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INFLUENCE OF TROUT CAGE CULTURE ON WATER QUALITY, PLANKTON AND BENTHOS IN AN ANATOLIAN DAM LAKE

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Abstract

The effects of rainbow trout cage culture on water quality, phytoplankton, zooplankton and benthos were investigated in a cage farm of 30 ton capacity in Kesikköprü dam lake. Water temperature did not differ among stations while dissolved oxygen and pH values were slightly lower in the station with cages. Significant and insignificant increases were detected in concentrations of ammonia, nitrate, orthophosphate and chlorophyll *a* in the cage station. Also, the abundance of phytoplankton, zooplankton and benthos was highest in the cage station. The composition of phytoplankton was not fundamentally different among stations except for a higher abundance of Chlorophyceae and Cyanophyceae species in the cage station in November. The composition of zooplankton and benthos did not differ among stations; rotifers and gastropods were dominant, respectively.

Introduction

The freshwater resources of Turkey are extremely rich, including 200 natural lakes, 2500 reservoirs and 33 rivers with a total area of 1.5 million ha. The most commonly cultured fish is trout, traditionally produced in concrete raceways and ponds. In recent years, there has been a rapid increase in the number of fish farms that use net cages to rear rainbow trout (*Onchorynchus mykiss* Walbaum, 1792) in lakes, rivers and dam lakes of Turkey. In 1999, 57 cage trout farms were reported with a total capacity of 4100 tons per year in fresh waters (Anonymous, 2000).

The most important effect of fish cage cul-

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ture on the environment is the accumulation of organic matter and nutrients in the water and sediments. The waste produced from fish cage culture largely consists of solid wastes (uneaten food, feces, fish scales, mucus) and soluble wastes (dissolved phosphorus and nitrogen compounds; Cornel and Whoriskey, 1993). Consequently, fish cage farming constitutes a eutrophication risk. However, the effects depend on farming practices, the size of the farm, the nature and volume of wastes produced, the volume of the lake, the water exchange rate and other characteristics of the water body (Phillips et al., 1985). The impacts of fish cage farming include increased nutrient levels, organic sediment matter and turbidity, and decreased Secchi depth, dissolved oxygen levels and pH (Beveridge, 1984; Phillips et al., 1985; Wisniewski and Planter, 1987; Pitta et al., 1999). But a rainbow trout cage farm with a capacity of 14 tons did not cause any changes in pH, chlorophyll *a*, conductivity or nutrients in the oligotrophic Lac du Passage (Cornel and Whoriskey, 1993) while inorganic nitrogen, orthophosphate, suspended solids and phytoplankton were significantly more numerous near the cages than near the control station in a 300 ton capacity trout farm in shallow, unstratified Fad lake (Stirling and Dey, 1990).

Zooplankton were less abundant during the summer in the cage area than at control sites and the richness and biomass of benthic organisms were lower in Lac du Passage (Cornel and Whoriskey, 1993). The composition of species in the zooplankton community changed and rotifers and crustaceans dominated in Lake Glebokie (Weglenska et al., 1987).

Although fish cage culture in marine waters has been evaluated by several authors in Turkey (Düzgünes et al., 1995; Pulatsü et al., 1999; Sahin et al., 1999; Demir and Atay, 2000), the impact of fish cage culture on freshwater environments has not yet been studied. Phytoplankton, zooplankton, benthic fauna and their seasonal variations in Kesikköprü dam lake were reported (Yigit-Atasagun, 1998; Ahiska, 1999; Demiryürek, 2000). The objective of this study was to evaluate the effects of rainbow trout cage culture on water quality, phytoplankton, zooplankton and benthos in a 30 ton capacity farm in Kesikköprü dam lake. As this is the first research about the impacts of a lake-based fish cage culture in Turkey, it is an important contribution to the future development of similar farms.

Materials and Methods

Kesikköprü dam lake is an oligotrophic lake (surface area 6.5 km^2) located 110 km southeast of Ankara in Central Anatolia, Turkey (Yigit-Atasagun, 1998; Ahiska, 1999). This study was carried out in a rainbow trout farm with a capacity of 30 tons in the Kesikköprü dam lake between January and November 1998. The mean flows in January, April, August and November were reported as 16, 9.8, 8.5 and 10.6 m^3/sec, respectively. The site of the farm is a narrow part near the bend of another dam (Hirfanly). Water, plankton and benthos were sampled in January, April, August and November from three stations (Fig. 1): amongst the fish cages (C), 200 m to the east (H), and 200 m to the west (K). Water flows from station H to station K. Because of this, station H represented the control. The depths of the stations were the same and fluctuated 6.5-9 m, depending on the season. The replicated water samples were collected just below the surface and at a depth of 5 m with a Ruttner sampler. Plankton samples were taken by a 55 µ plankton net for qualitative analysis.

