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COSMIC AND ECOLOGICAL INTEGRATION IN STRENGTHENING THE SOCIO-ECOLOGICAL RESILIENCE OF AQUATIC COMMUNITIES IN ZAMRUD LAKE, INDONESIA

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ABSTRACT

Aquatic communities living along water bodies not only coexist with ecosystems but also dynamically shape complex socio-ecological interactions. This study explores the role of a cosmic-environmental orientation in building aquatic community resilience in Lake Zamrud, Indonesia, through the integration of ecological-spiritual experiences, synomorphic fit, and socio-cultural transformation in the modernization era. The method used was mixed methods, with a survey of 120 households, in-depth interviews with 15 key informants, and participant observation. The results showed that a cosmic-environmental orientation increased compliance

with conservation practices (85% fish spawning ban, 65% environmentally friendly fishing methods), participation in decision-making (80–95%), and a sense of security (human security, 88%). The “lost-found” folklore serves as a mechanism for socio-ecological regulation, strengthening harmony between society, cultural values, and the ecosystem (synomorphic fit, score 0.78). Socio-cultural transformation integrated with modernization improves economic well-being (household income increases by approximately 200%) and community adaptive capacity. This research confirms that cosmic-environmental values support socio-ecological resilience, social cohesion, collective participation, and adaptive and inclusive sustainable development.

KEYWORDS: Cosmic-Environmental Orientation, Aquatic Community Resilience, Synomorphic Fit, Ecological-Spiritual Experience, Sustainable Development.

1. INTRODUCTION

Human communities living along water bodies, including rivers, lakes, estuaries, and tributary networks, represent a complex and mutually adaptable socio-ecological system, where human dynamics and the aquatic environment are shaped through long-term co-evolutionary processes. Developments in socio-hydrology studies indicate that the reciprocal relationship between human behavior, hydrological regimes, and ecosystem change is a key determinant of the resilience capacity of water systems and the communities that depend on them (Agit and Muharram 2024; Fischer et al. 2021; Herrera-franco et al. 2021; Prakash, George, and Barua 2025; Sheikahmad, Rostami, and Azadi 2025). Research in hydrology and freshwater ecology indicates that hydrological variability is a fundamental driver in the formation of habitat structure, ecological web stability, and ecosystem function in river and lake networks (Jack et al. 2021). In line with the development of resilience theory, contemporary understanding views resilience not only as the ability to return to initial conditions, but as the system's capacity to adapt, learn, and transform itself under increasing socio-ecological pressures (Amorim-maia and Olazabal 2025).

In the context of traditional aquatic communities, the relationship between humans and water is not only material and ecological, but also shaped through ecological experiences, relational values, and spiritual dimensions developed within cultural practices and local wisdom. The literature on relational values shows that coastal communities of rivers and lakes often interpret water as an ecological entity that also possesses moral, identity, and spiritual values, resulting in management mechanisms based on local norms such as seasonal fishing bans, flow rituals, and customary conservation zones (A Fernald et al. 2015; Alexander Fernald et al. 2012; Gould 2025). This relationship can be understood within a systems theory framework as a form of synomorphic fit, namely, a structural compatibility between humans and the environment that emerges through mutual adjustments to maintain socio-ecological sustainability. Research on socio-ecological fit in water governance shows that the alignment between ecological dynamics and social rules is a crucial factor for the sustainability of aquatic systems (Mou et al. 2021), supporting the relevance of the synomorphic fit approach in understanding aquatic communities.

However, the acceleration of modernization and the penetration of digital technology, as described in the Society 5.0 framework, presents new challenges

for water-based communities. While digital sensory and monitoring technologies have the potential to improve water management efficiency, this transformation often shifts the ecological-spiritual practices and community values that have traditionally been the foundation of local wisdom-based water management (Falkenmark, M., A. Berntell, A. Jägerskog, J. Lundqvist 2007; Wilson 2024). Recent socio-hydrology literature has criticized technocentric approaches for neglecting the ecological-spiritual dimension of experience, even though this element is a crucial component in shaping community adaptive capacity (Mcglynn et al. 2023; Vollmer et al. 2018). Thus, there is a significant research gap in understanding how the interaction of culture, spirituality, and technology shapes the resilience of aquatic communities in the era of digital transformation. A study (Kapinga et al. 2019) provides an empirical basis for how the loss of traditional cosmological-based ecological knowledge due to modernization leads to a decline in community adaptive capacity and ecological degradation. (Schulze et al. 2015) strengthens the ecological dimension of the study by demonstrating that biodiversity contributes significantly to ecosystem stability and productivity.

