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The Natural Food Base of Nursery Ponds and the Diet of the Common Carp Fry in Iraq

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ABSTRACT

This study examined the indigenous food sources found in nursery ponds and their influence on the diet of young carp (*Cyprinus carpio*). The study was conducted across a single growing season and specifically investigated the quantity and makeup of phytoplankton and zooplankton in ponds that were previously fertilized. Additionally, the study investigated the way carp fry utilized these organisms. During the study period, notable fluctuations were recorded in the density and biomass of phytoplankton, specifically *Bacillariophyceae*, *Chlorophyceae*, *Cyanophyceae*, and *Euglenophyceae*. The population dynamics of zooplankton, primarily consisting of Rotatoria, Copepoda, and Cladocera, exhibited significant variations. The results indicated that both phytoplankton and zooplankton played a crucial role in the early phases of carp fry growth. The fry mostly fed on rotifers, cladocerans, and various algae species. The nutritional composition and availability of plankton in the ponds were significantly affected by water temperature and fertilization techniques, which played a role in the overall productivity of the ponds. The study asserts that ensuring a well-balanced and diverse plankton population through suitable fertilization is crucial for maximizing the growth and survival of carp fry in nursery ponds. This study offers significant findings regarding inherent feeding behaviors of young carp and highlights the significance of effectively managing natural food sources to improve produce in aquaculture.

INTRODUCTION

The common carp (*Cyprinus carpio*) is the most widespread species of cyprinid fish, accounting for a significant part of fish production in inland freshwater reservoirs, especially in ponds. It has been introduced into inland waters such as lakes, reservoirs and streams in various regions of the world **(Vilizzi *et al.*, 2015)**, and is the third most important freshwater- farmed species in the world; it has also become the most important in Iraq. **Gyalog *et al.* (2017)** pointed out that carp farming played a key role in the Blue Revolution at the global level. The quality and quantity of natural food available in ponds, along with additional feeds, affect the growth of fish in the aquaculture process.

The consumption of natural food and fish growth is closely related to the presence of plankton and food consumption in ponds **(Rahman *et al*., 2008)**.

Since ancient times, the use of organic substances as fertilizers has been used to increase the productivity of earthen fish ponds **(Terziyski *et al*., 2007)**. Optimal fish growth requires the addition of the necessary farm resources, which must contain balanced nutrients through fertilization and additional feeding **(Sipauba-Tavares *et al.*, 2013)**.

Supplementary feeding is essential for intensive, semi-intensive, and extensive aquaculture systems. In carp farming, the use of supplementary feeds is crucial for the successful growth of juvenile fish, known as fingerlings **(Nazish & Mateen, 2011)**. To promote the growth of phyto- and zooplankton, organic manure and other fertilizers can be applied **(Sevilleja *et al*., 2001)**. The most common approach is still a combination of organic and mineral fertilizers **(Grozev *et al*., 2001; Rahman, 2015)**. However, the growing value of organic food production has also led to the resumption of research on the use of mineral fertilizers only in fish ponds **(Hossain *et al.*, 2015)**.

Phytoplankton and zooplankton play an important role in the biological productivity of aquatic ecosystems. Phytoplankton is the first trophic level and is the main source of nutrition for zooplankton organisms, as well as for fish fry. The simplified classical food web in the aquatic ecosystem includes phytoplankton as the main food for zooplankton, as well as zooplankton as food for planktophorous fish, which, in turn, are food for predatory fish. In the same way, the nutritional value of phytoplankton is transferred to zooplankton, then to fish, and finally to humans (by eating fish). Although zooplankton is an important component of the diet of carp larvae and fry, feeding behavior gradually changes as they grow, reflecting their specific feeding habits **(Chakrabarti & Sharma, 1998; Wojnarowicz & Wojnarowicz, 2010)**. At the initial stages of larval development, fish prefer phytoplankton, but only for a relatively short time **(Al-Hilali *et al.*, 2024)**. After that, the morphological features of the larvae develop and their ability to find more diverse food resources increases, which can help them switch from a diet of small and to large benthic zooplankton and large plants. However, phytoplankton residues are preserved in the aquatic food web in the form of phytonutrients, which contain primarily polyunsaturated fatty acids (PUFA) **(Terech-Majewska *et al.*, 2016)**. Phytoplankton is considered the main source of nutrients in the diet of fish, and it can be extremely useful for successful fish farming. However, it is necessary to correctly recognize phytoplankton (especially the category and species) as the basis of food webs **(Napiorkowska-Krzebietke, 2017)**. It has been well established that the natural food in fry ponds, consisting of zooplankton and phytoplankton, is more nutritious than the artificial feeds used in fish farming. This was confirmed by various studies, such as that by **Privezentsev (1991)**.

Natural pond fish feed contains essential compounds in sufficient amounts to ensure high production quality. This has been emphasized by several authors

(Kharitonova, **1978; Volynkin, 2006; Volynkin, 2007)**. Analysis of the chemical composition of natural pond feeds a dry matter can attain 70-80% protein, from 5 - 20% fat, and up to 5% different carbohydrates **(Privezentsev, 1991)**. The estimated mortality rate of fry for common carp (*Cyprinus carpio*) reared in Iraq culture is more than 60% of the stocked material each year (own observation). Even though carp culture is widespread in most provinces of Iraq, there is slight information published on the survival, growth, and dietary composition of carp fry in nursery ponds. However, there are a few studies that are limited to the feeding biology of adult carp in the wild and in cages and cyprinid species fry **(Mukhaysin & Jawad, 2012; Al-Awady, 2013; Abbas *et al.*, 2016; Fahad & Shuhaib, 2021; Al-Dubakel *et al*., 2022)**. In many fish farms in Iraq, limited attention has been paid to the formation and maintenance of an optimal natural food base in nursery ponds. Additionally, scientific research in Iraq has not sufficiently addressed the specifics of intensification measures for various types of pond stocking, including undergrown larvae, incubated larvae, or natural spawning. This study aimed to examine the development of the natural food base in ponds used for growing carp fingerlings in monoculture systems with undergrown larvae. The study also explored the use of organic and mineral fertilizers, as well as the introduction of compound feed. Specifically, the goal was set to analyze the dietary characteristics of the fingerlings during the rearing period.