Water temperature, Secchi disc transparency, dissolved oxygen and pH were measured *in situ*. Nitrate-N, nitrite-N, ammonia-N and orthophosphate were determined by spectrophotometric methods (APHA, 1975). Water samples (l liter) were filtered through Whatman GF/C filter papers. Chlorophyll *a* was extracted with 90% acetone and determined spectrophotometrically (Strickland and Parsons, 1972). The water samples (10 ml) were sedimented after preservation with Lugol solution in counting chambers. Phytoplankton counting followed the standard inverted microscope method as described by Lund et al. (1958). Colonies and filaments were counted as an organism (APHA, 1975). Phytoplankton were identified using a binocular microscope (Hustedt, 1930; Huber-Pestalozzi, 1942;

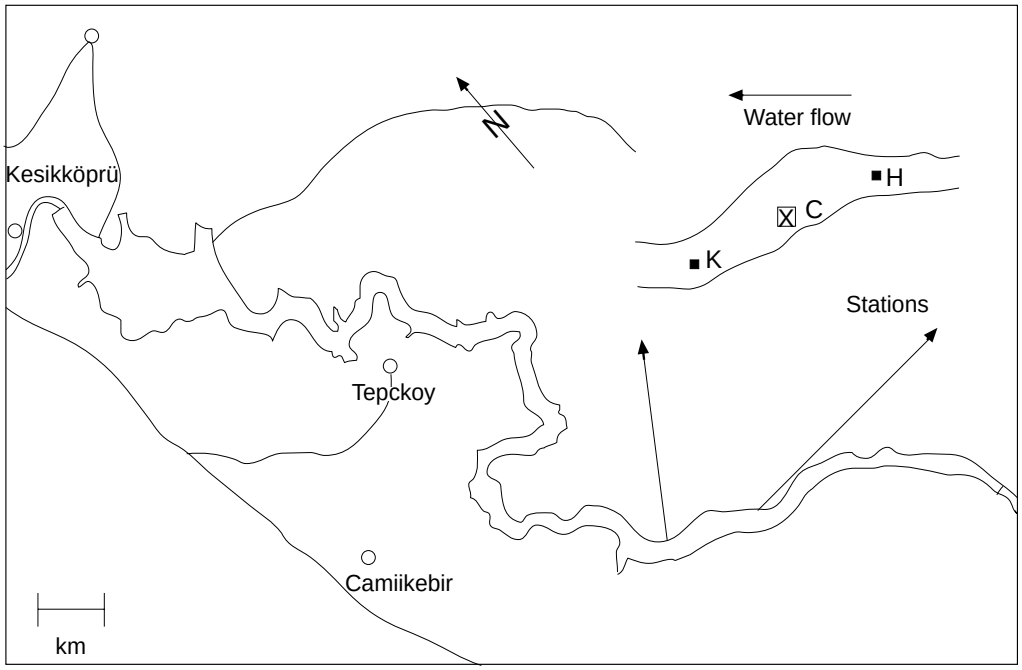

Fig. 1. Kesikköprü dam lake and location of the three sampling stations.

Huber-Pestalozzi, 1950; Prescott, 1973; Lind and Brook, 1980; Komarek and Fott, 1983; Popovski and Pfiester, 1990). For zooplankton counting, the water samples preserved in a 4% formaldehyde solution were allowed to settle in graduated cylinders, enumerated in chambers (Wetzel and Likens, 1991), and identified (Edmondson, 1959; Harding and Smith, 1974; Koste, 1978). The sediments were sampled with an Ekman grab, two samples were collected at each station and washed through a series of sieves ranging 260-3360 µ mesh. Benthic fauna were identified and counted with the aid of a stereoscopic microscope (Edmondson, 1959; Macan, 1975).

Statistical analyses were performed using Minitab and Mstat programs for Windows. Variance analysis (ANOVA) and Duncan multiple range test were used to evaluate differences in water quality, phytoplankton, zooplankton and benthos between the stations.

Results

The stations were located in a narrow part of the lake and there was a strong current from the Hirfanly dam. Because of this, the water column was mixed from surface to depth. Variations in water quality parameters, phytoplankton and zooplankton abundances between the samples of water from the surface and the samples of water from a depth of 5 m were statistically insignificant. The mean water temperature ranged from 9.1±0.3°C to 21.5±0.4°C. Transparency varied between 6.9 m (January) and 5 m (August; Fig. 2); the highest values were in station H and the lowest in station C. The mean values were lower in station C by 0.6 m and in station K by 0.3 m than that of station H.

