The Assessment of Water Quality and Primary Productivity in Earthen Fishponds Stocked with Stripped Mullet (*Mugil cephalus*) and Subjected to Different Feeding Regimes

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Abstract

The effects of different feeding regimes of striped mullet (*Mugil cephalus*) on water quality and phytoplankton fluctuations in earthen fishponds were studied. Striped mullet (35.1 ± 1 g) was stocked at a rate of 1 fish/m^2 for 105 days. The first treatment ponds (control) received only organic and inorganic fertilizers. The second treatment ponds (T1) received organic and inorganic fertilizers as in the first treatment and supplemental feed at a rate of 3% of fish body weight (bw). The third treatment ponds (T2) received only supplemental feed at a rate of 5% of bw. Each treatment was represented by three replicates. Results revealed that there were no significant differences in water temperature, pH, free ammonia, and water conductivity among the treatments. Dissolved oxygen, orthophosphate and nitrate concentrations in control and T1 ponds were significantly higher than those of T2 ponds. Water turbidity was significantly higher in T1 ponds than that of the other treatment ponds. Phytoplankton and zooplankton abundances were significantly higher in control and T1 ponds than those of T2 ponds. The final weight of striped mullet was maximized at T2 ponds, while the lowest one was in control ponds. It could be concluded that striped mullet could utilize both supplemental and/or natural food.

Key Words: Water quality, phytoplankton, zooplankton, supplemental feed, striped mullet, growth.

Introduction

Phytoplankton is a functional aquatic community base upon which the aquatic food web is culminating (Reynolds, 1984). Studies on physico-chemical factors and phytoplankton standing crop of its habitat are essential for the proper management of water resources and for the prediction of the potential changes in the aquatic ecosystem (Kobia, 1982; Descy, 1987). Sheehan (1984) reported that phytoplankton populations are mostly structured by the physical and chemical variables of their environment. These factors have also been reported to be responsible for the heterogeneity in phytoplankton composition and biomass (El-Ayouty *et al*., 1994, 1999; Ahmad *et al*., 2001; Ibrahim *et al*., 2003).

Striped mullet (*Mugil cephalus*) is one of the best-known members of Mugilidae and has significant commercial value in many countries (Oren, 1981). It is a euryhaline marine teleost that inhabits coastal waters but enters estuaries and rivers (Harrison and Senou, 1997), and it is widely cultured in both brackish and freshwater semi-intensive fishponds (Lupatsch *et al*., 2003). As adults, they eat all available food, microalgae including apiphytic and benthic forms, and decaying plant detritus. They feed at the lowest trophic level, being able to utilize the direct algal grazing or plant detritus as energy sources (Odum, 1970; Brusle, 1981). Porter *et al*. (1996) indicated that striped mullet is able to reduce the organic matter in the sediment underneath the cages. Moreover, Jana *et al*. (2004) found that grey mullet (*M. cephalus*) could efficiently use peryphyton that colonized the bamboo substrates in inland saline groundwater. Thus, Katz *et al*. (2002) and Lupatsch *et al*. (2003) used striped mullet (*Mugil cephalus*) to remove the organic matter deposited on the sea floor due to the deposition of solid waste from undigested feed. In Abbassa fishponds, striped mullet is one of the most important components of fish polyculturing system.

Organic and/or inorganic fertilizers are used in pond fertilization. Many studies have shown positive correlation between pond fertilization and fish production (Schroeder, 1974; Boyd, 1984; Abdel-Tawwab *et al*. 2002 a, b). Increases in fish production in fertilized ponds were attributed to the increments in primary productivity (Diana *et al*., 1991; Ahmad *et al*. 2001; Abdel-Tawwab *et al*., 2002a; 2002b). Phytoplankton in turn increases secondary production (zooplankton); thereby producing greater yields of fish (Stickney, 1979; Seymour, 1980).

The main aim of this study was to evaluate the phytoplankton productivity in relation to pond management. Also, the impact of striped mullet (*M. cephalus*) on phytoplankton abundance in fishponds that received either organic or inorganic fertilizers and/or artificial feed was studied.

Materials and Methods

The study was conducted in nine earthen ponds (surface area 1,000 m^2 each) at Central Laboratory of Aquaculture Research, Abbassa, Sharqia, Egypt. The

ponds were drained, cleaned and refilled with new freshwater from El-Wadi Canal derived from Ismailia Canal. The water level was kept at 0.8-1.0 m. This experiment started on September 9, 1994 and lasted for 105 days.