MATERIALS AND METHODS

The study area is located at the fry ponds of the Central State Hatchery in the province of Kut, district of Suwera (about 50km south of Baghdad). The selected nursery ponds were those in which experiments on the cultivation of carp fingerlings **(Al-Hilali *et al*., 2024)**. Hydrobiological studies were carried out, guided by the instructions of **Sadchikov (2003)** and **Danilov-Danil'yan *et al*. (2019)** through assessing the state of the natural food base of ponds using methods for determining the abundance and biomass of phyto- and zooplankton and their role in the diet of carp fry. The research was conducted for 60 days from May the 20^{th} in 2023 to July 19^{th} in 2023, but samples were taken every two weeks, i.e. – 20.05; 03.06; 18.06; 03.07, and 19.07. For phytoplankton analysis, fifty liters (50L) of water were collected from specific locations throughout the pond and passed through a 50µm phytoplankton mesh to obtain a concentrate. Each concentrated water sample was then placed in a 0.5L glass bottle, fixed with Lugol's solution (final concentration 2%), and stored in the refrigerator until analysis. Phytoplankton identification was performed to genus and/or species level where possible, using a microscope (Carl Zeiss Axiostar and Euromax microscope, EC 1152), standard manuals, textbooks, and scientific articles **(Verlecar & Desai, 2004; Bellinger & Sigiee, 2015)**. Phytoplankton density was counted using a Sedgwick–Rafter cell, and the abundance was expressed as cells per liter. A 1ml sample was placed in a Sedgwick–Rafter cell and was left for 5min to allow the phytoplankton to settle. Phytoplankton was counted in 100 randomly selected fields in the Sedgwick–Rafter cell, and the plankton density was calculated as cells per liter based on the data outlined in the study of **Pitchaikani and Lipton (2016):**

N= {n × v/ V} x 1000

Where, N is the total number of phytoplankton cells per liter of filtered water,

n is the average amount of phytoplankton in 1 ml of sample,

v is the volume of phytoplankton concentrates,

V is the total volume of filtered water. A small model of a Djedi net with an inlet diameter of 25cm and gas No. 73 (mesh 0.081mm) was used as a zooplankton fishing tool. The samples were fixed with 40% formalin, adding it in such a way that a 4% solution was obtained in the run. The identification of zooplankton organisms was carried out before the genus and or species according to the determinant **(Kutikova & Starobogatov, 1977; Borutsky *et al*., 1991; Plavilshchikov, 1994; Tsalolikhin, 1995)**. The processing of quantitative samples was carried out by the counting and weighing method **(Svirskaya, 1987)**. The weight of organisms was determined by the tables of average weights available in the literature and formulas of the linear dependence "length-mass" **(Mordukhai-Boltovskaya, 1954; Balushkina & Vinberg, 1979)**. Benthos collection was carried out using hand-held diving nets, when two people took samples along the shoreline for 15 minutes each, covering most of the shoreline of the ponds. The selected benthos was stored in glass bottles and aged in 96% ethanol. After returning from the field, all samples were stored in the dark and cold (4 °C) until analysis. Samples of fry for dietary composition studies were collected during the same hydrobiological sampling but after a 30min interval from the introduction of supplementary feed. Fifteen fry samples were collected from each pond every two weeks, considering all applicable international, national and/or institutional guidelines for the care and use of animals. Before gut content sampling, fish were anesthetized with 0.3ml l^{-1} of clove oil. For each individual, the gut contents were extracted by dissecting. Gut contents were analyzed to study food preference and the quantitative and qualitative composition of the fry's diet. Immediately after collection, all fish samples were injected with 10% formalin into the gut to stop the digestion of the food items. The fry was then dissected and the entire gut contents were analyzed microscopically (Carl Zeiss Axiostar and microscope) for dietary composition, preferences, and relative importance of the various food items. The number of guts in which a given food item was found was expressed as a percentage of all non-empty guts examined. This method allows an estimate of the proportion of the community that feeds on a particular food item **(Hyslop, 1980)**. The stomach contents were analyzed for quality and quantity. The food components found in the stomachs were divided into the following groups:

* Phytoplankton; * zooplankton; * crustaceans; * bottom animals; * insects; *

Supplementary feed

The relative number of preys is defined as a percentage of the total stomach contents (mass) fry per each, given the type of prey. The frequency of occurrence (FO) and the relative abundance (RA) of the prey species can be described by the equations: FO = X/Y x 100%, where X = the number of stomachs in which each food product is present, Y = the number of stomachs for experiments; RA = Si / ST, where Si is the amount of stomach contents, made up of type i prey, and ST is the total number of all prey species present in each stomach of the sample **(Hyslop, 1980; Amundsen & Sánchez-Hernández, 2019)**. Then, it was expressed as a percentage of the total weight of the stomach contents (Table 6). The indicators in the tables are presented in the form of a mean statistical value, a standard error and a significant difference at α = 5%.

