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The Effect of Rainbow Trout (*Oncorhynchus mykiss* Walbaum, 1792) Cage Culture on Sediment Quality in Kesikköprü Reservoir, Turkey

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Abstract

Sediment quality in Kesikköprü Reservoir, was monitored at two stations (one located under a rainbow trout cage farm with a capacity of about 20 t $year^{-1}$, the second serving as a control site, located about 60 m away from the cage farm) at monthly intervals from December 2005 to May 2006 in order to determine the effects of rainbow trout cage culture on the reservoir sediment. Variables measured including organic matter (OM), total carbon (TC), total nitrogen (TN) and total phosphorus (TP) were elevated in the sediment at the cage site in comparison with the control site ($P<0.01$). At the sampling station under the cages, redox potential (Eh) was found to decrease to negative values, measured in March, April and May. Compared to the control site, organic matter and total nitrogen in the sediment under the cages increased by 1.08 and 1.3 times, respectively. When compared to the control station, TP and TC concentrations in the cage sediment showed 2.6 and 1.4-fold increases, respectively, reaching the highest values in February. These results indicate that the cage farm had a localized effect on the reservoir sediment at its recent production level, so it is thought that sediment quality parameters particularly TP and TC concentrations of sediment must be monitored for the sustainable cage fish farming in the reservoir.

Key words: sediment, rainbow trout, cage culture, reservoir, total phosphorus.

Introduction

Aquaculture in freshwater and marine environments is a rapidly developing sector in Turkey, and trout is the major fish species used for cage culture in freshwater systems. According to official records, it is indicated that there were 72 cage farms in reservoirs, with an annual capacity of 4,777 tons in 2004 (Aydın *et al*., 2005).

Intensive fish farming causes large amounts of organic waste in the form of unconsumed feed, fecal and excretory matter to accumulate in the bottom sediment. This organic waste matter generates considerable changes in the benthic macrofauna and chemical structure of the sediment (Ackefors and Enell, 1990). While a number of studies observed the effects of marine cage culturing on sediment (Karakassis *et al*., 1998; 1999; Sunlu *et al*., 1999; Dominguez *et al*., 2001; Pawar *et al*., 2001; 2002; Pearson *et al*., 2001; Carol *et al*., 2003), there have been few assessments of the environmental impacts of inland cage culturing (Cornel and Whoriskey, 1993; Kelly, 1993; Troell and Berg, 1997; Temporetti *et al*., 2001).

Since the exchange time of freshwater systems is shorter than that in marine environments, the environmental effects of wastes produced by freshwater cage fish culture are much stronger than those of marine cage farming (Beveridge *et al*., 1997). It has generally been observed that fish farming has a comparatively lower impact on the water column than on the sediment and analysis of the nutrient concentration of the sediment is a matter of determining the prospective inputs of the cages (La Rosa *et al*., 2004; Schendel *et al*., 2004).

Five rainbow trout cage farms with capacities varying between 20 and 55 tons, exist in Kesikköprü Reservoir, one of the inland water areas in Turkey where cage culturing has been performed. Some studies have been conducted to determine optimal stocking density in the rainbow trout cage farming operations in the reservoir and effects of cage operations on water quality, zooplankton and benthos (Aşır, 2000; Demir *et al*., 2001; Karaca and Pulatsü, 2003a; 2003b). This study intended to determine the effect of rainbow trout culture on the quality of sediment, a study topic not undertaken before in that particular reservoir.

Materials and Methods

Study Site and Sampling Stations

Kesikköprü Dam is 110 km south-east of Ankara, 25 km downstream of the Hirfanlı Dam; it was built on the Kızılırmak River in 1996. The dam is located between lat 39°23' N and long 33°25' E, and is 785 m above sea level. It has an area of 6.5 km^2, a volume of $95x10^6$ m^3 and a water-replenishment period of 0.04 years. Water flows from Hirfanlı Dam to Kesikköprü Dam. The reservoir is of the soil-rock filling type; it was built for the purposes of irrigation and energy production (Anonymous, 1992).

