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The Effects of Grass Carp (*Ctenopharyngodon idella* Val., 1844) on Water Quality, Plankton, Macrophytes and Benthic Macroinvertebrates in a Spring Pond

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Abstract

Due to the excessive plant growth in the spring originated Sakaryabasi-West Pond which supplied water to a trout farm, grass carp was stocked at a rate of 2 fish/100 m^2 on March 2004 and its effects on aquatic plants, water quality, plankton, chlorophyll *a* and benthic macroinvertebrates were investigated until November 2004. A net cage with a dimension of 7x7x2 m was placed to the pond as control (without fish). Aquatic plant samples from eight stations and water, plankton, benthic macroinvertebrate samples from two stations were taken monthly. The variance of aquatic plant biomass, dissolved oxygen, pH, total hardness, ammonium nitrogen, nitrate nitrogen, nitrite nitrogen, total phosphorus, chlorophyll *a,* zooplankton and benthic macroinvertebrates were found statistically significant by months and stations ($p<0.01$). During the research period, the cage was covered by the aquatic plants such as *Potamogeton pectinatus*, *Ceratophyllum submersum* and *Lemna trisulca.* These aquatic plants were preferred primarily by grass carp and disappeared in the pond. Filamentous algae, *Cladophora* sp., *Zygnema* sp. and *Spirogyra* sp. decreased but not disappeared. The aquatic plant biomass increased 7 times inside the cage and decreased 2.5 times in the pond at the end of the study period. Phytoplankton abundance and chlorophyll *a* concentration were found higher inside the cage than those in the pond whereas zooplankton and benthic fauna were found to be higher in the pond than those in the cage ($p<0.05$).

Key words: Ctenopharyngodon idella, water quality, phytoplankton, zooplankton, benthic macroinvertebrate

Introduction

The nuisance aquatic vegetation can be controlled by chemical, mechanical and biological methods. The use of herbivorous fish species appeared to be a promising possibility. A desirable effect from the point of view of human interests could possibly be achieved without the danger of chemical methods, and furthermore could assist in avoiding labor outlay and the costs of mechanical vegetation control. The use of grass carp appeared to have considerable advantages because it was reasonably selective, less expensive and lasts considerably longer than other methods (Opuszynski, 1979; Miley *et al.*, 1979; Shireman and Smith, 1983; Çelikkale, 1988). However, in addition to reduction of weeds, grass carp may induce considerable changes in aquatic ecosystems.

In this research, grass carp was introduced to a spring originated pond which had an excessive aquatic plant growth in certain periods, and its effects on aquatic plants, water quality, chlorophyll *a,* plankton, benthic macroinvertebrate were investigated.

Material and Methods

Grass carp was stocked to the spring originating from the West Pond, which supplied water to the Cifteler Sakaryabasi Aquaculture and Research Station of Ankara University (Figure 1). Research was conducted between March and November 2004. The surface area of the pond is 0.92 ha and the average depth is 2.5 m (Pulatsu *et al*., 2004). Grass carp was stocked at a rate of 2 fish/100 m^2 (Santha *et al*., 1991) with 19.11± 2.4 cm in total length and 135.7±17.2 g in weight (Lembi *et al*., 1978). A net cage with a dimension of 7x7x2 m was also placed to the pond as a control (without fish) in order to observe and compare the growth of aquatic plants.

Aquatic plant, water, plankton and benthic macroinvertebrate samples were taken from the inside (Station 1) and the outside the cage (Station 2 - the deepest point near the center of the pond), monthly. All samples were replicated. Aquatic plant samples were collected with a pulling hook that sampled an area of 0.2 m^2 from eight stations; two were from the inside and six were from the outside of the cage. The samples were labeled in nylon bags, and the plants were identified under stereomicroscope (Prescott, 1973; Casper and Krausch, 1980; Casper and Krausch, 1981). Plants were allowed to drain for 30 min, and then dried for 24 h in an oven set at 105^{o}C for determination of dry weights. The biomass of plants was calculated as gram dry weight per square meter (Lembi *et al*., 1978).