Table 1 shows water quality in January, April, August and November 1998. The lowest dissolved oxygen was 7.1±0.1 mg/l in station C in August, the highest was 10.3±0.05 mg/l in January in station H. pH was lower in January

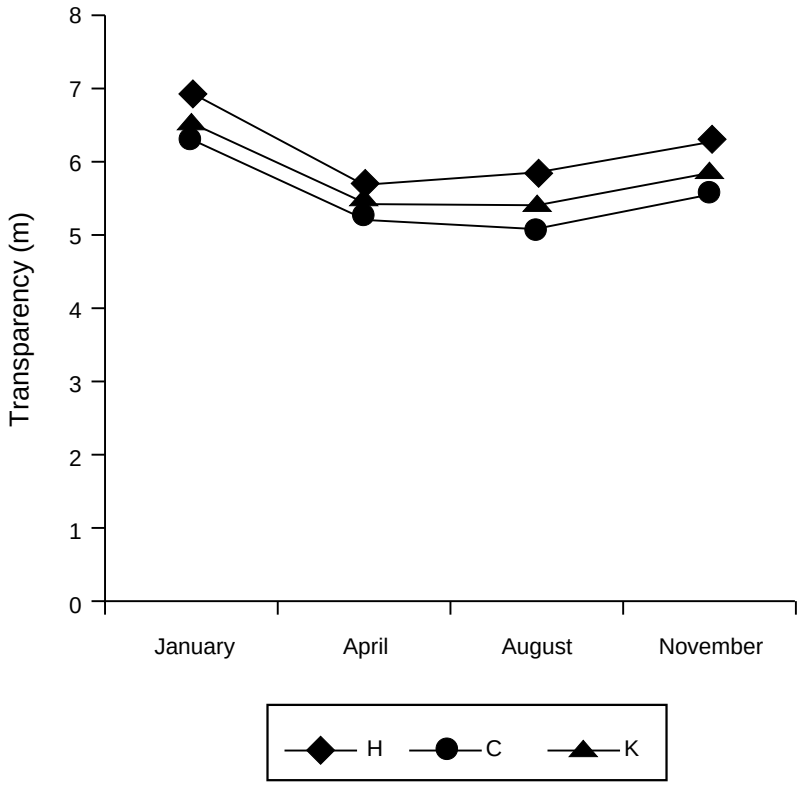

Fig. 2. Transparency in stations H, C and K.

than in other months. All the nutrients except nitrate-N had a similar annual cycle: they were high in January and April and slightly lower in November. Variations in these parameters were statistically significant between stations according to the Variance analysis ($p<0.05$). According to the Duncan test, variations in dissolved oxygen, pH, ammonia and nitrite were not significant, except dissolved oxygen in January was higher in station H, pH in April was higher in station H, and ammonia in January was lower in station H than in the other stations. Nitrate and orthophosphate values were analyzed by the Duncan test. Although these values were higher in station C than in the others, the variations were significant only in April and August for nitrate and in January, April and November for orthophosphate.

The chlorophyll *a* concentrations were highest in station C (Fig. 3) and changed seasonally from 1.9 mg/m^3 in January to 5.9 mg/m^3 in August. The variations among the stations each month were insignificant ($p>0.05$).

The highest phytoplankton counts were in station C in all months, followed by stations K and H (Table 2). Phytoplankton increased from January to August and declined in November due to the fall in water temperature. Results of the Duncan test showed that phytoplankton numbers were statistically different ($p<0.05$) among the stations in August and November.

Phytoplankton belonging to seven classes (Cyanophyceae, Euglenophyceae, Chrysophyceae, Bacillariophyceae, Dinophyceae and Cryptophyceae) were identified (Table 3). In January, April and November, Bacillario-

Table 1. Water quality in stations H, C and K (mean ± SE).

