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Climate-Smart Strategies for Sustainable Fisheries: Building Resilience in Indian Aquaculture

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Abstract

Climate change is increasingly impacting India's fisheries and aquaculture, affecting aquatic ecosystems, fish productivity, and the livelihoods of millions dependent on these resources. Rising water temperatures, erratic rainfall, salinity intrusion, ocean acidification, and extreme weather events pose significant risks to fish health, breeding cycles, and production systems. Climate-smart fisheries (CSF) offer an integrated approach to address these challenges by combining adaptation, mitigation, and sustainability measures. Key strategies include ecosystem-based management, restoration of blue carbon habitats, adoption of integrated multi-trophic aquaculture (IMTA), climate-resilient infrastructure, and renewable energy technologies. Veterinary professionals play a critical role in ensuring fish health, biosecurity, disease prevention, and community training to enhance resilience. Drawing on Indian initiatives under the NICRA program and global examples from Vietnam, Nigeria, Iceland, and the Mediterranean, this article highlights practical pathways for building climate-resilient, productive, and low-carbon fisheries. Emphasizing participatory research, technology adoption, policy support, and social equity, CSF can safeguard food security, protect aquatic ecosystems, and strengthen rural livelihoods. Implementing these measures positions India's fisheries sector as a model of sustainable development and a resilient contributor to the blue economy in a changing climate.

Keywords: Climate-smart fisheries, Aquaculture, Fish health, blue carbon, IMTA, Veterinary management, Adaptation, Resilience, Sustainable livelihoods

Introduction

Fisheries and aquaculture are vital to India's food security, rural livelihoods, and economic growth. They supply high-quality protein to millions and sustain employment in coastal and inland communities. Yet, the sector faces growing threats from climate change. Rising water temperatures, erratic rainfall, ocean acidification, and extreme weather events are

altering aquatic ecosystems, disrupting fish breeding cycles, and increasing disease risks in both freshwater and marine systems.

Veterinary professionals play a critical role in ensuring fish health, biosecurity, and sustainable production under these challenging conditions. To safeguard productivity and resilience, India's fisheries sector must adopt climate-smart strategies, integrating ecosystem management, technology, and community engagement.

Climate Change Impacts on Fisheries and Aquaculture

Climate variability affects fisheries in multiple ways:

- **Water temperature and oxygen fluctuations** impact fish metabolism, growth, and survival.
- **Hydrological changes**—floods, droughts, and salinity intrusion—disrupt inland aquaculture and natural habitats.
- **Extreme weather events** damage infrastructure and increase mortality risks for cultured and wild fish.
- **Emerging diseases and harmful algal blooms** threaten fish health, highlighting the need for veterinary oversight and preventive measures.

Studies predict that, if current trends continue, **global fish biomass may decline by 30% by 2100**, with tropical regions—including India—experiencing the most severe impacts.

Climate-Smart Fisheries Management

- **Ecosystem-Based Management:** Use adaptive quotas, protection zones, and restore blue carbon habitats (mangroves, seagrass, salt marshes) to boost biodiversity and climate mitigation.
- **Climate-Resilient Aquaculture:** Implement multi-trophic systems, select robust species, and manage ponds with temperature control and water recycling to maintain yields.
- **Water & Energy Efficiency:** Harvest rainwater, use micro-irrigation, and adopt solar/wind energy to save resources and reduce emissions.
- **Selective Fishing:** Employ gear innovations to reduce bycatch and protect ecosystems.
- **Community Capacity:** Train fishers, promote cooperatives, and enhance disaster preparedness.
- **Policy & Market Integration:** Enforce responsible fisheries codes, monitor illegal fishing, and adopt climate-adaptive trade policies.

