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Integrating Fish Taxonomy Knowledge and Partnerships for Sustainable Development Goals: Lessons from Brackish -Water Fish Management in the Gulf of Thailand

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ABSTRACT

The Gulf of Thailand is ecologically and economically vital, yet its brackish-water fish biodiversity remains inadequately studied and increasingly vulnerable to human-induced threats. This study addresses these gaps through four objectives: clarifying taxonomic status, assessing fisheries and biodiversity challenges, analyzing multi-level partnerships, and proposing integrative pathways aligned with SDGs 14 (Life below water) and 17 (Partnerships for the goals) Using qualitative synthesis and content analysis, the study identifies unresolved taxonomic ambiguities—including cryptic species and hybridization—as critical obstacles to effective conservation. Additional stressors such as overfishing, habitat degradation, and harmful algal blooms further diminish ecosystem resilience. Findings highlight that collaborative governance, involving state agencies, academic institutions, local communities, and international partners, is essential for data harmonization and adaptive management. The study proposes a dual framework in which taxonomic clarity forms the scientific foundation, and partnerships act as enablers of governance reform. Key recommendations include developing a centralized taxonomic database, adopting molecular tools, fostering regional research alliances, and ensuring inclusive stakeholder engagement. This integrative approach contributes to a scalable governance model for sustainable fisheries and biodiversity conservation in the Gulf of Thailand

KEYWORDS: taxonomy; brackish water; life below water; partnerships for the goals; sustainable communities.

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INTRODUCTION

Brackish water and estuarine ecosystems rank among the most biologically productive habitats globally, serving as transitional zones where freshwater and marine systems converge. These ecosystems provide essential nursery grounds for fish, regulate nutrient cycling, and sustain coastal livelihoods through small-scale fisheries and aquaculture. Despite their ecological significance, estuarine environments are increasingly imperiled by anthropogenic pressures such as overfishing, habitat alteration, and climate variability (UNEP, 2020). Compounding these threats are enduring taxonomic uncertainties that hinder species-level assessment and obstruct the development of scientifically grounded conservation strategies (Allen, 2015). Accurate taxonomy and integrated management are, therefore, indispensable for sustaining aquatic biodiversity. Understanding and knowing about economic situations, ecological systems and environments lead to increase sustainable economic growth and development of local people in the 21st century (Pansuwong et al., 2023).

In Southeast Asia—a region widely recognized for its aquatic species richness—these pressures are particularly acute. Rapid coastal urbanization, the expansion of aquaculture, and transboundary fishing activities have significantly degraded brackish water habitats (Teh & Pauly, 2018). Although regional efforts, such as those led by the Southeast Asian Fisheries Development Center (SEAFDEC), have promoted responsible fisheries and joint monitoring initiatives (SEAFDEC, 2021), major gaps persist in integrating taxonomic science into fisheries governance. Misidentification of species, a lack of standardized taxonomic databases, and disconnects between research and policy formulation continue to compromise sustainable resource management.

The Gulf of Thailand exemplifies these intersecting challenges in a national context. As a key ecological and economic zone, it supports diverse brackish water fish assemblages vital to food security and local economies (Koolkalya et al., 2015). However, increasing ecological degradation, including pollution, habitat fragmentation, and unsustainable fishing, has placed these systems under mounting stress. Taxonomic ambiguities—particularly within commercially significant groups such as gobiids and clupeids—have distorted biodiversity assessments and undermined the accuracy of fisheries statistics (Tranet al., 2020). The absence of a centralized taxonomic framework impairs policymakers' ability to balance ecological priorities with economic objectives.

Furthermore, the fragmentation of knowledge systems and institutional disconnects has impeded the establishment of comprehensive biodiversity baselines. Fisheries data are often generalized under broad commercial labels, masking cryptic species diversity and leading to erroneous stock assessments (Harrison et al., 2011). Partnerships among state actors, academic institutions, local communities, and international organizations remain insufficiently coordinated, thereby weakening governance capacity. Without integrative frameworks, the Gulf of Thailand remains vulnerable to cyclical exploitation absent adequate conservation safeguards.

