JIP
Jurnal Ilmiah PLATAX
Universitas Sam Ratulangi
Terakreditasi Ristekdikti No: 28/E/KPT/2019
ISSN : 2302-3589 (Online)
E_mail : jip_platax@unsrat.ac.id

Governability Challenges in Indonesian Aquaculture: A Political-Legal Analysis

Hanzel Mamuaya[1]*, Ockstan Kalesaran[2], Cyska Lumenta[3]

[1]Lecturer, Study Program of Law, FISH, Manado State University, Tondano, Indonesia
[2] Lecturer, Study Program of Aquaculture, FPIK, Sam Ratulangi University, Manado, Indonesia
[3] Professor [Em.] of Aquaculture Sciences; Lecturer - STTYB, Manado, Indonesia

Corresponding author: hanzelmamuaya@unima.ac.id

Manuscrcrip received: 2 June 2026. Revision accepted: 24 June 2026

Abstract. Aquaculture has become one of the fastest-growing food production sectors globally and is increasingly recognized as a strategic component of food security, economic development, and Blue Economy policies. In Indonesia, rapid aquaculture expansion has generated significant opportunities for production growth, employment, and export development. However, it has also intensified ecological pressures, institutional complexity, stakeholder conflicts, and governance challenges. This study aims to synthesize existing knowledge on Indonesian aquaculture governance and develop a conceptual framework for strengthening aquaculture governability. A Systematic Literature Review (SLR) was conducted following the PRISMA 2020 guidelines. Literature was collected from Scopus, Web of Science, ScienceDirect, Dimensions, SpringerLink, and Garuda databases, resulting in 68 studies published between 2015 and 2026 that met the inclusion criteria. The findings were analyzed using thematic synthesis and interpreted through the lens of Interactive Governance theory. The review identified five interrelated dimensions shaping aquaculture governability: economic growth orientation, ecological sustainability, institutional coordination, state–market–community interaction, and enforcement and knowledge systems. The results indicate that governance remains predominantly growth-oriented, while ecological resilience, social inclusion, regulatory coherence, and adaptive governance capacities often receive insufficient attention. Based on the synthesis, this study proposes a conceptual framework of Indonesian aquaculture governability that integrates economic, ecological, institutional, social, and informational dimensions. The framework contributes to governance scholarship by providing an analytical foundation for understanding and improving adaptive, participatory, and sustainable aquaculture governance in complex social-ecological systems.

Keywords: Aquaculture Governance, Blue Economy, Governability, Interactive Governance

INTRODUCTION

Aquaculture has become one of the most dynamic food-producing sectors in the world and is increasingly recognized as a strategic component of global food security (Afewerki *et al*., 2023; Toonen *et al*., 2025). Over the past two decades, aquaculture production has expanded at a rate exceeding that of most other animal-based food sectors, contributing substantially to global supplies of fish and aquatic foods for a growing population (FAO, 2024; Boyd *et al*., 2020; Troell *et al*., 2023; Froehlich *et al*., 2017). As capture fisheries face increasing ecological and economic constraints, aquaculture is expected to play an even greater role in supporting sustainable food systems and nutritional security. Boyd *et al*. (2020) described aquaculture as one of the fastest-growing food production sectors globally, highlighting its strategic importance within contemporary food systems.

Indonesia is among the world's leading aquaculture-producing countries, possessing extensive freshwater, brackish-water, and marine resources suitable for aquaculture development (FAO, 2024; MMAF, 2023). Within the framework of the national Blue Economy agenda, the government has prioritized the expansion of shrimp, seaweed, tilapia, and other commercially important commodities as drivers of economic growth, employment generation, and export earnings (MMAF, 2023; FAO, 2024; Engle *et al*., 2017). The strategic importance of aquaculture is reflected in various national development initiatives aimed at increasing productivity and strengthening Indonesia's position in global seafood markets. Nevertheless, the long-term success of aquaculture development depends not only on production growth but also on the ability of governance systems to ensure ecological sustainability, social equity, and institutional effectiveness.

The rapid expansion and intensification of aquaculture have generated a range of socio-ecological challenges. These include mangrove conversion, water quality degradation, disease outbreaks, increasing competition over coastal space, and growing pressures on coastal and marine ecosystems (Brugère *et al*., 2019; Troell *et al*., 2023; FAO, 2024). Such challenges have raised concerns regarding the environmental sustainability of aquaculture development and its broader implications for coastal communities. As Boyd *et al*. (2020) argue, environmentally responsible aquaculture is no longer optional but has become a prerequisite for the economic viability and social legitimacy of the sector.

These developments demonstrate that aquaculture cannot be understood merely as a production activity or technological enterprise. Rather, it represents a complex social-ecological system in which ecological processes, economic interests, legal institutions, governance arrangements, and social actors interact across multiple scales (Bueno & Soto, 2017; Chuenpagdee & Jentoft, 2019; Abate *et al*., 2018). Consequently, sustainability outcomes depend not only on technical efficiency but also on the capacity of governance systems to manage uncertainty, coordinate stakeholders, resolve conflicts, and distribute development benefits fairly and effectively (Afewerki *et al*., 2023; Tacon, 2020).

The governance of aquaculture is further complicated by the existence of overlapping institutional and regulatory arrangements (Jolly *et al*., 2023). Aquaculture activities are often governed simultaneously by fisheries regulations, environmental policies, coastal and marine spatial planning frameworks, water resource management rules, and economic development strategies (Boyd *et al*., 2020). Similar conditions can be observed in Indonesia, were multiple agencies and regulatory instruments influence aquaculture development. Such institutional complexity frequently generates fragmented authority, weak policy coordination, and inconsistencies in implementation, thereby reducing governance effectiveness (Chuenpagdee & Jentoft, 2019; Jolly *et al*., 2023).

In addition to institutional fragmentation, aquaculture governance involves multiple actors whose interests do not always converge. Governments seek economic growth and food security, private-sector actors prioritize profitability and market competitiveness, while local communities often emphasize livelihood security and environmental protection. Boyd *et al*. (2020) identifies these dynamics as manifestations of competing stakeholder interests within aquaculture governance systems. These governance tensions reveal that aquaculture regulation is not merely a technical instrument for resource management but also a site where competing interests and power relations are negotiated. From a Critical Legal Studies perspective, laws and policies are not entirely neutral instruments but are often shaped by competing economic, political, and ecological interests that influence the distribution of benefits, opportunities, and risks among stakeholders (Anderson *et al*., 2019; Kittinger *et al*., 2021; Meitasari *et al*., 2025; Mamuaya, 2025).

Despite the growing body of literature on aquaculture development, existing studies remain fragmented across disciplinary boundaries. Much of the available research focuses on production efficiency, environmental impacts, technological innovation, or sector-specific regulatory issues. Comparatively fewer studies examine how economic, ecological, institutional, and social dimensions interact to shape aquaculture governability as an integrated system. Moreover, very few studies explicitly connect aquaculture governance with the concept of governability within the Indonesian political-legal context. Consequently, there remains limited conceptual understanding of how interactions among state institutions, market actors, and local communities influence governance outcomes and sustainability transitions within

Indonesia's aquaculture sector (Jentoft & Chuenpagdee, 2015; Chuenpagdee & Jentoft, 2019; Garlock *et al*., 2022).

Accordingly, this study aims to synthesize the existing literature on Indonesian aquaculture governance, identify the principal dimensions influencing governability, and develop a conceptual framework capable of supporting adaptive and sustainable governance reforms. By integrating insights from governance studies, sustainability research, and policy analysis, the study seeks to clarify the relationships among ecological conditions, institutional arrangements, stakeholder interactions, and governance performance (Glencross *et al*., 2023; Mamuaya *et al*., 2026; Glencross *et al*., 2026).

Figure 1 illustrates the logical flow of the study, linking the broader challenges of Indonesia's aquaculture sector to the formulation of the research problem, research questions, and the intended scholarly contribution. The framework also illustrates how the identified governance challenges inform the thematic synthesis and subsequent development of the governability framework.

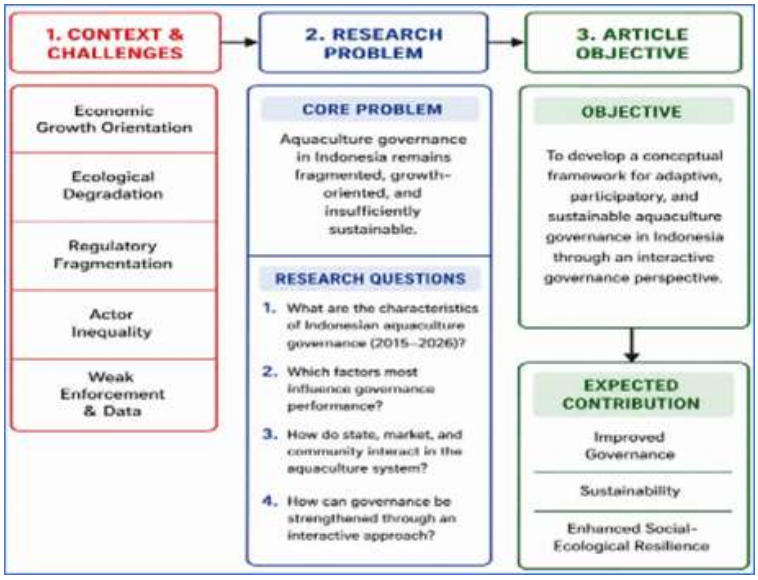

Figure 1. Conceptual Framework of the Study

The framework begins with five major contextual challenges affecting Indonesian aquaculture governance: economic growth orientation, ecological degradation, regulatory fragmentation, actor inequality, and weak enforcement and data systems. These interconnected challenges reflect persistent tensions between production-driven development objectives and the need for environmental sustainability, institutional coherence, and social inclusion. Collectively, they shape the governance environment within which aquaculture development takes place.

These conditions lead to the central research problem addressed in this study, namely that aquaculture governance in Indonesia remains fragmented, predominantly growth-oriented, and insufficiently equipped to support long-term social-ecological sustainability. To address this issue, the study investigates four interrelated research questions concerning the characteristics of Indonesian aquaculture governance, the factors influencing governance performance, the interactions among state, market, and community actors, and potential pathways for governance improvement through an Interactive Governance approach.

Based on these questions, the study seeks to develop a conceptual framework for adaptive, participatory, and sustainable aquaculture governance in Indonesia. Drawing upon Interactive Governance theory (Msomphora, 2024), the framework emphasizes the dynamic relationships

among governing institutions, market actors, communities, and ecological systems in shaping governability outcomes. The concept of governability provides a useful lens for understanding how governance systems respond to complexity, uncertainty, and competing stakeholder interests within social-ecological systems (Jentoft & Chuenpagdee, 2015; Carlino-Costa *et.al*., 2025; Malcorps *et al*., 2026).

The contribution of this study is threefold. First, it contributes to the emerging governability literature by extending Interactive Governance theory into the context of Indonesian aquaculture governance. Second, it integrates fragmented findings from governance, sustainability, and policy studies into a coherent analytical framework. Third, it provides a conceptual foundation for future governance reforms and empirical investigations aimed at strengthening adaptive, participatory, and sustainable aquaculture governance. Overall, the study contributes to the broader literature on Interactive Governance by demonstrating how governance challenges, institutional arrangements, and stakeholder interactions jointly shape the sustainability of aquaculture systems.

MATERIALS AND METHODS

Research Design

This study employs a Systematic Literature Review (SLR) to identify, evaluate, and synthesize scholarly evidence concerning the governance of Indonesia's aquaculture sector. The SLR approach was selected because it enables a rigorous and transparent examination of accumulated knowledge, allowing researchers to identify major research trends, conceptual developments, policy debates, and existing knowledge gaps within a particular field (Xiao & Watson, 2019; Snyder, 2019; Torracco, 2016).