RESULTS AND DISCUSSION

During the study period, measurements of physico-chemical parameters of pond water, such as temperature, dissolved oxygen (DO), and pH, were carried out, which turned out to be within the limits suitable for growing plankton and fry. During the growing phase, the water temperature varied from 23.5 to 30.7°C, and the pH from 6.5 to 9.5. The dissolved oxygen content was generally 5.7 - 8.8mg/ l **(Al-Hilali *et al*., 2024)**.

The quality, quantity and dynamics of plankton in nursery ponds were analyzed using an assessment of dominance and two-month fluctuations. When fish fries are first hatched, they are unable to eat on their own. Initially, their main source of nutrition comes from the yolk sac inside their bodies. As they grow, the yolk is gradually consumed, and a critical stage arrives when the fry must learn to find food in their environment. They begin by consuming phytoplankton and zooplankton—small algae and aquatic animals. Only after mastering, they change to specially formulated feed used in fish farming—natural feed. In the early stages of development, fish fry primarily feed on rotifers and small diatoms. As they grow, they start consuming smaller crustaceans, and eventually, they feed on larger organisms such as zooplankton and zoobenthos.

Therefore, creating a favorable environment in ponds to support the development of a natural food supply for growing fry is essential. This includes promoting the growth of phyto- and zooplankton, which provides a vital nutritional source for the fry. The results of the research showed that the composition of phyto- and zooplankton met the nutritional needs of the carp fry throughout their entire growth period. The analysis revealed the presence of 67 species of phytoplankton and 73 species of zooplankton, representing various taxonomic groups in the ponds (Table 1).

Table 1. Species composition of phytoplankton and zooplankton in experimental ponds

SPECIES	
ZOOPLANKTON 73	PHYTOPLANKTON 67
ROTATORIA 36	BACILLARIOPHYCEAE 26
Keratella hiemalis Carlin	*Bacillaria paxillifer*, Hendy (1951)
K. tropica (Apstein)	*Synedra acus* Kützing
K. quadrata (Müller)	*Nitzschia amphibian* Grunow
K. testudo (Ehrenberg)	*N. filiformis* (W. Smith) Hustedt
K. valga f. *monospina*	*N. obtusa* W. Smith
K. tecta Gosse 1851	*N. dissipata* (Kütz.) Grunow
Keratella sp.	*Diatoma vulgare* Bory
Brachionus angularis Gosse	*Surirella robusta* Ehrenberg, 1840
B. plicatilis Müller	*Amphora coffeaeformis,* Kützing
B. calyciflorus Pallas	*Amphora normanii* Rabenhorst 1864
B. fulcatis (Zacharias)	*Navicula lanceolate*, Agardh 1827
B. variabilis	*N. obtusa* W. Smith
Brachionus sp.	*N. parva* Ralfs
Lecane luna (Gosse)	*N. rhyncocephala* Kützing
Lecane bulla (Gosse)	*Pinnularia viridis*, Ehrenberg 1843
L. closterocerca (Schmarda)	*Pinnularia* sp.
L. stenroosi Meissner 1908	*Fragilaria capucina* Desmazieres
Lecane sp.	*Cyclotella comta* (Fhr.) Kutz
Asplanchna priodonta Gosse, 1850.	*Cyclotella ocellata* Pantocsek, 1901
Asplanchna brightwellii Gosse, 1850	*C. meneghiniana* Kuetzing. 1844
Asplanchna girodi de Guerne, 1888	*Melosira distance* (Ehr.) Kuetzing
Asplanchna silvestrii Daday, 1902	*Melosira granulate*, Ralfs 1861
Anuraeopsis coelata Beauchamp, 1932	*Stephanodiscus astrea*, Grunow 1880
Anuraeopsis cristata Berzinš, 1956	*Scenedesmus arcuatus* Lem. 1899
Colurella colurus Ehrenberg	*Scenedesmus dimorphus*, Kützing 1834
Euchlanis deflexa Gosse 1851	*Scenedesmus* sp.
Euchlanis contorta Wulfert 1939	CHLOROPHYTA 21
Euchlanis dilatata Ehrenberg 1832	*Actinastrum hantzschii Lagerhein*
Filinia opoliensis Zacharias, 1898	*Cladophora fracta* (Dillw) Kuetzing
Hexarthra mira Hudson, 1871	*Cladophora glomerata* Kuetzing
Hexarthra intermedia Wiszniewski,	*Gonium pectorale* Müller 1773
Polyarthra dolichoptera Idelson, 1925	*Pandorina morum* Bory, 1824
Polyarthra longirensis Garlin, 1943	*Pediastrum boryanum* Meneghini 1840
Polyarthra remata Skorikov, 1896	*P. tetras* (Ehr.) Ralfs
Pompholyx sulcata Hudson, 1885	*Scenedesmus denticulatus* Lagerheim