This study is founded on the premise that sustainable fisheries governance requires the integration of taxonomic science, ecological monitoring, and inclusive partnerships. It pursues four interrelated objectives: (1) to clarify the taxonomic status of brackish-water species; (2) to identify ecological and institutional constraints; (3) to synthesize lessons from multi-level partnerships; and (4) to propose integrated strategies aligned with SDG 14 and SDG 17. These objectives collectively offer a framework for reconciling scientific evidence with governance mechanisms to foster ecological resilience and social sustainability in one of Southeast Asia's most critical coastal regions.

LITERATURE REVIEW

The literature on brackish-water fish biodiversity and management in Southeast Asia reveals significant advances alongside persistent deficiencies. These gaps are particularly apparent in the integration of taxonomic science, ecological monitoring, fisheries governance, and theoretical frameworks—each of which constitutes a critical pillar for sustainable coastal resource management in regions such as the Gulf of Thailand.

Taxonomy has long served as the foundational discipline for biodiversity assessment; however, conventional morphological methods often prove inadequate for resolving cryptic species complexes and identifying hybrid taxa. Jaafar, Na-Nakorn et al. (2021) demonstrated that morphology-based classification of *Tor* species obscured species boundaries until molecular diagnostics were introduced. Similarly, Tuncharoen et al. (2025) revealed previously unrecognized lineages of *Rhinogobius* in Thailand through DNA barcoding, highlighting the limitations of morphology alone. Despite these advances, the application of integrative taxonomy—combining genetic, morphological, and ecological evidence—remains sporadic in the Gulf of Thailand. The lack of a standardized taxonomic database and harmonized identification protocols continues to undermine both biodiversity assessments and management responses (Hossain et al., 2015).

Ecological studies have reinforced the urgency of developing more robust monitoring frameworks. For example, Tran, Nguyen, My To, et al. (2020) found that gobiid assemblages in the Mekong estuaries exhibit high sensitivity to salinity gradients and habitat heterogeneity—ecological dynamics likely mirrored in the Gulf. Fu et al. (2021) employed DNA metabarcoding to document the growing diversity of harmful microalgae, identifying algal blooms as emergent stressors that disrupt trophic structure and habitat quality. Although localized studies, such as Lheknim's (2020) inventory in Thale Noi, offer valuable baseline data, these remain fragmented and poorly integrated into national monitoring systems. Consequently, the region lacks a longitudinal and taxonomically grounded approach to ecosystem assessment.

Fisheries research has consistently emphasized unsustainable exploitation as a central threat to biodiversity and livelihoods. Koolkalya et al. (2015) documented declining catch-per-unit-effort and a shift toward lower-trophic species in the Gulf of Thailand, reflecting a "fishing down the food web" pattern. Luo et al. (2022) further noted that rapid aquaculture expansion across Southeast Asia has altered coastal landscapes, increased nutrient loading, and degraded estuarine ecosystems. However, the absence of species-level taxonomic precision impairs the ability to disaggregate impacts and calibrate policy interventions effectively.

Governance literature accentuates the importance of partnerships and multi-scalar coordination. Briones and Garcia (2008) showed that poverty reduction linked to sustainable fisheries is most effective when ecological and social goals are addressed through collaborative mechanisms. More recent scholarship (Alamsyahbana & Chartady, 2025; Sunny et al., 2021) points to the role of blue economy frameworks and international collaborations in enhancing policy coherence and resilience. Nevertheless, in the Gulf of Thailand, partnerships are weakly institutionalized and rarely integrate scientific knowledge—particularly taxonomic evidence—into decision-making processes.

Theoretical frameworks provide further guidance for navigating these complexities. Integrative taxonomy (Dayrat, 2005) advocates the convergence of morphological, genetic, and ecological data for accurate species delimitation. Common-pool resource theory (Ostrom, 1990) explains the vulnerability of fisheries to overexploitation in the absence of aligned rules and monitoring. Collaborative governance theory (Ansell & Gash, 2008) underscores the role of trust and shared learning in building durable management systems, while sustainability transition theory (Geels, 2002) emphasizes multi-level alignment across knowledge, institutions, and socio-economic forces.

