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RESEARCH PAPER

Sediment-Focused Environmental Impact of Rainbow Trout (Oncorhynchus mykiss Walbaum, 1792) Cage Farms: Almus Reservoir (Tokat)

Doğukan Kaya[1], Serap Pulatsü[1,*]

[1] Ankara University, Faculty of Agriculture, Department of Fisheries and Aquaculture, Ankara, 06100, Turkey

* Corresponding Author: Tel.: +90.312 5961688; Fax: +90.312 3185298;
E-mail: spulatsu@agri.ankara.edu.tr

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Abstract

This study aimed to evaluate environmental sediment quality parameters (biological, chemical, sensory) and determine sediment quality parameters (organic matter, total nitrogen, total phosphorus, total carbon) in rainbow trout cage farms with a nearly 4,000-ton total production capacity in Almus Reservoir. For this purpose, two cage stations representative of the cage farm area and two control stations outside of the main current, located at 250 m and 500 m respectively from the cage stations, were selected. The results suggest that the sediment condition is "unacceptable" with regard to biological parameter. The environmental condition of the cage station sediment compared to the control stations with regard to chemical and sensory parameters were determined to be "transition area" and "partially acceptable", respectively. The organic matter and total nitrogen of the cage station sediment were found to be 1.23 and 1.70 times greater than that of the control stations, respectively. When compared to the control stations, the total phosphorus and total carbon concentrations in the cage sediments showed 1.40-fold increasess in April and October 2015. It is thought that the methods and results of this study will contribute to sediment-focused research related to the sustainability of cage farming in inland waters.

Keywords: Sediment, rainbow trout, reservoirs, cage culture, environmental impact

Introductıon

In recent years, a substantial world-wide increase in intensive aquaculture has led to an increase in awareness of the environmental impacts of fish farming, with increased importance given to sustainable farming. The negative effect on sediment in receiving environments caused by the input of nutrients from cage farms is increasingly significant in terms of water quality. Addditionally, the reversal of possible changes in the sediment chemistry takes more time when compared to changes in the water. Monitoring the sediment-oriented environmental effects of cage culture is important in determining at an early stage the potential unacceptable effects of farming on the receiving environment and taking necessary measures (La Rosa *et al*., 2004; Soto and Norambuena, 2004).

Rainbow trout farming is the most prevalent type of freshwater aquaculture in Turkey, and reservoirs have an important potential with regard to freshwater aquaculture products. The MOM (Modelling-Ongoing fish farms- Monitoring) system was developed to control the impact of organic waste from marine fish farms in Norway, but it is based on a general concept of environmental management and may be adapted to other fish species and inland waters (Anonymous, 2000). The MOM system is composed of a model and an observation program including Environmental Quality Standards (EQS). The observation program has three investigation types: A, B and C. The A-investigation takes basic measurements of the proportions of organic material in the sediment below the cage operation. The B-investigation is conducted in the local impact zone and includes parameters of three groups. Finally, the C-investigation is concerned with the benthic community structure in the mid- and regional-impact zones (Hansen *et al*., 2001; Stigebrandt *et al*., 2004). The B-investigation type, which is used in the measurement of the local impact of cage operations and combines three group parameters (biological, chemical, sensory), is preferred by virtue of its ease of use, ability to be applied frequently and possibility of use in areas of concentrated environmental impact. Combining more than one of these parameters rather than using one of them alone increases the reliability of the evaluations and minimizes errors resulting from differing measurements. However, the quantification of environmental quality parameters provides only limited information on the substances present in the aquatic environment and gives no information on the relationship between contaminant exposure and biological effects in aquatic organisms; thus, the impact of pollutants by biomarkers becomes of relevant interest (Fazio *et al*., 2012; Fazio *et al*., 2013; Bianchi *et al*., 2015).

Feed and feces create some negative effects in the sediment, and particle or dissolved nutrients have negative effects on the water column in intensive fish culture. When the main changes in water quality are characterized by changes in nitrogen and phosphorus concentrations, changes in sediment quality are observed as variations in total nitrogen, total phosphorus, total carbon, organic matter and redox potential. Several investigations have been conducted in to sediment quality parameters in freshwater ecosystems where rainbow trout are cultured (Cornel and Whoriskey, 1993; Alpaslan and Pulatsü, 2008; Rooney and Podemski, 2010; Özdal and Pulatsü, 2012; Karakoca, 2013).

