Prospects and opportunities for the introduction of digital technologies into aquaculture governance system

A V Gorbunova¹, V E Kostin¹, I L Pashkevich¹, A A Rybanov¹, A V Savchits¹, A A Silaev¹, E Yu Silaeva¹ and Yu V Judaev²

¹ Volzhsky Polytechnic Institute (branch) of Federal State Budget Educational Institution of Higher Education Volgograd State Technical University, 42a, Engelsa Street, Volzhsky, Volgograd region, 404121, Russia
² Azov-Black Sea Engineering Institute, 21, Lenina Street, Zernograd, Rostov region, 347740, Russia

E-mail: aa_silaev@mail.ru

Abstract. It is possible to increase the efficiency of pond farms by introducing new digital technologies into the technological processes of fish cultivation. Recirculating aquaculture systems serve a positive example of high technology applications in aquaculture. Automated control of all processes in pond fish farming starting from pond preparation for stocking of fish to placement and production of commercial fish will significantly increase the efficiency of fish farming by 70-80% thus increasing the overall profit by 20-30%. For properly organized feeding of fish it is necessary to take into account many factors, such as: fish-holding density, temperature of water and air, content of oxygen dissolved in water, pH-level of water and feed intake. The system of complex automation of any production enterprise shall be implemented taking into account the technologies of the fourth industrial revolution – Industry 4.0. The main unit of the system is an automated floating feeder with autonomous power supply from solar panels. The design and functional features of the feeder will determine the functionality of the entire automation system: automatic feeding, monitoring of water and environmental parameters, deoxidation of the water basin, supplementary feeding with insects, frightening of fish-eating birds. The innovative approach proposed by the authors is that if the pond is equipped with several floating feeders it is necessary to connect them to each other in a single information system, which functions through wireless radio communication. The assessment of the potential of the proposed modernization of a middle pond made it possible to increase the profit by 1.5 million rubles.

1. Introduction

Russia has the world’s largest water fund of inland water reservoir and areas of the sea, the potential of which provides the population of the country with a wide range of fish products.

Aquaculture is quite expensive economic activity requiring significant financial investments. This is due to significant capital costs for the construction of fish ponds, structures, costs for their subsequent maintenance, purchase of feed, mineral fertilizers, means of prevention and treatment of fish. In industrial fish farming, in addition to feed, large costs are spent on energy supply and water treatment.
The main direction of modern freshwater aquaculture in the Russian Federation is the pond farm. Pond fish farming is based on multicultural cultivation of carp and herbivorous fish. At the same time, it shall be noted that the efficiency of pond farms is extremely low, which does not provide the population of the country with cheap fish products. This is explained by the specificity of such enterprises: large areas of pond farms (one pond up to 100 hectares or more), obsolete, energy-intensive material and technical base.

The study showed that it is possible to increase the efficiency of pond farms by introducing new digital technologies in the technological processes of fish cultivation [1, 2].

At present, the digitalization of agriculture is becoming ever more relevant. Automation and robotic systems are used in livestock complexes especially in dairy-product-oriented farms, poultry farms and greenhouses. A positive example of high technologies in aquaculture is recirculating aquaculture systems (RAS) [3, 4, 5, 6].

The automatic control systems within RAS maintain optimal water parameters in basins, ensure automatic feeding, reduce consumption of energy, water and fodder resources during fish cultivation, minimize risks of errors in technological processes related to “human factors”, reduce total costs for the production of commercial fish [5].

The purpose of the study is to demonstrate the prospects and possibilities of introducing digital technologies into pond farms. Automated control of all processes in pond fish farming starting from pond preparation for stocking of fish to placement and production of commercial fish will significantly increase the efficiency of fish farming, reduce costs and lower fish production costs.

2. Materials and methods
In the Russian Federation there are more than 2000 enterprises engaged in pond aquaculture, most of which are located in the South, North Caucasus, Central and Volga federal districts, i.e. mainly in the IV, V and VI fish-growing zones characterized by a large number of sunny days during the feeding period. This makes it possible to implement modern innovative digital technologies due to autonomous equipment that use solar energy.

Such systems include autonomous, integrated into the common control system (Figure 1) of feeders and aerators (Figure 2, 3), the latter can be implemented in its stationary or mobile version.

![Figure 1. Autonomous feeder](image-url)
The data analysis presented in [7, 8] shows that the highest intensity of solar radiation for the V fish-growing zone occurs during the period from May to August, which corresponds to the period of intensive feeding and other technological operations, including those related to water quality control. The potential of solar energy in summer months is quite sufficient not only for autonomous operation of feeding and aeration devices, but also for sustainable operation of control and measurement systems and data transmission systems.

The most important aquaculture process is the feeding process [4, 5]. Fish nutrition is the most important factor affecting metabolism, formation of fish organism, their growth and reproduction functions. Feeding in general has a much greater effect on the fish body and their productivity than breed or origin.
The need for feeding is caused by the fact that it allows realizing the natural potency of fish growth in the shortest time and growing them at higher planting densities than at cultivation on a natural fodder base. This, in turn, significantly increases fish productivity of water reservoirs: lakes up to 400-500 kg/ha, ponds up to 2.5-5 t/ha, etc. About 70-80% of fish products are produced in pond farms due to artificial feeding.

