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# Smart Fishing Technologies: Integration of IoT, Sensors, and AI in Modern Fisheries

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***Abstract***

Digital transformation is redefining global fisheries and aquaculture through the convergence of Internet of Things (IoT) technologies, advanced sensor systems, and Artificial Intelligence (AI)-driven analytics. These "smart fishing" innovations have enabled real-time environmental monitoring, precision aquaculture, automated catch analysis, and data-driven fisheries governance. IoT networks incorporating physicochemical sensors, optical and acoustic systems, electronic monitoring (EM) cameras, and satellite data streams now form the backbone of modern fisheries management. Integrated AI and machine learning algorithms interpret these large datasets for optimizing fishing effort, identifying bycatch, monitoring vessel compliance, and predicting aquaculture system health. This review consolidates recent developments (2023–2025) in smart fisheries technology, discussing their architecture, field applications, socio-economic impact, and sustainability implications. It also highlights the current barriers related to data interoperability, infrastructure limitations, ethical issues, and policy gaps—proposing future research priorities to achieve global "blue digitalization" in fisheries.

## Introduction

The fisheries sector is undergoing a digital revolution, where data-driven tools are increasingly integrated into management, operations, and sustainability frameworks. As marine resources face threats from overfishing, Illegal, Unreported, and Unregulated (IUU) fishing, and climate variability, smart technologies have emerged as key enablers of sustainable and traceable fisheries (FAO, 2024).

IoT-based monitoring systems and AI-driven analytics are enabling both *capture fisheries* and *aquaculture* sectors to shift from reactive management to predictive and preventive systems. The Food and Agriculture Organization's *State of World Fisheries and Aquaculture 2024 (SOFIA)* report highlight digital transformation as a cornerstone for achieving the UN Sustainable Development Goal (SDG) 14—Life Below Water.

Recent technological convergence of sensors, low-power networks, and data science has resulted in what researchers' term "Smart Fisheries" (Abdullah et al., 2024; Yang et al., 2025). These technologies enhance monitoring precision, reduce labor costs, and ensure compliance through automated observation systems, remote sensing, and machine learning–based decision support.

## 2. System Architecture: From Sensors to Decision-Making

### 2.1. Sensing Layer

The foundation of smart fisheries lies in diverse sensor systems capable of monitoring both environmental and operational parameters. IoT-enabled sensor nodes continuously record:

- Physicochemical parameters — temperature, dissolved oxygen (DO), salinity, pH, and turbidity (Flores-Iwasaki et al., 2025);
- Optical and EM sensors — high-definition cameras for catch identification and bycatch monitoring (Saqib et al., 2024);
- Acoustic systems — echo sounders and hydrophones to estimate fish abundance and track animal behavior (Thorburn et al., 2024).

Such multi-modal sensing enables a continuous data stream that can be transmitted via LoRaWAN, 4G/5G, or satellite communication to centralized servers or edge nodes.

### 2.2. Edge–Cloud Computing

Edge devices such as NVIDIA Jetson and Raspberry Pi perform real-time inference (catch counting, fish classification, or anomaly detection) directly on-board vessels. The results are uploaded to cloud platforms for training, retraining, and analytics (Kim et al., 2024). This hybrid architecture minimizes latency and reduces the need for high-bandwidth satellite links.

### 2.3. Connectivity and Networking

For coastal fisheries, low-power wide-area networks (LPWANs) such as LoRa and Sigfox offer cost-effective connectivity up to 30 km offshore (Pinelo et al., 2023). Deep-sea operations rely on LEO satellites (Starlink, Iridium Certus) for continuous data transmission (Lyimo et al., 2025). A resilient “mesh” design ensures that data continuity is maintained even under harsh marine conditions (Soon et al., 2025).

## 3. Smart Sensors and Applications

### 3.1. IoT and Environmental Sensors

IoT nodes equipped with sensors provide automated water-quality monitoring in aquaculture systems. Abdullah et al. (2024) demonstrated a multi-sensor IoT system capable of maintaining ideal DO and temperature thresholds, reducing mortalities by 18%. Such applications reduce manual interventions and improve feed efficiency—key to sustainable aquaculture.

### 3.2. Acoustic Telemetry Systems

Acoustic telemetry has become indispensable in fisheries ecology, tracking species movement, stock connectivity, and MPA effectiveness (Bicknell et al., 2025; Gonse et al., 2024). Integration with AI models allows for automatic signal pattern classification, minimizing manual analysis.

