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COMPREHENSIVE ECOLOGICAL ASSESSMENT OF ENVIRONMENTAL FACTORS AND THEIR INFLUENCE ON 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 presents a comprehensive ecological assessment of the influence of environmental factors on broodstock formation of grass carp (*Ctenopharyngodon idella* Valenciennes, 1844) under pond aquaculture conditions in the Tashkent region. Water quality parameters, including temperature, pH, dissolved oxygen, mineralization, ammonia, nitrite, nitrate, and phosphate, together with hydrobiological characteristics, natural food resources, and reproductive performance of brood fish were evaluated. The obtained results were compared with recent studies conducted in China, Vietnam, Europe, and FAO recommendations. The findings demonstrate that a stable aquatic environment significantly improves the physiological condition, gonadal development, and reproductive efficiency of broodstock. The study provides a scientific basis for ecological monitoring and sustainable broodstock management in freshwater aquaculture.

Keywords*:* grass carp, broodstock, environmental factors, ecological assessment, hydrochemistry, hydrobiology, reproductive biology, pond aquaculture.

Introduction: Aquaculture is one of the fastest-growing sectors ensuring global food security today. According to the Food and Agriculture Organization of the United Nations (FAO), artificial cultivation systems accounted for more than half of the water bioresources consumed worldwide in 2024 (FAO, 2024). In the context of population growth, the reduction of fish stocks in natural water bodies, and climate change, the development of highly productive and environmentally sustainable aquaculture systems has become an urgent scientific and practical task. The grass carp (Ctenopharyngodon idella Valenciennes, 1844), one of the primary objects of freshwater fisheries, is widely cultivated in Asian, European, and American countries due to its rapid growth, plant-based nutrition, high meat quality, and reclamation value. The biological characteristics of this species allow for its effective application in polyculture systems. It also serves to maintain the ecological balance by reducing excess aquatic plants in the water bodies of garss carp fish.

Alongside the development of pond fish farming technologies, issues regarding the enhancement of the biological quality and reproductive potential of breeding parental flocks are becoming increasingly relevant. The quality of breeding fish is one of the key factors determining the viability, growth rate, disease resistance, and economic productivity of future generations. Therefore, the scientific management of environmental factors in the formation of parent fish is one of the priority areas of modern aquaculture. Environmental factors include water temperature, dissolved oxygen, pH, mineralization, ammonia, nitrite, nitrate, phosphate, water exchange, light

regime, hydrobiological state of the pond, natural food base, and anthropogenic load. These factors directly or indirectly affect the metabolism, immunological status, endocrine system, gonadal development, and reproductive functions of fish. Boyd and Tucker (2012) emphasized that water quality is a key factor for productivity in pond aquaculture, showing that a decrease in dissolved oxygen and an increase in ammonia and nitrite levels increase physiological stress in breeding fish. According to them, a deterioration in water quality leads to impaired energy metabolism, reduced nutrient absorption, and a decrease in reproductive function. Li et al. (2022) conducted research in the Yangtze River basin of China, where they found that in conditions with a water temperature of 22–26 °C, pH 7.2–8.3, and dissolved oxygen above 6 mg/L, the gonads of grass carp fish develop actively and their fertility rates are high. The authors note that environmental stability in the aquatic environment normalizes the secretion of reproductive hormones. Xu et al. (2021) studied the influence of environmental stress factors on the activity of antioxidant enzymes in the body of grass carp fish and found that under conditions of ammonia and oxygen deficiency, oxidative stress increases and degenerative changes occur in gonadal tissues. These results confirm that water quality is one of the key environmental factors determining reproductive health. Zhang et al. (2023) showed that changes in the composition of phytoplankton in pond ecosystems directly affect the trophic state of water and the natural food base. In ponds where diatoms (Bacillariophyta) and green algae (Chlorophyta) predominate, natural productivity is high, which improves the nutrition and physiological state of breeding fish. Miao et al. (2024) noted that in pond farms managed on the basis of environmental monitoring, the fertility rate of breeding fish, egg quality, and larva survival are higher compared to traditional management systems. According to them, regular hydrochemical and hydrobiological monitoring is an important factor in increasing reproductive efficiency. Research on European aquaculture also emphasizes the importance of environmental monitoring. Timmons and Ebeling (2022) showed that constant monitoring of water quality indicators is a necessary condition for maintaining fish health, increasing feeding efficiency, and forming productive breeding herds.