Meanwhile, (Trombetta 2009) expands the theoretical dimension by explaining how environmental issues are transforming into non-traditional security frameworks. This approach recognizes that environmental management is not only technical but also social, political, and value-based. Overall, these three papers complement each other: Kapinga et al. explaining the socio-ecological dynamics and the loss of cosmic instruments, Liang et al. provide an ecological scientific basis that underscores the urgency of conservation, and Trombetta provides a conceptual framework for positioning cosmic integration as part of an ecological security strategy. This combination confirms that the integration of local cosmology and ecological science is not a mere cultural nostalgia, but a relevant, evidence-based adaptation strategy compatible with the resilience agenda of the Emerald Lake aquatic ecosystem and community.

Based on these gaps, this study attempts to present a comprehensive study of the resilience of aquatic communities in the Emerald Lake environment through three integrated dimensions: (i) the ecological and spiritual experiences of communities in the aquatic environment; (ii) human-environment relations within the synomorphic fit framework as a structural adjustment process in the socio-ecological system; and (iii) the dynamics of the

socio-cultural transformation of aquatic communities in the face of the pressures of modernization and digitalization. This multidimensional approach is expected to contribute to the development of more inclusive theories and practices of aquatic management, by emphasizing that the sustainability and resilience of aquatic communities are not only determined by technical and ecological factors, but also by cultural experiences, spiritual values, and the community's ability to transform socially in the landscape of global change.

2. LITERATURE REVIEW

Socio-hydrology has developed as an approach that studies the co-evolution of humans and water systems through social-hydrological feedback mechanisms (Herrera-franco *et al.* 2021). These studies demonstrate that human behavior, risk perception, and traditional management practices influence hydrological dynamics, while hydrological changes also shape social patterns and community adaptation (Fischer *et al.* 2021; Prakash, George, and Barua 2025). In the context of general aquatic ecosystems, hydrological variability has been shown to determine habitat availability, community structure, and ecological stability in rivers and lakes (Cheng *et al.* 2020; Hoelting *et al.* 2024). The social-ecological systems (SES) framework reinforces the understanding that human-water relationships must be viewed as integrated systems with processes of adaptation, learning, and transformation within them (Viana *et al.* 2022).

The resilience paradigm has evolved from the "return to baseline" model to the concept of resilience as a system's ability to respond, adapt, and transform in the face of ecological and social disturbances (Amorim-maia and Olazabal 2025). In the context of aquatic communities, resilience is determined not only by ecological factors but also by social, economic, and cultural capacities to manage the dynamics of the aquatic environment (Ricardo, Eduardo, and Alfonso 2024). Several studies emphasize that the highest resilience occurs when there is a fit between social structures (rules, norms, local knowledge) and ecological dynamics, a concept referred to in the literature as social-ecological fit (Schernewski, Neumann, and Buř 2024).

In many river- and lake-based communities, the human-water relationship is not only material but also spiritual and symbolic. The concept of relational values demonstrates that communities interpret water as a moral and cultural entity that shapes local identities, rituals, and management practices (Gould 2025). Traditional rules such as seasonal fishing bans,

water rituals, and sacred zones are forms of culture-based governance that are effective in maintaining ecosystem resilience. This perspective aligns with the concept of synomorphic fit, namely the reciprocal structural adjustment between humans and the environment to create socio-ecological sustainability.

Digital transformation within the Society 5.0 framework presents both opportunities and risks for aquatic communities. Sensor technology, real-time monitoring, and hydrological models can improve the effectiveness of water management and disaster mitigation. However, the literature critiques that modernization has the potential to shift the ecological-spiritual practices that underpin local community resilience (Rohayati 2024). (Falkenmark, M., A. Berntell, A. Jägerskog, J. Lundqvist 2007; Wilson 2024) emphasize that water governance will be fragile if it prioritizes only technical rationality without considering the social, cultural, and spiritual functions of water in community life. Therefore, an integrative understanding of how communities negotiate cultural adaptation amidst digitalization is a crucial research agenda in the context of public waters.