Three treatments were assigned to evaluate the acceptability of natural food and/or supplemental feed by striped mullet. The first three ponds received only organic and inorganic fertilizers (control), the second three ponds (T1) received organic and inorganic fertilizers as in control ponds and supplementary feed at a rate of 3% of fish bw. The third three ponds (T2) received only supplementary feed at a rate of 5% of fish bw. Before the experiment started, control and T1 ponds were fertilized with cow manure at a rate of 300 kg/acre. The manure was distributed randomly on the bottom of pond. After stocking the fish, chicken manure was applied at a rate of 10 kg/acre biweekly. In addition to chicken manure, inorganic fertilizers of urea and monosuperphosphate were also applied biweekly at a rate of 1 kg/acre and 5 kg/acre, respectively. The inorganic fertilizers were dissolved and spread on the water surface of fishponds. Striped mullet (35.1±1 g) was stocked at a rate of 1 fish/m^2. In T1 and T2 ponds, the diet used contained 35% crude protein that was given to fish twice daily. Every two weeks, 25 fish from each pond were sampled and length and weight of each fish was measured. The amounts of feed given were readjusted according to changes in fish biomass.

Water samples for chemical analyses were collected weekly using a water sampler between 08:30 and 09:30 at 30 cm depth from each pond. Dissolved oxygen and temperature were measured at 30 cm depth with a YSI model 58 oxygen meter (Yellow Spring Instrument Co., Yellow Springs, Ohio, USA). Water conductivity was measured with YSI model 33 conductivity meter (Yellow Spring Instrument Co., Yellow Springs, Ohio, USA). pH and free ammonia were measured colorimetrically using Hach kits (Hach Co., Loveland, Colorado, USA). The chemical parameters were analyzed according to APHA (1985). Orthophosphate was colorimetrically determined using stannous chloride method and nitrate was colorimetrically determined using phenoldisulphonic acid method (Boyd, 1984).

Water samples for phytoplankton were collected using 1-liter bottle at the same depth and preserved by adding 1 ml of 4% formalin solution. Samples were allowed to settle for 15 days and the supernatant was siphoned to 50 ml. Samples for zooplankton determination were collected by plankton net (50 μm) filtering 20 litres and immediately preserved by adding 1 ml of 10% formalin solution. Phytoplankton and zooplankton counting was performed using Sedgwick-Rafter cell under a binocular microscope with appropriate magnification. The phytoplankton in samples was identified to genus level according to Prescott (1961). Shannon and Weaver (1949) equation

was used in order to determine phytoplankton diversity.

Water quality data were analyzed comparing the treatments with Kruskal-Wallis One Way Analysis of Variance on Ranks, using dates as blocks to determine significant differences. Mean separations were determined using Tukey's test at the 5% probability level. Spearman correlation and multiple stepwise regressions of the obtained data were done. All statistical analyses were conducted with SPSS software program (SPSS, Richmond, USA) version 10 as described by Dytham (1999).

Results

Water Quality Parameters

The variations in water quality parameters are presented in Figures 1, 2 and 3. Water temperature of different treatments was approximately the same. Moreover, water temperature showed remarkable decrease with maximum value of 29.3°C in September, and the lowest value of 15.3°C in December. pH did not vary much among treatments. It varied from 8.3 to 8.7 for all treatments. Dissolved oxygen was also affected significantly by treatments (P<0.01) where it was higher in T1 than that of control and T2. Turbidity was negatively affected by treatments (r = -0.76; P<0.01). Free ammonia in different treatments was approximately the same (0.13-0.14 mg/l; Figure 2). It was less than the critical concentration affecting fish health. Phosphate and nitrate concentrations were varied significantly (P<0.05) in the different treatments (Figure 2). They were significantly lower at T1 ponds than those of control and T2 (P<0.05). Water conductivity, total alkalinity and total hardness were not affected by treatments in this study (Figure 3).

Phytoplankton Abundance

The dominant phytoplankton groups were Bacillariophyceae, Chlorophyceae, Cyanobacteria, and Euglenophyceae in all treatments (P<0.05; Table 1). All of these groups except Cyanobacteria, were significantly affected by treatments (P<0.05). Cyanobacteria and Euglenophyceae exhibited low abundance compared with other groups. Euglenophyceae disappeared completely in some months. Bacillariophyceae and Chlorophyceae were the dominant groups. Bacillariophyceae and Chlorophyceae were recorded in control and T1 ponds without exhibiting significant differences. T2 yielded less phytoplankton numbers (Table 1).

