E-ISSN: 2582-9467
Popular Article
Chaturvedi et al. (2025)

Applications of Remote Sensing, Sensor Technologies, and Artificial Intelligence in Fisheries Management

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OPEN ACCESS

Keywords

Remote Sensing, Artificial Intelligence, Fisheries Management, Vessel Monitoring, IUU Fishing.

How to cite this article:

Chaturvedi, P., Biju, B., Padmanabha, A., Goswami, K., Soni, V. and Dewangan, D. 2025. Applications of Remote Sensing, Sensor Technologies, and Artificial Intelligence in Fisheries Management. *Vigyan Varta* 6 (12): 154-158.

ABSTRACT

The convergence of satellite technology, artificial intelligence, and advanced sensor networks is revolutionizing global fisheries management, creating unprecedented opportunities for sustainable ocean stewardship. This transformation encompasses real-time vessel tracking through Automatic Identification Systems (AIS) and Vessel Monitoring Systems (VMS), AI-powered species identification and catch quantification, and satellite-based habitat monitoring that supports ecosystem-based management approaches. Digital technologies enable comprehensive surveillance of previously unmonitored ocean areas, automated detection of illegal, unreported, and unregulated fishing activities, and data-driven stock assessments that integrate traditional fisheries science with machine learning algorithms. While challenges remain in data quality, technological integration, and capacity building, emerging digital solutions offer scalable pathways toward transparent, efficient, and sustainable fisheries governance in an era of increasing ocean pressures and climate change.

INTRODUCTION

The world's oceans, covering over 70% of Earth's surface, have historically remained largely unmonitored due to their vast scale and remote nature. Traditional fisheries management relied on limited observer coverage, periodic research surveys, and voluntary reporting systems that provided incomplete pictures of fishing activities and marine ecosystem dynamics. This monitoring gap has contributed to persistent challenges in combating illegal fishing, managing fish stocks sustainably, and understanding ecosystem-scale interactions.

The digital revolution now underway in fisheries management represents a paradigm shift comparable to the introduction of radar in maritime navigation. Satellite technology, originally developed for navigation and communication, has evolved into a comprehensive ocean monitoring system that tracks vessel movements, environmental conditions, and fishing activities in near real-time (Chassot *et al*., 2011). Complementing this spatial intelligence, artificial intelligence and machine learning algorithms process vast datasets to automate species identification, predict fishing behavior, and optimize management decisions.

This technological convergence addresses fundamental challenges in ocean governance: the need for comprehensive monitoring across scales, from individual fishing events to ecosystem-wide patterns, and the integration of diverse data streams into actionable management information. The implications extend beyond fisheries to encompass broader marine conservation, climate monitoring, and sustainable blue economy development.

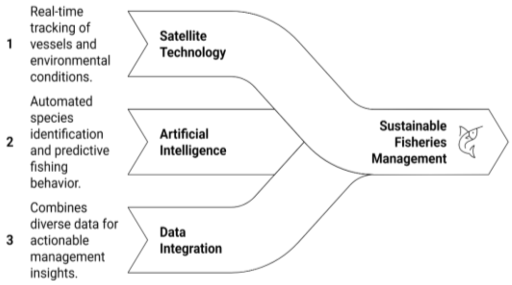

Fig.1 Digital Revolution in Fisheries Management

Satellite Technologies: Eyes on the Ocean

Remote Sensing for Habitat Assessment

Satellite remote sensing has become instrumental in mapping oceanographic conditions that determine fish habitat preferences and distribution patterns. Sea surface temperature, chlorophyll-a concentrations, and ocean color data provide continuous monitoring of primary productivity and thermal structure across ocean basins (Chassot *et al*., 2011). These measurements support ecosystem-based fisheries management by identifying critical habitats, tracking environmental changes, and predicting species distribution shifts under climate change.

Modern satellite sensors deliver daily, high-resolution images that enable detection of mesoscale oceanographic features such as eddies, fronts, and upwelling zones that concentrate fish populations. This capability has transformed fisheries science from reactive stock assessments based on historical catch data to proactive habitat monitoring that anticipates changes in fish distribution and abundance.

Vessel Tracking Systems

Two primary satellite-based technologies enable comprehensive vessel monitoring: AIS and VMS. AIS, originally designed for collision avoidance, requires vessels over 300 tons to broadcast their identity, position, speed, and course every few seconds. Global Fishing Watch processes over 22 billion AIS messages annually from approximately 60,000 fishing vessels, creating the first comprehensive global map of fishing activity (Kroodsma *et al*., 2018).

While AIS data represent only 2% of the world's estimated 2.9 million fishing vessels, these vessels account for over 50% of fishing effort beyond 100 nautical miles from shore and up to 80% of high-seas fishing activity (Global Fishing Watch, 2023). The number of AIS-equipped vessels increases by 10-30% annually, expanding coverage and improving data quality over time.

Artificial Intelligence in Fisheries Applications

Automated Species Identification and Catch Monitoring

Electronic monitoring systems equipped with cameras and AI algorithms are transforming catch documentation and compliance monitoring. Traditional observer programs face limitations in coverage, cost, and safety, monitoring less than 2% of global fishing operations. AI-powered video analysis addresses these constraints by automatically identifying species, counting fish, and detecting fishing events from onboard camera footage.

Recent advances demonstrate AI systems achieving over 90% accuracy in species identification for specific fisheries, with researchers developing models that can process hours of raw video footage into structured, actionable data without human intervention (Tryolabs, 2025). Edge computing enables real-time processing aboard vessels, reducing data transmission costs and providing immediate feedback to vessel operators and managers.

