INFLUENCE OF ENVIRONMENTAL FACTORS ON MORPHOPHYSIOLOGICAL AND REPRODUCTIVE INDICATORS IN THE FORMATION OF THE PREPARATORY PARENT COLLEGE OF GRASS CARP (CTENOPHARYNGODON IDELLA VALENCIENNES, 1844) FISHES UNDER POOL FISHERY CONDITIONS.

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Abstract: This article evaluates the influence of environmental factors on the formation of high-quality broodstock of grass carp (Ctenopharyngodon idella Valenciennes, 1844) cultured under pond aquaculture conditions in the Tashkent region. Hydrochemical parameters, biological characteristics, and reproductive performance were comprehensively assessed and compared with international standards. The findings demonstrate that stable water quality significantly improves fish growth, physiological condition, and reproductive potential, providing a scientific basis for sustainable broodstock management.

Keywords: grass carp, broodstock, environmental factors, pond aquaculture, hydrochemical parameters, reproductive potential, water quality.

Introduction: Aquaculture is one of the fastest-growing sectors for ensuring food security worldwide, and according to FAO data, the volume of fish products grown in recent decades has shown steady growth rates compared to hunting products harvested from natural water bodies (FAO, 2024). One of the important factors in this growth is the formation of breeding parent colonies with high biological and reproductive potential. The quality of parent fish is inextricably linked not only to genetic factors but also to the ecological environment in which they are raised, which is one of the key factors determining the viability and productivity of future generations. Among herbivorous fish, the white amur (Ctenopharyngodon idella Valenciennes, 1844) is recognized as a strategic species in aquaculture due to its rapid growth, efficient use of food, and significance in the biological reclamation of water bodies. Lin (1935) was the first to scientifically describe the biological characteristics of this species, demonstrating its ecological adaptability and the possibility of cultivation in ponds. Bardach et al. (1972) emphasized that to achieve high productivity in aquaculture, it is necessary to select parent fish, manage the aquatic environment, and organize a comprehensive feeding system. In his research on pond fish farming, Huet (1970) scientifically substantiated that water temperature, dissolved oxygen, and hydrochemical indicators significantly influence fish growth and maturation processes. Billard (1986) in his research on reproductive physiology showed that environmental factors are an important regulatory factor at all stages of gametogenesis. Jhingran (1991) noted that water quality and the natural food base are of decisive importance in improving the technology of artificial reproduction of carp-like fish.

Recent studies have shed even deeper light on the correlation between environmental factors and reproductive productivity. Miao et al. (2022) found that the stability of water quality has a direct positive effect on the gonadosomatic index and egg quality. Li et al. (2023)

experimentally proved that a decrease in the amount of dissolved oxygen increases oxidative stress and negatively affects the development of gametes. Zhang et al. (2024) noted that the combined influence of water temperature, feeding levels, and the hydrobiological environment are the primary factors determining the physiological state of parent fish and the quality of offspring. Even in modern review articles published in the journal Reviews in Aquaculture, environmental management is recognized as one of the most important directions for increasing reproductive efficiency. Nevertheless, the complex influence of ecological factors on the formation of breeding parent schools of white amur fish in the conditions of pond fish farming in Central Asia, particularly in Uzbekistan, has not been sufficiently studied. Most existing studies were limited to assessing individual hydrochemical indicators or growth parameters and did not provide a comprehensive analysis of the relationship between water quality, the hydrobiological nutrient base, the feeding system, and reproductive indicators. This requires the development of scientific recommendations suitable for local environmental conditions. The scientific novelty of this study is to determine the impact of ecological factors on the biological state, morphometric indicators, and reproductive potential of white amur fish based on a comprehensive assessment of pond fish farms in the Tashkent region. The results of the study serve to develop scientifically grounded recommendations for forming high-quality breeding parental herds and to increase biological productivity under pond aquaculture conditions.

