

SPEECTRA: Linking Inland Fisheries Conservation and Regional Learning in Southeast Asia

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Inland fisheries play an important role in supporting food security, nutrition, and livelihoods in Southeast Asia. However, these fisheries are increasingly affected by habitat degradation, climate variability, hydrological changes, and growing pressure on aquatic ecosystems. This article discusses the Special Area for Conservation and Fish *Refugia*, known as the SPEECTRA Model, as a practical conservation approach developed from local experience in swamp and floodplain ecosystems in South Sumatra, Indonesia. Implemented at Patra Tani in Muara Enim, SPEECTRA combines fish *refugia*, habitat protection, ecological monitoring, education, and community learning. Experience from the pilot site shows that conservation areas can function not only as protected habitats, but also as learning platforms for research, capacity building, and public awareness. The model highlights the importance of adapting conservation design to local ecological conditions, governance systems, and community needs. SPEECTRA offers useful lessons for strengthening sustainable inland fisheries management and regional cooperation in Southeast Asia.

water patterns, community practices, and governance systems. Effective management needs to be adaptive, locally appropriate, and supported by cooperation among government agencies, researchers, local communities, and other stakeholders (Schiemer *et al.*, 2024; Handayani & Ibrahim, 2025).

In this context, the Special Area for Conservation and Fish *Refugia*, known as the SPEECTRA Model, offers a practical example of how inland fisheries conservation can be linked with learning and community engagement. Developed in 2020 at Patra Tani in Muara Enim, South Sumatra, Indonesia, the model was initiated by the Southeast Asian Fisheries Development Center/Inland Fishery Resources Development and Management Department (SEAFDEC/IFRDMD) in collaboration with the Research Institute for Inland Fisheries and Extension (RIIFE). Rather than functioning only as a protected fish *refugia* site, SPEECTRA combines habitat protection, ecological monitoring, education, demonstration activities, and community learning.

Introduction

Inland fisheries are essential for food security, nutrition, livelihoods, and local economies in Southeast Asia. Rivers, floodplains, reservoirs, swamps, and wetlands provide important habitats for fish and support millions of people who depend on inland waters for food and income (Muthmainnah *et al.*, 2017; Utomo *et al.*, 2024). In flood-pulse-dependent systems such as the Mekong, inland fisheries are especially important because seasonal water movements support fish migration, breeding, nursery grounds, and local fish production (Tilley *et al.*, 2023).

However, these ecosystems are under increasing pressure. Habitat degradation, hydrological disruption, overexploitation, pollution, sedimentation, climate variability, and infrastructure development are changing the natural functions of inland waters (Sarkar *et al.*, 2020; Bond *et al.*, 2024; Utomo *et al.*, 2024). These pressures threaten both aquatic biodiversity and the social and nutritional benefits that inland fisheries provide to rural communities.

Conservation efforts, therefore, cannot rely solely on physical protection or top-down regulations. Inland fisheries are closely connected to local ecosystems, seasonal

Regional initiatives confirm that conservation success requires more than just the presence of protected water areas. In Cambodia, for example, Community Fish Refuges have contributed to inland fish production and rural food security, but their effectiveness depends on floodplain connectivity, local management capacity, coordination with irrigation systems, and sustained institutional support (Tilley *et al.*, 2023; Sithirith, 2026). These lessons show that fish *refugia* models must be tailored to local ecological and governance conditions.

This article discusses the SPEECTRA Model as a locally developed conservation approach with potential for wider regional learning. It highlights the ecological basis of the model, its flexible design, lessons from the Patra Tani pilot, and possible pathways for sharing SPEECTRA principles across Southeast Asia. Ultimately, SPEECTRA should not be promoted as a fixed design to be copied directly, but as an adaptable approach that can support sustainable inland fisheries management, biodiversity conservation, and regional cooperation through SEAFDEC/IFRDMD's knowledge-sharing role.

Conservation in Changing Inland Waters

The SPECTRA model was developed to address swamp and floodplain degradation in South Sumatra, Indonesia. These ecosystems are important habitats for native fish species, providing feeding, breeding, nursery, and refuge areas during different water seasons.

