АКВАКУЛЬТУРА

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SANITARY AQUACULTURE AS AN ELEMENT OF RATIONAL EXPLOITATION OF SMALL RESERVOIRS

Pylypenko Yu. *– doctor of Agriculture, professor,*
Kherson State Agricultural University, Ukraine,
pilipenko_yurii@ukr.net

The article considers the possibilities of sanitary aquaculture application to small water reservoirs intended for drinking and technical water supply, irrigation recreation and fish farming which occupy 14.8% of the Ukrainian water reserves. The introduction of balanced pasture aquaculture which provides for the purposeful formation of artificial ichthyocenoses by valuable fish species will ensure biological melioration of these reservoirs, bioregulation of production processes, reduction of eutrophication level, improved water quality characteristics, high quality and cheap fish products.

Keywords: small reservoirs, hydroecosystem, eutrophication, bioameliorative, bioregulation, fish-bioameliorators, sanitary aquaculture.

Problem formulation. Further development of human society is accompanied by a growing demand for water resources. Annual increase in fresh water consumption is estimated at an average of 5-6, and in some countries as much as 10-12 percent [4]. To optimize water supply for different sectors, various types of reservoirs have been created with the aim of daily, seasonal, long-lasting or territorial water flow control, which is a prerequisite for multi-purpose and integrated use of water resources.

According to expert estimates presented by Yu. M. Lebedev [5] in his study, the world's supply of fresh water accumulated in aquatic ecosystems amounts to 91.0 thousand km^3 in lakes, 4.3 thousand km^3 in reservoirs and 2.1 thousand km^3 in rivers. Given the fact that the average time of the complete renewal of water in lakes is 17 years, in reservoirs one year, in river systems 16 days, the actually available freshwater resources make up 5.3 thousand km^3 in lakes, 4.3 thousand km^3 in reservoirs, and 5.3 thousand km^3 in river systems.

The intensive construction of water development works in the Ukraine in the second half of the 20th century resulted in the emergence of 1.16 thousand reservoirs of different kinds that contained more than 55 bln m^3 of fresh water, with a total area of more than 1 mL/ha, which greatly increased the country's water resource potential as well as the total area of fresh water bodies by nearly 2.4 times [7].

Analysis of recent research and publications. The largest group among all reservoirs (up to 94 percent of their total number) is small reservoirs used for different special purposes (drinking, technical, irrigation, recreation, fish-breeding). Their individual area is less than one hectare [1] but they account for 14.8 percent of the total area of water resources of the Ukraine (Table 1).

Table 1. **Water resources of Ukraine** [6]

Water bodies	Area, thousand ha	Ratio, %
Pond fish farms	208.6	12.3
Lakes and estuaries	402.2	23.6
Small reservoirs (S < 1000 ha)	252.4	14.8
Middle-sized reservoirs (S = 1001 ÷ 10 000 ha)	123.4	7.2
Large reservoirs (S > 10 000 ha)	702.2	41.2
Water bodies cooling power plants	13.5	0.8
Total:	1702.3	100.0

Growing anthropogenic pressure on hydroecosystems of small reservoirs greatly aggravated the problem of their protection and restoration. Until recently, the water quality of this group of water bodies was evaluated only from the point of view of the consumer and was based on the technological requirements, depending on their purpose. Because of this approach, the pollution of the hydroecosystems of small reservoirs increased considerably, their self-cleaning capacity decreased, which led to crises, deterioration and loss of usable water for consumers [3].

It should be noted that small reservoirs serving different purposes are man-made water bodies having no analogues in nature and standard samples of these specific aquatic ecosystems are missing. Accordingly, they require special approaches that differ from those applicable to other types of aquatic ecosystems.

In our opinion, the starting point in identifying the place of small reservoirs in the system of water resources is the fact that they are an independent type of hydroecosystems of the same value as natural ones, but having a specific status characterized by a number of important differences, namely [8]:

● man-made origin (for the needs of corresponding water users);

● a short period and accidental character of the formation and development of the hydroecosystem;

● internal contradictions in the development of abiotic and biotic subsystems;

● dynamics of the main abiotic parameters subject to the interests of major water users;

● poor species composition and low saturation of spontaneously formed hydrobiocenoses;

● insufficient utilization of bioproducts;

● absence of biologically and economically valuable fish species in fish communities that could effectively exploit the biological production potential of hydroecosystems.

