Carpathian Journal of Earth and Environmental Sciences, August 2013, Vol. 8, No. 3, p. 125 - 136

WATER QUALITY CHANGES IN UZUNGOL LAKE DUE TO INFLUENT TRIBUTARIES AND LAND-BASED FISH-FARMS

Basak KILIC TASELI

The Environmental Protection Agency for Special Areas, Alparslan Turkes Str., 17/10, Bestepe Ankara, Turkey, e-mail: basaktaseli@hotmail.com

Abstract: Uzungöl Lake is situated in the eastern region of Turkey which is one of the most important ecological regions in terms of biological diversity. In this region important economic activities are tourism and fisheries. However, the lake is currently threatened by pollution because of; (i) poorly managed septic systems; (ii) land-based fish farms located on Haldizen Creek; (iii) sediment and debris flow to the lagoon through creeks; (iv) excessive erosion in the catchment area; and (v) flow of fertilizers, nutrients and pesticides into the lake due to agricultural activities. The objectives of the present study are to evaluate historical water quality data from 2006 to 2011 at four monitoring sites, three located at Haldizen Creek and one in the middle of Uzungöl Lake. Specific objectives are to: (i) determine concentration trends in Uzungöl Lake during the study period; (ii) estimate nutrient loads from Haldizen Creek to Uzungöl Lake; (iii) assess water quality classification of Haldizen Creek; (iii) evaluate how land-based fish farm affects Haldizen Creek's water quality; (iv) use the Trophic State Index (TSI), Water Quality Index (WQI) and Total Nitrogen/Total Phosphorus (TN:TP) ratio to evaluate the eutrophication trends. A six-year data set showed that TSI values of Secchi Depth (SD) and TP remained within the range of hypereutrophic and eutrophic category, respectively. TN/TP ratios suggest Uzungöl Lake can be considered P limited and that the TN/TP ratio is generally always greater than 12 (57 out of 61 measurements). The WQI for Uzungöl Lake shows some slight improvement from "POOR WQI" to "MARGINAL WQI" from 2006 to 2011. Haldizen Creek moderately influences Uzungöl Lake's water quality in terms of ammonium–nitrogen, total phosphate, and number of total and fecal coliforms. However, this study demonstrated the significant effect of fish farm discharges in terms of NH_4-N and TP loadings during study period although its water quality class didn't change before and after fish farming.

Keywords Land-based fish farms, Water quality, Eutrophication, Uzungöl Lake, Water Quality Index Trophic State Index, TN:TP Ratio.

1. INTRODUCTION

It is well known that lakes obtain most of their external phosphorus and nitrogen loads from tributary rivers. River water quality is a function of land uses such as agriculture, urbanization and fish farms which in turn affects the receiving body. Moreover, extreme external loads of phosphorus are related to plankton biomass increase, water clarity decrease and in lake phosphorus concentration increase. The primary purpose of the current environmental monitoring of fish farms is to meet the goals of surface water quality.

Camargo et al., (2004) stated that rivers and streams worldwide have doubled their content of nitrogen and phosphorus as a consequence of human activities. Enhanced deposition of inorganic nitrogen causes eutrophication and also increases the concentration of hydrogen ions in freshwater ecosystems with low acid-neutralizing capacity, resulting in acidification of those systems. Nitrogen can even become toxic and damage the ability of aquatic animals to survive, grow, and reproduce. At high concentrations, ammonia, nitrite, and nitrate are all toxic to aquatic animals (Camargo & Alonso, 2006).

Urbanization alters adversely the hydrology (artificial variation in flow speed by dams, usage of water for irrigation and drinking water) of the catchment area, water quality (eutrophication, acidification, organic, chemical and microbiological contamination) of creeks and other water bodies, morphology (changed channel form, river bed degradation, bents for flood protection), and composition of soil and air. Natural ecological systems are substituted by urban ecology. Waste emissions increase dramatically, and the sources of these contaminants are miscellaneous, such as household heating, transportation, sewage disposal, solid waste disposal, and street salting.

One of the most important activities in the Uzungöl catchment area is aquaculture. It has been a rapid-growing industry because of significant increases in demand for fish. It is well known that nitrogen and phosphorus are significant waste products of fish farms. Ammonia is emitted mainly through the gills and represents 75% to over 85% of the nitrogen loss, whereas phosphorus is mainly emitted as phosphate by the kidney. Metabolic waste concentration reaches a high level in ponds thus producing pollution in a closed aquatic environment and they are considered to be a point source of pollution, affecting directly the receiving bodies (Handy & Poxton 1993). The primary source of ammonia in aquaculture systems is fish feed. Ammonia levels vary dramatically after feeding. Wu (1995) stated that dissolved inorganic forms of nitrogen are rapidly assimilated by algae and thereby help and cause eutrophication and result in significant increases in a river's ammonium and organic carbon concentrations downstream of fish farms. The degradation of water resources by eutrophication can result in losses of their component species, as well as losses of the amenities or services that these systems provide. In general, 85% of phosphorus, 80–88% of carbon and 52–95% of nitrogen input into a fish culture system as feed may be lost into the environment through uneaten feed, fish excretion, and respiration.

The problems faced by Uzungöl Lake and its vicinity can be summarized as; (i) poorly managed septic systems, (ii) land-based fish farms located on Haldizen Creek, (iii) sediment and debris transport to the lagoon through creeks, (iv) excessive erosion in the catchment area, and (v) agricultural activities, and transportation of fertilizers and pesticides into the lake.

Water temperature, pH, flowrate, dissolved oxygen (DO), ammonium–nitrogen (NH_4–N), nitrate–nitrogen (NO_3–N), nitrite–nitrogen (NO_2-N), total phosphate (TP), chemical oxygen demand (COD), fecal coliform and total coliform were measured in Haldizen Creek before and after fish farming; whereas pH, secchi depth, dissolved oxygen (DO), suspended solids (SS), total nitrogen (TN), total phosphorus (TP), total coliform, and chemical oxygen demand (COD) were measured in Uzungöl Lake. Evaluating water quality using various methods enables watershed managers to develop and implement specific plans targeting factors affecting water resources. Trend analysis and nutrient quantification methods have been used extensively in water quality studies. Trend analysis (concentration trends), load estimation (mass of pollutants delivered), TN:TP Ratio (trophic status trends), TSI (eutrophication trends), and the WQI (environmental quality trends) were used to supply additional understanding of water quality of Uzungöl Lake.

