



Review Paper

Modern Approaches in Fisheries Extension Education: ICT, Participation and Livelihood Enhancement

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Abstract

This review aims to synthesize recent advances in fisheries extension education, highlighting the transition from conventional technology transfer approaches to participatory, ICT-enabled, and livelihood-oriented extension systems. It also examines the role of innovative extension strategies in promoting sustainable fisheries development and improving the socio-economic well-being of fishing communities. Fisheries extension education has evolved from a traditional top-down model of technology transfer into a more participatory, ICT-enabled, and livelihood-oriented system. Modern extension now uses mobile applications, digital advisory services, and e-governance platforms to improve access to timely information, while participatory tools such as Participatory Rural Appraisal (PRA), co-management, and farmer-led innovation strengthen stakeholder ownership and resource sustainability. These approaches also support livelihood enhancement through income diversification, employment generation, improved market access, and food security. Despite challenges such as the digital divide, institutional constraints, and socio-economic inequality, integrated extension models offer significant potential for inclusive, resilient, and sustainable fisheries development.

1. Introduction

According to PIB (2026), the fisheries sector is vital for global food security and rural livelihoods. India, the world's second-largest fish producer, contributes about 8% of global output. The International Year of the Woman Farmer (2026) has strengthened inclusive, gender-responsive, and digitally driven fisheries extension initiatives. According to Soni (2026), traditional extension methods often fail to address real-time challenges such as weather variability and market fluctuations. Fisheries extension education bridges scientific knowledge and fishing communities, moving beyond linear technology transfer toward more responsive and stakeholder-oriented approaches. According to Forum IAS (2026), the Blue Economy and climate-related challenges, including the 2025 Palghar cyclones, have transformed fisheries extension from technology transfer to resilience building and economic empowerment. Modern extension now focuses on ICT integration, stakeholder participation, and livelihood enhancement, making 2026 a significant milestone in global extension policy. According to PIB (2026), United Nations' declaration of the International Year of the Woman Farmer (IYWF 2026) has refocused fisheries

extension on gender-inclusive strategies, recognizing that women constitute a significant portion of the post-harvest and small-scale aquaculture workforce. According to Abdullahi et al (2025), the shift toward Industry 5.0 which prioritizes human-centric AI and robotics is redefining how technical advice is delivered to remote coastal communities. Early extension was rooted in Everett Rogers' (1962) theory, which viewed technology adoption as a linear process from "innovators" to "laggards." According to Robert Chambers (1983), challenged this top-down approach, advocating for "putting the last first" and recognizing the indigenous knowledge of fishers. Fals Borda and Rahman (1991) established PAR as a mechanism for marginalized communities to analyze their own situations and implement solutions, which later informed the Participatory Rural Appraisal (PRA) methods used in modern fisheries (FAO, n.d.). According to Joshua (2023), fisheries extension has transitioned from a traditional "top-down" Transfer of Technology (ToT) model to a multidimensional, stakeholder-driven approach. In 2026, the sector faces dual pressures: the need to meet global food security demands and the imperative to manage dwindling marine resources, FAO (1999). According to PIB (2026b) modern fisheries extension education acts as a bridge between scientific innovation and Traditional Ecological Knowledge (TEK), supporting

sustainable Blue Economy development. Growing challenges such as climate change, population growth, and resource scarcity have increased the importance of extension services in promoting climate-smart practices, including efficient water management, disease control, and species diversification.

2. Conceptual Framework of Modern Fisheries Extension

The conceptual framework of modern fisheries extension has shifted from traditional technology transfer models to participatory, pluralistic, and livelihood-oriented systems. It integrates multiple stakeholders, knowledge sources, ICT tools, and innovation networks to address complex fisheries challenges. Guided by theories such as Diffusion of Innovations and communication models, modern extension emphasizes sustainability, inclusiveness, resilience, and stakeholder empowerment for effective fisheries development and resource management.