The fish farm studied had 12 net- cages and was located at a 20 m depth (approximately 100 m^3 per cage), with a total production of 20 tons per year of rainbow trout (*Oncorhynchus mykiss*). Rainbow trout with a mean size of 60.0±5 g were introduced into the cages in December 2005 and harvested at 250±10 g throughout the following six months. Sediment samples were collected using an Ekman-Birge dredge from beneath the cages (cage station) and the control station (at a 20 m depth) was about 60 m away from the cage station and located on the downstream of the reservoir (Figure 1).

Samples were kept in plastic bags in cold and dark conditions in the laboratory until analysis. Three sediment samples for sediment quality were taken monthly at the stations for six consecutive months, from December 2005 to May 2006. Water temperature, dissolved oxygen and pH were measured *in situ* using YSI 51B oxygenmeter and WTW pH 330 pHmeter. Secchi depth was also measured on-site during sampling events. Current velocity was determined according to Wetzel and Likens (1991) at the cage station in December.

Analytical Methods

Weighed sediment samples were dried in an oven at 105°C until they reached a constant weight. Sediment composition (particle-size analysis) was then performed using a sieve (Anonymous, 1990). Organic matter content was estimated by heating dried and homogenized samples in a muffle furnace at 550°C for 5 hours. Total phosphorus content of the sediment was determined by the vanadium-molybdate method (Kacar, 1995). Analyses for carbon and nitrogen were made using a LECO CHN-1000 elemental analyser. Redox potential was also measured using a reference calomel electrode.

Estimation of Nitrogen and Phosphorus Input to the Farm

The nitrogen and phosphorus input per unit area of the farm per month was estimated from the data on monthly feed input of the farm, the average area of the farm under fish culture during the growing season and the nitrogen and phosphorus content of the feed (Pawar *et al*., 2002).

Statistical Analyses

Statistical analyses were performed using the Minitab and MStat programs for Windows. ANOVA and Duncan's multiple-range test were used to evaluate differences in sediment quality parameters between stations and months.

Results

During the study, period the mean water temperature ranged from 3.9°C to 18.0°C. Secchi depth varied between 2.20 m (May) and 6.10 m (January); the highest value was observed in the control station and the lowest in the cage station. The lowest dissolved oxygen reading was 6.60 mg L^{-1} in the cage station in April, whereas the highest value was 12.43 mg L^{-1} in January in the control station.

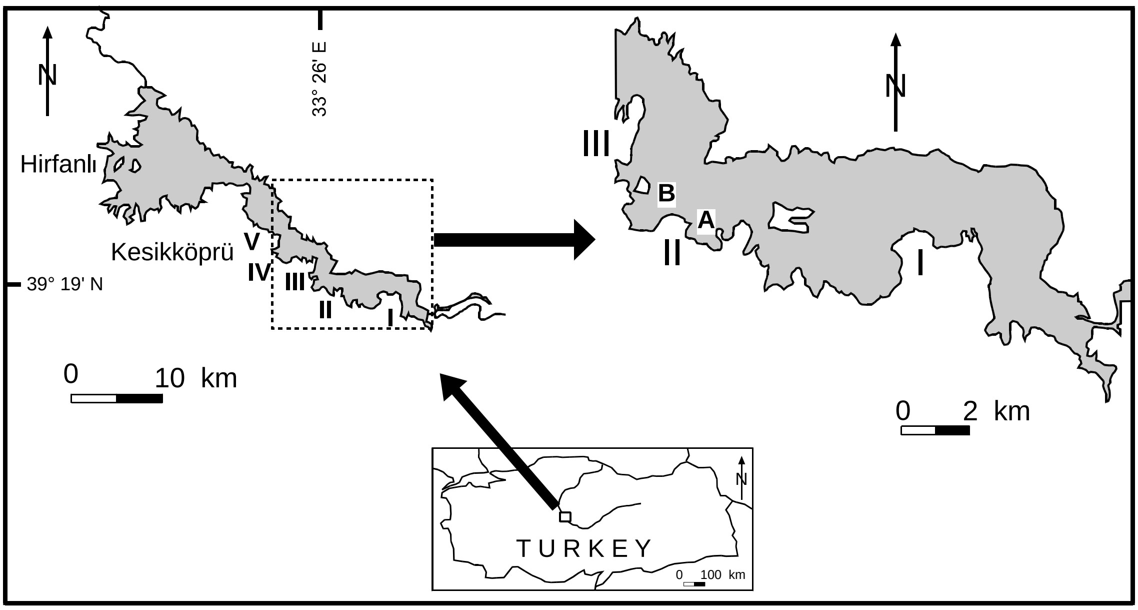

Figure 1. Location of cage trout farms (I, II, III, IV, V), selected cage station (A) and control station (B) in Kesikköprü Reservoir.