Trichocerca ruttus Muller, 1776	*Scenedesmus obliquus,* Kützing 1833
COPEPODA 21	*Scenedesmus* sp.
Diaptomus amatitlanensis Wilson, 1941	*Cosmarium subtumidum* Nordstedt 1878
Diaptomus gracilis Sars, 1863	*Cosmarium leave* Rabenhorst
Diaptomus sarsi Rylov, 1923	*Spirogyra fluviatilis* Hilse 1863
Diaptomus novemdecimus Wilson, 1953	*Spirogyra* sp.
Diaptomus floridanus Marsh, 1926	*Hormidium mucosum* B. Petersen 1915
Diaptomus sp.	*Staurastrum gracile* Ralfs, 1848
Cyclops exilis Coker, 1934	*S. bohlinianum* Schmidle 1898
Cyclops venustoides Coker, 1934	*Ankistrodesmus spiralis* (Turner)
Cyclops vernalis Fisher, 1853	*Clostrum venus* Kuetz
Cyclops capillatus Sars G.O., 1863	*Tetraëdron regulare,* Kützing
Cyclops jeanneli Chappuis 1929	*Strastrum gracile* Ralfs
Macrocyclops albidus Jurine, 1820	*Sorastrum spinulosum Nägeli 1849*
Mesocyclops albicanus Smith, 1909	CYANOPHYTA 14
Mesocyclops hylalinus Rehberg, 1880	*Aphanocapsa litoralis* Hansgirg, 1892
Mesocyclops leuckarti Claus, 1857	*Anabaena flos-aquae,* Breb
Mesocyclops hylalinus Rehberg, 1880	*Calothrix crustacea*, Bornet, 1886
Eucyclops agilis Koch, 1838	*Chroococcus dispersus* (Keissler) 1904
Paracyclops affinis Sars, 1863	*Chroococcus pallidus* Nägeli 1849
Nitokra lacustris Schmankevitch, 1875	*Lyngbya aestuarii,* Lemmermann 1905
Ergasilus von Nordmann, 1832	*Merismopedia glauca (Ehr.) Naegeli*
Lernaea Linnaeus, 1758	*Microcystis aeruginosa,* Kützing 1846
CLADOCERA 14	*Oscillatoria amphibian,* Gomont, 1892
Daphnia lumholtzi Sars	*O. angusitssimum*
Daphnia hyalina Leydig, 1860	*Phormidium tenue* Gomont
Daphnia longispina Müller, 1776	*Phormidium* sp.
D. magna Straus, 1820	*Spirulina laxa,* Smith 1916
D. hyaline Leydig, 1860	*S.subsalsa* Kuetzing
Diaphanosoma brachyurum (Lieven)	EUGLENOPHYTA 2
Bosmina coregoni Baird	*Euglena gracilis* Klebs.
B. longirostris Müller, 1785	*E. polymorpha* Dangread
Alona rectangula Sars 1862	another 4
A. intermedia Sars 1862	
Chydorus sphaericus Müller, 1776	
Epbemeroporus barroisi Richard 1894	
Alonella lineolata Sars, 1901	
Alonella sp.	
another 2	

Phytoplankton was relatively low in diversity, with only 67 species identified. These species were mainly grouped into three categories: diatoms (Bacillariophyceae), green algae (Chlorophyceae), and blue-green algae (Cyanophyceae). Among the phytoplankton, diatoms were the most diverse, represented by two prominent genera—*Nitzschia* and *Navicula*—each containing four species. Green algae, including *Cladophora* sp. and *Scenedesmus* sp., were also prevalent and were found in all the ponds involved in the experiment.

In contrast, zooplankton exhibited greater diversity, with 73 species. The rotifer group stood out, containing 36 different species (Table 1). According to Fig. (1), the highest average percentage of phytoplankton was observed in diatoms (41.3%), followed by green algae (33.3%), blue-green algae (22.2%), and euglenic algae (3.2%).

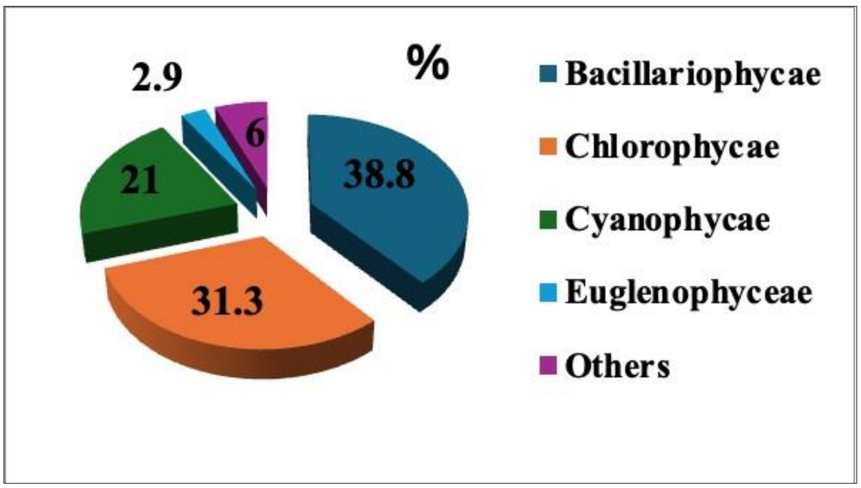

Fig. 1. Percentage of phytoplankton groups

The research revealed that the zooplankton in the ponds consisted of 73 species, primarily represented by four groups of organisms: Rotatoria (36 species), Copepoda crustaceans (21 species), and Cladocera (14 species). Among these, Copepoda dominated the biomass (Table 1, Fig. 2).

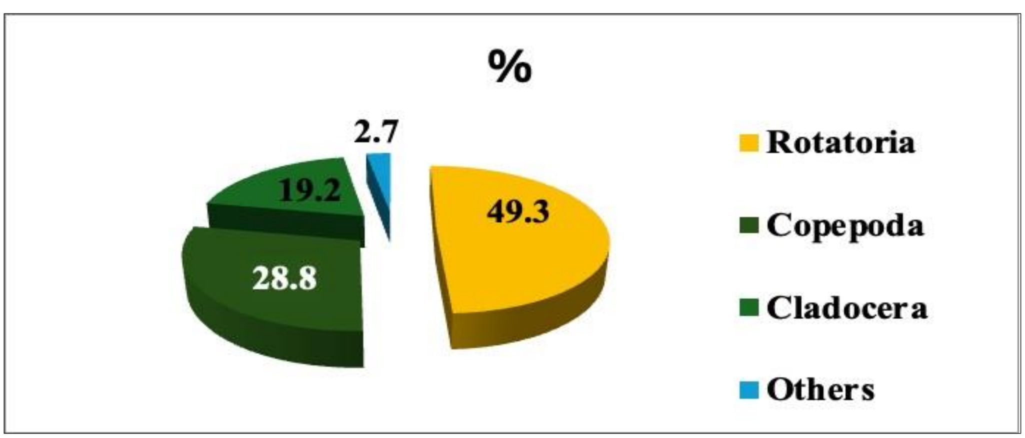

Fig. 2. Percentage of zooplankton groups

By converting the qualitative content of Table (1) into quantitative expression, it is possible to obtain the data presented in Tables (2, 3 and 4).