The pilot was launched at the Patra Tani installation in Muara Enim, South Sumatra (**Figure 1**), through a collaboration between SEAFDEC/IFRDMD and RIIFE of the Ministry of Marine Affairs and Fisheries (MMAF), Indonesia. The site has been used for conservation, monitoring, research, education, and demonstration activities related to sustainable swamp fisheries management.

SPECTRA is built on a clear ecological premise: in seasonally dynamic swamp and floodplain systems, fish persistence depends on access to safe refuge habitats and on maintaining hydrological connections that allow movement between open waters and protected habitats across wet and dry phases. These *refugia* protect fish during critical periods, such as low-water seasons or habitat disturbances, keeping fish populations connected to their natural environment.

This logic aligns with foundational floodplain research indicating that floodplains with permanent, either one- or two-sided lateral connectivity to the main channel, significantly favor total fish abundance and serve as essential nursery areas for riverine species (Stoffers *et al.*, 2022). During wet-season flood pulses, these connected floodplain habitats provide vital opportunities for feeding, breeding, and juvenile growth. As waters recede, strategic refuge areas retain fish, sustaining assemblages between flood events and supporting the recovery or recolonization of adjacent waterways.

However, establishing functional *refugia* is highly complex. Empirical data from tropical wet-dry river systems show that both wet-season connectivity and dry-season pool

persistence dictate fish assemblage structures (Pratt *et al.*, 2025). For instance, species richness increases dramatically when wet-season connection to the river lasts more than 25 days and refuges sit less than 2,000 meters from the main channel; conversely, persistent dry-season pools remain twice as species-rich as those that dry out (Pratt *et al.*, 2025).

Because these eco-hydrological requirements vary across landscapes, river and floodplain restoration offers no “one-size-fits-all” design (Stoffers *et al.*, 2022). This reality justifies SPECTRA’s structural diversity. Rather than enforcing a rigid blueprint, its varied configurations, such as integrated agroforestry networks and interconnected pond systems, are purposefully engineered to adapt to these precise distance, duration, and persistence thresholds.

SPECTRA Model Adaptive Design Principles

A key feature of the SPECTRA Model is its flexible design. It is not intended as a single pond layout that must be copied from one site to another; rather, SPECTRA provides a set of fish *refugia* principles that can be adjusted to local hydrology, landform, fish behavior, community needs, and management capacity.

This flexibility is important because swamp and floodplain ecosystems vary by location. Water depth, seasonal flooding, vegetation, connectivity with surrounding waterways, and fish movement patterns can vary greatly across inland water systems. Therefore, effective conservation design should respond to local ecological conditions rather than follow a standardized blueprint.

At the pilot site, several design variations have been developed to demonstrate how SPECTRA principles can be applied in different forms. These include fish refuge ponds, conservation ponds integrated with aquaculture, pond networks for predator protection, agroforestry-based