Moreover, pH values ranged between 7.10 and 8.24.

Sediment at the cage and the control stations displayed a different color, such that the color of the sediment was dark-gray at the control station, turned visibly to black at the cage station.

Silt percentage of the cage station was higher (73.68%) than that of the control station (68.34%). Clay values under the cage and the control stations did not show variation (21.92%), but sand values were found to be higher at the control station (9.74%) with respect to the values at the cage station (4.40%).

An interaction was established between station-month in sediment parameters. Differences in the average redox potential, organic matter, total carbon, total nitrogen and total phosphorus parameters were significant (P<0.01).

Negative redox potential values were observed in March, April and May at the cage station, while no phenomenon observed at control station during the study period (Table 1). Organic matter levels in the sediment show small changes both at the cage and control stations. The organic matter value of the sediment reached maximum level of 15.71% at the cage station in January (Table 1).

There were significant differences between the total carbon and total nitrogen values of the sediment at the cage and control stations during the study period. Furthermore, the farm sediment had notably higher concentrations compared to that of the control station (P<0.01). The total phosphorus levels of the sediment at the cage station ranged between 0.06 and 0.13% and total phosphorus content of the cage-station sediment in all the months during the growing period was higher than that of the control station (Table 2).

Fish were fed by hand using commercial, extruded diets with average nutrient content of 46% crude protein, 22% fat, 6.87% nitrogen and 1.3% phosphorus. Amount of feed given during the sampling months was as follows: December, 1,450 kg; January, 1,650 kg; February, 2,331 kg; March, 2,700 kg; April, 2,400 kg; May, 2,600 kg. Average area of the farm under the fish farm during the on-growing season was 300 m^2. Estimated nitrogen and phosphorus input (kg N, P m^{-2} $month^{-1}$) values at the stations and nitrogen and phosphorus levels of the sediment are shown in Figure 2 and 3. The general increase in the feed input of the cage farm is reflected on increased nitrogen and phosphorus levels in the sediment.

Discussion

The results for nutrient values in our study are similar to previous studies (Cornel and Whoriskey, 1993; Kelly, 1993; Troell and Berg, 1997; Karakassis *et al*., 1998; 1999; Pawar *et al*., 2001; 2002; Temporetti *et al*., 2001; Carol *et al*., 2003) and

Table 1. Redox potential and organic matter values of sediment in cage and control stations during the study period

Parameters	Cage station		Control station	
Months	Redox potential (mV)	Organic matter (%)	Redox potential (mV)	Organic matter (%)
December	7.00±0.46 ^{Bb*}	13.12±0.04 ^{Da}	16.50±0.29 ^{Aa}	12.23±0.04 ^{Db}
January	9.50±0.29 ^{Ab}	15.71±0.03 ^{Aa}	13.50±0.29 ^{Ba}	14.45±0.03 ^{Ab}
February	1.50±0.29 ^{Cb}	14.78±0.19 ^{Ba}	6.50±0.29 ^{Ca}	13.85±0.19 ^{BCb}
March	-5.50±0.29 ^{Db}	14.25±0.14 ^{Ca}	6.00±0.00 ^{Ca}	13.72±0.14 ^{Cb}
April	-7.50±0.29 ^{Eb}	14.84±0.09 ^{Ba}	1.50±0.29 ^{Ea}	14.11±0.10 ^{Bb}
May	-10.50±0.29^{Fb}	14.41±0.07 ^{Ca}	3.50±0.00 ^{Da}	14.10±0.07 ^{Bb}

* Differences between means with the same small letters in a row for each station and differences between means with the same capital letters in a column for each month are not statistically significant (P<0.01).

