

Iermakova, Olga; Zhuvahina, Iryna; Metelytsia, Volodymyr; Dmytryshyn, Roman

Conference Paper — Published Version

Conceptual principles of ecologically safe development of aquaculture

Suggested Citation: Iermakova, Olga; Zhuvahina, Iryna; Metelytsia, Volodymyr; Dmytryshyn, Roman (2024) : Conceptual principles of ecologically safe development of aquaculture, 4th International Conference on Environmental Sustainability in Natural Resources Management 2024 (ISCES 2024), In: 4th International Conference on Environmental Sustainability in Natural Resources Management 2024 (ISCES 2024) 31/10/2024 - 31/10/2024 Online, IOP Publishing, Bristol, pp. 1-12, <https://doi.org/10.1088/1755-1315/1429/1/012004>, <https://iopscience.iop.org/article/10.1088/1755-1315/1429/1/012004>

This Version is available at:

<https://hdl.handle.net/10419/308750>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by/4.0/>

Conceptual principles of ecologically safe development of aquaculture

Olga Iermakova ^{1*}, Iryna Zhuvahina ², Volodymyr Metelytsia ³ and Roman Dmytryshyn ⁴

¹ Department of Economic and Ecological Development of Seaside Regions, State Organization "Institute of Market and Economic&Ecological Researches of the National Academy of Sciences of Ukraine", Odesa, Ukraine

² Pervomaisk Educational and Scientific Institute of Admiral Makarov National University of Shipbuilding, Pervomaisk, Ukraine

³ Department of Accounting and Consulting, State Tax University, Irpin, Ukraine

⁴ Educational and Research Institute of International Relations, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine

*E-mail: impeer@ukr.net

Abstract. In the past, when the aquaculture industry was just beginning to develop in the world, the main goal of fish farming was to provide the population with food. The development of fish farming led to the emergence of environmental problems, which made it necessary to include the factor of environmental safety, along with economic and social factors, into the agenda of the development of the aquaculture sector. The purpose of this study is to determine the conceptual basis for the implementation of environmental safety principles for the development of the aquaculture sector. The article examines the peculiarities of aquaculture development in terms of modern ecological concepts, the mutual influence of factors of ecologically safe market-oriented development of aquaculture, the sustainable development model of the aquaculture sector is proposed, the tools for ensuring ecologically safe market-oriented development of the aquaculture sector are systematized.

1. Peculiarities of aquaculture development in terms of modern ecological concepts.

The development of the aquaculture sector contains a significant potential in terms of the implementation of the Sustainable Development Goals, which determines the inseparable unity of the economic, ecological and social components of the development of the sector. Understanding these components and their interactions is a prerequisite for the application of effective organizational and economic mechanisms for the development of the aquaculture sector. The dominant ecological concept in the world is the concept of sustainable development. The development of aquaculture corresponds to the vast majority of Sustainable Development Goals:

Goal 1. No poverty:

- Aquaculture development contributes to poverty reduction by creating employment opportunities in all links of the added value chain (preparation, production, processing, sale).
- Medium- and large-scale production have a transformative effect by making fish more accessible to consumers.



Goal 2. Zero hunger:

- Aquaculture meets the growing global demand for food. The limited stocks of traditional fishing facilities and the reduction in the number of the most valuable species of fish (sturgeon, salmon) determine the urgency of the development of artificial reproduction of aquatic living resources.

- Aquaculture provides affordable and nutritious food for poor communities.

- Ensuring agrobiodiversity.

Goal 3. Good health and well-being:

- Due to the intensive use of biological resources of the hydrosphere, humanity annually receives 20-25% of protein of animal origin.

- Available foods derived from aquaculture are a source of protein, omega-3 fatty acids and other micronutrients (e.g. calcium, iron, zinc, vitamins A and B12). This is especially important for reducing micronutrient deficiencies in vulnerable populations, improving cognitive abilities and longevity.

- Achieving the population's consumption of fish within medically recommended norms will contribute to the introduction of a healthy diet throughout the world.

Goal 4. Quality education:

- The development of aquaculture determines the demand for relevant specialists, in particular, such as: fish farmers, biologists, technologists, veterinarians, biotechnologists, land reclamationists, ecological technologists, ichthyologists, engineers of hydrotechnical structures, hydrobiologists, etc., as well as entrepreneurs, marketers, sellers, developers of software for the implementation of digital tools, etc.

