

SECTION 7. AQUATIC BIORESOURCES AND AQUACULTURE

DOI <https://doi.org/10.30525/978-9934-26-657-7-11>

INNOVATIVE APPROACHES TO THE REPRODUCTION OF AQUATIC ORGANISMS IN INDUSTRIAL AQUACULTURE AND MARICULTURE

ІННОВАЦІЙНІ ПІДХОДИ ДО ВІДТВОРЕННЯ ГІДРОБІОНТІВ У ПРОМИСЛОВІЙ АКВАКУЛЬТУРІ ТА МАРИКУЛЬТУРІ

Oleshko V. P.

*Candidate of Agricultural Sciences,
Associate Professor at the Department
of Aquaculture and Applied
Hydrobiology
Bila Tserkva National Agrarian
University
Bila Tserkva, Ukraine*

Олешко В. П.

*кандидат сільськогосподарських
наук,
доцент кафедри аквакультури та
прикладної гідробіології
Білоцерківський національний
аграрний університет
м. Біла Церква, Україна*

Trofymchuk A. M.

*Candidate of Agricultural Sciences,
Associate Professor at the Department
of Aquaculture and Applied
Hydrobiology
Bila Tserkva National Agrarian
University
Bila Tserkva, Ukraine*

Трофимчук А. М.

*кандидат сільськогосподарських
наук,
доцент кафедри аквакультури
та прикладної гідробіології
Білоцерківський національний
аграрний університет
м. Біла Церква, Україна*

Heiko L. M.

*Candidate of Agricultural Sciences,
Associate Professor at the Department
of Aquaculture and Applied
Hydrobiology
Bila Tserkva National Agrarian
University
Bila Tserkva, Ukraine*

Гейко Л. М.

*кандидат сільськогосподарських
наук,
доцент кафедри аквакультури
та прикладної гідробіології
Білоцерківський національний
аграрний університет
м. Біла Церква, Україна*

Global aquaculture demonstrates steady growth and plays a key role in ensuring food security, accounting for more than half of the total production of food fish. According to international organizations, the further

development of the sector is associated with the implementation of innovative technologies aimed at increasing juvenile survival, improving resource-use efficiency, and enhancing the environmental sustainability of production [1, 3, 4].

Therefore, the aim of our study was to assess modern innovative technologies and methods for the reproduction of aquatic organisms in industrial aquaculture and mariculture, including genetic, biotechnological, engineering, and digital approaches, and to determine their impact on productivity, juvenile survival, and the environmental sustainability of production.

The research was based on the analysis of current scientific literature and a review of international experience in industrial aquaculture and mariculture. Genetic, biotechnological, engineering, and digital approaches to the reproduction of aquatic organisms were examined, including selective breeding, hormonal induction, cryopreservation, recirculating aquaculture systems (RAS), biofloc and integrated multitrophic systems, as well as automated monitoring of technological processes [1–21].

The reproduction of aquatic organisms is a critical stage of the technological cycle, as survival, growth, and resistance to stress factors are established during the early stages of ontogenesis [10]. In this regard, current research focuses on genetic, biotechnological, ecological, and digital innovations capable of optimizing artificial reproduction processes in freshwater and marine aquaculture [11].

One of the key directions in the development of aquatic organism reproduction is the application of modern selective breeding methods. Traditional approaches based on mass and individual selection are gradually being complemented by molecular genetic technologies, which accelerate the breeding process and improve selection accuracy [9].

Promising areas include genomic selection, marker-assisted selection, the development of disease-resistant lines, and genome editing technologies [19]. The application of genomic approaches enhances productivity and offspring survival, as well as the adaptive capacity of fish and invertebrates under various rearing conditions [8].

In mariculture, breeding programs are aimed at increasing growth rates, tolerance to salinity and temperature fluctuations, and resistance to pathogens, which is particularly important for mollusks, shrimp, and marine fish [20, 21].

Biotechnological approaches play an important role in regulating reproductive processes [11]. The most widely used innovative methods include hormonal induction of spawning, control of photoperiod and temperature, the use of probiotics and functional feeds, and gamete cryopreservation.

