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Evaluation of the primary production of the summer fishpond I, within the Malina fish farm, Galati County

Adina POPESCU[1]*, Daniela Cristina IBANESCU[1], Ion VASILEAN[2]

[1]*Food Science Faculty, "Dunarea de Jos" University of Galati, Romania*
[2]*Department of Applied Sciences, Cross–Border Faculty," Dunărea de Jos" University of Galati, Romania*
*Adina.popescu@ugal.ro

Abstract

This work aims to assess the productivity of the summer I juvenile rearing pond and the water quality at the Malina Fish Farm, Galati County. Various physico-chemical and biological parameters are related, and overall water quality depends on deviations from the allowed range. During the monitoring of the physico-chemical parameters, the water quality in the summer I juvenile rearing pond, within the Mălina fish farm, was within the allowed and recommended limits for waters used in fish farming, the water falling into the II quality category. In nutrient-rich waters - generally rich in phosphorus and nitrogen - chlorophyll levels tend to be high. These nutrients encourage algal blooms, which can deplete dissolved oxygen as the algae die and decompose - a major factor in fish mortality. The level of quantitative development of phytoplankton as a direct result of ecological conditions and interactions, and primarily of trophic ones, through the amount of chlorophyll can be considered a measurable and objective indicator of these characteristics. The quantitative analysis of the photosynthetic pigment showed that the photosynthetic potential is higher in the vegetative season (the concentration of chlorophyll a plus the concentration of pheophytin fell within the range of 22.374-36.681 mg/l) and according to the normative the pond is eutrophic. The eutrophic basin is characterized by high trophicity, a lower water transparency (well-developed plankton) and good biological production. The gross production being 4.08 mg/l.

Keywords: phytoplankton, productivity, parameters, chlorophyll, eutrophic

Introduction

Algae and phytoplankton are terms that are often used interchangeably; however, they do not have the same meaning. Algae comprise a diverse group of photosynthetic aquatic organisms, including both microscopic forms and larger macroalgae. Phytoplankton represents the microscopic fraction of algae and consists of unicellular or colonial photosynthetic organisms suspended within the water column. Due to their high sensitivity to environmental changes, particularly fluctuations in nutrient concentrations, phytoplankton communities are considered valuable biological indicators of aquatic ecosystem health. The determination of chlorophyll *a*, the primary photosynthetic pigment

found in phytoplankton, provides essential information regarding biological productivity and water quality (Wetzel, 2001).

Aquatic ecosystems enriched with nutrients, especially nitrogen and phosphorus compounds, generally exhibit increased phytoplankton biomass, reflected by elevated chlorophyll *a* concentrations. Excessive nutrient inputs stimulate algal blooms, which may disrupt the ecological balance of aquatic environments. As algal cells die and decompose, microbial degradation consumes large amounts of dissolved oxygen, frequently leading to hypoxic or even anoxic conditions. Such oxygen depletion can result in fish mortality, habitat degradation, and a decline in overall ecosystem health (Boyd & Tucker, 2012).

In most cases, elevated nutrient concentrations in aquatic ecosystems are associated with anthropogenic activities. Major sources of nitrogen and phosphorus pollution include wastewater treatment plant discharges, septic system leakage, and agricultural runoff from fertilized fields. These nutrient inputs accelerate eutrophication processes and alter the composition and structure of aquatic biological communities (Carpenter et al., 1998).

For this reason, chlorophyll *a* concentration is widely recognized as an indirect indicator of nutrient enrichment and the trophic status of aquatic ecosystems. In aquaculture, chlorophyll *a* is also considered an important indicator of pond productivity because it reflects the abundance of phytoplankton, which forms the foundation of the aquatic food web. Regular monitoring of chlorophyll *a* enables fish farmers to evaluate the natural productivity of culture ponds, optimize fertilization practices, and improve overall production efficiency (Boyd & Tucker, 2012).

Chlorophyll is the essential photosynthetic pigment responsible for capturing solar energy and converting it into chemical energy through the process of photosynthesis. During this process, photosynthetic organisms utilize carbon dioxide and water to synthesize organic matter while simultaneously releasing oxygen into the aquatic environment. Consequently, phytoplankton plays a fundamental role not only in primary production but also in oxygenating the water and sustaining aquatic food webs (Wetzel, 2001).