Despite the intensive development of pond fish farming in Uzbekistan, research dedicated to the comprehensive ecological assessment of environmental factors in the formation of breeding parent schools of grass carp fish is limited. Most of the works are limited to fish growth indicators or hydrochemical analyses, and the relationship between the aquatic environment, the natural food base, and reproductive biology is insufficiently covered. The aim of the study is to conduct a comprehensive assessment of the ecological state of environmental factors in pond fish farms in the Tashkent region, determine their impact on the biological quality and reproductive efficiency of the breeding parental herd of grass carp fish, and conduct a comparative analysis of the results obtained with modern foreign scientific research.

Materials and methods. The studies were conducted during 2023–2025 at the fish farms "Khoorrot Fish House" LLC, "Zafar Asad" FE, and "Imkon Baliq Fayz" LLC, located in the Kuyichirchik district of the Tashkent region. The object of the study was the parental groups of grass carp (Ctenopharyngodon idella Valenciennes, 1844) kept for breeding purposes. The studies were conducted based on regular observations and laboratory analyses during the growing season for three years. The main goal of the study was to conduct a comprehensive ecological assessment of environmental factors influencing the formation of breeding parent schools of grass carp fish in pond fish farming conditions and to determine their impact on reproductive indicators. For this purpose, ecological factors were analyzed by dividing them into abiotic, biotic, and anthropogenic groups. When assessing abiotic factors, water temperature (°C), pH, dissolved oxygen (mg/L), ammonia (NH_3), nitrite (NO_2^-), nitrate (NO_3^-), phosphate (PO_4^{3-}), mineralization, and water

transparency were regularly measured. Hydrochemical analyses were performed according to the APHA (2023) "Standard Methods for the Examination of Water and Wastewater" methodology. Water temperature was determined using a digital thermometer, pH using a portable pH meter, and dissolved oxygen using a DO meter. Nitrogen and phosphorus compounds were analyzed using the photometric method under laboratory conditions. The transparency of the water was assessed using a Sekki disk. In the study of biotic factors, the microbiological and parasitological status of ponds was assessed, including phytoplankton, zooplankton, benthos, aquatic macrophytes, and others. Phytoplankton samples were collected using the Utermohl method, taxonomically identified using a microscope, and grouped according to the main divisions (Bacillariophyta, Chlorophyta, Cyanobacteria). The zooplankton composition was evaluated across the groups Rotifera, Cladocera, and Copepoda. A Petersen grab was used to obtain benthos samples. Parasitological studies of the fish were conducted using macroscopic and microscopic methods. When assessing anthropogenic factors, the feeding technology used in farms, water exchange regime, fish load density of ponds, organic fertilization system, veterinary and preventive measures, and environmental monitoring system were analyzed. Feeding was carried out at a rate of 2% of fish biomass, and compound feeds from various producers were used in the farms. Water exchange, operation of reservoirs and preventive measures were carried out on the basis of technological regulations of farms. To evaluate the biological effectiveness of environmental factors, the body length, body weight, Fulton obesity coefficient, developmental stages of gonads, and reproductive status of the parent fish were studied. The obtained ecological and biological data were analyzed in interconnection, and a comprehensive assessment of the role of environmental factors in the formation of the breeding parental herd was conducted.

Table 1. Comprehensive assessment of environmental factors affecting the formation of breeding parental colonies of grass carp (Ctenopharyngodon idella Valenciennes, 1844) in pond fisheries. (Abiotic factor effect)

Environmental factors (Abiotic)	Key indicators	In the results of the study	Effect on offspring parental cluster
Water temperature	22–24 °C	Optimal range	An acceleration of metabolism and gonadal development was observed.
Oxygen dissolved	>6 mg/L	Moderately	Respiration, energy metabolism, and gametogenesis were observed to be in good condition.
pH	7,4–8,2	Due to being in a stable state	A favorable environment was created for enzymatic processes and fertilization.
Ammonia	<0,05 mg/L	Due to low content	No toxic stress was

			observed in the fish.
Nitrites and nitrates	Moderately	Due to being in a stable state	The hematological and physiological condition was normal.
Phosphate	Medium	Supported default performance	The development of phytoplankton was stimulated
Water transparency	Optimal	Due to good light penetration	The process of photosynthesis improved, and an improvement in the natural food base was observed.

