



Food and Agriculture
Organization of the
United Nations

THE DIGITAL BLUE REVOLUTION

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How digital technologies – including cloud computing, the internet of things, artificial intelligence and machine learning – are facilitating the advance of precision aquaculture.

In the past few decades, the digital revolution has completely changed the way the world acquires and processes data, as well as how it communicates and interprets information.

Concepts like artificial intelligence (AI) have become household terms and the AI market has been growing steadily to its current value of USD 327.5 billion (Statista, 2021). Agriculture has not been immune to the AI revolution. The AI component of the agriculture market is estimated to be worth USD 1 billion and it is predicted that it will grow at a compound annual growth rate of over 25 percent, to reach USD 4 billion by 2026 (Facts and Factors, 2021).

Aquaculture is not lagging far behind. In the past five years, there has been a proliferation of not only start-ups, but also established agriculture multinationals and mainstream aquaculture service companies, developing their own digital offerings in the sector.

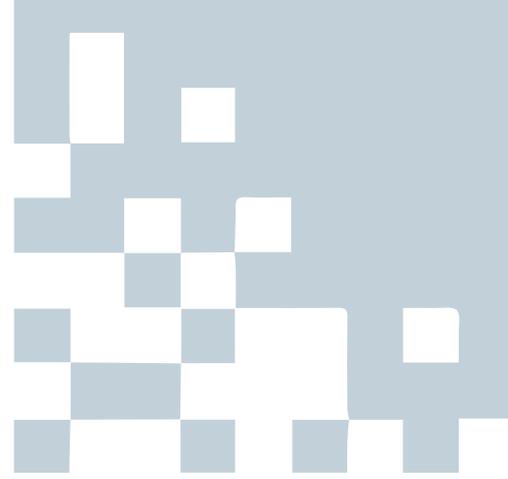
But what can digital solutions do for aquaculture? Even though fish and shrimp are often farmed in opaque waters and farmers may not know what biomass they have, digital solutions still have plenty to offer.

Digital technologies – including cloud computing, the internet of things (IoT), AI and machine learning – are today facilitating the sustainable growth of aquaculture production. Intelligent application of digital technology and meaningful processing of data already guide systems and humans in making feeding and farming decisions. Technology and data will also allow further development of efficient production methods – in terms of resource use, capital and sustainability.

Major improvements in civil infrastructure such as 4G and satellite internet have allowed the development of technologies, which were not previously possible on remote farms. And, as these evolve – via 5G and other forms of high-speed internet coupled with edge cloud services – the potential to improve today's digital offerings and develop new systems will be realized, even in remote locations.



TECHNIQUE AND APPROACH USED



Broadly speaking there are three types of digital solutions, namely:



digital platforms



digital sensors and (intelligent) hardware



trading and financing platforms.

These three types are often interconnected and, as such, provide broader, end-to-end services. The result is often increased efficiency, with IT-engaged companies reporting feed conversion ratio (FCR) reductions that ranged between 5 percent and 28 percent in 2020 (Aqua Spark, 2020).

Digital platforms are arguably the most common digital solution applied to aquaculture. These allow the collection and storage of data from different sources such as publicly available databases, as well as sensors, video cameras and manual collection. Data are then analysed (often using AI, but increasingly big data, machine learning and even deep learning approaches) to provide recommendations to farmers on factors such as farming practices and inputs.

Digital sensors allow the automatic digital collection of data. In addition to water quality sensors (measuring factors like temperature and oxygen), there have also been advances in both passive and active acoustic sensors, as well as acceleration-based sensors that forecast fish appetite and behaviour.

Imaging-based data capture equipment that calculates growth rate and forecasts growth and harvest times is becoming increasingly popular. In addition, intelligent hardware capable of distributing feed in response to the data collected can also be part of the digital suite. Data on feeding and growth are being used to provide a track record for financial institutions that finance feed purchase, provide insurance and provide faster payment services. This shortens time between crops and allows forecasting of harvest sizes and volumes needed to fulfil trading contracts.