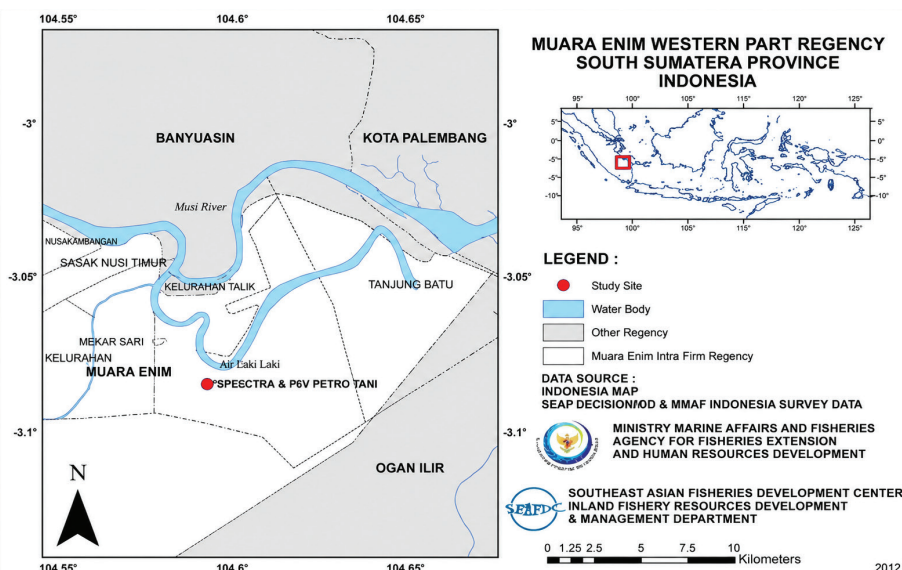
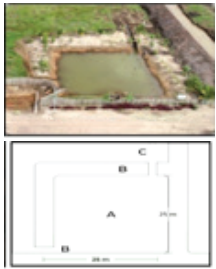
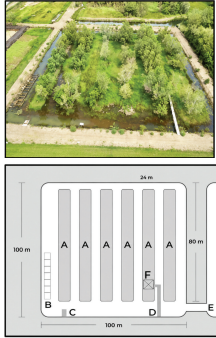
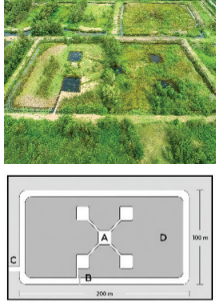
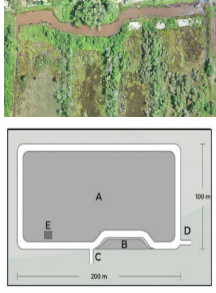
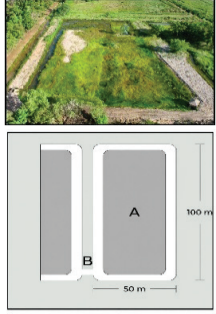


Figure 1. Location of the SPECTRA pilot site at Patra Tani, Muara Enim, South Sumatra, Indonesia

conservation areas, and larger interconnected pond systems. Each design has a specific function, but all are based on the same principle: providing safe habitats where fish can

survive, grow, reproduce, and later contribute to surrounding inland waters. **Box 1** summarizes these variations and their ecological functions.

Box 1. Main design variations and ecological functions of the SPECTRA Model				
SPECTRA Model	Main characteristics	Ecological function	Suitable conditions	Scheme
Model 1: Fish refuge pond with bamboo boundary	A refuge pond with a bamboo boundary system. The pond is around 4 meters deep to maintain water during low-water periods.	Provides safe refuge for fish during dry seasons or habitat disturbance. Fish can grow and reproduce, while juveniles can later move back to surrounding waters.	Suitable for swamp or floodplain areas that experience seasonal water decline and require simple, low-cost protection.	
Model 2: Conservation pond integrated with aquaculture	A conservation pond of about 1 hectare and around 4 meters deep. The system is supported by surrounding vegetation and can be linked with aquaculture activities.	Supports fish conservation while allowing controlled aquaculture or learning activities. Vegetation contributes to organic matter and may support natural food production.	Suitable for sites that combine conservation, demonstration, education, and sustainable aquaculture practices.	
Model 3: Pond network for predator protection	A conservation area with smaller ponds inside the main pond system. The area covers about 2 hectares and includes pathways for juvenile fish movement.	Helps protect fish, especially juveniles, from predators. The inner pond network provides additional shelter and supports fish recruitment.	Suitable for areas where predator pressure is high or where juvenile fish need additional protection during early growth stages.	
Model 4: Agroforestry-based conservation area	A conservation concept that links fish <i>refugia</i> with surrounding trees, plants, and site stewardship.	Supports habitat quality through vegetation cover, organic matter input, water quality improvement, and phytoplankton growth.	Suitable for sites where fisheries conservation can be integrated with vegetation management, environmental education, and community stewardship.	
Model 5: Larger interconnected conservation pond system	A larger pond system of about 5 hectares, with interconnected water bodies, trees, grasses, and natural habitat features.	Provides broader habitat space for fish breeding, feeding, movement, and protection. It can support more complex ecological functions.	Suitable for larger areas with sufficient land and water availability, especially where long-term habitat protection and demonstration activities are planned.	

These designs show that SPECTRA is an adaptable conservation package that can be translated into different designs according to site conditions. For regional application, other countries do not need to copy the Patra Tani design exactly; instead, they can adopt core SPECTRA principles and adjust them to their own inland water ecosystems, governance systems, and community priorities.