Water samples were collected with a Ruttner sampler. Water temperature, dissolved oxygen and pH were measured *in situ*. Total hardness was determined titrimetrically. Ammonium-N, nitrate-N, nitrite-N and

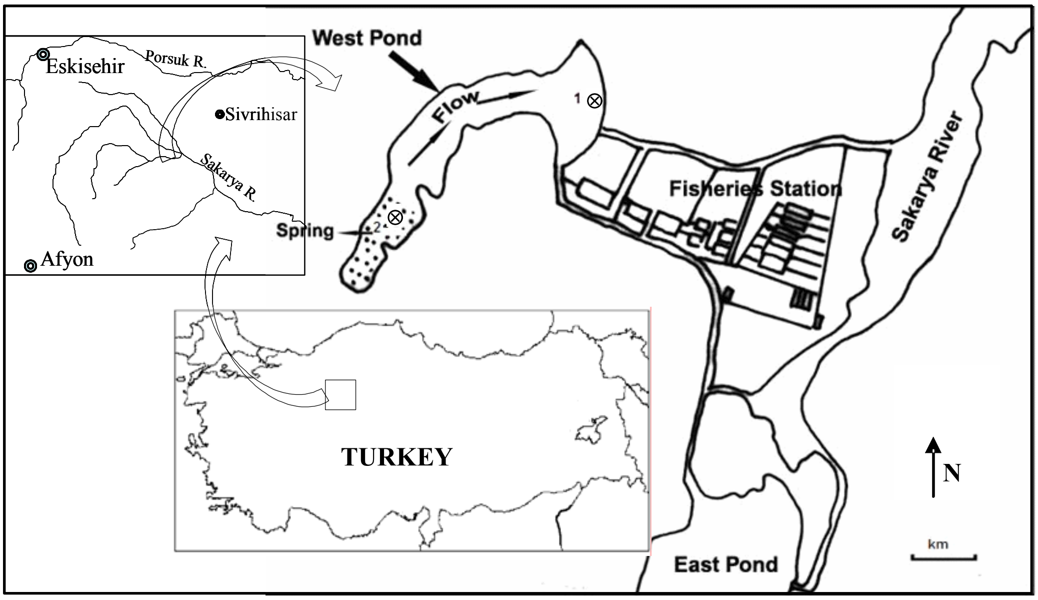

Figure 1. The location of Sakaryabasi-West Pond (·⊗ stations).

total phosphorus were determined by spectrophotometric methods (APHA 1975).

The phytoplankton abundance was estimated from the water samples, which were sedimented 10-20 ml each after preservation with Lugol solution in counting chambers and counted under inverted microscope (Lund *et al*,. 1958). Phytoplankton was identified under binocular microscope (Hustedt, 1930; Huber-Pestallozzi, 1942, Huber-Pestallozzi, 1950; Lind and Brook, 1980; Komarek and Fott, 1983; Popovski and Pfiester, 1990). Chlorophyll *a* concentration was determined spectrophotometrically after filtration of water samples through Whatman GF/C filter paper and extracted with acetone (Strickland and Parsons, 1972).

The zooplankton abundance was estimated from the water samples, which were taken as for phytoplankton analyses. Water samples were preserved with a 4% formaldehyde solution and were settled each one liter in a graduated cylinder, enumerated in counting chambers (Edmondson and Winberg, 1971; Mc Cauley, 1984; Wetzel and Likens, 1991). Zooplankton was identified under binocular microscope (Edmondson, 1959; Kolisko, 1974; Koste, 1978; Smith, 2001).

Benthic macroinvertebrate samples were collected with an Ekman Birge grab (15x15 cm) from the Station 1 and 2. The samples were washed through a series of sieves that varied between 210-3360 micron mesh. The organisms were preserved in 4% formaldehyde solution. Benthic fauna abundance was estimated as individual per m^2 and identified under a stereoscopic microscope (Edmondson, 1959; Macan, 1975).

Statistical analyses were carried out using Minitab and Mstat programmes for Windows. The variations by the stations and months in the biomass of the aquatic plants, water quality parameters, chlorophyll *a* concentration, and the number of phytoplankton, zooplankton and benthos were evaluated with ANOVA and LSD test.

Results

In Sakaryabasi-West Pond, the identified aquatic plants were given in Table 1. During the study, the biomass of aquatic plants changed between 96±4 g dry weight/m^2 and 690±15 g dry weight/m^2 in the Station 1, 41±2 g dry weight/m^2 and 103±7 g dry weight/m^2 in the Station 2 (Table 2). The variations of aquatic plant biomass according to months and stations were found statistically significant ($p<0.01$). The differences in the aquatic plant biomass were found statistically significant between stations, except for March and April ($p<0.05$).

The lowest average water temperature value of 13±1°C was measured in November and the highest average value of 24±1°C was measured in August in the pond. The differences in average water temperature values between stations were found insignificant ($p>0.05$). The average dissolved oxygen values were given in Table 3. The variations of the average dissolved oxygen values between stations were found insignificant except for August, October and November ($p>0.01$). In the pond the average pH values and average total hardness values were also given in Table 3. The variations in pH between stations were found significant ($p<0.01$). The differences in the average total hardness values were found significant among months ($p<0.01$), but found insignificant between stations ($p>0.05$) (Table 3). Ammonium-nitrogen, nitrate-nitrogen, nitrite-nitrogen, total phosphorus were found statistically significant by months and stations ($p<0.01$) (Table 4).