Table 2. Comprehensive assessment of environmental factors affecting the formation of breeding parental colonies of grass carp (Ctenopharyngodon idella Valenciennes, 1844) in pond fisheries (Effect of the biotic factor)

Environmental factors (Biotic)	Key indicators	In the results of the study	Effect on offspring parental cluster
Phytoplankton	*Bacillariophyta*, *Chlorophyta* ustun	Dominant groups	Contributed to the formation of a natural food base
Zooplankton	Rotifera, Cladocera, Copepoda	In sufficient quantity	Assistance in creating a natural food source for young and breeding fish.
Benthos	Chironomidae, Oligochaeta, etc.	Somewhat observed	Served as an additional source of nutrition
Aquatic plants	Macrophytes	It was observed that it developed normally.	A full range of natural food sources has been created for grass carp fish, and an improvement in their habitat has been observed.
Microbiological status	Beneficial microflora predominant	It was in a stable state	Helped break down organic matter and maintain water

			quality
Parasites	Rare occurrence	The epizootic situation was observed to be stable (control measures were implemented).	Due to the timely implementation of necessary measures, no negative impact on reproductive function was observed.

Results and discussion. The results of studies conducted in three fish farms in the Tashkent region between 2023 and 2025 showed that the formation of the breeding parental herd of grass carp (Ctenopharyngodon idella Valenciennes, 1844) fish occurs under the complex influence of environmental factors. During the study, abiotic, biotic, and anthropogenic factors were regularly monitored, and their correlation with biological and reproductive indicators was evaluated.

Influence of abiotic factors: According to Table 1, the water temperature in all three farm ponds ranged from 22 to 24 °C, creating favorable ecological conditions for the parent fish of the grass carp. This temperature range activated metabolism and gonadal development. Optimal water temperature contributed to the normal course of enzymatic processes, effective absorption of nutrients, and stable functioning of the reproductive system. Maintaining dissolved oxygen levels above 6 mg/L supported aerobic respiration and energy metabolism in the fish. This condition had a positive effect on the normal course of gametogenesis and the preservation of the physiological state of the parent fish. The absence of oxygen deficiency indicates that it also created a favorable environment for embryonic development. The pH of the water ranged from 7.4 to 8.2, ensuring the stability of hydrobiological processes. In this environment, the activity of enzymes and the development of microorganisms that form the basis of the food chain occurred normally. As a result, favorable conditions have emerged for the formation of a natural food base. The fact that the concentrations of ammonia, nitrite, and nitrate did not exceed the recommended limits prevented toxic effects. This ensured a reduction in physiological stress in fish and the normal functioning of the circulatory and respiratory systems. Maintaining sufficient water transparency increased the intensity of photosynthesis and had a positive impact on the development of phytoplankton. These results are consistent with the optimal hydrochemical parameters recorded by Li et al. (2022) and Boyd and Tucker (2012). In their studies, conditions with a water temperature of 22–26 °C, pH 7.0–8.5, and dissolved oxygen above 6 mg/L were also assessed as the most favorable environment for the reproductive biology of grass carp fish.

Influence of biotic factors: The results of Table 2 show that the biological components of the pond ecosystem play an important role in the formation of the breeding parental group. In the composition of phytoplankton, the predominance of the Bacillariophyta and Chlorophyta divisions was observed. These groups contributed to the formation of primary productivity in the ponds and formed the basis of the natural food base. The stable development of phytoplankton also had a positive impact on the increase in zooplankton biomass. Rotifera, Cladocera, and Copepoda groups are found in sufficient quantities within the zooplankton. These organisms played an important role in the supplementary nutrition of young fish and breeding parent fish. Chironomidae larvae and representatives of Oligochaeta were identified in the benthos, which served as an additional food source. The normal development of aquatic macrophytes not only expanded the natural food base for grass carp fish but also contributed to maintaining the ecological stability of the aquatic environment. The stability of the microbiological state accelerated the decomposition of organic

matter and contributed to the preservation of water quality. The low frequency of parasites and the timely implementation of preventive measures prevented negative impacts on reproductive processes. These results confirm the data obtained by Zhang et al. (2023) regarding the relationship between phytoplankton composition and the natural food base. Also, De Silva and Anderson (2019) emphasized the important role of zooplankton in the nutrition of breeding fish.