Goal 5. Gender equality:

- Emerging aquaculture sectors provide livelihoods and employment opportunities for women who may previously have been limited to traditional activities.

Goal 6. Clean water and sanitation:

- Aquaculture is an efficient and non-consumptive use of available water resources that can be integrated with related activities, including irrigation, recreation, agriculture (aquaponics).

- The possibility of using organic methods of cleaning fish ponds, for example, single-celled green algae - chlorella.

Goal 8. Decent work and economic growth:

- Aquaculture, in contrast to fishing, is a profitable activity, and is one of the directions of the world economy that is developing at the fastest pace, providing a growing contribution to the provision of food to the population.

- Aquaculture development create opportunities for productive employment.

- Fish farming ensures continuity of value chains and related industries.

- The taxes from aquaculture entities contributes to the growth of state budget revenues.

Goal 9. Industry, innovation and infrastructure:

- The aquaculture sector determines the development of related industries.

- Investments in infrastructure (e.g. communications, electricity, water supply and drainage, roads) contribute to the development of aquaculture, which in turn provides government revenues to support improved infrastructure.

- The maturity of the aquaculture sector promotes innovation.

Goal 10. Reduced inequalities:

- Growing the aquaculture sector stimulate social and economic development in poor countries and rural communities.

- The formation of farmer cooperatives and clusters contributes to the involvement of small producers in value chains.

- Domestic and international trade in aquaculture products increase the amount of aquatic food products available to poor consumers.

Goal 11. Sustainable cities and communities:

- New opportunities for economic development in coastal and rural areas.

- Spatial planning includes natural solutions and "blue" infrastructure for aquaculture, creation of open spaces for leisure.

Goal 12. Responsible consumption and production:

- Consumption of artificially grown fish in aquaculture conditions does not affect biodiversity and does not damage ecosystems.

Goal 13. Climate action:

- Aquaculture products can potentially replace food products that produce more greenhouse gas emissions, contributing to the fight against climate change.

- Aquaculture production systems contribute to resilience to climate change by providing food and job security and help communities adapt to the effects of climate change.

Goal 14. Life below water:

- Aquaculture can be developed on the surface, in the water column, or on the bottom of marine, brackish, and freshwater ecosystems, creating a variety of opportunities for efficient use of available land and water areas in terms of food produced per unit surface area.

- The development and large-scale implementation of aquaculture allows to increase the volume of fish farming in the shelf zone of the seas and oceans and in internal reservoirs, to manage the processes of increasing the overall productivity of ecosystems, to preserve and expand their biological diversity.

- Cultivation of bivalve molluscs and seaweed can bring direct benefits to the aquatic ecosystem.

Goal 15. Life on land:

- Aquaculture integrated with land-based farming systems (e.g. rice fish and rice shrimp farming) produce nutritious and valuable crops of aquatic products, which has a positive impact on food security, healthy nutrition, and overall socio-economic development.

Goal 16. Peace, justice and strong institutions:

- The creation of producer groups and clusters can help ensure the widespread adoption of best practices, as well as the resolution of water sharing, disease control and other issues in accordance with jointly agreed plans.

- Tax revenues and foreign currency revenues from the sale of aquaculture products have a positive effect on increasing state budget revenues.

Goal 17. Partnerships for the goals:

- Creation of international and regional institutions and discussion forums for the aquaculture sector contribute to the establishment of partnerships between interested stakeholders.

- Scientific research and the policy of attracting investments to the aquaculture sector should be oriented towards sustainable development.

- National and international partnerships address gaps in institutional support for aquaculture development.

- Substantial private sector investments and partnerships contribute to the achievement of the Sustainable Development Goals, while profitability motivates further investment and business scaling [1, p. 12-13].

The development of aquaculture is aimed at achieving the goals of food security (SDGs 2, 3, 12) and poverty alleviation (SDGs 1, 8, 10). Education (SDG 4), gender equality (SDG 5), industry, innovation, infrastructure (SDG 9), opportunities for economic development in coastal and rural areas (SDG 11), institutional environment (SDG 16, 17) also benefit from development of the aquaculture sector. All these socio-economic benefits are provided alongside environmentally-oriented goals, including clean water (SDG 6), mitigation of climate change (SDG 13), conservation of marine resources (SDG 14), protection and restoration of terrestrial ecosystems (SDG 15), which determines the socio-economic-ecological value of the aquaculture sector. All this makes the aquaculture sector one of the strategic sectors of the national economy.

