Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(3): 1545 – 1560 (2024)
www.ejabf.journals.ekb.eg

The Effect of Zooplankton Density on the Growth and Survival of the Common Carp Larvae in Aquaculture Ponds

Naeem S. Hammadi[1*], Mujtaba A. T. Ankush[1], Adil Q. Jassim[1], Majid M. Taher[2], Alaa A. Maytham[1]

[1] Department of Fisheries and Marine Resources, College of Agriculture, University of Basrah, Iraq
[2]Aquaculture Unit, College of Agriculture, University of Basrah, Iraq
*** Corresponding Author:** naeem.hammadi@uobasrah.edu.iq

ARTICLE INFO

Article History:
Received: May 9, 2024
Accepted: May 20, 2024
Online: June 30, 2024

Keywords:
Zooplankton,
Rotifer,
Copepod,
Common carp,
Growth

ABSTRACT

To measure the effect of zooplankton density on the growth and mortality of the common carp fry in fish farm ponds, four clay ponds of area 2500 m^2 were chosen, with each having no water for one month. One ton of organic fertilizer (buffalo waste) was added to each pond and then filled with water. After a week-long of restocking, the weight of 10.000 common carp larvae of 0.104 ± 0.002g was filled in each tank. All the artificial food like pellets were not kept for the fish during the experimental period (April 2 to May 18, 2019). For the results, the initial fish growth was high and then exhibited a significant decrease or ceased toward the end of the experiments. At the beginning of the experiment, zooplankton population was at the highest number, but the figure gradually went down, forming a linear trend, as the experiment progressed. That pointed out the likelihood of a strong relationship between the expected and actual growth rate with the total quantity of zooplankton, which is 99% with the significance level ($P\leq 0.05$). This hence leads to the establishment of the right weight for the larvae in order for zooplankton to serve as their natural food. In the process of zooplankton classification through the research in four basins, rotifers proved to be the leading group for being followed by the copepods.

INTRODUCTION

The zooplankton provides most of the nutrients for fish larvae; among these, rotifers and small crustaceans such as copepods, cladocerans, ciliates and artemia are the ones that are mainly used for this purpose; however recently, live zooplankton has become a significant feed for fish farming with the success in farming relying on its quality as well as its fitness to be taken by the larvae in relation to size and taste **(Davis *et al*., 2018)**. Due to their rapid growth rates, the omnivorousness and capacity to reproduce in confined waters, the common carp is the most suitable for pond culture in Asia either alone or in conjunction with other species **(Mohale *et al*., 2020)**. This species stands the third among the globally exploited freshwater fishes after tilapia and trout, respectively, since it contributes 8% of the total production worldwide while grass carp (*Ctenopharyngodon idella*) represents 11% of the fish yield followed by the silver carp

(*Hypophthalmichthys molitrix*), which makes up to 10% **(Hammadi *et al*., 2024)**. In aquaculture, it has now become a common practice to fertilize fishponds organically and inorganically so as to enhance their productivity **(Boyd, 2018)**. It has been widely recognized that increasing the abundance of various plankton in a culture system can lead to a significant boost in fish production **(Palupi *et al*., 2023).** It has been indicated that the objective of adding fertilizers to ponds is to enhance fish production through autotrophic and heterotrophic processes. Animal waste fertilizers are extensively employed in ponds across numerous countries as a cost-effective means to maintain productivity levels **(Boyd, 2018**). Because ponds receive soluble organic matter, it promotes the growth of phytoplankton and leads to an increase in the biomass of zooplankton and benthic organisms **(Hammadi *et al*., 2024)**.

Given that ponds are the primary setting for aquaculture operations worldwide, **Piska and Naik (2013)** emphasized that the fundamental concept behind the composite fish culture system involves the cultivation of diverse, rapidly growing fish species with complementary feeding patterns. This approach allows for the efficient utilization of natural food sources found in various ecological niches within the pond, thereby enhancing fish production. The incorporation of both organic and inorganic fertilizers within a polyculture system supplies essential nutrients and elements necessary for the development of phytoplankton and zooplankton; these organisms play a vital role as a primary food source for fish **(Hussein, 2012)**. **Mageed and Konsowa (2002)** claimed that the growth of fish exhibited a robust correlation with the rise in the natural production of phytoplankton and zooplankton due to fertilization. **Woynarovich *et al*., (2011)** stated that the main objective of nursery operations is to produce large advanced fry, about 1 month old (0.2–1.5 g.), where zooplankton is the main source of essential proteins in the diet of these fry, so establishing a dense zooplankton population is the key to success.

The occurrence of carp has caused a transition in ecosystems, leading to the dominance of phytoplankton in cloudy waters, a decrease in the number of macrophytes, and a subsequent decline in biodiversity **(Zambrano & Hinojosa, 1999; Khan *et al*., 2003)**. **Rahman *et al*. (2010)** pointed out that the density of the cultivated common carp plays a vital role in the aquatic ecosystem of certain western countries. When the density is within reasonable limits, an increase in nutrient availability can boost photosynthesis and plankton production. However, if the density becomes excessive, it results in significant ecological disturbances at both the community and ecosystem levels. It has also been described as an "ecological engineer" since the common carp has the capability to alter the ecological characteristics of aquatic systems. **Weber and Brown (2009)** claimed that the common carp has the capacity to alter the ecological characteristics of the aquatic systems. **Rahman *et al*. (2010**) elucidated that the presence of the common carp in an aquatic environment with benthivorous habitats enhances the proliferation of phytoplankton. The reason behind this was that the carp has the capacity to release nutrients, especially soluble phosphorus, from the sediment. The presence of the common carp in ponds enhances the production of fish, especially for species like the rohu, which feed on natural food, and the rohu grows better in ponds with the common carp than in a single species pond since the former has a more diversified planktonic food source that the planktivorous fish will feed on. The capacity of the sediment to retain nutrients is 100 times higher than the capacity of the water column, as described by **Rahman and Verdegem (2007)**.