In summary, the literature identifies four critical gaps: the absence of a unified taxonomic framework, fragmented biodiversity monitoring, insufficient linkage between ecological stressors and taxonomic clarity, and weak institutionalization of scientific partnerships. This study addresses these deficiencies by proposing an integrative model that synthesizes taxonomic science, ecological insight, and collaborative governance to guide sustainable brackish-water fisheries management in the Gulf of Thailand.

METHODOLOGY

This study employed a qualitative synthesis methodology to integrate diverse strands of empirical and conceptual evidence concerning brackish-water fish taxonomy, ecological stressors, and governance frameworks in the Gulf of Thailand. The methodological design was calibrated to accommodate the fragmented and multi-scalar nature of available data sources, incorporating peer-reviewed literature, governmental documentation, and regional policy instruments. Source selection was conducted through targeted searches of academic databases such as Scopus and Web of Science, and was complemented by reports from national agencies—particularly the Department of Fisheries, Thailand—and international bodies including SEAFDEC and UNEP. Literature published between 2010 and 2025 was prioritized to ensure both temporal depth and contemporary relevance, while seminal works predating this period were retained to provide foundational context.

Content analysis was applied to identify recurring thematic patterns and knowledge gaps across the selected materials. This entailed coding textual data under analytical categories including taxonomic classification, ecological stressors, fisheries governance, and inter-institutional partnerships. Within the domain of taxonomy, emphasis was placed on inconsistencies in species identification, the neglect of hybridization phenomena, and the underutilization of molecular diagnostics such as DNA barcoding. In examining fisheries governance, analytical focus was directed toward identifying systemic pressures such as overexploitation, habitat alteration, and the proliferation of harmful algal blooms as emerging ecological disruptors. A subsequent thematic synthesis was undertaken to interlink coded insights, thereby facilitating the development of a conceptual framework that articulates the nexus between taxonomy, ecological monitoring, and collaborative governance in achieving sustainability outcomes.

To ensure methodological rigor, the study employed triangulation strategies to enhance both reliability and validity. By cross-verifying findings derived from academic publications, policy reports, and regional case studies, the research mitigated potential biases associated with any single data domain. Comparative analyses with analogous contexts in Southeast Asia—particularly the Mekong estuaries and fisheries management experiences in Bangladesh—were conducted to extract transferable lessons and to bolster analytical generalizability. Although qualitative and interpretive by design, the study's systematic coding structure and multi-source validation confer methodological robustness. This approach is well-suited to address the study's four central objectives: to clarify taxonomic uncertainties, assess ecological and institutional challenges, distill partnership-based insights, and propose integrative pathways toward the realization of SDG 14 and SDG 17.

RESEARCH FINDINGS

Objective 1: Taxonomic Status of Brackish-water Fish in the Gulf of Thailand

The analysis reveals that the taxonomic classification of brackish-water fishes in the Gulf of Thailand remains insufficiently resolved, posing significant challenges for biodiversity assessment and resource management. Conventional morphological identification continues to dominate, yet proves inadequate in distinguishing species within cryptic complexes or cases of hybridization. Jaafar et al. (2021) illustrated that Tor species in Southeast Asia could not be reliably differentiated based on morphology alone, whereas integrative taxonomic methods offered more precise species delineation. Similarly, cryptic diversity within gobiids in Thailand has been uncovered only through the application of DNA barcoding (Tuncharoen et al., 2025). These taxonomic ambiguities have direct implications for conservation and fisheries management. Species such as Mystus gulio are often excluded from national biodiversity strategies due to inconsistent identification, which diminishes their visibility in policy frameworks (Hossain et al., 2015). Moreover, hybridization between native and non-native species remains underexplored, raising concerns about genetic integrity and long-term population viability. The absence of a centralized, standardized taxonomic database exacerbates these issues, limiting the precision of stock assessments and undermining conservation planning. Addressing this foundational gap is essential for improving ecological baselines and developing management strategies that align with sustainability objectives under SDG 14 and SDG 17.