There have been ground-breaking technological advances made in digital equipment. For example, over the last two decades underwater cameras have become the tool of choice to monitor salmon feeding, fish weight and stock health, as well as undertaking net pen inspections. Today cameras can provide extremely high-definition quality video images live that can be streamed online in real time, shared via the Internet and viewed in company offices around the globe, reflecting the improvements in hardware (camera), software (file compression) and Internet speeds. The latest video-related technologies, coupled with AI, go much further and provide machine learning-enhanced feeding, based on high-quality video streams, as well as accurate automated fish sizing, parasite load estimation and net inspection. Diagnosis of individual health and welfare status via cameras is currently under development and will likely be available in 2022.



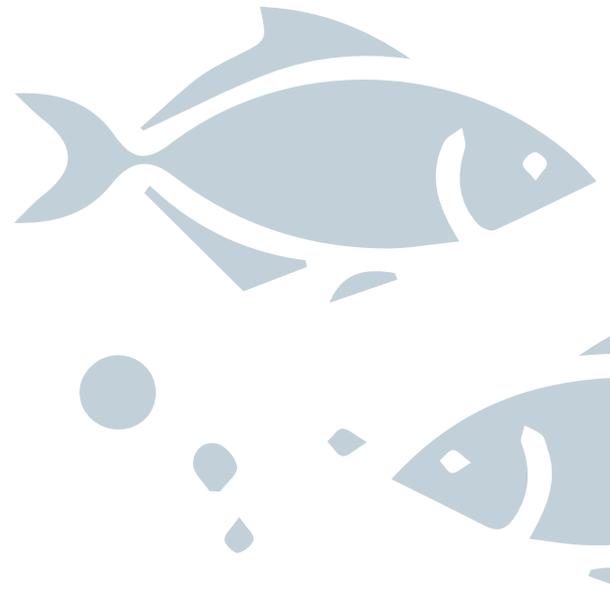
Computer vision-based pellet detector giving real time pellet number counts from a video stream. Specific training distinguishes pellets from both lesions on fish and faeces. The data provide valuable information for feeding algorithms, fish health and welfare monitoring, and assessment.

However, given that most aquaculture production – particularly in tropical inland ponds – takes place in opaque water systems, cameras are not always effective. In these situations, hydroacoustics have come to the fore. Passive hydroacoustics ('listening' within ponds) have been used successfully for controlling feeding in shrimp aquaculture for a few years now. More recently, active hydroacoustics (sonar systems, similar to fish finders) have emerged for monitoring fish and shrimp behaviour, with tools for estimating weight and total biomass of stock developing quickly. Using hydroacoustics to map aquatic animal behaviour 24 hours a day, independent of light and water quality, makes it possible to feed them according to their appetites, without reliance on a camera, as well as to monitor whole populations for behavioural patterns.

Machine learning that can recognize such patterns for individual populations, coupled with AI that recognizes changes in the patterns and which identifies any that are indicative of specific diseases and/or sources of stress are currently under development. The potential for using such systems to enable early diagnosis has already been illustrated by Måløy (2020) who found that a retrospective analysis of echograms from feeding behaviour alone demonstrated that pancreas disease – a major issue in European salmon farms – could be diagnosed a month earlier than the use of conventional methods (i.e. sampling of fish at farms once symptoms such as reduced appetite appear, with material sent to a laboratory for analysis). An early diagnosis system can provide even earlier alarms – and across many farms at once – by developing a dedicated algorithm. This will allow fish health efforts to be more efficiently directed at sites which need attention, rather than regularly screening all farms, and usually only catching the problem at the 'firefighting stage', as is the current practice.

These in-cage fish (and in-pond in the case of shrimp) monitoring systems can also be coupled with digital diagnostics systems to speed up verification and implementation of mitigation, hopefully to prevent rather than having to treat clinical symptoms of disease outbreaks in aquaculture. This will also improve fish welfare, reduce losses to mortality or poor growth, and improve cost-effectiveness.

Overall, digital systems and internet technology used appropriately have the potential to provide significant improvements in aquaculture production efficiency and sustainability, while enabling humans to oversee a greater number of production units and greater volumes of stock.



SCOPE AND SCALE OF APPLICATION

It has been estimated that there are currently less than 100 000 farmers using full-suite digital solutions, with the largest proportion in North America and Europe.