Almus Reservoir is one of several reservoirs in Turkey in which rainbow trout cage aquaculture is practiced, and rainbow trout cage farms with different capacities are operated in large numbers there. This study aimed to use the MOM B-investigation in a freshwater ecosystem for the first time in order to determine the local environmental impact of cage farming in the reservoir. To this purpose, the measurement and evaluation of sediment-related environmental quality parameters (biological: macrofauna presence; chemical: pH and redox potential; and sensory: outgassing, colour, odour, consistency, and thickness of deposits) were undertaken. Additionally, the comparison of sediment quality parameters (organic matter, total nitrogen, total phosphorus, total carbon) between the stations representing the cage farms and the control stations was an objective of this study.

There are no legal regulations in Turkey which focus on the observation of sediment in freshwater cage operations. It is thought that the results of this study will contribute to sediment-focused research related to the sustainability of cage aquaculture, which is becoming more and more common in Turkey's reservoirs.

Material and Methods

Study Site

The Almus Dam type (Tokat, Turkey) is an earthen embankment dam that is near the town of Almus (28 kilometers East of Tokat city in center north of Turkey) and is located on the River Yesilirmak which runs into the Black Sea. The main purposes of the dam are irrigation, flood control and hydroelectricity. The surface area of the reservoir is about 108 km^2 and total capacity 950 hm^3 (Anonymous, 2015).

Twenty-five rainbow trout (*Oncorhynchus mykiss*, Walbaum 1792) cage farms are in operation there, mostly concentrated in the reservoir's northern region and with a capacity ranging from 100 up to 975 tons per year. In this study, the reservoir is considered as one site and two cage stations were established, representing the areas where rainbow trout cage farms are found in large numbers and with differing production capacities, along with two control stations outside of the main current, located at 250 m and 500 m respectively from the cage stations (Figure 1).

Sample Collection

The sediment samples were taken from 15x15 cm^2 areas of the above-mentioned stations using an Eckman-Grab sampler. Sediment analyses were performed in four samples for April and October 2015 in each station. The choice of these months for

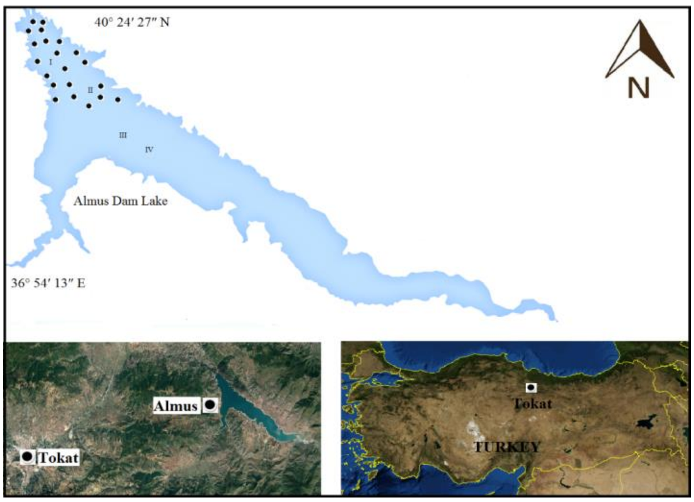

Figure 1. Location of sampling stations (I, II, III, IV) and cage farms (●) on the Almus Dam Lake

sampling was based on the legislative regulation for the observation of water quality parameters in freshwater fish cages (Anonymous, 2014).

Determination of the Mean Score of the Sediment

A scoring system for the environmental condition of the sediment was perfomed according to Hansen *et al*. (2001). Firstly, macrofauna was observed in the sediment by sieving the sediment through a 1mm sieve and the materials remaining on the mesh screen were identified. The biological parameter (Group 1), distinguishes between acceptable (macrofauna present) and unacceptable (no macrofauna) sediment conditions and the presence of animals yields a score of 0 and the absence a score of 1. If the mean score of all the samples taken at a given site is ≤ 0.5 the sediment condition is 1, 2 or 3. Else if (> 0.5) the sediment condition is 4.