Abundance of phytoplankton was positively affected by treatments (r = 0.578; P< 0.01), and it was significantly higher at control and T1 than that of T2 (Table 1). The maximum number was recorded in November at control and at T1 (122 and 111 org./ml,
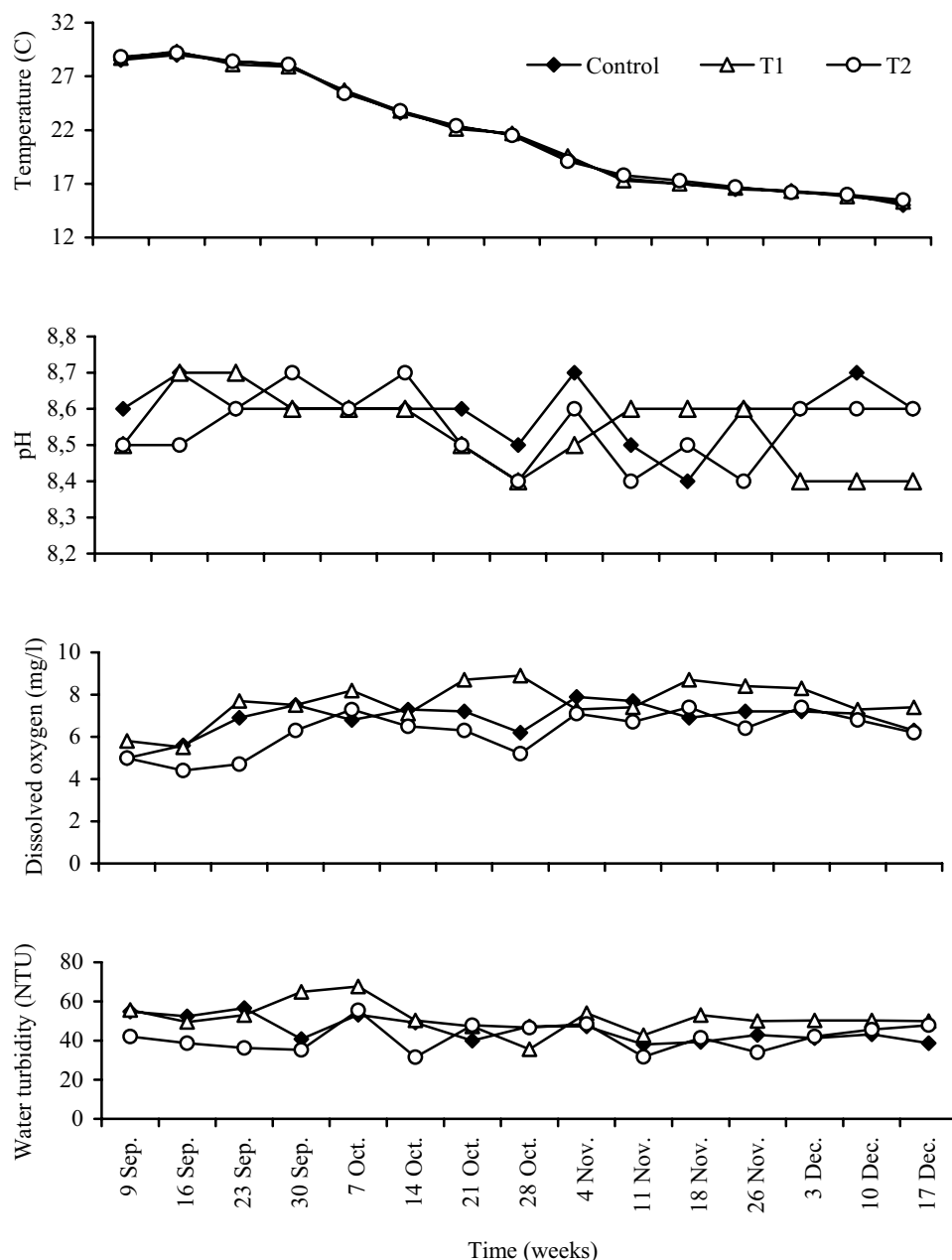
Figure 1. Weekly variations in water temperature (°C), pH, dissolved oxygen (mg/l) and water turbidity (NTU) in earthen ponds stocked with stripped mullet and subjected to different feeding regimes.

respectively), while the minimum value was recorded in September and October at T2 (21 and 30 org./ml, respectively).

Table 2 shows the different genera of each phytoplankton group. The recorded genera were 8, 8, 5 and 2 for Bacillariophyceae, Chlorophyceae, Cyanobacteria and Euglenophyceae, respectively. The most abundant genera of Bacillariophyceae were *Navicula, Nitzschia,* and *Synedra*. Other genera of Bacillariophyceae were *Cyclotella, Cymbella, Gyrosigma, Melosira,* and *Pinnularia*. *Navicula* and *Nitzschia* were the most abundant genera at all treatments during the study period. *Navicula* exhibited

the highest number in September and November at T1 (18 and 15 org./ml, respectively). The highest number of *Nitzschia* was recorded in November at control (16 org./ml) and in September at T1 (15 org./ml). Moreover, *Synedra* was abundant at control, and the highest number was obtained in November in control (13 org./ml).

