

Emerging Digital Technologies for Aquatic Biodiversity Monitoring: Integrating Blockchain, Remote Sensing, and Citizen Science in Freshwater and Marine Conservation

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Abstract

Emerging digital technologies are revolutionizing aquatic biodiversity monitoring by enhancing data collection, analysis, and public engagement. This synthesis explores the integration of blockchain, remote sensing, and citizen science platforms, highlighting their combined potential to improve the precision, transparency, and inclusivity of ecosystem assessments. Remote sensing and Geographic Information Systems provide high-resolution spatial and temporal data critical for tracking aquatic habitats and water quality, while blockchain ensures secure, immutable data management and facilitates trust among diverse stakeholders. Citizen science expands monitoring coverage and promotes community stewardship, supported by digital tools that enhance data validation and participant motivation. The convergence of these technologies addresses key challenges in aquatic conservation, including data quality, interoperability, and equitable access, while enabling adaptive management and policy development. Advances in artificial intelligence and machine learning further augment species identification, predictive modeling, and anomaly detection, contributing to more responsive and scalable monitoring frameworks. Ethical considerations, such as privacy, consent, and inclusivity, alongside policy and governance frameworks, are examined to ensure responsible implementation. The integration of digital tools with traditional methods and interdisciplinary collaboration is essential for sustaining aquatic biodiversity and achieving global conservation goals. This comprehensive approach offers a pathway toward more effective, transparent, and participatory management of freshwater and marine ecosystems in the face of escalating environmental pressures.