The objectives of the present study are to evaluate historical water quality data from 2006 to 2011 at four monitoring sites, three located on Haldizen Creek and one in the middle of Uzungöl Lake. Specific objectives: (i) determine concentration trends in Uzungöl Lake during the study period; (ii) estimate nutrient transfer from Haldizen Creek to Uzungöl Lake; (iii) assess water quality classification of Haldizen Creek; (iii) evaluate how land-based fish farm influences Haldizen Creek's water quality; (iv) use the Trophic State Index (TSI), Water Quality Index (WQI) and TN:TP Ratio to evaluate the eutrophication trends.

2. MATERIALS AND METHODS

2.1 Site Description

The Turkish Cabinet of Ministers declared 15 Special Environmental Protection Areas (SEPAs) based on the addendum protocol of the Barcelona Convention according to the following criteria: (i) the area has endangered flora and fauna, (ii) the area is an entity together with its wetlands such as rivers, lakes, (iii) the area has archeological value, and (iv) the area provides recreational activities for the public. The Environmental Protection Agency for Special Areas (EPASA) was established in 1989 to protect the environmental values; to take all measures necessary to reverse the existing environmental problems of the areas at the maximum extent possible and designate these areas as SEPAs; to determine the conservation and management priorities of those areas; to prepare development plans and; to revise and approve existing changes and/or improvements at all scales of the development plans.

Uzungöl Lake is situated in the eastern Black Sea region of Turkey one of 200 important ecological regions in terms of biological diversity which includes 200 highlands and has lake tourism potential. For these reasons, the Uzungöl watershed was declared a Natural Park in 1989, a Tourism Center in 1990 and a Special Environmental Protection Area (SEPA) in 2004 to protect the natural assets of the region. Uzungöl Lake has surface area of 8.5 ha with a mean depth of about 2.1 m. and a deeper zone of approximately 6.9 m. The Uzungöl SEPA consists of 1 sub-district and 3 villages annexed to Çaykara town in Trabzon. The population of Uzungöl was 4707 in 2010. It is located at an elevation of 1090 meters and with its steep slopes and magnificent forests may even surpass the beauty of the

Alps. The lake located in the center of a valley named Uzungöl was formed by the closure of Haldizen Creek Valley as a result of landslides. The watershed contains various streams which drain into Haldizen Creek, which subsequently drains into the lake. In terms of wild life in the area, various animal species inhabit in the mountains around Uzungöl Lake such as bears, wolves, wild goats, foxes and Caucasian Mountain Roosters. Nearly 125 subspecies and 68 varieties, totaling 658 plant taxa under 311 families, nearly 24 biotopes and 59 mammals and 250 birds were identified during the Project of Terrestrial Biological Diversity of Uzungöl Special Environmental Protection Area (EPASA, 2011a).

Uzungöl, an attraction for domestic and international tourists, has great potential in terms of tourism. Tourism activities in the area include trekking, bird watching and botanic tours. There are 41 touristic accommodations (hotels, motels and pensions) in the region with a total capacity of 1191 beds. In 2009, 156,000 domestic, 7,000 foreign and 110,000 daily guests visited the area. Since the completion of the road connecting Çaykara and Uzungöl, there has been a 125% increase in the amount of construction within the lake basin within the last 35 year period (Atasoy, 2010).

In addition, six fish farms are located in the lake basin with a total area of 3,108 m^2. Because of climatic conditions and high level of ground water, there is always water in the river bed even during dry periods. The flow of Haldizen Creek reaches to its maximum level from April to May because of snow melting and plentiful rainfall. Due to such steep slopes, floods readily occur after severe rainfall. In order to avoid rapid filling of Uzungöl, one sedimentation bent was constructed in 1991 another in 1993 and eventually artificial lakes were formed behind these two bents where fish farms were located.

2.2. Water Sampling and Analysis

Monthly water samples taken were covered to prevent exposure to direct sunlight, stored in ice and then analyzed in the laboratory within 24 hours. Standard methods, equipments and method of measurement used in analysis are given in table 1.

3. RESULTS AND DISCUSSION

A six-year data set is used to evaluate changes in water quality whereas trend analyses are used to determine whether constituent trends are improving over time or getting worse.

3.1. Overall Water Quality of Uzungöl Lake

3.1.1. Concentration Trends

The results of 6 projects (EPASA 2006, 2007, 2008, 2009, 2010, 2011b) were examined to investigate the present status of and the monthly and yearly (2006–2011) changes in, the water quality of the Uzungöl Lake. Its water quality was examined in terms of dissolved oxygen (DO), suspended solids (SS), total nitrogen (TN), total phosphate (TP), chemical oxygen demand (COD) concentrations, and number of total coliforms. The parameters in question were measured at sampling station 4 which is located in the middle of Uzungöl Lake (Fig. 1).

Table 1. Standard methods, equipments and method of measurement used in analysis

Parameter	Equipment	Standard Method	Method of Measurement
pH	Portable HACH Sension 156	TS 3263 ISO 10523-1999	Electrochemical
Temperature	Portable HACH Sension 156		Electrochemical
Dissolved oxygen	Portable HACH Sension 156	TS 5677 EN 25814-1996	Electrochemical
Nitrite nitrogen	DRLANGE–XION 500 spectrophotometer	TS ISO 8466-1:1997 TS 7526 EN 26777:1996	Spectrophotometric
Nitrate nitrogen	DRLANGE–XION 500 spectrophotometer	TS ISO 8466-1:1997 TS 6232:1988	Spectrophotometric
Ammonia nitrogen	DRLANGE–XION 500 spectrophotometer	TS ISO 8466-1:1997 TS EN ISO 11732:1999	Spectrophotometric
Total phosphorous	DRLANGE–XION 500 spectrophotometer	TS ISO 8466-1:1997 TS EN ISO 10304-2:1997	Spectrophotometric
Total nitrogen	DRLANGE–XION 500 spectrophotometer	TS ISO 8466-1:1997 TS ISO 8466-1:1997	Spectrophotometric
Chemical oxygen demand	DRLANGE–XION 500 spectrophotometer	TS 2789 ISO 6060:2000 TS 7094 EN 872:1999	Spectrophotometric
Suspended solids	SARTORIUS vacuum filter	TS 7094 EN 872:1999	Membrane Filtration
Fecal coliform	SARTORIUS vacuum filter	TS EN ISO 9308-1:2004	Membrane Filtration
Total coliform	SARTORIUS vacuum filter	TS EN ISO 9308-1: 2004	Membrane Filtration