Table 2. Total carbon, total nitrogen and total phosphorus values of sediment in cage and control stations during the study period

Parameters	Cage station			Control station		
Months	Total carbon (%)	Total nitrogen (%)	Total phosphorus (%)	Total carbon (%)	Total nitrogen (%)	Total phosphorus (%)
December	5.41±0.02 ^{Ba*}	0.26±0.003 ^{Ea}	0.07± 0.002 ^{Ca}	4.38±0,02 ^{Fb}	0.23±0.003 ^{Cb}	0.06±0.002 ^{Bb}
January	6.43±0.00 ^{Ba}	0.32±0.006 ^{Ca}	0.07± 0.002 ^{Ca}	4.88±0.00 ^{Eb}	0.25±0.006 ^{Bb}	0.06±0.002 ^{Bb}
February	7.31±0.04 ^{Aa}	0.35±0.005 ^{Ba}	0.13±0.002 ^{Aa}	5.30±0.04 ^{Cb}	0.26±0.005 ^{Bb}	0.05±0.002 ^{Cb}
March	6.18±0.003 ^{Ca}	0.30±0.002 ^{Da}	0.07±0.00 ^{Ca}	5.18±0.03 ^{Db}	0.26±0.002 ^{Bb}	0.05±0.002 ^{Cb}
April	5.83±0.002 ^{Da}	0.27±0.03 ^{Ea}	0.06±0.002 ^{Da}	5.74±0.02 ^{Ba}	0.21±0.003 ^{Db}	0.05±0.002 ^{Cb}
May	8.59±0.00 ^{Ea}	0.44±0.005 ^{Aa}	0.10±0.03 ^{Ba}	8.49±0.00 ^{Ab}	0.34±0.005 ^{Ab}	0.07±0.003 ^{Ab}

* Differences between means with the same small letters in a row for each station and differences between means with the same capital letters in a column for each month are not statistically significant (P<0.01).

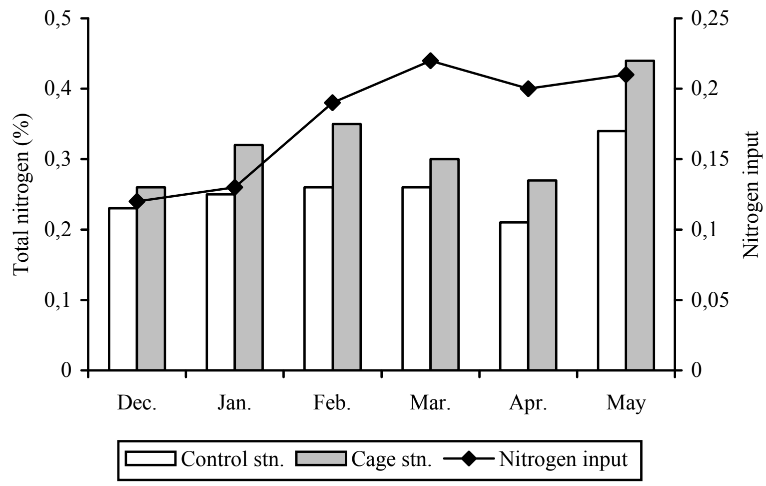

Figure 2. Total nitrogen and nitrogen input (kg N m^{-2} $month^{-1}$) values at the stations by month.

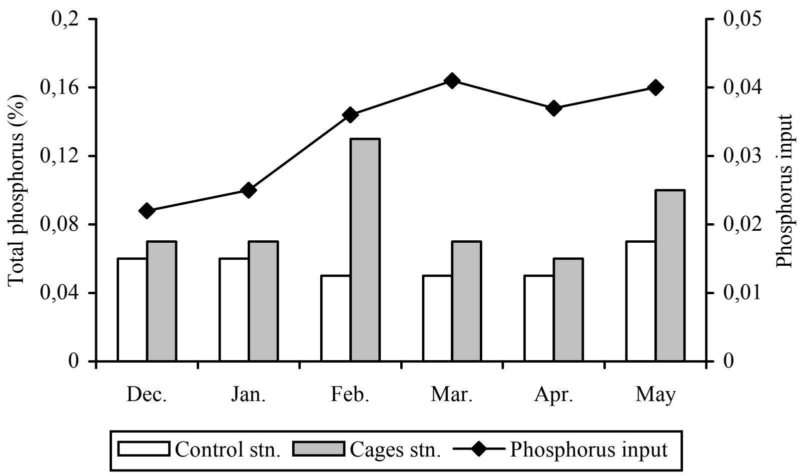

Figure 3. Total phosphorus and phosphorus input (kg P m^{-2} $month^{-1}$) values at the stations by month.

generally the differences in sediment quality parameters between the cage and control stations were found to be statistically significant (Table 1, P<0.01).

