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Research Article

Effect of feeding level on water quality and plankton community structure in the yellow catfish (*Pelteobagrus fulvidraco*) rearing enclosure ecosystem

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Abstract

Four feeding levels (40%, 60%, 80% and 100% of satiation) were designed as the different treatment groups to assess its effects on water quality and plankton community structure in the yellow catfish rearing enclosure ecosystem. The results showed that the weight gain and specific growth rate decreased significantly as the feeding level decreased. The soluble nutrients (except for NO_2-N) concentrations were significantly affected by the feeding level with the prolonging of rear time. A significant increase in phytoplankton biomass before 9 days was observed in all the treatments, and then decreased significantly until 21 days, while the zooplankton biomass was significantly increased during the entire experiment. Both the phytoplankton and zooplankton biomass were significantly affected by the feeding level. Our results suggested that the increment of nitrogen compounds before 9 or 12 days could be explained by the input of compound diets, while the decrement of nitrogen compounds afterward and phosphorous compounds could be explained by the changes of zooplankton biomass. Based on water quality and plankton structure, moderate nutrient restriction (60%-80% of satiation) is a feasible feeding strategy for better growth performance as well as better water quality and balanced plankton structure. On the other hand, input of moderate phosphorus by dietary supplementation and/or fertilization is necessary in yellow catfish culture both for the better plankton structure and the health of fish. In addition, the polyculture of the minority members of zooplankton filter feeders might be a feasible strategy to control the excessive zooplankton.

Keywords: Feeding, Water quality, Plankton, *Pelteobagrus fulvidraco*, Enclosure ecosystem

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Introduction

Currently in inland China, intensive pond aquaculture is the dominated aquaculture model. Pond aquaculture has developed rapidly over the last few decades in China; however, the enormous expansion has been accompanied by strong controversies on the environmental and economic impacts. Traditionally, fishpond farmers preferred using cheaper materials such as poultry and swine waste, food waste and agriculture waste as fertilizer stuff in aquaculture ponds (Wong *et al*., 2004; Mo *et al*., 2014). In the last few years, the aquacultural fish species have turned from traditional major Chinese carp (e.g. *Hypophthalmichthys molitrix* and *Aristichthys nobilis*) to high economical species (e.g. *Pelteobagrus fulvidraco* and *Siniperca chuatsi*) resulted from the developing of commercial diet industry and aquaculture technique.

In fishpond aquaculture, the advanced approaches for cost-effective and environment-friendly water quality control are highly expected. However, high stocking density and unreasonable feeding strategy always lead the aquatic ecosystem to bad condition. It is commonly known that a favourable aquatic ecosystem depends on the community and biomass of phytoplankton, because they are primary producers for the entire aquatic body and comprise the major portion in the ecological pyramids (Chisti, 2007; Lukwambe *et al*., 2015). Low level of phytoplankton biomass is unacceptable in fishpond, it responds to low dissolved oxygen levels and high toxic contaminants which may reduce growth and breed pathogens (Casé *et al*., 2008). Various efforts have been done to reveal the change of plankton community structure and water quality (Arcifa *et al*., 1986; Reid *et al*., 2000; Dalsgaard and Krause-Jensen, 2006; Skejić *et al*., 2011; Huang *et al*., 2012; Hoque *et al*., 2014; Mo *et al*., 2014; Lukwambe *et al*., 2015).

Yellow catfish (*P. fulvidraco*), a freshwater omnivorous fish, is one of the most commercially important cultured species in China because of the high nutritive and economic values (Ruan *et al*., 2015; Shen *et al*., 2015). In yellow catfish rearing ponds, a uncommon and interesting phenomenon was observed in practice, which was that abundant zooplankton was found while the phytoplankton was barely observed. For a fishpond, this unbalanced plankton community structure is disastrous to aquatic fish because the zooplankton would plunder the dissolved oxygen. Under this condition, discontinuous use of pesticide is one of the effective solutions, however it is not acceptable for a perspective of healthful aquaculture and food safety. This attractive phenomenon give us several scientific problems, such as why occur, what affect it and how to solve it. Consequently, the objective of the present study was to determine the effect of feeding level on water quality and plankton community structure and provide information to answer the above questions.