Month	Dissolved oxygen (mg/l)			pH			NH_3-N (mg/l)		
	H	C	K	H	C	K	H	C	K
January	10.25^{a} ±0.05	10.15^{ab}±0.05	9.9^{b}±0.099	7.45^{a}±0.049	7.4^{a}±0.099	7.45^{a}±0.049	0.041^{b}±0.004	0.064^{a}±0.002	0.061^{a}±0.002
April	9.0^{a}±0.2	8.95^{a}±0.049	8.75^{a}±0.049	8.25^{a}±0.049	7.85^{b}±0.048	8.0^{ab}±0.099	0.034^{a}±0.01	0.035^{a}±0.001	0.03^{a}±0.0
August	7.3^{a}±0.099	7.1^{a}±0.099	7.25^{a}±0.049	8.5^{a}±0.099	8.25^{a}±0.049	8.4^{a}±0.099	0.04^{a}±0.005	0.055^{a}±0.002	0.048^{a}±0.002
November	7.8^{a}±0.4	7.9^{a}±0.099	7.95^{a}±0.049	8.05^{a}±0.149	7.95^{a}±0.049	8.0^{a}±0.099	0.021^{a}±0.004	0.038^{a}±0.0	0.035^{a}±0.0
Month	NO_2-N (mg/l)			NO_3-N (mg/l)			PO_4-P (mg/l)		
	H	C	K	H	C	K	H	C	K
January	0.015^{a}±0.002	0.011^{a}±0.01	0.012^{a}±0.01	0.083^{a}±0.01	0.118^{a}±0.02	0.096^{a}±0.01	0.057^{b}±0.004	0.073^{a}±0.002	0.067^{ab}±0.002
April	0.01^{a}±0.0	0.013^{a}±0.0	0.011^{a}±0.0	0.275^{b}±0.019	0.542^{a}±0.01	0.272^{b}±0.017	0.055^{c}±0.003	0.081^{a}±0.0	0.060^{b}±0.0
August	0.01^{a}±0.0	0.012^{a}±0.0	0.01^{a}±0.0	0.077^{b}±0.016	0.155^{a}±0.01	0.132^{a}±0.014	0.05^{a}±0.0	0.065^{a}±0.01	0.05^{a}±0.01
November	0.005^{a}±0.0	0.004^{a}±0.0	0.006^{a}±0.0	0.11^{a}±0.004	0.125^{a}±0.018	0.1^{a}±0.01	0.03^{b}±0.01	0.05^{a}±0.01	0.02^{b}±0.0

Differences between means with the same superscript in each row are not significant (p>0.05).

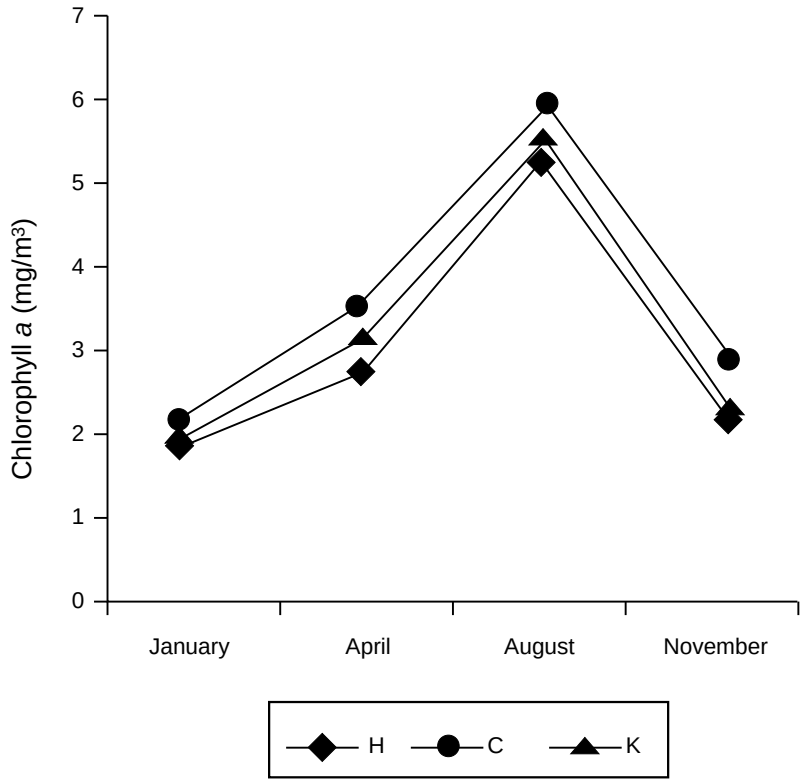

Fig. 3. Chlorophyll *a* concentration in stations H, C and K.

phyceae was dominant in all stations (Fig. 4). The percentages of diatoms were 61.2%, 78.8% and 40% of the total phytoplankton numbers in January, April and November, respectively. In August, the Chrysophyceae species, *Dinobryon divergens,* increased and comprised 70% of the total phytoplankton. The composition of phytoplankton varied similarly between stations, except for a slight increase of Chlorophyceae and Cyanophyceae in station C in November.