The Climate-Smart Fisheries Approach

Climate-smart fisheries (CSF) combine **adaptation, mitigation, and sustainability**. Core objectives include:

1. **Adaptation:** Developing resilient aquaculture systems that withstand climatic stressors.
2. **Mitigation:** Reducing greenhouse gas emissions, conserving blue carbon habitats (mangroves, seagrasses), and optimizing energy use in production and processing.
3. **Sustainability:** Maintaining high-quality fish production while conserving ecosystems and supporting community livelihoods.

Strategies for Indian Fisheries

Veterinary and Aquaculture Management

- **Disease Monitoring and Biosecurity:** Early detection of pathogens and harmful algal blooms helps reduce mortalities. Vaccination, pond disinfection, and regular water quality assessments are critical.
- **Integrated Multi-Trophic Aquaculture (IMTA):** Combining species such as fish, seaweed, and shellfish balances nutrients, reduces waste, and enhances resilience. India's NICRA initiative demonstrates the success of IMTA in coastal and inland farms.
- **Adaptive Pond and Cage Management:** Temperature regulation, water aeration, stocking density adjustments, and salinity-tolerant strains improve survival under variable conditions.

Community and Livelihood Measures

- **Diversification:** Fishers can adopt mixed aquaculture, poultry, or horticulture to reduce climate vulnerability.
- **Capacity Building:** Training programs on climate-smart practices, veterinary interventions, and disaster preparedness empower communities to sustain production.

Policy, Extension, and Innovation

Participatory Research and Data Integration

- Site-specific climate impact modeling and participatory research platforms anchor adaptation planning, especially in data-poor regions.
- ICT and mobile technology for weather forecasting, disease alerts, and market connections empower both large and small-scale operators.

Institutional Frameworks and Financing

- Climate adaptation must be mainstreamed in national fisheries policies and linked to disaster risk reduction, climate finance mechanisms, and international climate agreements.
- Financial products—insurance, microcredit, and investment funds—can accelerate the shift to resilient practices.

Challenges and Barriers

- High initial costs, tenure insecurity, and limited credit access deter rapid transition to climate-smart fisheries.
- Information gaps, extension service scarcity, and sometimes conflicting regulations slow innovation adoption.

Case Studies and Global Insights

Case 1: Nigerian Aquaculture Adaptation

Rising temperatures and extreme weather—like droughts, floods, and heavy rain have affected 24% of fish farming households in Nigeria, causing disrupted fish cycles, disease outbreaks, and pond degradation. In response, over 80% of farmers have adopted climate-smart measures such as water-conserving tarpaulin-lined ponds, diversified stocking schedules, shaded pond-dike cropping, improved water exchange, reinforced pond dikes, solar-powered operations, and water treatment. Community insurance and income stabilization initiatives also help mitigate risks. However, limited access to credit, extension services, and government support hinders wider adoption. Strengthening aquaculture resilience requires integrating climate adaptation into policies, increasing financial support for small-scale farmers, improving access to climate information, and promoting resilient fish species.

Case 2: Catfish Farming in Vietnam

Vietnam's catfish aquaculture is highly productive, yielding 250–400 tonnes per hectare per crop, and reduces waste by converting byproducts into fish oil and feed. Challenges include rising sea levels and salinity. Adaptation measures include moving farms upstream, breeding salt-tolerant catfish, and strengthening biosecurity and ecosystem-based management to enhance climate and disease resilience.

Case 3: Mussel Farming in Chile, Ireland, and China

Mussel farming in Chile and Ireland is climate-friendly, as mussels need no feed and emit minimal greenhouse gases while reducing water eutrophication. Climate risks include harmful algal blooms, water quality changes, and ocean acidification. Adaptation strategies include food safety monitoring, resilient strain selection, and hatchery-based seed production.

Case 4: Integrated Multi-Trophic Aquaculture (IMTA) in India

Under the National Innovations in Climate Resilient Agriculture (NICRA) initiative, Indian researchers demonstrated IMTA by integrating seaweed (Kappaphycus alvarezii) with cage farming of cobia fish. This system enhances resource use efficiency, reduces environmental impacts, and improves overall resilience to fluctuating climatic conditions. IMTA allows balancing of nutrients and reduces farm waste, turning challenges into opportunities for both productivity and environmental protection.