Materials and methods

Experimental fish and enclosure ecosystem

The experimental yellow catfish juveniles were obtained from a local fish farm (Qichun, China) and the juveniles were weaned to compound diet. A total of 2400 fingerlings (initial weight=7.59±1.25 g, initial total length=7.37±0.92 cm) were

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randomly distributed in 12 enclosure ecosystems (2 m×2 m×1.5 m) (200 fish each) with 1 m depth of water which placed in a earth fishpond (1 hm^2). The rectangular enclosures made of opaque high density polyethylene plastic-coated fabric were set up at a site of 1.8 m depth (30 cm were buried into mud to ensure no water exchange between external and internal enclosure). A 1.5 KW aerator was assembled to maintain the favorable dissolved oxygen.

Fish rearing

Four feeding levels were designed as the different treatment groups, group F1 (100% of satiation), group F2 (80% of satiation), group F3 (60% of satiation) and group F4 (40% of satiation), and each group had three replicates. In present study, apparent satiation was defined as the 100% of satiation, and the feeding amounts were recorded. The feeding amount of 80% of satiation group=80% × the feeding amount of 100% of satiation and so on. And the feeding amount of 100% of satiation was corrected every three days to adjust the somatic growth. All the experimental fish were fed a commercial compound diet (crude protein ≥ 40%, crude lipid ≥ 4%) manually in two rations per day (9:00 and 17:00) and the residual feeds were collected, dried, weighed and recorded after the end of feeding. The aerator worked 11 hours (12:00-14:00 and 23:00-8:00) at least every day. Water temperature, pH and dissolved oxygen were recorded as follows during the 21 d (from 10 May to 31 May, 2016) of experimental time: water temperature 18-25 ℃, pH 6.8-8.0, dissolved oxygen 3.0-6.0 mg L^{-1}, respectively.

Sample collection and preparation

The water and plankton samples were collected at 0, 3, 6, 9, 12, 15, 18 and 21 d. These samples were collected at the water depth from 30 to 50 cm. Water samples for water quality assay were collected by an organic glass water sampler (1 L), added 1 ml trichloromethane immediately and analysed in 24 h. The samples for phytoplankton analysis were collected with a 1-L organic glass water sampler and stained with Logoul's iodine (Zhao, 2005). Then the sample was transferred and precipitated for 24 h. The supernatant was siphoned and the lower sediment was collected for phytoplankton assay. Zooplankton sampling was conducted according to Rahman *et al*. (2008), Mo *et al*., (2014) and Ćirić *et al*., (2015). At the end of experiment, 50 individuals of fish each enclosure were randomly collected for growth performance evaluation.

Sample analysis

Water nutrient parameters, viz. total phosphorous (TP), total nitrogen (TN), nitrite nitrogen (NO_2-N), nitrate nitrogen (NO_3-N), ammonia nitrogen (NH_4-N), phosphate phosphorous (PO_4-P) were determine spectrophotometrically following standard methods (APHA, AWWA. and WPCF, 2012). For phytoplankton and zooplankton samples, 1 ml of the prepared solution from the concentrated sample were used for identification and counting using the methods described by Zhao (2005) and MWR and YWEMC (2012).

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Calculations

Weight gain (WG, %) = [(final weight (g) - initial weight (g)) / initial weight (g)] × 100,

Specific growth rate (SGR, %/d) = [ln final weight (g) - ln initial weight (g)] / feeding period (day) × 100,

Condition factor (CF) = final weight (g) / [final length (cm)]^3 × 100,

Phytoplankton density (ind ml^{-1}) = [C_s / (F_s× F_n)]×(V/v)×P_n;

where C_s is area of phytoplankton cell counting chamber (usually 400 mm^2); F_s is the area of one field (mm^2); F_n is the counting filed number; V is the volume of lower sediment of phytoplankton sample (ml); v is the volume of counting chamber; P_n is the numbers of phytoplankton in F_n fileds (Zhao, 2005).

The biomass of phytoplankton is calculated using the species specific cell-wet weight relationship (Zhao, 2005).

Zooplankton density (ind L^{-1}) = (V_s × n) / (V × V_a);

where V_s is the volume of zooplankton sample after filtered (ml); n is the counting numbers of zooplankton; V_a is the volume of sample for counting; V is the volume of collected zooplankton sample (10 L) (Zhao, 2005).

Values of the measured variables are expressed as mean±standard deviation. The variance homogeneity of the data was performed using Levene's test. Data were compared by one-way ANOVA followed by Duncan's test when significant differences were found at 0.05 level. Statistics were performed using SPSS 18.0 software (SPSS Inc. Chicago, IL, USA).