Table 1. A list of phytoplankton, zooplankton, benthic fauna and aquatic plants found in Sakaryabasi - West Pond

PHYTOPLANKTON	ZOOPLANKTON
Bacillariophyceae	**Rotifera**
Amphora ovalis Kütz.	*Ascomorpha* sp.
Caloneis ventricosa (Ehr.) Meister	*Cephalodella gibba* (Ehr.)
Cocconeis placentula Ehr.	*Colurella obtusa* Gosse
Cyclotella kützingiana Thwaites	*Lecane luna* (O.F.M.)
C. meneghiniana Kütz.	*Lepadella patella* (O.F.M.)
Cymbella asparea (Ehr.) Cleve	*Monostyla bulla* (Gosse)
C. cistula (Hemp.) Grun.	*Mytilina mucronata* O.F.M.
Cymatopleura solea (Breb.) W.Smith	*Testudinella* sp.
Epithemia turgida (Ehr.) Kütz.	*Squatinella mutica* (Ehr.)
E. zebra (Ehr.) Kütz.	*Trichocerca* sp.
Fragilaria virescens Ralfs	**Cladocera**
Gomphonema acuminatum Her.	*Chydorus sphaericus* (O.F.M.)
G. olivaceum (Lyngbye) Kütz.	**Copepoda**
Gyrosigma acuminatum (Kütz.) Rahb.	*Cyclops* sp.
Hantzschia amphioxys (Ehr.) Grun.	
Navicula cryptocephala Kütz.	**BENTHIC MACROINVERTEBRATE**
N. cuspitata Kütz.	**Gastropoda**
Nitzschia littoralis Grun.	*Lymnaea* sp.
N. palea (Kütz.) W. Smith	*Planorbis* sp.
N. scalaris (Her.) W. Smith	*Valvata* sp.
N. sigmoidea (Ehr.) W. Smith	**Diptera**
Pinnularia viridis (Nitszch.) Ehr.	Chironomid larvae
Rhoicosphenia curvata (Kütz.) Grun.	
Surirella linearis W. Smith	**AQUATIC PLANTS**
Synedra acus Kütz.	**Chlorophyta**
S. capitata Her.	*Cladophora* sp
S. ulna (Nitzsch.) Ehr.	*Zygnema* sp.
Chlorophyceae	*Spirogyra* sp.
Ankistrodesmus gracilis (Reinsch.) Kors.	**Spermatophyta**
Ankyra judayi (G.M.Smith) Fott	*Ceratophyllum submersum* L.
Botryococcus braunii Kütz.	*Lemna trisulca* L.
Coelastrum sphaericum Naeg.	*Myriophyllum aquaticum* (Vellosa) Verdcourt
Cosmarium depressum (Naeg.) Lund.	*Phragmites australis* (Cavanilles) Trinius *et* Steudel
Crucigenia tetrapedia (Kirch.)West *et* West	*Potamogeton pectinatus* L.
Eudorina elegans Ehr.	
Monoraphidium circinale (Nyg.) Nyg.	
Pediastrum boryanum (Turp.) Menegh.	
P. duplex Meyen	
Planktosphaeria gelatinosa G.M.Smith	
Scenedesmus acutus Meyen	
S. ecornis (Ehr.) Chod.	
Staurastrum paradoxum Meyen West	
Tetraedron minimum (A. Braun) Hansg.	
Cyanophyceae	
Anabaena affinis Lemm.	
A. spiroides Klebahn	
Chroococcus minutus (Kütz.) Naeg.	
Gomphosphaeria aponina Kütz.	
Merismopedia tenuissima Lemm.	
Oscillatoria tenuis Ag.	
Phormidium sp.	
Pseudoanabaena sp.	
Cryptophyceae	
Cryptomonas marssonnii Skuja	
Rhodomonas sp.	
Dinophyceae	
Ceratium hirundinella (O.F.M.) Dujardin	
Peridinium bipes Stein	
P. pusillum (Pen.) Lemm.	
P. volzii Lemm.	