Unlike traditional literature reviews, which may rely heavily on subjective selection and interpretation of sources, SLR follows a structured and replicable procedure based on predefined protocols. Such an approach enhances the transparency, reliability, and reproducibility of the review process while reducing potential selection bias (Xiao & Watson, 2019). In the present study, SLR is used to explore and synthesize scientific evidence regarding how economic growth orientation, regulatory dynamics, state–market–community relations, and sustainability challenges shape the governability of aquaculture systems in Indonesia.

The analytical framework is grounded in the Interactive Governance Theory developed by Kooiman *et al*. (2005) and further elaborated by Msomphora (2024). This perspective conceptualizes governance as an interaction between the *system-to-be-governed*, the *governing system*, and the broader concept of *governability*. The framework is particularly relevant for examining complex social-ecological systems such as aquaculture, where governance outcomes emerge from interactions among governmental institutions, private actors, local communities, and ecological conditions. To strengthen the legal and political analysis, the study also draws upon insights from Critical Legal Studies (CLS), which view law not merely as a neutral regulatory instrument but as a social arena through which power relations are produced, negotiated, and reproduced (Mamuaya *et al*., 2026; Unger, 1983; Sutisna *et al*., 2025).

The conceptual framework presented in Figure 1 guided the entire review process. The five contextual challenges identified in the figure—economic growth orientation, ecological degradation, regulatory fragmentation, actor inequality, and weak enforcement and data systems—served as the initial analytical categories for literature screening, coding, and interpretation. These contextual challenges were subsequently linked to the study's research problem, research questions, and the development of a conceptual governance framework for Indonesian aquaculture

Literature Search Strategy

The literature identification and selection process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines developed by Page *et al*. (2021). PRISMA was adopted because it provides internationally recognized standards for conducting and reporting systematic reviews, thereby enhancing methodological rigor and transparency. Literature searches were conducted across several major international and national academic databases, including Scopus, Web of Science, ScienceDirect, Dimensions, and Garuda. These databases were selected due to their extensive coverage of peer-reviewed literature in environmental governance, marine policy, fisheries management, sustainability science, and public policy. The review included journal articles, review papers, and policy-related publications relevant to aquaculture governance.

The search strategy employed Boolean operators and combinations of the following primary keywords:

("Aquaculture Governance" OR "Aquaculture Policy" OR "Aquaculture Regulation")
AND
("Indonesia")
AND
("Sustainability" OR "Blue Economy" OR "Governability" OR "Interactive Governance")

To ensure broader coverage of governance-related studies, additional keywords were incorporated, including: sustainable aquaculture; coastal governance; fisheries governance; legal framework; environmental governance; blue economy; marine policy; socio-ecological systems; interactive governance; governance capacity; governability; co-management; multi-level governance. The search strategy was iteratively refined throughout the review process to capture institutional, legal, ecological, and socio-political dimensions of aquaculture governance, following recommendations for governance-oriented systematic reviews (Snyder, 2019; Xiao & Watson, 2019).

The review focused on publications published between 2015 and 2026. This period was selected to capture recent developments associated with the global expansion of the blue economy agenda, sustainable aquaculture transitions, and emerging governance challenges in marine and coastal resource management (FAO, 2024; Troell *et al*., 2023).

Literature Selection and Data Extraction

The literature selection process followed the four-stage PRISMA 2020 procedure consisting of: identification, screening, eligibility assessment, and inclusion (Page *et al*., 2021; Xiao & Watson, 2019).

The inclusion criteria were as follows:

a. peer-reviewed academic publications indexed in recognized scholarly databases;
b. studies addressing aquaculture governance, policy, regulation, sustainability, or institutional management;
c. studies directly related to Indonesia or presenting conceptual frameworks applicable to the Indonesian context;
d. publications available in English or Indonesian.

Studies focusing exclusively on technical aquaculture production, engineering aspects, or biological cultivation processes without explicit connections to governance, policy, institutional arrangements, or sustainability were excluded from the review. For each selected publication, the following information was systematically extracted:

- author(s) and publication year;

- study location and geographical focus;
- methodological approach;
- governance dimensions examined;
- governance issues and challenges identified;
- actors involved in governance processes;
- state–market–community interactions;
- regulatory and institutional issues;
- sustainability dimensions;
- recommendations for governance improvement.

The extracted information was organized into a synthesis matrix to facilitate comparison, categorization, and interpretation across studies. The matrix-based approach enabled the identification of recurring themes, emerging patterns, and conceptual relationships among governance variables (Snyder, 2019; Rouhani & Bozorgi, 2026).

Data Analysis and Conceptual Framework Development

Data analysis was conducted using thematic synthesis, following the approach proposed by Marzi et al. (2025). This method allows qualitative findings from diverse studies to be systematically coded, categorized, and integrated into higher-order analytical themes.

The initial coding framework was deductively derived from the conceptual structure illustrated in Figure 1, namely:

1. economic growth orientation;
2. ecological degradation;
3. regulatory fragmentation;
4. actor inequality;
5. weak enforcement and data systems.

During the analytical process, these initial categories were refined and integrated into broader governance themes that emerged across the reviewed literature, including:

1. economic development orientation;
2. ecological sustainability;
3. institutional governance;
4. stakeholder participation;
5. state–market relations;
6. social justice and equity;
7. governability capacity.

These themes were subsequently mapped onto the Interactive Governance framework to evaluate the relationships between the *system-to-be-governed* and the *governing system*, as well as the extent to which governance arrangements contribute to or constrain the governability of Indonesian aquaculture systems (Kooiman *et al*., 2005; Jentoft & Chuenpagdee, 2015; Msomphora, 2024).

The final stage involved a conceptual synthesis aimed at developing an integrative governance framework for Indonesian aquaculture. Following recommendations for theory-building from systematic reviews, findings from the reviewed studies were synthesized to identify pathways through which aquaculture governability may be strengthened. Particular attention was given to legal adaptability, ecological sustainability, institutional coordination, market accountability, stakeholder participation, and social-ecological resilience. The resulting framework does not seek to prescribe a single governance model; rather, it provides a conceptual explanation of how governance arrangements can evolve toward more adaptive,

participatory, and sustainable aquaculture systems in Indonesia (Torraco, 2016; Msomphora, 2024)).

Methodological Limitations

While the Systematic Literature Review approach offers the strength of a rigorous, transparent, and replicable synthesis of existing knowledge, several methodological limitations need to be acknowledged. First, this study relies entirely on secondary sources, including peer-reviewed publications and policy-related documents. Consequently, the analysis is limited by the scope, quality, and availability of the published literature. This limitation is particularly relevant in Indonesia, where aquaculture governance often operates through complex formal and informal relationships across multiple administrative levels (Snyder, 2019; Xiao & Watson, 2019).

Furthermore, the Indonesian aquaculture sector exhibits substantial geographic, institutional, and socio-cultural diversity. Governance challenges faced in major aquaculture producing regions may differ significantly from those encountered in small-scale, remote, or customary-based aquaculture systems. While this review attempts to capture broad national patterns, it cannot fully account for the contextual variations that shape governance across local environments. Nevertheless, these limitations do not diminish the value of this study. They highlight its role as a theory-building and knowledge-synthesizing effort, aiming to integrate fragmented insights from various studies into a coherent analytical framework. The conceptual governance framework developed through this review is intended to serve as a foundation for future empirical research

RESULTS AND DISCUSSION

Overview of the Systematic Literature Review Results

The initial search identified 1,286 records. Following the removal of duplicate publications and preliminary screening of titles and abstracts, a substantially smaller number of potentially relevant studies remained for full-text assessment (Tabel 1). The screening process applied predefined inclusion and exclusion criteria to ensure consistency and minimize selection bias, in accordance with systematic review principles (Xiao & Watson, 2019; Rouhani & Bozorgi, 2026). Studies focusing exclusively on technical aquaculture production without explicit governance, policy, regulatory, or sustainability dimensions were excluded from further analysis.

Table 1. Summary of the Literature Selection Process

PRISMA Stage	Number of Records
Records identified through database searching	1,286
Duplicate records removed	214
Records screened (title and abstract)	1,072
Records excluded during screening	869
Full-text articles assessed for eligibility	203
Full-text articles excluded	135
Studies included in thematic synthesis	68

Subsequent full-text eligibility assessment resulted in the inclusion of 68 publications for thematic synthesis. These studies collectively represent the current body of knowledge on aquaculture governance and provide a robust foundation for examining institutional arrangements, governance challenges, sustainability concerns, stakeholder interactions, and policy responses across different aquaculture contexts (Page *et al*., 2021; Snyder, 2019).

The relatively small proportion of studies included in the final synthesis (68 of 1,286 records) reflects the stringent eligibility criteria adopted in this review. While numerous publications addressed aquaculture production, technology, or biological performance, far fewer explicitly examined governance processes, institutional dynamics, legal frameworks, stakeholder participation, or sustainability-oriented policy interventions. This finding suggests that governance-related scholarship remains a relatively specialized but increasingly important area within the broader aquaculture literature (Partelow *et al*., 2022; Anderson *et al*., 2019; Biazi & Marques, 2023).

To better understand the composition of the reviewed literature, the selected studies were further categorized according to publication year, document type, and methodological approach (Table 2). This characterization provides important context for interpreting thematic patterns and identifying emerging research trends in aquaculture governance.

Table 2. Characteristics of the Included Studies (n = 68)

Category	Classification	Number	(%)
Publication Year	2015–2017	12	17.6
	2018–2020	21	30.9
	2021–2023	24	35.3
	2024–2026	11	16.2
Document Type	Journal Articles	58	85.3
	Review Articles	6	8.8
	Policy Reports	4	5.9
Methodological Approach	Qualitative	32	47.1
	Quantitative	21	30.9
	Mixed Methods	15	22.0

The distribution of publication years indicates a growing scholarly interest in aquaculture governance, particularly after 2020. More than half of the reviewed studies were published between 2021 and 2026, coinciding with increasing global attention to Blue Economy policies, sustainable food systems, climate adaptation, and social-ecological resilience in aquatic food production (Hardy & Kaushik, 2021; FAO, 2024; Naylor *et al*., 2023; Troell *et al*., 2023). This trend suggests that governance considerations are becoming increasingly central to contemporary aquaculture research.

Journal articles constituted the overwhelming majority of the reviewed literature, indicating that knowledge on aquaculture governance is primarily generated through peer-reviewed academic research. The comparatively limited number of policy reports and review papers suggests that although governance issues are receiving increasing scholarly attention, opportunities remain for more integrative policy-oriented analyses that bridge academic knowledge and governance practice (Anderson *et al*., 2019; Jolly *et al*., 2023; Sulthana *et al*., 2026).

Regarding methodological orientation, qualitative studies represented the largest proportion of the reviewed literature. This predominance reflects the complex nature of governance research, which frequently requires in-depth examination of institutions, stakeholder interactions, legal frameworks, and policy processes that are not easily captured through quantitative indicators alone (Kooiman *et al*., 2005; Jentoft & Chuenpagdee, 2015). Nevertheless, the growing presence of quantitative and mixed-methods studies suggests an increasing effort to develop measurable indicators of governance performance, sustainability, and governability within aquaculture systems (Anderson *et al*., 2025; Toonen *et al*., 2025).

Overall, the systematic review demonstrates that aquaculture governance has evolved into a multidimensional research field encompassing economic development, environmental

sustainability, institutional effectiveness, stakeholder participation, and governance innovation. The following sections present the thematic synthesis of the reviewed studies, organized around the major governance dimensions that emerged from the literature and that collectively shape aquaculture governability in Indonesia and comparable social-ecological contexts (Jolly *et al*., 2023; Troell *et al*., 2023).