Results

Growth performance

The results of growth performance including final weight, weight gain, specific growth rate and condition factor of juvenile yellow catfish are shown in Table 1. Weight gain and specific growth rate decreased significantly as the feeding level decreased (p<0.05), while the condition factor was not affected by the feeding level.

Table 1: Effect of feeding level on growth performance of yellow catfish.

Group	Final weight (g)	WG (%)	SGR (%/d)	CF
F1	15.39±2.51^a	102.77±10.74^a	2.95±0.15^a	1.88±0.12
F2	14.29±2.31^{ab}	88.27±7.43^b	2.64±0.16^b	1.82±0.14
F3	11.03±2.10^{bc}	45.32±5.27^c	1.56±0.11^c	1.73±0.11
F4	9.23±1.72^c	21.61±2.01^d	0.82±0.09^d	1.71±0.21

Note: Initial weight =7.59±1.25 g;

Different superscripts (a, b, c) between feeding level groups are significantly different (p<0.05).

Water quality

The changes in concentrations of soluble nitrogen and phosphorous compounds are shown in Figs. 1 and 2, respectively. A general increment trend in NO_2-N and decrement trend in phosphorous compounds (PO_4-P and TP) was observed during the entire experiment. While the other soluble nutrients (NO_3-N, NH_4-N and TN) were significant increased before 9 or 12 days, then decreased significantly until the end of the experiment. The soluble nutrients (except for NO_2-N) concentrations were significantly affected

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by the feeding level with the prolonging of rear time. The highest TN concentration was found in group F1, while the highest TP concentration was found in group F4.