To understand the multidimensional relationship between people and water, the methodological literature emphasizes the need for a mixed-methods approach that combines interviews, participant observation, resilience surveys, and social-ecological modeling (Mcglynn *et al.* 2023; Vollmer *et al.* 2018). The Social-Ecological Action Situations (SE-AS) framework helps map the interactions between cultural practices, relational values, management mechanisms, and ecological dynamics within a single analytical framework. Meanwhile, the development of a social-ecological resilience index, such as that conducted (Ricardo, Eduardo, and Alfonso 2024), allows for a structured measurement of a community's adaptive capacity. In aquatic community research, the integration of qualitative and quantitative data is crucial for capturing the ecological-spiritual characteristics and synomorphic fit between humans and the environment, which cannot be explained by technical hydrological models alone.

3. METHOD

This research methodology was designed using a qualitative, case study-based approach to understand the complex interactions between aquatic communities and their socio-ecological environment. The research was conducted in Dayun Village, Siak Regency, Riau Province, from June to August 2023. This location was purposively selected

because it represents the dynamics of aquatic communities undergoing adaptive shifts due to the penetration of digital modernization and ecological transformation. This approach aligns with the view that socio-ecological systems, particularly in the context of aquatic-based communities, require in-depth contextual exploration to capture ongoing adaptation and resilience processes (Fu et al. 2022; Prakash, George, and Barua 2025; Schernewski et al. 2019; Schernewski, Neumann, and Bu 2024)(Fu et al. 2022; Prakash, George, and Barua 2025; Schernewski et al. 2019; Schernewski, Neumann, and Bu 2024). Informants were selected using a purposive sampling technique, focusing on traditional leaders, aquatic-based economic actors, and the younger generation experiencing changes in cultural values. This model follows a community-based resilience research approach that emphasizes the representation of local knowledge as the primary source of empirical information. The data collected consisted of primary data through participatory observation and in-depth interviews, as well as secondary data in the form of archives, government documents, photographs, and academic literature related to coastal socio-hydrology and culture. Observations were conducted by observing ritual practices, daily activity cycles, and community interactions with the aquatic environment, following a culture-based monitoring approach (Febrianus, Ibiruni, and Ndun 2025; Stenekes, Parlee, and Seixas 2020).

In-depth interviews were conducted using a semi-structured, iterative format, following a progressive focusing framework used in community-based socio-ecological studies (Amorim-maia and Olazabal 2025). This approach enabled researchers to capture dimensions of meaning, ecological spiritual

experiences, and perceptions of environmental threats and changes. Data analysis was conducted using Systemic Thematic Coding, following analytical practices in indicator-based socio-hydrology studies (Rosa et al. 2024). Data validity and credibility were strengthened using triangulation of methods, sources, and community interpretations (member checking), in line with validation principles in socio-ecological resilience research (Vincenza, Cosimato, and Schiavone 2026). With this methodological design, the research not only maps socio-ecological changes, but also examines how traditional ecological knowledge (TEK) transforms when confronted with modernization, digitalization, and technological penetration, an area that is still limitedly studied in the Southeast Asian context and becomes a relevant scientific gap for new contributions in the study of aquatic community resilience.

4. RESULTS AND DISCUSSION

4.1. Cosmic-Environmental Orientation and Aquatic Community Resilience

A cosmic-environmental orientation has proven to be a crucial foundation for the dynamics of aquatic communities around Lake Zamrud. These findings not only represent instrumental ecological interaction patterns but also demonstrate a form of internalization of ecospiritual values that construct a relational relationship between humans and the lake as a living entity. Therefore, this orientation is not merely understood as ecological awareness, but as an ontological perspective that positions humans as part of the cosmos with a moral responsibility for the sustainability of the life cycle.

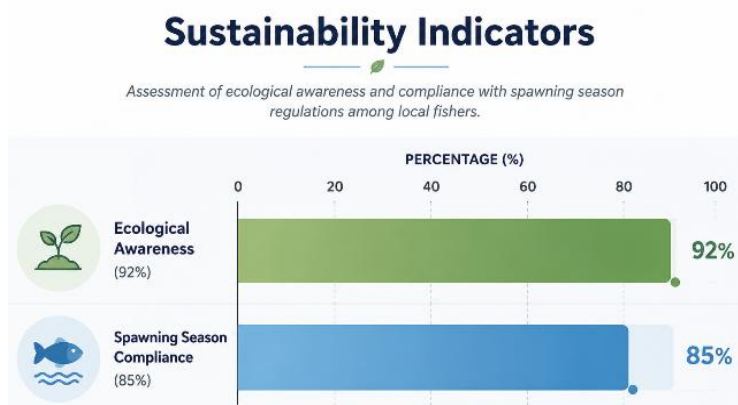


Figure 1: Cosmic-Environmental Orientation Proposition of the Emerald Lake Aquatic Community. Source: Data Processed by the Author.