Secondly, a measurement of pH and redox potential is performed. pH and redox potential values are measured by using EcoSense pH100A Model pHmeter. The results of pH and redox potential (chemical parameters- Group 2) measurements are placed on a pH/Eh diagram which is divided into five categories (Figure 2). The sediment conditions are found as follows: Mean score ≤ 1: condition 1, 1 < mean score ≤ 2: condition 2, 2 < mean score ≤ 3: condition 3 and mean score > 3: condition 4. The first three categories each corresponds to a degree of exploitation and the values of fourth category are considered to describe unacceptable sediment conditions (Hansen *et al*., 2001).

Sensory parameters (Group 3) has been scored from zero (no effect - undisturbed condition) to four (strong effect - unacceptable) condition categories as follows: Mean score < 4: condition 1, 4 ≤ mean score < 10: condition 2, 10 ≤ mean score ≤ 14: condition 3, mean score > 14: condition 4. As the amount of organic matter in the sediment increases, sensory parameters indicate differences in the colour and odour of the sediment, gas bubbles, and the thickness of the deposits in the top layer of the sediment (Hansen *et al*., 2001).

Determination of The Environmental Condition of The Sediment on the Site

The environmental condition of the site is equivalent to conditions given by the three groups of parameters. Once the condition of Group 1 is acceptable, then environmental condition of the site corresponds to 1, 2 or 3. If Groups 2 and 3 shows the same sediment conditions, this is considered the condition of the site. Group 2 is taken into account for acceptable and unacceptable conditions when the conditions of Group 2 and 3 differs. Condition 4 is equivalent to unacceptable sediment conditions according to each group of parameters (Hansen *et al*., 2001).

Determination of The Sediment Quality Parameters

Organic matter content was estimated by placing the dried samples in a muffle furnace at 550 °C and determining the loss in weight (Kacar, 1995). Total phosphorus content of the sediment was determined by vanadomolibdophosphoric yellow color method according to Kacar and İnal (2008). Total nitrogen and total organic carbon analyses were made using a Dumas method.

Statistical Analyses

The change in the quality parameters of the sediment that are considered in investigation bases with respect to months are determined by T-test and the difference between the research stations with respect to months are measured by Duncan Test

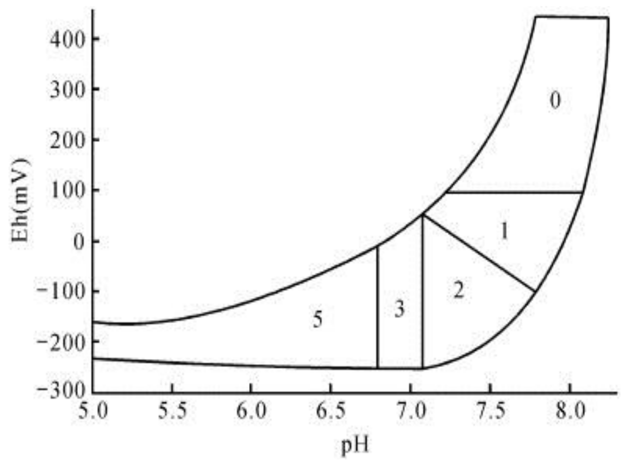

Figure 2. Variation of score (0-5)* according to pH and redox potential values (Hansen *et al*., 2001)* (0: High oxygen, low inorganic input; 1 or 3: Transition zones; 2: An environment with hydrogen sulphide, low redox potential; 5: An environment with metan gas, low pH)

(Düzgüneş *et al.*, 1983).

Results

Environmental Sediment Quality Parameters

The results of the MOM B-investigation of Group 1, 2 and 3 are shown in Figures 3 and 4 for April and October, respectively. Redox potential and pH values (Group 2) were measured in the surface sediment (Table 1). Scores are applied according to Figure 2.

Sediment quality parameters

The average organic matter, total nitrogen, total phosphorus and total carbon values of sediment at the cage and control stations for the two months are presented in Table 2.

Discussion

The sediment quality parameters determined by the MOM method were measured in three categories. The first category, presence of macrofauna, was not observed. The fact that macrofauna were not found at any of the stations chosen for our study appears to verify the findings of Zengin and Buhan (2007) and Anonymous (2013): that reservoirs are not rich in benthic fauna. Furthermore, the fact that no macrofauna was detected at the control stations shows that an assessment stating that cage aquaculture has negative effects on macrofauna is out of the question. More sampling and detailed study of Almus Reservoir could bring clarification to the question of the presence of macrofauna in the sediment. This is because in reservoirs, which differ from lakes in their morphometric and hydrological qualities, benthic macroinvertebrates are especially sensitive to the water fluctuations, temperature regime, wave-induced sediment redistribution and allochthonous inputs of organic matter affecting the sediment (Trichhova *et al.*, 2013).