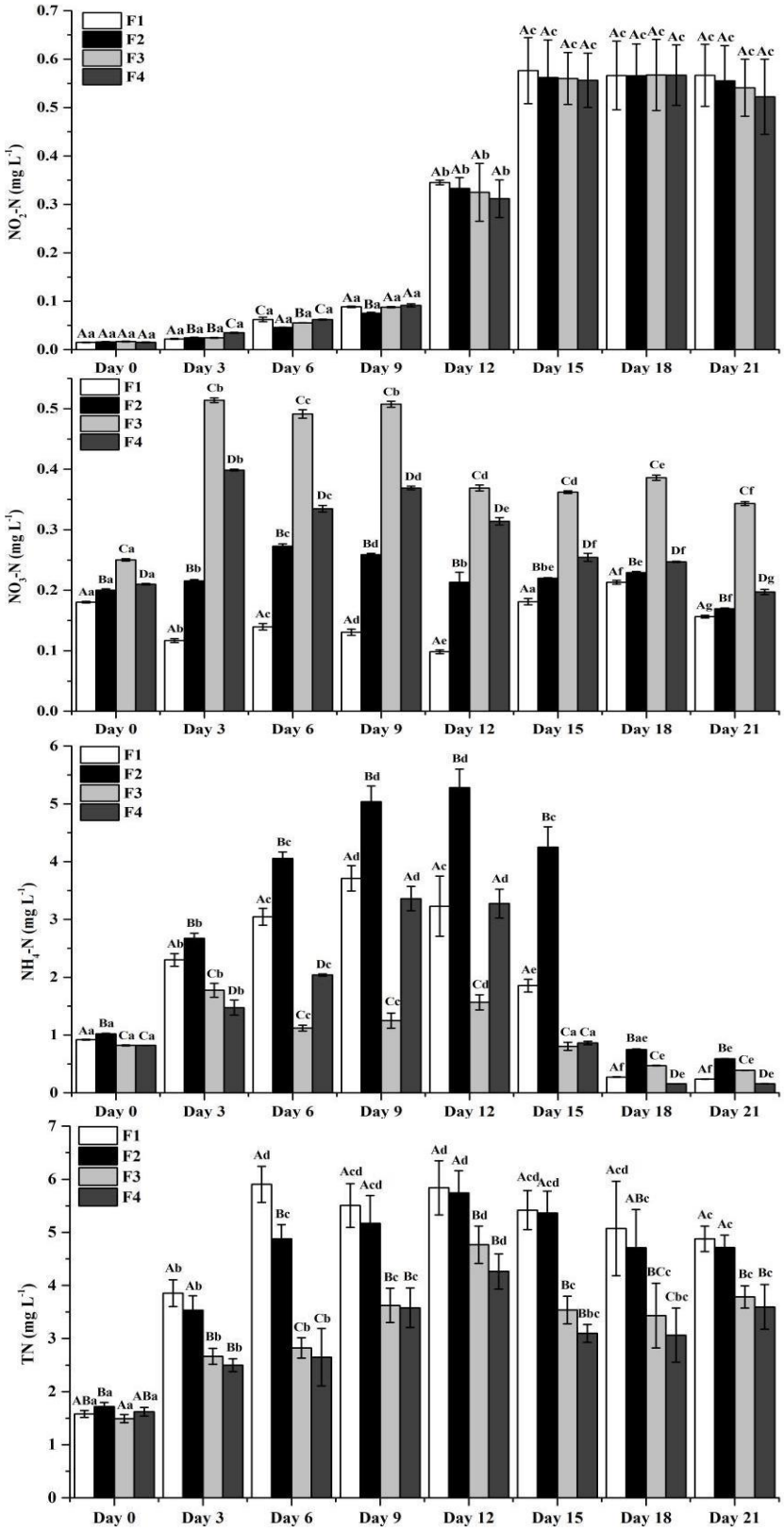

Figure 1: Effect of feeding level on nitrogen compounds in the yellow catfish rearing enclosure ecosystem. Different uppercase superscripts in same sample time and different lowercase superscripts in same feeding level are significantly different (p<0.05).

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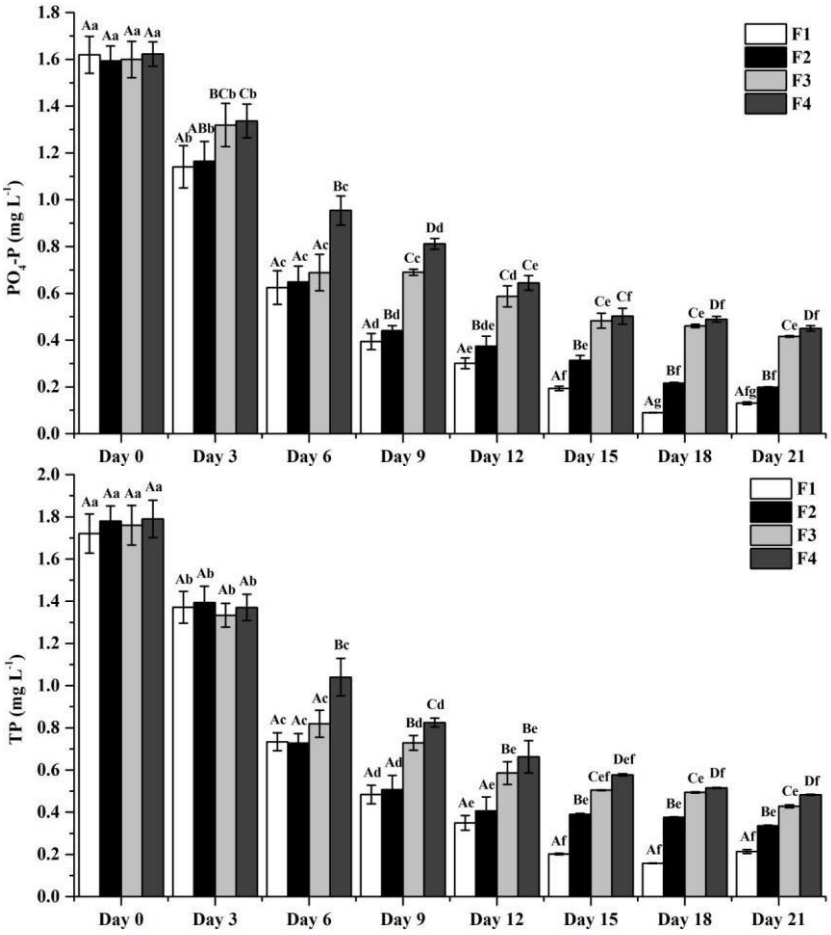

Figure 2: Effect of feeding level on phosphorous compounds in the yellow catfish rearing enclosure ecosystem. Different uppercase superscripts in same sample time and different lowercase superscripts in same feeding level are significantly different (*p*<0.05).

Plankton community structure

We have identified a total of 86 species of phytoplankton arranged in seven phylum (Chlorophyta, Cyanophyta, Bacillariophyta, Euglenophyta, Cryptophyta, Pyrrophyta and Xanthophyta) and 58 genera, and a total of 46 species of zooplankton arranged in four categories (Protozoa, Rotifera, Cladocera, Copepoda) and 32 genera. The plankton composition and plankton biomass in different feeding level groups are summarized in Table 2 and Fig. 3, respectively. A significant increase in phytoplankton biomass before 9 days was observed in all the treatments, and then decreased significantly until 21 days, while the zooplankton biomass was significantly increased during the entire experiment. Both the phytoplankton and zooplankton biomass were significantly affected by the feeding level, and the highest phytoplankton biomass and the lowest zooplankton biomass were found in group F4 and F2, respectively.