Economic Growth Orientation in Indonesian Aquaculture Governance

Economic growth has emerged as one of the most influential drivers of aquaculture development worldwide. Over the past two decades, aquaculture has expanded rapidly in response to growing demand for aquatic foods, international trade opportunities, and concerns regarding global food security. This expansion has positioned aquaculture as a central component of the Blue Economy agenda and a strategic contributor to economic development in many coastal nations, including Indonesia (Garlock *et al*., 2020; Naylor *et al*., 2021; FAO, 2024). Consequently, policy frameworks increasingly emphasize production growth, export competitiveness, and investment attraction as primary indicators of sectoral success.

The thematic synthesis revealed that economic growth orientation is the most frequently discussed governance dimension within the reviewed literature (Table 3). A substantial proportion of studies focus on increasing production capacity, expanding aquaculture areas, enhancing export performance, and promoting private-sector investment. These priorities are reflected in national development strategies as well as international policy initiatives that seek to position aquaculture as a major contributor to food systems transformation and economic resilience.

Table 3. Major Themes Associated with Economic Growth Orientation (n = 68)

Theme	Frequency	%	Representative Studies
Production Expansion	46	67.6	Garlock *et al*. (2020); Naylor *et al*. (2021); Tacon (2020); Troell *et al*. (2023)
Export Competitiveness	39	57.4	Anderson *et al*. (2019); Asche *et al*. (2018); Roheim *et al*. (2018); Naylor *et al*. (2023)
Investment Promotion	34	50.0	Hall et al. (2017); World Bank (2021); Anderson *et al*. (2019); MMAF (2023)
Environmental Concerns	27	39.7	Boyd *et al*. (2020); Gephart *et al*. (2021); Troell *et al*. (2023)
Social Inclusion	19	27.9	Béné *et al*. (2016); Brugère *et al*. (2023); Rashid *et al*. (2018)
Community Participation	17	25.0	Partelow *et al*. (2022); Campbell *et al*. (2021); Engle & van Senten (2022)

As shown in Table 3, production expansion constitutes the dominant theme, appearing in 67.6% of the reviewed studies. This finding reflects a strong policy emphasis on increasing aquaculture output to meet domestic consumption needs and strengthen participation in global seafood markets. Garlock *et al*. (2020) describe this trend as part of a broader "blue revolution," characterized by rapid growth across species, production systems, and geographic regions. Similarly, Naylor *et al*. (2021) argue that aquaculture has become one of the most significant contributors to global aquatic food production, creating substantial opportunities for economic development and food security.

Export competitiveness represents the second most prominent theme identified in the literature. Numerous studies highlight the importance of international markets in shaping aquaculture policies, production standards, and investment decisions. Sustainability certification, traceability systems, and quality assurance mechanisms have become increasingly important tools for maintaining access to global seafood markets and enhancing the competitiveness of aquaculture products (Asche *et al*., 2018; Roheim *et al*., 2018). In Indonesia,

export-oriented development strategies have been particularly evident in shrimp and seaweed industries, which are regarded as priority commodities under the national Blue Economy framework (MMAF, 2023; Naylor *et al*., 2023).

The literature also demonstrates that investment promotion has become a central component of contemporary aquaculture governance. Governments and development agencies frequently view investment as a mechanism for improving infrastructure, increasing productivity, accelerating technological innovation, and strengthening market integration. Several studies argue that investment-friendly regulatory environments can enhance economic performance and attract private-sector participation, particularly in emerging aquaculture regions. However, the benefits of investment are not always distributed evenly among stakeholders, creating concerns regarding equity and access to development opportunities.

Despite the strong emphasis on economic performance, the literature increasingly recognizes that growth-oriented aquaculture development may generate significant environmental and social challenges. Environmental concerns were identified in nearly 40% of the reviewed studies, indicating growing awareness of the ecological consequences associated with production intensification. Issues such as habitat degradation, water pollution, disease outbreaks, and resource-use conflicts frequently emerge when production objectives are pursued without adequate governance safeguards (Boyd *et al*., 2020; Gephart *et al*., 2021; Troell *et al*., 2023). These findings suggest that economic growth alone cannot serve as a sufficient indicator of governance success.

The relatively lower frequencies associated with social inclusion and community participation further reveal an imbalance within existing governance discourse. While economic objectives receive substantial attention, fewer studies explicitly address questions of distributive justice, stakeholder empowerment, and community engagement. This pattern suggests that governance systems remain primarily oriented toward production and market performance, while social dimensions of sustainability often receive secondary consideration. Such findings are consistent with broader critiques of Blue Economy policies that emphasize economic expansion without adequately addressing social equity and governance legitimacy.

From the perspective of Interactive Governance theory, these findings indicate a potential mismatch between economic ambitions and governance capacity. Kooiman *et al*. (2005) argues that governability depends on the degree of alignment between the complexity of the system-to-be-governed and the adaptive capabilities of governance institutions. When economic expansion proceeds more rapidly than institutional adaptation, governance systems may struggle to manage environmental pressures, stakeholder conflicts, and emerging sustainability risks. Consequently, achieving long-term aquaculture sustainability requires balancing economic growth objectives with ecological resilience, social inclusion, and institutional effectiveness.

Overall, the literature suggests that economic growth remains a dominant organizing principle within Indonesian aquaculture governance. However, the thematic synthesis also reveals increasing recognition that future governance strategies must move beyond production-centered approaches toward more integrated models that simultaneously address economic performance, environmental sustainability, and social well-being. This transition provides the foundation for the next governance dimension examined in this review: ecological sustainability and environmental pressures within aquaculture systems (Troell *et al*., 2023; FAO, 2024).

Ecological Sustainability and Environmental Pressures

Ecological sustainability has become one of the most critical concerns in contemporary aquaculture governance. Although aquaculture is frequently promoted as a solution to

increasing global demand for aquatic foods, its expansion and intensification may generate substantial environmental pressures when not supported by effective governance mechanisms. Consequently, environmental sustainability has emerged as a central theme within policy debates concerning the future of aquaculture development and the broader Blue Economy agenda (Boyd *et al*., 2020; Troell *et al*., 2023; FAO, 2024).

The reviewed literature consistently identifies ecological degradation as a major challenge affecting the long-term sustainability of aquaculture systems. Environmental impacts reported across studies include mangrove conversion, declining water quality, nutrient loading, disease outbreaks, habitat degradation, and increasing competition for coastal space. These issues demonstrate that aquaculture development is closely linked to the health and resilience of surrounding ecosystems and therefore cannot be separated from broader environmental governance considerations (Gephart *et al*., 2021; Davies *et al*., 2019).

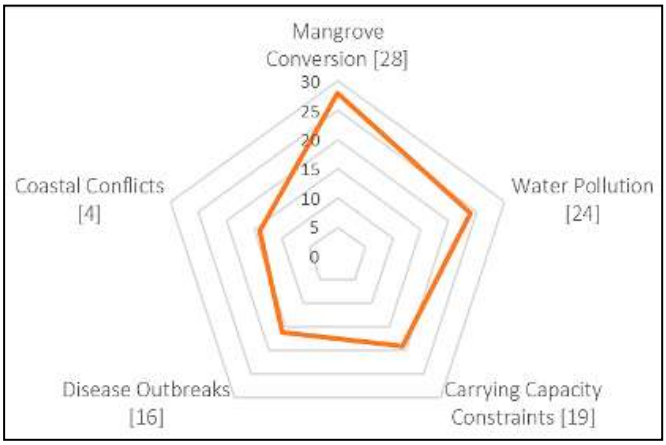

Figure 2. Distribution of Ecological Governance Issues Identified in the Literature
Representative studies: Mangrove conversion (Luo et al., 2022; Boyd et al., 2020; Troell et al., 2023; Davies et al., 2019); Water pollution (Gephart et al., 2021; Yang et al., 2025; Henriksson et al., 2021); Carrying capacity (Aguilar-Manjarrez et al., 2017; Brugère et al., 2019; Falconer et al., 2023; Davies et al., 2019); Disease outbreaks (Henriksson et al., 2021; Boyd et al., 2020; Ahmed & Turchini, 2021; Thornber et al., 2026); Coastal conflicts (Oremus et al., 2020; Davies et al., 2019; Partelow et al., 2022).

As shown in Figure 2, mangrove conversion emerged as the most frequently discussed ecological issue in the reviewed literature. The expansion of shrimp ponds and coastal aquaculture facilities has historically contributed to the loss of mangrove ecosystems in many tropical regions, including Southeast Asia. Mangroves provide essential ecosystem services, including coastal protection, carbon sequestration, biodiversity conservation, and nursery habitats for aquatic species. Their conversion therefore raises concerns regarding both environmental sustainability and long-term aquaculture resilience (Luo *et al*., 2022; Boyd *et al*., 2020; Crona *et al*. 2023; Troell *et al*., 2023).

Water pollution represents the second most frequently reported ecological challenge. Several studies highlight the impacts of excessive nutrient discharge, organic waste accumulation, chemical inputs, and antimicrobial use on surrounding aquatic ecosystems. Such environmental pressures may reduce water quality, alter ecosystem functioning, and increase vulnerability to disease outbreaks. These findings suggest that environmental performance remains a critical determinant of sustainable aquaculture development and requires effective monitoring and management systems (Edwards, 2015; Henriksson *et al*., 2021; Gephart *et al*., 2021).

Carrying-capacity limitations constitute another recurring theme within the literature. The concept of carrying capacity refers to the ecological ability of a water body or coastal ecosystem to support aquaculture activities without experiencing unacceptable environmental degradation. Studies increasingly emphasize ecosystem-based approaches to aquaculture planning that integrate ecological thresholds, spatial suitability assessments, and adaptive management principles into governance frameworks (Aguilar-Manjarrez *et al*., 2017; Brugère *et al*., 2019; Falconer *et al*., 2023). Failure to account for ecological carrying capacity may undermine both environmental sustainability and economic performance over time.

Disease outbreaks were also identified as a significant environmental governance concern. Intensification of aquaculture production often increases stocking densities and biological interactions that facilitate the spread of pathogens. In addition to direct production losses, disease events may generate broader ecological impacts through increased use of chemicals, antibiotics, and other management interventions. Recent studies therefore emphasize the importance of biosecurity measures, ecosystem health monitoring, and adaptive governance strategies capable of addressing emerging environmental risks (Ahmed & Turchini, 2021; Henriksson *et al*., 2021; Boyd *et al*., 2020).

The literature further highlights the growing incidence of coastal-use conflicts associated with aquaculture expansion. Competition among aquaculture, fisheries, tourism, conservation, urban development, and other coastal activities often creates tensions regarding access to resources and space. Such conflicts illustrate the interconnected nature of coastal social-ecological systems and underscore the need for integrated governance approaches capable of balancing multiple stakeholder interests (Partelow *et al*., 2022; Mamuaya *et al*., 2026).

Beyond individual environmental issues, several studies argue that ecological sustainability should be understood as a broader question of social-ecological resilience. Rather than focusing exclusively on environmental impacts, resilience-oriented approaches emphasize the capacity of ecosystems and governance institutions to adapt to change, absorb disturbances, and maintain essential functions over time. Climate change, biodiversity loss, and increasing resource competition have further strengthened the relevance of resilience-based governance frameworks within contemporary aquaculture policy discussions (Brugère *et al*., 2019; Troell *et al*., 2023; FAO, 2024).