The abundance of three groups of zooplankton was estimated: rotifers, cladocerans and copepods (Table 3). Variations between stations were significant ($p<0.05$;Table 2). Zooplankton was highest in station C in all months, followed by stations K and H, but significantly higher only in January and April, according to the Duncan test. The percentage of rotifers was the highest in all stations (Fig. 5), composing more than 90% of the individuals counted. The composition did not vary from station to station. The rotifer community consisted mostly of *Polyarthra, Keratella* and *Brachionus* spp. Other species of rotifers were rarely found.

The abundance of four groups of benthic fauna were estimated: Gastropods, Oligochaetes, Diptera and Crustacea (Table 3). The variance between stations was significant ($p<0.05$; Table 2). The highest values were in station C, followed by station K and H; these differences were significant in January, August and November, according to the Duncan test. Gastropods (dominant) and oligochaetes were found in all stations (Fig. 6). The percentage of diptera was higher in station C than in the other stations in April.

Table 2. Abundance of phytoplankton, zooplankton and benthic fauna in stations H, C and K (mean ± SE).

Month	*Station*		
	H	*C*	*K*
Phytoplankton (individuals/l)			
January	81,320[a]±12,840	98,441[a]±1426	78,467[a]±4279
April	94,161[a]±11,413	118,414[a]±7133	104,147[a]±9986
August	406,603[b]±35,666	579,232[a]±17,120	532,151[a]±1481
November	90,951[b]±16,049	137,318[a]±5349	109,497[ab]±1069
Zooplankton (individuals/l)			
January	28.0[b]±2.99	59.0[a]±4.0	34.5[b]±4.4
April	229.0[b]±0.5	778.0[a]±110.3	384.5[b]±54.5
August	348.5[a]±132.2	614.0[a]±108.2	472.5[a]±36.5
November	6.0[a]±1.0	19.5[a]±1.5	16.0[a]±5.0
Benthic fauna ((individuals/m^2)			
January	169.0[b]±14.0	688.5[a]±67.5	182.5[b]±6.5
April	975.0[ab]±111.7	1082.5[b]±2.5	1082.5[b]±2.5
August	3056.0[c]±125.2	7445.0[a]±243.2	6005.5[b]±75.5
November	303.5[b] ±15.5	1221.0[a]±88.0	1123.0[a]±14.9

Differences between means with the same superscripts in a row are not significant ($p>0.05$).

Crustaceans were found in stations C and K in April, August and November. The abundance of phytoplankton, zooplankton and benthos was higher in station K than in station H because the water flowed from H to K. The organisms in station K might have been affected by the cage farm.

Discussion

The results of the present study showed that the rainbow trout cage farm (30 ton capacity) in the Kesikköprü dam lake affected water quality, phytoplankton, zooplankton and benthos in several ways. Water temperatures showed seasonal trends, but the variation between stations was not statistically significant according to Variance analysis. Fish cage culture had no measurable effect on water temperature.

Although the lowest values of dissolved oxygen were measured in station C, there was no important oxygen depletion in the vicinity of the cages. It has been reported that oxygen depletion in water surrounding cages is due to the respiration of the caged fish (Cornel and Whoriskey, 1993). The average flow rate in our study was 11 m^3/sec, approximately 1 million

Table 3. Phytoplankton, zooplankton and benthic fauna found in study sites.

