

2. Use Of Gis And Remote Sensing For Improved Fisheries Resource Monitoring And Management

Pranay Kumar Rai¹, Soumi Iaha², Kadam Bihari³, Kolli Nandini⁴, Dr Vishnu Kiran Manam⁵

¹Research Scholar, Fisheries Resource Management, College of Fisheries, Lembucherra, Agartala, Central Agricultural University, Imphal, India

²Research Scholar, Fishing Technology and Engineering, Faculty of Fishery sciences, West Bengal University of Animal and Fishery Sciences

³Ph.D. Scholar, Department of Fisheries Resources Management, College of Fisheries Science, Junagadh. Somnath Bypass Road, KamdheNu University, Veraval. 362265

⁴Pg scholar, Department of Fishing Technology, Faculty of Fisheries Science, Kerala University of Fisheries and Ocean Studies

⁵Senior Scientist/DGM - R&D, IB Group. Chhattisgarh 491411.

1. Introduction

Fisheries contribute significantly to global nutrition, economic activity, and employment, particularly in coastal and inland communities. According to FAO (2020), approximately 3.3 billion people rely on fish for at least 20% of their animal protein intake. However, fisheries resources are increasingly under threat due to overexploitation, habitat loss, pollution, invasive species, and climate-induced environmental changes. Traditional monitoring techniques, including field surveys and catch statistics, often fail to provide timely or spatially comprehensive information, limiting the effectiveness of management strategies.

GIS and Remote Sensing have revolutionised fisheries monitoring by enabling large-scale, cost-effective, and continuous observation of aquatic

environments. They allow managers to integrate spatial, temporal, and environmental data to make informed decisions. These technologies also facilitate ecosystem-based management approaches, integrating ecological, biological, and socioeconomic data for sustainable resource use.

2. Overview of GIS and Remote Sensing in Fisheries

2.1 Geographic Information Systems (GIS)

GIS is a computer-based system for capturing, storing, analyzing, and visualizing spatially referenced data. In fisheries, GIS allows the integration of bathymetric maps, fishing grounds, landing centers, and socio-economic data. It supports habitat mapping, stock assessment, identification of overfished

areas, and the management of marine protected areas (MPAs).

2.2 Remote Sensing (RS)

Remote sensing involves acquiring information about the Earth's surface without direct contact. Satellite sensors detect reflected or emitted electromagnetic radiation, providing data on sea surface temperature, chlorophyll concentration, turbidity, and habitat extent. Key satellite systems used in fisheries include MODIS, Sentinel-2, Landsat series, AVHRR, and NOAA series.

RS offers advantages such as synoptic coverage, repetitive observations, and cost-effective monitoring of remote areas, which are essential for large-scale fisheries management.

3. Environmental Parameters Derived from Remote Sensing

Several oceanic and freshwater parameters derived from RS are critical for understanding fish distribution and abundance:

3.1 Sea Surface Temperature (SST)

SST influences fish physiology, migration, and spawning patterns. Thermal fronts detected via SST are often associated with high fish abundance.

3.2 Chlorophyll-a Concentration

Chlorophyll-a serves as a proxy for phytoplankton biomass, which forms the base of the aquatic food web. High

chlorophyll areas often indicate productive fishing zones.

3.3 Ocean Color and Turbidity

Measurements of suspended sediment and dissolved organic matter provide information on water quality, habitat suitability, and pollution stress.

3.4 Sea Surface Height and Ocean Currents

Altimetry data allow the detection of eddies, upwellings, and currents that affect nutrient transport and fish aggregation.

3.5 Inland Water Monitoring

RS is useful in inland fisheries for monitoring lake levels, river flooding, wetland extent, and water quality indicators like turbidity and algal blooms.