From an Interactive Governance perspective, environmental sustainability is not merely an ecological objective but also a governance challenge. The capacity of governing systems to understand ecological complexity, respond to uncertainty, and adapt management practices determines the extent to which aquaculture systems remain governable under changing environmental conditions. Effective governability therefore requires governance institutions capable of integrating scientific knowledge, stakeholder participation, and adaptive management into decision-making processes (Colson *et al*., 2025; Cojocaru *et al*., 2026).

Overall, the thematic synthesis demonstrates that ecological sustainability constitutes a foundational dimension of aquaculture governability. While aquaculture offers significant opportunities for food production and economic development, its long-term viability depends on governance systems that can effectively manage environmental pressures, maintain ecosystem resilience, and balance competing demands on coastal and aquatic resources. These findings lead directly to the next governance challenge identified in the literature: regulatory fragmentation and institutional coordination.

Regulatory Fragmentation and Institutional Coordination

Regulatory and institutional arrangements play a fundamental role in determining the effectiveness of aquaculture governance. As aquaculture systems become increasingly

integrated with environmental management, spatial planning, food security, trade, and rural development policies, governance responsibilities are often distributed across multiple agencies and regulatory frameworks (Figure 3). While such institutional diversity may provide opportunities for comprehensive governance, it can also generate fragmentation, overlapping authority, and policy inconsistency when coordination mechanisms are weak (Abate *et al*., 2018; Anderson *et al*., 2019; Schøning *et al*., 2023).

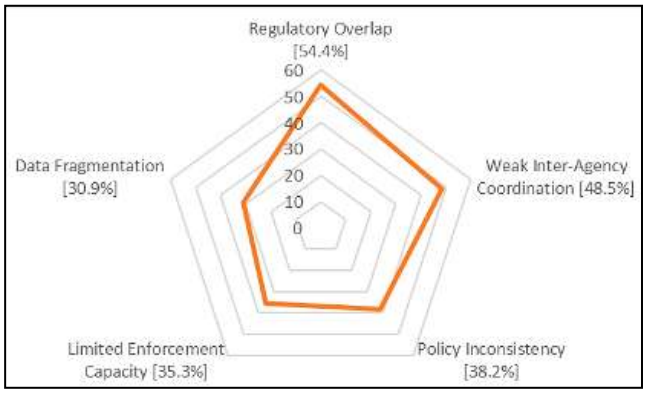

Figure 3. Institutional Governance Challenges Identified in the Literature

The reviewed literature consistently identifies regulatory fragmentation as one of the most significant barriers to sustainable aquaculture governance. Aquaculture activities are commonly regulated through a combination of fisheries laws, environmental regulations, coastal management policies, water-use permits, investment regulations, and local government ordinances. The coexistence of multiple legal and institutional frameworks often creates ambiguity regarding authority, accountability, and enforcement responsibilities (Davies *et al*., 2019; Clark *et al*., 2026).

As presented in Figure 3, regulatory overlap emerged as the most frequently reported governance challenge. More than half of the reviewed studies highlighted situations in which multiple institutions exercised authority over the same resources, activities, or geographic areas. Such overlap often leads to duplication of administrative procedures, conflicting policy objectives, and uncertainty among stakeholders regarding compliance requirements. Abate *et al*. (2018) demonstrate that institutional rivalry within shared regulatory spaces can reduce governance efficiency and negatively affect overall social welfare. Similar concerns are evident in aquaculture governance systems where multiple agencies pursue competing mandates without sufficient coordination.

Weak inter-agency coordination represents the second most prominent institutional challenge. Effective aquaculture governance requires collaboration among agencies responsible for fisheries, environmental protection, spatial planning, investment promotion, public health, and local development. However, many studies report insufficient communication, fragmented decision-making processes, and limited information sharing among these institutions. As a result, governance responses often become reactive rather than adaptive, reducing the capacity of institutions to address complex and rapidly changing challenges (Anderson *et al*., 2019; Falconer *et al*., 2023; Schøning *et al*., 2023).

Policy inconsistency also emerged as a recurring concern within the reviewed literature. Development-oriented policies frequently prioritize production expansion and investment attraction, while environmental regulations emphasize ecosystem protection and resource conservation. In some cases, these objectives are not adequately aligned, creating contradictory signals for both regulators and industry actors. Such inconsistencies may weaken policy

implementation and reduce stakeholder confidence in governance systems (Naylor *et al*., 2023; Schøning *et al*., 2023; Endarto *et al*., 2025; Bankes & VanderZwang, 2016).

Another important challenge involves limited enforcement capacity. Although regulatory frameworks often contain comprehensive provisions concerning environmental management, licensing, and operational standards, implementation remains constrained by insufficient financial resources, personnel limitations, technical expertise, and monitoring infrastructure. Several studies suggest that enforcement deficiencies can undermine regulatory legitimacy and reduce incentives for compliance among aquaculture operators (Engle & van Senten, 2022; Clark *et al*., 2026; Anderson *et al*., 2025).

Data fragmentation constitutes an additional governance constraint that has gained increasing attention in recent years. Effective governance depends upon reliable information regarding production systems, environmental conditions, disease outbreaks, spatial planning, and market performance. However, many institutions continue to operate with fragmented databases, inconsistent reporting mechanisms, and limited interoperability among information systems. Such deficiencies hinder evidence-based decision-making and weaken adaptive governance capacity (Jolly *et al*., 2023; Toonen *et al*., 2025; Falconer *et al*., 2023).

The reviewed literature further suggests that regulatory fragmentation is not merely an administrative problem but also reflects deeper institutional and political dynamics. From a governance perspective, fragmentation often arises because different agencies pursue distinct objectives, operate under separate legal mandates, and respond to different stakeholder constituencies. Consequently, governance outcomes are shaped not only by formal regulations but also by institutional relationships, power structures, and negotiation processes among actors (Abate *et al*., 2018; Unger, 1983; Mamuaya *et al*., 2026).

This interpretation aligns closely with the Interactive Governance perspective. Kooiman (2003) argues that governance effectiveness depends on the capacity of institutions to manage complexity through coordination, learning, and adaptation. When governance systems become fragmented, their ability to respond coherently to social-ecological challenges is diminished. Institutional coordination therefore becomes a critical component of governability, particularly in sectors such as aquaculture where ecological, economic, and social processes are highly interconnected (Yang *et al*., 2025; Jentoft & Chuenpagdee, 2015; Li & Li, 2020).

Recent literature increasingly advocates integrated governance approaches as a means of addressing regulatory fragmentation. Such approaches emphasize cross-sectoral collaboration, ecosystem-based planning, harmonized regulatory frameworks, shared information systems, and multi-level governance arrangements capable of linking national policies with local implementation processes. These strategies are viewed as essential for improving policy coherence and strengthening the adaptive capacity of aquaculture governance systems (Brugère *et al*., 2019; Falconer *et al*., 2023; Toonen *et al*., 2025).

Overall, the thematic synthesis demonstrates that regulatory fragmentation and weak institutional coordination remain major constraints on aquaculture governability. Although regulatory systems continue to expand in scope and complexity, their effectiveness ultimately depends on the ability of institutions to coordinate actions, share information, reconcile competing objectives, and adapt to changing environmental and socio-economic conditions. These findings lead directly to the next governance dimension examined in this review: the interactions among state institutions, market actors, and local communities in shaping aquaculture governance outcomes.

State–Market–Community Interactions

A central premise of Interactive Governance theory is that governance outcomes are shaped not solely by government intervention but by the interactions among multiple actors operating within a social-ecological system. In aquaculture, these actors typically include state institutions, private-sector enterprises, producer organizations, local communities, non-governmental organizations, research institutions, and consumers (Figure 4). The effectiveness of governance therefore depends not only on formal regulations but also on the quality of relationships, coordination mechanisms, and power dynamics among these actors (Jentoft & Chuenpagdee, 2015; Chuenpagdee & Jentoft, 2019).

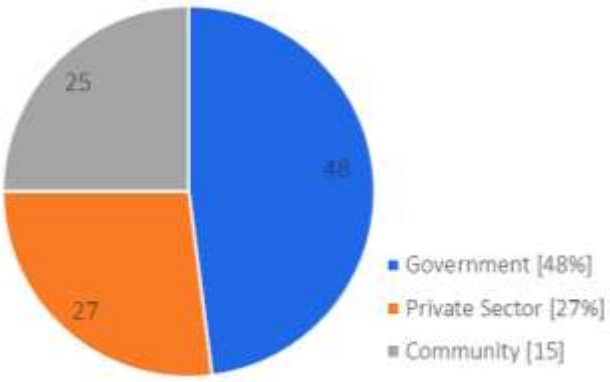

Figure 4. Relative Emphasis of Governance Actors in the Literature
Representative studies: Government (Anderson et al., 2019; Abate et al., 2018; Clark et al., 2026; Schøning et al., 2023); Private Sector (Roheim et al., 2018; Alfnes et al., 2017; Cozzolino et al., 2025); Community (Partelow et al., 2022; Campbell et al., 2021; Engle & van Senten, 2022; Rashid et al., 2018).

The thematic synthesis revealed that the literature on aquaculture governance remains predominantly focused on governmental institutions, while comparatively less attention is devoted to the interactions between public authorities, market actors, and local communities. Nevertheless, the reviewed studies consistently emphasize that governance challenges and sustainability outcomes emerge from the interplay among these stakeholder groups rather than from the actions of any single actor alone (Davies *et al*., 2019; Partelow *et al*., 2022; Toonen et al., 2025).

As illustrated in Figure 4, government institutions constitute the most prominent governance actors within the reviewed literature. Nearly half of the studies focus primarily on regulatory systems, policy frameworks, institutional performance, and administrative arrangements. This emphasis reflects the traditional assumption that governments are the primary actors responsible for designing, implementing, and enforcing governance systems. Regulatory agencies remain central in establishing licensing procedures, environmental standards, spatial planning frameworks, and monitoring mechanisms that shape aquaculture development (Anderson *et al*., 2019; Abate *et al*., 2018; Clark *et al*., 2026).

However, the literature increasingly recognizes that government-centered governance models alone are insufficient for addressing the complexity of contemporary aquaculture systems. Markets play a growing role in shaping production practices, sustainability standards, technological innovation, and investment decisions. Certification schemes, traceability requirements, consumer preferences, and international trade regulations increasingly influence governance outcomes, often operating alongside or even beyond formal state regulation (Roheim *et al*., 2018; Bush *et al*., 2013; Alfnes *et al*., 2017). As a result, private-sector actors have become important governance agents within global seafood systems.

Market-based governance mechanisms have expanded significantly in recent years. Sustainability certification programs, eco-labeling initiatives, and value-chain governance arrangements seek to encourage environmentally responsible and socially acceptable production practices. Several studies suggest that these mechanisms can complement governmental regulation by creating economic incentives for improved environmental performance and market accountability (Roheim et al., 2018; Alfnes et al., 2017; Toonen et al., 2025). Nevertheless, concerns remain regarding unequal access to certification systems, compliance costs, and the ability of small-scale producers to participate effectively in increasingly regulated markets (Brugère *et al*., 2023).

Local communities represent the third major actor group identified in the literature. Community participation is widely recognized as essential for achieving socially legitimate and environmentally sustainable governance outcomes. Local stakeholders often possess valuable ecological knowledge, long-term resource stewardship experience, and direct exposure to the impacts of governance decisions. Their involvement can therefore improve the quality of decision-making, strengthen compliance, and enhance governance legitimacy (Partelow *et al*., 2022; Campbell *et al*., 2021).

Despite growing recognition of participatory governance principles, the literature indicates that community involvement often remains limited in practice. Decision-making processes are frequently dominated by governmental agencies and commercial interests, while local communities and small-scale producers have comparatively less influence over policy formulation and resource allocation. Such imbalances may contribute to governance conflicts, reduced stakeholder trust, and unequal distribution of development benefits (Rashid *et al*., 2018; Brugère *et al*., 2023; Chuenpagdee & Jentoft, 2019).