Objective 2: Fisheries Management and Biodiversity Challenges

Brackish-water fish biodiversity in the Gulf of Thailand is increasingly constrained by interrelated ecological and anthropogenic pressures. Overfishing remains a dominant threat, evidenced by declining catch-per-unit-effort and shifts toward lower trophic-level species—indicators of systemic ecosystem degradation (Koolkalya et al, 2015; Katangchol et al., 2023). These pressures are intensified by rapid aquaculture expansion, which has resulted in widespread habitat fragmentation and ecological disruption across coastal zones (Luo et al., 2022). Emerging environmental stressors, such as harmful algal blooms, further complicate fisheries governance. Fu et al. (2021) used DNA metabarcoding to demonstrate the rising diversity and ecological impact of harmful microalgae in the Gulf, underscoring the combined influence of nutrient enrichment and climate variability. Meanwhile, studies in the Mekong estuaries highlight the sensitivity of gobiid species to salinity fluctuations and habitat heterogeneity, suggesting that analogous vulnerabilities exist in Gulf ecosystems (Tran et al., 2020). Despite these challenges, comprehensive biodiversity indices and long-term ecological monitoring remain underdeveloped. Localized inventories, such as those by Lheknim (2020), are infrequent and disconnected from national governance structures. Consequently, the lack of integrated data, taxonomic clarity, and institutional coordination hampers adaptive management, threatening both ecological resilience and fisheries sustainability.

Objective 3: Synthesizing Lessons from Multi-Level Partnerships

The findings emphasize that multi-level partnerships are critical to enhancing the governance of brackish-water fisheries in the Gulf of Thailand. Current institutional arrangements remain fragmented, with limited integration between scientific research, policy implementation, and community engagement. This disconnects results in weak enforcement and underutilization of ecological data. Comparative experiences across Southeast Asia demonstrate that well-structured partnerships can yield

significant governance benefits. Briones and Garcia (2008) revealed that poverty reduction linked to sustainable fisheries is most effective when ecological and socio-economic goals are aligned through collaborative frameworks. Similarly, Bangbon et al. (2023), Alamsyahbana & Chartady (2025), Phromphithakkul et al. (2025), and Bhandari et al. (2024) found that regional initiatives guided by SDG 14 and blue economy policies have improved harmonization across national jurisdictions. In the Gulf context, such alignment could strengthen monitoring capacity, facilitate technology transfer, and promote the adoption of best practices in taxonomic science. At the community level, participatory models have demonstrated enhanced resilience and legitimacy. Sunny, Prodhanet al. (2021) showed how co-managed fisheries in Bangladesh adapted more effectively to shocks during the COVID-19 pandemic. However, in the Gulf of Thailand, community participation remains marginal and poorly institutionalized. Overall, the study confirms that partnerships are not peripheral but foundational. Without institutionalized collaboration across state, academic, community, and international actors, efforts to improve taxonomy and ecological monitoring risk failing to influence governance outcomes meaningfully.

Objective 4: Proposing Integrated Pathways for Achieving SDG 14 and SDG 17

Achieving sustainability in brackish-water fisheries in the Gulf of Thailand requires integrative pathways that align scientific knowledge, governance mechanisms, and inclusive social participation. Taxonomic clarity serves as a foundational prerequisite for accurate biodiversity assessment and resource management. Kura and Kawarazuka (2021) emphasized that fisheries not only support biodiversity but also contribute to sustainable food systems, reinforcing the need to embed taxonomic data within broader development agendas. Aquaculture emerges as a key sector in this integrated approach. Haque and Mahmud (2025) demonstrated that sustainable aquaculture in Bangladesh can alleviate pressure on wild stocks and advance multiple Sustainable Development Goals (SDGs). For the Gulf of Thailand, harmonizing aquaculture practices with taxonomy-informed planning offers a dual strategy for ecological conservation and economic growth. However, this approach necessitates investment in scientific infrastructure and policy coordination (Channuwong et al., 2025; Tayossyingyong et al., 2025; Rattananda et al., 2025). Social inclusion is equally vital. Sornkliang et al. (2018) revealed that recognizing gender roles in fisheries governance strengthens both equity and institutional legitimacy. Therefore, integrated pathways must institutionalize participation by women and marginalized communities to ensure broad-based compliance and resilience. In sum, the findings propose a governance model in which taxonomy, aquaculture, and inclusive partnerships function as interdependent pillars—providing a coherent strategy for advancing SDG 14 (Life Below Water) and SDG 17 (Partnerships for the Goals) in the Gulf of Thailand.