ISO International Organization for Standardization

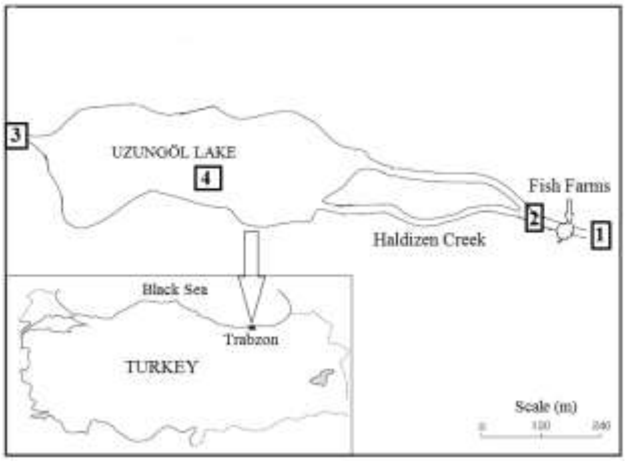


Figure 1. Uzungöl Lake Sampling Sites (SEPA, 2011a)

Dissolved oxygen concentration

Dissolved oxygen (DO) is required for the support of aquatic plants and animals and may vary in the water system due to temperature, salinity, biological activity and rate of transfer from the atmosphere. Its concentration mainly depends on the salinity and temperature of the water. In general, cold water with low salinity level has a higher concentration of dissolved oxygen. Due to in-stream photosynthetic and respiratory activity of aquatic plants, dissolved oxygen concentration is lower at night than during daylight hours. During decomposition of biodegradable organic substances the concentration of dissolved oxygen is reduced because oxygen is used by bacteria for this process. The other factor responsible for a significant reduction in the concentration of dissolved oxygen is human-induced pollution. Excess waters from agriculture, waste water of the land-based fish farms and urban sewage that drain to the river are decomposed by aquatic bacteria that use dissolved oxygen for this process.

The DO concentrations in unpolluted waters are typically in the range of 8 to 10 mg/l, with concentrations below 5 mg/l known to adversely affect aquatic life. In Turkey, the acceptable DO concentration (within the context of eutrophication symptoms) for lakes designated as protected areas and/or used for recreational purposes is 7.5 mg/l (Turkish Water Pollution Control Regulation (TWPCR), 2004. As noted in tables 2-7, the DO concentrations in Uzungöl Lake were well below the standard value of 7.5 mg/l in August, September and October in all sampling years at sampling site 4.

Suspended solids concentration

Land use practices in the catchment are thought to be the major cause of the various water quality problems in the river. Suspended solids affect light penetration which in turn affects ecological processes that depends on sunlight. Moreover, light penetration also affects the temperature regime of surface waters. Large quantities of SS in water can smother fish eggs, plants and animals living at the bottom of a lake. Furthermore, suspended sediments floating in the water column can make it difficult for fish to breathe and elevated SS levels can be even more harmful when combined with such contaminants as nutrients and toxic chemicals.

The acceptable Turkish limit for SS for the control of eutrophication in lakes designated as protected area, and used for recreational activities, is 5 mg/l (TWPCR, 2004). As noted in tables 2 to 7, SS concentrations in Uzungöl Lake exceeded the standard value of 5 mg/l from 2009 to 2011.

Chemical oxygen demand

Tables 2 to 7 reveal that the COD values in from 2006 to 2011 at sampling site 4 significantly exceeded the 3 mg/l limit identified in the TWPCR, disqualifying the lake for recreational activities. COD concentration ranged from 5 to 33.6 mg/l (July 2008).

Number of total coliform

Investigations showed that elevated concentrations of coliform bacteria in the effluents from fish farms. Niemi & Taipalinen (1982) stated that the total number of indicator bacteria in the effluents from fish farms was high enough to be detected in the receiving body. The total number of coliform is also a major parameter for assessing possible sewage contamination in a water body. High bacterial levels can cause the closure of recreational facilities around a lake, reduce its water quality, and cause sickness in wildlife using a lake as a water source.

Tables 2 to 7 show that the total coliform number exceeded the limit (1000 CFU/100 ml) defined in the TWPCR in 2007 May (3000 CFU/100 ml), 2007 June (2000 CFU/100 ml), 2007 August (2900 CFU/100 ml), 2007 October (2500 CFU/100 ml), 2007 November (3000 CFU/100 ml), 2008 June (2500 CFU/100 ml), 2008 August (2000 CFU/100 ml) and October 2006 (1400 CFU/100 ml) indicating wastewater inputs were reaching the lake. The number of coliforms complied with the standards in 2010 & 2011.

Total phosphorus concentration

Excessive nutrient levels (e.g. phosphorus), often found in sewage effluents and lawn fertilizers, also can cause negative water quality, a result mainly of the negative effects of excessive algal growth on beneficial human water uses. In addition to reducing the water transparency because of the elevated biomass levels, algal cells can cause oxygen depletion as they are decomposed by bacteria in a water body.

As noted above, low DO concentrations can negatively impact the ability of an aquatic ecosystem to support a range of aquatic life.

The acceptable Turkish limit for TP concentrations for the control of eutrophication in lakes is 0.005 mg/l (TWPCR, 2004).

Table 2. Water Quality of Uzungöl Lake (Station 4) in 2006.

Parameters	April	May	June	July	August	September	October	November	December	Objective
Total Coliform (CFU/100 ml)	200	400	1000	500	1000	500	**1400**	600	100	1000
DO (mg/l)	8.15	7.81	10.02	7.83	**4.96**	**5.36**	**5.94**	7.89	7.81	7.5
pH	8.13	7.56	7.77	7.18	6.99	7.2	**6.29**	**6.28**	7.62	6.5-8.5
SS (mg/l)	**12.8**[1]	2.3	0.7	2.8	1	1.4	**5.9**	0.7	1.7	5
TN (mg/l)	**0.738**	**0.209**	**0.291**	**0.602**	**0.713**	**4.18**	**0.399**	**0.872**	**0.525**	0.1
TP (mg/l)	**0.044**	**0.001**	**0.034**	**0.025**	**0.013**	**0.01**	**0.149**	**0.029**	**0.007**	0.005
COD (mg/l)	**5**	**5**	**5**	**5**	**5**	**5**	**7.55**	**5**	**6.32**	3
TN/TP	16.77	209	8.56	24.08	54.85	418	2.68	30.07	75	
TSI(TP)	58.72	4.15	55	50.57	41.14	14.15	76.31	52.71	32.21	
WQI	Water Quality Index: 23.29 POOR									

[1]bolded values do not meet the objective.

Table 3. Water Quality of Uzungöl Lake (Station 4) in 2007.