Table 2. The biomass of aquatic plants, abundance of phytoplankton, concentration of chlorophyll *a*, abundance of zooplankton and benthic macroinvertebrate of Sakaryabasi-West Pond by months and stations (Mean±SE)

Months	Aquatic Plants (g-dry weight./m^2)		Phytoplankton (numbers/ml)		Chlorophyll *a* (mg/m^3)		Zooplankton (numbers/L)		Benthic Macroinvertebrate (numbers/m^2)	
	Inside the cage	Outside the cage	1.station*	2.station**	1.station	2.station	1.station	2.station	1.station	2.station
March	96±4$^{a\,I}$	103±7$^{a\,A}$	100±1^{aC}	97±3^{aE}	1.51±0.03^{aG}	1.46±0.01^{aCD}	4±1$^{a\,EF}$	3±0$^{a\,F}$	481±11^{aH}	496±21$^{a\,I}$
April	110±8^{aH}	98±5$^{a\,A}$	110±1^{aC}	100±1^{aE}	1.67±0.01^{aG}	1.58±0.03^{aCD}	2±0$^{a\,F}$	5±1$^{a\,F}$	503±1^{bG}	522±17$^{a\,H}$
May	135±4$^{a\,G}$	87±10$^{b\,B}$	175±3^{aB}	141±2^{bD}	3.01±0.02^{aF}	1.45±0.03^{bCD}	6±2$^{a\,DEF}$	18±4$^{a\,E}$	617±3^{bF}	780±7$^{a\,G}$
June	170±9$^{a\,F}$	80±8$^{b\,C}$	263±8^{aA}	183±6^{bB}	9.80±0.08^{aA}	2.54±0.08^{bB}	8±1$^{b\,BCD}$	33±3$^{a\,CD}$	650±3^{bE}	922±23$^{a\,F}$
July	210±6$^{a\,E}$	68±6$^{b\,D}$	249±8^{aA}	176±6^{bB}	8.38±0.16^{aB}	1.97±0.08^{bC}	16±4$^{b\,A}$	41±6$^{a\,BC}$	693±4^{bD}	1015±28^{aE}
August	330±20$^{a\,D}$	55±3$^{b\,E}$	296±2^{aA}	197±20^{bA}	7.65±0.09$^{a\,C}$	4.44±0.21^{bA}	12±3$^{b\,AB}$	46±9$^{a\,AB}$	716±15^{bC}	1130±14^{aD}
September	519±27$^{a\,C}$	51±4$^{b\,EF}$	279±26^{aA}	102±2^{bE}	5.53$^{a\,D}$±0.01	2.51±0.01^{bB}	10±1^{bBCD}	52±6$^{a\,A}$	732±11^{bB}	1340±41$^{a\,C}$
October	641±18$^{a\,B}$	48±5$^{b\,F}$	255±3^{aA}	167±6^{bC}	4.50$^{a\,E}$±0.01	1.88±0.00^{bC}	8±3$^{b\,BCD}$	39±3$^{a\,BC}$	780±13^{bA}	1573±58$^{a\,B}$
November	690±15$^{a\,A}$	41±2$^{b\,G}$	57±3^{aD}	45±4^{aF}	0.90$^{a\,H}$±0.01	0.55±0.01^{bE}	5±1$^{b\,EF}$	27±4$^{a\,DE}$	740±24^{bB}	1927±36$^{a\,A}$

*: inside the cage; **: outside the cage

$^{a,\,b}$: Means with the different letters in the same line for every parameters are significant statistically (p<0.05)

$^{A\,B\,C\,D\,E\,F\,G\,H\,I}$: Means with the different letters in the same column for every parameters are significant statistically (p< 0.05).

Table 3. The concentrations of dissolved oxygen, pH, total hardness, of Sakaryabasi -West Pond by months and stations (Mean±SE)