Research on natural food in earthen ponds in Iraq has, however, been sparse, except for that of **Al-Agidi (2008)**, which investigated the population of zooplankton in the earthen ponds of the Mahaweel District of Babel Government. The aim of this study was to determine the effect of zooplankton on the growth of the juvenile common carp reared in earthen ponds.

MATERIALS AND METHODS

The study was conducted at the Agricultural Research Station affiliated with the College of Agriculture/University of Basrah, located in Al-Haritha District, north of Basra Governorate. Four large earthen ponds were selected, each with an area of 2500 m^2, in addition to 14 small ponds with an area of 600m^2 each. The source of water was from the Shatt al-Arab River, which was drawn using an electric pump, while the water was drained based on gravity. The incoming water was provided by an electric pump, while the outlet was through gravity.

The experiment took place in four expansive ponds; the four ponds were dried for a month, and one ton of organic fertilizer (buffalo dung) was added to each before being refilled with water. Then, one week after refilling, 10,000 common carp larvae weighing 0.104 ± 0.002 grams were added to each pond. The common carp specimens were brought from the Marine Science Center's ponds on 4/2/2019 and transported by a small truck. Artificial food was not provided to the fishes, and they solely relied on natural food as their source of nourishment. Throughout the duration of the experimental research, which continued until the fish's growth ceased (approximately 47 days), the weight of fish samples from each pond was measured using a precise electronic top loading scale. Over this period, five sets of data were gathered for the purpose of calculating the equations described below.

The weight increments (WI, g) can be expressed as the difference between FW and IW.

The formula for calculating the daily growth rate (DGR, g/day) is obtained by subtracting the initial weight (IW) from the final weight (FW) and dividing the result by the number of days.

Specific growth rate SGR, %/day = 100 * [(lnFW) - (lnIW) / days.

It can be measured relatively in percent RGR. When we multiply the final weight by 100 and subtract it from the initial weight, we can get the answer. The general formula shows the relationship of the final weight to the initial one of the fish, and the second is also measured in grams: FW-grams, IW-grams.

During each of the sampling periods, the temperature, pH, and salinity of the water were measured in all the ponds. Samples of zooplankton were collected by filtering water through a 50µ mesh plankton net and fixed with 4% neutral formalin. All samples were examined for identification using a compound binocular Olympus microscope. All measurements are in micrometers, and were taken with a well-calibrated ocular micrometer. The identification of the zooplankton was mainly based on that described in the studies of **Fernando (2002)**, **Al-Yamani and Prusova (2003)** and **Hammadi (2019).**

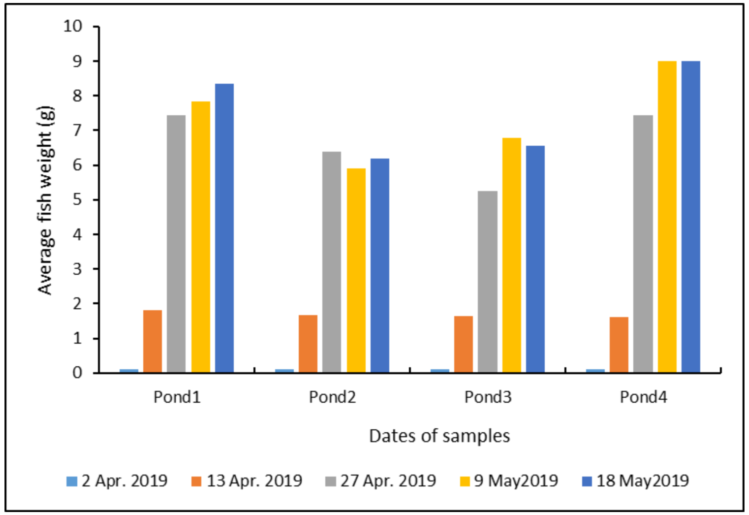
RESULTS

Fig. (1) displays the average fish weight recorded throughout the experiment across four ponds, along with the corresponding measurements of water temperatures, pH levels, and salinities. The accountable files of the fish from ponds 1, 2, 3, and 4 were 8.35, 6.20, 6.55, and 9.01g. The temperature and pH ranged from a low of 21- to a high of 26ºC and from 6.1 to 7.5. While, the salinity varied from 3.3 to 7.3ppt.

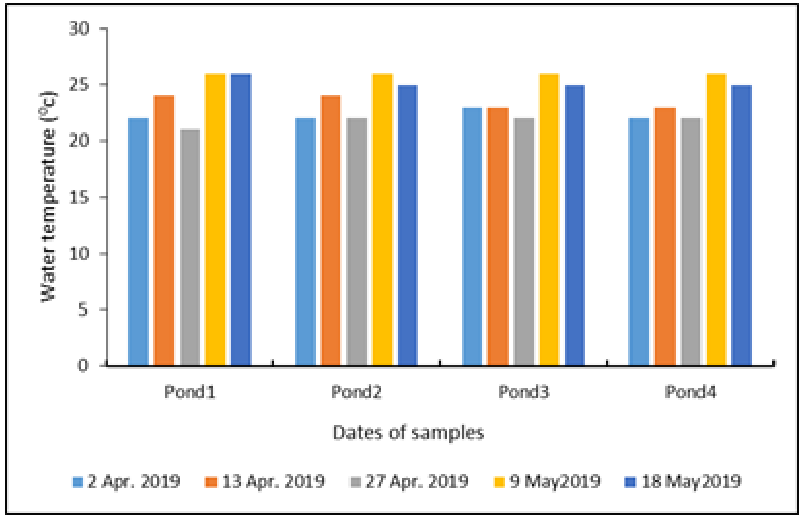
Fig. (2) illustrates various growth standards observed in the common carp experiment. It can be observed that the fish in the four ponds exhibited the highest weight increments during the second period, followed by the first period. However, during the third and fourth periods, the weight increments either decreased or displayed negative values. In Fig. (3a), the four ponds exhibited weight increments of 8.25, 6.10, 6.45, and 8.91g during the experiment. The daily growth rate exhibited a similar progression of weight gains across various ponds. Combined with the values given above, the growth rate of fish in the four ponds calculated was 0.16, 0.12, 0.12, and 0.17g/ day, respectively (Fig. 3b**)**. The growth quickly increases after the ponds are introduced to a fish population, as indicated by these growth rates. Nevertheless, it eventually dropped and became negative to 0.0, as expected in ponds 2 and 3. In Fig. (3c), the specific growth rates of the four ponds were 9.30, 8.67, 8.87, and 9.36% per day, respectively. Conversely, in Fig. (3d), the average specific growth rates of the same four ponds were 4.93, 4.47, 4.33, and 4.58% per day, respectively.