3. Evolution of Fisheries Extension Models

The conceptual framework of modern fisheries extension can be understood through its historical evolution, which reflects changing paradigms in development thinking (Fig 1). The journey from colonial-era command systems to modern decentralized models can be categorized into four distinct phases:

3.1. The Pre-Modern Era (1950s–1970s)

According to Sajesh et al (2020), this period was characterized by the Community Development Programme (CDP) and the National Extension Service (NES). While these models utilized village-level workers, they often lacked the technical depth required for specialized fisheries management.

3.2. The Training and Visit (T&V) Era (1970s-1990s)

According to Swanson & Mathur (2003), the T&V system introduced a single line of command, focusing on disseminating research from scientists directly to "contact farmers." While effective for cereal crops during the Green Revolution, it struggled in the fisheries sector due to the high diversity of aquatic ecosystems and the mobility of capture fishers.

3.3. The Institutional Reform Phase (2000s-2020)

According to Sajesh et al (2020), the implementation of the Agricultural Technology Management Agency (ATMA) marked a shift toward a bottom-up, decentralized approach. ATMA integrated various departments (Fisheries, Agriculture, Animal Husbandry) under one umbrella to provide holistic advisory services.

3.4. The Modern "Phygital" Era (2021-Present)

According to Forum IAS (2026), current models combine

physical field presence with digital platforms. The Marine Fisheries Census 2025 and the rise of Fish Farmer Producer Organizations (FFPOs) exemplify this shift, where data-driven insights are delivered through social-network-based learning.

4. Transfer of Technology (ToT) Model

The Transfer of Technology (ToT) model was the dominant approach in early fisheries extension, emphasizing a linear flow of information from researchers to extension workers and ultimately to fishers. Its primary goal was to enhance productivity through the adoption of improved technologies. Common mechanisms included Front Line Demonstrations (FLDs), where institutions such as ICAR and State Agricultural Universities showcased improved pond management and cage culture practices, and Lab-to-Land programmes that delivered research outputs directly to fishing communities. Although the ToT model contributed to increased production, it suffered from several limitations, including inadequate feedback mechanisms, limited consideration of local ecological and socio-economic conditions, and low adoption rates. As noted by Sajesh et al. (2020), the model often followed a "one-size-fits-all" approach, overlooking the diverse realities of fisheries systems, where technologies successful in controlled environments may not perform effectively under local conditions.

5. Participatory Extension Model

Modern extension relies on the Participatory Rural Appraisal (PRA) and Participatory Action Research (PAR) frameworks. i) Co-Design: According to MDPI (2020), technologies are now developed with fishers rather than for them. This ensures that the tools (e.g., GPS-linked sonar) are compatible with local fishing vessels. ii) Participatory Monitoring and Mapping: Using local knowledge to map "hotspots" for fish breeding, as seen in tropical river studies where fisher's geo reference Peacock bass habitats. iii) PAME (Participatory Assessment, Monitoring and Evaluation): Beneficiaries themselves track the success of an intervention, leading to higher sustainability rates, FAO (n.d). According to Bhat et al (2024); Penn State Extension (2024) explained that this approach identifies and leverages existing community resources such as local knowledge or traditional infrastructure to drive development from within. According to Bhat et al (2024) and PIB (2026), FFS promote "learning by doing," where fishers experiment with new technologies, such as Circulatory Aquaculture Systems (RAS) and Bio-floc, in a group setting to mitigate risks.

6. Pluralistic and Innovation System Approach

The modern conceptual framework is characterized by a pluralistic system involving multiple actors, including government agencies, research institutions, private sector organizations, and non-governmental organizations. This approach aligns with the concept of Agricultural Innovation Systems (AIS), where innovation is seen as a

result of interactions among various stakeholders. Key elements include: i) Multi-stakeholder collaboration ii) Knowledge co-creation iii) Market-oriented extension iv) Integration of ICT tools.