While not all farmers can afford full-suite coverage, partial digital solutions are proving beneficial for farmers of all sizes – from industrial salmon farmers in Norway to small-scale shrimp farmers in Asia – and their uptake is attracting increasingly large investments. The digital blue revolution is here to stay.





ACCESSIBILITY

Full-suite digital packages are targeted at large-scale commercial companies – particularly vertically integrated companies involved in hatchery, nursery, grow-out, feed production and aquatic product processing and marketing – because of the significant investment costs in the equipment, software and staff required to operate the systems.

That said, commercial companies are developing software and mobile phone applications for FCR calculation and least cost fish diet formulation that can and are being used on android and smartphones worldwide by vastly increasing numbers of aquaculture operators, including small-scale and medium-scale farmers.

Big data initiatives are being used to develop algorithms for predictive purposes for the benefit of all users, although there are still some potential users who are concerned about security issues and the possibility of competitors gaining commercial advantage. The digital and AI industry needs to increase people's awareness of the benefits of open data sharing and the safeguards put in place to protect the collected data. There are also ethical issues and questions must be asked about who owns the data.

To prevent the poorer resourced farmers falling further behind, inclusivity of access needs to be facilitated.

THE OUTCOME AND BENEFITS

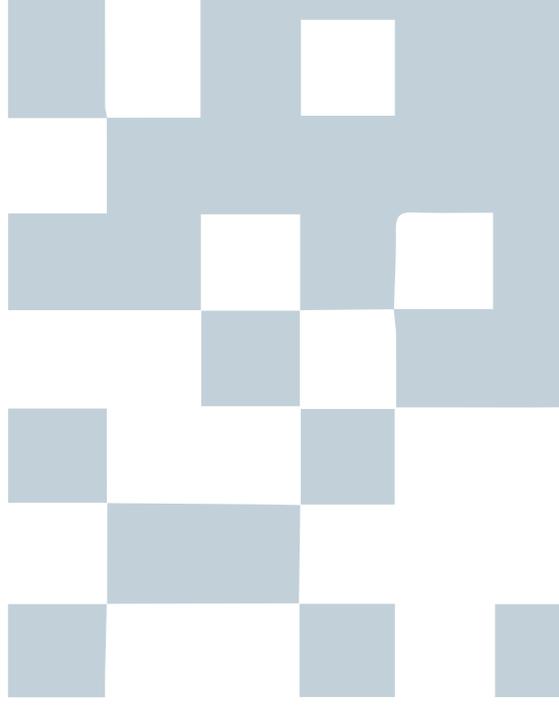
Norwegian salmon farming companies have been using feed control centres for a number of years, with those in Australia, Canada, Chile and Scotland now following suit. Costing up to USD 14.6 million each, these centres can be connected to hundreds of underwater cameras and water temperature and dissolved oxygen monitoring sensors at different depths within the salmon cages, allowing one operator to distribute feed pellets to 15 million salmon. These centres are increasingly making use of AI and active acoustic systems in order to take the stress out of all that responsibility placed on a single human operator, guiding and allowing the operator to focus on the cages that most need their attention rather than all of them at once. The system also keeps the operator informed of the biomass of salmon in each cage and their growth rates, as well as forecasting harvest dates.

While digital solutions of this scale are beyond the grasp of all but the largest farming companies, there is a growing range of affordable digital offerings that are increasingly being adopted by small-scale producers. As well as helping to guide farmers in their decision-making and alerting them to possible dangers to their crops, they are also making aquaculture more efficient and precise – reducing wasted feed and improving the welfare of farmed aquatic animals.

More precision in production methods can also reduce environmental impact and open up new opportunities for farmers wishing to comply with aquaculture standards that can in turn open up new market opportunities.

The downside of the digital revolution and the use of AI is a reduction in lower skill level job opportunities, while the upside is greater job opportunities for staff operating digital systems.





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ACKNOWLEDGEMENTS

This brief was prepared by Flavio Corsin (Aqua Spark, Netherlands), Don Griffiths (FAO consultant, Thailand) and Sunil Kadri (Aquaculture Innovation, New Zealand).

Required citation: FAO. 2022. *The digital blue revolution*. Bangkok.

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