During the experiment, Table (1) provided data on the various types of zooplankton found in pond 1, along with their respective quantities. The most prominent zooplankton group observed was rotifers that was subsequently followed by copepods. The groups had a high number of participants at the start of the experiment, but their numbers significantly dwindled by the conclusion. The total number of copepods in the first sample was 258.90 indi. /L, while it was 15.55 for the final sample. The total number of rotifers for the first sample was 1110 indi. /L, while it was nil for the final sample. Table (2) shows the quality and quantity of zooplankton in pond 2 during experiment. Total numbers of zooplankton were high at the beginning of experiment and very low at the end. Total number of copepod decreased from 430.75 indi. /L at the beginning to 20 at the end, while total number of rotifers decreased from 1025.94 to 8.89 indi. /L.

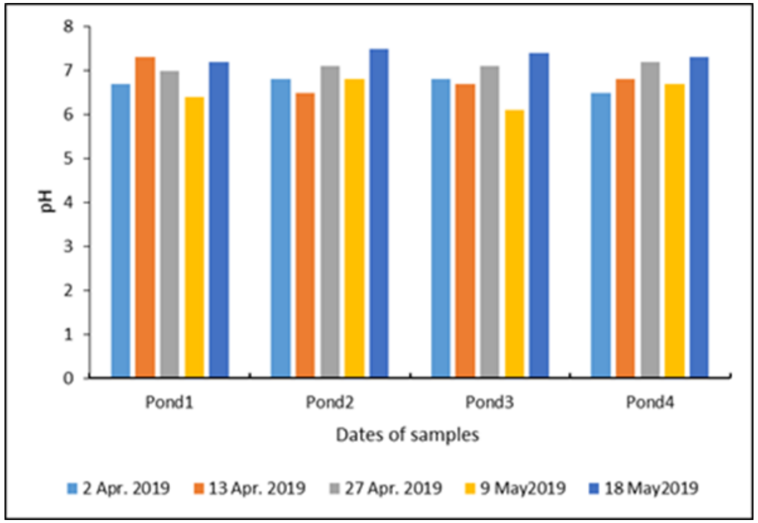
Table 3 shows quality and quantity of zooplankton in pond 3 during experiment. The total numbers of zooplankton decreased from 1482.77 indi. /L at the beginning to 13.33 at the end. The *Copepoda nauplii* specimens were important copepods in all samplings and it decreased from 210.30 to 13.33 indi. /L at the end. The *Brachionus* spp. was the important rotifera that decreased from 435.90 indi. /L at first sample to nil at last sample. Table (4) exhibits the quality and quantity of zooplankton in pond 4 during experiment. Like previous ponds, the main important group of zooplankton were the rotifers, followed by the copepods. The total numbers of the rotifers decreased from 1046.16 indi. /L at the beginning to nil at the end, while the total numbers of the copepods decreased from 220.78 to 20.00 indi. /L at the end.



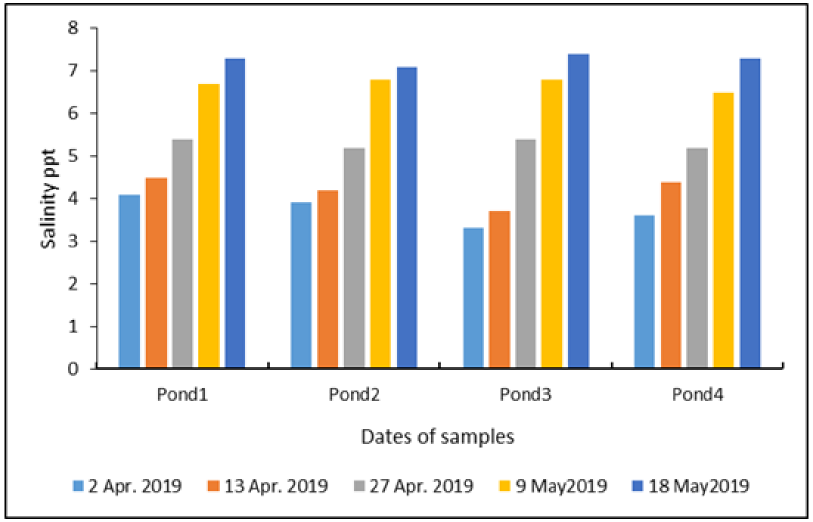
a



b



c



d

Fig. 1 (a- d). Measurements of average fish weight, water temperatures, pH, and salinity during the study period