7. Role of ICT in Fisheries Extension

ICT has transitioned from a simple communication tool to the backbone of modern extension.

7.1. Mobile Technologies & Apps

According to PIB (2026), apps like Fisher Friend and eFishery provide real-time information on i) Potential Fishing Zones (PFZ): Derived from satellite data to reduce scouting time. ii) Ocean State Forecasts: Critical for safety at sea, especially during the increased frequency of cyclones seen in 2025. According to Biswal et al (2026), tools like Aqua Brahma, mJhinga, and Mathsya Kiran provide real-time market prices, disease diagnostics, and water quality management. Fisher Friend Mobile Application (FFMA) and Sagar Vani offer Potential Fishing Zone (PFZ) advisories, wave height alerts, and GPS navigation to enhance safety and catch efficiency (Fig 4).

7.2. AI and Machine Learning (Sota 2026)

According to MDPI (2025), AI is used for predictive aquaculture management. Sensors monitor dissolved oxygen and temperature, while AI algorithms optimize feeding schedules to reduce waste and environmental impact. According to Prusty et al (2025) said that These help fishers and policy-makers analyze complex data, such as the socio-economic impacts of river ecology changes or yield fluctuations. According to Li et al (2023); Prasad et al (2025) described that AI algorithms (e.g., YOLOv4) are now used for aquatic disease detection with accuracies reaching 95.41% for specific parasites.

7.3. Block Chain for Traceability

According to MDPI (2026) explained that Block chain platforms (e.g., Aruna) allow small-scale fishers to record their catch immutably. This enables "farm-to-fork" traceability, allowing fishers to access premium export markets by proving their catch is sustainably sourced and free from IUU (Illegal, Unreported, and Unregulated) fishing. The integration of Internet of Things (IoT) for real-time water monitoring. According to MANAGE (2025), artificial intelligence (AI) for pest/disease forecasting, and Block chain for ensuring traceability in the supply chain is becoming standard in modern extension portfolios. According to Ismail et al (2023), block chain technology is being integrated into fish supply chains to provide decentralized, transparent records from "farm to fork," reducing fraud and ensuring food safety.

8. Integration of ICT and Participatory Approaches

According to Abdullahi et al (2025), the synergy between

ICT and participation creates Interactive Digital Extension Services (DES). "The fusion of digital tools with human-centric participation overcomes the 'innovation resistance' often found in traditional communities." (The UTAUT-IRT Model (Unified Theory of Acceptance and Use of Technology combined with Innovation Resistance Theory) explains this integration. By involving fishers in the co-design of mobile apps, extension agencies reduce the "image" and "value" barriers that previously hindered adoption (Fig 2).

9. Livelihood Enhancement Through Extension

According to Forum IAS (2026) discussed that extension education is no longer just about catching fish; it is about Value Chain Management. Post-Harvest Loss Reduction: With losses reaching up to 37% for dry fish in some regions, extension focuses on cold-chain logistics and hygienic processing (Fig 5). Market Intelligence: According to PIB (2026), digital platforms bridge the gap between fishers and consumers, ensuring fair pricing and reducing dependency on middlemen. Financial Literacy: Modern extension includes training on insurance coverage and institutional finance, particularly for FFPOs. The Pradhan Mantri Matsya Sampada Yojana (PMMSY) remains the central pillar of development, with a 2026-27 budgetary allocation of ₹2,500 crore focused on value chain modernization (Table 1).

Table 1: Livelihood Enhancement and Socio-Economic Impact: The integration of modern extension approaches has led to measurable improvements in the livelihoods of fishing communities.