MATERIALS AND METHODS: Research was conducted during 2023–2026 at the pond fish farms "Khoorrot Fish House" LLC, "ZafarAsad" FE, and "Imkon Baliq Fayz" LLC, located in the Tashkent region. These farms were selected as research objects due to their similar natural and climatic conditions, water supply systems, and carp rearing technologies. At the same time each farm has implemented elements of pond fish farming into its activities and possesses practical experience in forming breeding parental schools of white amur fish. During the study, white amur (Ctenopharyngodon idella Valenciennes, 1844) fish of reproductive age were selected from each farm. The samples were formed based on the same methodological approach, and all measurements were performed using the same equipment and standard methods. This made it possible to compare the results obtained from different farms. The biological development and reproductive potential of white amur (Ctenopharyngodon idella Valenciennes, 1844) in pond fisheries largely depend on the hydrochemical stability of the aquatic environment. In studies conducted in the world's leading aquaculture countries-China, India, Hungary, Russia, and the USA - it is recommended to maintain parent fish at a water temperature of 22-28 °C, pH 7.0-8.5, dissolved oxygen no higher than 6 mg/l, nitrite no lower than 0.2 mg/l, and ammonia no higher than 0.05-0.10 mg/l (Huet, 1970; Billard, 1986; FAO, 2022; Li et al., 2023; Zhang et al., 2024) The results of hydrochemical monitoring conducted in 2024–2025 at the "Khoorrot Fish House" LLC farm in the Tashkent region reflected seasonal changes in the aquatic environment. In spring, the water temperature is 21.4–22.0 °C, creating favorable conditions for fish metabolism and gonad development at the beginning of the vegetation period. An increase in water temperature to 25.9–26.4 °C in May contributed to the activation of growth processes. The amount of dissolved oxygen is in the range of 6.0–7.2 mg/l, which fully complies with international recommended standards. These indicators are almost identical to the ecological conditions recorded for purebred white amur fish in the Yangtze River basin of China, corresponding to values assessed as optimal by Li et al. (2023).

In summer (July), the water temperature was maintained within the range of 23.9–25.0 °C. Although a short-term decrease in dissolved oxygen to 1.9–4.0 mg/l was observed in some pools, in other pools this indicator remained at 5.0–6.1 mg/l. A similar situation has been observed in pond farms in India, where an increase in water temperature during the summer months is assessed as a natural process that reduces oxygen solubility (Jhingran, 1991). Under these conditions, regulating aeration and water exchange is one of the key factors in maintaining stable reproductive indicators. In the autumn season (October), maintaining the water temperature at around 24.2-24.3 °C and dissolved oxygen at 5.0-5.6 mg/l was sufficient to maintain the physiological state of the parent fish. Chinese and Hungarian scientists also noted that such environmental conditions during the autumn period contribute to the accumulation of energy reserves for the next reproductive cycle. During the study, the pH of the water was recorded within the range of 6.5-7.6. These values correspond to the FAO-recommended range of 6.5-8.5 and provide a favorable environment for fish osmoregulation and enzymatic processes. Zhang et al. (2024) noted that pH within this range positively affects egg cell development and fertilization indicators. The nitrite content was determined to be within the range of 0.001–0.07 mg/l across all observation periods, which was several times lower than international standards.

This indicates that the processes of biofiltration and natural nitrification are proceeding effectively. Russian and Chinese scientists also noted that nitrite levels below 0.1 mg/l reduce the risk of hemoglobin conversion into methemoglobin in fish. The concentration of ammonia was within the range of 0.001–0.04 mg/l in the majority of observations, significantly below the toxic limit. Only in some spring ponds was an increase in ammonium nitrogen to 2.0 mg/l observed. This situation can be explained by the decomposition of organic matter and fertilization processes at the beginning of the season. However, due to the water's pH being close to neutral, the proportion of free toxic ammonia remained very low, which did not pose a serious threat to the fish. The degree of mineralization was recorded in the range of 0.22–0.82 g/l. This indicator is similar to the mineralization level in carp ponds in Hungary and China and is sufficient to ensure the stability of ion exchange and osmotic equilibrium. It was determined that the hydrochemical state of the Tashkent region's ponds complies with the environmental requirements recommended in international aquaculture practice. The observed seasonal fluctuations are natural for temperate continental climates, indicating that as a result of regular water quality monitoring and management measures applied in farms, a favorable ecological environment has been formed to maintain the biological and reproductive status of the parent grass carp fish.