On the other hand, ensuring the sustainable development of the aquaculture sector itself requires the application of an ecosystem approach as a strategy for the development of the sector. The ecosystem approach is based on the Convention on Biological Diversity (UNCBD, 1993), which defines this approach as a strategy for the integrated management of land, water resources and means of livelihood, which involves their conservation and sustainable (ecologically rational) use. The main goals of applying the ecosystem approach to aquaculture include the following:

- guarantee of social well-being: aquaculture should increase the well-being of society, including food security, without harming the interests of any social strata;
- guarantee of ecological well-being: ensuring better use of natural resources;
- effective management: taking into account the interests of all parties, harmonious combination with other production sectors [2].

World practice has developed various concepts of ecologically safe development of aquaculture, which are proposed to be considered within business processes of the sector (Figure 1).

This approach corresponds to the European concept "From Farm to Fork", which is built on the implementation of ecological safety principles at each stage of the value chain. At the same time, it should be added that the distribution of concepts by business processes is conditional, as their influence is systemic for the sector as a whole.

In parallel with the Sustainable Development Goals, the concept of Sustainable Blue Economy was developed within the framework of the United Nations, which is based on the goals of using and preserving the natural capital of the seas and oceans in the interests of food security, the development of coastal regions and economic activities, and biodiversity.

The implementation of the blue economy meets the SDG 14. In the European Union, the blue economy together with the Green Deal forms the EU's strategic course for the coming decades. In 2012, within the framework of new approaches to maritime activity, the European Commission developed the Blue Growth Strategy. This initiative is aimed at the effective use of the economic potential of the sea waters and coastal areas of the European Union to create new jobs and ensure socio-economic development. The main goal is to achieve smart, sustainable and inclusive growth in maritime sectors with an emphasis on innovation [3].

Aquaculture is one of the sectors of the blue economy [4]. A character feature of aquaculture is the use of water resources at the stages of product preparation and production, which requires considering the principles of the blue economy concept, in particular, conducting aquaculture activities without harming aquatic ecosystems.

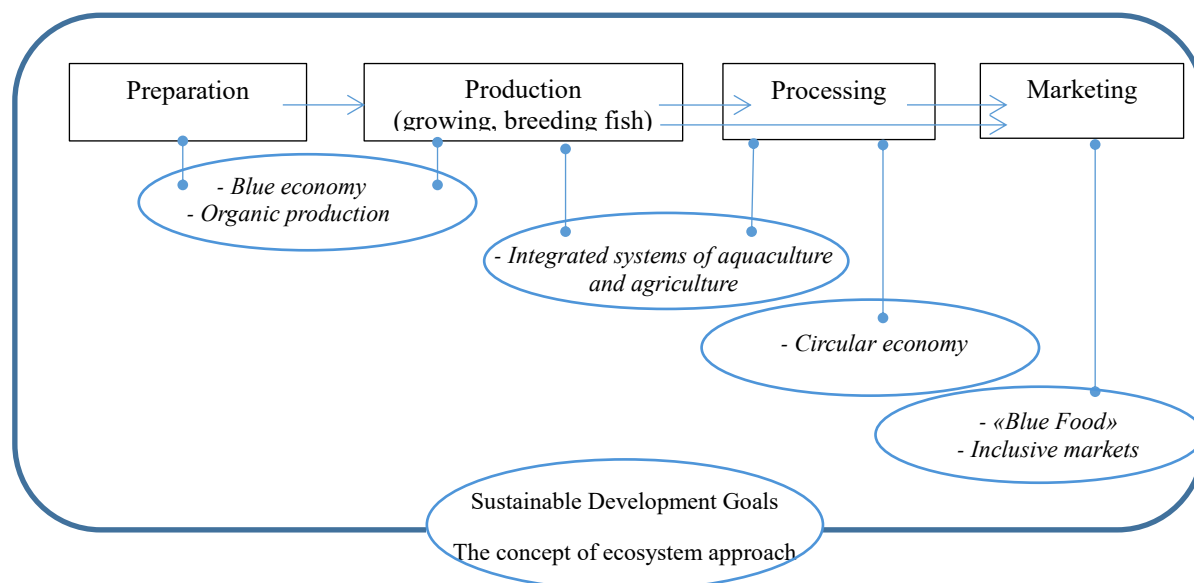


Figure 1. Concepts of ecologically safe development within business processes in the aquaculture sector.