Metric (as of Jan 2026)	Impact
Direct/Indirect Employment	74.66 lakh jobs generated since 2014-15
Kisan Credit Card (KCC)	4.39 lakh beneficiaries with institutional credit access
Insurance Coverage	3.3 million fishers covered under accidental insurance
Annual Fish Production	Reached 197.75 lakh tonnes (106% increase over a decade)
Seafood Exports	Record value of ₹62,408 crore in FY 2024-25

10. Institutional Framework and Policy Support

According to Forum IAS (2026) expressed that the global framework is guided by the FAO Code of Conduct for Responsible Fisheries and UNCLOS. i) Government Support: In India, schemes like the PMMSY facilitate formalization and insurance. ii) NGOs & International Bodies: These organizations often lead the "participation" aspect, facilitating focus groups and gender-responsive training. iii) Center for Gender in Agriculture, MANAGE (2026) institutes like MANAGE have trained over 60,000 women in digital technologies and leadership.

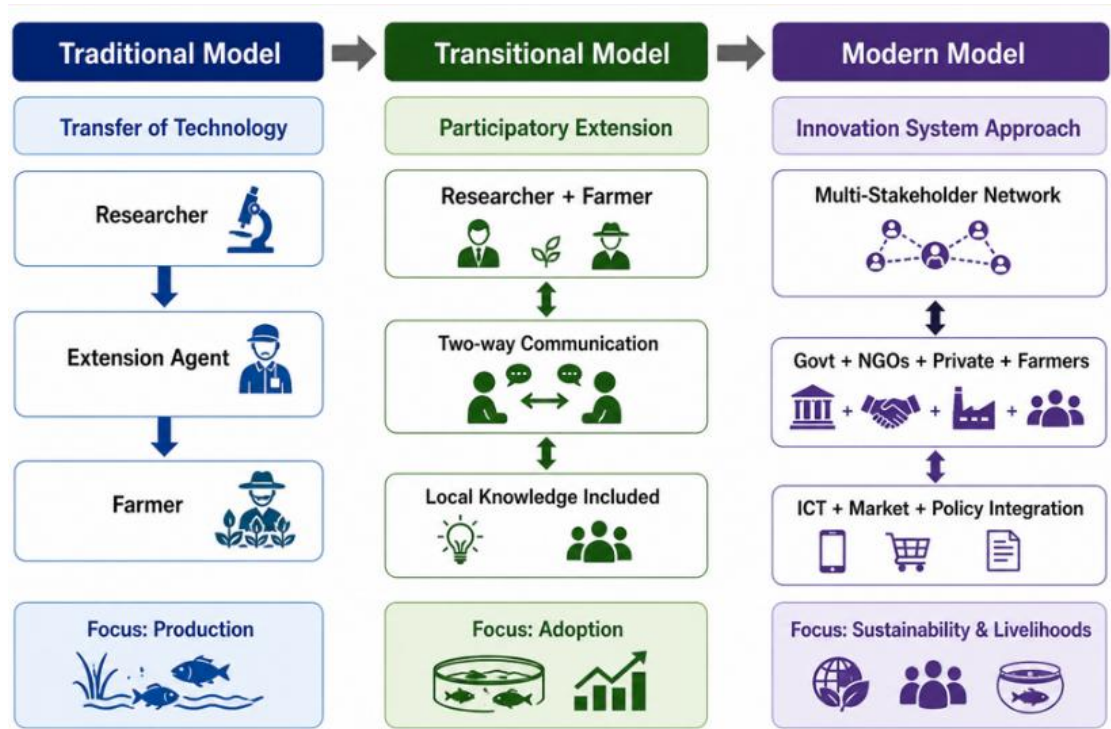


Figure 1: Evolution of Fisheries Extension Approaches: The figure shows the paradigm shift from linear, top-down extension to participatory and innovation-driven systems.