For properly organized feeding of fish it is necessary to take into account many factors [9, 10], such as:
- fish-holding density;
- water and air temperature;
- content of oxygen dissolved in water;
- water level;
- feed intake.

At present, the system of complex automation of any production enterprise shall take into account the technologies of the fourth industrial revolution – Industry 4.0. This will make it possible to achieve higher profit and success of the enterprise in general [11, 12, 13].

3. Results
The study proposes the intelligent process control system of pond farm, which is logically divided into three levels:
- field level;
- control level;
- cloud storage of information.

The automated floating feeder with autonomous power supply from solar panels is the main field level unit. The work [14, 15] proves the efficiency of such solutions. The design and functional features of the feeder will determine the functionality of the entire automation system:
- automatic feeding;
- monitoring of water and environment parameters;
- deoxidation of water reservoir;
- supplementary feeding with insects;
- frightening of fish-eating birds.

Automatic feeding provides for feed distribution process performed in automatic mode via a screw doser depending on ambient parameters and a feeding plan.

Monitoring of water and environment parameters is designed to measure such parameters as water and air temperature, concentration of oxygen dissolved in water, air speed, water level and others. The
work [16] considers the analogue of such system to measure water body parameters using catamaran. Deoxidation of the water body is carried out by replacing fodder in the feeder with special technological mixtures, which are also introduced into the pond.

The supplementary feeding with insects is carried out by attracting flying insects at night and their electric shock. The frightening of fish-eating birds is carried out via acoustic signals.

The most important condition for increasing the production of fish products is technical reequipment, creation of new technologies, acquisition and introduction of modern technical equipment and mechanization tools, as well as innovative approaches to aquaculture management in pond farms.

The innovative approach proposed by the authors is that if the pond is equipped with several floating feeders, it is necessary to connect them to each other in a single information system, which functions through wireless radio communication.

As a result of the proposed innovative approach, the pond farm aquaculture management system will include the following blocks:

- Purchase or Feed Preparation Unit;
- Central Warehouse Unit;
- Feeding Plan Unit;
- Automated Feed Control Unit;
- Central Control Unit.

**The Purchase or Feed Preparation Unit.** Depending on the fodder used and the presence of a shop for its preparation, this module can serve as an application for accounting and forecasting fodder consumption or a complex separate automated fodder production line taking into account its consumption.

**The Central Warehouse Unit.** Performs automated recording and storage of feed from the central warehouse. The unit represents an automated product accounting application and can be expanded to an automated feed storage control system taking into account climatic conditions.

**The Feeding Plan Unit.** In this unit the information is processed from the monitoring unit of water and environment parameters, which controls temperature and composition of water, and on the basis of the obtained data the number of fodders for the introduction into the water body during the current day is determined. The feeding plan also takes into account the type of fish, the time of the year and the prevention of diseases. It is proposed to implement the unit as an application.

**The Automated Feed Control Unit.** Takes into account the amount of feed delivered from the central warehouse to a tank installed on the pond and the distribution of food from this tank to automated feeders. It is proposed to implement it in the form of a robotic complex with a feed tracking system from the central warehouse to automated feeders.

**The Central Control Unit.** Coordinates the operation of all units on the basis of received information. It also allows storing the received data on a cloud server and accessing the system remotely.

**4. Discussion**

The increase of economic efficiency of fish breeding and fishing directly depends on the reduction of costs per unit of fish production and the growth of its cost. Recently, there has been an increase in fish consumption. According to medical standards, 18.2 kg of fish products per year is necessary for normal development of the human body. In the future this requires measures mainly aimed at conditions to increase the production volume of commercial fish, expand its range, improve the quality and competitiveness of products.

The ability to manage the living conditions of bred fish, improve their breed qualities and aquaculture in general allows achieving high productivity of fish farming, which is many times higher than the fish productivity of natural water bodies.

The efficiency of automation within the framework of digitalization allows increasing fish production in pond farms by 70-80%, which entails profit increase by 20-30%. On average fish productivity of used water bodies is as follows: lakes up to 400-500 kg/ha, ponds up to 2.5-5 t/ha. Today the average cost of fish is 150 rub/kg, then per 1 ha the fish productivity will make 5 t and
accordingly the revenue – 7500 thousand rub, and per 10 ha the profit will increase by 1.5 million rub, which will provide for 30% of net profit to be allocated for the purchase of modern technical equipment, mechanical equipment, automation and intelligent aquaculture management systems of pond farms.

At present, the olga Polytechnic Institute has manufactured and implemented a floating automated fish feeder with power supply from solar panels. Field tests of catamaran capabilities, on which the feeder is installed, were carried out. Additional functions were analyzed: development of a system of supplementary feeding with flying insects and protection of fish from fish-eating birds.

Besides, some modules serve as applications thus making it possible to obtain a more flexible solution for different needs of fish farms.