Phytoplankton	*Zooplankton*
BACILLARIOPHYCEAE	ROTIFERA
Amphora ovalis Kütz.	*Anuraeopsis fissa* Gosse
Asterionella formosa Hassall	*Asplanchna multiceps* (Schrank)
Cocconeis placentula Ehr.	*A. sieboldi* Leydig
Cyclotella ocellata Pantocs.	*Brachionus angularis* Gosse
Cymatopleura solea (Breb.) W. Smith	*B. calyciflorus* Pallas
Cymbella asparea (Ehr.) Cleve	*Hexarthra fennica* (Levander)
C. cistula (Hemprich) Grun.	*Keratella cochlearis* (Gosse)
C. parva (W. Smith) Cleve	*K. quadrata* (O.F.M.)
Diatome elongatum (Lyngby.) Ag.	*Lecane aquila* H.&M.
Gomphonema acuminatum Ehr.	*Lepadella ovalis* (O.F.M.)
Navicula cryptocephala Kütz.	*Polyarthra remata* (Skor.)
Nitzschia linearis W. Smith	*P. vulgaris* Carlin
N. sigmoidea (Nitzsch.) W. Smith	*Pompholyx triloba* Pejler
Synedra acus Kütz.	*Synchaeta litoralis* (Rouss.)
S. capitata Ehr.	*Testudinella epicopta* Myers
S. ulna (Nitzsch.) Ehr.	*T. tridentata* Smirnov
Rhicosphaenia curvata (Kütz.) Ehr.	
	CLADOCERA
CHLOROPHYCEAE	*Bosmina longirostris* (O.F.M.)
Ankistrodesmus falcatus (Corda) Ralfs	*Daphnia longispina* (O.F.M.)
Botryococcus braunii Kütz.	*Diaphanosoma lacustris* (Korinek)
Closterium acutum (Lyngby.) Breb.	
Coelastrum microporum Naeg.	COPEPODA
Monoraphidium arcuatum (Kors.) Hınd.	Cyclopoid copepod
M. mirabile (W&G. S. West) Pankow	Calanoid copepod
Pandorina morum (Müll.) Bory	
Pediastrum boryanum (Turp.) Meneg.	
P. dublex Meyen	*Benthic fauna*
Scenedesmus acuminatus (Lagerh.) Chod.	
S. linearis Kom.	CRUSTACEA
Staurastrum paradoxum Meyen West	*Gammarus* sp.
Tetraedron minimum (A. Br.) Hansg.	
	DIPTERA
CHRYSOPHYCEAE	*Chironomus* sp.
Dinobryon divergens Imhof	
	GASTROPODA
CRYPTOPHYCEAE	*Dressenia* sp.
Cryptomonas erosa Ehr.	*Lymnaea* sp.
C. ovata Ehr.	*Pisidium* sp.
	Planorbis sp.
CYANOPHYCEAE	
Pseudoanabaena sp.	OLIGOCHAETA
	Tubifex sp.
DINOPHYCEAE	
Ceratium hirundinella (O.F.M.) Schrank	
Gymnodinium austriacum Schiller	
Peridinium aciculiferum Lemm.	
P. cinctum (Müll.) Ehr.	
EUGLENOPHYCEAE	
Euglena acus Ehr.	
Trachelomonas sp.	

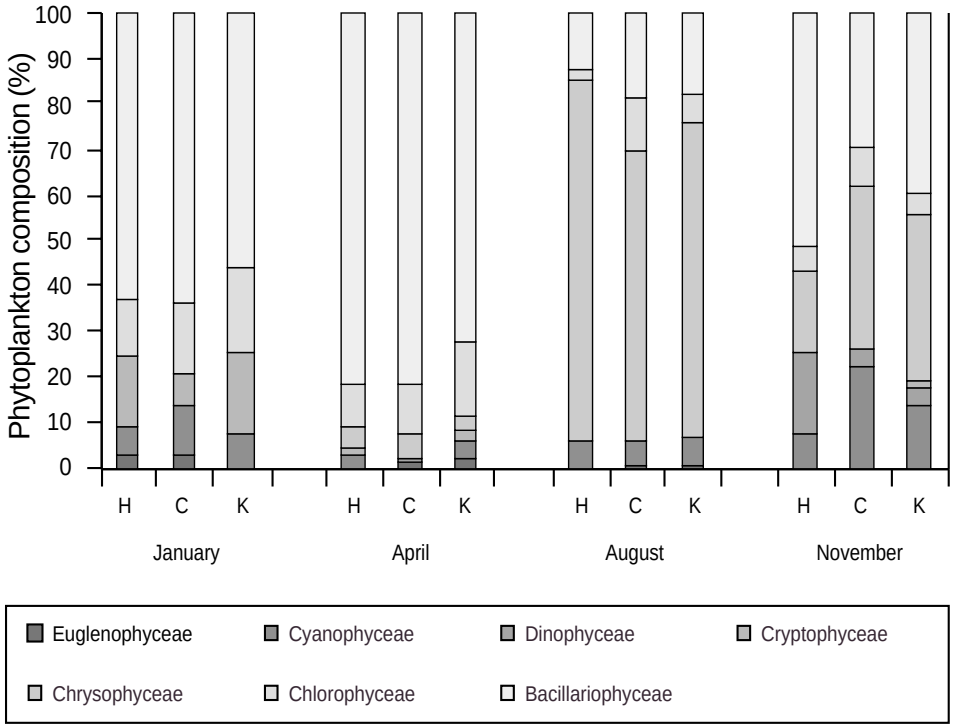

Fig. 4. Phytoplankton composition in stations H, C and K.

m^3/day. For 30 tons fish, we assumed a 3% daily feeding, equal to 1 ton feed/day. Oxygen consumption is approximately two-thirds the feed quantity. Hence, expected oxygen consumption is 0.66 t/day or 0.66 mg/l for a flow of 1 million m^3/day. Our results did not confirm this; dissolved oxygen at the cage station was only 0.2-0.05 mg/l lower than in station H, apparently due to re-aeration. The farm is located in the narrow part of the lake, and the water flow tends to be high, so the possibility that oxygen was continuously replenished is good. Problems, such as de-oxygenation resulting from blooms of Cyanophyceae as indicated by Stirling and Dey (1990), were not recorded.

pH was slightly lower in station C than in station H. Cornel and Whoriskey (1993) found that pH values were similar in their cage station and other stations, indicating that the farm had no affect on pH. But it was also reported that pH may drop in fish cage culture because of waste deposits (Beveridge, 1984; Pitta et al., 1999). In our study, the slightly lower pH in station C might be an impact of the cage culture.