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Table 2: The plankton composition in different feeding level groups.

Categories		x species arranged in y genera			
		F1	**F2**	**F3**	**F4**
Phytoplankton	Chlorophyta	37/21	32/19	31/19	33/19
	Cyanophyta	17/12	15/11	18/13	13/10
	Bacillariophyta	10/8	10/9	9/7	10/8
	Euglenophyta	8/7	5/4	6/6	5/5
	Cryptophyta	1/1	1/1	1/1	1/1
	Pyrrophyta	2/2	1/1	2/2	2/2
	Xanthophyta	1/1	1/1	1/1	1/1
	Total	76/52	65/41	68/49	65/46
Zooplankton	Protozoa	20/15	19/16	21/15	20/15
	Rotifera	17/12	17/11	18/12	18/12
	Cladocera	2/2	2/2	2/2	2/2
	Copepoda	2/2	3/2	3/2	3/2
	Total	41/31	41/31	44/31	43/31

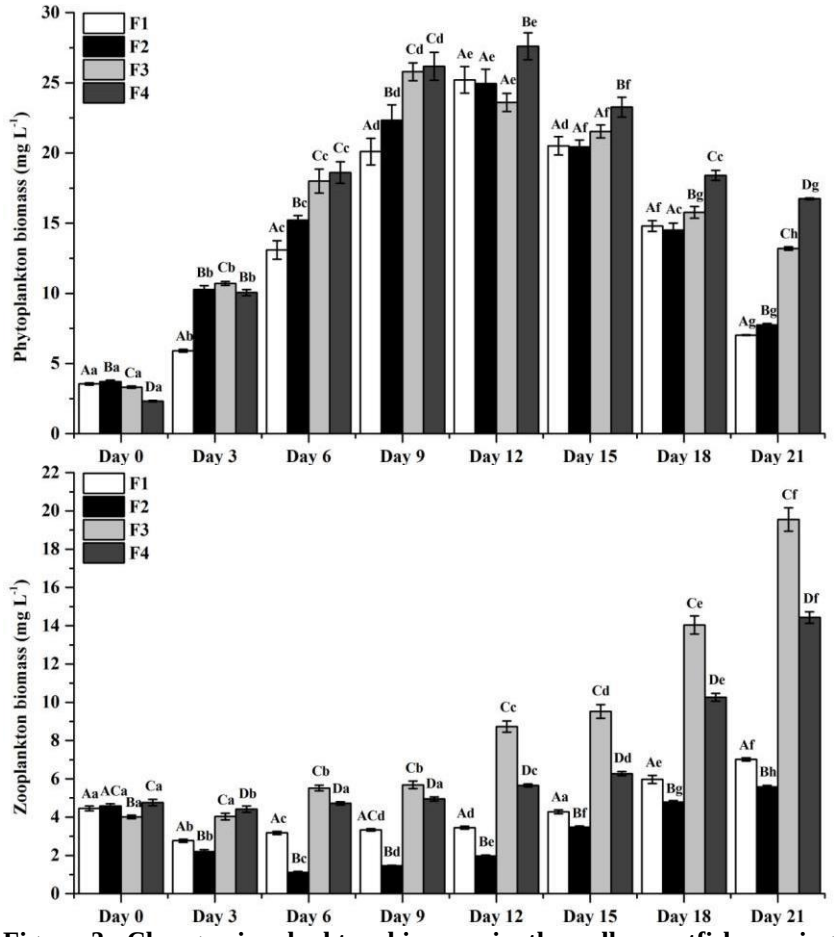

Figure 3: Changes in plankton biomass in the yellow catfish rearing enclosure ecosystem. Different uppercase superscripts in same sample time and different lowercase superscripts in same feeding level are significantly different (*p*<0.05).