The interaction between state, market, and community actors also influences governance legitimacy. Governance systems are more likely to achieve compliance and long-term effectiveness when stakeholders perceive decision-making processes as fair, transparent, and inclusive. Conversely, governance arrangements that privilege particular interests while marginalizing others may generate resistance, conflict, and reduced institutional credibility. Several studies therefore emphasize the importance of collaborative governance mechanisms that facilitate dialogue, trust-building, and shared responsibility among stakeholders (Engle & van Senten, 2022; Partelow *et al*., 2022; Toonen *et al*., 2025).

From the perspective of Critical Legal Studies, these interactions reflect broader power relations embedded within legal and institutional structures (Mamuaya, 2025). Regulatory frameworks often shape access to resources, economic opportunities, and political influence, thereby affecting the distribution of benefits and risks among stakeholder groups. Consequently, governance should not be viewed solely as a technical process of rule implementation but also as a political process involving negotiation, contestation, and the exercise of power (Unger, 1983; Abate *et al*., 2018).

Interactive Governance theory provides a useful framework for understanding these dynamics. Rather than focusing exclusively on government authority, the theory conceptualizes governance as a process of interaction among diverse actors operating within complex social-ecological systems. Effective governability therefore depends on the capacity of these actors to communicate, cooperate, learn, and adapt collectively in response to changing environmental and socio-economic conditions (Kooiman *et al*., 2005; Jentoft & Chuenpagdee, 2015).

Overall, the reviewed literature demonstrates that aquaculture governance outcomes are strongly influenced by the relationships among state institutions, market actors, and local communities. While governmental institutions continue to play a dominant role, growing

evidence suggests that sustainable aquaculture governance requires more collaborative and participatory approaches capable of integrating diverse interests, knowledge systems, and governance capacities. These findings provide an important foundation for examining the next governance dimension emerging from the thematic synthesis: social equity, inclusion, and governance legitimacy.

Social Equity, Inclusion, and Governance Legitimacy

Beyond economic performance and environmental sustainability, social equity has emerged as a critical dimension of aquaculture governance. Increasingly, scholars argue that governance systems should be evaluated not only by their ability to enhance production and protect ecosystems, but also by their capacity to distribute benefits fairly, reduce social vulnerabilities, and ensure meaningful participation among affected stakeholders. Consequently, social equity has become a central component of sustainability discourse within fisheries, aquaculture, and broader Blue Economy debates (Béné *et al*., 2016; Brugère *et al*., 2023; Tigchelaar *et al*., 2022; Belton *et al*., 2018).

The reviewed literature indicates that aquaculture development generates both opportunities and challenges for social inclusion (Table 6). On the one hand, aquaculture contributes to employment generation, income diversification, food security, and rural development. On the other hand, unequal access to capital, technology, markets, information, and governance processes may create disparities among stakeholder groups. Small-scale producers, traditional resource users, women, and marginalized coastal communities often face greater barriers to participation and benefit sharing than larger commercial enterprises.

Table 6. Social Equity and Inclusion Issues Identified in the Literature

Social Equity Issue	Representative Studies
Unequal access to resources and capital	Rashid *et al*. (2018); Béné *et al*. (2016); Brugère *et al*. (2023)
Marginalization of small-scale producers	Chuenpagdee & Jentoft (2019); Partelow *et al*. (2022); Engle & van Senten (2022)
Uneven distribution of economic benefits	Béné *et al*. (2016); Naylor *et al*. (2023); Gephart *et al*., (2021)
Limited stakeholder participation	Campbell *et al*. (2021); Partelow *et al*. (2022); Froehlich *et al*. (2017)
Governance legitimacy and social acceptance	Abate *et al*. (2028); Engle & van Senten (2022); Boyd *et al*. (2020)

One of the most frequently reported concerns involves unequal access to resources and economic opportunities. Several studies demonstrate that larger and better-capitalized aquaculture enterprises are generally better positioned to access financing, technology, certification systems, and export markets. In contrast, small-scale producers often face structural constraints that limit their competitiveness and adaptive capacity. Such inequalities may reinforce existing socio-economic disparities and reduce the inclusiveness of aquaculture development strategies (Brugère *et al*., 2023; Naylor *et al*., 2023).

The literature also highlights the vulnerability of small-scale aquaculture operators within increasingly globalized seafood markets. As sustainability standards, traceability requirements, and certification schemes become more influential, compliance costs may disproportionately affect smaller producers. While these governance mechanisms can improve environmental performance and market accountability, they may also create unintended barriers to market participation if adequate support mechanisms are not provided (Roheim *et al*., 2018; van Senten *et al*., 2018).

Participation emerges as another critical factor influencing social inclusion and governance outcomes. Numerous studies emphasize that meaningful stakeholder engagement improves policy legitimacy, strengthens compliance, and enhances governance effectiveness. Participatory governance approaches enable local communities to contribute knowledge, articulate concerns, and influence decisions affecting their livelihoods and environments. Such involvement is particularly important in social-ecological systems characterized by uncertainty, complexity, and diverse stakeholder interests (Partelow *et al*., 2022; Campbell *et al*., 2021).

However, participation alone does not automatically guarantee equitable governance outcomes. Several studies note that stakeholder engagement processes may be influenced by unequal power relations, differences in access to information, and varying levels of organizational capacity. Consequently, governance arrangements that appear participatory on paper may still produce outcomes that favor more powerful actors. Addressing such imbalances requires governance mechanisms that actively promote inclusiveness, transparency, and accountability throughout decision-making processes.

The concept of governance legitimacy provides an important lens through which these issues can be understood. Governance legitimacy refers to the extent to which stakeholders perceive governance institutions, regulations, and decision-making processes as appropriate, fair, and trustworthy. Legitimacy is particularly important in aquaculture governance because compliance often depends not only on legal obligations but also on stakeholder acceptance and social support. Governance systems perceived as legitimate are generally more effective in fostering cooperation, reducing conflicts, and encouraging collective action (VanderZwang & Chao, 2006; Taufiqurrohman *et al*., 2023).

Several studies suggest that governance legitimacy is strengthened when stakeholders are genuinely involved in decision-making processes and when governance outcomes are perceived as equitable. Conversely, perceptions of exclusion, unequal treatment, or disproportionate benefit allocation can undermine trust in institutions and weaken governance effectiveness. Thus, social equity should be viewed not merely as a normative objective but also as a practical condition for achieving long-term governability and sustainability (Engle & van Senten, 2022; Chuenpagdee & Jentoft, 2019; Partelow *et al*., 2022).

From an Interactive Governance perspective, social equity and inclusion are integral components of governability. his requires not only effective institutions but also governance arrangements that recognize different interests, values, and capacities within society. Consequently, governability depends as much on social relationships and legitimacy as it does on formal regulatory structures.

Overall, the thematic synthesis demonstrates that social equity, inclusion, and governance legitimacy are fundamental dimensions of sustainable aquaculture governance. While economic growth and environmental protection remain important objectives, long-term governance success ultimately depends on the extent to which governance systems distribute benefits fairly, facilitate meaningful participation, and maintain stakeholder trust. These findings also suggest that future governance reforms should pay greater attention to social justice considerations alongside economic and ecological objectives. The next section examines an emerging dimension that has received increasing attention in recent years: digitalization and smart aquaculture governance.

Emerging Trends: Digitalization and Smart Aquaculture Governance

One of the most significant developments identified in the reviewed literature is the growing integration of digital technologies into aquaculture production and governance systems. Advances in artificial intelligence (AI), the Internet of Things (IoT), big data analytics,

cloud computing, autonomous monitoring systems, and decision-support platforms are transforming how aquaculture operations are managed and regulated. These technologies are increasingly viewed not only as tools for improving production efficiency but also as mechanisms for strengthening governance capacity, transparency, environmental monitoring, and adaptive management (Li & Li, 2020; Yue & Shen, 2022; Rowan, 2023).

The thematic synthesis indicates that digitalization has become a rapidly expanding area of aquaculture research, particularly since 2020. Several studies emphasize that smart aquaculture technologies can generate real-time information on water quality, fish health, feeding efficiency, environmental conditions, and production performance. Such information can improve managerial decision-making while simultaneously supporting governance objectives related to environmental compliance, traceability, and sustainability assessment (Table 7).

Table 7. Emerging Digital Governance Themes in Aquaculture

Digital Governance Theme	Representative Studies
Artificial Intelligence and Decision Support	Yang *et al*. (2025); Ratan *et al*. (2026); Li & Li (2020); Frederico (2023)
Internet of Things (IoT) Monitoring Systems	Prapti *et al*. (2022); Al-Hussaini *et al*. (2018); Biazi & Marques (2023)
Smart Aquaculture and Automation	Afewerki *et al*. (2023); Rowan (2023); Yue & Shen (2022); Amundsen *et al*. (2021)
Digital Traceability and Market Governance	Roheim *et al*. (2018); Rowan (2023); Toonen *et al*. (2025); Ali *et al*., (2021)
Data-Driven Governance and Performance Indicators	Anderson *et al*. (2025); Toonen *et al*. (2025); Jolly *et al*. (2023)
Environmental Monitoring and Early Warning Systems	Ahmed & Turchini (2021); Falconer *et al*. (2023)

Among the emerging technologies discussed in the literature, IoT-based monitoring systems represent one of the most widely adopted innovations. These systems enable continuous monitoring of water quality parameters such as temperature, dissolved oxygen, pH, salinity, and nutrient concentrations. Real-time monitoring can enhance operational efficiency while reducing environmental risks associated with poor water quality management. Furthermore, digital monitoring systems provide valuable information for regulatory agencies seeking to improve environmental oversight and compliance monitoring (Al-Hussaini *et al*., 2018; Prapti *et al*., 2022; Biazi & Marques, 2023).

Artificial intelligence has also received growing attention as a tool for supporting decision-making in aquaculture governance. AI applications include disease prediction, feeding optimization, production forecasting, environmental risk assessment, and automated management systems. Several studies suggest that AI-driven approaches may significantly improve resource efficiency and reduce environmental impacts through more precise and adaptive management practices (Li & Li, 2020; Yang *et al*., 2025; Ratan *et al*., 2026). However, the adoption of AI technologies also raises questions regarding data ownership, algorithmic transparency, and equitable access to technological innovation.

Digitalization is also reshaping market governance within global seafood supply chains. Increasing consumer demand for transparency, sustainability, and food safety has stimulated the development of digital traceability systems capable of tracking products throughout the production and distribution process. These systems can strengthen accountability, improve market access, and support certification programs by providing verifiable information regarding production practices and environmental performance (Roheim *et al*., 2018; Rowan, 2023; Toonen *et al*., 2025).

Several studies further emphasize the potential role of digital technologies in strengthening governance performance through improved data integration and evidence-based decision-making. Governance systems often suffer from fragmented information, inconsistent reporting mechanisms, and limited monitoring capacity. Digital platforms capable of integrating environmental, production, and socio-economic data may help address these challenges by enhancing institutional coordination and supporting adaptive governance processes (Anderson *et al*., 2025; Jolly *et al*., 2023; Toonen *et al*., 2025).

Despite these opportunities, the literature also identifies several governance challenges associated with digital transformation. Technological adoption remains uneven across regions, production systems, and stakeholder groups. Small-scale producers often face financial, technical, and infrastructural barriers that limit access to advanced digital technologies. Consequently, digitalization may unintentionally reinforce existing inequalities if governance systems fail to address issues of accessibility, affordability, and capacity building (Brugère *et al*., 2023; Engle & van Senten, 2022; Rowan, 2023).