Months	Dissolved Oxygen (mg/L)		pH		Total Hardness (FH°)	
	1.station*	2.station**	1.station	2.station	1.station	2.station
March	7.1±0.14$^{a\,EF}$	7.05±0.7^{aD}	7.2±0.1^{aD}	7.45±0.07$^{a\,BC}$	51.2±0.4$^{a\,B}$	50.8±1.8$^{a\,A}$
April	7.45±0.07$^{a\,D}$	7.65±0.07^{aBC}	7.45±0.0^{aBC}	7.40±0.0$^{a\,BC}$	48.8±0.9$^{a\,DE}$	48.5±0.9$^{a\,AB}$
May	7.1±0.14$^{a\,EF}$	7.45±0.07^{aC}	7.55±0.1^{aABC}	7.50±0.14$^{a\,AB}$	49.5±0.7$^{a\,BC}$	50.4±0.4$^{a\,AB}$
June	7.1±0.10$^{a\,EF}$	7.0±0.3$^{a\,D}$	7.45±0.1^{aBC}	7.50±0.0$^{a\,AB}$	48.5±0.7$^{a\,DE}$	51±1.4$^{a\,A}$
July	8.1±0.1$^{a\,C}$	7.8±0.01^{aB}	7.70±0.14^{aA}	7.7±0.14$^{a\,A}$	47±1.4$^{a\,E}$	50±1.4$^{a\,AB}$
August	7.3±0.14$^{a\,DE}$	8.45±0.7^{bA}	7.10±0.1^{aD}	7.05±0.1$^{a\,D}$	50.6±2.9$^{a\,BC}$	50.1±0.8$^{a\,AB}$
September	7±0.0$^{a\,F}$	6.6±0.2^{aE}	7.65±0.1^{aAB}	7.75±0.1$^{a\,A}$	54.9±0.9$^{a\,A}$	51.8±0.2$^{a\,A}$
October	8.7±0.4$^{a\,A}$	7.45±0.07^{bC}	7.35±0.1^{aC}	7.30±0.1$^{a\,C}$	51.2±2.1$^{a\,B}$	47.7±1.0$^{a\,BC}$
November	8.4±0.4$^{a\,B}$	7.6±0.1^{bBC}	7.65±0.1^{aAB}	7.75±0.1$^{a\,A}$	49.3±0.6$^{a\,BC}$	45.5±0.6$^{a\,C}$

*: inside the cage; **: outside the cage

$^{a,\,b}$ Means with the different letters in the same line for every parameters are significant statistically (p<0.05)

$^{*A\,B\,C\,D\,E\,F}$ Means with the different letters in the same line for every parameters are significant statistically (p< 0.05).

Table 4. The concentrations of ammonium nitrogen, nitrite nitrogen , nitrate nitrogen, total phosphate of Sakaryabasi -West Pond by months and stations (Mean±SE)

Months	NH_3-N (mg/L)		NO_3-N (mg/L)		NO_2-N (mg/L)		TP (mg/L)	
	1.station*	2.station**	1.station	2.station	1.station	2.station	1.station	2.station
March	0.070±0.003$^{a\,G}$	0.079±0.002^{aF}	0.323±0.007^{aH}	0.351±0.008^{aG}	0.009±0.001^{aB}	0.010±0.00^{aA}	0.030±0.00^{aC}	0.035±0.00^{aC}
April	0.090±0.00$^{a\,E}$	0.078±0.00^{bF}	0.403±0.005^{aG}	0.405±0.007^{aF}	0.008±0.00^{aC}	0.007±0.001^{aCD}	0.050±0.001^{aB}	0.040±0.002^{bC}
May	0.080±0.001$^{a\,F}$	0.086±0.001^{aE}	0.509±0.005^{aDE}	0.504±0.004^{aD}	0.008±0.001^{aC}	0.009±0.001^{aB}	0.070±0.001^{aA}	0.050±0.00^{bBC}
June	0.071±0.00^{bG}	0.189±0.00^{aA}	0.518±0.001^{bD}	0.550±0.007^{aC}	0.010±0.001^{aB}	0.008±0.00^{bBC}	0.066±0.001^{aA}	0.070±0.00^{aAB}
July	0.166±0.001^{bB}	0.185±0.001^{aA}	0.596±0.001^{aC}	0.475±0.001^{bE}	0.008±0.00^{aC}	0.008±0.001^{aBC}	0.070±0.00^{aA}	0.063±0.001^{aAB}
August	0.109±0.001^{bD}	0.151±0.00^{aB}	0.465±0.001^{aF}	0.398±0.001^{bF}	0.013±0.001^{aA}	0.006±0.00^{bDE}	0.071±0.001^{bA}	0.080±0.00^{aA}
September	0.134±0.001^{bC}	0.144±0.001^{aC}	0.702±0.005^{aB}	0.595±0.001^{bB}	0.00±0.008^{aC}	0.007±0.001^{aCD}	0.060±0.00^{bAB}	0.085±0.001^{aA}
October	0.176±0.00^{aA}	0.137±0.003^{bD}	0.736±0.007^{aA}	0.699±0.00^{bA}	0.006±0.00^{aD}	0.004±0.001^{bF}	0.060±0.00^{aAB}	0.077±0.00^{aA}
November	0.050±0.00^{aH}	0.057±0.001^{aG}	0.505±0.007^{aD}	0.501±0.005^{aD}	0.007±0.001^{aCD}	0.005±0.00^{aE}	0.050±0.00^{aB}	0.050±0.00^{aBC}

*: inside the cage; **: outside the cage

$^{a.b}$ Means with the different letters in the same line for every parameters are significant statistically (p<0.05)

$^{*A\,B\,C\,D\,E\,F\,G\,H\,I}$ Means with the different letters in the same line for every parameters are significant statistically (p< 0.05).