From Conservation Infrastructure to Knowledge Sharing

Beyond physical conservation, SPECTRA implementation shows that a fish refugium can also serve as a multifunctional learning hub. Currently, the site integrates fish population monitoring, water quality observation, native fish aquaculture, environmental education, and community-based ecotourism activities (Sawestri *et al.*, 2023; Supriyadi *et al.*, 2023).

These activities generate practical field experience for managing fish *refugia* in swamp and floodplain ecosystems. Continuous monitoring provides useful information on fish growth, population structure, habitat conditions, and seasonal changes which are crucial for evaluating performance over time and for identifying aspects that may need adjustment. Insights from the Patra Tani experience regarding the application and adaptation of SPECTRA principles in other inland water systems are summarized in **Box 2**.

Box 2. Key messages from the SPECTRA experience
1. Conservation should follow ecological processes
The SPECTRA experience shows that conservation design should work with natural inland water dynamics. Seasonal water movements, floodplain conditions, and native fish behavior need to be considered so that fish can find suitable areas for feeding, breeding, nursery, and refuge. This ensures that conservation activities support, rather than disrupt, natural ecological cycles.
2. Local knowledge should be valued and integrated
Community understanding of fish habitats, seasonal water changes, and traditional <i>refugia</i> practices provides an important foundation for conservation. When combined with scientific monitoring and technical documentation, this knowledge becomes stronger, easier to explain, and more useful.
3. Conservation sites can serve multiple functions
A fish <i>refugia</i> site can be more than a closed sanctuary; it can also support research, education, demonstration activities, community awareness, and ecotourism. This multifunctionality strengthens local acceptance and encourages support from communities, local authorities, universities, and development partners.
4. Flexibility remains essential
SPECTRA is an adaptable approach, not a fixed design. Its application should respond to local water systems, land characteristics, fish habitats, governance arrangements, and community priorities. This flexibility is important if SPECTRA principles are to be shared and adapted in other inland water systems in Southeast Asia.

SPECTRA also offers learning opportunities for students, researchers, fisheries practitioners, local communities, and visitors. By combining habitat protection with research, capacity building, and public awareness, the site helps connect ecological knowledge with practical field management.

This multifunctional role gives SPECTRA broader value as a learning model for regional knowledge sharing. Rather than transferring a fixed model directly, lessons from the site can help other countries consider how similar principles may be adapted to their own ecological conditions, governance systems, and community needs.

Adapting SPECTRA for Regional Learning

Across several SEAFDEC Member Countries (Lao PDR, Thailand, Cambodia, Viet Nam, and Malaysia), inland waters such as rivers, floodplains, reservoirs, and wetlands support important fish habitats and local livelihoods. These seasonally connected ecosystems serve as feeding, breeding, nursery, and refuge areas, contributing to food security, income, and community-based fisheries in rural areas (Barut, 2016; Funge-Smith & Bennett, 2019; Lynch *et al.*, 2016).

However, inland water systems are increasingly affected by habitat degradation, hydrological changes, infrastructure development, pollution, climate variability, and competing water uses. In addition, inland fisheries often receive less attention in international development and conservation agendas compared with marine and terrestrial ecosystems despite their importance (Funge-Smith & Bennett, 2019; Lynch *et al.*, 2016).

These conditions create an opportunity to position the SPECTRA Model as a practical approach for regional learning. Instead of a fixed infrastructure design that must be copied directly, SPECTRA offers a set of adaptable principles for protecting critical fish habitats, maintaining refuge areas, supporting ecological monitoring, and linking conservation with education and community participation.

For example, in countries with floodplain systems, SPECTRA principles may be used to strengthen seasonal fish *refugia* and maintain connectivity between water bodies. In reservoirs, the approach may support habitat protection, fish monitoring, and community awareness activities. In swamps or wetlands, SPECTRA may help integrate fish conservation with vegetation management, local stewardship, and livelihood-oriented learning. Similar regional initiatives show that conservation outcomes depend on the ability to align ecological design with local governance, community participation, and long-term institutional support (Kunda *et al.*, 2022; Sithirith, 2026).