The fish were fed 40% protein trout pellets twice a day; 1 ton feed/day contains 0.06 t N (15.5% N of protein). Krom et al. (1985) reported that 70-80% of the nutrients were exported from fish ponds. If we assume that 70% of the N was released into the water, the increase of inorganic nitrogen values should be about 0.04 mg/l in the cage station. Our results agreed with this value in January and November. In the warmer months, the nitrate fraction increased, most probably due to the effect of temperature on nitrification. If we accept the tolerable total inorganic nitrogen concentration for the lake as 1 mg/l, the carrying capacity of the lake is less than 300 tons fish. (Inorganic nitrogen

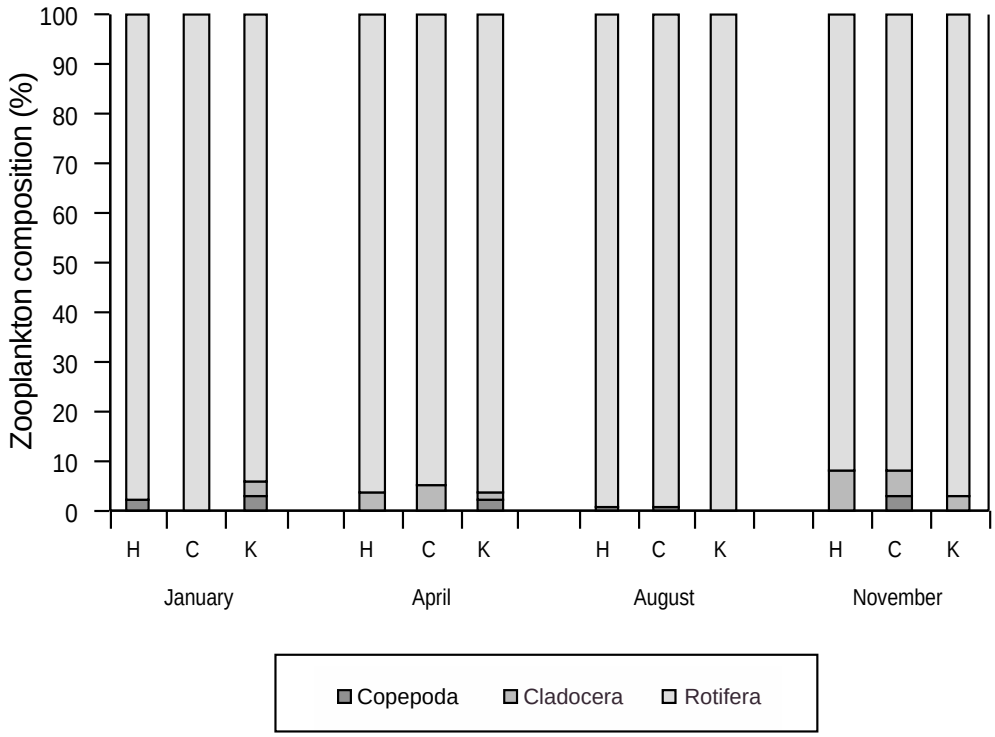

Fig. 5. Zooplankton composition in stations H, C and K.

increased 0.1 mg/l in the cage station for 30 tons fish production.) The nitrite variations among stations were not significant. This result agrees with Stirling and Dey (1990) who showed that nitrite concentration did not differ between the cage and control stations. But values of ammonia, nitrate and orthophosphate differed among stations and varied by month. The highest values were in station C. Cornel and Whoriskey (1993), however, found that ammonia, nitrate and orthophosphate levels at the farm and at control sites were similar. In our study, the capacity of the trout farm was more than two-fold that of Cornel and Whoriskey. Unfortunately the accumulation of organic matter in the sediment was not determined and the total phosphorus concentration was not measured in this study. Phillips (1984) predicted that total phosphorus loading from a trout farm was 18.8 kg/ton fish. According to this proportion, total phosphorus loading into Kesikköprü lake from the farm (30 ton trout production and 65 ha total surface area of the lake) was 0.87 g P/m^2/year. Phosphorus loading was calculated as 1.70 mg P/m^2/year by Cornel and Whoriskey (1993), as 5.3 g P/m^2/year by Stirling and Dey (1990), and as 1.3 g P/m^2/year by Weglenska et al (1987). Several authors indicated that nutrient levels might be increased by fish cage culture depending on the site and size of farms, water exchange rates and other characteristics of the water body (Phillips et al., 1985; Stirling and Dey, 1990; Pitta et al., 1999).