In Chlorophyceae, *Pediastrum, Scenedesmus* and *Tetraedron* were found to be the most abundant genera. In addition, *Ankistrodesmus, Chlorella, Coilastrum, Crucigenia,* and *Pandorina* were recorded. The maximum *Scenedesmus* number was recorded in November in T1 (34 org./ml), while the
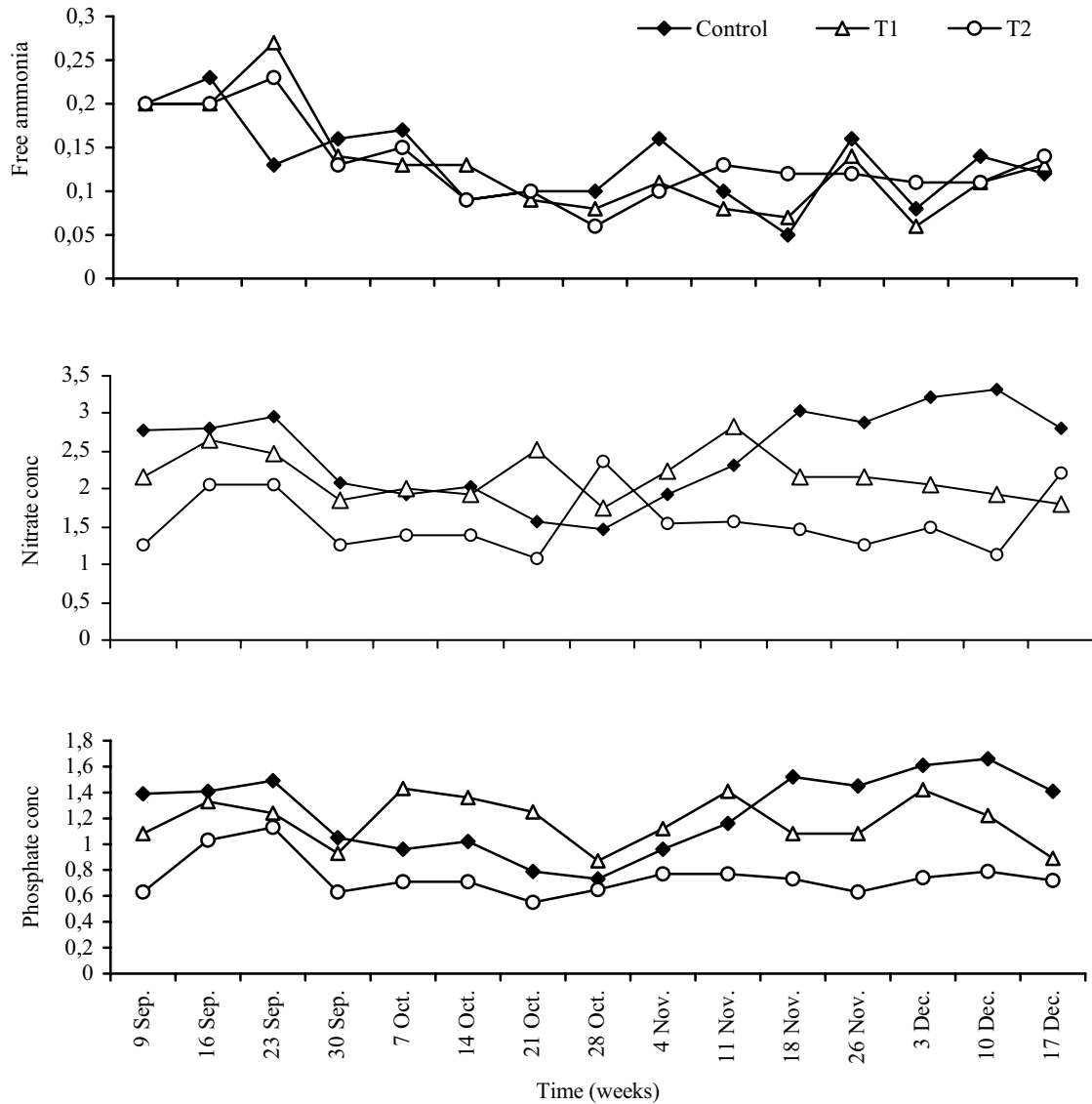
Figure 2. Monthly variations of free ammonia, nitrate and phosphate concentrations (mg/L) in earthen ponds stocked with stripped mullet and subjected to different feeding regimes.