Table 2. Average value of the main natural food resources in terms of abundance (individuals/L). (Averaged data for the entire period)

Treatments**	T1	T2	T3	T0	Mean	Significant differences
Bacillariophyceae	24.73×10^4	24.41×104	26.82×10^4	25.40×10^4	$25.46 \times 10^4 \pm 0.16$	NS
Chlorophyceae	20.12×10^4	20.84×10^4	20.15×10^4	20.41×10^4	$20.53 \times 10^4 \pm 0.25$	NS
Cyanophyceae	13.06×10^4	14.24×10^4	13.64×10^4	12.02×10^4	$13.39 \times 10^4 \pm 0.12$	NS
Euglenophyceae	1.65×10^4	2.24×10^4	1.81×10^4	2.16×10^4	$1.97 \times 10^4 \pm 0.05$	NS
Total Phytoplankton:	61.6×10^4	62.7×10^4	58.4×10^4	65.6×10^4	$61.65 \times 10^4 \pm 0.32$	NS
Rotifera	83×10^3	74×10^3	87×10^3	93×10^3	$83.25 \times 10^3 \pm .056$	NS
Copepods	38×10^3 a	35×10^3 b	42×10^3 a	27×10^3 b	$34.57 \times 10^3 \pm 0.13$	*
Cladocera	31×10^3	28×10^3	34×10^3	25×10^3	$28.16 \times 10^3 \pm 0.37$	NS
Others	11×10^3 a	6×10^3 b	8×10^3 b	8×10^3 b	$8.68 \times 10^3 \pm 0.46$	*
Total Zooplankton:	163×10^3 a	143×10^3 b	171×10^3 a	153×10^3c	$155.47 \times 10^3 \pm 0.35$	*
Benthic organisms*	12.2	13.7	12.6	10.73	12.38 ±0.06	NS
Insecta*: (larvae and nymphs)	24	29	22	18	24.75 ±0.11	NS

* Ind. /m2. ** There was no significant difference between phytoplankton treatments (Turkey. *P*> 0.05). Different letters in the same row indicate significant differences (*P*< 0.05).

The abundance of phytoplankton was relatively uniform, with average concentrations ranging from $58.4 \times 10^4 \pm 3.742$ to $65.6 \times 10^4 \pm 4.45$ cells/L, and a biomass of 75.89 mg/L in the ponds (Tables 2 and 3). Bacillariophyceae was the most abundant class, with an average of 25.46×10^4 cells/L and an average mass of 55.72 ± 0.31 mg/L. This was followed by Chlorophyceae, with $20.53 \times 10^4 \pm 0.25$ cells/L and a mass of 10.61 ± 0.36 mg/L. Cyanophyceae had a concentration of 13.39×10^4 cells/L, with a biomass of 7.45 ± 0.15 mg/L, and Euglenophyceae was present at $1.97 \times 10^4 \pm 0.05$ cells/L, with a biomass of less than 1.91 mg/L (Tables 2, 3).

In ponds stocked with carp larvae at different densities, a high level of zooplankton development was observed throughout the growing period, ranging from 7.92 to 27.86 g/L. The average number of Zooplankton ranged from 97,000 to 1,645,000 specimens/L, which notably contributed to increasing the availability of natural food for carp fry during their initial stages of growth. Zooplankton in these ponds were primarily crustaceans, including *Cyclops* sp. and *Diaptomus* sp., with a smaller presence of branchiopods such as *Moina rectirostris* and *Bosmina longirostris*, found in 75% of the zooplankton samples (Table 4).

The development of rotifers and copepods was particularly prolific throughout the period. The biomass of these groups ranged from 210.55 ± 0.61g/ L for rotifers to 190.30

± 0.61g/ L for copepods, with populations of 83.25 ± 0.56 and 34.57 ± 0.13 thousand individuals/L, respectively (Tables 2 and 3). The most abundant rotifer species across all ponds were *Keratella tropica*, *K. quadrata*, *K. tecta*, *Brachionus* sp., *Polyarthra* sp., and *Lecane sp.* Among the copepods, the naupliar stages of *Calanoida* and *Cyclopoida* were the most abundant. The most prevalent cladoceran species were *Bosmina longirostris* and *Daphnia longispina*, which dominated throughout the growing period in all the ponds.

Table 3. Average value of the main natural food resources in terms of total biomass (mg/l) at the middle of the growing period

Treatments	T1	T2	T3	T0	Mean	**Significant differences**
Total Phytoplankton*:	80.22 a	80.68 a	72.38 b	73.53 c	75.89 ±0.47	*
Bacillariophyceae	60.34 a	60.11 a	52.62 b	51.88 c	55.72 ±0.31	*
Chlorophyceae	10.54	10.66	10.71	11.45	10.61 ±0.36	NS
Cyanophyceae	8.42 a	8.29 a	6.96 b	5.82 c	7.45 ±0.15	*
Euglenophyceae	0.81	0.95	1.03	2.43	1.25 ±0.19	
Others	0.11 a	0.67 a	1.06 b	1.95 c	0.86 ±0.02	*
Total Zooplankton*:	440.22	400.03	450.7	400.29	439.05 ±0.5	NS
Rotifera	203.42	192.46	210.39	240.18	210.55 ±0.61	NS
Copepods	208.97 a	184.45 a	212.57 a	130.86 b	190.30 ±0.61	*
Cladocera	21.17	19.60	22.26	24.05	21.05 ±0.35	NS
Others	6.64 a	3.53 b	5.48 a	5.2 c	5.23 ±0.25	*
Benthic organisms**	6.23	7.1	5.8	4.5	6.05 ±0.25	NS
Insecta**: (larvae and nymphs)	74.4	87	63.8	52.8	69.55 ±0.25	NS

*mg/L; **gr/m^2. Superscripts mean significantly different ($P<0.05$).