Data governance emerges as another important concern. The increasing reliance on digital technologies generates vast quantities of information that must be collected, managed, shared, and protected appropriately. Questions concerning data ownership, privacy, interoperability, transparency, and institutional responsibility are becoming increasingly important within contemporary governance discussions. Effective digital governance therefore requires not only technological innovation but also appropriate regulatory frameworks and institutional arrangements capable of managing digital resources responsibly (Afewerki *et al*., 2023; Toonen *et al*., 2025; Schøning *et al*., 2023).

From an Interactive Governance perspective, digitalization should not be viewed merely as a technological transformation but as a governance transformation. Digital technologies have the potential to reshape relationships among governments, markets, communities, and ecosystems by improving information flows, facilitating stakeholder participation, and enhancing adaptive management capabilities. At the same time, technological innovations introduce new governance challenges that require institutional learning, regulatory adaptation, and inclusive decision-making (Jentoft & Chuenpagdee, 2015; Jolly *et al*., 2023).

The findings of this thematic synthesis suggest that digitalization represents both an opportunity and a challenge for aquaculture governability. When effectively integrated into governance systems, digital technologies can strengthen monitoring, transparency, accountability, and adaptive management. However, their benefits depend on the capacity of governance institutions to ensure equitable access, maintain data integrity, and integrate technological innovations within broader sustainability objectives. These developments are particularly relevant to the governance challenge identified in Figure 1 concerning weak enforcement and data systems.

Taken together, the preceding themes—economic growth orientation, ecological sustainability, institutional coordination, stakeholder interactions, social equity, and digital governance—illustrate the multidimensional nature of aquaculture governability. The following section synthesizes these findings into an integrated conceptual framework for understanding and strengthening aquaculture governance in Indonesia.

Toward a Conceptual Framework of Indonesian Aquaculture Governability

The preceding thematic synthesis demonstrates that aquaculture governance is shaped by multiple interdependent economic, ecological, institutional, technological, and social factors. Rather than operating independently, these dimensions interact dynamically within a complex social-ecological system, collectively influencing the capacity of governance arrangements to

achieve sustainability objectives. Consequently, understanding aquaculture governance requires an integrative perspective capable of capturing the relationships among governance actors, institutions, environmental conditions, and development priorities (FAO, 2017; Chuenpagdee & Jentoft, 2019).

Across the 68 reviewed studies, five recurring governance dimensions consistently emerged as the most influential determinants of aquaculture governability. These dimensions include economic growth orientation, ecological sustainability, institutional coordination, state–market–community interactions, and enforcement and knowledge systems. Although each dimension has been examined separately within the literature, the thematic synthesis indicates that governance outcomes are primarily shaped by their interactions rather than by any single factor operating in isolation.

Table 8. Governance Dimensions Emerging from the Thematic Synthesis

Governance Dimension	Main Issues Identified	Representative Studies
Economic Growth Orientation	Production expansion, export competitiveness, investment promotion	Garlock *et al*. (2020); Anderson *et al*. (2019); Naylor *et al*. (2023); MMAF (2023)
Ecological Sustainability	Environmental degradation, carrying capacity, ecosystem resilience	Boyd *et al*. (2020); Gephart *et al*. (2021); Troell *et al*. (2023); Brugère *et al*. (2019)
Institutional Coordination	Regulatory overlap, policy inconsistency, fragmented authority	Abate *et al*. (2018); Anderson *et al*. (2019); Schøning *et al*. (2023); Clark *et al*. (2026)
State–Market–Community Interaction	Stakeholder participation, market governance, collaborative governance	Roheim *et al*. (2018); Partelow *et al*. (2022); Bush *et al*. (2013)
Enforcement and Knowledge Systems	Monitoring capacity, digital governance, data integration	Jolly *et al*. (2023); Anderson *et al*. (2025); Toonen *et al*. (2025); Rowan (2023)

Table 8 summarizes the principal governance dimensions identified through the thematic synthesis. Economic growth orientation emerged as the dominant driver of aquaculture development, reflecting the strategic importance of production growth, export earnings, and investment expansion within national development agendas. However, the literature also reveals that growth-oriented governance approaches may generate sustainability challenges when ecological constraints, social equity considerations, and institutional capacities are insufficiently integrated into policy design and implementation (Naylor *et al*., 2023; Troell *et al*., 2023; FAO, 2024).

Ecological sustainability constitutes the second major dimension within the conceptual framework. The reviewed studies consistently demonstrate that environmental conditions fundamentally shape the long-term viability of aquaculture systems. Ecosystem degradation, habitat loss, declining water quality, disease outbreaks, and climate-related pressures directly affect both production performance and governance effectiveness. Consequently, ecological resilience should be viewed not merely as an environmental objective but as a prerequisite for long-term governability (Boyd *et al*., 2020; Gephart *et al*., 2021; Troell *et al*., 2023).

Institutional coordination represents another critical determinant of governance performance. The literature repeatedly identifies fragmented regulatory frameworks, overlapping mandates, and weak inter-agency coordination as significant barriers to effective governance. In complex governance environments, the capacity of institutions to collaborate, share information, and align policy objectives becomes essential for addressing social-

ecological challenges and reducing governance inefficiencies (Abate *et al*., 2018; Schøning *et a*l., 2023; Clark *et al*., 2026).

The thematic synthesis further highlights the importance of interactions among state institutions, market actors, and local communities. Governance outcomes are strongly influenced by the quality of stakeholder relationships, levels of participation, and mechanisms for conflict resolution and collective decision-making. Studies increasingly suggest that collaborative governance arrangements are better suited to managing the complexity of aquaculture systems than traditional state-centered approaches. Such arrangements facilitate knowledge exchange, improve stakeholder legitimacy, and enhance adaptive capacity (Partelow *et al*., 2022; Chuenpagdee & Jentoft, 2019; Msomphora, 2024)).

A fifthdimension concerns enforcement and knowledge systems, including monitoring mechanisms, scientific information, digital governance tools, and data management capabilities. Effective governance requires timely, reliable, and accessible information to support decision-making, environmental oversight, and adaptive management. Recent advances in digital technologies, artificial intelligence, and integrated information systems offer new opportunities for strengthening governance performance, although challenges related to accessibility, institutional capacity, and data governance remain significant (Jolly *et al*., 2023; Rowan, 2023; Toonen *et al*., 2025).

The relationships among these dimensions are synthesized in Figure 5, which presents the conceptual framework of Indonesian aquaculture governability developed through this review. The framework illustrates that governability emerges from the interaction of economic, ecological, institutional, social, and informational dimensions rather than from isolated governance interventions. Improvements in one dimension may strengthen or weaken outcomes in another, highlighting the need for integrated and adaptive governance strategies.

Figure 5. Conceptual Framework of Indonesian Aquaculture Governability

The conceptual framework proposes that economic growth orientation, ecological sustainability, institutional coordination, state–market–community interaction, and enforcement and knowledge systems collectively influence the overall level of aquaculture governability. These dimensions operate through continuous feedback relationships, shaping the capacity of governance systems to respond to environmental uncertainty, stakeholder diversity, market dynamics, and institutional complexity. Governability therefore emerges as a dynamic property of the broader social-ecological system rather than as a fixed outcome of regulatory intervention alone.

From an Interactive Governance perspective, the framework highlights the importance of achieving an appropriate fit between the complexity of the system-to-be-governed and the adaptive capacity of the governing system. Governance systems that effectively integrate environmental knowledge, institutional coordination, stakeholder participation, and adaptive learning are more likely to achieve sustainable outcomes than systems relying primarily on centralized regulation or production-oriented policy objectives (Chuenpagdee & Jentoft, 2019).

The framework also provides a bridge between theoretical and practical dimensions of aquaculture governance. Theoretically, it contributes to the growing literature on governability by integrating insights from Interactive Governance, social-ecological systems theory, and governance studies. Practically, it offers a conceptual foundation for policymakers seeking to strengthen sustainability, resilience, and governance effectiveness within Indonesia's aquaculture sector (Troell *et al*., 2023).

Overall, the thematic synthesis suggests that future aquaculture governance should move beyond narrowly defined production objectives toward more holistic and adaptive governance approaches. By recognizing the interconnected nature of economic, ecological, institutional, social, and technological dimensions, *governance* systems may become better equipped to address the complex challenges associated with sustainable aquaculture development. The conceptual framework developed in this study therefore provides an analytical basis for understanding, evaluating, and improving aquaculture governability in Indonesia and potentially in other comparable social-ecological contexts.

CONCLUSION

Based on these findings, this study proposes a conceptual framework of Indonesian aquaculture governability in which economic growth orientation, ecological sustainability, institutional coordination, state–market–community interaction, and enforcement and knowledge systems function as mutually reinforcing dimensions. The framework contributes to the literature by integrating fragmented governance insights into a coherent analytical structure and provides a foundation for understanding how governance systems can evolve toward more adaptive, participatory, and sustainable forms of aquaculture development. Ultimately, governability should be understood as the capacity of governance systems and social-ecological systems to co-evolve in response to changing environmental, economic, and societal conditions

The findings suggest that future aquaculture policies in Indonesia should move beyond a predominantly production-centered paradigm toward an integrated governability approach that simultaneously strengthens ecological resilience, institutional coordination, stakeholder inclusion, and knowledge-based decision-making. Policy priorities should include improving regulatory coherence across sectors, strengthening ecosystem-based aquaculture management, expanding participatory governance mechanisms, enhancing digital monitoring and information systems, and promoting equitable access to economic opportunities for small-scale producers and coastal communities. Such measures would not only improve governance effectiveness but also strengthen the long-term sustainability and resilience of Indonesia's aquaculture sector.

While the conceptual framework developed in this study offers an integrated perspective on aquaculture governability, its practical application requires further empirical validation. Future research should therefore operationalize the five governance dimensions into measurable indicators and examine their relationships through case studies, stakeholder surveys, governance network analysis, and mixed-method approaches across diverse aquaculture regions in Indonesia. Such empirical work would enable the development of evidence-based governability indices and policy evaluation tools capable of supporting adaptive governance

interventions. In this way, the framework may serve not only as a theoretical model but also as a practical instrument for guiding governance reforms and sustainable aquaculture development in Indonesia.

REFERENCES

Abate, T.G., Nielsen, R. & Nielsen, M. (2018). Agency rivalry in a shared regulatory space and its impact on social welfare: The case of aquaculture regulation. *Aquaculture Economics & Management* 22(1), 27-48. doi:10.1080/13657305.2017.1334243

Afewerki, S., Asche, F., Misund, B., & Thorvaldsen, T. (2023). Innovation in the Norwegian aquaculture industry. *Rev Aquac.*, 15:759–771. doi:10.1111/raq.12755

Alfnes, F., Chen, X., & Rickertsen, K. (2017): Labeling farmed seafood: A review. *Aquaculture Economics & Management*, DOI: 10.1080/13657305.2017.1356398

Aguilar-Manjarrez, J., Soto, D., & Brummett, R. (2017). *Aquaculture zoning, site selection and area management under the eco-system approach to aquaculture*. Report ACS113536 (p. 395). Rome, FAO, and World Bank Group.