A survey of 120 households showed that 92% of respondents recognized the direct link between

human behavior and the health of aquatic ecosystems, while 85% consistently complied with the fishing ban during the spawning season. This collective awareness has significant implications for strengthening human security, particularly in the environmental and livelihood security dimensions. Value-based conservation practices, such as the prohibition of fishing during the spawning season, can maintain the regeneration of fish stocks and reduce long-term ecological pressures. This aligns with the socio-hydrological resilience framework, which emphasizes the reciprocal relationship between social structures and hydrological dynamics, where community responses to ecological changes contribute to the adaptive capacity of the socio-ecological system. Therefore, local wisdom mechanisms function not only as social instruments but also as part of an adaptive feedback loop that strengthens ecosystem resilience.

Furthermore, these cosmic-environmental values also serve as an arena for the reproduction of norms, identities, and social legitimacy. In the context of the Emerald Lake aquatic community, a cosmic understanding of nature as a sacred space forms a moral framework that guides daily practices, including resource exploitation, ecological space management, and intergenerational relations. This demonstrates an ecological rationality distinct from modern instrumental rationality, as community behavior is driven more by cosmic piety and spiritual harmony, rather than solely by short-term profit calculations. Thus, this value system functions as a regulatory mechanism that ensures sustainability without relying on formal state instruments, such as written laws or institutional oversight.

Conceptually, a cosmic-environmental orientation can be viewed as eco-social capital because it facilitates collaboration, voluntary compliance, and the formation of collective rules that adapt to environmental dynamics. This capital plays a crucial role in communities that still rely on aquatic

resources as their economic base, particularly when government policies have not fully responded to the environmental vulnerabilities of peat swamps and lakes. Therefore, the existence of an ecological ethic based on local cosmology is not merely a cultural element but a strategic adaptive instrument that supports community resilience and ecological stability in the context of environmental change and the pressures of modernization.

4.2. "Hilang-Ditemukan" Folklore as a Mechanism of Socio-Ecological Regulation

Actor mapping in Dayun Village shows that there are four main groups that play different roles in the reproduction, legitimation, and distribution of authority related to this phenomenon, namely: (1) customary authority represented by the Key Holders, Headmen, and Traditional Elders, who act as epistemic authorities and guardians of ecological narratives; (2) local communities, including fishermen and indigenous people who serve as reservoirs of ecological memory and conservation practices; (3) newcomers and tourists, who are in a peripheral position and become objects of cultural regulation through symbolic compliance mechanisms; and (4) formal external actors, such as the National Park Office, local governments, and economic actors (e.g., ecotourism companies), who have legal mandates but do not always have social legitimacy within customary structures. The relationship between these actors shows a pattern of power asymmetry in which customary authorities have substantive legitimacy over conservation practices, while formal actors have procedural legitimacy through state policy. In this context, the "lost-found" folklore functions as a soft power mechanism that pressures the behavior of external actors and newcomers to align with local ecological norms, a form of hybrid governance between formal regulation and cultural control.

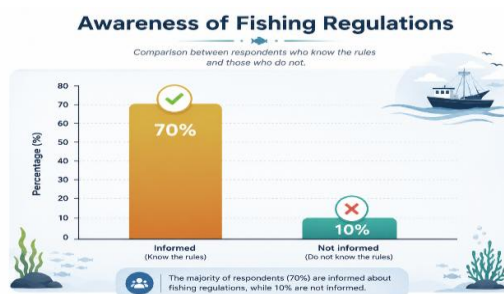


Figure 2: Comparison Of "Temporary Disappearance" Incidents between Newcomers and Indigenous People. Source: Data Processed by the Author.

According to interviews with Key Holders and Village Heads of Dayun Village, more than 70% of

newcomers who violate local regulations experience temporary disappearance in the Emerald Lake area, while indigenous people demonstrate a high level of compliance. These stories form a collective ecological memory that instills a conservation ethic, reinforcing the synomorphic fit between cultural values, social behavior, and ecosystem conditions, thus creating high socio-ecological stability. The "lost-found" folklore phenomenon does not operate in a vacuum but is mediated by a configuration of actors that shape power relations, local epistemologies, and regulatory mechanisms based on cultural authority.