Zooplankton abundance remained relatively stable during the study period and was determined mainly by factors such as water temperature, dissolved oxygen content, and phytoplankton availability for nutrition. Phytoplankton also turned out to be rich and stable due to a balanced and saturated fertilizer, plus the water temperature, which turned out to be within the limits suitable for the development of plankton. Among the predators that were the most numerous and had the largest biomass in these ponds were, of course, carp fingerlings and large representatives of their own zooplankton, such as large branched crustaceans (*Cladocera*) and copepods (*Copepoda*). Based on Table (4), there are significant differences in the dynamics of natural food resources before and after growing fry. This is due to the fact that the natural resources used in ponds for cultivation are depleted faster than they can be restored, due to the fact that carp fry begin to actively feed on them, as shown in the Table (5).

Table 4. Dynamics of natural food resources before and after growing fingerlings

Components	Before planting the fry		The middle of the growing season (June 18)		End of the growing period	
	cell. /L	mg /L	cell. /L	mg /L	cell. /L	mg /L
Phytoplankton *	60.8×10^4	60.15	40.5×10^4	75.89	39.2×10^4	3.92
Zooplankton*	156.3×10^3	405.93	168.4×10^3	439.05	128.2×10^3	322.24
Benthic organisms **	12	6.17	11	5.9	8	3.16
Insects (larvae and nymphs)**	83	47.6	79	69.5	54	37.8

* Cells; gr /L. ** Cell /m^2

The average abundance of plankton and benthos, as shown in Table (4), is higher at the beginning of the study compared to the end. This suggests that the fertility of the ponds has relatively decreased over time. The increased nutrient content observed at the start of the study is due to the application of fertilizers during the initial pond preparation before fry stocking. This treatment provided an adequate supply of nutrients, which contributed to the development of plankton. However, it is noticeable that phytoplankton decreases much faster from the beginning of the period to the middle compared to the decrease from the middle to the end of the period. While the quantity remains almost the same, their mass decreases, indicating that small organisms remain (Table 4). The fertility of ponds, determined by the amount of phytoplankton and zooplankton at the beginning of the hatching period, is characterized as eutrophic, meaning highly productive. By the end of the period, the fertility of the ponds could be classified as mesotrophic rather than oligotrophic **(Gold & Morozova, 2004)**. A total of 600 fish samples with non-empty intestines were analyzed to study the contents of their digestive tracts. The composition of the food in the intestines throughout the experiment revealed that, during the first stage of cultivation (up to 3 weeks of age), the fry fed exclusively on zooplankton and phytoplankton, primarily consuming rotifers, cladocerans, Chlorophyta, and diatoms (Table 5). Around 22 days of age, the fry shifted to feeding mainly on phytoplankton, such as diatoms (primarily *Nitzschia* and *Navicula*) and Chlorophyta (*Pediastrum*, *Scenedesmus*, and *Spirogyra*). However, as they approached two months of age (the end of the experiment), the abundance of these phytoplankton species decreased in the stomachs of the fry.

Table 5. The average value for 3 treatments taking into account the composition of feed and diet density and biomass in %

Parameters	Larvae 15 day age*	Sampling periods (age. days)			
		7 (22)**	15 (30)	30 (45)	45 (60)
Total length. cm	2.16±0.14 1.57- 3.17	3.08 ± 0.22 2.11- 4.36	4.21 ± *0.01* 3.92 - 5.26	5.62 ± 0.06 4.28 - 6.35	6.74 ± 0.12 5.72 - 8.16
Mass. gr.	0.24 ± 0.01 0.18- 0.57	0.95 ± 0.02 0.68 – 1.37	2.18 ± 0.04 1.53 – 4.17	4.46 ± 0.41 3.17- 6.45	7.48 ± 0.17 4.33 – 9.17
Compound feed. %	-	-	18.4	51.5	66.8
Fry weight gain. gr (General gain. gr)			1.31±0.13	2.58±0.25	3.22±0.17 (6.53)
Weight gain due to compound feed 75% (gr)					4.9
Consumed Compound feed kg.			1480.3	4143.7	5376
FCR (General FCR)			3.7	3.4	3.6 (3.3)
Phytoplankton:	11	59.7	32.2	4.6	1.5
Diatomaceous	-	53.2	21.7	3.8	1
Chlorophyceae	6	6.5	10.5	0.8	0.3
Cyanophyceae	-	-	-	-	0.2
Euglenaceae	5	-	-	-	-
Zooplankton:	89.0	37.3	35.9	21.4	14.8
Rotifera	62.0	10.5	4.6	1.4	0.5
Copepod	13.3	10.3	18.9	8.6	1.6
Cladocera	13.7	16.5	12.4	11.4	12.4
Benthic animals:	-	-	1.4	11.3	4.5
Insecta: eggs. larva. nymphs	-	3	12.1	11.2	12.3
Plants: fragments	-	-	-	-	0.4
Total	100	100	100	100	100

Although rotifer cells are completely absorbed by carp fry, they are only quantitatively significant when consumed in large quantities. During the experimental period, studies of the food composition revealed that, at the initial stage of cultivation, the fry primarily fed on natural food, mainly plankton. However, before supplemental feeds were introduced, the absolute amount of natural food decreased as the fish grew. Over 60 days, the amount of natural food in the fish decreased by 7 to 10 times in the ponds. Early in their development, zooplankton were most commonly found in the fry's intestines. As the fry grew, compound feed became more prevalent, and by the end of the period, bottom-dwelling organisms and insects, such as larvae and nymphs, appeared in their intestines (Table 5).