Ahmed, N., & Turchini, G.M. (2021). Recirculating aquaculture systems (RAS): Environmental solution and climate change adaptation. *J. Clean. Prod.*, 297, 126604. doi:10.1016/j.jclepro.2021.126604

Al-Hussaini, K., Zaionol, S.M., Ahmed, R.B., & Daud, S. (2018). IoT monitoring and automation data acquisition for recirculating aquaculture system using fog computing. *J.Comput.Hardw.Eng.*, 1. doi:10.63019/jche.v1i2.610

Ali, I., Cheng, Q., Ding, T., Yiguang, Q., Yuechao, Z., Sun, H., Peng, C., Naz, I., Li, J., & Liu, J., (2021). Micro-and nanoplastics in the environment: occurrence, detection, characterization and toxicity–A critical review. *J. Clean. Prod.*, 313, 127863. doi:10.1016/j.jclepro.2021.127863

Amundsen, H.B.., Caharija, W., & Pettersen, K.Y. (2021). Autonomous ROV inspections of aquaculture net pens using DVL. *IEEE J. Ocean. Eng.*,47(1), 1–19. doi:10.1109/JOE.2021.3105285

Anderson, J.L., Asche, F., Eggert, H., & Garlock, T.M. (2025) Introducing the aquaculture performance indicators: A tool to assess the triple bottomline in aquaculture systems, *Aquaculture Economics & Management*, 29:2, 136-158. doi: 10.1080/13657305.2024.2446143

Anderson, J. L. F., Asche, F., & Garlock, T. (2019). Economics of Aquaculture policy and regulation. *Annual Reviews of Resource Economics*, 11, 101–123.

Asche, F., Garlock, T. M., Anderson, J. L., Bush, S. R., Smith, M. D., Anderson, C. M., Chu, J., Garrett, K. A., Lem, A., Lorenzen, K., Oglend, A., Tveterås, R., Vannuccini, S., & Verner-Jeffreys, D. W. (2018). Three pillars of sustainability in fisheries and aquaculture: Environmental, social, and economic dimensions. *Marine Policy, 87*, 1–9. doi:10.1016/j.marpol.2017.10.013

Bankes, N., Dahl, I., VanderZwaag, D.L. (Eds.). (2016). *Aquaculture Law and Policy: Global, Regional, and National Perspectives*. Cheltenham. Edward Elgar Publishing.

Belton, B., Bush, S.R., Little, D.C. (2018). Not just for the wealthy: rethinking farmed fish consumption in the Global South. *Global Food Secur*. 16:85–92. doi:10.1016/jgfs.2017.10.005

Béné, C., Arthur, R., Norbury, H., Allison, E. H., Beveridge, M., Bush, S., Campling, L., Leschen, W., Little, D., Squires, D., Thilsted, S. H., Troell, M., & Williams, M. (2016). Contribution of fisheries and aquaculture to food security and poverty reduction:

Assessing the current evidence. *World Development, 79*, 177–196. doi:10.1016/j.worlddev.2015.11.007

Biazi, V., & Marques C. (2023). Industry 4.0-based smart systems in aquaculture: A comprehensive review. *Aquacultural Engineering*, 103, 102360. doi:10.1016/j.aquaeng.2023.102360

Boyd, C. E., D'Abramo, L. R., Glencross, B. D., Huyben, D. C., Juarez, L. M., Lockwood, G. S., McNevin, A. A., Tacon, A. G. J., Teletchea, F., Tomasso, J. R., & Tucker, C. S. (2020). Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges. . *J World Aquac Soc.*, *51*(3), 578–633. doi:10.1111/jwas.12714

Bueno, P., & Soto, D. (2017) *Adaptation strategies of the aquaculture sector to the impacts of climate change*. FAO Fisheries and Aquaculture Circular No. 1142.

Brugère, C., Aguilar-Manjarrez, J., Beveridge, M.C.M., & Soto, D. (2019). The ecosystem approach to aquaculture 10 years on – a critical review and consideration of its future role in blue growth. *Reviews in Aquaculture*, 11, 493–514. doi: 10.1111/raq.12242

Brugere, C., Bansal, T., Kruijssen, F., & Williams, M. (2023). Humanizing aquaculture development: Putting social and human concerns at the center of future aquaculture development. *J World Aquac Soc.*, 54:482–526. doi:10.1111/jwas.12959

Campbell, S. J., Jakub, R., Valdivia, A., Setiawan, H., Setiawan, A., Cox, C., Kiyo, A., Darman, Djafar, L. F., & Yulianto, I. (2021). Immediate impact of COVID-19 across tropical small-scale fishing communities. *Ocean & Coastal Management, 200*, 105485. doi:10.1016/j.ocecoaman.2020. 105485

Carlino-Costa, C., & de Andrade Belo, M.A. (2025). Ensuring Fish Safety Through Sustainable Aquaculture Practices. *Hygine*, 5(4), 51. doi:10.3390/hygiene5040051

Chuenpagdee, R., & Jentoft, S. (2019). *Transdisciplinarity for Small-Scale Fisheries Governance*. Springer. doi:10.1007/978-3-319-94938-3

Clark, C., van Senten, J., & Engle, C.R. (2026). The regulatory cost burden on Atlantic Coast shellfish farms. *North American Journal of Aquaculture*, 88(1). doi.:10.1093/naaqua/vraf039.

Cojocaru, A.L., Liu, Y., Smithz, M.D., Akpalu, W., Chavez, C., Dey, M.M., Dresdner, J., Kahui, V., Pincinatozz, R.B.M., & Tran, N. (2026). The "Seafood" System: Aquatic Foods, Food Security, and the Global South. *Review of Environmental Economics and Policy*, 16 (2), 306-326. doi:10.1086/721032

Colson, R., Arunkumar, A.S., Al Dahdah, M., & Jayaprakash, P. (2025). The Shrimp, the Judge and the Amendment: Courts' Contribution to Aquaculture Regulation in India. *Journal of Environmental Law*, 37 (1), 151-158. doi:10.1093/jel/eqaf001

Cozzolino, M., Salomone, R., Ricca, R., & Gulotta, T.M. (2025). Circular economy in aquaculture: An Italian survey to understand perceptions, challenges and options for transition. *Marine Policy*, 176, 106660. doi:10.1016/j.marpol.2025.106660.

Crona, B.I., Wassénius, E., Jonell, M., Koehn, J.Z., Short, R., Tigchelaar, M., Daw, T.D., Golden, C.D., Gephart, J.A., Allison, E.H., Bush, S.R., Cao, L., Cheung, W.W.L., DeClerck, F., Fanzo, F., Gelcich, S., Kishore, A., Halpern, B.S., Hicks, C.C., …& Wabnitz, C.C.C. (2023). Four ways blue foods can help achieve food system ambitions across nations. *Nature*, 616(7955):104–12. doi:10.1038/s41586-023-05737-x

Davies, I.P., Carranza, V., Froehlich, H.E., Gentry, R.R., Kareiva, P., & Halpern, B.S. (2019). & Governance of marine aquaculture: Pitfalls, potential, and pathways forward, *Marine Policy*, 104, 29-36. doi:10.1016/j.marpol.2019.02.054

Endarto, B., Indriastuty, D.E., & Mardiana, P. (2025). Legal transplantation of blue bond regulation in Indonesia, *Environmental Development*, 53, 101118, doi:10.1016/j.envdev.2024.101118.

Engle, C.R., & van Senten, J. (2022). Resilience of Communities and Sustainable Aquaculture: Governance and Regulatory Effects. *Fishes*, 7, 268. doi.10.3390/fishes7050268

Engle, C.R., D'Abramo, L., Ponniah, A.G., &Slater, M. (2017) Global aquaculture 2050. Editorial. . *J World Aquac Soc.*, 48 (1): 3–6.

Falconer, L., Cutajar, K., Krupandan, A., Capuzzo, E., Corner, R.A., Ellis, T., Jeffery, J., Mikkelsen, E., Moore, H., O'Beirn, F.X., O'Donohoe, P., Ruane, N.M., Shilland, R., Tett, P., & Telfer, T.C. (2023). Planning and licensing for marine aquaculture. *Rev Aquac*., 15:1374–1404. doi:10.1111/raq.12783

FAO. (Food and Agriculture Organization). (2017). *The 2030 Agenda and the Sustainable Development Goals: The challenge for aquaculture development and management*, by John Hambrey. Fisheries and Aquaculture Circular No. 1141, Rome

FAO (Food and Agriculture Organization). (2024). *The State of World Fisheries and Aquaculture 2024: Blue Transformation in Action*. Rome.

Frederico, G.F. (2023). ChatGPT in Supply Chains: Initial Evidence of Applications and Potential Research Agenda. *Logistic*, 7(2), 26. doi:10.3390/logistics7020026

Froehlich, H.E., Gentry, R.R., Rust, M.B., Grimm, D., Halpern, B.S. (2017) Public Perceptions of Aquaculture: Evaluating Spatiotemporal Patterns of Sentiment around the World. *PLoS ONE*, 12(1): e0169281. doi:10.1371/journal.pone.0169281

Garlock, T., Asche. F., Anderson, J., Bjørndal, T., Kumar, G., Lorenzen, K., Ropicki, A., Smith, M.D., & Tveterås, R. (2020). A global blue revolution: aquaculture growth across regions, species, and countries. *Rev Fish Sci Aquacult*., 28(1):107-116. doi:10.1080/23308249.2019.1678111

Garlock, T., Anderson, J. L., Asche, F., Smith, M. D., Camp, E., Chu, J., Lorenzen, K., & Vannuccini, S. (2022). Global insights on managing fishery systems for the three pillars of sustainability. *Fish and Fisheries*, 23, 899–909. doi.org/10.1111/faf.12660

Gephart JA, Henriksson PJG, Parker RWR, Shepon A, Gorospe KD, Bergman K., Eshel, G., Golden, C.D., Halpern, B.S., Hornborg, S., Jonell, M., Metian, M., Mifflin, K., Newton, R., Tyedmers, P., Zhang, W., Ziegler, F., & Troell, M. (2021). Environmental performance of blue foods. *Nature*., 597(7876):360–5. doi:10.1038/s41586-021-038892

Gephart, J. A., Golden, C. D., Asche, F., Belton, B., Brugere, C., Froehlich, H. E., Fry, J. P., Halpern, B. S., Hicks, C. C., Jones, R. C., Klinger, D. H., Little, D. C., McCauley, D. J., Thilsted, S. H., Troell, M., & Allison, E. H. (2021). Scenarios for global aquaculture and its role in human nutrition. *Reviews in Fisheries Science & Aquaculture, 29*(1), 122–138. doi:10.1080/23308249. 2020. 1782342

Glencross, B., Fracalossi, D. M., Hua, K., Izquierdo, M., Mai, K., Øverland, M., Robb, D., Roubach, R., Schrama, J., Small, B., Tacon, A., Valente, L. M. P., Viana, M.-T., Xie, S., & Yakupityage, A. (2023). Harvesting the benefits of nutritional research to address global challenges in the 21st century. . *J World Aquac Soc.*, 54(2), 343–363. doi.:10.1111/jwas.12948

Glencross, B., Bureau, D., Carr, I., DeSantisf, C., Morais, S., Schrama, J., & Zatti, K. (2026). Optimization of precision nutrition for aquaculture feed application. *Critical Insights in Aquaculture*, 2. doi: 10.1080/29932181.2025.2610126

Hall, S. J., Delaporte, A., Phillips, M. J., Beveridge, M., & O'Keefe, M. (2017). *Blue Frontiers: Managing the Environmental Costs of Aquaculture*. Penang: WorldFish.