From an ecological point of view, the most important component of aquaculture is the reproduction of aquatic biological resources and the replenishment and restoration of their natural populations, as well as decrease of industrial catch due to the expansion of commercial cultivation of hydrobionts in aquaculture. Considering the ecologically safe concepts is necessary within the fisheries and aquaculture sector development policy (Table 1).

Table 1. Core ideas of the key ecologically safe concepts for the aquaculture development [5-10].

Concepts	Preparation	Production (growing, breeding fish)	Processing	Marketing
Sustainable Development Goals	The inseparable unity of the economic, ecological and social components of the sector development			
The concept of ecosystem approach	Social welfare, ecologically rational use of natural resources, effective management			
Blue economy	Sustainable use and preservation of the natural capital of the seas and oceans			
Organic production	Rational use of water bioresources, prohibition of the use of GMOs			
Integrated systems of aquaculture and agriculture		Expanding the resource base without harming the natural environment and biodiversity, reducing environmental pollution by optimizing the metabolic functioning of integrated systems of fish farming, animal husbandry and crop production		
Circular economy		Reusing by-products, reducing waste and preventing it from the environment		
«Blue food»				Increasing the consumption of seafood as an

		affordable healthy food and causing minimal negative impact on the environment
Inclusive markets		Ensuring the availability of aquaculture products for the poorest consumers and vulnerable sections of the population
	Equal opportunities for mutually beneficial development of market participants at all stages of the value chain	

In order to take into account the ecological component in the state policy for the aquaculture sector, it is necessary to research the factors of the model of ecologically safe its development.

2. Interaction of factors of ecologically safe market-oriented development of aquaculture

In 2023, the world volume of production of aquaculture products increased by 4.3% and amounted to 96 million tons, which accounted for 51.4% of the total volume of fish production. The share of aquaculture in world fish production is growing steadily. Thus, in 2023, compared to 2007, the growth of the aquaculture share amounted to 16 percentage points (Figure 2).

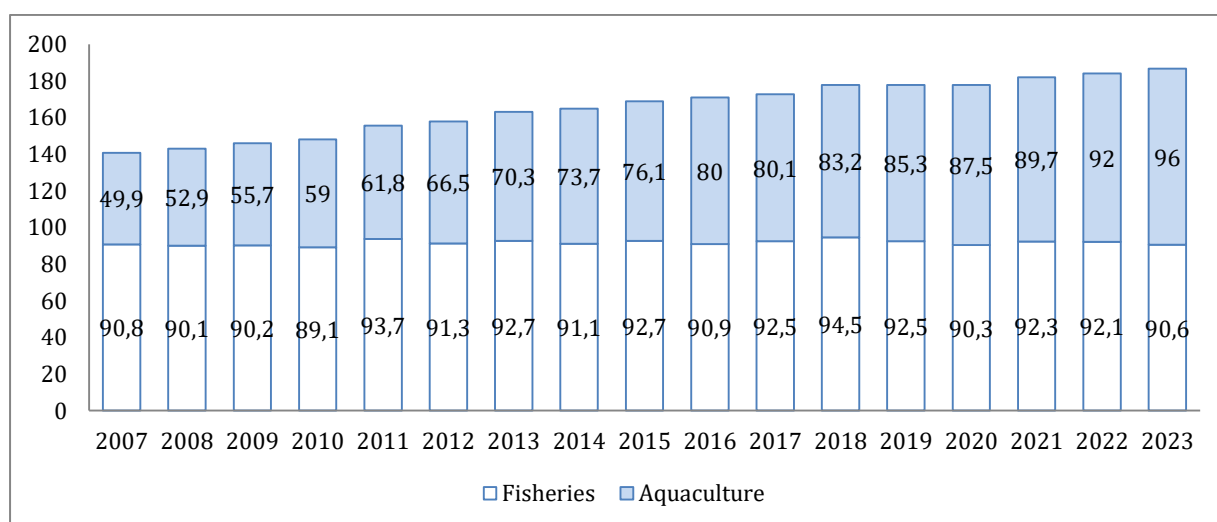


Figure 2. Global fisheries and aquaculture production in 2007-2023, million tons [11].