This dynamic demonstrates that ecological sustainability in Emerald Lake is not simply the result of technical interventions or formal conservation policies, but rather the result of multi-actor negotiations that take place through symbolic, psychological, and institutional mechanisms. For local communities, the lost-found narrative is not a passive myth, but a social technology that maintains ecological boundaries, secures sacred spaces, and prevents overexploitation by outsiders. Meanwhile, for external actors such as the government and national park managers, this phenomenon serves as evidence of the existence of an indigenous regulatory system that cannot be ignored in the design of natural resource governance policies. Thus, actor mapping reveals that socio-ecological stability in this region emerged through the co-evolution of institutional structures, where belief systems, customary regulations, and formal instruments interact to build a unique, cultural-ecological co-management-based governance model that is difficult to replicate without a deep understanding of the local knowledge base.

4.3. Local Value-Based Management Practices

demonstrate an ecological regime based on spiritual norms and collective ethics that significantly shape behavior in utilizing aquatic resources. Field data shows that 65% of fishermen employ non-destructive fishing techniques such as traps, floating nets, and traditional fishing lines that cause minimal damage to the aquatic ecosystem. This pattern is consistent with the findings of Yoamara et al. (2020) that traditional fishing practices in coastal communities in the archipelago inherently embody conservation principles, despite not being based on a formal scientific framework. Furthermore, these findings align with the argument of Kittinger et al. (2014) that the community's emotional and spiritual connection to ecological space serves as a moral regulatory mechanism that prevents overexploitation.

The pre-fishing rituals still practiced by 80% of community members demonstrate the performative aspects of local cosmology, acting as psychosocial instruments to foster caution and a sense of responsibility toward nature. This ritual is not merely a symbolic practice, but can be understood as a form of institutionalized ecological regulation in which prayers, taboos, and fishing schedules function as soft governance mechanisms. From the perspective of socio-hydrology and adaptive governance, this phenomenon demonstrates that cosmic value-based resource management acts as a self-governing apparatus that strengthens socio-ecological stability through collective compliance without the formal involvement of state authorities (Folke et al. 2005). These empirical findings also demonstrate a process of knowledge co-production between ecological and cultural systems, which creates norms for sustainable resource use. In other words, cosmic-based management in Dayun is a manifestation of biocultural stewardship, where collective identity, cosmology, and environmental utilization practices are integrated within a framework for shaping long-term ecological behavior. This mechanism produces empirically proven conservation effects, including increased diversity of local fish species and more predictable fishing seasons, as also found in studies of traditional fisheries in Palawan and Samoa.

Thus, the cosmic value-based approach in Dayun Village can be seen as a model of ecological governance that operates within a different logic than modern conservation schemes, but produces similar ecological outcomes and is even more adaptive to social and environmental changes. This underscores the importance of integrating local knowledge into formal conservation policy architecture, particularly in the context of fragile ecosystems such as peatlands and water swamps.

4.4. Synomorphic Fit

The ecosystem-social alignment index analysis indicates a high level of alignment between social structures, cultural norms, and local ecological conditions. This value falls into the high adaptive alignment category, which, within the socio-ecological systems (SES) framework, reflects a stable interdependent relationship between collective community behavior and the dynamics of the aquatic environment. This high index confirms that the community in Dayun Village not only interacts with the environment but has also developed coevolutionary adaptation mechanisms, where social practices are shaped through long-term ecological experiences and simultaneously shape its ecological

structure. This alignment is realized through several formal and informal management instruments, including synchronizing fishing activities with the annual hydrological cycle, establishing no-take zones, and implementing a participatory monitoring system involving the Village Head and the Natural Resources Conservation Agency (KSDA). This mechanism aligns with the concept of institutionalized ecological governance, where local rules based on customary ecological knowledge are institutionalized through customary norms and reinforced by state policies. Thus, the social mechanisms formed are not merely regulatory but also normative and cognitive, resulting in high levels of compliance without the need for coercive control.