Parameters	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dece.	Obj.
Total Coliform (CFU/100 ml)	280	600	**3000**	**2000**	**1500**	**2900**	150	**2500**	**3000**	0	1000
DO (mg/l)	9.33	**7.45**	**6.43**	7.54	8.09	**5.67**	**6.12**	**7.3**	8.82	8.09	7.5
pH	7.68	7.92	8.08	7.63	7.41	8.02	6.82	8.83	7.15	8.17	6.5-8.5
SS (mg/l)	0.2	4.3	**28.5**	3.7	2	2	1	2	2	2	5
TN (mg/l)	**0.656**	**0.533**	**0.732**	**0.551**	**1.56**	**0.509**	**0.131**	**2.26**	**0.438**	**1.92**	0.1
TP (mg/l)	**0.011**	**0.008**	**0.112**	**0.019**	**0.018**	**0.016**	**0.075**	**0.029**	**0.021**	**0.013**	0.005
COD (mg/l)	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**9.18**	**5**	3
TN/TP	59.64	66.63	6.54	29	86.67	31.81	1.75	77.93	20.86	147.69	
TSI (TP)	38.73	34.14	72.19	46.61	45.83	44.13	66.41	52.71	48.05	41.14	
WQI	Water Quality Index: 27.51 POOR										

Table 4. Water Quality of Uzungöl Lake (Station 4) in 2008.

Parameters	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Obj.
Total Coliform (CFU/100 ml)	150	400	200	**2500**	500	**2000**	100	500	100	50	1000
DO (mg/l)	13.06	11.41	9.46	**6.61**	8.56	**6.77**	**6.1**	7.91	10.46	8.41	7.5
pH	7.11	7.42	7.7	7.78	7.63	7.58	8.24	7.93	8.01	7.61	6.5-8.5
SS (mg/l)	**42.6**	2	2	**6.8**	2	2	2	2	2	2	5
TN (mg/l)	**1.18**	**1.32**	**1.91**	**0.628**	**0.72**	**0.808**	**0.845**	**1.04**	**0.553**	**0.818**	0.1
TP (mg/l)	**0.01**	**0.025**	**0.101**	**0.01**	**0.01**	**0.02**	**0.019**	**0.01**	**0.01**	**0.01**	0.005
COD (mg/l)	**5**	**28.3**	**5**	**5**	**33.6**	**8.91**	**5**	**5**	**5**	**5**	3
Chlorophyll-a (µg/l)	2.67	2.14	2.14	2.1	1.6	1.14	1.12	1.14	1.14	0.89	8
Temperature (^{o}C)	7.3	6	14.4	11.1	15	18.6	19.7	11.3	9.3	6.8	
SD (m)	1.9	0.6	0.7	0.2	0.7	0.6	0.6	1	0.5	2	
TN/TP	118	52.8	18.91	62.8	72	40.4	44.47	104	55.3	81.8	
TSI(TP)	37.35	50.57	70.7	37.35	37.35	47.35	46.61	37.35	37.35	37.35	
TSI(SD)	50.75	67.61	65.14	83.19	65.14	67.61	67.61	60	69.99	50.01	
WQI	Water Quality Index: 36.83 POOR										

Table 5. Water Quality of Uzungöl Lake (Station 4) in 2009.

Parameters	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Obj.
Total Coliform (CFU/100 ml)	400	50	45	20	25	100	150	50	40	50	30	1000
DO (mg/l)	10.6	10.5	7.6	9.98	10.92	9.2	**7.08**	9.5	**7**	8.81	8.98	7.5
pH	7.28	7.87	7.56	7.04	7.62	7.69	6.52	7.69	7.22	7.83	7.72	6.5-8.5
SS (mg/l)	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	5
TN (mg/l)	**0.66**	**0.71**	**0.36**	**0.62**	**0.55**	**0.42**	**0.46**	**0.91**	**1**	**0.3**	**0.57**	0.1
TP (mg/l)	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	0.005
Chlorophyll-a (μg/l)	0.89	0.89	0.89	0.89	0.95	0.89	0.89	1.12	1.16	1.17	0.94	8
Temperature (^{o}C)	5.3	4.5	6.3	6.1	12.5	15	15.9	7.5	9.4	9.1	4.2	
SD (m)	1	1.5	2	0.2	0.55	1	0.7	0.65	0.6	0.2	0.3	
TN/TP	66	71	36	62	55	42	46	91	100	30	57	
TSI(TP)	37.35	37.35	37.35	37.35	37.35	37.35	37.35	37.35	37.35	37.35	37.35	
TSI(SD)	60	60	54.16	50.01	83.19	68.61	65.14	66.21	67.61	83.19	77.35	
WQI	Water Quality Index: 41.84 POOR											

Table 6. Water Quality of Uzungöl Lake (Station 4) in 2010

Parameters	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Obj.
Total Coliform	0	0	14	36	0	28	0	10	10	21	10	38	1000
DO (mg/l)	11.93	11.63	11.39	9.86	10.68	9.08	8.22	8.46	7.58	8.45	8.84	7.86	7.5
pH	7.56	7.96	7.72	7.26	7.7	8.14	7.8	7.49	7.33	7.45	7.26	7.59	6.5-8.5
SS (mg/l)	1.15	1	1.7	4.3	2.25	1	**10**	**10**	**10**	**10**	**10**	**10**	5
TN (mg/l)	**0.34**	**0.79**	**0.9**	**0.83**	**0.17**	**0.71**	**0.73**	**0.65**	**0.65**	**0.5**	**1.24**	**0.72**	0.1
TP (mg/l)	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.014**	**0.014**	**0.012**	0.005
COD (mg/l)	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**9.8**	**5**	3
Chlorophylla (μg/l)	0.1	0.1	2.86	2	5	2	2.42	1.74	1.74	0.89	0.92	0.89	8
Temperature (^{o}C)	4.4	5.9	5.7	7.6	9.8	12.2	16.4	20.1	17.5	12.1	7.8	7.2	
SD (m)	1.5	2	3	2	1.3	1	1.2	2.1	2	2	2.2	2	
TN/TP	34	79	90	83	17	71	73	65	65	35.71	88.57	60	
TSI(TP)	37.35	37.35	37.35	37.35	37.35	37.35	37.35	37.35	37.35	42.21	42.21	39.98	
TSI(SD)	54.16	50.01	44.17	50.01	56.22	60	57.37	49.31	50.01	50.01	48.64	50.01	
WQI	Water Quality Index: 53.6 MARGINAL												

As noted in tables 2 to 7, the TP concentrations in Uzungöl Lake significantly exceeded this limit at sampling site 4 during the study period. The measurements showed that eutrophication and plant-related water quality impacts have been becoming increasingly serious problems in Uzungöl Lake.

Total nitrogen concentration

The acceptable Turkish limit for TN for the control of eutrophication in lakes is 0.1 mg/l (TWPCR, 2004). The TN concentrations in Uzungöl Lake (Tables 2 to 7) significantly exceeded this limit from 2006 to 2011.