Environmental quality parameters, the second category measured by the MOM method, are the pH and redox potential values. Eh results (+1 mV - +14mV) were compared with the related values from different studies (Alpaslan and Pulatsü, 2008; Özdal and Pulatsü, 2012; Karakoca, 2013). There were spatial differences between the sediment conditions and negative values for redox potential were not measured at all stations. It has been scientifically demonstrated that as the environmental conditions of the cage and control stations in Almus Reservoir have been labeled “transition areas”, the reservoir is sounding the alarm with regard to aquaculture. Almus Reservoir has had sustainable rainbow trout culture for over 20 years and on the basis of the second group of parameters, it has been scientifically proven that the reservoir is approaching carrying capacity. However, the absence of anaerobic conditions (mean dissolved oxygen of the surface water: 7.25 mg L^{-1}) and the measurement of the current speed at approximately 10 cm s^{-1} can be counted as positive indicators of the sustainability of cage farms.

Finally, regarding the third group of sediment quality parameters, the colour and odour parameters of this category were the most effective elements in determining the environmental condition of the cage and control stations. Moreover, the fact that the environmental conditions of the cage stations were found to be similar in both chemical and sensory parameters appears to confirm the validity of evaluation with sensory parameters.

In this study, our finding suggesting that the total organic substance values at the cage stations (7.02-7.77 %) showed an increase with respect to those at the control stations seems to coincide with the results of different research (Jiwyam and Chareontesprasit, 2001; Temporetti *et al.*, 2001; Alpaslan and Pulatsü, 2008; Rooney and Podemski, 2010).

The total nitrogen (0.12-0.28 %) and carbon (3.39-3.87 %) values observed in the cage station sediments in Almus Reservoir were found to be greater than those at the control stations; this appears to be parallel to the findings of the studies carried out by Temporetti *et al.* (2001), Alpaslan and Pulatsü (2008), and Rooney and Podemski (2010).

It has been noted that intensive cage aquaculture in lakes appears to increase total phosphorus levels in the sediment, and it has been observed in different studies that the sediment total phosphorus levels at cage stations show an increase when compared with the control station values (Troell and Berg, 1997; Alpaslan and Pulatsü, 2008; Rooney and Podemski, 2010). The total phosphorus parameters obtained from the cage stations in Almus Reservoir increased substantially over time when compared with the control station values, indicating an alignment with the above-mentioned findings.

Accordingly, the monitoring of sediment quality parameters is considered as the basis for sustainability of inland aquaculture activity; they are also considered to be important in preserving the natural composition of inland water ecosystems. However, these results are only preliminary. In the future it will be necessary to compare these findings with farm cages in other regions in order to improve the obtained results. Additionally, more detailed studies will be necessary to understand the link between the environmental sediment quality parameters and the health of fish (e.g., haematological parameters), especially in the country's reservoirs where cage culture is concentrated.

Turkey’s “Regulation for the Prevention of Eutrophication of Standing Inland Freshwater Bodies” (Anonymous, 2014) has the aim of taking into consideration the trophic state of lakes and reservoirs when aquaculture operations are being planned. While

Measured or observed in each grab sample ⇨

- Fauna
- pH, Redox potential
- Outgassing, colour, odour, thickness of deposits, consistency

Scores of the measurements or observations in each grab sample ⇨

Station No	Score
I	1
II	1
III	1
IV	1

St. No	pH	Eh	Score*
I	7.08	+6	3
II	7.05	+5	3
III	7.13	+8	3
IV	7.17	+7	3

*According to Fig. 2

Parameters \ Stations	I	II	III	IV
Outgassing	0	0	0	0
Colour	2	2	0	0
Odour	2	2	0	0
Thickness of deposists	0	0	0	0
Consistency	2	2	2	2
Sum (Scores)	6	6	2	2

The mean score of all samples according to each group of parameters ⇨

- mean score > 0.5
- 2< mean score?3
- Station I and II: 4<mean score?10
- Station III and IV: mean score<4

Environmental condition of the sediment ⇨

- Condition 4 (Unacceptable sediment condition)
- Condition 3 (Acceptable sediment condition)
- Station I and II: Condition 2 (Partially acceptable sediment condition)
- Station III and IV: Condition 1 (Acceptable sediment condition)

Figure 3. Environmental condition of sediment at cage (I, II) and control (III, IV) stations in April.