Phytoplankton belonging to five classes and a total of 56 species were identified in the pond (Table 1). The highest abundance and species richness were found in Bacillariophyceae, so it was the dominant group in phytoplankton (Figure 2). The mean phytoplankton numbers were changed between 45 ± 4 and 296 ± 2 numbers/ml (Table 2). The differences in phytoplankton number by the months and the stations were found significant ($p<0.01$). Phytoplankton numbers in the Station 1 were higher than those in the Station 2. In both stations, phytoplankton numbers reached to their highest values in August and then decreased.

The mean chlorophyll *a* concentration ranged between 0.55±0.01 and 9.80±0.08 mg/m^3 (Table 2). The differences in the mean chlorophyll *a* concentration by the months and the stations were found significant ($p<0.01$).

The zooplankton community was examined in three groups such as Rotifera, Cladocera and Copepoda. Ten species from Rotifera, 1 species from Cladocera and 1 genus from Copepoda were identified (Table 1). During the study, Rotifera was the dominant group in both stations (Figure 3). While Cladocera was represented by *Chydorus sphaericus*, the majority of Copepoda was in nauplii stage and identified such as *Cyclops* sp. The mean zooplankton abundance ranged between 2±0 and 52±6 numbers/l (Table 2). The differences in the mean zooplankton abundance by the months and the stations were found significant ($p<0.01$).

Benthic macroinvertebrate community consisted of the members of Gastropoda and Diptera (Table 1). Additionally, *Lymnaea, Planorbis* and *Valvata* from Gastropoda and chironomidae larvae from Diptera were identified. The mean abundance of benthic macroinvertebrate changed between 481 ±11 and 1927 ±36 numbers/m^2 (Table 2). The differences in the mean benthic macroinvertebrate abundance by the months and the stations were found significant ($p<0.01$).

Discussion

The effectiveness of grass carp in controlling plant overgrowth in water bodies depends on a number of factors, such as individual weight of fish and stock density, composition of plant species, and the most important is probably the water temperature (Opuszynski and Shireman, 1995).

It was indicated that vegetation control by grass carp was excellent when using fish with total length longer than 190-195 mm (Lembi *et al.*, 1978) in order to avoid themselves from their predators. In this

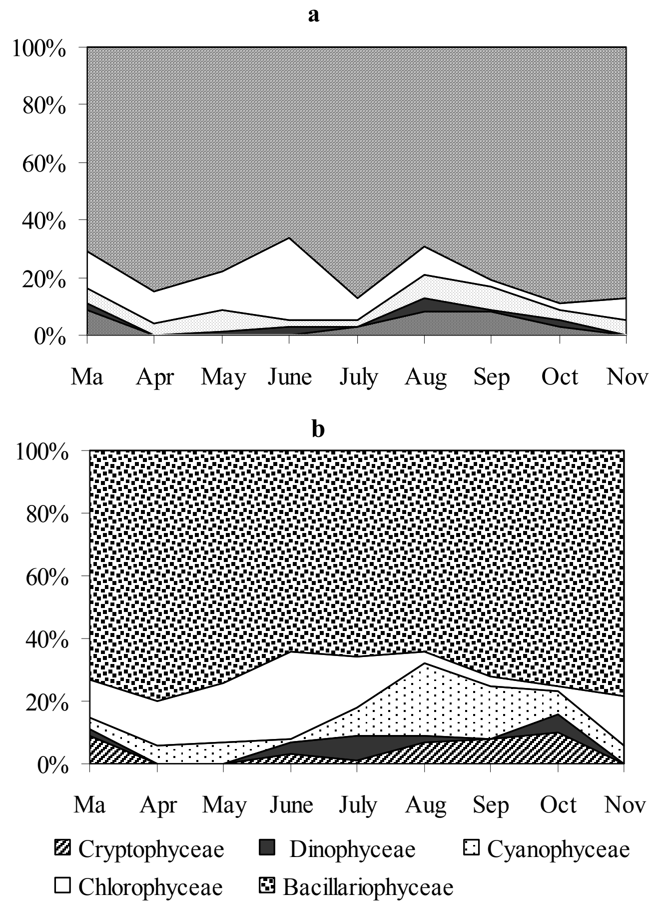

Figure 2. The phytoplankton composition of Sakaryabasi-West Pond (%).
a. Inside the cage b. Outside the cage