Table 1. Variance and distribution of major phytoplankton groups (org/ml) in earthen ponds stocked with stripped mullet and subjected to different feeding regimes

Phytoplankton Groups	Control				T1				T2			
	Sep.	Oct.	Nov.	Dec.	Sep.	Oct.	Nov.	Dec.	Sep.	Oct.	Nov.	Dec.
Cyanobacteria	9	4	11	5	4	5	9	4	4	5	7	4
%	11.2	7.7	9.0	9.6	4.6	10.2	8.1	8.3	19.1	16.7	10.4	11.8
Chlorophyceae	30	17	69	31	39	23	59	28	7	13	35	19
%	37.5	32.7	56.5	59.6	44.9	46.9	53.2	58.4	33.3	43.3	52.3	55.8
Bacillariophyceae	28	18	39	16	37	14	38	16	6	6	21	11
%	35.0	34.6	32.0	30.8	42.5	28.6	34.2	33.3	28.6	20.0	31.3	32.4
Euglenophyceae	13	13	3	0	7	7	5	0	4	6	4	0
%	16.3	25.0	2.5	0.0	8.0	14.3	4.5	0.0	19.0	20.0	6.0	0.0
Total number	80	52	122	52	87	49	111	48	21	30	67	34
%	100	100	100	100	100	100	100	100	100	100	100	100

Control: ponds received only organic and inorganic fertilizers.
T1: ponds received organic and inorganic fertilizers, and 3% artificial feed.
T2: ponds received 5% artificial feed only.
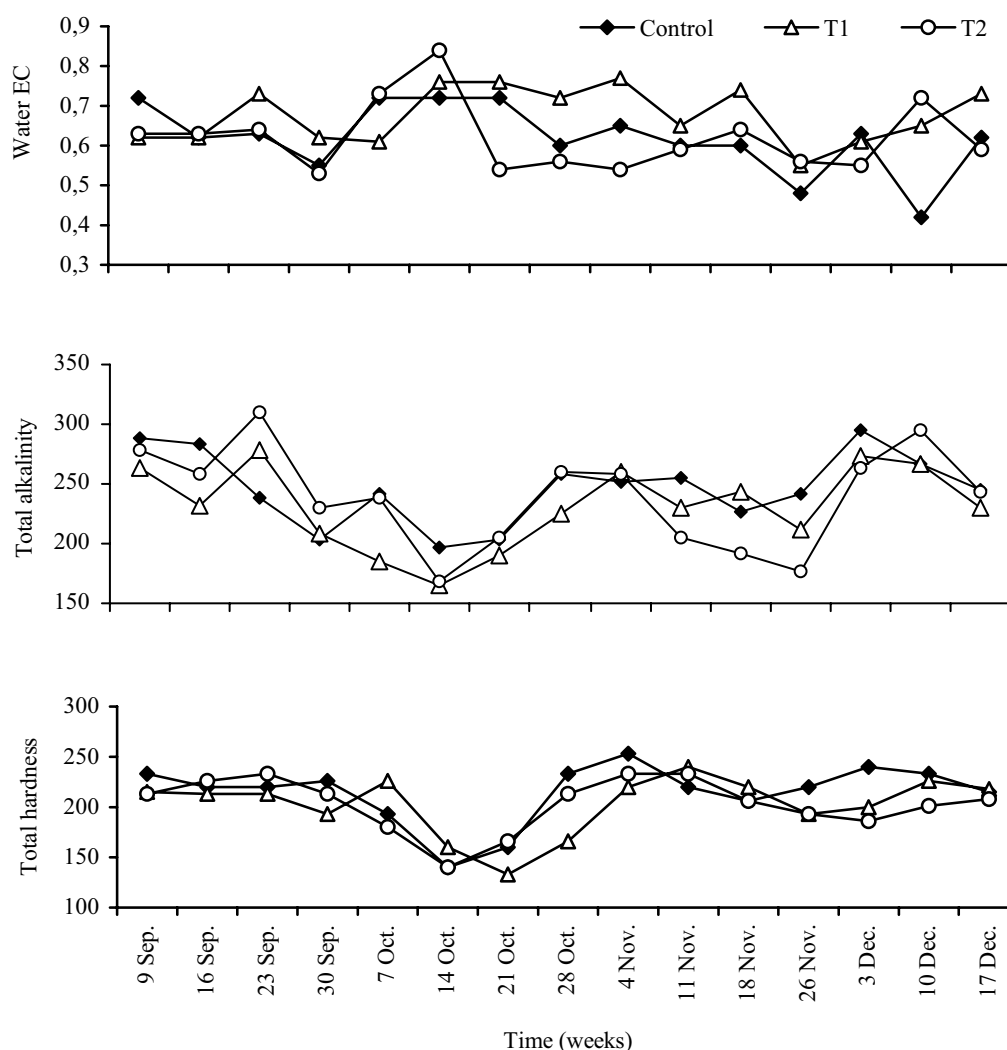
Figure 3. Monthly variations of water conductivity (μS/cm), total alkalinity and total hardness (mg/l as $CaCO_3$) in earthen ponds stocked with stripped mullet and subjected to different feeding regimes.

minimum number was obtained in September in T2 (3 org./ml). The highest number of *Pediastrum* was recorded in November in T1 (11 org./ml).

Among Cyanobacteria, *Anabaena* and *Merismopedia* were the most dominant genera. Other genera such as *Chroococcus, Gleocapsa,* and *Oscillatoria* were also present in the ponds. The highest number was recorded for *Anabaena* in November and *Oscillatoria* in September at control ponds and *Merisomopedia* in November at T1 ponds with the same number (4 org./ml).