Hormonal preparations and synthetic analogues of gonadotropin-releasing hormone make it possible to synchronize gamete maturation and increase the yield of viable larvae [14].

Sperm cryopreservation is gaining increasing importance in breeding programs, as it ensures the long-term preservation of genetic material, the establishment of gene banks, and the optimization of crossbreeding across different seasons [12].

One of the key factors for successful reproduction is the creation of optimal conditions for incubation and early rearing. In modern practice, the following technologies are widely used: recirculating aquaculture systems (RAS), automated incubators, microalgae and biofloc technologies, and integrated multitrophic systems [16, 17].

RAS technologies ensure stable water quality parameters, reduce water consumption, and minimize disease risks, which is particularly important at larval stages [2, 6, 7, 15].

In mariculture, biofloc systems are increasingly applied, contributing to the development of a natural feed base and improving the survival of shrimp and fish larvae [16–18].

The digitalization of aquaculture is one of the most dynamic areas of innovation. Modern technologies enable automatic control of water quality parameters, remote monitoring of incubation processes, prediction of juvenile survival, and optimization of feeding regimes [3].

The use of sensor systems, the Internet of Things (IoT), and machine learning algorithms enhances the precision of technological process management and reduces the risk of losses at early developmental stages [4–6].

Digital solutions are particularly effective in large-scale industrial farms and marine facilities, where it is necessary to control substantial production volumes under variable environmental conditions [5].

Modern innovations are also aimed at wastewater detoxification and reducing the environmental impact on coastal ecosystems, particularly in mariculture. The use of closed-loop systems and energy-efficient equipment makes it possible to establish farms that comply with stringent international eco-labeling standards [2, 6].

Thus, innovative approaches to the reproduction of aquatic organisms are based on the integration of genetic, biotechnological, environmental, and digital solutions. Selective breeding and genomic technologies ensure increased productivity and enhanced resistance of juveniles.

Biotechnological methods, including hormonal induction and cryopreservation, improve the efficiency of artificial reproduction. The use of RAS, biofloc, and integrated systems contributes to higher survival rates at early developmental stages.

Digitalization and automation of production processes open new opportunities for industrial aquaculture and mariculture. The further development of the sector is associated with the implementation of environmentally sustainable technologies and the reduction of anthropogenic impacts on aquatic ecosystems.

Bibliography:

1. Aquaculture International Special Issue (AI & Aquaculture). Application of artificial intelligence in aquaculture: Current insights. *Aquaculture International*. 2025.32:8763–8789. DOI: <https://doi.org/10.1007/s10499-024-01589-y>.
2. Bregnballe J. A guide to recirculation aquaculture – An introduction to the new environmentally friendly and highly productive closed fish farming systems. Rome: FAO and Eurofish International Organisation, 2022. 105 p. DOI: <https://doi.org/10.4060/cc2390en>
3. Chen J., Xu Y., Li H., Zhao X., Su Y., Qi C., Qu K., Cui Z. The application of digital twin technology in the development of intelligent aquaculture: Status and opportunities. *Fishes*. 2025;10(8):363. DOI: <https://doi.org/10.3390/fishes10080363>.
4. FAO. The State of World Fisheries and Aquaculture 2022. Rome: FAO, 2022. 266 p. DOI: <https://doi.org/10.4060/cc0461en>.
5. Fish Tracking, Counting, and Behaviour Analysis in Digital Aquaculture: A Comprehensive Review. 2025. 17(1), e13001 DOI: <https://doi.org/10.48550/arXiv.2406.17800>
6. Gupta S., Makridis P., Henry I. et al. Recent Developments in Recirculating Aquaculture Systems: A Review. *Aquaculture Research*. 2024; Article ID 6096671. DOI: <https://doi.org/10.1155/are/6096671>.
7. Hao Li, Cui Z., Hongwu Cui et al. A review of influencing factors on a recirculating aquaculture system: Environmental conditions, feeding strategies, and disinfection methods. *J World Aquac Soc.* 2024;54(3):566–602. DOI: <https://doi.org/10.1111/jwas.12976>.
8. Houston R. D., Bean T. P., Macqueen D. J. et al. Harnessing genomics to fast-track genetic improvement in aquaculture. *Nature Reviews Genetics*. 2020. Vol. 21. P. 389–409. DOI: <https://doi.org/10.1038/s41576-020-0227-y>
9. Hrytsyniak I. I., Kurinenko G. A., Gurbik V. V. Native types of carp in aquaculture of Ukraine (a review). *Hydrobiological Journal*. 2022;58(1):34–44. DOI: <https://doi.org/10.1615/HydrobJ.v58.i1.40>.
10. Jéhannet P., Palstra A. P., Giménez Nebot I. et al. Recombinant Gonadotropins to Induce Oocyte Development In Vitro and In Vivo in the European Eel *Anguilla anguilla*. *Fishes*. 2023;8(3):123. DOI: <https://doi.org/10.3390/fishes8030123>.