DISCUSSION

Objective 1: Taxonomic Status of Brackish-water Fish in the Gulf of Thailand

The findings reaffirm that unresolved taxonomic ambiguities remain a fundamental obstacle to effective fisheries governance and biodiversity conservation in the Gulf of Thailand. Species complexes, cryptic diversity, and hybridization contribute to misidentification and inaccurate ecological assessments. This issue mirrors challenges observed in other marine regions, such as the Persian Gulf, where taxonomic reliance on morphology delayed conservation interventions (Owfi, 2015). Comparative studies reinforce the importance of systematic taxonomic inventories. Rao et al. (2024) provided a comprehensive species checklist in the Gosthani River, which has informed localized biodiversity planning. Similarly, Hatkar et al. (2024) demonstrated that baseline taxonomic data are essential for understanding marine ecosystem functions in India's Gulf of Kutch. These examples underscore the practical utility of taxonomy in guiding ecological management. The Gulf of Thailand lacks such integrative taxonomic infrastructure, including centralized databases and standardized identification protocols. This gap severely undermines stock assessments and limits the effectiveness of conservation measures. The findings align with Dayrat's (2005) integrative taxonomy framework, which advocates for the convergence of morphological, molecular, and ecological evidence. Without adopting such an approach, the region cannot reliably track biodiversity or fulfill SDG 14 and SDG 17 targets. Advancing taxonomic clarity is therefore not only a scientific imperative but also a policy necessity.

Objective 2: Fisheries Management and Biodiversity Challenges

This study confirms that the Gulf of Thailand's brackish-water fisheries are increasingly compromised by intersecting ecological and institutional stressors. Overfishing, habitat degradation, and the lack of taxonomically precise monitoring collectively undermine ecological resilience and governance effectiveness. Tran et al. (2020) demonstrated that gobiid assemblages in the Mekong estuaries are highly sensitive to environmental fluctuations, a dynamic likely paralleled in the Gulf's estuarine systems. However, the absence of longitudinal biodiversity indices in the Gulf hinders adaptive management. Fu et al. (2021) identified harmful algal blooms as an emergent stressor through DNA metabarcoding, linking nutrient loading and climate variability to ecosystem instability. Localized surveys, such as Lheknim's (2020) inventory in Thale Noi, underscore the value of baseline data but remain isolated and poorly integrated into national governance frameworks. These findings are consistent with Ostrom's (1990) common-pool resource theory, which posits that without well-defined rules and monitoring, shared natural resources are susceptible to degradation. The Gulf exemplifies this pattern, where fragmented data, insufficient enforcement, and unresolved taxonomy impede sustainable fisheries governance. Addressing these deficiencies necessitates the development of integrative ecological monitoring systems that are taxonomically informed, policy-aligned, and responsive to evolving environmental conditions.

Objective 3: Synthesizing Lessons from Multi-Level Partnerships

The findings underscore the indispensable role of multi-level partnerships in operationalizing scientific knowledge for effective brackish-water fisheries governance in the Gulf of Thailand. Institutional fragmentation and limited coordination between research, policy, and local implementation reduce the impact of scientific advancements on actual management practices. Allen (2015) demonstrated that advances in coral reef taxonomy in the Indo-Pacific were enabled by sustained international collaborations. Similarly, White and Last (2012) highlighted that progress in chondrichthyan taxonomy depended on integrated

partnerships that combined morphological and molecular expertise. These cases affirm that long-term, cross-sectoral partnerships foster methodological innovation and data standardization—both of which are lacking in the Gulf of Thailand. Furthermore, Harrison et al. (2011) emphasized the importance of global cooperation in maintaining genetic databases and standardized nomenclature. In the absence of such frameworks, taxonomic data remain fragmented and underutilized. These findings align with collaborative governance concepts presented by Ansell & Gash (2008) and Ning et al. (2025), Channuwong et al. (2022) and Zafri et al. (2023) which emphasizes trust, mutual learning, and shared accountability as prerequisites for effective cooperation. For the Gulf, strengthening institutionalized collaboration among state agencies, academia, communities, and international bodies is imperative for embedding science within governance systems and achieving sustainability goals under SDG 14 and SDG 17.