Euglenophyceae was represented only by the genera *Euglena* and *Phacus*. They were recorded in all treatments during the experimental period except December. Generally, *Phacus* was less abundant than *Euglena*. The high occurrence of *Euglena* was recorded during September and October in control (9 and 8 org./ml, respectively). In case of *Phacus*, the highest number was obtained in September and

October in control (4 and 5 org./ml, respectively).

The Shannon-Weaver diversity index of overall phytoplankton genera decreased by time in control and T2 ponds, while it increased in T1 (Figure 4). It could be seen that the diversity index in September and October was lower than that of November and December in all treatments, except T1.

Zooplankton Abundance

The common zooplankton groups were Cladocera, Copepods and Rotifers in all treatments. Cladocera was dominant zooplankton group, while Copepods and Rotifers exhibited lower abundance in all treatments (Table 3). Zooplankton abundance was positively affected by treatments (r = 0.420; P<0.01), and it was greater in control and T1 than that of T2 (P<0.05). The maximum number of zooplankton was obtained in November at T1 (18 org./L) followed by

Table 2. Monthly variation in phytoplankton taxa in earthen ponds stocked with stripped mullet and subjected to different feeding regimes

Phytoplankton General	Control				T1				T2			
	Sep.	Oct.	Nov.	Dec.	Sep.	Oct.	Nov.	Dec.	Sep.	Oct.	Nov.	Dec.
Bacillariophyceae												
Cyclotella	1	-	1	2	-	-	1	2	1	-	1	-
Cymbella	-	3	4	1	-	-	-	-	-	1	-	-
Gyrosigma	1	1	-	-	-	1	2	-	-	-	1	1
Melosira	-	-	1	-	2	-	1	-	-	-	2	-
Navicula	3	2	4	2	18	7	15	4	2	2	7	2
Nitzschia	9	3	16	7	15	5	12	6	2	2	3	5
Pinnularia	14	6	-	-	-	-	-	-	-	-	2	-
Synedra	-	3	13	4	2	1	7	4	1	1	5	3
Chlorophyceae												
Ankistrodesmus	6	-	4	-	-	4	3	2	-	-	-	1
Chlorella	4	2	7	2	-	2	4	-	-	3	8	-
Coilastrum	-	-	4	2	-	-	-	3	-	-	-	2
Crucigenia	3	-	19	1	-	1	2	5	1	2	5	3
Pandorina	-	1	4	-	5	-	-	-	-	-	-	-
Pediastrum	3	1	6	3	5	2	11	3	2	2	7	1
Scenedesmus	12	9	20	21	23	12	34	6	3	5	13	12
Tetraedron	2	4	7	2	4	2	5	9	1	-	2	-
Cyanobacteria												
Anabaen	2	2	4	1	2	-	2	1	2	2	-	1
Chroococcus	2	1	2	3	-	-	-	1	1	-	2	2
Gleocapsa	1	1	2	-	-	1	-	-	-	1	2	-
Merismopedia	-	-	1	1	1	1	4	1	1	1	2	1
Oscillatoria	4	-	2	-	1	3	3	1	-	1	1	-
Euglenophyceae												
Euglena	9	8	2	0	5	4	3	0	2	4	2	0
Phacus	4	5	1	0	2	3	2	0	2	2	2	0

Control: ponds received only organic and inorganic fertilizers.

T1: ponds received organic and inorganic fertilizers, and 3% artificial feed.

T2: ponds received 5% artificial feed only.
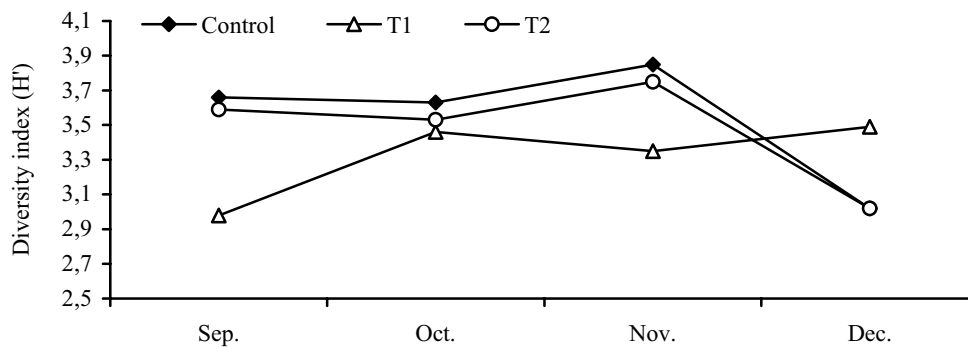
Figure 4. Changes in Shannon-Weaver diversity index (H`) of phytoplankton genera in earthen fishponds cultured with striped mullet at different feeding regimes.

that in October in control (16 org/L). The minimum number of zooplankton was recorded in December in control and T2 ponds (5 and 4 org./L; Table 3). Dominant Cladocera included *Moina*, *Bosmania*, *Diaphanosoma* and *Daphnia*. *Cyclops* was the most common copepod and common rotifers included *Brachionus* and *Keratella*.