Water quality is determined by the complex interaction of physical, chemical, and biological parameters, all of which are closely interconnected. Variations in one parameter often influence the others, affecting the overall ecological balance of the aquatic ecosystem. Maintaining these parameters within their optimal ranges is essential for preserving biodiversity, supporting healthy fish populations, and ensuring sustainable aquaculture production.

Materials and methods

Study of area

The Mălina fish farm is in Galați county, near the towns of Șendreni and Movileni, approximately 6–7 km west of the city of Galați. The fish farm is in a low-lying area, characteristic of the lower sector of the Covurlui Plain, under the direct influence of the Danube–Siret–Prut hydrographic system. The surface area of the water is approximately 140 ha, part of which is intended for recreational fishing and part for fish farming and exploitation activities.

The nursery within the Mălina fish farm has an area of 40 ha. The nursery comprises five ponds supplied with and drained of water through a pumping system connected to the Siret River. Among these are a 7-hectare pond designated for rearing one-summer juveniles (the

pond included in the monitoring program) and a 30-hectare pond intended for the rearing of two-summer juveniles.
Water and biological samples for analytical purposes were collected in the field from three sampling stations selected to characterize the spatial variability of environmental conditions within the pond designated for rearing first-summer juveniles.
Water samples were taken seasonally (summer, autumn in 2024 and spring in 2025) from three stations (denoted S1, S2 and S3) established in the fry rearing pond within the Malina farm.



Figura 2. Cyprinid fry rearing pond subject to monitoring

Determination of physicochemical parameters.
Nutrients were determined spectrophotometrically using reagent kits and their reading was done on the Spectro quant NOVA 60 Spectrophotometer, pH and conductivity were determined using the WTW inolab electrode device from the EEBA research laboratory at the Faculty of Food Science and Engineering and the determination of dissolved oxygen in water was done by the Winkler method.

Determination of phytoplankton primary production by determining chlorophyll pigments.

The determination of chlorophyll a is carried out by the method of extracting chlorophyll pigments, this method consists of extracting them in an appropriate solvent and determining the concentration in the respective solvent based on determining the optical density of the chlorophyll extract.

Determination of phytoplankton primary production by the Gaarder-Gran method.

The method is based on the determination of dissolved oxygen in water after a 24-hour exposure of certain volumes of water in special bottles. Some bottles are transparent (white glass = A), and the others are opaque (black glass = N). In the transparent bottles, the

respiration of phytoplankton organisms takes place as well as the photosynthesis carried out by them during the daylight period. In the opaque bottles, only respiration takes place. By the difference of the values obtained in the two variants and by comparing them with the initial concentration of dissolved oxygen, determined in the control sample (glass fixed on the ground = M), the values of gross primary production (GPP), net primary production (NPP) and oxygen consumption through respiration (CR) are obtained during the exposure interval (GPP=NPP+CR) (Florea Luiza, 2007).

Results and discussion

Determining water quality using physicochemical parameters

Water is the main environmental factor that conditions the existence and development of aquatic organisms, being at the same time the essential element in the development of aquaculture and fish farming activities. Its quality directly influences the physiological processes of fish, the development of biological communities, the natural productivity of ponds and the efficiency of growth technologies. For this reason, monitoring the physicochemical parameters of water is an indispensable step in assessing the ecological status of aquatic ecosystems and in the management of fish farms (Boyd & Tucker, 2012).

In aquaculture, maintaining physicochemical parameters within optimal limits is one of the fundamental conditions for obtaining high fish production. Deviations from normal values can cause physiological stress, reduced food consumption, slowed growth, decreased immunity and the occurrence of diseases or even mass mortalities (Wedemeyer, 1996). For this reason, permanent water quality monitoring is an essential component of modern fish farm management.

Table 1. Values of physico-chemical parameters for waters used in fish farming

Parameter	Class II Ord.161/2006	Minimum*	Optimum*	Maximum*	Recommendations according to Sclotfeldt**
pH (upH)	6,5-8,5	6,5-6,9	7-7,9	8-8,2	<5,5 - >8 upH
N-NH_4 (mg/l)	0,8	0,05-05	0,5-1	2	for pH<8,5 up to 1 mg/l
N-NO_3 (mg/l)	3	1	2,5-4	4	up to 50 mg/l
N-NO_2 (mg/l)	0,03	0	0-0,005	0,2	up to 0,2 mg/l
O_2 (mg/l)	7	4	7-12	14	above 4 mg/l
CBO5 (mg/l)	5	5	6	7	up to 6 mg/l
CCO -Cr (mg/l)	25	5	35-50	55-60	up to 20 mg/l

*Recommendations for specialized literature - EAFP Bulletin 1995

**cited by Munteanu G., 2003

In fish farms, periodic monitoring of physicochemical parameters allows for the rapid identification of environmental changes and the adoption of management measures to prevent water quality degradation. Correlating these parameters with biological indicators, such as phytoplankton biomass and natural productivity, provides a complex picture of the functioning of the ecosystem and the conditions for the development of aquatic organisms.