The mean Secchi transparency and chlorophyll *a* values (5.8 m and 3.3 mg/m^3, respectively) indicated the oligotrophic conditions (OECD, 1982). The concentration of chloro-

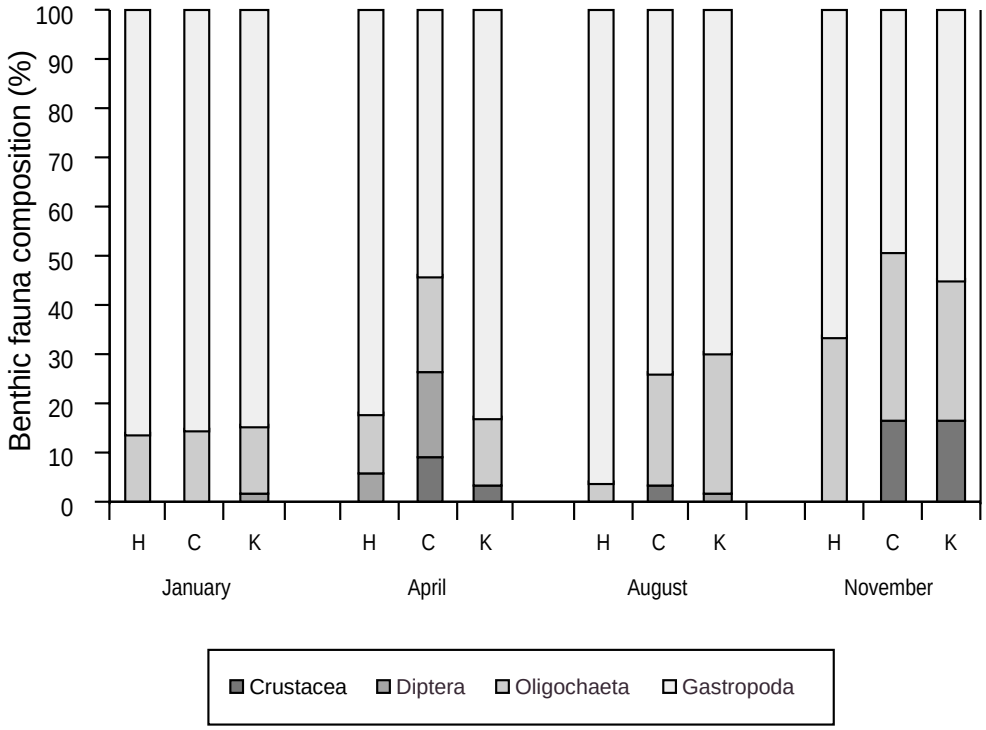

Fig. 6. Benthic fauna in stations H, C and K.

phyll *a* showed a seasonal trend and was highest in station C, but the difference from other stations was insignificant. Chlorophyll *a* levels remained low (<10 mg/m^3 recommended to avoid eutrophication) despite loading from a farm in the oligotrophic Lac du Passage (Cornel and Whoriskey, 1993). Also, the abundance of phytoplankton, zooplankton and benthos was highest in station C. The composition of organisms was not very different among stations, except for Chlorophyceae and Cyanophyceae spp. which were higher in station C. It has been reported that the phytoplankton count was higher in the cage station than in an open station in a cage farm in Bodrum (Demir and Atay, 2000) but, contrarily, the phytoplankton composition seemed to be similar. Their study was conducted in a sea bream and bass farm, and their results overlapped ours. Stirling and Dey (1990) concluded that the abundance of Chlorophyceae was higher at the cage station than at the control. Phytoplankton composition did not vary even though the numbers of phytoplankton, zooplankton and benthos were highest in manured carp ponds (Köksal et al., 1997; Atay and Demir, 1998; Kirkagac and Köksal, 1999). Cage culture and pond culture may have different effects on organisms but the increases of artificial food or nutrients change the abundance.

Generally, water renewal time is shorter in reservoirs than in natural lakes (not always the case), and changes in ecosystems such as eutrophication resulting from fish cage culture may be less harmful. Because of this, reservoirs are very appropriate water bodies for cage culture. In our study, results showed that there were localized short-term impacts of the

rainbow trout farm (about 30 ton capacity/year) but the long-term effects of different farm capacities are still unknown and need to be monitored.

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