5. Conclusion

Thus, it has been proved that the development of aquaculture is impossible using current material and technical base of pond farms. There is a need for a new approach to the automation of management system of fish farming enterprises taking into account advanced digital technologies such as the Industrial Internet of Things, large data banks and a unified system of data storage and processing. The implementation of all these technologies in a single automation system can only ensure the competitiveness of domestic enterprises compared to foreign fish producers thus making fish farms attractive for investment.

It is proposed to create robotic aquaculture control systems, the basis of which will include automated floating feeders ensuring optimal feeding of fish in pond farms.

All these measures will help to achieve the main goal of the strategy for the development of aquaculture in Russia – a reliable provision of the population of the country with a wide range of fish products of domestic aquaculture at prices available for the population with different income levels.

References

[1] Aubakirova G, Adilbekov Z, Inirbayev A and Saleemi S 2019 Fish Fauna and Assessment of Fish Safety in the Reservoirs of Akmola Region of Northern Kazakhstan Pakistan J. Zool. 51 1919 – 1925 DOI: 10.17582/journal.pjz/2019.51.5.1919.1925

[2] Elsokah M M and Sakah M 2019 Next Generation of Smart Aquaponics with Internet of Things Solutions Sciences and Techniques of Automatic Control and Computer Engineering (STA) 106 – 111 DOI: 10.1109/STA.2019.8717280

[3] Bartelme R P, Smith M C, Sepulveda-Villet O J and Newton R J 2019 Component Microenvironments and System Biogeography Structure Microorganism Distributions in Recirculating Aquaculture and Aquaponic Systems American Society for Microbiology Journals 4 1 – 15 DOI:10.1128/mSphere.00143-19

[4] Zhang L, Yang M D and Hu Q 2017 Design of 360° moveable and uniform feeding system IOP Conf. Series: Earth and Environmental Science 69 DOI:10.1088/1755-1315/69/1/012135

[5] Rekha P N, Ambasankar K, Stanline S, Sethuraman K, Syamadayal J, Panigrahi A and Aguruvasagam K 2017 Design and development of an automatic feeder for Penaeus vannamei culture Indian J. Fish 64 83 – 88 DOI: 10.21077/ijf.2017.64.special-issue.76209-12

[6] Yudaev I V 2019 Analysis of Variation in Circuit Parameters for Substitution of Weed Plant Surface Engineering and Applied Electrochemistry 55(2) 219 – 224

[7] Daus Y V, Yudaev I V, Taranov M A, Voronin S M and Gazalov V S 2019 Reducing the costs for consumed electricity through the solar energy International Journal of Energy Economics and Policy 9(2) 19 – 23

[8] Nagayo A M, Mendoza C, Vega E, Izki Raad K S Al and Jamisola R S 2017 An automated solar-powered aquaponics system towards agricultural sustainability in the Sultanate of Oman IEEE International Conference on Smart Grid and Smart Cities (ICSGSC) 42 – 49 DOI: 10.1109/ICSGSC.2017.8038547
[9] Liu Y Q, Wu Y X and Cao L L 2014 The Design of Automatic Control System for Industrialized Recirculating Aquaculture Advanced Materials Research 1046 246 – 249 DOI: 10.4028/www.scientific.net/AMR.1046.246

[10] Wahid H, Noor A F M, Burhanuddin D H and Ghazali R 2017 Design of an automated hybrid system for aquaculture and agriculture process and its performance analysis International Journal of Integrated Engineering – Special Issue on Electrical Electronic Engineering 9 (4) 49 – 56

[11] Romli M A, Daud S, Zainol S M, Kan P L Eh and Ahmad Z A 2017 Automatic RAS data acquisition and processing system using fog computing Conference: 2017 IEEE 13th Malaysia International Conference on Communications (MICC) 229 – 234 DOI: 10.1109/MICC.2017.8311764

[12] Luna F D Von B, Aguilar E de la R, Naranjo J S and Jagüey J G 2017 Robotic System for Automation of Water Quality Monitoring and Feeding in Aquaculture Shadehouse IEEE Transactions on Systems, Man, and Cybernetics: Systems 47(7) 1575 – 1589 DOI: 10.1109/TSMC.2016.2635649

[13] Martínez-de Dios J R, Sernay C and Ollero A 2003 Computer vision and robotics techniques in fish farms Robotica 21(3) 233 – 243

[14] Deroy M C U, Espaldon A J, Osa J E F, Macalla G P B and Pascua D A D 2017 Design and Implementation of an Automated Fish Feeder Robot for the Philippine Aquaculture Industry: Feeding Mechanism and Float Design Module Mindanao Journal of Science and Technology 15 89-102

[15] Menicou M and Vassiliou V 2010 Prospective energy needs in Mediterranean offshore aquaculture: Renewable and sustainable energy solutions Renewable and Sustainable Energy Reviews 14 (9) 3084-3091 DOI: 10.1016/j.rser.2010.06.013

[16] Wiora J, Kozyra A and Wiora A 2017 Towards automation of measurement processes of surface water parameters by a remote-controlled catamaran Bulletin of the polish academy of sciences technical sciences 65 (3) 351-359 DOI: 10.1515/bpasts-2017-0039