Tabel 2. Physico-chemical parameters of water in the monitored basin, Mălina farm

Seasons	pH (u pH)	T (°C)	Cond. (mS/cm)	O_2 (mg/l)	NH4-N (mg/l)	NO2-N (mg/l)	PO4-P (mg/l)	BOD_5 (mg/l)
summer	8.34+0.11	26.27+0.40	2.09+0.03	7.15+0.10	0.08+0.02	0.04+0.01	0.41+0.07	5.27+0.40
autumn	8.00+0.03	12.23+0.12	1.49+0.03	7.40+0.25	0.06+0.04	0.06+0.02	0.37+0.06	3.43+0.59
spring	7.40+0.21	17.37+0.15	2.27+0.02	7.11+0.11	0.07+0.03	0.03+0.01	0.58+0.10	5.04+0.19

The analysis of these indicators allows the assessment of water quality and the degree of favorability for the development of aquatic organisms and the conduct of aquaculture activities.

Tabel 3. Quality class by seasons

Quality class	pH (u pH)	T (°C)	O_2 (mg/l)	NH4-N (mg/l)	NO2-N (mg/l)	PO4-P (mg/l)	BOD_5 (mg/l)
summer	6.5 - 8.5	Nu se normează	II	I	III	III	II
autumn			II	I	III	II	II
spring			II	I	III	III	II

The seasonal analysis of the physical-chemical parameters highlights that the water of the fishpond showed relatively good stability throughout the monitoring period, all values falling within limits favorable to the development of aquatic organisms. The parameters with the best quality status were pH and ammonia nitrogen, the latter constantly falling within quality class I, which indicates a low degree of pollution with fresh nitrogen compounds.

Dissolved oxygen and BOD_5 characterized a quality class II water, demonstrating the existence of a balance between the processes of biological production and those of decomposition of organic matter. In contrast, nitrites and phosphates indicated a moderate ecological status (classes II–III), with slightly increased values in certain seasons, suggesting seasonal nutrient inputs and more intense biological productivity.

Overall, the results show that the analyzed water is suitable for the growth of Asian cyprinids, as the physico-chemical parameters are within the optimal ranges for their development. At the same time, monitoring phosphate and nitrite concentrations remains important for preventing eutrophication processes and maintaining a favorable ecological state of fishponds.

Assessment of Pond Primary Productivity Based on Chlorophyll a Concentration

Primary productivity is a key ecological process that determines the natural productivity of aquatic ecosystems. In fishponds, it is mainly driven by phytoplankton, which converts solar energy into organic matter through photosynthesis, forming the basis of the aquatic food web and supporting higher trophic levels (Wetzel, 2001; Odum, 1971).

Chlorophyll *a*, the principal photosynthetic pigment of phytoplankton, is widely recognized as the most reliable indicator of phytoplankton biomass and an indirect indicator of primary productivity. Its concentration reflects the abundance of photosynthetically active algae and provides valuable information on the trophic status, ecological condition, and productive potential of aquatic ecosystems (Wetzel, 2001; Reynolds, 2006; APHA, 2017).

In aquaculture ponds, appropriate chlorophyll *a* concentrations indicate the presence of a well-developed phytoplankton community, which supports zooplankton production and

provides natural food for filter-feeding fish, particularly silver carp (*Hypophthalmichthys molitrix*). Consequently, phytoplankton biomass plays a fundamental role in maintaining the natural productivity of fishponds and improving aquaculture efficiency (Boyd & Tucker, 2012). However, excessively high chlorophyll *a* concentrations may indicate nutrient enrichment and eutrophication, resulting in algal blooms, increased community respiration, and pronounced fluctuations in dissolved oxygen concentrations that may adversely affect fish health and pond productivity (Boyd & Tucker, 2012; Wetzel, 2001).

Therefore, the determination of chlorophyll *a* concentration represents an effective tool for evaluating the biological productivity of fishponds and complements the assessment of primary production by providing reliable information on phytoplankton biomass, trophic status, and ecosystem functioning (Reynolds, 2006; APHA, 2017).