Objective 4: Proposing Integrated Pathways for Achieving SDG 14 and SDG 17

The findings underscore that achieving SDG 14 and SDG 17 in the Gulf of Thailand necessitates the development of integrated pathways that synthesize taxonomic science, ecological monitoring, and inclusive governance. Without such alignment, sustainability initiatives risk remaining fragmented and ineffectual. Alamsyahbana and Chartady (2025) demonstrated that blue economy frameworks in Southeast Asia enhance policy coherence by aligning biodiversity conservation with national development priorities. Compared with the fragmented taxonomic and governance systems in the Gulf, their findings highlight the necessity of embedding scientific knowledge into cross-border policy platforms. Yeh et al. (2022) further emphasized that institutional fragmentation impedes SDG implementation, a challenge mirrored in the Gulf's disconnect between ecological evidence, policy action, and local participation. Fakhruddin et al. (2018) illustrated that integrating biodiversity with ecosystem-based adaptation offers dual benefits—ecological resilience and socio-economic stability. These insights resonate with sustainability transition theory (Geels, 2002), which advocates for systemic change through multi-level alignment of science, governance, and societal forces. For the Gulf of Thailand, integrated pathways anchored in taxonomic clarity, community inclusion, and policy coherence offer a strategic framework for transforming sustainability aspirations into actionable outcomes.

IMPLICATIONS AND RECOMMENDATIONS

1. Establishing a comprehensive taxonomic database for Gulf of Thailand fishes

It is imperative to develop a centralized, standardized taxonomic repository that integrates morphological, molecular, and ecological data for brackish-water fish species in the Gulf of Thailand. Such a database would enhance the accuracy and consistency of biodiversity assessments, facilitate conservation prioritization, and support evidence-based fisheries governance. Accessibility for governmental agencies, academic researchers, and local communities should be a key design principle to ensure broad utility and stakeholder engagement.

2. Promoting international research collaborations

To elevate scientific standards and foster methodological innovation, Thailand should actively pursue strategic research alliances with regional and global entities such as SEAFDEC, ASEAN biodiversity platforms, and international taxonomic consortia. These partnerships will enable the exchange of expertise, harmonization of protocols, and the establishment of interoperable data systems—aligning national efforts with international best practices and advancing progress toward SDG 14 and SDG 17.

3. Applying molecular tools to detect hybridization and cryptic diversity

The incorporation of molecular diagnostics—including DNA barcoding, phylogenetics, and next-generation sequencing—into fisheries monitoring programs is essential for uncovering cryptic species and assessing genetic integrity. These tools will improve species identification, support accurate stock assessments, and ensure that conservation and management targets are biologically valid. National fisheries policy should formally institutionalize the use of such tools to strengthen scientific precision.

4. Enhancing community participation in fisheries governance

Strengthening participatory governance mechanisms is vital for ensuring legitimacy, compliance, and equity in fisheries management. Local fishers, women, and marginalized groups should be meaningfully included through co-management frameworks, participatory monitoring systems, and inclusive decision-making processes. Recognizing and integrating gendered roles in fisheries value chains will contribute to more equitable benefit distribution and reinforce the resilience of coastal livelihoods. Such inclusive approaches are indispensable for realizing the socio-political dimensions of SDG 17.