Case 5: Coastal Blue Carbon in Vanuatu (South Pacific)

A multidisciplinary program in Efate, Vanuatu, investigated seagrass habitats' carbon storage capacity—a blue carbon solution closely tied to fisheries resilience. The project measured carbon storage linked to water quality and sediment characteristics, providing crucial baseline data for national blue carbon strategies and informing efforts to restore and protect coastal ecosystems vital for climate-smart fisheries.

Case 6: Community-Based Fisheries Management in the Philippines & Indonesia

Fisher communities in the Philippines and Indonesia, with support from pilot initiatives and microcredit schemes, have adapted to climate risks by upgrading fishing gear and infrastructure, using blended finance models, and cooperating on local resource management. These approaches have improved both their resilience to climate shocks and the sustainability of local fish stocks.

Case 7: Icelandic Fisheries: Adaptive Harvest Management

Icelandic fisheries are pioneering adaptive, climate-informed management, such as dynamic quota systems to respond to increased storminess and shifting fish stock distributions caused by changing temperatures. These adaptive governance models enable continued productivity and sustainability with changing environmental conditions.

Technology and Innovation for Veterinarians

Veterinary professionals can leverage technology for proactive management:

- **ICT and Mobile Platforms:** Deliver real-time weather, disease alerts, and best-practice guidelines to fish farmers.
- **AI and Remote Monitoring:** Predictive models for stock health, disease outbreaks, and water quality allow early intervention.
- **Blockchain and Traceability:** Ensure sustainable and transparent supply chains, reducing illegal or unsafe practices.

Social Equity and Community Empowerment

Small-scale and indigenous fishers are disproportionately affected by climate risks. Veterinary

experts can contribute by:

- Advising on biosecurity, pond health, and disease prevention.
- Training women and marginalized groups in adaptive aquaculture practices.
- Supporting cooperative models and local insurance schemes to stabilize incomes.

Building Resilience and Adaptive Capacity

- Restore blue carbon habitats (mangroves, seagrass, and salt marshes) to boost carbon capture and fish productivity.
- Apply ecosystem-based management: adaptive quotas, seasonal closures, protected spawning sites, and multi-species focus.
- Use heat- and salinity-tolerant strains and integrated multi-trophic aquaculture to reduce risks.
- Develop disaster plans, insurance schemes, and GIS-based risk mapping for floods and disease.

Research and Extension

- Strengthen participatory research, local data repositories, and modelling for site-specific adaptation (especially in developing countries).
- Establish extension programs for disseminating climate-smart technologies, practices, and management models.
- Design adaptive institutional frameworks that allow flexibility in fisheries governance, responsive to climate impacts and changing resource distributions.

Future Directions for Indian Fisheries

To ensure sustainable, resilient fisheries:

- **Collaboration across Sectors:** Government, research institutions, veterinary experts, and communities must work together.
- **Innovation in Aquaculture:** Climate-resilient strains, low-carbon feeds, and IMTA systems should be scaled.
- **Policy Integration:** Align fisheries management with climate goals, biodiversity conservation, and the blue economy.
- **Sustainable Financing:** Expand microcredit, insurance, and ecosystem-based payments to facilitate adoption of climate-smart practices.

Conclusion

Climate-smart fisheries provide a roadmap for India to maintain food security, protect aquatic ecosystems, and sustain rural livelihoods under changing climatic conditions.

Veterinary professionals play a central role in **disease prevention, biosecurity, and capacity-building**, bridging science and community needs. By adopting ecosystem-based management, innovative aquaculture practices, and inclusive policies, India's fisheries sector can become a **climate-resilient, low-carbon, and sustainable model** for the world.

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