Tabel 4. The amounts of *chlorophyll a* and phaeophytin by seasons

Seasons	Stations	Cca+f* (µg/l)	Cca** (µg/l)	Cf*** (µg/l)
summer	S1	32.099	24.434	12.683
	S2	22.407	15.568	11.315
	S3	36.681	27.932	14.477
autumn	S1	17.374	13.619	6.2127
	S2	18.681	13.886	7.9345
	S3	25.637	19.921	9.4585
spring	S1	7.582	3.899	6.095
	S2	6.308	4.540	2.925
	S3	10.791	7.103	6.102

The concentration of chlorophyll a exhibited pronounced seasonal variations, with mean values of 22.644 µg/l during summer, 15.808 µg/L in autumn, and 5.180 µg/l in spring. These seasonal fluctuations reflect the dynamics of phytoplankton biomass and primary productivity within the fishpond and are primarily influenced by climatic conditions, nutrient availability, and the physicochemical characteristics of the water.

The highest *chlorophyll a* concentration was recorded during the summer season (27.932µg/l-S3), indicating intensive phytoplankton development and high primary productivity. During this period, elevated water temperature (26.27°C), extended daylight duration, and increased solar radiation created optimal conditions for photosynthesis and phytoplankton growth. Moreover, the availability of nutrients, particularly phosphorus and nitrogen compounds, promoted phytoplankton biomass accumulation, as reflected by the elevated *chlorophyll a* concentration. Such conditions are characteristic of biologically productive fishponds, where phytoplankton constitutes the foundation of the aquatic food web and serves as the primary natural food source for filter-feeding fish, particularly silver carp (Boyd & Tucker, 2012).

During autumn, the mean *chlorophyll a* concentration decreased to 19.921µg/L – S3, indicating a reduction in phytoplankton biomass compared with the summer period. This decline can be attributed mainly to lower water temperatures, shorter photoperiods, and reduced photosynthetic activity. In addition, part of the phytoplankton biomass is consumed

by zooplankton or settles to the bottom as organic matter, contributing to the observed decrease in *chlorophyll a* concentration. Nevertheless, the recorded value indicates that the pond maintained a moderate to high level of natural productivity even after the peak growing season.

The lowest *chlorophyll a* concentration was observed in spring (7.103µg/L – S3). This value is typical of the early growing season, when phytoplankton development is still limited by relatively low water temperatures and lower solar irradiance. During this period, phytoplankton communities are in the initial stages of development, resulting in comparatively low algal biomass. However, this represents a normal phase in the seasonal succession of pond ecosystems, with phytoplankton biomass expected to increase progressively as temperature rises and nutrient availability improves.

Comparison of the seasonal data revealed an approximately 4.4-fold increase *in chlorophyll a* concentration from spring to summer, followed by an approximately 30% decline during autumn. This seasonal pattern is characteristic of temperate freshwater ecosystems and reflects the strong influence of climatic conditions on phytoplankton growth and primary productivity.

The chlorophyll results were consistent with the physicochemical characteristics recorded throughout the study. During summer, the highest water temperatures and favorable nutrient concentrations stimulated phytoplankton development and enhanced photosynthetic activity. Furthermore, dissolved oxygen concentrations remained above 7 mg/L throughout all monitoring periods, indicating that the elevated primary productivity did not result in oxygen depletion and that the pond ecosystem remained ecologically balanced, providing suitable conditions for fish growth and development.

From a trophic perspective, the mean chlorophyll a concentration of 5.180 µg/L recorded in spring indicates an ecosystem located at the transition between mesotrophic and eutrophic conditions, characterized by moderate biological productivity. The autumn concentration of 15.808 µg/L is typical of a eutrophic ecosystem, reflecting high primary productivity and a well-developed phytoplankton community. The highest value, 22.644 µg/L, recorded during summer confirms the eutrophic status of the pond, characterized by high natural productivity and favorable environmental conditions for the cultivation of Asian carp species. Although this *chlorophyll a* concentrations indicate an abundant natural food base, they also emphasize the importance of continuous water quality monitoring to prevent excessive eutrophication and maintain ecological stability.

