for complex, easily corrupted accounting ledgers.
4. **A Sacred Meeting Place:** A physical location at the apex of the resource gradient (e.g., the spring source or highest peak) dedicated to an unquestionable cosmological postulate, guaranteeing safe passage and inviolable rules for inter-group negotiations.

**The First Failure to Expect:** The immediate, predictable failure will be the emergence of a "Big Man" (a dark-triad operator) who utilizes a temporary, localized resource surplus (e.g., a bumper crop or scavenged industrial cache) to host a feast or provide defense, plunging neighbors into a cycle of unpayable social debt. This operator will attempt to decouple the ritual calendar from ecological realities to maximize their own short-term political prestige, triggering a rapid biophysical crash.

# Principles

1. **The Principle of Nested Synchronization:** Optimal resource extraction occurs when local units maintain absolute autonomy over daily operations, but are strictly synchronized by a regional calendar to mitigate systemic externalities (e.g., pest proliferation).
2. **The Principle of the Physical Ledger:** Trust in distribution systems scales only if the allocation mechanism is physically observable and geometrically verifiable by the lowest-ranking participant, precluding bureaucratic obfuscation.
3. **The Principle of Institutional Vulnerability:** Any governance structure capable of commanding regional ecological logistics will inevitably be targeted and captured by rent-seeking state actors or commercial factions unless physically constrained by the topography of the resource itself.
4. **The Principle of Ritual Inviolability:** To survive generational drift, the rules of ecological limits cannot be presented as mere economic policy; they must be encoded as ultimate sacred postulates, rendering violation not just illegal, but cosmologically dangerous.
5. **The Principle of Trophic Illusion:** The belief that complex ecosystems can be engineered into a desired state via a single top-down intervention (whether introducing apex predators or imposing a Green Revolution schedule) inevitably triggers catastrophic, unforeseen socio-ecological cascades.

## Summary of Robust Findings

The removal of a keystone governance function predictably triggers socio-ecological trophic cascades, as demonstrated by the Green Revolution's disastrous disruption of the Balinese *subak*. Conversely, claims of pure top-down ecological control—such as wolves restoring Yellowstone aspen via a behaviorally mediated "landscape of fear"—are frequently overstated mathematical artifacts that mask multi-causal environmental variables and ignore fundamental hydrological shifts. At the tribal scale, the Tsembaga *kaiko* cycle effectively prevented permanent agricultural collapse but relied on violent inter-group warfare as the ultimate homeostatic reset, leaving it vulnerable to the prestige-seeking machinations of Big Men. At the regional scale, the Balinese *subak* optimizes the trade-off between pest control (requiring coordinated fallowing) and water scarcity (requiring staggered planting), proving that watershed-scale governance scales successfully to millions by utilizing nested, federated temple hierarchies. Water distribution is successfully enforced through physically verifiable geometry (the *tektek* proportional dividers), though historical evidence proves these temples were heavily influenced by royal dynasties extracting the *soewinih* water tax. Ultimately, replacing adapted, ritually synchronized ecology with centralized, continuous-yield mandates leads to catastrophic systemic fragility.

## Contested or Open Questions

- **Self-Organization vs. State Coercion:** To what extent were the Balinese water temples genuinely self-organizing complex adaptive systems (as Lansing argues), versus instruments of royal hydraulic statecraft and corvée labor extraction (as Schulte Nordholt argues)?
- **Ecology vs. Political Prestige:** Does the Tsembaga *kaiko* ritual actually fulfill systemic human nutritional requirements by providing a protein buffer for warfare, or is the ecological outcome merely an accidental byproduct of sociopathic political

prestige-seeking by Big Men manipulating debt?

- **Predation vs. Hydrology:** Can a behaviorally mediated trophic cascade (BMTC) truly regenerate degraded landscapes through fear alone, or is physical landscape alteration (e.g., restoring incised stream water tables via beaver dams) an absolute biophysical prerequisite for vegetation recovery?

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