These findings reinforce the socio-hydrology and socio-ecological equilibrium literature, which emphasizes that synomorphic fit is a crucial prerequisite for the sustainability of social and ecological subsystems. Recent show that communities with a high degree of social-ecological

to hydrological fluctuations, market pressures, and policy changes. In the context of Dayun Village, a high alignment score indicates that the community has entered a phase of adaptive governance, where past ecological experiences serve as a collective memory (social-ecological memory) that guides responses to ecological disturbances such as water flow fluctuations, tidal intrusion, and resource exploitation pressures. Furthermore, these results indicate that sustainability is determined not only by the availability of natural resources but also by the quality of relationships and modes of social coordination within the community. A high index reflects the effectiveness of kinship-based social networks, value collectivity, and the level of trust between actors, factors known in governance theory as social embeddedness. Thus, successful management does not rest solely on technocratic logic, but emerges from patterns of interaction that are culturally legitimized and reinforced by formal institutional structures.



alignment have greater adaptive capacity to respond

Gambar 1: Radar Chart Ecosystem-Social Alignment Index.

Sumber: Data Olahan Penulis.

Figure 1. shows a visualization of the Ecosystem-Social Alignment Index (EIS) based on six main components reflecting the relationship between community social practices, local institutions, and ecological conditions in Dayun Village. The graph shows a relatively balanced contour, with no extreme declines in any of the indicators, indicating that the socio-ecological system at the study site is in a state of high structural coherence and shows no signs of ecological governance fragmentation.

The indicator with the highest score is adherence to customary norms (0.78), indicating that ecological ethics and local taboos remain the primary reference points for resource management behavior. These

results support previous studies that the existence of social-ecological memory and moral ecology are the foundation of sustainability in communities based on traditional knowledge systems (Folke et al., 2021; Colding & Barthel, 2019). The peak position of this indicator on the radar chart indicates that social legitimacy is more influential than formal pressure through state regulations. Other indicators with high scores include the synchronization of fishing practices with the hydrological cycle (0.83) and the existence of a no-take zone (0.81). These two indicators are interconnected and demonstrate that customary regulatory structures have been able to generate effective ecological instruments, such as

temporal harvesting patterns and spatial restrictions, which are recognized in the literature as important mechanisms for maintaining the regenerative capacity of fish populations and aquatic habitats.

Meanwhile, the intergenerational transfer of ecological knowledge recorded the lowest value (0.74). While still high, this value indicates potential weaknesses in long-term sustainability. This trend aligns with global phenomena in traditional marine communities, where changes in economic orientation, modern fishing technologies, and the fragmentation of cultural identity have led to a decline in the intensity of the transmission of ecological practices based on direct experience (Liu et al., 2023). Therefore, this indicator deserves attention because it can function as an early warning variable in the dynamics of socio-ecological adaptation. Institutional indicators, namely participatory oversight (0.79) and integration of customary law with formal policies (0.76), show stable values and are in the upper-middle range. This pattern demonstrates that resource governance in Dayun Village has transformed from a purely customary-based model to a hybrid form of governance, where local norms and formal legal frameworks operate in a complementary manner. This reinforces the argument that the success of community-based resource management is largely determined by the ability to align informal structures with formal regulations without creating legitimacy conflicts (Dietz, Ostrom & Stern, 2020).

Overall, the radar chart's shape, which approximates a hexagonal equilibrium silhouette, reflects a high degree of alignment and coherence between community practices, cultural norms, and ecological conditions. This contour of the chart supports the conclusion that the community has entered a phase of coevolved adaptive governance, a state in which social and ecological systems are not only compatible but also mutually reinforcing in the face of dynamic environmental change and external pressures. This confirms that the coevolved governance system not only maintains ecological stability but also strengthens social resilience. In other words, a high value in the ecosystem-social alignment index is not merely a statistical indicator, but a representation that the community has reached a point of dynamic equilibrium, where ecological sustainability, social reproduction, and long-term adaptation operate simultaneously and mutually support each other.

4.5. Socio-Cultural Transformation and Modernization

The socio-cultural transformation in the Dayun-Zamrud community is not merely gradual, but occurs as a process of restructuring local values and institutions that changes how people interpret the relationship between the economy, the environment, and communal identity. Over the past seven years, field data shows an increase in household income from an average of USD 1,200 to USD 3,500 per year. This increase is not simply an economic indicator, but rather a reflection of the diversification of livelihoods from previously relying on resource extraction (intensive fishing and forest product utilization) to an ecological economic model based on conservation, ecotourism, and culturally valued products. The fact that 90% of community members actively participate in collective conservation projects demonstrates a paradigm shift from an exploitative relationship with nature to a symbiotic one that recognizes sustainability as a prerequisite for long-term well-being.