Determination of Phytoplankton Primary Production Using the Gaarder–Gran Method

Primary production is one of the most important indicators of aquatic ecosystem functioning, as it reflects the capacity of autotrophic organisms, primarily phytoplankton, to convert solar energy into organic matter through photosynthesis. In fishpond ecosystems, primary production forms the basis of natural productivity, directly influencing the development of phytoplankton and zooplankton communities and, consequently, the growth performance of cultured fish species (Wetzel, 2001; Boyd & Tucker, 2012).

In the present study, phytoplankton primary production was determined using the Gaarder–Gran method, which is based on measuring changes in dissolved oxygen concentrations in transparent and dark incubation bottles exposed under natural environmental conditions (Gaarder & Gran, 1927). During the summer season, the following values were obtained: gross primary production (GPP) – 4.08 mg O_2/l24 h, net primary production (NPP) – 0.65 mg O_2/l/24 h, and community respiration (CR) – 3.43 mg O_2/l/24 h.

The gross primary production value of 4.08 mg O_2/l/24 h indicates intense photosynthetic activity of the phytoplankton community and demonstrates that the fishpond possesses a high capacity for organic matter production. This value is typical of highly productive aquaculture ponds and reflects favorable environmental conditions for the development of microscopic algae. According to Boyd and Tucker (2012), gross primary production values ranging between 3 and 6 mg O_2/l/day are characteristic of well-managed fishponds with high natural productivity.

The obtained result is further supported by the relatively high concentration of chlorophyll *a* (22.644 µg/l) measured during the same period. Chlorophyll *a* is the principal photosynthetic pigment in phytoplankton and is widely recognized as a reliable indicator of algal biomass. Numerous limnological studies have demonstrated a strong positive relationship between chlorophyll *a* concentration and primary production, since chlorophyll content reflects the amount of photosynthetically active phytoplankton biomass (Wetzel, 2001; Reynolds, 2006).

The physicochemical conditions recorded during the summer season strongly favored this photosynthetic activity. The water temperature (26.27 ± 0.40°C) fell within the optimal range for phytoplankton growth and photosynthesis. Moreover, the pH value (8.34 ± 0.11) indicated slightly alkaline water, a characteristic feature of ecosystems experiencing intensive photosynthetic activity, where carbon dioxide uptake shifts the carbonate equilibrium toward higher pH values (Wetzel, 2001). At the same time, the concentrations of reactive phosphorus (0.41 ± 0.07 mg/l) and ammonium nitrogen (0.08 ± 0.02 mg/l) provided sufficient nutrients to support phytoplankton development without indicating excessive nutrient pollution. Phosphorus and nitrogen are considered the principal limiting nutrients controlling phytoplankton productivity in freshwater ecosystems (Wetzel, 2001; Boyd & Tucker, 2012).

The net primary production, amounting to 0.65 mg O_2/l/24 h, represents the amount of oxygen remaining in the ecosystem after the respiratory demands of the biological community have been met. Although considerably lower than gross primary production, the positive value indicates that photosynthetic oxygen production exceeded respiratory oxygen consumption, resulting in a positive net production of organic matter. From an ecological perspective, this demonstrates that the ecosystem functioned predominantly as an autotrophic system capable of supporting higher trophic levels (Odum, 1971).

The community respiration rate (CR = 3.43 mg O_2/l/24 h) accounted for approximately 84% of gross primary production, highlighting the high metabolic activity of the ecosystem. Such values are typical of productive fishponds where phytoplankton, zooplankton, bacteria, and other aquatic organisms consume substantial amounts of oxygen through respiration and organic matter decomposition. Elevated summer temperatures accelerate enzymatic activity and metabolic processes in aquatic organisms, thereby increasing respiratory oxygen demand (Odum, 1971; Wetzel, 2001).

The results obtained using the Gaarder–Gran method are further supported by the other environmental indicators measured during the study. The summer season was characterized by the highest chlorophyll *a* concentration, confirming the presence of abundant phytoplankton biomass, as well as the highest biochemical oxygen demand (BOD_5 = 5.27 ± 0.40 mg/l**)**, indicating enhanced biological and microbial activity in the pond. Despite this intense metabolic activity, the dissolved oxygen concentration remained at 7.11 ± 0.11 mg/l, well above the minimum threshold required for the optimal growth of Asian carp species.

This finding demonstrates that oxygen production through photosynthesis, together with natural atmospheric reaeration, effectively compensated for biological oxygen consumption, thereby maintaining ecosystem stability (Boyd & Tucker, 2012).