3.1.2. Eutrophication Trends

Nutrient Loading Ratio: TN:TP Ratio

The ratio between TN and TP (i.e. TN/TP) can be used as a trophic status indicator for lakes, and also can provide an estimate of which nutrient (phosphorus or nitrogen) is the algal growth-limiting nutrient in an aquatic ecosystem. Grayson et al., (1997) stated that a TN/TP ratio of less than 10 generally indicated nitrogen was the algal growth-limiting nutrient, whereas a ratio of greater than 12 was suggestive of P-limited environment. The calculated TN/TP ratios (Tables 2 to 7) suggest that Uzungöl Lake can be considered to be P limited (Fig. 2); the TN/TP ratio is generally greater than 12 (57 out of 61 measurement).

Table 7. Water Quality of Uzungöl Lake (Station 4) in 2011.

Parameters	Jan.	March	April	May	June	July	Aug.	Sept.	Oct.	Dec.	Obj.
Total Coliform (CFU/100 ml)	0	0	10	0	13	14	0	0	0	0	1000
DO (mg/l)	7.79	11.02	10.04	9.69	10.69	8.57	**6.49**	**6.6**	9.48	10.02	7.5
pH	7.19	8.4	8.19	7.13	6.43	7.09	7.74	7.55	7.7	7.43	6.5-8.5
SS (mg/l)	**10**	**12.7**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	5
TN (mg/l)	**0.09**	**0.24**	**0.31**	**0.33**	**0.4**	**0.4**	**0.4**	**0.41**	**0.3**	**0.35**	0.1
TP (mg/l)	**0.01**	**0.02**	**0.03**	0.001	**0.01**	**0.012**	**0.01**	**0.01**	**0.01**	**0.01**	0.005
COD (mg/l)	10	5	10	7	8	5	7	5	5	5	3
Chlorophyll-a (µg/l)	1.14	0.22	6.03	0.1	4.32	2.32	3.62	2.12	0.1	0.1	8
Temperature (^oC)	4.9	4.3	6.8	11.2	11.8	19.2	15.7	13.2	7.7	3.7	
SD (m)	1.5	3.3	3	2	2	2	2	3.5	2	2	
TN/TP	90	12	10.33	330	40	33.33	450	41	30	35	
TSI(TP)	37.35	47.35	53.2	4.15	37.35	39.98	37.35	37.35	37.35	37.35	
TSI(SD)	54.16	41.95	75.83	50.01	50.01	50.01	50.01	41.95	50.01	50.01	
WQI	Water Quality Index: 46.40 MARGINAL										

Trophic State Indices (TSI)

A Secchi depth (transparency) is commonly used to measure the depth to which one can easily see through the water. Secchi disk, chlorophyll a and total phosphorus are frequently used to define the degree of eutrophication, or the trophic status of a lake. Carlson's Trophic State Indices (TSI) for total phosphorus (TP) and secchi depth (SD) assume values between 0 and 100 according to the following equations:

TSI_{SD} =0 60- 14.41 ln (SD) (1)

TSI_{TP} = 14.42 ln (TP) + 4.15 (2)

where TP is expressed in µg/l and SD in m. The range between 40 & 50, greater than 50 and less than 40 is associated with mesotrophy (moderate productivity), eutrophy (high productivity) and oligotrophy (low productivity), respectively (Carlson, 1977).

TSI indices were calculated (Table 2-7) for Uzungöl Lake from 2006 to 2011 and expressed in figures 3(a) and (b). TSI values of SD and TP remained within the range of hypereutrophic and eutrophic category, respectively.

Water Quality Index

A water quality index is the index that sums up great amounts of water quality data and rates them according to simple terms (e.g., excellent, good, fair, poor etc.) in order to inform managers and the public about environmental conditions and detect changes in environmental quality over time (Wright et al., 1999).

In this study, the CCME Water Quality Index (1.0) was used. It is based on a Formula developed by the British Columbia Ministry of Environment, Lands and Parks and modified by Alberta Environment. The Index includes three elements like scope (the number of variables not meeting water quality objectives), frequency (the number of times these objectives are not met) and amplitude (the amount by which the objectives are not met). The index generates a number between 0 (worst water quality) and 100 (best water quality). Once the CCME WQI value has been

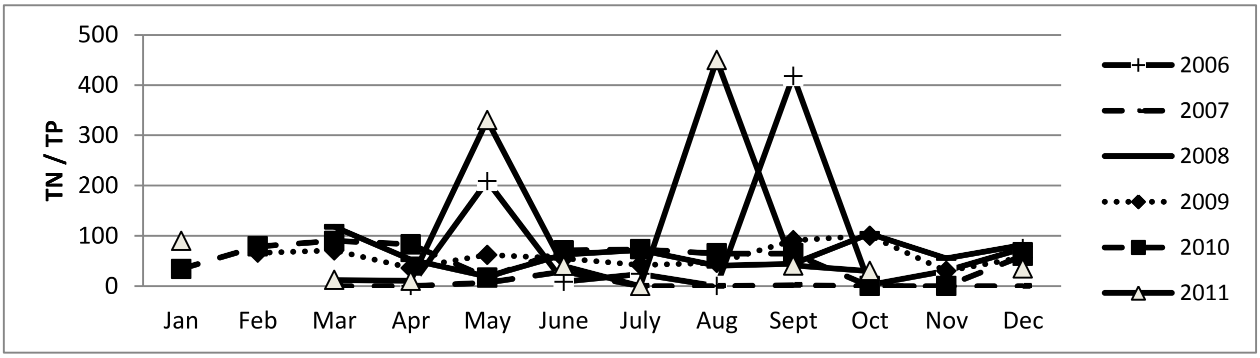


Figure 2. Annual variation of TN:TP ratio for Uzungöl Lake between 2006 and 2011.