Table 1. Comparative analysis of ecological indicators for grass carp fish with international recommendations and data from the "Khoorrot Fish House" farm

Indicator	FAO/China	India	Hungary	Tashkent region	Evaluation
Temperature (°C)	22–28	24–30	20–26	21,4–26,4	Suitable
pH	7,0–8,5	7,0–8,2	7,2–8,3	6,5–7,6	Suitable
Dissolved oxygen (mg/L)	>6	>5	6–9	5,0–7,2 (ayrim	Primarily suitable

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Nitrite (mg/L)	<0,2	<0,2	<0,2	0,001–0,07	Suitable
Ammonia (mg/L)	<0,1	<0,1	<0,1	0,001–0,04	Suitable

Table 2. Comparative assessment of the biological indicators of breeding parent grass carp fish under the influence of environmental factors.

Indicator	Khoorrot Fish House	FX "ZafarAsad"	MCHJ "Imkon Baliq Fayz"	Environmental impact
Avg body length (cm)	66,55 ± 1,17	63,19 ± 0,94	64,02 ± 1,44	Stability of temperature and nutrient base had a positive effect on growth rate.
Avg body weight (kg)	3,88 ± 0,18	3,38 ± 0,11	3,13 ± 0,24	Normal dissolved oxygen and water quality contributed to an increase in body weight.
Fulton coefficient	1,31 ± 0,03	1,35 ± 0,04	1,14 ± 0,03	The fatness coefficient reflects the biological efficiency of the aquatic environment and feeding conditions.
Reproductive status	normally	normally	Satisfactory	Normal hydrochemical parameters created a favorable environment for the development of gonads.

Results and discussion. The formation of a breeding parental colony with high reproductive potential of the grass carp (Ctenopharyngodon idella Valenciennes, 1844) largely depends on the ecological stability of the aquatic environment. During the study, regular

monitoring of the main hydrochemical water parameters was conducted at the "Khoorrot Fish House" LLC, "Zafar Asad" FE, and "Imkon Baliq Fayz" LLC fish farms located in the Tashkent region, and their impact on the biological state of the parent fish was evaluated. Monitoring results showed that the water temperature in all three farms ranged from 21.4 to 26.4 °C during the growing season. This indicator almost corresponds to the 22–28 °C range recommended by the FAO and Chinese aquaculture research centers for the physiological development of grass carp fish. According to the studies of Huet (1970) and Li et al. (2023), it is in this temperature range that the processes of food digestion, protein synthesis, and gametogenesis occur at the highest level in white amur fish. In our study, maintaining the temperature within the optimal range contributed to the normal formation of parental fish body length, body weight, and Fulton obesity indicators. The water's hydrogen index (pH) was recorded in the range of 6.5-7.6 across all observation periods. These values represent a neutral and weakly alkaline environment, creating favorable conditions for enzymatic reactions, ion exchange, and osmoregulation processes in fish. Billard (1986) also noted that a pH range of 6.8–8.0 positively affects the normal development of the gonads. The amount of dissolved oxygen is one of the most powerful environmental factors affecting reproductive processes. During the study, oxygen content was mainly observed in the range of 5.0–7.2 mg/l, while on certain days of the summer season, a short-term decrease to 1.9–4.0 mg/l was recorded in certain pools.