Discussion

There are many good reasons to study optimum feeding level in fish because of its economic and environmental relevance. For instance, lower feeding level (50% of near satiation) have the highest feed efficiency ratio in *Oncorhynchus mykiss* rearing (Bureau *et al*., 2006), lower feeding level would result in slowest rates of protein degradation and highest levels

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of nutrient retention in *O. mykiss* (Cleveland *et al*., 2012), moderate nutrient restriction is an optimum feeding strategy for fish retained for additional breeding cycles (Manor *et al*., 2015). In the present study, the growth decreased significantly as the feeding level decreased as reported in many species, such as *O. mykiss* (Bureau *et al*., 2006), *Paralichthys olivaceus* (Cho *et al*., 2006, 2007), *Acanthopagrus schlegeli* (Guo *et al*., 2015) and *Meiacanthus atrodorsalis* (Moorhead and Zeng, 2017). However, the maximum feed efficiency ratio is reported to have been achieved at feeding levels that required for maximum growth (Bureau *et al*., 2006; Cho *et al*., 2006, 2007), suggesting that feed efficiency ratio archives its maximum at moderate feed restriction and this optimum is maintained up to maximum voluntary feed intake of the fish.

Appropriate water quality in earthen ponds benefited fish for prospering plankton as foods and dissolved oxygen source, and poor water quality easily resulted in lessening fish yields and cheapening production quality. However, the balanced and stable water quality is quite hard in aquaculture, it is affected by human activities and/or other abiotic factors (e.g. aquaponics, application of microbial products, stocking density, fish transport) (Salam *et al*., 2013; Broach *et al*., 2016; Sampaio and Freire, 2016; Tang *et al*., 2016). In this study, the NO_3-N, NH_4-N and TN concentrations were significant increased before 9 or 12 days, then decreased significantly until the end of the experiment. The increment of nitrogen compounds before 9 or 12 days could be explained by the input of compound diets, while the decrement of nitrogen compounds afterward and phosphorous compounds could be explained by the changes of zooplankton biomass. The similar phenomenon has been described in the food waste based diets polyculture ponds (Mo *et al*., 2014). The soluble nutrients (except for NO_2-N) concentrations and plankton biomass were significantly affected by the feeding level under the present experimental condition. The lowest NH_4-N/TN concentrations and highest NO_3-N concentration were observed in group F3, suggesting that sufficient nitrobacteria have produced NO_3-N from NH_4-N. The lowest zooplankton biomass was found in group F2 indicated that the feeding level at 80% of satiation was optimal for yellow catfish culture. Based on water quality and plankton structure, moderate nutrient restriction (60%-80% of satiation) is a feasible feeding strategy for better growth performance as well as better water quality and balanced plankton structure.

It is notable that the soluble phosphorous compounds decreased significantly with the rearing time and the phytoplankton biomass increased significantly before 9 days, then decreased significantly. Besides, the PO_4-P and TP concentrations in the higher feeding level group were significant low than the lower group. These results suggested that the compound diets fed in the present experiment was not added. However, the soluble phosphorous compounds are a restrictive factor for growing of phytoplankton (Hessen *et al*., 2007; Liess *et al*., 2009). Consequently, the dramatic increase of zooplankton biomass was observed after 9 days. It is well known that

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excessive zooplankton density would consume too much dissolved oxygen, causing the fish stock to suffocate (Lau *et al*., 2003). In the present study, the similar slower growth was also found in group F3 and F4 accompanied with the higher zooplankton biomass. On the other hand, phosphorus is also important for body metabolism as well as immunity of fish (Chen *et al*., 2017). Therefore, input of moderate phosphorus by dietary supplementation and/or fertilization is necessary in yellow catfish culture both for the better plankton structure and the health of fish. In addition, some zooplankton filter feeders like *Hypophthalmichthys nobilis* would be helpful for control the density of zooplankton (Mo *et al*., 2014). Thus, the polyculture of the minority members of zooplankton filter feeders might be a feasible strategy to control the excessive zooplankton.

In conclusion, the growth performance of juvenile yellow catfish decreased significantly as the feeding level decreased because of the reduction of food intake. The increment of nitrogen compounds before 9 or 12 days could be explained by the input of compound diets, while the decrement of nitrogen compounds afterward and phosphorous compounds could be explained by the changes of zooplankton biomass. Based on water quality and plankton structure, moderate nutrient restriction (60%-80% of satiation) is a feasible feeding strategy for better growth performance as well as better water quality and balanced plankton structure. On the other hand, input of moderate phosphorus by dietary supplementation and/or fertilization is necessary in yellow catfish culture both for the better plankton structure and the health of fish. In addition, the polyculture of the minority members of zooplankton filter feeders might be a feasible strategy to control the excessive zooplankton.

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