Therefore, the regional relevance of SPECTRA lies in its flexibility. Each country can adapt the model according to its own inland water characteristics, fish species, management institutions, and community needs. Through SEAFDEC/IFRDMD's role in knowledge sharing, technical cooperation, and regional networking, the experience from Patra Tani can provide useful lessons for strengthening sustainable inland fisheries management across Southeast Asia.

Pathways for Wider Knowledge Sharing

The wider promotion of SPECTRA requires more than explaining its technical design. To be useful for other inland water systems, the model needs to be communicated clearly, supported by field evidence, and shared through sustained partnerships. This is important because countries and communities may have different ecological conditions, institutional capacities, and management priorities.

Strengthening regional awareness is a priority. Although SPECTRA has been introduced through SEAFDEC-related forums and institutional discussions, broader recognition is still needed. Communication materials should be tailored for diverse audiences, including government agencies, universities, local governments, non-government organizations, community groups, private sector partners, and development agencies.

Documentation is also essential. Technical reports, monitoring summaries, case studies, maps, photographs, videos, and simple guidelines can help explain how SPECTRA works in practice. These materials would allow potential partners to understand the model, compare it with their own inland water systems, and identify suitable elements for local adaptation. A digital repository could also support wider access to these materials and strengthen regional learning across sites.

Knowledge sharing should not depend solely on one-time meetings or short-term activities. Workshops, webinars, field visits, technical exchanges, and collaborative research can build trust among institutions and countries. These activities can also encourage comparative learning between different types of inland water ecosystems, such as floodplains, reservoirs, swamps, wetlands, and riverine systems.

SPECTRA should also be framed within broader regional priorities. The model is not only about fishponds or conservation infrastructure. It is also linked to habitat protection, biodiversity conservation, climate resilience, sustainable livelihoods, environmental education, and ecosystem-based fisheries management. Where appropriate, SPECTRA-related sites could also be assessed in relation to area-based conservation approaches, including Other Effective Area-Based Conservation Measures (OECMs).

At the same time, wider application will require institutional and financial support. Interested countries may face constraints related to funding, land availability, technical capacity, monitoring systems, and long-term maintenance. For this reason, regional promotion should be gradual and realistic. Partnerships, site assessments, technical guidance, and phased planning are needed before pilot activities are expanded.

Table 1 summarizes how SPECTRA can be promoted gradually, beginning with awareness and documentation, followed by pilot exploration and partnerships, eventually moving toward institutional support and long-term sustainability. The table should be read as an indicative guide for regional knowledge sharing, not as a fixed implementation plan.

Table 1. Proposed phased roadmap for regional knowledge sharing on SPECTRA

Phase	Strategic focus	Possible activities	Expected contribution
Short-term	Awareness and documentation	Policy briefs, popular articles, technical guidelines, regional seminars, digital repository, and improved monitoring documentation	Stronger visibility, shared understanding, and initial regional recognition
Medium-term	Pilot exploration and partnerships	Site assessments in interested countries, joint research, field learning visits, regional working group, and engagement with universities, NGOs, CSR programs, and communities	Evidence for adaptation and stronger multi-stakeholder collaboration
Long-term	Institutionalization and sustainability	Integration into SEAFDEC programs, funding mechanisms, regional conservation initiatives, OECM-oriented assessment where relevant, and adaptive regional roadmap	Policy legitimacy, continuity, and wider use of SPECTRA principles