Machine Learning for Stock Assessment

Traditional stock assessment models face increasing challenges in ecosystems altered by climate change and anthropogenic stressors. Machine learning approaches offer solutions by identifying complex patterns in fisheries data that conventional statistical models may miss. Hybrid models that combine classical stock assessment approaches with gradient boosted trees show improved forecast accuracy for recruitment and spawning stock biomass across multiple fish stocks (Lüdtke & Pierce, 2023).

These AI-enhanced assessments integrate diverse data sources including satellite observations, vessel tracking data, environmental variables, and biological sampling to produce more robust population estimates and fishing mortality projections. The ability to process heterogeneous datasets at scale enables incorporation of previously unused information sources into stock evaluations.

Digital Platforms and Data Integration

Global Fishing Watch and Transparency Initiatives

Global Fishing Watch exemplifies the transformative potential of open data platforms in fisheries governance. By making AIS-based fishing activity data publicly available through interactive maps and analytical tools, the platform democratizes access to information previously available only to government agencies (Global Fishing Watch, 2023). This transparency enables civil society organizations, researchers, and fishing communities to monitor compliance with fishing regulations and hold governments accountable for enforcement.

The platform integrates multiple data sources including AIS, VMS (where available), and satellite imagery to create comprehensive pictures of fishing activity. Machine learning algorithms process this information to identify fishing events, classify vessel types, and detect potential illegal activities across all ocean basins.

Regional Implementation and Success Stories

Pacific Islands Fisheries Monitoring

The Pacific Islands region, home to the world's most productive tuna fisheries worth approximately $26 billion annually, demonstrates advanced implementation of digital monitoring technologies. Recent studies quantifying IUU fishing in the Pacific region utilized diverse datasets including Global Fishing Watch tracking data to provide comprehensive assessments of illegal activities and their economic impacts (MRAG Asia Pacific, 2021).

This integration of satellite technology with traditional monitoring methods enables more accurate estimates of fishing effort and compliance rates across the region's vast ocean territories.

Performance Metrics and Effectiveness

Table 1 presents key digital technologies and their applications in fisheries management:

Technology	Primary Function	Coverage/ Capability	Management Application	Source
AIS Satellite Tracking	Vessel monitoring	60,000+ vessels globally	Illegal fishing detection	Kroodsma *et al.* (2018)
VMS Monitoring	Regulatory compliance	Government-controlled fleets	Quota enforcement	Global Fishing Watch (2023)
AI Species ID	Automated fish classification	>90% accuracy (specific fisheries)	Electronic monitoring	Tryolabs (2025)
Satellite Remote Sensing	Habitat monitoring	Global ocean coverage	Ecosystem management	Chassot *et al.* (2011)

Table 1: Key digital technologies transforming fisheries management and their applications. Source: Compiled from various studies.

Table 2 summarizes performance improvements achieved through digital monitoring:

Application	Performance Metric	Improvement vs. Traditional	Implementation Status	Source
AI Species ID	Classification accuracy	90%+ for specific fisheries	Pilot deployment	Tryolabs (2025)
Satellite Tracking	Global coverage	Comprehensive ocean monitoring	Operational	Kroodsma *et al.* (2018)
ML Stock Assessment	Forecast accuracy	Variable improvement	Research phase	Lüdtke & Pierce (2023)
Habitat Monitoring	Ecosystem coverage	Global daily observations	Operational	Chassot *et al.* (2011)

Table 2: Performance metrics of digital fisheries monitoring technologies. Source: Compiled from various studies.

Challenges and Future Directions

Despite remarkable advances, digital fisheries monitoring faces significant challenges in data quality, standardization, and integration. AIS data suffer from incomplete coverage of smaller vessels, potential manipulation of broadcast signals, and gaps in satellite reception in remote areas. Integration of diverse data streams requires sophisticated data management systems and standardized protocols that remain under development.

Future fisheries management systems will increasingly integrate with broader Earth system monitoring networks to understand climate impacts on marine ecosystems. Predictive models combining fisheries data with climate projections will enable proactive management approaches that anticipate distribution shifts and abundance changes before they impact fishing communities and ecosystems.

CONCLUSION

Digital technologies are fundamentally transforming fisheries management by providing unprecedented visibility into ocean activities and ecosystem dynamics. Satellite tracking systems, AI-powered monitoring, and integrated data platforms create opportunities for transparent, efficient, and adaptive governance of marine resources. The combination of comprehensive vessel monitoring, automated species identification, and ecosystem-scale environmental observations addresses longstanding challenges in fisheries science and management. Current implementations demonstrate significant improvements in monitoring coverage, illegal fishing detection, and data-driven decision making. Global

Fishing Watch's analysis of over 60,000 vessels provides the most comprehensive view of fishing activity ever assembled, while AI systems achieve human-level accuracy in species identification tasks that previously required extensive manual effort (Kroodsma *et al*., 2018; Tryolabs, 2025). Machine learning approaches to stock assessment show promise for improving prediction accuracy in rapidly changing marine environments (Lüdtke & Pierce, 2023). The future of fisheries management lies in the continued evolution of these digital systems, their integration with broader Earth system monitoring networks, and their adaptation to emerging challenges including climate change and increasing human pressures on marine ecosystems. Success will be measured not only by technological capabilities but by the contribution of these tools to sustainable fisheries, healthy marine ecosystems, and thriving coastal communities worldwide.

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