Hardy, R.W., & Kaushik, S.J. (Eds). (2021). *Fish nutrition*. London, United Kingdom, Academic Press

Henriksson, P. J. G., Rico, A., Troell, M., Kli.nger, D. H., Buschmann, A. H., Saksida, S., Chadag, M. V., & Zhang, W. (2021). Unpacking factors influencing antimicrobial use in global aquaculture. *Reviews in Aquaculture, 13*(1), 457–482. doi:10.1111/raq.12487

Jentoft, S., & Chuenpagdee, R. (2015). *Interactive Governance for Small-Scale Fisheries: Global Reflections*. Cham: Springer. doi:10.1007/978-3-319-17034-3

Jolly, C.M., Nyandat, B., Yang, Z., Ridler, N., Matias, F., Zhang, Z., Murekezi, P., & Menezes, A. (2023). Dynamics of aquaculture governance. *J World Aquac Soc*., 54:427–481. doi: 10.1111/jwas.12967

Kittinger, J.N., Bernard, M., Finkbeiner, E., Murphy, E., Obregon, P., Klinger, D.H., Schoon, M.L., Dooley, K.J., & Gerber, L.R. (2021). Applying a jurisdictional approach to support sustainable seafood. *Conservation Science and Practice*, 3, e386. doi:10.1111/csp2.386

Kooiman, J., Bavinck, M., Jentoft, S., & Pullin, R. (Eds.). (2005). *Fish for Life: Interactive Governance for Fisheries*. Amsterdam University Press

Li, D., & Li, C. (2020). Intelligent aquaculture. *Journal of the World Aquaculture Society*, 51(4), 808-814. doi:10.1111/jwas.12736

Luo, J. Sun, Z., Lu, L., Xiong, Z., Cui, L., & Mao, Z. (2022). Rapid expansion of coastal aquaculture ponds in Southeast Asia: Patterns, drivers and impacts. *Journal of Environmental Management*, 315, 115100. doi:10.1016/j.jenvman.2022.115100

Malcorps, W., Newton, R., Horn, S., Kok, B., Troell, M., & Little, D.C. (2026). Fish as Food or Feed? Aligning FIFO with LCA and Food System Objectives. *Reviews in Fisheries Science & Aquaculture*, doi:10.1080/23308249.2026.2679959

Meitasari, I., Suratno, & Yuniwati. (2025). Normative Approach to Law and Economics in Developing Countries: Challenges in Establishing Efficient and Just Market Regulations. *Journal of Law and Economics*, 4(2), 237-249. doi:10.56347/jle.v4i2.373

Mamuaya, H. (2025). *Pluralisme Aliran Hukum: Implikasi dalam Sistem Hukum Indonesia*. PT. Samudra Solusi Profesional.

Mamuaya, H., Lasabuda, R, Mamuaya, G. (2026). System Dynamics Apprroach for Analysing Coastal Legal Issues. *Jurnal Ilniah Platax*, 14(2), 481-507. doi:10.35800/jip.v14i2.68304

Marzi, G., Balzano, M., Caputo, A., & Pellegrini, M.M. (2025). Guidelines for Bibliometric-Systematic Literature Reviews: 10 steps to combine analysis, synthesis and theory development. *Int J Manag Rev*., 27:81–103. doi:10.1111/ijmr.12381

MMAF (Ministry of Marine Affairs and Fisheries Republic of Indonesia). (2023). *Annual Report of Marine and Fisheries Development 2023*. Jakarta: MMAF.

Msomphora, M.R. (2024). Interactive governance of fisheries and aquaculture: Transdisciplinary challenges and stakeholder involvement in coastal zone management. *Marine Reports*, 3(2), 91-110. doi:org/10.5281/zenodo.14562737

Naylor, R.L., Hardy, R.W., Buschmann, A.H., Bush, S.R., Cao, L., Klinger, D.H., Little, D.C., Lubchenco, J., Shumway, S.E., & Troell, M. (2021). A 20-year retrospective review of global aquaculture. *Nature*, 591(7851):551–63. doi:10.1038/s41586-02103308-6

Naylor, R., Fang, S., & Fanzo, J. (2023). A global view of aquaculture policy. *Food Policy*, 116:102422. doi:10.1016/j.foodpol.2023.102422

Oremus, K.L., Bone, J., Costello, C., Molinus, J.G., Lee, A., Mangin, T., & Salzman, J. (2020). Governance challenges for tropical nations losing fish species due to climate change. *Nat Sustain*, 3, 277–280. doi:10.1038/s41893-020-0476-y

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372*, n71. doi:10.1136/bmj.n71

Partelow, S., Schlüter, A., Manlosa, A.O., Nagel, B., & Paramita, A.O. (2022). Governing aquaculture commons. *Rev Aquac*. 2022;14:729–750. doi:10.1111/raq.12622

Prapti, D.R., Mohamed Shariff, A.R., Che Man, H., Ramli, N.M., Perumal, T., & Shariff, M. (2022). Internet of Things (IoT)-based aquaculture: An overview of IoT application on water quality monitoring. *Rev Aquac*., 14:979-992. doi:10.1111/raq.12637

Rashid, S., Minot, N., Lemma, S. (2018). Does a "Blue Revolution" help the poor? Evidence from Bangladesh. *Agricultural Economic*, 50(2), 127-246. doi:10.1111/agec.12472

Ratan, R., Ashwini, M., Kamilya, D., & Nagarajan, V. (2026). Artificial intelligence and digital innovations in precision aquaculture: Advancements, applications, and future directions. *Franklin Open*, 5, 100567. doi:10.1016/j.fraope.2026.100567

Roheim, C. A., Bush, S. R., Asche, F., Sanchirico, J. N., & Uchida, H. (2018). Evolution and future of the sustainable seafood market,*Nature Sustainability*,1,392–398.doi:10.1038/s41893-018-0115

Rouhani, S., & Bozorgi, S.A. (2026). Text analytics and new service development: a hybrid thematic analysis with systematic literature review approach. *EuroMed Journal of Business*, 21(1), 193–233. doi:10.1108/EMJB-01-2024-0017

Rowan, N.J. (2023). The role of digital technologies in supporting and improving fishery and aquaculture across the supply chain – Quo Vadis? *Aquaculture and Fisheries*, 8(4), 365-374. doi:10.1016/j.aaf.2022.06.003

Schøning, L., Hausner, V.H., & Morel, M. (2023). Law and sustainable transitions: An analysis of aquaculture regulation, *Environmental Innovation and Societal Transitions*, 48,100753. doi:10.1016/j.eist.2023.100753

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research, 104*, 333–339. doi.10.1016/j.jbusres.2019.07.039

Sulthana, S.R., Mishra, S., & Rede, G.D. (2026). Reviewing the Global Aquatic Food Production and Trade: A Review. *Asian Journal of Dairy and Food Research*, 45(3), 367-375. doi: 10. 18805/ajdfr.DR-2443

Sutisna, N., Firdaus, M.A., & Sundarta, M.A. (2025). Legal Frameworks for Sustainable Blue Economy: Harmonizing Maritime Resource Governance and Environmental Protection. *IOP Conf. Series: Earth and Environmental Science, 1566,* 012005, IOP Publishing. doi:10.1088/1755-1315/ 1566/1/012005

Tacon, A.G.J. (2020). Trends in Global Aquaculture and Aquafeed Production: 2000–2017, *Reviews in Fisheries Science & Aquaculture*, 28:1, 43-56, doi:10.1080/23308249.2019.1649634

Taufiqurrohman, A.H.A., Wibowo, D.E., & Ariadi, H. (2023*). Aquaculture Development Strategy Based on the Study of UU Nomor 31 Tahun 2014*. The 1st International Conference on Social Science Humanities Arts (INCOSHA) Pekalogan, 7 – 8 Juni 2023. Pp 277-282

Thornber, K., Haque, M.M., Rouf, M.A., Fardoshi, T., Hasan, N.A., Golder, Md.R., Bashar, A., Debnath, P.P., Rahman, M.M., Kawahigashi, D., Vishnumurthy Mohan Chadag, V.M., & Tyler, C.R. (2026). Improving sustainable water usage in extensive shrimp aquaculture in Bangladesh. *Aquaculture*, 624, 744134. doi:10.1016/j.aquaculture

Tigchelaar, M., Leape, J., Micheli, F., Allison, E.H., Basurto, X., Bennett, A., Bennette, A., Bushf, S.R., Caog, L., Cheungh, W.W.L., Cronai, B., DeClerckk, F., Fanzom, J., Gelcichn, S., Gepharto, J.A., Goldenp, S.D., Halpernq, B.S., Hickss, C.C., Jonelli, M., …& Wabnitza, C.C.C. (2022). The vital roles of blue foods in the global food system. *Global Food Security*, 33:100637. doi:10.1016/j.gfs.2022.100637

Toonen, H.M., Bush, S.R., Ibarra, R., O'Sullivan, C., Hudson, E., Asif, F., Bridson, P., Corsin, F., Fitzsimmons, K., Kruk, S.R.L., Madeira, J., Little, D.C., Norden, W., Stark, M., & Tucker, L. (2025). Aquaculture Governance Indicators: A diagnostic framework for steering towards sustainability. *PLOS Sustain Transform* 4(4): e0000165. doi:10.1371/journal.pstr.0000165

Torraco, R. J. (2016). Writing integrative literature reviews: Guidelines and examples. *Human Resource Development Review, 15*(4), 404–428. doi:10.1177/1534484316671606

Troell, M., Costa-Pierce, B., Stead, S., Cottrell, R.S., Brugere, C., Farmery, A.K., Little, D.C., Strand, A., Pullin, R., Soto, D., Beveridge, M., Salie, K., Dresdner, J., Moraes-Valenti, P., Blanchard, J., James, P., Yossa, R., Allison, E., Devaney, C., & Barg, U. (2023). Perspectives on aquaculture's contribution to the Sustainable Development Goals for improved human and planetary health. *J World Aquaculture Soc*., 54(2):251–342. doi:10.1111/jwas.12946

Troell, M., Henriksson, P. J. G., Buschmann, A. H., Chopin, T., Froehlich, H. E., Klinger, D. H., Metian, M., Rydberg, T., Deines, A. M., & Hall, S. J. (2023). Rethinking aquaculture development for a sustainable blue future. *Nature Sustainability*, *6*(9),1050–1061.doi:10.1038/s41893-023-01137-5

Unger, R. M. (1983). *The Critical Legal Studies Movement*. Cambridge, MA: Harvard University Press.

VanderZwang, D.L., & Chao, G. (Eds) (2006). *Aquaculture Law and Policy: Toward Principled Acces and Operations*. London. Routledge.

van Senten, J., Engle, C.R., Hartman, K., Kamina K. Johnson, K.K., & Gustafson, L.L. (2018). Is there an economic incentive for farmer participation in a uniform health standard for aquaculture farms? An empirical case study. *Preventive Veterinary Medicine*, 156, 58-67. doi:10.1016/j.prevetmed.2018.05.007

World Bank. (2021). *Blue Economy Development Framework: Sustainable Aquaculture and Coastal Livelihoods*. Washington, DC: World Bank.

Xiao, Y., & Watson, M. (2019). Guidance on conducting a systematic literature review. *Journal of Planning Education and Research, 39*(1), 93–112. doi:10.1177/0739456X17723971

Yang, H., Tan, T., Du, X., Feng, Q., Liu, Y., Tang, Y., Bai, G., Liu, Z., Xia, S., Song, S., Quintana, M., Zhou, Q., Wu, Z., & Zhang, Y. (2025). Advancements in freshwater aquaculture wastewater management: A comprehensive review. *Aquaculture*, 594, 741346. doi:10.1016/ j.aquaculture.2024.741346

Yang, H., Feng, Q., Xia, S., Wu, Z., & Zhang, Y.2025. AI-driven aquaculture: A review of technological innovations and their sustainable impacts. *Artificial Intelligence in Agriculture*, 15 (3), 508-525. doi:10.1016/j.aiia.2025.01.012

Yue, K., & Shen, Y. (2022). An overview of disruptive technologies for aquaculture. *Aquaculture and Fisheries*, 7(2), 111-120. doi:10.1016/j.aaf.2021.04.009.