Phytoplankton was the predominant food source at the age of 22 days but decreased thereafter in all treatment groups, with diatoms accounting for about 80% of the phytoplankton consumed (Table 5). After the fry reached 22 days of age, the total amount of consumed food increased. It appeared that the fry began using compound feeds as early as their introduction. Insects, both adult and larval forms, living near the water's surface, were found in the fry's intestines. However, adult bottom-dwelling insects were not present, although their larvae and nymphs appeared in the fry's stomachs during the final weeks of cultivation.

It's important to note that, not all components of plankton and benthos identified in the pond water were found in the fry's stomachs. For example, despite the prevalence of zooplankton in the fry's early diet, rotifers dominated their stomach contents, comprising nearly 70%. Several species of *Keratella* (3 species), *Brachionus* (3 species), *Lecane* (2 species), *Asplanchna* (2 species), and *Filinia* (1 species) were the most common. Cladocerans and their larvae (nauplii) were also part of the fry's diet, primarily represented by *Daphnia* and *Bosmina*, but in smaller quantities (Table 5). While copepods were absent from the stomachs of 15-day-old fry, they later appeared in small quantities, including species such as *Cyclops*, *Diaptomus*, *Mesocyclops*, and copepod *Nauplii*.

Despite the early introduction of compound feed, it was not a significant part of the diet until the fry reached 30 days of age. Within two weeks, compound feed made up more than 50% of the fry's food, and by the end of the experiment, it accounted for about two-thirds of their diet.

The most abundant nutrients in the stomachs were zooplankton, followed by phytoplankton, and then compound feed (Table 6). Among the zooplankton, cladocerans were the most common, while *Bacillariophyceae* were the most abundant in the phytoplankton. Other stomach contents varied in abundance, with *Euglenaceae* at 3.6% and *Chlorophyceae* at 88.34% (Table 6). Compound feed was moderately abundant, starting to appear in the stomachs at three weeks of age (Table 6). The relative abundance of compound feed was highest at 37.7%, followed by zooplankton at 31.5%. Phytoplankton had a lower relative abundance at 18.1%, while insects and benthos were of minor importance (Table 6).

Table 6. Frequency of occurrence (FO (%)) and relative abundance (RA (%)) of different food items consumed by *C. carpio* (n=600)

Food Items	**FO (%)**	**RA (%)**
Zooplankton	97.5 ±4.7	31.5 ± 1.04
Rotifers	18.6 ± 2. 41	2
Copepods	85. 63 ± 2.9	11.5
Cladocerans	92.81 ± 3.5	18
Phytoplankton	86.65 ± 1.9	18.1 ± 1.2
Bacillariophyceae	95.5 ± 1.41	7.2
Chlorophyceae	88. 34 ± 4.31	9.5
Cyanophyceae	61.26 ± 1.62	1.0
Euglenophyceae	3.26 ± 0.59	0.4
Benthos	6. 69 ± 3.3	4.7
Insects	5.18 ± 0.36	7.9 ± 1.3
Supplementary feed	67.5 ± 0.15	37.7 ± 2.7

The hydrological, hydrophysical, and hydrochemical parameters remained within normal ranges for Iraq throughout the experiment **(Farhan *et al*., 2021)**. The continuous application of organic fertilizers in carefully calculated doses ensured the consistent development of both phyto- and zooplankton in terms of quantity and biomass. The availability of zooplankton and benthos as food was high, which led to the proportion of natural food in the carp's stomach averaging 25%. As a result, the experiment achieved high productivity indicators, as shown in Table (7). The favorable combination of both the natural and artificial nutrition allowed for successful carp fry cultivation, yielding more than 5.5 tons per hectare of fish productivity. At the same time, feed costs in the experimental ponds were just over 2 feed units (Table 7).

Table 7. Indicators of fish farming productivity of growing carp fingerlings and the degree of conversion of food products

Parameters	**Larvae 15 day age***	**Sampling periods (age, days)**			
		7 (22)**	**15 (30)**	**30 (45)**	**45 (60)**
Individual fry mass, (gr)	0.24 ± 0.01 0.18 - 0.57	0,95 ± 0.02 0.68 – 1.37	2,18 ± 0.04 1.53 – 4.17	4,46 ± 0.41 3.17- 6.45	7,48 ± 0.17 4.33 – 9.17
Compound feed, %	-	-	18.4	51.5	66.8
Fry weight gain, gr (General gain, gr)			1.31±0.13	2.58±0.25	3,22±0.17 (6.53)
Weight gain due to compound feed 75% (gr)					4.9
Total weight of produced fingerlings (kg)					4453
fish productivity of experimental ponds (kg/hectare)					5606.7
Consumed Compound feed kg. (total)			1254.2	3510	4553.8 (9318)
FCR (General FCR)					(2.1)