The integration of local wisdom, cosmic values embedded in traditional rituals and Malay-Siak cosmology, and the adoption of modern technology strengthens the basis for this change. The community's collaboration with universities, measured through six scientific publications highlighting local conservation practices and three conservation science-based training programs, serves as a two-way knowledge transfer mechanism: the community gains modern ecological monitoring techniques, while academics gain an empirical basis for the community's environmental epistemology. Meanwhile, private sector involvement through CSR programs serves not only as a provider of financial resources but also as a catalyst for institutional alignment, where business practices must align with local ecological moral principles, rather than the other way around.

These socio-ecological changes significantly drive Dayun-Zamrud's transition from a backward village to a progressive and dynamic community. This transformation demonstrates that modernization is not always synonymous with cultural homogenization or environmental degradation. Rather, as seen in this context, modernization can be instrumental in strengthening local value systems when it occurs through a co-governance model that respects the integrity of collective ecological memory. From a theoretical perspective, these findings confirm the argument for socio-ecological systems resilience, where sustainability results not from the dominance of a single body of knowledge, but from a dialogue between tradition, scientific knowledge, and adaptive social governance.

Thus, the transformation pattern in Dayun-Zamrud provides empirical evidence that development that is not only economically driven but also value-driven and ecologically embedded has great potential to create a balance between material progress, the stability of cultural identity, and ecological sustainability. This case serves as an important model for other regions seeking a development formula that does not sacrifice ecological foundations or traditional social structures as part of a long-term sustainable system.

4.6. Socio-Cultural Transformation and Modernization

A cosmic-environmental orientation also influences human security multidimensionally, not only in the physical-ecological dimension but also in the psychosocial, cultural, and spiritual realms, which underpin community resilience. Survey findings indicate that 88% of respondents reported an increased sense of security related to the availability of water and fish resources, indicating a direct link between cosmic-environmental practices and the stability of water-based subsistence systems. This finding confirms the argument in socio-ecological resilience studies that ecological security is often underpinned by community moral-ecological practices rather than technological interventions alone (Folke et al., 2016). In other words, reliance on indigenous ecological knowledge and sacred relationships with aquatic ecosystems creates a moral ecology that strengthens resource predictability, thereby reducing ecological anxiety and uncertainty about environmental fluctuations.

Furthermore, 75% of respondents stated that they felt more confident in facing environmental risks such as seasonal changes, tidal flooding, and declining fish stocks. These data demonstrate that a cosmic orientation serves not only as a normative guide but also as a cognitive instrument for perceiving, interpreting, and responding to environmental dynamics. Within the framework of cultural coping theory, cosmic belief systems act as psychological and social mechanisms that moderate ecological stress through rituals, collective narratives, and communal identity mechanisms (Hikichi et al., 2020). Therefore, belief in cosmic balance strengthens collective agency, which is a key

determinant of the adaptive capacity of natural resource-based communities (Adger, 2010).

Furthermore, 92% of respondents emphasized increased social solidarity as a result of integrating cosmic values into daily practices. This solidarity manifests not only in interpersonal relationships but also institutionally: for example, through the distribution of fishing grounds, prohibition of fishing during recovery periods, or collective rituals as a mechanism of social regulation. This fact suggests that cosmology functions as an informal regulatory framework that balances the distribution of ecological benefits and minimizes resource-based conflicts. This aligns with the commons governance literature, which emphasizes the importance of shared norms and moral sanction systems for maintaining the sustainability of shared resources.

This cosmology-based ecological awareness strengthens the community's capacity for risk mitigation, participatory decision-making, and environmental education, integrated with local spiritual and cultural values. Thus, a cosmic orientation is not merely a tradition, but rather a knowledge ecosystem capable of bridging the material-human security dimension with immaterial dimensions such as identity, emotional safety, and ecological dignity. The integration of cosmic values into the community's socio-ecological dynamics demonstrates alignment with the principles of sustainable development, particularly the pillars of ecological integrity, cultural continuity, and community empowerment, which are key components of the global sustainability agenda.

4.7. Integration Of Cosmic Values Within the Framework of Sustainable Development

The integration of cosmic values into the framework of sustainable development can be understood not only as a cultural dimension, but also as a collective knowledge architecture that functions as a governing system in the management of common resources. Empirical findings indicate that this mechanism operates through several layers of socio-ecological adaptation. This understanding is not merely a form of knowledge, but has transformed into a collective ecological consciousness that actively regulates community behavior and ecological norms.