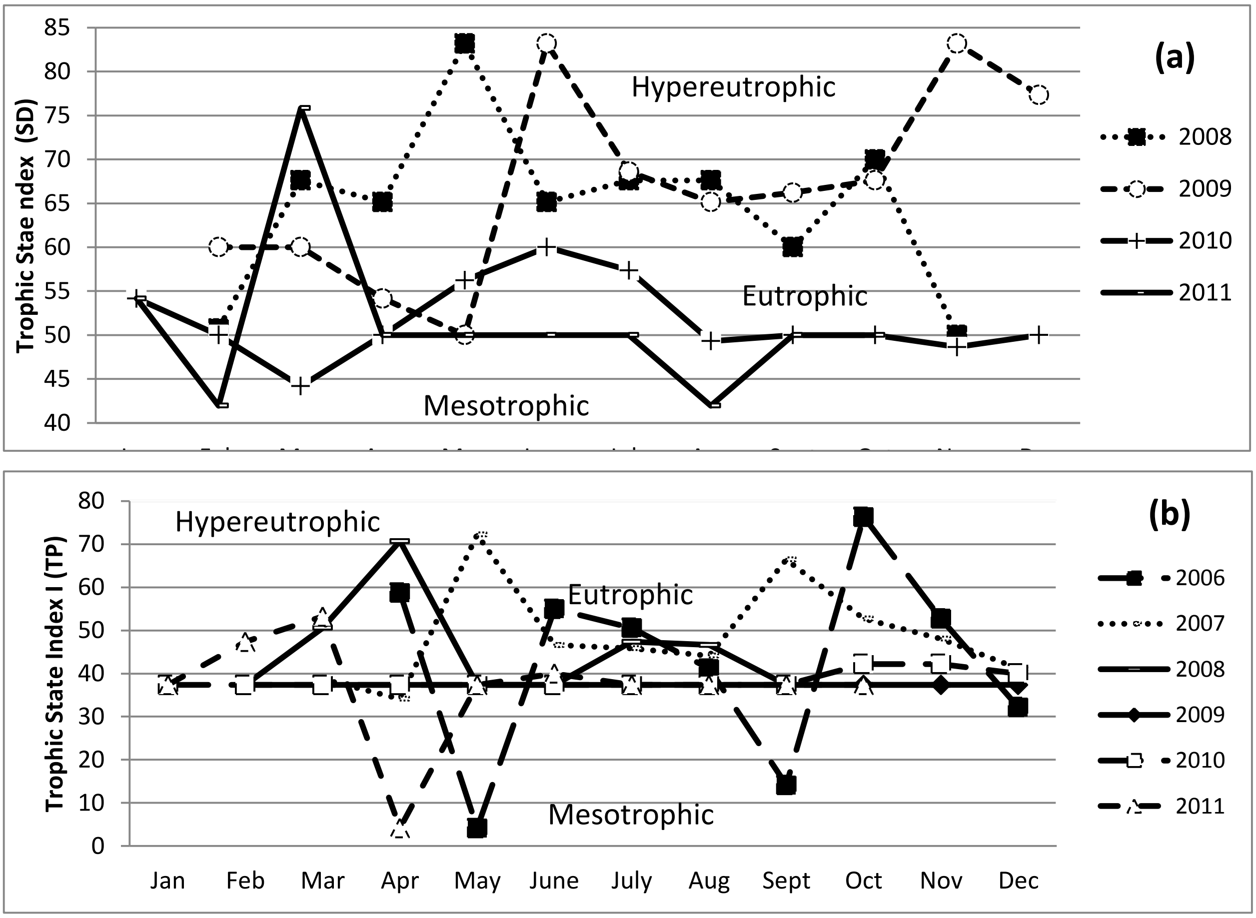


Figure 3. Annual variation of Trophic State Index (a) for Secchi Depth (SD) and (b) for Total Phosphate (TP) for the study period.

determined, water quality is ranked by relating it to one of the following categories:

- ✓ "Excellent: (CCME WQI Value 95-100) – water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels.
- ✓ Good: (CCME WQI Value 80-94) – water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
- ✓ Fair: (CCME WQI Value 65-79) – water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
- ✓ Marginal: (CCME WQI Value 45-64) – water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
- ✓ Poor: (CCME WQI Value 0-44) – water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels" (Wright et al., 1999)".

WQI indices were calculated for Uzungöl Lake from 2006 to 2011 and tabulated in tables 2 to 7. WQI for Uzungöl Lake slightly improved from "POOR WQI" to "MARGINAL WQI" from 2006 to 2011.

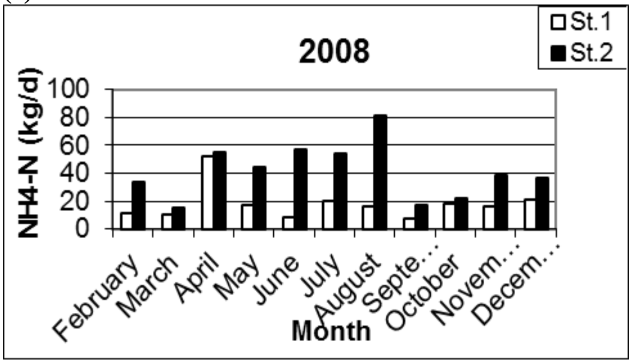
3.2. Evaluation of Effect of Land-Based Fish Farm on the Water Quality of Haldizen Creek

The water quality of creeks in the Turkish Water Pollution Control Regulation (TWPCR, 2004) has four primary designations, as follows:

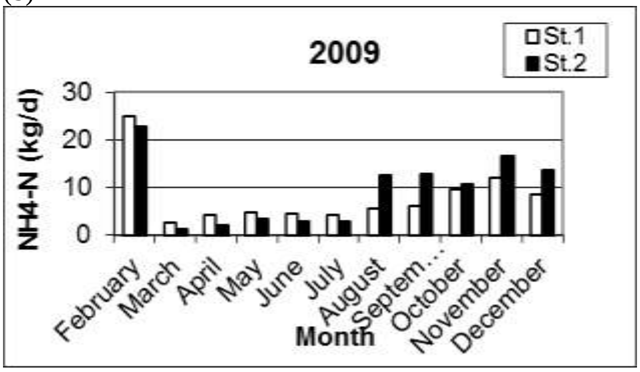
- ➢ Class I: high-quality water (suitable for drinking water supply after disinfection, used for recreational activities, and for fish (trout) production).
- ➢ Class II: minimally polluted water (suitable for drinking water supply after treatment process, for recreational activities, fish production (other than trout), and for irrigation in compliance with TWPCR irrigation standards).
- ➢ Class III: polluted water (used for industrial water supply, but not for food and/or textile industry, or for irrigation),
- ➢ Class IV: highly polluted water (not suitable for irrigation; used for industrial water supply).

The results of 6 projects (EPASA 2006, 2007, 2008, 2009, 2010, 2011b) were examined to investigate the present status of, and the monthly and yearly (2006–2011) changes in the water quality of Haldizen Creek before (Station 1) and after (Station 2) land-base fish farms. NH_4–N, NO_3–N, NO_2–N, TP concentrations, the number of total and fecal coliforms were measured at sampling points 1 and 2 (Fig. 1).