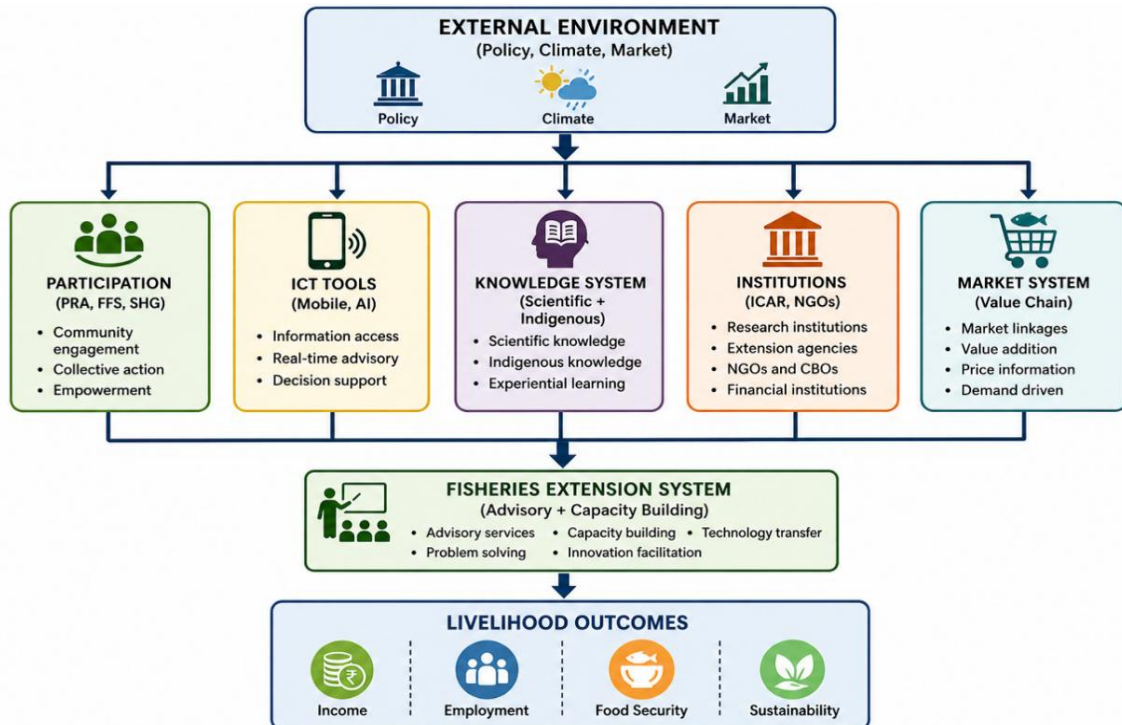


Figure 2: Integrated Conceptual Framework of Modern Fisheries Extension: Demonstrates how ICT, participation, institutions, and markets interact to influence livelihood outcomes.