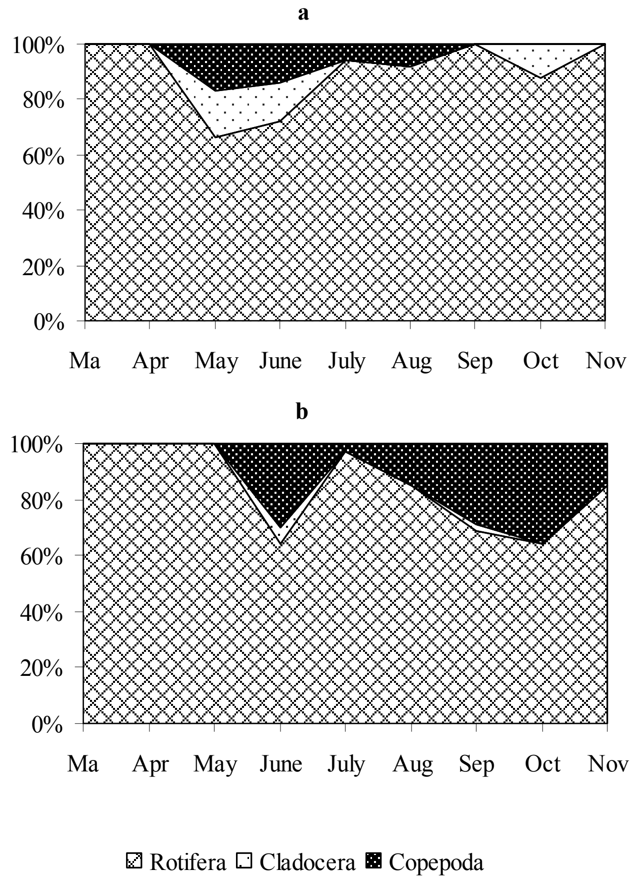

Figure 3. The zooplankton composition of Sakaryabasi-West Pond (%).
a. Inside the cage b. Outside the cage

study, grass carp was used in an average length of 19.11± 2.4 cm.

The cage was covered by aquatic plants such as *Potamogeton pectinatus, Ceratophyllum submersum, Myriophyllum aquaticum, Lemna trisulca* entirely. Outside the cage, *Potamogeton pectinatus, Ceratophyllum submersum, Myriophyllum aquaticum, Lemna trisulca* were preferred by grass carp over filemanteous algae and disappeared in the pond after May. Filamentous algae such as *Cladophora, Zygnema* and *Spirogyra* were maintained in the pond. Grass carp could not consume *Phragmites* due to its hard tissue as it was reported (Altınayar *et al.*, 1994; Opuszynski and Shireman, 1995). In general, the most desired food by grass carp is soft submerged plants. The aquatic plants which are consumed include *Elodea canadensis*, *Potamogeton pectinatus, Ceratophyllum submersum, Myriophyllum spicatum*. The emergent plants and filamentous algae frequently occur in great abundance and create considerable difficulty in the management of fisheries and proper use of water bodies for other purposes. Reluctant consumption of filamentous algae by grass carp has been confirmed in some studies. When given a choice, grass carp clearly prefer macroflora to algae (Opuszynski, 1979).

During the research, aquatic plant biomass inside the cage increased 7 times compared to the beginning and the differences were found significant between the stations, except for March and April ($p<0.05$). However, aquatic plant biomass decreased 2.5 times in the pond cage following grass carp stocking. Kirkagac and Demir (2004) also reported that aquatic plant biomass decreased 2.5-4 times in earthen fish ponds with different grass carp stocking rates (200-400-600 fish/ha) between May and September 2000.

In the pond, the lowest average water temperature (13±1°C) was measured in November and the highest average value (24±1°C) was measured in August. It was reported that two factors limiting grass carp utilization for aquatic weed control were food selectivity and the relatively high temperature needed for active feeding (Opuszynski, 1979; Riemer, 1984). It was stated that effective aquatic plant control could not be expected when water temperatures were below 18°C (Opuszynski and Shireman, 1995). Optimum feeding water temperature for grass carp ranges between 21 and 26^{o}C. For an effective weed control, water temperature must be above 20^{o}C at least for 30 and 60 days in a year (Baran and Seçer, 1979).

The variations of the average dissolved oxygen values between stations were found insignificant except for August, October and November ($p>0.01$). Studies conducted to determine water quality changes after the introduction of grass carp indicated that temperature and oxygen values remained relatively unaffected. Oxygen levels after macrophyte removal were usually maintained by an increase in phytoplankton (Opuszynski and Shireman, 1995). The variations of pH values between stations were found significant ($p<0.01$). The highest average pH value was in July inside the cage and in July, September and November outside the cage. The differences in the average total hardness values were found significant among months ($p<0.01$), but found insignificant between stations ($p>0.05$). Total hardness in Sakaryabasi-West Pond was above 350 mg $CaCO_3$ and can be classified as hard water according to Fox (1992) and Yaramaz (1992). Such an excessive aquatic plant growth especially the plant species that adapted to hard waters was encouraged by hardness of Sakaryabasi-West Pond.