Measured or observed in each grab sample	Fauna	pH, Redox potential	Outgassing, colour, odour, thickness of deposits, consistency

Scores of the measurements or observations in each grab sample

Station No	Score
I	1
II	1
III	1
IV	1

St. No	pH	Eh	Score*
I	6.94	+4	3
II	7.11	+1	3
III	6.90	+20	3
IV	6.70	+14	3

*According to Fig. 2

Stations / Parameters	I	II	III	IV
Outgassing	0	0	0	0
Colour	2	2	0	0
Odour	2	2	0	0
Thickness of deposists	0	0	0	0
Consistency	2	2	2	2
Sum (Scores)	6	6	2	2

The mean score of all samples according to each group of parameters	mean score > 0.5	2< mean score?3	Station I and II 4<mean score?10	Station III and IV mean score<4
Environmental condition of the sediment	Condition 4 (Unacceptable sediment condition)	Condition 3 (Acceptable sediment condition)	Station I and II Condition 2 (Partially acceptable sediment condition)	Station III and IV Condition 1 (Acceptable sediment condition)

Figure 4. Environmental condition of sediment at cage (I, II) and control (III, IV) stations in October.

Table 1. Monthly changes of pH and redox potential (Eh) values in cage (I, II) and control (III, IV) stations (Mean±S.E.) (N=4)

Station	April		October	
	pH	Eh	pH	Eh
I	7.08±0.006^{cA*}	+6±0.4^{bcA}	6.94±0.011^{bB}	+4±0.2^{cB}
II	7.05±0.006^{dA}	+5±0.4^{cA}	7.11±0.006^{aB}	+1±0.2^{dB}
III	7.13±0.004^{aA}	+8±0.2^{aA}	6.90±0.006^{bB}	+20±0.4^{aB}
IV	7.17±0.003^{aA}	+7±0.4^{abA}	6.70±0.025^{cB}	+14±0.2^{bB}

* Differences between means with the different small letter in a column for each month and differences between means with the different capital letter in a row for each station are statistically significant ($P < 0.05$)

Table 2. Organic matter, total nitrogen, total phosphorus and total carbon values of sediment in cage and control stations in April and October (N=4)

Parameters	Month	Cage stations		Control stations	
		I	II	III	IV
Organic matter (%)	April	7.16±2.08 ^{aA*}	7.02±1.09 ^{aA}	6.10±0.24 ^{aA}	5.58±0.35 ^{aB}
	October	7.61±0.00 ^{aA}	7.77±0.03 ^{bA}	6.30±0.12 ^{dA}	6.44±0.00 ^{cA}
Total nitrogen (%)	April	0.19±0.00^{aB}	0.12±0.01^{bB}	0.11±0.05 ^{bB}	0.11±0.02 ^{bA}
	October	0.15±0.02 ^{bA}	0.28±0.07 ^{aA}	0.14±0.00^{bA}	0.08±0.00 ^{cB}
Total phosphorus (%)	April	0.08±0.00 ^{bA}	0.10±0.00^{bA}	0.07±0.00^{cB}	0.06±0.00^{dB}
	October	0.08±0.00 ^{aB}	0.09±0.00^{bB}	0.07±0.00^{cA}	0.06±0.00 ^{dA}
Total carbon (%)	April	3.87±0.03 ^{aA}	3.68±0.06^{bB}	3.40±0.03 ^{cA}	2.91±0.01 ^{dA}
	October	3.57±0.00^{bA}	3.39±0.00 ^{aA}	2.94±0.03 ^{cB}	2.00±0.02 ^{dB}

it aims to observe (in April and October) parameters such as total phosphorus, total nitrogen and chlorophyll-a in the water column of active freshwater aquaculture operations, the regulation does not include a parameter for sediment-focused observation. However, monitoring programs based on sediment quality parameters are an effective evaluation tool to determine the environmental conditions, that is, the local impact, of cage farming. Therefore, it is believed that until a more appropriate system is recommended for Turkey's freshwater bodies, the MOM B-investigation, which contains methods that are reliable and simple as well as fast and easy to use, will contribute a significant mechanism and lead the way to improving the monitoring of cage farms.

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