The study of ecologically safe development of the aquaculture sector must be carried out in the aspect of mutual influences of aquaculture activities and the environment. The factors of ecological interactions of the aquaculture sector and the environment, systematized by business processes, are presented in Figure 3.

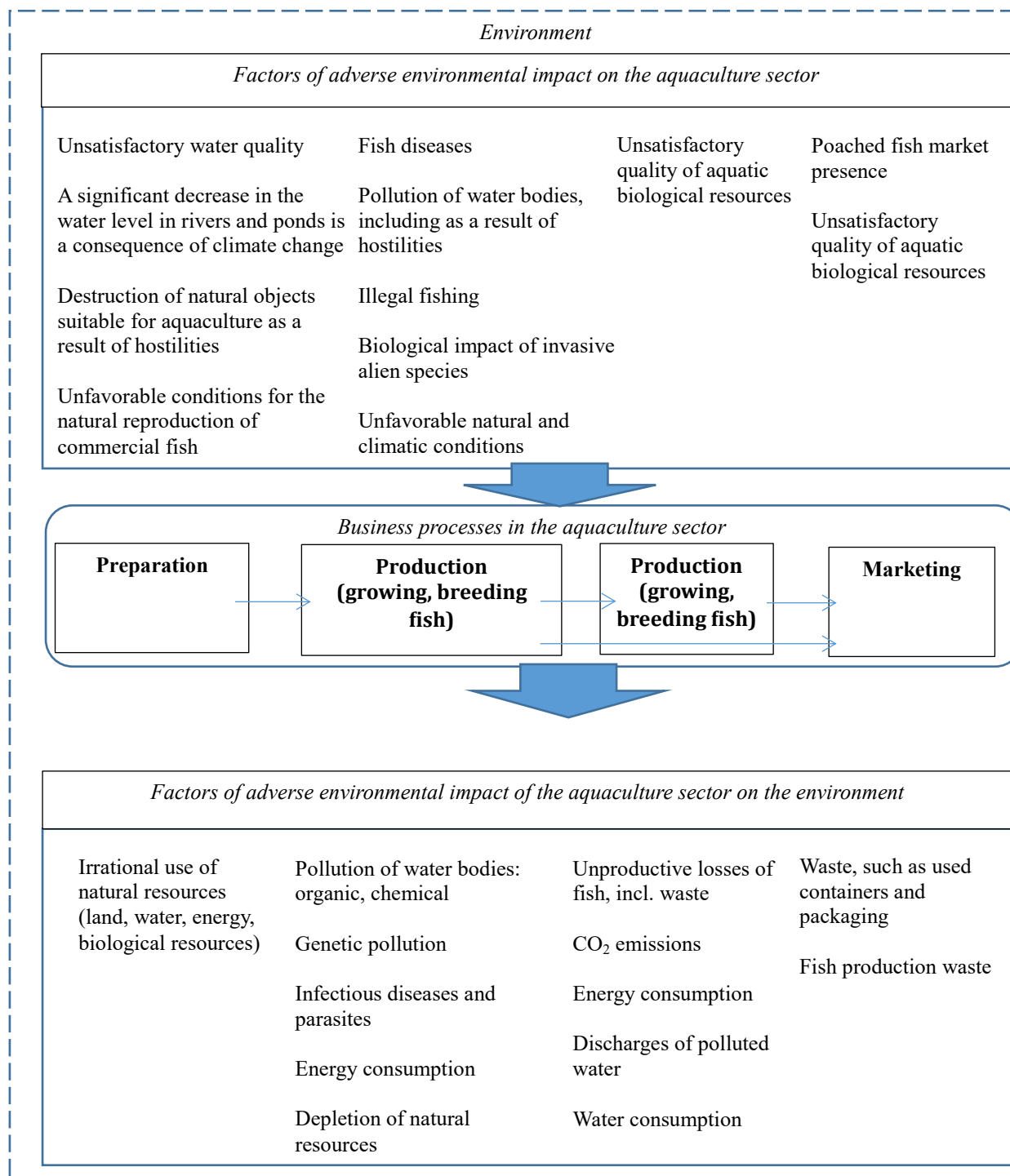


Figure 3. Factors of adverse ecological impact of the environment and anthropogenic factors on the aquaculture sector

On the one hand, aquaculture facilities are sensitive to changes in environmental conditions:

- water pollution (pollutants, radioactive waste, pesticides, heavy metals, industrial and domestic effluents, etc.);
- unsatisfactory indicators of water quality: temperature, salinity, pH, dissolved oxygen content, presence of toxic metabolites;
- evaporation and significant lowering of the water level in rivers and ponds, drying up of ponds (consequences of climate change and technogenic influence, for example, water withdrawal and creation of artificial reservoirs);
- pollution and destruction of natural objects suitable for aquaculture as a result of hostilities;
- unfavorable conditions for the natural reproduction of industrial fish, the improvement of which is a fishery reclamation: improvement of the natural paths of migration of fish for spawning and construction of fish passage facilities, improvement of natural spawning grounds, creation of artificial spawning grounds, fish protection constructions, etc.;
- unsatisfactory quality of aquatic biological resources, due to fish diseases, pollution of the habitat of biological resources, biological impact of invasive alien species, etc.;
- illegal fishing that disrupts the biobalance.

On the other hand, aquaculture activities have an impact on the environment, both positive (Sustainable Development Goals, Table 1) and negative. In particular, the negative impact of the aquaculture sector on the environment is characterized by the following factors:

- irrational use of resources, overcoming which is a global trend through the introduction of intensive technologies based on the principles of ecology safety, in particular, the introduction of an innovative aquaponic model, the development of ecological engineering and complex biotechnology (mathematical models to increase the biological production of aquaculture farms and reduce the damage caused by them to the environment), development systems of multipurpose rational use of the bioproduction potential of inland water bodies. Spatial competition also takes place - plots of recreational value can be allocated for aquaculture farms;

- pollution (chemical, organic) of water bodies, in particular, as a result of the application of fertilizers: bacteria, sediment, the formation of sapropel in the locations of farms, the accumulation of various organic substances, medicines, chemical compounds, etc., the concentration of large numbers of representatives of the microflora, sometimes pathogenic, a sharp change in the chemical composition of water, an increase in the number of parasites and predators. As a result - self-pollution of water areas and loss of commercial value of the crop. The first information about the negative impact of the development of mariculture on the environment appeared in Japan in the 60s. For example, in some areas of the Inland Sea of the Japanese archipelago, self-pollution began to be observed, which leads to a decrease in the growth rate of cultivated objects, deterioration of the quality of the water environment or (as a result) to sharp outbreaks of the growth of toxic microalgae that cause "red tides". Cultivated molluscs, feeding on toxic microalgae, lose their nutritional value and cause cases of severe food poisoning (mollusk toxicosis syndrome). The desire of farmers to protect the cultivation facilities from storms led to the deterioration of water exchange and self-pollution of water areas and the loss of the commercial value of the crop. Reduction of damage can be achieved through careful and better selection of places for marine aquaculture (state regulation), use of a feeding strategy with control of feed quality and quantity, development of recirculating systems, strict control of veterinary services for fish health, conducting research to reduce pollution pressure on the genetic structure of fish populations and the cultivated organisms

themselves, the cultivation of brown algae, gracilaria, which absorb harmful substances due to their sorption capacity. Getting rid of excess organic matter accumulated in the zone of mariculture farms can be ensured by the organization of bicultural farms: molluscs - detritophagous fish, kelp - molluscs. The use of artificial upwelling - the rise of deep waters saturated with organic matter [12]. Restoration of the quality of polluted water can be carried out according to the concept of integrated multitrophic aquaculture, which consists in the use of by-products formed in the process of growing the main object as a nutrient substrate for other organisms cultivated in the system;

- genetic pollution – fish grown in aquaculture can escape and compete with wild fish and interbreed with local wild herds, worsening genetic diversity;
- infectious diseases and parasites that can be transmitted to wild populations. In Norway, a website has been created with up-to-date, constantly updated information on the health of Norwegian fish;
- energy consumption by aquaculture production;
- depletion of natural resources, especially under conditions of intensive methods of aquaculture management;
- CO₂ emissions: activities in the field of aquaculture make a significant contribution to greenhouse gas emissions during production activities, as well as transportation, processing and storage of fish. Particularly high emissions are at the transportation stage. International fish trade, which provides export earnings for many countries, is constantly growing, which will increase the contribution of fisheries to CO₂ emissions;
- pollution of sewage and underground water;
- unproductive losses of fish, including fish waste and fish products. The solutions to this and the following problems are provided by the implementation of the principles of the circular economy;
- generation of other waste: used containers and packaging, fishing gear, etc.