Fish Growth

Concerning fish growth, Figure 5 shows that the mean weight of striped mullet gradually increased up to the end of the experimental period. The maximum final weight of striped mullet was obtained at T1 and T2 treatments without significant difference (78.5 and

Table 3. Variance and distribution of zooplankton groups (org/L) in earthen ponds stocked with stripped mullet and subjected to different feeding regimes

Zooplankton Groups	Control				T1				T2			
	Sep.	Oct.	Nov.	Dec.	Sep.	Oct.	Nov.	Dec.	Sep.	Oct.	Nov.	Dec.
Cladocera	8	9	4	3	6	7	10	4	5	4	3	2
%	57.2	56.3	50.0	60.0	60.0	53.8	55.6	50.0	55.6	57.1	50.0	50.0
Copepods	4	5	2	1	2	4	5	2	2	2	2	1
%	28.6	31.3	25.0	20.0	20.0	30.8	27.8	25.0	22.2	28.6	33.3	25.0
Rotifers	1	1	1	1	1	1	2	2	1	1	1	1
%	7.1	6.2	12.5	20.0	10.0	7.7	11.1	25.0	11.1	14.3	16.7	25.0
Others	1	1	1	0	1	1	1	0	1	0	0	0
%	7.1	6.2	12.5	0.0	10.0	7.7	5.5	0.0	11.1	0.0	0.0	0.0
Total number	14	16	8	5	10	13	18	8	9	7	6	4
%	100	100	100	100	100	100	100	100	100	100	100	100
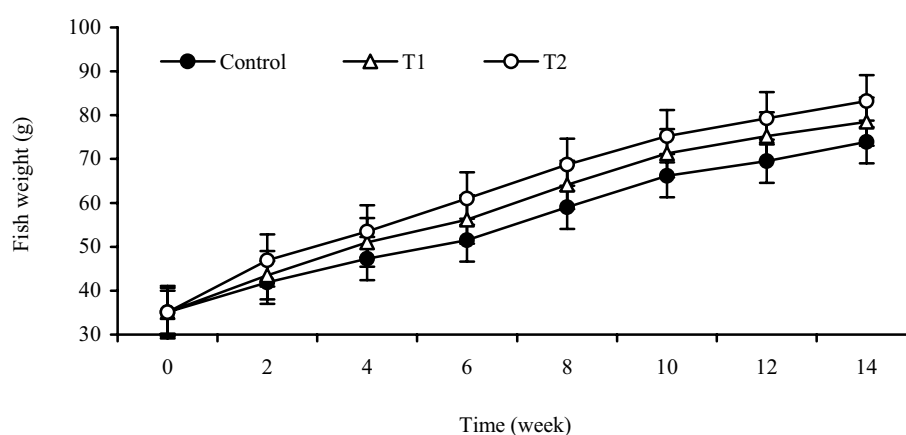
Figure 5. Change in mean weight of stripped mullet reared in only fertilized earthen ponds (control), earthen ponds received combination of fertilization and feed (T1) or earthen ponds received supplemental feed only (T2).

83.2 g, respectively), while the lowest final weight of fish was obtained in control (74.0 g).

Discussion

Effective water management in fishponds is one of the important factors contributing to the success of fish culture, reducing the occurrence of fish disease and enhancing fish growth and survival. Factors such as light, temperature and nutrients play an important role in phytoplankton productivity in aquatic systems (Hutchinson, 1967; Wetzel, 1983). In this study, water temperature was decreasing until the end. So, the number of phytoplankton and zooplankton was almost less than that reported before in Abbassa fishponds by El-Ayouty *et al*. (1994), (1999), Ahmad *et al*. (2001) and Ibrahim *et al*. (2003). Certainly, the low water temperature affected the growth of striped mullet (r = -0.968; P<0.01) although it could survive and grow at temperature range of 8–24°C (Harrison and Senou, 1997).

There were no significant variations in water conductivity, free ammonia, total alkalinity and total hardness among treatments. Significantly higher concentrations of phosphate and nitrate at control and T1 treatments might have been principally due to the fertilizer inputs. However, T2 ponds did not receive fertilizers. In this concern, Diana *et al*. (1994) found no significant differences in water quality between combined treatments (feed and fertilizer) and fertilizer alone. Furthermore, Diana *et al*. (1996) reported that the efficient use of supplemental feed at a limiting rate, along with fertilizer and natural feeds did not adversely affect water quality.