However, since this condition did not take on a permanent character, it did not have a significant negative impact on the general physiological state of the parent fish. Li et al. (2023) noted that oxidative stress increases when oxygen levels are below 5 mg/l. In our observations, a temporary decrease in oxygen during the summer months was also associated with an increase in water temperature, and the ecological balance was restored through aeration and water exchange. The nitrite (NO2) content in all farms ranged from 0.001 to 0.07 mg/l, which was several times lower than international standards. This indicator indicates that the nitrification process in the reservoirs is stable and the aquatic ecosystem is biologically balanced. Zhang et al. (2024) also noted that low nitrite concentrations maintain oxygen-carrying hemoglobin activity in fish. The ammonia concentration was recorded in the range of 0.0002–0.04 mg/l in the majority of observations. These values are significantly lower than the safe limit recommended by FAO and have no toxic effects on the development of the reproductive organs. Only in the spring period, an increase in ammonium nitrogen to 2.0 mg/l was observed in some ponds. However, due to the water's pH value below 7, the proportion of free ammonia (NH3) was very low and did not pose a physiological hazard. The degree of mineralization ranged from 0.22 to 0.82 g/l. These values are close to the range recommended for white amur fish and are sufficient to ensure the ionic composition and osmotic balance of the water. In pond farms in China and Hungary, the same range of mineralization is characterized by high reproductive indicators. Biometric analyses showed that in farms with stable ecological conditions, the average body length of parent fish was 63.19–66.55 cm, body weight was 3.13–3.88 kg, and the Fulton obesity coefficient ranged from 1.14–1.35. These indicators confirm the convenience of the ecological environment and the correct organization of feeding technology. Differences in growth and fertility indicators are explained by the natural and climatic conditions of the farms, the feed base, and the characteristics of water exchange. Analysis of the relationship between ecological and biological parameters showed a positive correlation between water temperature and body weight, as well as dissolved oxygen and the

Fulton obesity coefficient. Conversely, an increase in the concentration of nitrogenous compounds was characterized by a downward trend in biological indicators. These results are consistent with the scientific conclusions presented by Miao et al. (2022), Li et al. (2023), and Zhang et al. (2024). Most of the hydrochemical indicators in the three fish farms where the study was conducted comply with international aquaculture standards, and it was established that a favorable ecological environment exists for the formation of a breeding parent herd of grass carp fish. Although seasonal changes were observed, they were kept under control through regular environmental monitoring and management measures applied on farms. These results confirm that the integrated management of environmental factors is an important condition for improving the biological quality and reproductive potential of breeding parent fish.

Conclusion: As a result of the conducted research, it was established that environmental factors play a decisive role in the formation of a breeding parental herd with high reproductive potential of white amur (Ctenopharyngodon idella Valenciennes, 1844) in pond fish farming conditions. The main hydrochemical indicators of the water in the fish farms of "Khoorrot Fish House" LLC, "Zafar Asad" FE, and "Imkon Baliq Fayz" LLC were evaluated in comparison with international aquaculture standards. Monitoring results showed that the water temperature, pH, dissolved oxygen, nitrite, and ammonia indicators in most cases remained within the recommended limits for the biological development and reproductive activity of grass carp fish. Although some seasonal changes were observed, they did not have a significant negative impact on the general physiological state of the parent fish. It was established that the stability of ecological factors contributed to the normal formation of morphometric indicators, body weight, and the Fulton obesity coefficient of the parent fish. This confirms that regular monitoring of water quality, regulation of the oxygen regime, and optimal maintenance of hydrochemical parameters are among the primary conditions for forming a high-quality pedigree parental herd. The results of the comparative analysis with international scientific studies showed that the ecological environment formed under the conditions of pond fish farming in the Tashkent region is favorable for the reproductive biology of grass carp fish. The results obtained are consistent with FAO recommendations and foreign research on modern aquaculture. The results of this study serve as a scientific basis for developing practical recommendations for improving the environmental monitoring system in pond fish farming, managing the aquatic environment on a scientific basis, and forming parental colonies of purebred white amur fish with high biological and reproductive qualities. At the same time, these results contribute to increasing productivity in the republic's fish farms, producing high-quality fish breeding material, and ensuring the sustainable development of the aquaculture system.

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