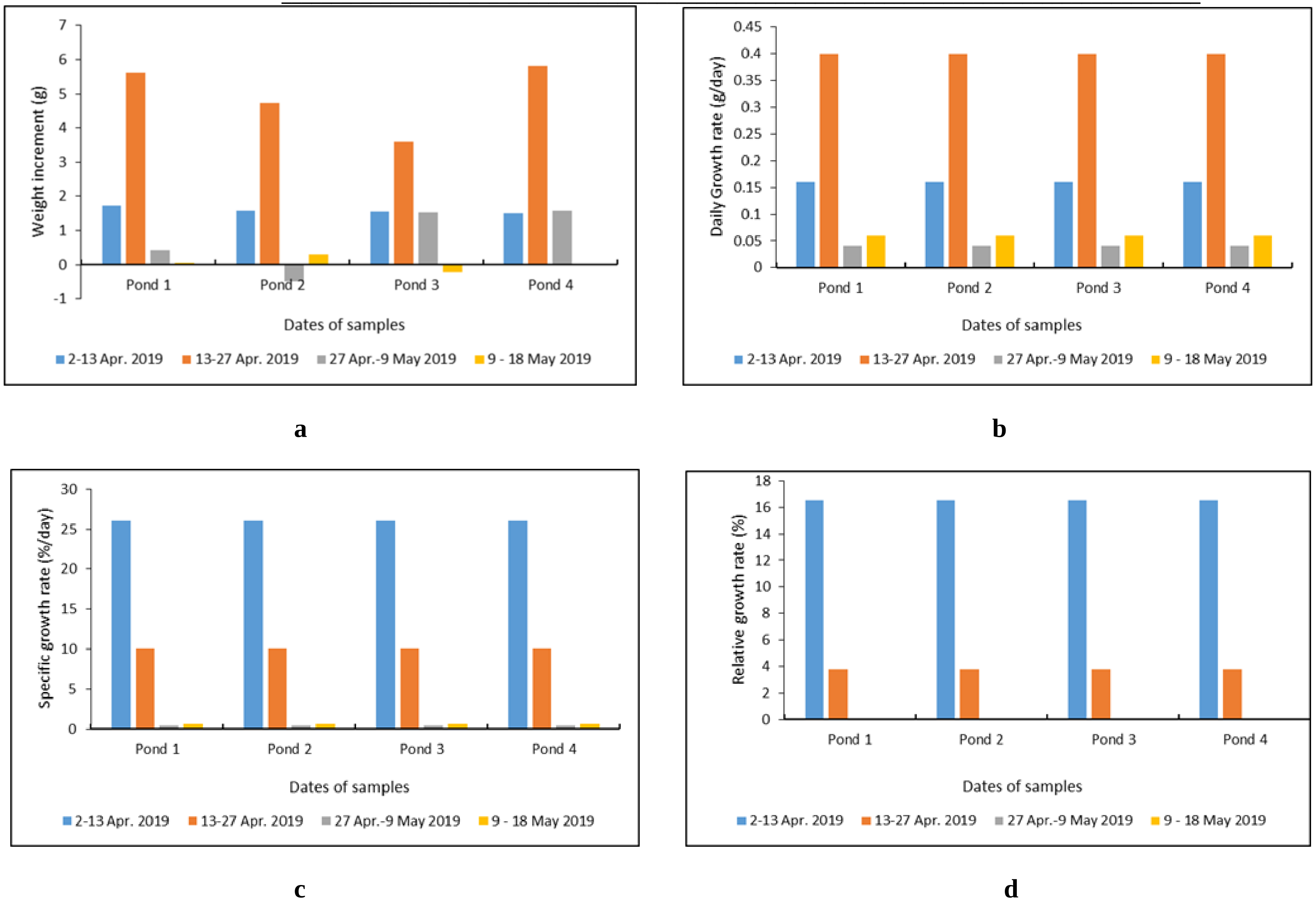


Fig. 2 (a- d). Growth criteria for the common carp fish in the ponds during the study period