CONCLUSION

This study advances an integrated framework for the sustainable management of brackish-water fish biodiversity in the Gulf of Thailand by synthesizing taxonomic science, ecological challenges, and multi-level governance. The research demonstrates that unresolved taxonomic ambiguities, compounded by ecological degradation and institutional fragmentation, impede effective fisheries management and conservation planning. Through the analysis of regional case studies and theoretical insights, the study affirms that taxonomic clarity must serve as the epistemological foundation upon which biodiversity monitoring and policy formulation are constructed.

Equally, partnerships that span governmental, academic, community, and international domains are shown to be indispensable for translating scientific knowledge into actionable governance. Such collaborations enable data harmonization, methodological innovation, and inclusive decision-making—conditions necessary for institutional resilience and socio-ecological sustainability. By proposing a model in which taxonomy and partnerships operate as interdependent pillars, the study contributes both conceptual and practical value. It offers a coherent structure for aligning local management practices with global sustainability agendas, particularly SDG 14 (Life Below Water) and SDG 17 (Partnerships for the Goals). The findings underscore the need for systemic

integration—across scientific disciplines, governance tiers, and societal stakeholders—as the only viable pathway toward enduring sustainability in the Gulf of Thailand's brackish-water ecosystems.

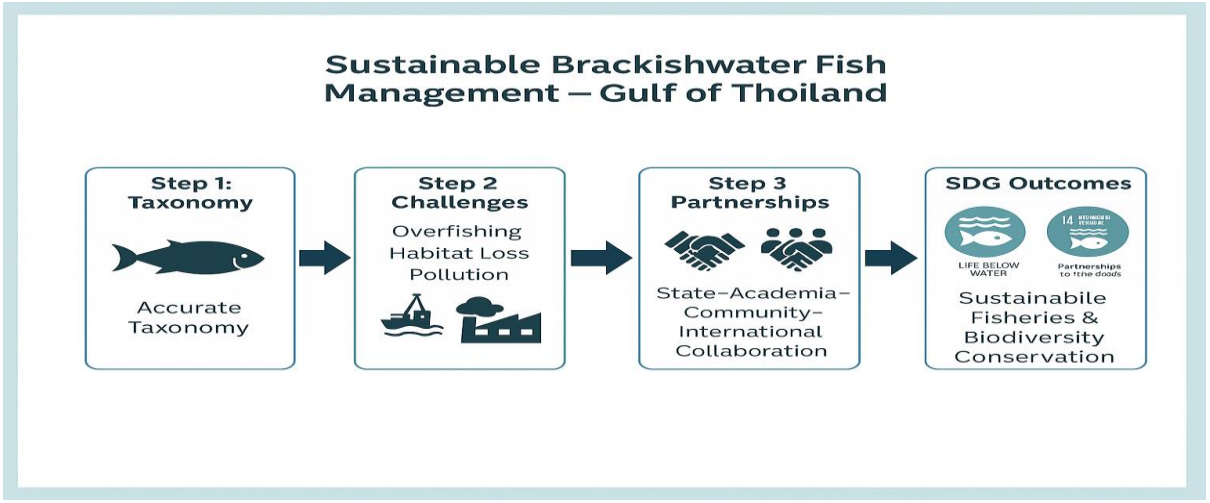

Figure 1. Conceptual Framework for Sustainable Brackishwater Fish Management in the Gulf of Thailand (Revised Description)

The conceptual framework delineated in Figure 1 presents an integrated model wherein accurate taxonomy constitutes the scientific foundation for biodiversity assessment and fisheries governance. It situates taxonomic clarity at the base of the framework, ensuring species-level resolution essential for monitoring and policy precision. Surrounding this foundation are key ecological challenges—including overfishing, habitat degradation, pollution, and emergent stressors such as harmful algal blooms—that threaten system resilience.

Overlaying these components are multi-level partnerships that link state agencies, academic institutions, local communities, and international organizations. These partnerships serve as mechanisms for translating taxonomic and ecological insights into adaptive governance structures. The model culminates in the attainment of SDG 14 and SDG 17, reflecting the convergence of science and policy as mutually reinforcing pillars of sustainability.

This framework is designed not only as an academic contribution but as an operational guide for policymakers and practitioners seeking to implement integrated, scalable, and participatory approaches to coastal ecosystem management.

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