The considered factors are general, and depending on the form of aquaculture (extensive, semi-intensive, intensive) have their own characteristics. The impact of aquaculture on the environment depends on the species grown, the intensity of production and the location of the farm. The more complex and intensive the system, the greater the impact on the environment [4].

The essence of the model of sustainable development of the aquaculture sector is that the development of the sector should be accompanied by the improvement of economic and social indicators while simultaneously reducing the negative impact on the environment.

The indicators for this model are presented in the Table 2.

Table 2. Indicators for the sustainable development model of the aquaculture sector [13].

Indicators of the positive impact of aquaculture (→max)	Indicators of the negative impact of aquaculture (→min)
<i>Economy</i>	<i>Environmental</i>
The ratio between net income and initial investment	Energy use
Net profit	Use of nitrogen
Annual income	Use of phosphorus
Diversification of markets	CO ₂ emissions
Actual consumed products	Pollution by hormones
The ratio between consumers' spendings in the	Heavy metal pollution

domestic market and spending as a whole by the sector	
Investments in new technologies and innovations	Accumulation of organic substances
	Pollution by chemical substances
<i>Social</i>	
The share of local workers in the total number of workers in the sector	
Payment of labor per unit of production	
Share of self-employed persons	
The share of consumption of the sector's products in the total volume of consumption	

The development of the aquaculture sector must be accompanied by the improvement of economic and social indicators while simultaneously reducing the negative impact on the environment.

3. Tools for ensuring ecologically safe market-oriented development of the aquaculture sector

On the basis of the conducted analysis, the following main tasks of implementing the policy of ecologically safe development of the aquaculture sector are defined: water use: regulating the volume of water use and ensuring water quality in aquaculture production; purification of water used in aquaculture production; optimization of energy use, including the involvement of alternative energy sources, the use of geothermal water, warm industrial water, etc.; reduction of CO₂ emissions; waste processing.

The tools for achieving the specified tasks of ecologically safe development of the aquaculture sector are systematized according to the following groups: monitoring, institutional, financial, technological innovations, organizational and economic:

Monitoring. The introduction of any environmental-oriented tools is based on primary information. Indicators of the impact of the aquaculture sector on the environment should be subject to monitoring, in particular, those listed in Table 3. Also, the assessment of water quality is necessary for determining the quality and safety of aquaculture products, ensuring the principles of organic production.

Institutional. The ecological component should be integral in the development of strategies and programs for the development of the aquaculture sector. adoption of the Code of Responsible Fishing at the national level will contribute to the implementation of the principles of sustainable development of fisheries and aquaculture. At the global level, the Code of Conduct for Responsible Fisheries was developed and adopted by FAO in 1995. Designed to promote a responsible approach to fishing and aquaculture, the Code covers all aspects of the sector, from responsible fishing and aquaculture practices to trade and marketing. It serves as a reference point for the development of public policy measures on all continents.

Financial. Stimulation of environmentally-oriented activities of enterprises in the aquaculture sector through preferential taxation, lending on the basis of environmental licensing. The accumulation of financial resources at the regional level is possible with the help of the regional fund for the development of aquaculture. The functioning of the Fund will ensure financing of the aquaculture sector according to the European model, according to which the funds generated by the sector are directed to its development. In Ukraine local, regional environmental protection funds, which are formed by compensation for damage caused to fish

stocks, were previously used for the construction and reconstruction of fish breeding enterprises, and now they are directed to environmental protection measures that are not related to the replenishment of fish stocks and fish farming.

Technological innovations. Modern technologies are capable of increasing the productivity of aquaculture farms while simultaneously reducing their negative impact on the environment. These are, in particular, technologies of mechanization and automation of production processes, water treatment technologies, integrated and combined production technologies, in particular, aquaponics, etc.

Organizational and economic. A comprehensive approach to solving the problem of minimizing the negative impacts of the development of the aquaculture sector on the environment could be provided through the mechanism of eco-industrial parks.

An eco-industrial park is a special zone of industrial purpose with social, economic, and ecological parameters in the processes of location selection, planning, management, and day-to-day functioning. Within the framework of eco-industrial parks, a high level of cooperation is achieved in matters of joint use of resources and waste management. These parks represent a high level of cooperation, ensuring industrial symbiosis, which is a way of implementing the principles of the circular economy, when the waste of some enterprises becomes raw material for others. Natural resources such as water, energy, aquatic bioresources are the most significant for aquaculture. Eco-industrial clusters should be built around these resources, ensuring their rational, waste-free use.