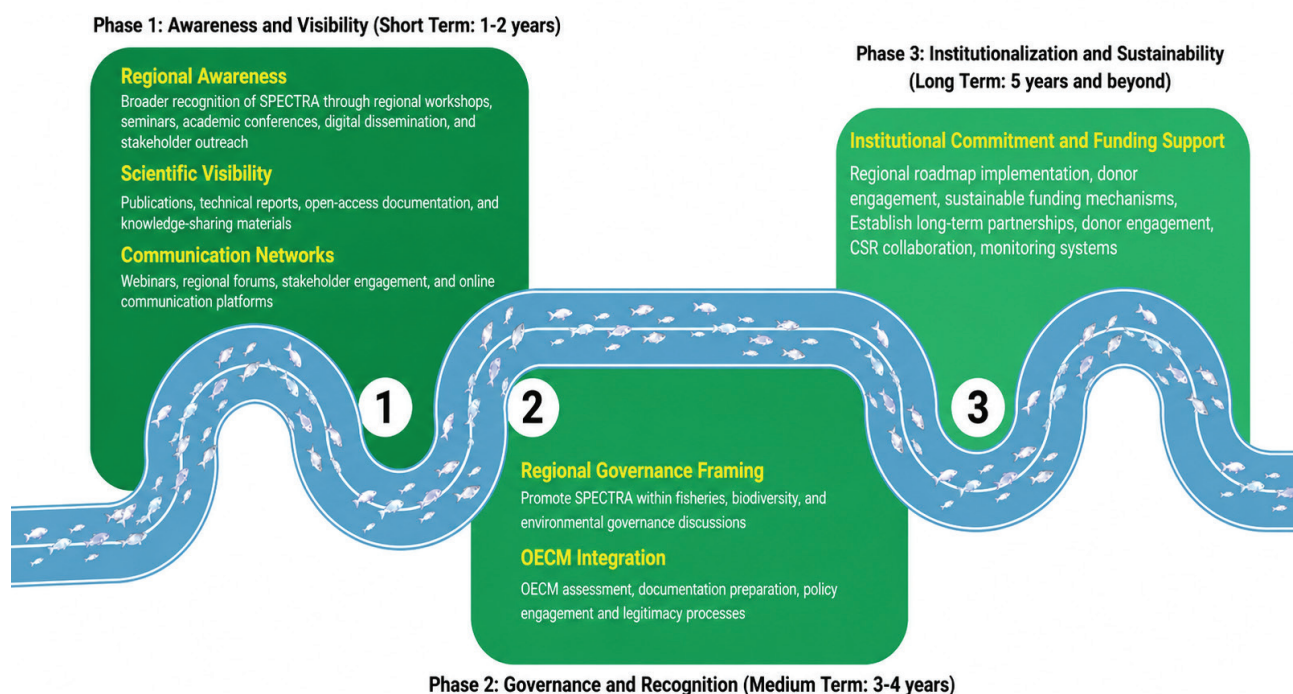


Figure 2. Regional roadmap for promoting the SPECTRA Model in Southeast Asia

As illustrated in **Figure 2**, adaptive replication should begin with site assessment. Potential sites need to be reviewed based on ecological suitability, water availability, fish habitat conditions, and local fisheries dependence. Local governance and community readiness should also be considered before any technical design is selected.

The roadmap shows that SPECTRA promotion should be carried out gradually. The process begins with identifying suitable sites and understanding local ecological and social conditions, before moving to technical adaptation, stakeholder engagement, pilot implementation, monitoring, and wider knowledge sharing. This step-by-step approach ensures that SPECTRA principles are adapted to local contexts rather than copied as a fixed design.

For SEAFDEC/IFRDMD, this approach reinforces its role as a regional knowledge broker for inland fisheries. By documenting experiences, facilitating learning, and connecting countries with similar challenges, SEAFDEC/IFRDMD can help SPECTRA develop from a local pilot model into a regional platform for cooperation and capacity building.

Conclusion and Way Forward

The SPECTRA Model offers a practical example of inland fisheries conservation that works with natural swamp and floodplain dynamics. Its value lies in combining fish *refugia*, habitat protection, ecological monitoring, education, and stakeholder engagement within one learning site.

For Southeast Asia, the main lesson is not to replicate the physical design of SPECTRA exactly. A more effective approach is to learn from its principles: protecting critical fish habitats, using local hydrological conditions, documenting ecological changes, involving communities, and linking conservation with learning and livelihoods.

With stronger documentation, continuous communication, inclusive participation, and regional cooperation, SPECTRA can contribute to sustainable inland fisheries, biodiversity conservation, and more resilient livelihoods in Southeast Asia. By strengthening partnerships and adaptive learning, SPECTRA can also support SEAFDEC/IFRDMD's role in promoting practical, ecosystem-based approaches for sustainable inland fisheries management in the region.

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