Most studies evaluated the effect of fertilization on pond productivity without the use of compound feeds **(Magomaev *et al*., 1994; Ber & Magomaev, 2008; Soderberg, 2012; Kozhaeva *et al*., 2013; Boyd, 2018, Otieno *et al*., 2021)**. This practice sometimes leads to a decrease in productivity since natural feeds are not enough to feed fish contained in large quantities. Productivity in fertilized ponds without an allochthonous diet is low, while ponds with intensive nutrition are highly productive. The allochthonous diet is the main source of nutrients in semi-intensive or intensively grown monocultures of fish **(Milstein *et al*., 2003; Boyd *et al*., 2020)**. However, it was heavily reported that, natural feed can complement or partially replace prescription feed in ponds **(Boyd, 2018)**. They are even necessary for the cultivation of some species for which there are no suitable and well-balanced diets **(Azim *et al*., 2002; Azim *et al*., 2008)**. Thus, understanding the role of fertilizers, associated with the allochthonous diet, can provide information on the effectiveness of aquaculture and align it with restoration approaches **(Alleway *et al*., 2023)**. By the way, recent studies have shown that the combined use of inorganic and organic fertilizers is effective in increasing productivity in earthen ponds **(Afzal *et al*., 2007**; **Jha *et al*., 2008)**. Moreover, the combined use of inorganic and organic fertilizers is effective for maintaining phytoplankton and zooplankton populations in outgrowth ponds **(Afzal *et al*., 2007)**. The results of our observations have shown that using floating fry food has a positive impact on both the survival and feeding of carp fry. However, the technology of using fingerling feed still requires improvement. Although the balance and digestibility of the fingerling feed are high, in the first weeks after being planted in the pond, the larvae did not consume it. During this time, they should be provided with live food due to the high level of development of natural food sources. For its development, ponds must be properly fertilized 7-10 days before stocking, as indicated in several previous studies **(Woynarovich & Woynarovich, 1998; Privezentsev & Vlasov, 2004; Tucker & Hargreaves, 2008; Rahman *et al.*, 2010; Woynarovich *et al.*, 2011; Moruzi *et al.*, 2023)**. In our study, natural food was the optimal and acceptable diet for carp fingerlings. This is precisely due to the proper use of aquaculture measures in the pond before filling and subsequent fertilization; after planting fry, there is a rich and rapid development of planktonic and benthic organisms, and this conclusion was recorded in the study of **Billard (1999)**. The study of the stomach contents of fish provides valuable information about the diversity and shifting of the ontogenetic diet of these fish. It helps understand the role played by fish in the environment. This investigation also contributes to the development of knowledge on how to maintain the most cultivated species in monoculture or multiculture systems. As it is well known, the common carp usually eats both plants and animals, although the amount of animal food in its diet usually makes up more than 70% **(Michael & Oberdorff, 1995)**. Although zooplankton is a significant part of the diet of young carp, as they grow up, their eating habits change, reflecting their specific feeding preferences and the range of food sources available to them **(Chakrabarti & Sharma, 1998)**. Many authors believe that the common carp feeds on benthic macro invertebrates and plankton **(Hepher & Pruginin, 1981; Spataru *et al.*, 1983)**. However, when using artificial feeds, carp readily accept it **(Spataru *et al.*, 1980; Schroeder, 1983; Milstein & Hulata, 1993)**. This trend was clearly observed in our experiment, as the fry transitioned to supplemental feeds in a rapid and gradual manner. From the moment they were introduced at 22 days of age, the fry began incorporating the additional feeds into their diet, gradually replacing natural food sources (Table 5). Phytoplankton and zooplankton remained important components of the fry's digestive contents throughout the experiment. The feeding behavior of fish gradually changes as they grow in a new environment, which is reflected in their specific feeding habits and assortment **(Whitfield *et al.*, 2022)**. The study of the food habits of a species is important for assessing the ecological role and position of a species in the food web **(Allan *et al*., 2021)**. Our findings revealed that after 22–30 days, the fish successfully transitioned to concentrated feed. For fry measuring between 3.2 and 4.5 centimeters in size, aged 22 to 30 days, the preferred prey items were Cladocera and diatoms. These were followed by rotifers and Chlorophyta, insect larvae, and bottom organisms. These latest results are supported by studies conducted by **Billard (1995)** and **Dulce *et al.* (2011)**. In this context, **Billiard *et al*. (1995)** found that common carp fry aged between 19 and 33 days primarily consume large crustaceans and insect larvae. Given the unlimited number of commercial dry feeds currently available for growing carp fry, **Demine and others (2012)** proved experimentally, as our research showed **(Al-Hilali *et al*., 2024)**, that initial cultivation on live feed followed by a gradual transition to dry feed remains necessary. This is due to the fact that at this stage, the digestive tract is not yet fully formed, using exogenous enzymes to digest food, which are consumed together with prey **(Dabrowski, 1984a, b)**. The survival rate of carp larvae during 21 days of cultivation was satisfactory (about 80%).

CONCLUSION

These are the first documented results of *C. carpio* fry rearing under the natural conditions of earthen ponds in Iraq. Our research demonstrated that, by applying balanced organic and mineral fertilizers and maintaining a moderate stocking density of carp, the ponds provided an abundant natural food supply. This resulted in a favorable composition of phyto- and zooplankton, which met the nutritional needs of the carp fry throughout their growth period. Notably, the role of the natural food base was especially significant during the early stages of the fry's growth. Additionally, the use of special floating feed, introduced in the second week after stocking, allowed the fry to reach their growth potential more fully. With moderate stocking density, this approach facilitated the production of large carp fingerlings for subsequent cultivation. By the end of the experiment, 2-month-old carp fingerlings (averaging 7.5 grams) were ready for stocking in feeding ponds for commercial cultivation.

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- **The study complied with official Russian guidelines for the care and use of animals for scientific and educational purposes (Federal Law No. 498-FZ of 12/27/2018)**

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