Water turbidity was higher in T1 than that in control and T2, which might have resulted from the dispersion of colloidal clay particles, and the suspended organic particles due to fish movement in pond and the abundance of phytoplankton (Boyd, 1984). Moreover, the high concentration of dissolved oxygen in T1 compared to control and T2 could be due to the high occurrence of phytoplankton that

increased in photosynthetic activity leading to oxygen production. In this respect, Talling (1986) stated that, oxygen supersaturation due to photosynthetic activity is often recorded with abundant phytoplankton. Generally, dissolved oxygen in this study was adequate for fish culture in the three treatments.

The control and T1 ponds exhibited high number of phytoplankton organisms in comparison to that of T2. This result might be due to the availability of nutrients required for phytoplankton flourishing on account of fertilizers application. The low abundance of phytoplankton recorded in T2 might be because of the low nitrogen and phosphorus concentrations. However, no organic and/or inorganic fertilizers were added.

The number of phytoplankton depended mainly on the number of Bacillariophyceae and Chlorophyceae, which were the most abundant groups (r = 0.956 and 0.931, respectively; P<0.05), while Cyanobacteria and Euglenophyceae were the less abundant ones in all treatments (r = 0.605 and 0.189, respectively; P<0.05). Some of Cyanobacteria algae apparently disappeared at certain periods and reappeared later. These results are quite similar to those found in studies on Abbassa ponds (El-Ayouty *et al.*, 1994; 1999; Ahmad *et al.*, 2001). Moreover, Cyanobacteria have slower growth rate than the green algae (Benemann *et al.*, 1977; Cromar and Fallowfield, 1997). Such temporary disappearance of these algae is probably due to the fact that the species concerned either become too scarce or occur as spores, resting eggs, etc., which are not easily detectable (Hutchinson, 1967).

The great diversity in the phytoplankton biomass and structure might be related to environmental fluctuations and competition on nutrients (D'Elia *et al.*, 1986), predation by zooplankton (Verity, 1986) and planktivorous fish. All of these factors might cause major changes in plankton community structure (Lazzaro 1987; Northcote 1988) and the size of phytoplankton (Lynch and Shapiro 1981; Lehman and Sandgren 1985). On the other side, the impact of fish on phytoplankton depends on the rate of filter feeding by fish and phytoplankton growth rates as well as the predatory pressure on phytoplankton (Turker *et al.*, 2003).

The effect of zooplankton on phytoplankton is not simply related to filtering and nutrients regeneration rates. It might also vary considerably with body size (Peters and Downing, 1984) and zooplankton actively generates nutrients through their feeding and metabolic activities. These nutrients are usually in forms directly available for algal intake (Gardner and Scavia, 1981). Moreover, the necessity of zooplankton for young fish is considered universal (Fernando, 1994) as well as its importance for adults of many fish (Mavuti, 1990).

In this investigation, phytoplankton is not affected by zooplankton (r = -0.318; P>0.05). This result was in contrast to the finding of Ahmad *et al.* (2001) in Abbassa fishponds. They found a significant interaction between zooplankton and phytoplankton, which should be considered when discussing productivity and trophic structure in pond system. The difference herein probably was due to the low water temperature that negatively affected the growth and flourishing of phytoplankton and in turn zooplankton abundance. Jeppesen *et al.* (2004) found low zooplankton biomass in winter because of low specimen turnover during winter mediated by low fecundity, which, in turn, reflects food shortage and low winter hatching from resting eggs. They also found that in shallow lakes, the zooplankton : phytoplankton biomass ratio was substantially higher during summer than in winter, suggesting a higher zooplankton grazing potential during summer.

The optimum fish growth could be obtained when supplemental feed was given to fish. These results are much as expected where the feed supplementation to fishponds resulted in significantly higher yields and growth rates compared to fertilization alone. However, fish growth was high at T2 due to considerable consumption of supplemental food. Green (1992) found that the growth of Nile tilapia was significantly lower in fertilization-alone ponds than in feed-alone or combined fertilizer-feed treatments.

The stepwise regression indicating that fish growth, as a dependant variable was affected by treatments, phytoplankton abundance and temperature. These relations were summarized in the following equation:

$$\text{Fish growth} = 17.857 + 0.849 \text{ Treatments} - 2.743 \text{ Temperature} - 0.128 \text{ Phytoplankton}$$

In conclusion, there were no significant differences in water temperature, pH-value, free ammonia and water conductivity among the different treatments. Dissolved oxygen and concentrations of orthophosphate and nitrate in control and T1 were significantly higher than those of T2. Water turbidity was significantly higher in T1 ponds than the other treatments. Number of phytoplankton and zooplankton was significantly higher in control and T1 than that in T2. Striped mullet could utilize both supplemental feed and/or natural food, and could completely consume artificial feed.

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