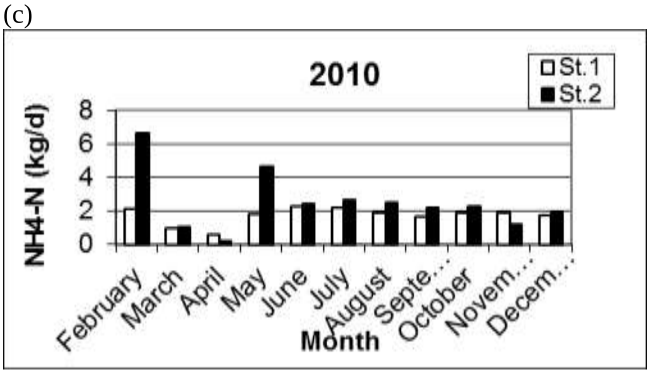
(a)



(b)



(c)



(d)

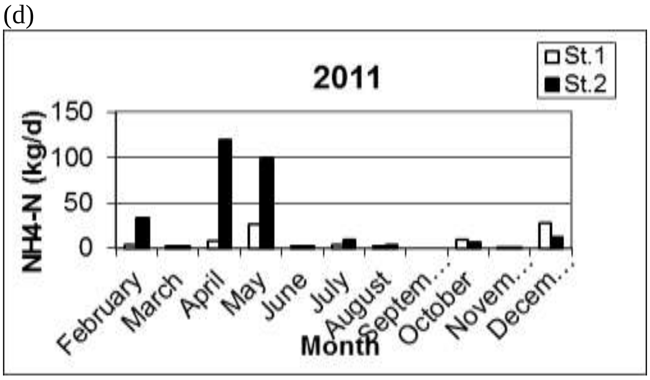


Figure 4. Ammonia nitrogen (NH_4-N) loadings before (St.1) and after (St. 2) fish farms from 2008 to 2011

In addition to concentration trend analysis, loadings of ammonia nitrogen and total phosphorus before and after fish farms were also calculated and presented in figures 4 and 5, respectively. Mass discharge was calculated by multiplying the water flow rate by the corresponding concentration of each compound, multiplied by units of conversation factor. Since Haldizen Creek drains into Uzungöl Lake after fish farms, Station 2's loads represents the contaminants entering Uzungöl Lake.

Ammonia–nitrogen concentration

The creek's water quality was Class I (0–0.2 mg/l) both for Station 1 (before fish farms) and Station 2 (after fish farms) in all sampling years (TWPCR, 2004). Exceptions for this trend were detected in July 2007, February 2008 and April 2011 with water quality Class II (0.2–1 mg/l) after fish farming. Although water quality class doesn't change before and after fish farming, it is clear from figure 6 that NH_4-N concentration incidence increases after fish farm. This study also showed the significant effect of fish farm discharges in terms of NH_4-N loadings in 2008 (Fig. 4a) and from August to December 2009 (Fig. 4b). The same trend was observed in 2010 except for in April & November (Fig. 4c). It is apparent that there is no effect of fish farming discharges on the water quality of Haldizen Creek after fish farming in February, October and December 2011 (Fig. 4d).

Nitrite–nitrogen concentration

The creek's water quality was Class III (0.01–0.05 mg/l) in 2006, Class II (0.002–0.01 mg/l) in 2008, Class I in 2010 and 2011 both for Station 1 and Station 2. In 2007, NO_2-N concentration ranged from 0.06 to 0.082 mg/l after fish farming. These values earn Haldizen Creek a Class III water quality designation according to 16 measurements and Class IV according to 2 measurements. It can be concluded that there was no massive difference between NO_2-N concentrations before and after fish farms.

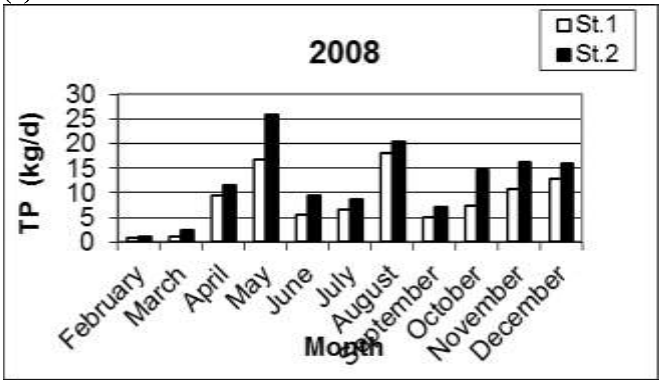
Nitrate–nitrogen concentration

The creek's water quality was Class I (0–5 mg/l) both for Station 1 and Station 2 from 2007 to 2011. Based on 18 measurements Haldizen Creek had a Class I water quality for 12 measurements, Class II (5-10 mg/l) for 5 measurements and Class III (10-20 mg/l) for one measurement in 2006. It can be concluded that there was no massive difference between NO_3-N concentrations before and after fish farms.

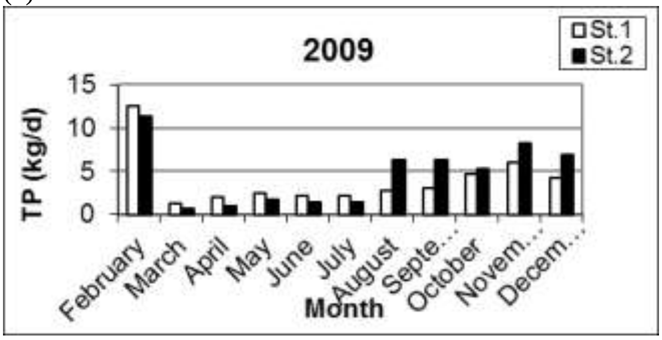
Total phosphorus concentration

Haldizen Creek was given a Class I (<0.02 mg/l) water quality designation according to 14, 10, 20, 22, 16 and 17 measurements in 2006, 2007, 2008, 2009, 2010 and 2011, respectively. It was given a Class II (0.02-0.16 mg/l) water quality designation after 4, 6, 2, 6 and 5 measurements in 2006, 2007, 2008, 2010 and 2011, respectively. There is no huge difference between concentrations before and after fish farming. Although water quality class doesn't change before and after fish farming, TP concentration incidence increases after fish farm. This study also showed the significant effect of fish farm discharges in terms of TP loadings in 2008 (Fig. 5a) and from August to December 2009 (Fig. 5b). The same trend was observed in 2010 except in April (Fig. 5c). It is apparent that there is no effect of fish farm discharges on the water quality of Haldizen Creek after fish farming in February, April, October and December 2011 (Fig. 5d).