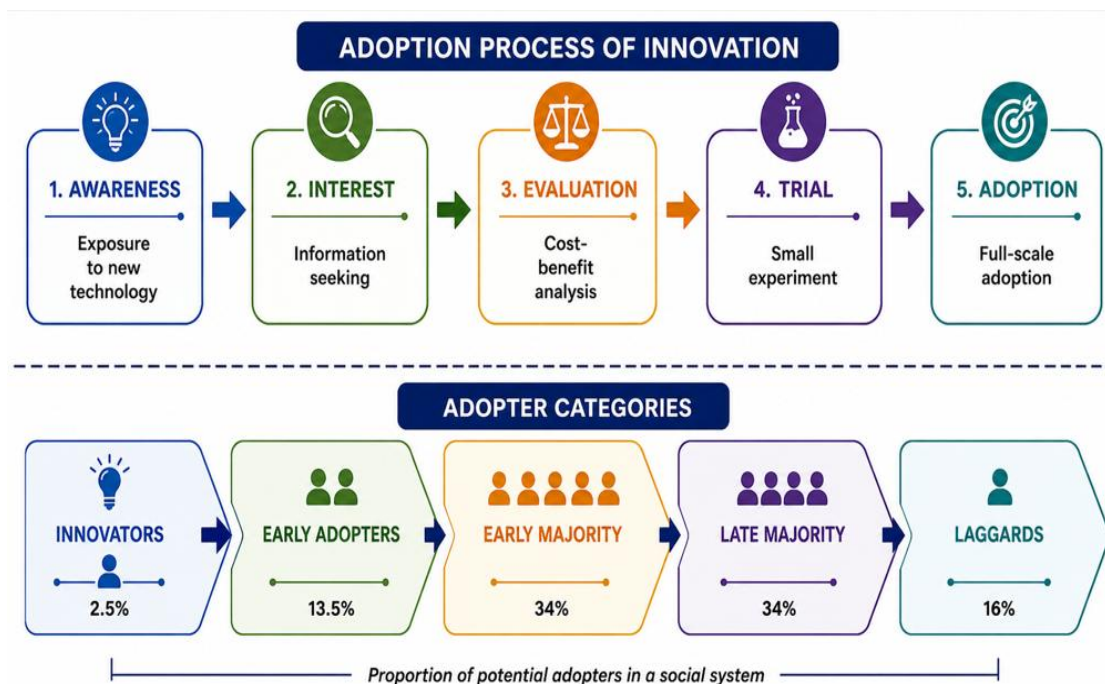


Figure 3: Adoption Process of Fisheries Technologies: Illustrates stages of adoption and adopter categories relevant to fisheries technologies.

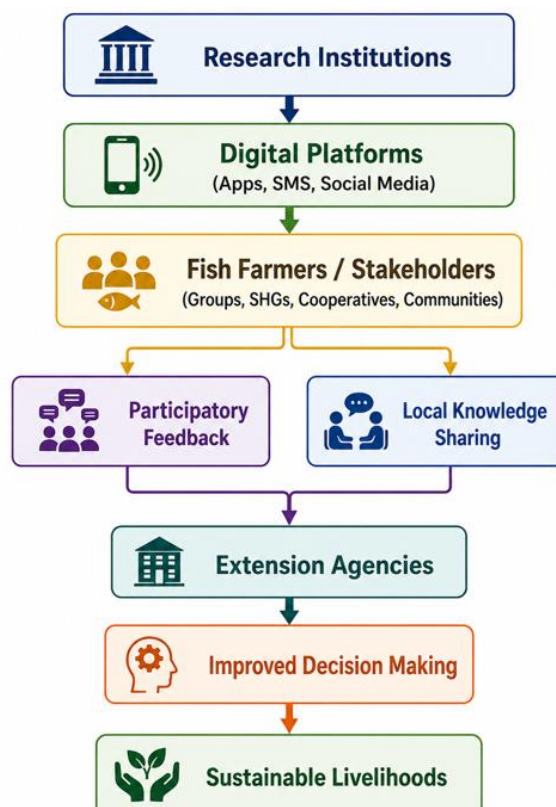


Figure 4: Digital Participatory Fisheries Extension Model: Shows integration of ICT tools with participatory approaches for effective extension delivery.

11. Challenges in Modern Extension

According to MDPI (2025), despite advancements, several hurdles remain: i) Digital Divide: Access to high-speed internet in remote coastal hamlets is still inconsistent. ii) Climate Change: Unpredictable rainfall patterns and rising sea temperatures (causing species like sardines to shift north) require extension models to be highly adaptive, Forum IAS (2026). iii) Input Costs: According to Soni (2026), rising prices for fishmeal (70% of production costs) threaten the profitability of small-scale farmers. Inadequate cold chain logistics still lead to significant wastage. Socio-economic inequalities continue to hinder the universal adoption of ICT tools among older or marginalized fishers.