Ammonium-nitrogen, nitrate-nitrogen, nitrite-nitrogen, total phosphorus were found statistically significant by months and stations ($p<0.01$). The highest average ammonium-nitrogen concentration was found in October in the Station 1 and in June in the Station 2, and then tend to decrease in both stations. The average nitrate-nitrogen concentrations increased in both stations until October and then decreased. While the nitrite-nitrogen concentrations increased until August in the Station 1, reductions were observed in the nitrite-nitrogen concentrations in the Station 2 during the research. The average total phosphorus concentrations were found higher in both stations in summer months. It was indicated that an important part of the nutrients in aquatic plants was retained in grass carp after consumption (Lembi *et al.*, 1978; Kırkağaç and Pulatsu, 2001a; Kırkağaç and Demir, 2004). However, Shireman and Smith (1983) found an increase in nutrient concentrations and phytoplankton abundance after stocking grass carp in a lake. In Sakaryabasi-West Pond, it was thought that the differences in nutrient concentrations between stations resulted from the excessive aquatic plant growth, decomposition of death plants, the factors related to the water temperature, the consumption of aquatic plants by grass carp, and also the seasonal variations in zooplankton, phytoplankton and benthic fauna communities and complex relationships among them. However, it was reported that water quality parameters may increase in the short term (first year), but will return to prestocking levels in the subsequent years (Shireman *et al.*, 1985).

The differences in the number of phytoplanktons by the months and the stations were found significant ($p<0.01$). The number of phytoplanktons in the Station 1 was higher than that in the Station 2. It was indicated that in nutrient poor lakes algal abundance changes very little, even if large amounts of vegetation were removed. Controversy in nutrient rich lakes algal blooms would occur when macrophytes were removed from these systems (Opuszynski and Shireman, 1995). Although phytoplankton abundance was low in pond, there was an increase in the cage. This resulted from the epiphytic algae such as diatoms with an excessive plant growth. The differences in the mean chlorophyll *a* concentrations by the months and the stations were found significant ($p<0.01$). The mean chlorophyll *a* concentration reached to its highest value in June in the Station 1 and in August in the Station 2. In this study, chlorophyll *a* concentrations were found higher than the early findings in 2001-2002 years in Sakaryabasi-West Pond (Demir and Kırkağaç, 2005). It was reported that there was no change in chlorophyll *a* concentration after stocking grass carp in order to control aquatic plant growth in a lake (Cooke *et al.*, 1986). However, increases in chlorophyll *a* concentrations in the ponds after stocking grass carp in comparison to control pond were indicated by Lembi *et al.* (1978), Kırkağaç and Demir (2004). In this study, chlorophyll *a* concentration was higher inside the cage than the outside due to clogging the net cage by algae.

The differences in the mean zooplankton abundance by the months and the stations were found significant ($p<0.01$). During the study, the mean zooplankton abundance was found higher in the Station 2 than the Station 1. The highest abundance of zooplankton was observed inside the cage in July and outside the cage in September. Afterwards the mean zooplankton abundance decreased in both stations. Rotifera was the dominant group in zooplankton community during the research. Subjected to gradual decrease or elimination of the vegetation, zooplankton assemblages shifted to small suspension feeders, especially rotifers with increased abundance (Richard *et al.*, 1985; Kırkağaç and Pulatsü, 2001b). In this study, zooplankton composition was not affected by grass carp directly; the differences in zooplankton abundance might be after the elimination of aquatic plants.

The differences in the mean benthic macroinvertebrate abundance by the months and the stations were found significant ($p<0.01$). In both stations, the mean benthic macroinvertebrate abundance increased during the study. Diptera members consisted of 1-3% of the benthic macroinvertebrate and Gastropoda was the dominant group in both stations. Benthic fauna increased twice outside the cage in comparison with the Station 1. As it was indicated, responses of macroinvertebrate to reduced vegetation vary from decreases to increases in density and diversity due to counteracting effects of reduced plant surface habitat and increased invertebrate food supplies (Bain, 1993; Opuszynski and Shireman, 1995; Kırkağaç and Demir, 2004).

In Sakaryabasi-West Pond, grass carp had a direct effect on submerged plants. Other biological effects are mostly secondary consequences of vegetation changes. The results of the study showed the short term effects of grass carp on the pond ecology, and, further investigations should be focused on the long term effects of grass carp on aquatic ecosystems in the light of this study.

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