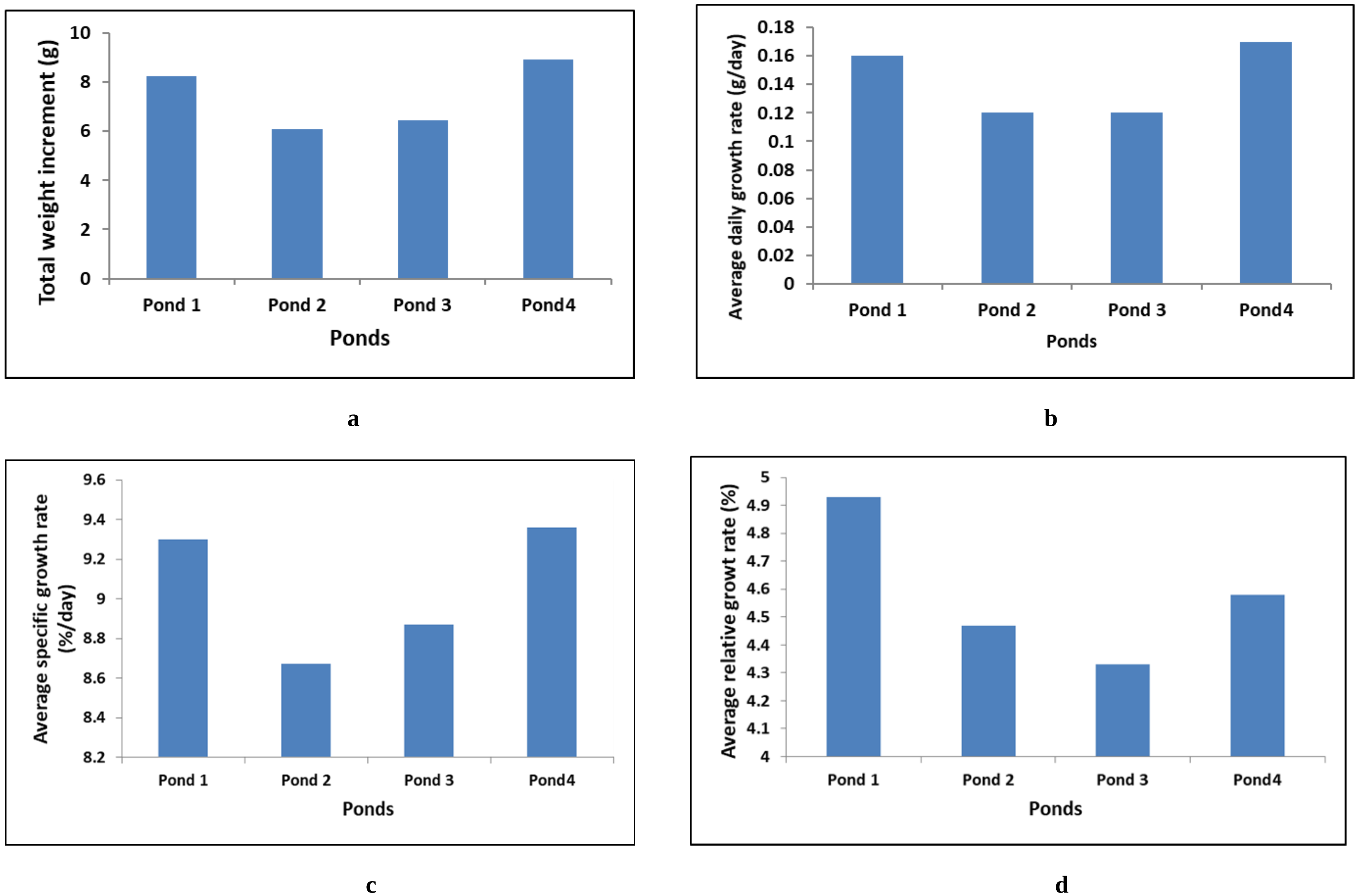


Fig. 4 (a-d). Total weight increment, average daily growth rate, average specific growth rate, and average relative growth rate for ponds during experiment.

Table 1. Diversity and density of zooplankton in pond 1 during the study period

Zooplankton taxa	Zooplankton density (indi./L)				
	2/4/2019	13/4/2019	27/4/2019	9/5/2019	18/5/2019
Cladocera					
Daphnia magna (Straus, 1820)	0	0	5.13	0	0
Total of cladocera	0	0	5.13	0	0
Copepoda					
Acanthocyclops americanus (Marsh, 1893)	0	125.88	0	0	0
Calanoid sp.	10.25	54.91	0	4.04	0
Cyclops sp.	30.77	149.02	15.39	0	2.22
Harpacticoida	10.25	219.61	0	0	0
Paracyclops chiltoni (Thomson, 1882)	5.13	7.85	0	0	0
Copepoda nauplii	202.50	47.06	15.39	12.12	13.33
Total of copepoda	258.90	604.33	30.78	16.16	15.55
Rotifera					
Brachionus calyciflorus (Pallas, 1799)	35.9	0	0	0	0
B. plicatilis (Müller, 1786)	30.77	0	0	0	0
B. urceolaris (Müller, 1773)	143.60	54.91	0	0	0
B. angularis (Gosse, 1751)	0	23.53	0	0	0
B. quadridentatus (Hermann, 1783)	10.25	0	0	0	0
B. rotundiformis (Tschugunff, 1921)	15.39	0	0	0	0
B. rubens (Ehrenberg, 1838)	5.13	0	0	0	0
Brachionus spp.	87.15	78.44	5.13	0	
Bdelloidea	378.70	0	0	0	0
Cephalodella gibba (Ehrenberg,1830)	0	0	0	0	0
Colurella adriatica	88.94	0	5.13	0	0
Keratella heimalis (Carlin, 1943)	10.25	0	0	0	0
K. tropica (Apstein,1907)	0	23.53	56.41	0	0
K.tecta (Gosse,1851)	15.65	0	0	0	0
Polyarthra major	0	7.85	0	0	0
P. euryptera	41.02	0	0	0	0
Polyarthra sp.	0	0	5.13	0	0
Proales sp.	12.67	0	0	0	0
Synchaeta lakowitiziana (Lucks, 1930)	120.50	0	0	0	0
Trichocerca sp.	87.32	0	0	4.04	0
Rotifera eggs	26.76	0	0		
Total of rotifera	1110.00	188.26	71.80	4.04	0
Other zooplankton					
Nematoda	23.44	0	0	0	0
Total of other zooplankton	23.44	0	0	0	0
Total of all zooplankton	1392.43	792.59	107.70	20.20	15.55

Table 2. Diversity and density of zooplankton in pond 2 during the study period

Zooplankton Taxa	Zooplankton density (indi./L)				
	2/4/2019	13/4/2019	27/4/2019	9/5/2019	18/5/2019
Copepoda					
Acanthocyclops americanus (Marsh, 1893)	0	47.06	0	0	0
Calanoid sp.	46.15	0	20.52	0	0
Cyclops sp.	102.56	54.91	30.77	0	2.22
Harpacticoida	10.25	62.74	15.13	4.04	
Copepoda nauplii	271.79	39.21	10.25	4.04	17.78
Total of copepoda	430.75	203.92	76.67	8.08	20.00
Rotifera					
Brachionus calyciflorus (Pallas, 1799)	82.31	0	0	0	0
B. urceolaris (Müller, 1773)	159.23	0	0	0	0
B. angularis (Gosse,1751)	20.54	0	0	0	0
B. rotundiformis (Tschugunff, 1921)	15.39	0	0	0	0
Brachionus spp.	286.92	7.85	0	0	2.22
B. variabilis (Hempel,1896)	240.77	0	0	0	0
Cephalodella gibba (Ehrenberg,1830)	5.13	0	0	0	0
Cephalodella megalotrocha (Wiszniewski,1934)	5.13	0	0	0	0
Hexarthra sp.	0	0	0	4.04	0
K. serrulata (Ehrenberg, 1838)	0	0	0	4.04	0
K. tropica (Apstein,1907)	0	15.68	5.13	0	0
K. quadrata (Műller, 1786)	41.02	0	0	0	0
K. tecta (Gosse,1851)	20.52	0	5.13	8.08	0
Polyarthra major	128.46	39.21	0	0	0
Proales sp.	0	0	0	4.04	0
Synchaeta lakowitiziana (Lucks, 1930)	20.52	0	0	0	0
Trichocerca sp.	0	0	0	0	0
Rotifera eggs	0	0	0	0	6.67
Total of rotifera	1025.94	62.74	10.26	20.20	8.89
Other zooplankton					
Chironomid pupa	0	0	0	4.04	0
Foraminifera	0	0	5.13	0	0
Protozoa	0	0	5.13	0	0
Total of other zooplankton	0	0	10.26	4.04	0
Total of all zooplankton	1456.69	266.66	97.19	32.32	28.89