The practice of forming an eco-industrial park with the participation of fish farming exists in the Danish city Kalundborg: the energy company supplies residual steam to an oil refinery, which, in turn, supplies gas that was previously burned to a power plant. In turn, the power plant directs steam to the centralized heating system of a fish farm, a pharmaceutical enterprise and 3,500 residential buildings. Sludge from ponds and waste from pharmaceutical production are used by local farmers as fertilizers. The ash produced at the power plant is used to produce cement, and the gypsum obtained as a result of desulfurization at the power plant goes to a company that produces plasterboard. An oil refinery removes sulfur from natural gas and sells it to a company producing sulfuric acid [14].

The implementation of this model into practice will contribute to the increase of environmental standards of aquaculture products, the attraction of foreign investments, carbon neutrality of production, the development of industrial and high-quality social infrastructure, and the creation of new jobs with high labor standards.

4. Conclusions

It is defined that conceptual principles of ecologically safe development of aquaculture are sustainability, ecosystematicity, organicity, integrity, circularity, inclusiveness.

Ecologically safe development of the aquaculture sector takes place in conditions of mutual influence of aquaculture activities and the environment. Sustainable development is a necessary condition for meeting the growing demand for aquatic food products. This means that the development of the economic potential of aquaculture should be inextricably linked with the preservation of ecosystems, the reduction of pollution, the protection of biodiversity and the social equality.

References

- [1] World Economic Forum (2022). The Road to Sustainable Aquaculture: On current knowledge and priorities for responsible growth. Cologny, Switzerland.
- [2] FAO Technical Guidelines for Responsible Fisheries (2003). The ecosystem approach to fisheries. Rome: FAO, №4.
- [3] European Economic and Social Committee. Opinion of the European Economic and Social Committee on the «Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Blue Growth: opportunities for marine and maritime sustainable growth», COM (2012) 494 final, 06.06.2013. Retrieved from <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52012AE2274>.
- [4] UNCSO. (2014). Blue economy concept paper. Retrieved from <https://sustainabledevelopment.un.org/content/documents/2978BEconcept.pdf>.
- [5] Busaidi, R. (2021). What is integrated aquaculture and how can it help feed the world? World Economic Forum official web-site. <https://www.weforum.org/agenda/2021/08/integrated-aquaculture>.
- [6] Hughes, A., Day, J.G., Greenhill, L., & Stanley M.S. (2016). Aquaculture. Commonwealth Blue Economy Series, No. 2. Commonwealth Secretariat, London.
- [7] Fraga-Corral, M. , Ronza, P., Garcia-Oliveira, P., Pereira, A.G., Losada, A.P., Prieto, M.A., Quiroga, M.I., & Simal-Gandara, J. (2022). Aquaculture as a circular bio-economy model with Galicia as a study case: How to transform waste into revalorized by-products. Trends in Food Science & Technology, 119, 23-35.
- [8] Building Blue Food Futures for People and the Planet (2021). The Report of the Blue Food Assessment. DOI: 10.25740/rd224xj7484.
- [9] Why does blue food matter? Blue Food Partnership web-site. Retrieved from <https://www.weforum.org/blue-food-partnership/why-blue-food>.
- [10] Moores, D., & Hunter A. (2018). Inclusive Market Systems Development: Sustainable growth for everyone. Australia: World Vision. <https://beamexchange.org/resources/1083>.
- [11] Statista. World fish production from 2007 to 2023. Retrieved from <https://www.statista.com/statistics/272311/world-fish-production-by-fishing-and-aquaculture-since-2004>.
- [12] Kononeko, R.V., Shevchenko, P.G., Kondratyuk, V.M., & Kononenko, I.S. (2016). Intensive technologies in aquaculture: training manual. K: "Center for Educational Literature" [in Ukrainian].
- [13] Valenti W.C., Kimpara J.M., Preto B.d.L., Moraes-Valenti P. (2018). Indicators of sustainability to assess aquaculture systems. Ecological Indicators, 88, 402-413.
- [14] Desrochers, P. (2001). Eco-industrial parks. The case for private planning. The Independent Review, 5, 3, 345-370. Retrieved from <https://www.jstor.org/stable/24562610>.