Negative redox potential values varying from -96 mV to -149 mV at the cage stations have been reported by several researchers (Karakassis *et al*., 1998; Pearson and Black, 2001; Pawar *et al*., 2002). In this study, compared to other studies of freshwater and marine cage farming, negative values at the cage station were not significantly higher. However, redox potential values of sediment showed a seasonal trend and negative values in this parameter were confirmed in parallel with increasing amounts of feed input. These circumstances indicate the presence of anaerobic microbial processes (Table 1).

Basically, the influence of aquaculture on sediment and the benthic environment is due to the deposit of organic wastes (Cornel and Whoriskey, 1993; Sunlu *et al*., 1999; Dominguez *et al*., 2001; Schendel *et al*., 2004). As it can be seen in Table 1, organic matter in sediment showed a variation between the two stations (P<0.01). In this study, organic matter values of the cage-station sediment were observed to be lower than the organic matter level that is determined between 39-69% in the cage station of oligotrofic Passage Lake, Canada (Cornel and Whoriskey, 1993), where rainbow trout is cultured with a capacity of 14 tons.

Troell and Berg (1997) determined the total carbon level of the tilapia cages sediment in tropical Kariba Lake between 2.8% and 4.49%. Additionally, Temporetti *et al*. (2001) declared values of the sediment of a cage station where salmonid culturing was carried out by 0.2% to 5.3%. As it is seen from Table 2, the maximum value based on the total carbon level of the sediment (7.31%) was observed to be higher than the results of these researches.

Total nitrogen levels of sediment were markedly different from those of the control station ($P<0.01$) and are determined as between 0.26% and 0.44% (Table 2). These values are different from the data of Troell and Berg (1997) (0.22-0.40%; based on the tilapia cages in tropical Kariba Lake) and of Temporetti *et al*. (2001) (0.1–0.8% recorded in the cage systems where salmonid culturing was carried out).

In the study by Troell and Berg (1997) the maximum phosphorus value was 0.26% observed at the base of cages in tropical Kariba Lake where tilapia culturing is performed. Although the P-content of the feed (1.3%) used was similar in our study, the highest phosphorus level in our research, 0.13%, is lower than the data of Troell and Berg (1997). The difference in total phosphorus level of the sediment both at the cage station and the control station is increased by 2.6% reaching its maximum level in February (Table 2).

Nutrient concentrations of the sediment reflect cage-farm waste inputs. Continuous stocking and harvesting was performed during the year at the rainbow trout cage farms in Kesikköprü Reservoir, which means that the nutrient values of sediment could be expected to increase greatly due to the increase in fish biomass and feed inputs (Figure 2, 3).

During the study period, the decrease in dissolved oxygen (6.60 mg L^{-1}) and transparency (2.20 m) did not affect water quality negatively at the cage station. In our study even though the current velocity seems sufficient for distribution of cage wastes (4 cm sec^{-1}; at the cage station in December), it has been a matter of discussion that this value may be variable; because redundant water from the Hirfanlı Reservoir is irregularly discharged into the Kesikköprü Reservoir. Furthermore, the short replenishment time of the water (0.04 years) in Kesikköprü Reservoir is an important issue for reducing the environmental effects of cages. Moreover, the results of the sediment composition study support the idea that cages do not affect water current velocity.

It can be concluded that at its current production level, the farm had a localized effect on sediment quality. The small capacity of operation and sufficient current velocity may be considered as major reasons for such local impact. Considering that other cage culturing operations exist in Kesikköprü Reservoir, attention should be paid primarily to the type and amount of feed, preferably highly-digestible, low-phosphorus, and high-energy, dry and floating-type feed. Moreover, the close monitoring of stocks in cages is another important issue, and rotational processes should be applied to the cages in order to reduce the environmental effects of cage operations in terms of sediment quality.

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