Environment-oriented activities on established and functioning small reservoirs designed for different special purposes are to be aimed at preserving hydroecosystem parameters that will provide an optimal economic effect of the exploitation of the water body.

In our view, three aspects can be highlighted in the structure of managerial decisions on water protection activities related to small reservoirs: spatial, technological and biological [8, 9].

The spatial aspect includes a system of measures on the adjacent catchment area to prevent the development of water and wind erosion causing significant amounts of pollutants to get into hydroecosystems.

The technological aspect of water protection activities is directly related to target operation of small reservoirs and provides the control of their hydrological regime to maintain the optimal water flow and normal backup water level. This will prevent stagnation as a prerequisite for degradation processes.

It is expedient to elaborate on the biological aspect that involves the introduction of bioamelioration elements. On the one hand, it will ensure the bioameliorative effect and, on the other hand, it will help to get high-quality fish products [2, 7].

The progressive eutrophication of small reservoirs under the anthropogenic load is a stimulating factor for the activation of certain groups of hydrobionts, especially plant associations (macrophytes, phytoplankton). The absence of efficient consumers of organic mass produced at different trophic levels in the spontaneously formed hydrobiocenoses of small reservoirs leads to the formation of shortened trophic chains and dead-end productive branches. This causes gradual accumulation of organic matter and energy within the hydroecosystem, as well as formation of massive detrital and silt masses, increased destructive processes, particularly under anaerobic conditions. As a result, we observe a lack of dissolved oxygen and release of hydrogen sulphide.

This is the way of recontamination of water areas, which gradually leads to a crisis. The introduction of bioamelioration elements by purposeful forming fish communities whose representatives are able to efficiently consume the surplus organic mass of food organisms allows creating more extensive trophic chains and a fish-productive branch of productive-destructive processes, which changes their course towards energy dispersal. When the biomass of fish-ameliorators increases, a considerable amount of organic matter is transformed into high-quality fish products and is withdrawn from the cycle, providing a bioameliorative effect. This is the pre-condition of the development of a specific area of fish culture – sanitary aquaculture.

For the utilization of organic matter formed by macrophytes and for the regulation of overgrown areas of small reservoirs it is expedient to introduce effective bioameliorators – grass carp (*Ctenopharyngodon idella*). In this case, the stocking density of viable young grass carp depends on the intensity of algae development (Table 2). Because of a lack of criteria for determining the optimal development of macrophytes for small reservoirs in terms of the formation of quality parameters of hydroecosystems, the index reflecting the overgrowing of water areas within 10-15 percent of the water surface is taken as an optimal parameter. It is, therefore, recommended for fish culture reservoirs.

Table 2. **Bioregulation of macrophytes overgrowing water areas of small reservoirs**

Water areas overgrowing, %	Level of microphyte development	Recommended level; of utilization, %	Stocking density of grass carp, pcs/ha
< 10	Low	40	20 – 50
10 – 15	Optimal	50	51 – 150
> 15	Increased	60	151 – 270

The elements of control of the bioproductive potential of small reservoirs formed by planktonic and benthic aquatic groups with the aim of reaching a bioameliorative effect through the introduction of compensatory ichthyocenoses are shown in Table 3. However, depending on the level of food supply for aquatic organisms, a different degree of product utilization and, consequently, a different stocking density of fish-bioameliorators is recommended. For suppressing phytoplankton development, it is proposed to introduce silver carp (*Hypophthalmichthys molitrix*); in case of zooplankton it is expedient to introduce spotted silver carp (*Aristichthys nobilis*), and for the reduction of zoobenthos development, common carp (*Cyprinus carpio*), appears to be effective. It should be noted that silver and silver spotted carp, which can be adequately replaced by hybrid forms of these species, additionally consume detritus accumulating in small reservoirs [7, 11].