4. Applications of GIS and Remote Sensing in Marine Fisheries

4.1 Identification of Potential Fishing Zones (PFZs)

Potential Fishing Zone (PFZ) identification is one of the most successful applications of GIS and Remote Sensing in marine fisheries. PFZ advisories are generated by integrating satellite-derived sea surface temperature (SST), chlorophyll-a concentration, ocean fronts, and historical catch data within GIS-based models. These parameters indicate areas of high primary productivity, which attract plankton, small pelagic fish, and ultimately large commercial fish species. By providing

location-specific advisories, PFZs help fishers reduce search time, fuel consumption, and operational costs, while improving catch efficiency. This technology is particularly beneficial for small-scale and artisanal fishers with limited resources. In India, PFZ advisories issued by INCOIS through mobile messages, radio, and online platforms have significantly improved livelihoods. Additionally, PFZ forecasting supports sustainable fishing by preventing random fishing efforts and minimizing pressure on non-productive or ecologically sensitive marine zones.

4.2 Habitat Mapping and Conservation

GIS and Remote Sensing play a vital role in mapping and monitoring critical marine habitats such as coral reefs, mangroves, seagrass beds, estuaries, and fish spawning and nursery grounds. High-resolution satellite imagery and GIS tools enable accurate spatial delineation of these ecosystems, assessment of habitat extent, health, and degradation trends. Habitat maps serve as essential inputs for designing Marine Protected Areas (MPAs), coastal zone management plans, and biodiversity conservation strategies. Remote sensing also allows continuous monitoring of habitat loss due to coastal development, pollution, climate change, and destructive fishing practices. GIS-based analysis

supports habitat restoration planning by identifying priority areas for mangrove afforestation or coral reef rehabilitation. Furthermore, integrating habitat maps with fisheries data helps managers understand habitat-fishery linkages, ensuring ecosystem-based fisheries management. Overall, GIS and RS strengthen conservation decision-making while balancing ecological protection with sustainable resource utilization.

4.3 Stock Assessment and Effort Analysis

GIS enhances fisheries stock assessment by enabling spatial and temporal analysis of fishing effort, catch distribution, and stock health. When integrated with Vessel Monitoring Systems (VMS), Automatic Identification Systems (AIS), and logbook or landing data, GIS allows managers to visualize fishing intensity across different marine regions. This spatial approach helps identify overfished areas, illegal fishing hotspots, and zones experiencing excessive fishing pressure. GIS-based effort mapping improves accuracy in estimating catch per unit effort (CPUE), a key indicator of stock status. It also supports ecosystem-based management by highlighting overlaps between fishing grounds and sensitive habitats. Temporal GIS analysis reveals seasonal trends, fleet behavior, and changes in stock distribution over time. Such insights assist policymakers in

implementing spatial management measures like seasonal closures, fishing bans, or effort redistribution, thereby promoting sustainable exploitation and long-term conservation of marine fish stocks.

4.4 Monitoring Fish Migration

Remote Sensing and GIS are powerful tools for monitoring fish migration patterns influenced by seasonal changes and climate variability. Satellite-derived environmental variables such as sea surface temperature, ocean currents, chlorophyll concentration, and salinity are integrated with catch data, tagging information, and acoustic telemetry in GIS platforms. This integration enables the identification of migration routes, spawning migrations, and feeding grounds of commercially important and migratory fish species. Understanding migration dynamics is crucial for managing transboundary fish stocks shared by multiple countries. GIS-based migration models help predict shifts in species distribution due to climate change, ocean warming, and changing productivity patterns. Such information supports adaptive fisheries management, international cooperation, and conflict reduction among fishing nations. Additionally, migration monitoring aids in timing fishing seasons and implementing area-specific regulations, ensuring

sustainable harvest while protecting breeding populations and maintaining marine ecosystem balance.

5. Applications in Inland Fisheries

Inland fisheries contribute significantly to livelihoods in freshwater ecosystems. GIS and RS assist in:

- Mapping water bodies and seasonal floodplains
- Monitoring water extent, depth, and quality
- Assessing habitat fragmentation and connectivity
- Evaluating impacts of irrigation, dams, and land-use changes

Floodplain monitoring using RS enables prediction of recruitment and productivity cycles in riverine and reservoir systems. GIS-based models support fishery zoning and sustainable harvest planning.