Table 3. Diversity and density of zooplankton in pond 3 during the study period

Zooplankton Taxa	Zooplankton density (indi./L)				
	2/4/2019	13/4/2019	27/4/2019	9/5/2019	18/5/2019
Cladocera					
Simocephalus vetulus (O. F. Müller, 1785)	5.13	0	0	0	0
Total of Cladocera	5.13	0	0	0	0
Copepoda					
Acanthocyclops americanus (Marsh, 1893)	0	54.91	0	0	0
Calanoid sp.	41.02	47.67	61.54	4.04	0
Cyclops sp.	30.77	54.91	15.13	24.20	0
Harpacticoida	0	23.53	10.13	0	0
Copepoda nauplii	210.3	54.91	15.39	24.20	13.33
Total of copepoda	282.09	235.95	102.19	52.44	13.33
Rotifera					
Ascomorpha ecandis	5.13	0	0	0	0
Brachionus calyciflorus (Pallas, 1799)	35.90	0	0	0	0
B. plicatilis (Müller,1786)	0	0	0	0	0
B. urceolaris (Müller, 1773)	210.30	0	0	0	0
B. angularis (Gosse,1751)	30.77	0	0	0	0
B. quadridentatus (Hermann,1783)	5.13	0	0	0	0
B. rotundiformis (Tschugunff, 1921)	20.52	0	0	0	0
B. variabilis (Hempel,1896)	82.31	0	0	0	0
B. rubens (Ehrenberg, 1838)	138.50	0	0	4.04	0
Brachionus spp.	435.90	7.85	0	0	0
K. tropica (Apstein,1907)	0	0	0	8.08	0
K. valga (Ehrenberg, 1834)	0	0	0	4.04	0
K. quadrata (Műller, 1786)	30.77	0	0	0	0
K. tecta (Gosse,1851)	10.25	0	0	0	0
Lepadella ovalis (müllerl, 1786)	0	0	0	8.08	0
Polyarthra major	113.10	19.61	0	0	0
P. remata	76.92	0	0	0	0
Rotifera eggs	0	0	0	8.08	0
Total of Rotifera	1195.50	27.46	0	32.32	0
Total of all zooplankton	1482.77	263.39	102.19	84.76	13.33

Table 4. Diversity and density of zooplankton in pond 4 during the study period

Zooplankton Taxa	Zooplankton density (indi./L)				
	2/4/2019	13/4/2019	27/4/2019	9/5/2019	18/5/2019
Copepoda					
Acanthocyclops americanus (Marsh, 1893)	0	0	0	0	0
Calanoid sp.	15.39	7.85	36.41	0	2.22
Cyclops sp.	30.77	133.33	20.21	0	2.22
Harpacticoida		23.53	18.77	0	
Copepoda nauplii	174.62	31.38	5.13	32.32	15.56
Total of copepoda	220.78	196.09	80.52	32.32	20
Rotifera					
Anuraeopsis fissa (Gosse, 1851)	15.39	0	0	0	0
Brachionus calyciflorus (Pallas, 1799)	10.25	0	0	0	0
B. urceolaris (Müller, 1773)	348.72	0	0	0	0
*B. angularis (*Gosse,1751)	56.41	0	0	0	0
B. quadridentatus (Hermann,1783)	0	0	0	0	0
B. variabilis (Hempel,1896)	61.54	0	0	0	0
B. rubens (Ehrenberg, 1838)	184.62	0	0	0	0
Brachionus spp.	256.41	0	0	0	0
Bdelloidea	0	7.85	0	0	0
Keratella tropica (Apstein,1907)	15.39	7.85	25.64	12.12	0
K. quadrata (Műller, 1786)	46.15	7.85	0	0	0
K. tecta (Gosse,1851)	5.13	0	0	0	0
Lepadella ovalis (müllerl, 1786)	0	0	0	0	0
Polyarthra major	46.15	0	0	0	0
Total of Rotifera	1046.16	23.55	25.64	12.12	0
Other zooplankton					
Nematoda	0	0	0	0	2.22
Total of other zooplankton	0	0	0	0	2.22
Total of all zooplankton	1266.94	219.64	106.16	44.44	22.22

The total zooplankton decreased from 1266.94 indi. /L in the first sample to 22.22 in the last sample. Table (5) refers to the relationship between the total numbers of zooplankton and growth criteria of common carp in different ponds. Results appeared a non-significant correlation between the total numbers of zooplankton with the weight increments and daily growth rate, while there was a significant correlation between the total numbers of zooplankton in four ponds with a specific and relative growth rate.