Table 3. **Control of bioproductive potential of small reservoirs [10]**

Food group	Parameter	Level of development				
		Moderate	Fair	Increased	High	Very high
Phytoplankton	Average seasonal biomass, g/m²	1.0–2.0	2.1–5.0	5.1–10.0	10.1–50.0	> 50.0
	Recommended level of utilization, %	20	40	50	60–65	70–75
	Stocking density of white carp*, pcs/ha	50–150	155–500	505–1000	1005–3950	4000–5200
Zooplankton	Average seasonal biomass, g/m²	1.1–2.0	2.1–4.0	4.1–8.0	8.1–16.0	> 16.0
	Recommended level of utilization, %	30	40	50	60	70
	Stocking density of spotted silver carp*, pcs/ha	35–50	51–150	151–300	301–450	451–600
Zoobenthos	Average seasonal biomass, g/m²	2.5–5.0	5.1–10.0	10.1–20.0	20.1–40.0	> 40.0
	Recommended level of utilization, %	20	30	40	50	60
	Stocking density of carp, pcs/ha	10–40	41–100	101–200	201–350	351–500

** Adequate replacement by hybrid forms of silver carp is possible.*

The present experience of fish management in small reservoirs gives ground to the recommendation of stocking them with fish-ameliorators at the fingerling age with an average weight of 20-30 g.

Taking into account the amount of brackish water areas in small reservoirs, it is expedient to recommend the introduction of viable young mullet *Liza (Mygil) so-iuy* Basilewsky with a planting density of 60-100 pcs/ha, which will create conditions for the partial utilization of the accumulated detritus.

The proposed biotechnological parameters of sanitary aquaculture aimed at the bioameliorative regulation of the excessive growth of the main groups of food hydrobionts create conditions for preventing biological contamination of hydroecosystems of small reservoirs. The cultivation of fish-ameliorators in polyculture will provide the transformation of excess organic matter into useful fish products.

However, it is necessary to provide an industrial load on the formed populations of fish-ameliorators, which in small reservoirs of the Ukraine, can most effectively exercise their productive and bioameliorative capacities up to four years of age. Further, with age, as determined by our research, there is a natural and obvious growth slowdown in all fish-ameliorators without exception, which proves the expediency of their catch in the third - fourth years of life, after reaching maximum weight increment rates. Therefore, the market weight of grass carp of this age group is 1.0-1.5 kg, of silver carp 1.5-2.0 kg, of spotted silver carp 2.0-3.0 kg, of carp and European carp 1.1-1.7 kg.

Conclusion. Thus, we believe that the proposed principles of rational exploitation of small special-purpose reservoirs should become the underlying principles of water protection activities that will harmonize economic and environmental functions and prevent the degradation of these specific artificial technogenic hydroecosystems.

САНІТАРНА АКВАКУЛЬТУРА ЯК ЕЛЕМЕНТ РАЦІОНАЛЬНОГО ВИКОРИСТАННЯ МАЛИХ ВОДОСХОВИЩ

Пилипенко Ю.В. – *д. с.-г. наук, проф.,*
Херсонський державний аграрний університет,
pilipenko_yurii@ukr.net

У статті розглянуто можливість застосування санітарної аквакультури на малих водосховищ, призначених для питного і технічного водопостачання, іригації, рекреації та риборозведення, які займають 14,8% водного фонду України. Впровадження збалансованої пасовищної аквакультури, що передбачає цілеспрямоване формування штучних іхтіоценозів цінними видами риб,

дозволить провести біомеліорацію цих водойм, забезпечити біорегулювання продукційних процесів, зменшити рівень евтрофікації, покращити якісні характеристики води, отримати якісну і дешеву рибопродукцію.

Ключові слова: малі водосховища, гідроекосистема, евтрофікація, біомеліорація, біорегуляція, риби-біомеліоратори, санітарна аквакультура.

САНИТАРНАЯ АКВАКУЛЬТУРА КАК ЭЛЕМЕНТ РАЦИОНАЛЬНОГО ИСПОЛЬЗОВАНИЯ МАЛЫХ ВОДОХРАНИЛИЩ

Пилипенко Ю.В. *– д. с.-х. наук, проф.,*
Херсонський государственный аграрный университет,
pilipenko_yurii@ukr.net

В статье рассмотрены возможности применения санитарной аквакультуры на малых водохранилищах, предназначенных для питьевого и технического водоснабжения, ирригации, рекреации и рыборазведения, которые занимают 14,8% водного фонда Украины. Внедрение сбалансированной пастбищной аквакультуры, что предусматривает целенаправленное формирование искусственных ихтиоценозов ценными видами рыб, позволит провести биомелиорацию этих водоемов, обеспечить биорегулирование продукционных процессов, снизит уровень эвтрофикации, улучшить качественные характеристики воды, получить качественную и дешевую рыбопродукцию.

Ключевые слова: малые водохранилища, гидроэкосистема, евтрофикация, биомелиорация, биорегуляция, рыбы-биомелиораторы, санитарная аквакультура.

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