

DIGITAL TECHNOLOGIES IN AQUACULTURE

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June 2020

Brief Report

Digital technologies have been rapidly incorporated into aquaculture farming operations, impacting the efficiency and sustainability of the different phases and organizational levels, such as company value-chain operations, integrated decision-making systems within firms, multi-company platforms in areas of common interest, and public-private systems for the design, monitoring, and management of sectoral development plans. These advances have largely resulted from the work of companies supplying goods and services to the industry, including many startups created through instruments that channel public-private resources for innovation and scale-up, democratizing innovation that was previously almost exclusive to large supplier companies.

The establishment of sectoral strategic programs based on smart specialization has helped focus efforts and resources on the main gaps that need to be addressed through innovation, encouraging collaboration among the public and private sectors and academia. This has strengthened decentralized innovation ecosystems, strongly supported by micro and small enterprises that make intensive use of digital technologies.

Improved fish breeding and production practices

The application of big data analytics in the production of selected eggs or larvae is considered by industry to be a fundamental tool for genetic research. This work enables production based on lines of specimens with better disease resistance, lower mortality, and higher growth rates, thereby improving the sustainability and resilience of farming.

Farm-level monitoring

Machine learning systems to improve fish farming practices:

IoT technologies are being used in recirculation systems to monitor water quality, ensuring not only better production yields but also greater efficiency in water use and reduced environmental impact on water bodies. Automatic feeding systems have also been further developed to minimize feed losses that deteriorate water quality and increase disease risks.

Sensors to monitor fish fattening or grow-out:

Meteorological sensors are being actively incorporated to determine current and historical environmental conditions, enabling better decisions regarding structures and equipment appropriate to local conditions. Information collected by sensors is also used as input for models that assess environmental variables and provide early warning information.

Intelligent fish feeding systems:

Artificial vision and hydroacoustic technologies record indicators of fish behavior that define algorithms to control the start and end of feeding, significantly minimizing feed losses with consequent economic and environmental benefits. Given the remote location of many farms, much of the information is transmitted via satellite to the cloud, where algorithms channel the results to dashboards that support better decision-making on feeding.

Using drones to map water quality:

Traditional water sampling techniques can only cover one specific point at a time; however, with new drone-based technologies it is possible to monitor water quality over larger areas in support of field staff using in-situ instruments.

Applied analytics to monitor the distribution of environmental and pathogen indicators:

Data collected in farming areas are used by applied analytics algorithms to improve the precision of forecasts of environmental indicators and to predict the evolution of diseases in aquaculture production. These systems are of great interest to the private, public, and academic sectors to enhance farming practices and improve regulations in the medium and long term.

Sustainable fish transport**Fish transport solutions for increased fish welfare:**

Specialized sensors are used during the transport of juvenile fish to ensure adequate water exchange, appropriate oxygen levels, and other key parameters. There are also sensors that minimize risks associated with theft, malpractice, and accidents; the most common include those installed in fuel tanks, day and night vision cameras, and smoke-detection systems linked to remote transmission interfaces.

Technologies to digitize production and the entire supply chain**Automation, robotization, and artificial vision in fish processing plants:**

Significant technological advances have been made in weighing, cutting and standardizing fish products, detecting foreign elements, packaging, and product traceability. These technologies have spread rapidly across aquaculture industries, reducing repetitive jobs and health risks for operators, who have been able to specialize in tasks requiring higher qualifications and offering better income opportunities. The application of automatic monitoring and control systems—either in specific stages or across entire plants—has improved production efficiency and effectiveness, reduced environmental impacts by minimizing waste, and ensured higher safety standards. The decreasing cost of equipment and technologies has allowed small producers to access these solutions, expand their potential markets, and meet essential supply and safety standards.

Blockchain methodologies for fish traceability:

Supply chain traceability is one of the most promising use cases for blockchain technology and is now being applied to facilitate information sharing among aquaculture producers, suppliers, customers, and authorities. This contributes to the indispensable transparency required for regulatory compliance, quality and safety standards, and pricing, while

enhancing the efficiency and competitiveness of the industry as a whole. This technology will undoubtedly continue to strengthen in the future.