Influence of anthropogenic factors: According to the data in Table 3, scientifically grounded pond management had a significant impact on the biological quality of the breeding parental herd. As a result of feeding the fish with balanced compound feed, the stoutness coefficient and general physiological condition improved. The body's reserve substances supported the development of gonads during the reproductive period. Regular water exchange limited the accumulation of metabolites, maintained a stable oxygen regime, and contributed to the normalization of hydrochemical parameters. The operation of ponds with normal density reduced competition between fish and led to a reduction in stress factors. The scientific basis of organic fertilization stimulated the development of phytoplankton and enriched the natural food base. Regular veterinary and preventive measures contributed to maintaining a stable epizootic situation. The control of diseases and parasites was an important factor in maintaining the reproductive health of the parent fish. Ongoing environmental monitoring has made it possible to identify changes in water quality early and implement management measures in a timely manner. As a result, the reproductive indicators of the breeding parents in all three farms were stable. These results align with the environmental management principles recommended by Miao et al. (2024) and FAO (2024).

Comprehensive ecological assessment It has been established that abiotic, biotic, and anthropogenic factors act not separately, but as interconnected ecological systems. For example, optimal water temperature and dissolved oxygen stimulated the development of phytoplankton; phytoplankton supported zooplankton biomass; and zooplankton and macrophytes enriched the natural food base. At the same time, regular water exchange, balanced nutrition, and veterinary preventive measures have ensured the stability of this ecological system. The results of the study indicate that to achieve high biological quality and reproductive efficiency in the breeding parental herd of grass carp fish, it is necessary to evaluate environmental factors as a unified management system rather than separately. This approach, applied in the conditions of the Tashkent region, serves as a scientific and practical basis for improving environmental monitoring, improving the quality of breeding fish, and sustainable development of pond fish farming efficiency. These conclusions align with international research and allow for the development of practical recommendations for regional conditions.

Table 3. Comprehensive assessment of environmental factors influencing the formation of breeding parental populations of grass carp (Ctenopharyngodon idella Valenciennes, 1844) in pond fisheries (Anthropogenic factor impact)

Environmental factors (Anthropogenic)	Key indicators	In the results of the study	Effect on offspring parental cluster
Feeding	Balanced compound feeds were applied	Conducted according to plan	Obesity rate and reproductive potential increased
Water exchange	Regular	Stable hydrological regime	Decreased accumulation of

			metabolites
Pool density	According to the norm	No overload detected	Stress levels decreased in fish
Organic fertilization	Under supervision	Primary productivity increased	An enrichment of the natural food base for grass carp fish was observed.
Veterinary and preventive measures	Regularly	Diseases were prevented	The reproductive health of breeding fish was maintained in good condition.
Environmental monitoring	Continuously monitored	Hydrochemical and biological monitoring was conducted.	Reproductive indicators remained stable.

Conclusion: Based on the results of research conducted during 2023–2025 at the fish farms of "Khoorrot Fish House" LLC, "ZafarAsad" FX, and "Imkon Baliq Fayz" LLC in the Tashkent region, the following conclusions were drawn: It was established that the formation of the breeding parental herd of grass carp (Ctenopharyngodon idella Valenciennes, 1844) fish occurs under the complex influence of environmental factors. Abiotic, biotic, and anthropogenic factors interact with each other and influence the physiological state of fish, the development of gonads, and reproductive indicators. Among abiotic factors, water temperature (22–24 °C), pH (7.4–8.2), dissolved oxygen (>6 mg/L), and the maintenance of ammonia and nitrite at normal levels ensured the stable progression of metabolism, gametogenesis, and puberty in the breeding parent fish. It was determined that these indicators comply with the internationally recommended standards. Among the biotic factors, the predominance of algae belonging to the Bacillariophyta and Chlorophyta groups, the sufficient development of zooplankton, and the normal state of macrophytes formed a natural food base in the ponds, supporting the feeding and reproductive potential of the parent fish. Anthropogenic factors, including balanced feeding, regular water exchange, operation of ponds with a standard load, timely implementation of veterinary and preventive measures, and the establishment of an environmental monitoring system, played an important role in improving the biological quality and reproductive stability of breeding parent fish. When comparing the research results with data from Li et al. (2022), Xu et al. (2021), Zhang et al. (2023), Miao et al. (2024), Boyd and Tucker (2012), and FAO (2024), it was established that the ecological indicators observed under the conditions of pond fisheries in the Tashkent region comply with international scientific recommendations. The scientific novelty of the study is that the ecological factors influencing the formation of the breeding parental herd of grass carp fish were evaluated not as separate, but as a single ecological system. Their hydrochemical, hydrobiological, and anthropogenic components were analyzed in interconnection and substantiated as the primary factors determining reproductive efficiency. The results obtained expand the possibilities of improving the environmental monitoring system in pond fisheries, maintaining water quality at a normal level, supporting the natural food base, and forming breeding parental flocks of high-productivity grass carp fish through the application of scientifically grounded management measures.

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