6. Climate Change and Fisheries Management

Climate change alters water temperatures, sea levels, salinity, and hydrological cycles, affecting fish distribution, productivity, and habitats. GIS and RS allow:

- Detection of temperature shifts, sea-level rise, and flooding
- Assessment of habitat loss and degradation
- Development of adaptive management strategies

Predictive models integrating RS data and climate projections help anticipate shifts in fish abundance and guide management decisions.

7. Decision Support and Fisheries Governance

7.1 Marine Spatial Planning (MSP)

GIS supports MSP by integrating fisheries, shipping, energy development, tourism, and conservation data, enabling conflict-free, ecosystem-based resource use.

7.2 Monitoring, Control, and Surveillance (MCS)

VMS and AIS data integrated in GIS enhance monitoring of illegal, unreported, and unregulated (IUU) fishing activities. Spatial analytics allow targeted enforcement.

7.3 Participatory GIS (PGIS)

PGIS integrates fishers' local knowledge with scientific datasets, improving stakeholder engagement, equity, and legitimacy in management planning.

8. Case Studies

8.1 Indian Ocean PFZs

India's ICAR-Central Marine Fisheries Research Institute (CMFRI) uses MODIS and IRS satellite data to provide weekly PFZ advisories. Fishers have reported 20–30% reduction in search time and improved catch efficiency.

8.2 Mekong River Basin Inland Fisheries

RS-based floodplain monitoring in the Mekong supports prediction of seasonal fish migrations, aiding local fishery communities in planning harvests and conserving critical habitats.

8.3 Coral Reef Fisheries in the Caribbean

GIS mapping of coral reef habitats has guided the designation of MPAs, reducing overfishing pressure and improving ecosystem resilience.

9. Advantages of GIS and Remote Sensing in Fisheries

- Large-scale, repetitive, and synoptic coverage
- Cost-effective and timely monitoring
- Integration of environmental, biological, and socioeconomic data
- Supports ecosystem-based and adaptive management
- Improves decision-making and policy formulation

10. Challenges and Limitations

- High-resolution satellite data may be costly or inaccessible
- Technical expertise is required for data processing and interpretation
- Cloud cover and atmospheric interference can reduce data quality
- Ground-truthing and validation are essential
- Data integration across agencies may be limited

Capacity-building and infrastructure investment are essential for maximizing the benefits of GIS and RS.

11. Emerging Trends and Future Directions

- Integration of drones and unmanned aerial vehicles (UAVs) for fine-scale monitoring
- Hyperspectral and high-resolution satellites for habitat and species identification
- AI and machine learning for predictive modeling of fish abundance and distribution
- IoT-based smart fisheries for real-time environmental and catch data
- Open-access platforms and cloud computing for data sharing and collaboration

12. Conclusion

GIS and remote sensing have transformed fisheries resource monitoring by providing spatially explicit, timely, and comprehensive environmental and biological information. These technologies facilitate identification of PFZs, habitat mapping, stock assessment, climate adaptation, and ecosystem-based management. While challenges such as data

accessibility, technical expertise, and validation remain, emerging technologies and participatory approaches can overcome these barriers. The integration of GIS and RS into fisheries policy and management ensures sustainable exploitation, ecosystem conservation, and improved livelihoods for millions dependent on fisheries worldwide.

References

- FAO (2020). *The State of World Fisheries and Aquaculture 2020*. Rome: Food and Agriculture Organization of the United Nations.
- Palanisamy, H., (2021). GIS-based fisheries resource assessment and management. *Ocean & Coastal Management*, 204, 105521.
- Klemas, V. (2013). Fisheries applications of remote sensing: An overview. *Fishery Bulletin*, 111, 2–19.
- Longhurst, A. (2010). *Ecological Geography of the Sea*. Academic Press.
- Robinson, I. S. (2010). *Discovering the Ocean from Space*. Springer.
- Demarcq, H., & Souissi, S. (2015). Remote sensing of oceanographic processes and fisheries. *ICES Journal of Marine Science*, 72(3), 123–134.