Table 5. The correlation coefficient between total numbers of zooplankton and growth criteria

ponds	Correlation factor for different growth criteria			
	WI	DGR	SGR	RGT
Pond 1	0.300	0.367	0.999	0.976
Pond 2	0.168	0.250	0.999	0.999
Pond 3	0.116	0.222	1.000	0.999
Pond 4	-0.029	0.041	0.962	0.995

DISCUSSION

Although the organic fertilizers are consumed directly or as a manure-derived detritus after heterotrophic microbial activity, the extent to which they function as a source of fish food remains poorly understood **(Knud-Hansen *et al*., 1993)**. According to **Elnady *et al*. (2010)**, manure serves as a free fertilizer that enhances the growth of phytoplankton and zooplankton, which are essential sources of natural food. The presence of animal waste contributes to an amplified pond production by engaging in diverse autotrophic and heterotrophic processes, thereby resulting in an augmentation of fish output **(Chiquito-Contreras *et al*., 2022)**. According to the findings of **Dhawan and Kaur (2002)**, there was a notable increase in the abundance of phytoplankton and zooplankton in ponds that received manure compared to ponds without manure. Additionally, the growth of fish was significantly higher in the manured ponds as well. Zooplankton was significantly higher in manured ponds comparing with other treatments **(Kumar *et al*., 2005)**. Organic fertilizers consist of the primary nutrient elements necessary to promote phytoplankton growth. As a result, organic fertilizers contain significant amounts of nutrients crucial for fish production **(Reinl *et al*., 2022)**. **Thanh *et al*. (2023)** observed a notable enhancement in both fish growth and yield in a commercial pond as a result of the application of organic fertilizer, which positively influenced the primary and secondary production.

The results of the current experiment for the four ponds revealed at the beginning of experiment that fish growth was high, then decreased or stopped at the end of experiment. The possible reason for that is the high viability of zooplankton at the beginning of experiment and the gradually decreasing of zooplankton during experiment. This result is supported by a significant high correlation (0.99) between the specific and relative growth rate with the total numbers of zooplankton. Non-significant correlation between weight increments and daily growth rate with total numbers of zooplankton related to the very small weight (0.104 ± 0.002 g) of fish at the beginning of experiment. This mean that fish weight at the beginning of experiment was very suitable to consume zooplankton. **Jaeger and Aubin (2018)** stated that the common carp and roach cultivated extensively had lower growth performances and K- values. They may have been too large to feed effectively in the water column on phytoplankton and zooplankton **(Rahman *et al*., 2010)**. As the carp larvae and fry grow, they gradually consume larger organisms, with zooplankton serving as their primary dietary component **(Anton-Pardo & Adamek, 2015)**. **Taher and Al-Dubakel (2020)** pointed those manured ponds yielded the highest production of the common carp. **Al-Agidi (2008)** found in Babel the same current outcomes, where the occurrence ratio of three sizes of zooplankton measured varied with time, where big and medium sizes of zooplankton were reduced through the experiment period and disappeared in the last month of the experiment.

Results of examination zooplankton in different ponds showed that the main group of zooplankton is rotifers, which consist, at the beginning of experiment, of about 70- 80% of total zooplankton, followed by copepods which consist most of the residual ratio. **Pearson and Duggan (2018)** pointed that the most common taxa of zooplankton were rotifer species, followed by cladocerans with single copepod species found in five ponds. **Anton-Pardo *et al*., (2014)** showed that copepods were the predominant zooplankton group found in the ambient environment for nearly the entire duration of the study, while rotifers were the dominant group in the first sample only. **Kloskowski (2011)** stated that the consumption of zooplankton declined while the consumption of benthic diptera and other insects increased. Additionally, significant quantities of copepods and rotifers were exclusively discovered in the digestive systems of the carp (0-group carp).

Based on the current experiment, it was concluded that, the common carp cultivated in fertilized earthen ponds must be fed by artificial feeding upon reaching a weight range of 6- 8g after around 30- 40 days from hatching.

REFERENCES

FAO (2018). The state of world fisheries and aquaculture: Meeting the sustainable development goals. Rome, License: CC BY-NC-SA 3.0 IGO, 210 pp.

Al-Agidi, H. G. S. (2008). The effect of gradual replacement of a high protein aliment substitute another low protein aliment on carp production. Ms. Sc. Thesis, Al-Musaib Technical College, 146 pp.

Al-Yamani, F. and Prusova, I. (2003). Common copepods of the northwestern Arabian Gulf: Identification Guide. Kuwait Institute for Scientific Research, 161 pp.

Anton-Pardo, M. and Adamek, Z. (2015). The role of zooplankton as food in carp pond farming: a review. Journal of Applied Ichthyology, 31 (Suppl. 2): 7–14.

Anton-Padro, M.; Hlavac, D.; Masilko, J.; Hartman, P. and Adamek, Z. (2014). Natural diet of mirror and scaly carp (*Cyprinus carpio*) phenotypes in earth ponds. Folia Zool, 63 (4): 229-237.

Boyd, C. E. (2018). Aquaculture pond fertilization. CAB Reviews, 13(002): 1-12.

Chiquito-Contreras, R. G.; Hernandez-Adame, L.; Alvarado-Castillo, G.; Martínez-Hernández, M. d. J.; Sánchez-Viveros, G.; Chiquito-Contreras, C. J.; Hernandez-Montiel, L. G. (2022). Aquaculture—Production System and Waste Management for Agriculture Fertilization—A Review. Sustainability 14(7257): 1-13. https://doi.org/10.3390/su14127257

Davis, A. D.; Derbes, T. J. and Head, M. E. (2018). Culture of Small Zooplankton for the Feeding of Larval Fish. SRAC Publication No. 0701: 1-6.

Dhawan, A. and Kaur, S. (2002). Pig dung as pond manure: Effect on water quality, pond productivity and growth of carps in polyculture system. NAGA, the ICLARM quarterly, 25(1):11-14.

Elnady, M. A.; Hassanien, H. A.; M.A. Salem, M. A. and Marian Samir, H. (2010). Algal Abundances and Growth Performances of Nile Tilapia (*Oreochromis niloticus*) as Affected by Different Fertilizer Sources. Journal of American Science, 6(11): 584-393.

Fernando, C. H. (2002). A guide to tropical freshwater zooplankton, identification, ecology and impact on fisheries. Backhuys Publishers, Leiden, 291 pp.

Hammadi, N. S. (2019). An ecological study of the Rotifera of Shatt Al-Arab Region. LAP LAMBERT Academic Publishing, 351pp.