11. Manan H., et al. Recent developments in aquaculture – A review. *Annals of Animal Science*. 2023;23(3):663–680. DOI: <https://doi.org/10.2478/aoas-2023-0044>.
12. Martínez-Páramo S., Horváth Á., Labbé C., Zhang T., Robles V., Herráez M. P., Cabrita E. Cryobanking of aquatic species. *Aquaculture*. 2017. Vol. 472. P. 156–177. DOI: <https://doi.org/10.1016/j.aquaculture.2016.05.042>
13. Mohammadzadeh S., Ahmadifar E., Dhama K. et al. Applications of recombinant proteins in aquaculture. *Aquaculture*. 2022;561:738701. DOI: <https://doi.org/10.1016/j.aquaculture.2022.738701>
14. Mylonas C. C., Duncan N. J., Asturiano J. F. Hormonal manipulations for the enhancement of sperm production in cultured fish and evaluation of sperm quality. *Aquaculture*. 2017. Vol. 472. P. 21–44. DOI: <https://doi.org/10.1016/j.aquaculture.2016.04.021>
15. Persson D., Makridis P., Gupta S., Henry I. et al. Recirculating aquaculture systems: Advances, impacts, and integrated pathways for sustainable growth. *Bioresource Technology Reports*. 2025;32:102340. DOI: <https://doi.org/10.1016/j.biteb.2025.102340>.
16. Roy S. M., Choi H., Kim T. Review of state-of-the-art improvements in recirculating aquaculture systems: Insights into design, operation, and statistical modeling approaches. *Aquaculture*. 2025;605:742545. DOI: <https://doi.org/10.1016/j.aquaculture.2025.742545>.
17. Sallam G. R., El Basuini M. F., Alhoshy M. et al. Strategic application of biofloc technology for optimizing physiological homeostasis and reproductive efficiency in red tilapia (*Oreochromis spp.*) broodstock under long-term rearing conditions. *Aquaculture International*. 2025;33(6):464. DOI: <https://doi.org/10.1007/s10499-025-02141-2>.
18. Sallam G. R., Shehata A. I., Basuini M. F. E. et al. Integrated biofloc technology in red tilapia aquaculture: salinity-dependent effects on water quality, parental stock physiology, reproduction, and immune responses. *Aquaculture International*. 2024;32:8731–8761. DOI: <https://doi.org/10.1007/s10499-024-01588-z>.
19. Yáñez J. M., Houston R. D., Newman S. Genomics in aquaculture to better understand species biology and accelerate genetic progress. *Frontiers in Genetics*. 2015. Vol. 6. Article 128. DOI: <https://doi.org/10.3389/fgene.2015.00128>
20. Yang X., Zhang S., Liu J. et al. Deep learning for smart fish farming: applications, opportunities and challenges. *Reviews in Aquaculture*. 2021. Vol. 13. P. 66–90. DOI: <https://doi.org/10.1111/raq.12458>
21. Zhang H., Gui F. The application and research of new digital technology in marine aquaculture. *Journal of Marine Science and Engineering*. 2023;11(2):401. DOI: <https://doi.org/10.3390/jmse11020401>.