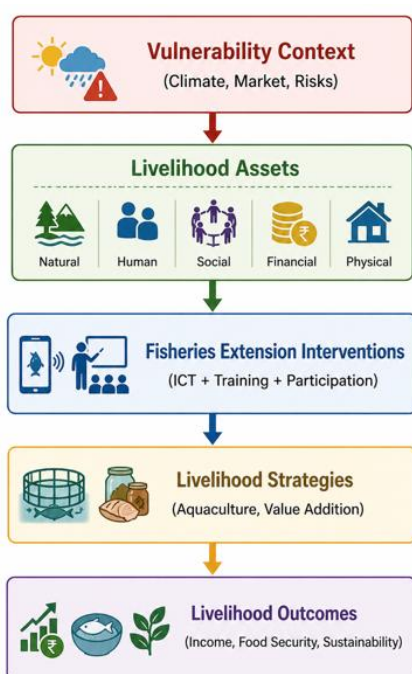


Figure 5: Livelihood Framework in Fisheries Extension: Sustainable Livelihood Framework in Fisheries

12. Case Studies: Participatory and ICT Integration

To understand the efficacy of modern extension, it must look at where the "rubber meets the water." These cases illustrate the shift from top-down instruction to collaborative innovation.

12.1. Indonesia: The 'Aruna' Model and Digital Cooperatives

In Indonesia, the platform Aruna has revolutionized how small-scale fishers interact with the global market. The Approach: Aruna acts as a digital aggregator. Instead of an extension officer just teaching "how to fish," they facilitate the use of a digital dashboard that tracks catch data in real-time. Outcome: According to MDPI (2025), participating fishers saw a 20% increase in income due to the elimination of predatory middlemen. The extension

component here is "market literacy" teaching fishers to understand global demand cycles through data.

12.2. Vietnam: Integrated Mangrove-Shrimp Farming (Participatory Co-Management)

In the Mekong Delta, the shift toward organic, mangrove-integrated shrimp farming was driven by participatory extension. The Approach: Extension officers didn't just hand out manuals. They used Farmer Field Schools (FFS) where farmers experimented with different mangrove densities to see which naturally filtered the water best. Outcome: This co-design led to the "Ca Mau" certification, allowing farmers to export to high-end EU markets. It proved that sustainability isn't a burden; it's a premium brand.

12.3. India: The 'Matsya Setu' App and Virtual Learning

The Matsya Setu app, developed by ICAR-CIFA, serves as a cornerstone of the Indian "Phyigital" model. The Approach: It uses short, module-based videos in local languages. However, the "participatory" twist is the Ask-a-Scientist feature, where fishers upload photos of diseased fish for real-time AI and human diagnosis. According to PIB (2026), the integration of Regional Language LLMs now allows fishers to speak to the app in dialects, receiving instant advice on pond chemistry.

13. Future Perspectives

The future of fisheries extension lies in the Blue Economy 2.0. Digital Twins: Creating digital replicas of ponds to simulate the impact of different stocking densities or weather events. Decentralized Finance (DeFi) in Fisheries: Using block chain to provide micro-loans directly to fishers based on their catch history. Sustainable Development Goals (SDGs): Extension will be the primary vehicle for achieving SDG 14 (Life Below Water) and SDG 5 (Gender Equality) by 2030. According to PIB (2026), extension efforts must shift toward deep-sea fishing and high-value species diversification (e.g., tilapia and scampi) while strictly adhering to the 2025 Sustainable Fisheries Rules.

14. Conclusion

Modern fisheries extension education has evolved into a dynamic, multi-dimensional system integrating ICT, participatory approaches, and livelihood strategies. These approaches have significantly improved the effectiveness, inclusiveness, and sustainability of extension services. However, challenges such as digital divide and institutional limitations must be addressed through policy support, capacity building, and innovation. A holistic and integrated approach is essential for achieving sustainable fisheries development and improving livelihoods. The modernization of fisheries extension is not a luxury but a necessity for the survival of small-scale fisheries. By marrying high-tech ICT tools with high-touch participatory methods, extension education can empower fishers to become resilient stakeholders in the global food system. The future of fisheries lies in an extension model that is data-driven, community-led, and livelihood-focused.

15. Statements and Declarations

Ethical Approval: Not Applicable

Disclaimer (Artificial Intelligence): Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

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