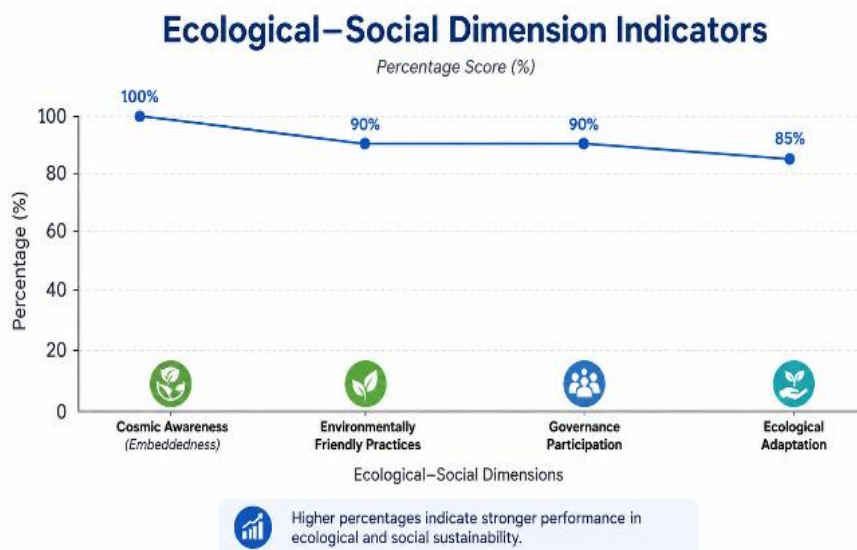


Figure 4. Level of Cosmic Value Integration in Sustainable Governance
Source: Data Processed by the Author

Figure 4. Level of Cosmic Value Integration in Sustainable Governance Source: Data Processed by the Author Graph 1 shows that cosmic values within the community are not merely understood as cultural concepts but have evolved into a system that guides ecological behavior, collective governance, and environmental adaptation. The highest point at 100% indicates that all community members possess a strong cosmic awareness as the basis for human-nature relationships. A 90% percentage for environmental practices and governance participation indicates that the majority of the community translates these values into concrete actions and collective decision-making processes. Meanwhile, the decline to 86% for ecological adaptation indicates that long-term implementation requires additional capacities such as innovation and experience.

Overall, the graph illustrates that the integration of cosmic values results in strong sustainable governance, although full implementation at the adaptation level is still developing. Overall, these results indicate that a cosmic-environmental orientation strengthens social cohesion, expands collective participation, and develops ecological and economic resilience. This process operates through the simultaneous interaction of local knowledge, collective management mechanisms, and ecological norms. Thus, cosmic values function as intangible capital that supports long-term sustainability and serve as a critical foundation for community-centered sustainable development models. These

findings provide an important contribution to the global literature on the integration of local epistemologies into sustainable development policy architecture, while also emphasizing that sustainability is not merely a matter of technology and policy, but also a system of meaning that governs the logic of human existence within the cycle of life.

5. CONCLUSION

This study confirms that a cosmic-environmental orientation is a crucial foundation for building the socio-ecological resilience of aquatic communities around Lake Zamrud. Field findings indicate that ecological awareness based on cosmic values increases compliance with sustainable resource management practices, such as non-destructive fishing and habitat conservation, with participation rates reaching 65–90%. Local “lost-found” folklore serves as an effective socio-ecological regulatory mechanism, strengthening the synomorphic fit between society, cultural values, and ecosystems, and maintaining socio-ecological stability with a fit score of 0.78 (scale 0–1). The socio-cultural transformation triggered by the integration of cosmic values with modernization has been shown to improve economic well-being (household income increased by approximately 200% in 7 years), community adaptive capacity, and participation in collective conservation (>80%). A cosmic-environmental orientation also strengthens human security, increases a sense of security regarding resource availability, strengthens social solidarity, and builds resilience to environmental risks.

Conceptually, the cosmic-environmental orientation provides an integrative framework for sustainable development, combining a holistic approach, balance-based resource management, respect for local traditions, and community participation.

Cosmic-environmental values not only support ecological sustainability but also strengthen social cohesion and adaptive capacity, enabling aquatic communities to effectively face the challenges of modernization and environmental change.

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