Hammadi, N. S.; Ankush, M. A. T.; Taher, M. M.; Al-Dubakel, A. Y. and Muhammed, S. J. (2024). Impact of phytoplankton on the growth of common carp *Cyprinus carpio* L. larvae. Egyptian Journal of Aquatic Biology & Fisheries, 28(2): 1101-1118.

Hussein, M. S. (2012). Effect of organic and chemical fertilization on growth performance, phytoplankton biomass and fish production in carp polyculture system. Egyptian Journal of Aquatic Biology & Fisheries, 16(2): 133 – 143.

Jaeger, C. and Aubin, J. (2018). Ecological intensification in multi-trophic aquaculture ponds: an experimental approach. Aquat. Living Resour. 31-36: 1-12.

Khan, T. A.; Wilson, M. E. and Khan, M. T. (2003). Evidence for invasive carp mediated trophic cascade in shallow lakes of western Victoria, Australia. Hydrobiologia, 506-509: 465-472.

Kloskowski, J. (2011). Differential effects of age-structured common carp (*Cyprinus carpio*) stocks on pond invertebrate communities: implications for recreational and wildlife use of farm ponds. Aquac. Int. 19: 1151–1164.

Knud-Hansen, C. F.; Batterson, T. R. and Mcnabb, C. D. (1993). The role of chicken manure in the production of Nile tilapia, *Oreochromis niloticus* (L.). Aquacult. Fish. Manage., 24(4): 483-493.

Kumar, M. S.; Binh, T. T.; Burgess, S. N. and Luu, L. T. (2005). Evaluation of optimal species ratio to maximize fish polyculture production. Journal of Applied Aquaculture, 17(1): 35-49.

Mageed, A. A. and Konsowa, A. H. (2002). Relationship between phytoplankton, zooplankton and fish culture in a freshwater fish farm. Egyptian Journal of Aquatic Biology & Fisheries, 6(2): 183 – 206.

Mohale, H. P.; Sarang, N. and Desai, A. Y. (2020). The Common Carp and its Culture System Management. Academic Publications, 103pp.

Palupi, M.; Kasprijo; Wijaya, W.; Chanda, R. A.; Azhari, R. F. and Fitriadi, R. (2023). Biodiversity and abundance of phytoplankton in rice-fish farming system. Iraqi Journal of Agricultural Sciences, 54(4):1084-1093.

Pearson, A. A. C. and Duggan, I. C. (2018). A global review of zooplankton species in freshwater aquaculture ponds: what are the risks for invasion? Aquatic Invasions,13(3): 311–322.

Piska, R. S. and Naik, S. J. K. (2013). Introduction to fresh water aquaculture. Intermediate vocational course State Institute of Vocational Education and Board of Intermediate Education, Piska, R. S. (Ed). Department of Zoology, University College of Sciences, Osmania Univ., 305 p.

Rahman, M. M. and Verdegem, M. C. J. (2007). Multi-species fishpond and nutrients balance. In: ven der Zijpp, A. J.; Verreth, A. J. A.; Tri, L. Q.; ven Mensvoort, M. E. F.; Bosma, R. H. and Beveridge, M. C. M. editor. Fishponds in farming systems. Wageningen: Wageningen. Academic Publishers: 79–88.

Rahman, M. M, Kadowaki, S.; Balcombe, S. R. and Wahab, Md. A. (2010). Common carp (*Cyprinus carpio* L.) alters its feeding niche in response to changing food resources: direct observations in simulated ponds. Ecol. Res., 25: 303–309.

Rahman, M. M.; Verdegem, M. C. J.; Nagelkerke, L. A. J.; Wahab, M. A.; Milstein, A, and Verreth, J. A. J. (2006). Growth, production and food preference of rohu *Labeo rohita* (H.) in monoculture and in polyculture with common carp *Cyprinus carpio* (L.) under fed and non-fed ponds. Aquaculture, 257: 359–372.

Reinl, K. L.; Harris, T. D.; Elfferich, I.; Coker, A.; Zhan, Q.; De Senerpont Domis, L. N.; Morales-Williams, A. M.; Bhattacharya, R.; Grossarti, H.; North, R. L. and Sweetman, J. N. (2022).

The role of organic nutrients in structuring freshwater phytoplankton communities in a rapidly changing world. Water Research, 219(118573): 1-19.

Taher, M. M. and Al-Dubakel, A. Y. (2020). Growth Performance of Common Carp (*Cyprinus carpio*) in Earthen Ponds in Basrah Province, Iraq by Using Different Stocking Densities. Biol. Appl. Environ. Res., 4(1): 71-79.

Thanh, D. T.; Ty, N. M.; Hien, N. V.; Berg, H.; Nguyen, T. K. O.; Vu, P. T.; Minh, V. Q. and Da, C. T. (2023). Effects of organic fertilizers produced from fish pond sediment on growth performances and yield of Malabar and *Amaranthus* vegetables. Front. Sustain. Food Syst. 7:1045592. doi: 10.3389/fsufs.2023.1045592

Weber, M. J., & Brown, M. L. (2009). Effects of Common Carp on Aquatic Ecosystems 80 Years after "Carp as a Dominant": Ecological Insights for Fisheries Management. Reviews in Fisheries Science, 17(4), 524–537. https://doi.org/10.1080/10641260903189243

Woynarovich, A.; Bueno, P. B.; Altan, Ö.; Jeney, Zs.; Reantaso, M.; Xinhua, Y. and Van Anrooy, R. (2011). Better management practices for carp production in Central and Eastern Europe, the Caucasus and Central Asia. FAO Fisheries and Aquaculture Technical Paper. No 566, Ankara, FAO, 153 pp.

Zambrano, L., and Hinojosa, D. (1999). Direct and indirect effects of carp (*Cyprinus carpio* L.) on macrophyte and benthic communities in experimental shallow ponds in central Mexico. Hydrobiologia, 408/409: 131-138.