From an ecological standpoint, the ratio between net primary production and gross primary production (NPP/GPP ≈ 0.16) indicates that approximately 16% of the oxygen produced during photosynthesis remained available as net production, whereas about 84% was utilized to support the respiratory metabolism of the biological community. Such a ratio is characteristic of highly productive aquatic ecosystems with abundant phytoplankton biomass and intense biological activity (Odum, 1971; Wetzel, 2001).

Conclusions

The monitoring of the physicochemical parameters of the water, the determination of chlorophyll *a* concentration, and the assessment of phytoplankton primary production using the Gaarder–Gran method revealed a close functional relationship between water quality and the biological productivity of the fishpond ecosystem.

The physicochemical parameters indicated favorable environmental conditions for phytoplankton development and the maintenance of metabolic processes characteristic of productive aquaculture ecosystems. Throughout the study period, water pH remained within the slightly alkaline range (7.40–8.34), while dissolved oxygen concentrations consistently exceeded 7 mg/L, demonstrating adequate oxygen availability for aquatic organisms and favorable conditions for biological activity. Furthermore, moderate concentrations of phosphates and nitrogen compounds provided sufficient nutrient availability to support primary producers without indicating excessive organic pollution or severe eutrophication.

The seasonal dynamics of chlorophyll *a* accurately reflected changes in phytoplankton biomass. The highest concentration, recorded during the summer season (22.644 µg/L), coincided with the most favorable environmental conditions, particularly a water temperature of 26.27°C, which stimulated phytoplankton growth and photosynthetic activity. In contrast, chlorophyll *a* concentrations decreased during autumn (15.808 µg/L) and reached their lowest value in spring (5.180 µg/L), highlighting the influence of seasonal variations in temperature and solar radiation on phytoplankton development. Similar seasonal patterns have been widely reported in freshwater ecosystems and confirm that temperature is one of the principal environmental factors regulating primary productivity (Wetzel, 2001; Reynolds, 2006).

The results obtained using the Gaarder–Gran method further support these observations. The gross primary production (4.08 mg O_2/L/24 h) indicates a relatively high photosynthetic capacity and an efficient conversion of solar energy into organic matter. In contrast, the net primary production (0.65 mg O_2/L/24 h) demonstrates that only a limited proportion of the oxygen produced during photosynthesis remained available after satisfying the respiratory requirements of the aquatic community. The community respiration rate (3.43 mg O_2/L/24 h) accounted for most of the gross oxygen production, indicating intense metabolic activity within the ecosystem. Such a metabolic balance is characteristic of highly productive fishponds, where elevated phytoplankton biomass and active microbial communities result in substantial oxygen consumption through respiration and organic matter decomposition (Odum, 1971; Wetzel, 2001).

The strong relationship observed between chlorophyll *a* concentration, primary production, and the physicochemical characteristic of the water demonstrates that temperature and nutrient availability are the primary drivers of biological productivity in the investigated

pond. The increase in water temperature during summer enhanced photosynthetic activity, leading to higher chlorophyll *a* concentration and increased gross primary production. Simultaneously, elevated values of biochemical oxygen demand (BOD_5) and community respiration reflected intensified biological processes associated with increased phytoplankton biomass and microbial activity.

An important finding of the present study is that, despite the high metabolic activity recorded during the summer season, dissolved oxygen concentrations remained above the minimum threshold required for the optimal growth and survival of Asian carp species. This result indicates that oxygen production through photosynthesis, combined with atmospheric reaeration, successfully compensated for respiratory oxygen consumption, thereby maintaining a stable ecological balance within the pond ecosystem.

From a trophic perspective, the *chlorophyll a* concentrations, primary production values, and nutrient availability collectively indicate that the investigated pond can be classified as a eutrophic ecosystem with high biological productivity. Such environmental conditions provide a rich natural food base for filter-feeding fish, particularly silver carp, which directly utilizes phytoplankton as its principal food source, while also indirectly supporting the development of zooplankton consumed by bighead carp. Consequently, the natural productivity of the pond contributes significantly to improving the efficiency and sustainability of polyculture systems based on Asian carp species.

Overall, the present study demonstrates that the integrated evaluation of physicochemical parameters, *chlorophyll a* concentration, and phytoplankton primary production provides a comprehensive assessment of both the ecological status and the productive potential of aquaculture ponds. The combined use of these indicators allows a more accurate characterization of ecosystem functioning and represents a valuable scientific approach for optimizing pond management practices, maintaining water quality, and enhancing sustainable fish production.

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