### 3.3. Optical and EM Monitoring

AI-powered electronic monitoring (EM) cameras are increasingly replacing onboard observers. The *AI-RCAS* system developed by Kim et al. (2024) achieved 81% species identification accuracy for tuna longlines, demonstrating field feasibility. Such automation reduces observer bias and enhances data transparency.

## 4. Artificial Intelligence in Fisheries and Aquaculture

### 4.1. Automated Catch Estimation

Deep learning models particularly YOLOv5, Faster-RCNN, and Efficient Net—are applied to detect species and estimate catch volume from EM video footage (Saqib et al., 2024). The *AI-Fish Project* (2025) reports near-human accuracy in classifying demersal species using edge vision.

### 4.2. Fishing Effort and Compliance Mapping

Machine learning applied to AIS (Automatic Identification System) and VMS (Vessel Monitoring System) data enables activity classification (Welch et al., 2024). However, Turner et al. (2025) and Hintzen et al. (2025) warn that AIS spoofing or gaps can bias estimates, calling for integrated validation using EM and logbook data.

### 4.3. AI in Aquaculture

In aquaculture, AI algorithms use sensor data to predict feeding times, growth rates, and detect harmful algal blooms (Yang et al., 2025; Chandran et al., 2025). Neural networks trained on ORP (Oxidation-Reduction Potential) and dissolved oxygen datasets predict fish health anomalies, thereby reducing feed waste and disease outbreaks.

## 5. Networking at Sea: Challenges and Innovations

A reliable communication backbone is crucial for smart fisheries.

- Satellite and LEO systems ensure data transfer from offshore operations but remain cost-intensive.
- LoRa and mesh networks (Lyimo et al., 2025; Pinelo et al., 2023) are effective for coastal and cage-based aquaculture.
- Hybrid models combining satellite backhaul with LoRa edge networks offer scalable and low-cost solutions.

These technologies enable "always-on" data streams for analytics and early warning systems, forming the infrastructure of connected fisheries.

## 6. Case Studies

1. Global Fishing Watch (GFW): Combines ML and satellite data to map fishing activity worldwide (Welch et al., 2024).
2. AI-Fish Initiative: Demonstrates real-time catch analytics using embedded AI (AI-Fish, 2025).
3. LoRa on Ice Project: Monitors sea-ice dynamics and maritime telemetry via IoT nodes over 30 km range (EWSN, 2024).
4. Gulf of Mexico EM Program: Mote Marine Laboratory's EM project increased observer coverage by 250% while cutting costs by 30%.

## 7. Benefits and Socio-Economic Impact

- Operational efficiency: Real-time decisions reduce fuel use and optimize effort (Yang et al., 2025).
- Transparency and traceability: EM and blockchain integration enhance product credibility in seafood markets (Chandran et al., 2025).
- Sustainability gains: Improved monitoring aids compliance with national and international fisheries regulations.
- Empowerment of small-scale fishers: Low-cost IoT sensors democratize access to environmental intelligence, particularly in developing countries.

## 8. Challenges and Risks

Despite promise, technological and ethical hurdles remain:

- Data quality and bias: AIS data manipulation and false positives affect global analyses (WIRED, 2025).
- Infrastructure limitations: Marine corrosion, biofouling, and power instability constrain sensor reliability (Lyimo et al., 2025).
- Cost and inclusivity: Many small-scale fisheries lack financial capacity for digital adoption.
- Privacy and data governance: EM video raises ethical issues around data ownership and labor monitoring (Hintzen et al., 2025).

## 9. Future Research and Policy Directions

1. Development of interoperable data standards for cross-platform EM and IoT data.
2. Establishment of open-access fisheries datasets for AI benchmarking.
3. Expansion of hybrid connectivity architectures integrating LoRa, DTN, and LEO satellites.
4. Creation of AI validation frameworks for explainability and uncertainty quantification.

5. Implementation of inclusive digital governance policies to protect fisher privacy and ensure equitable access.

## 10. Conclusion

Smart fishing technologies driven by IoT, sensors, and AI represent a transformative frontier for global fisheries. From predictive aquaculture management to automated catch analytics and real-time vessel tracking, these innovations can dramatically improve efficiency, sustainability, and transparency. However, to realize their full potential, integrated frameworks must address challenges of cost, interoperability, ethics, and policy harmonization. The future of fisheries lies in the successful collaboration between technologists, fishers, and policymakers under a unified vision of sustainable digital oceans.

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