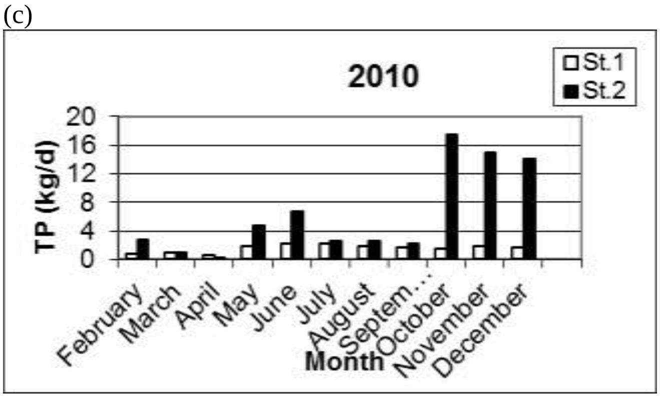
(a)



(b)



(c)



(d)

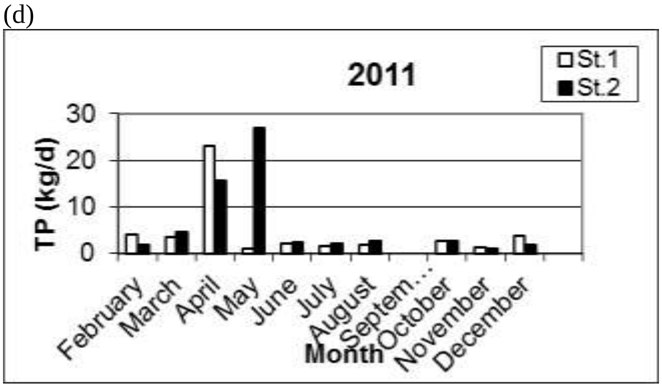


Figure 5. Total phosphorus (TP) loadings before (St.1) and after (St. 2) fish farms from 2008 to 2011

Total coliform number

The number of total coliforms before and after fish farm indicated Class I water quality (the Class I limit for total coliforms is 0-100 CFU/100 ml) after 5, 3, 14, 22, 22 and 22 different measurements in 2006, 2007, 2008, 2009, 2010 and 2011, respectively. However, it had a Class II water quality (Class II limit for total coliforms is 10– 20,000; TWPCR, 2004) for 13, 15 and 8 measurements in 2006, 2007 and 2008, respectively. Although water quality class doesn't change before and after fish farming, the total coliform number increased after fish farm.

Fecal coliform number

The number of fecal coliforms before and after fish farming indicated Class I water quality (the Class I limit for fecal coliforms is 0-10 CFU/100 ml) after 11, 4, 13, 20, 17 and 16 measurements in 2006, 2007, 2008, 2009, 2010 and 2011, respectively. However, it had a Class II water quality (Class II limit for fecal coliforms is 10– 200; TWPCR, 2004) for 7, 14, 5, 2, 5, and 6 measurements in 2006, 2007, 2008, 2009, 2010 and 2011, respectively. Although water quality class doesn't change before and after fish farming, the number of fecal coliforms increased after fish farm.

Based on these comparisons, it is clear that there is limited influence of Haldizen creek on Uzungöl Lake's water quality in terms of ammonium–nitrogen, total phosphate, and number of total and fecal coliforms.

3.3. Water Quality of Haldizen Creek after leaving Uzungöl Lake

The results of 6 projects (EPASA 2006, 2007, 2008, 2009, 2010, 2011b) were examined to investigate the present status of and the monthly and yearly (2006–2011) changes in, the water quality of Haldizen Creek after leaving Uzungöl Lake. NH_4–N, NO_3–N, NO_2–N, TP concentrations, the number of total and fecal coliforms were measured at the sampling point 3 (Fig. 1).

Ammonia–nitrogen concentration

The creek's water quality was Class I (0–0.2 mg/l) in all sampling years. Exceptions for this trend were detected in April and August 2011 with water quality Class II (0.2–1 mg/l).

Nitrite–nitrogen concentration

The creek's water quality was Class III (0.01–0.05 mg/l) in 2006, Class III and Class IV (>0.05 mg/l) after 2 and 7 measurements, respectively in 2007. In 2008, it was designated Class III after 3 measurements and Class IV after 9 measurements. It was both Class I and Class II after 6 measurements in 2009. It had Class I water quality status in 2010 and 2011 except for in May 2011, and May & October 2010.

Nitrate–nitrogen concentration

The creek's water quality was Class I (0–5 mg/l) in all sampling years.

Total phosphorus concentration

Haldizen Creek was designated Class I (<0.02 mg/l) water quality status in 2009 and 2010 for all measurements, 8, 8, 4, and 6 measurements in 2011, 2008, 2007 and 2006, respectively. It had a Class II (0.02-0.16 mg/l) water quality for 4, 3, 3, 3 measurements in 2011, 2008, 2007 and 2006, respectively. Creek had a Class IV (>0.65 mg/l) water quality in April 2007.

Total coliform number

Based on 12 measurements, the creek had Class I water quality status (0-100 CFU/100 ml) in 2010, 2011 and 10 measurements in 2009 and 3 measurements in 2008. However, it had a Class II water quality (10– 20,000; TWPCR, 2004) for 7, 8, and 2 measurements in 2006, 2008 and 2009, respectively.

Fecal coliform number

The creek had a Class I water quality status (0-10 CFU/100 ml) after 4, 1, 4, 6, 6, and 8 measurements in 2006, 2007, 2008, 2009, 2010 and 2011, respectively. Moreover, it had Class II water quality status (10– 200 CFU/100 ml) after 5, 4, 6, 4, 6 and 4 measurements in 2006, 2007, 2008, 2009, 2010 and 2011, respectively.

4. CONCLUSIONS

Water quality changes throughout the course of a river and is influenced by altitude, geology, habitat type, wetlands, riparian areas, climate, flow regime, land use, fresh water withdrawal from ground and surface water sources, point and nonpoint water pollution, nutrient transfer mechanisms between terrestrial and aquatic environments.

Although concentration measurements are convenient for comparing field data to water quality criteria, additional methods are available to quantify nutrients, such as loads and indices like WQI and TSI. Loads assess the mass of constituents transported over time and help to quantify the total amount delivered and yield measurements estimate the mass of constituents delivered per unit area per unit time, which can help to assess best management practices.

Evaluating water quality using various methods enables watershed managers to develop and implement specific plans targeting factors affecting water resources. Trend analysis and nutrient quantification methods have been used extensively in water quality studies. Trend analysis (concentration trends), load estimation (mass of pollutants delivered), TN:TP Ratio (trophic status trends), TSI (eutrophication trends), and the WQI (environmental quality trends) can be used together to supply additional understanding of water quality.

A six-year data set showed that TSI values of SD and TP remained within the range of hypereutrophic and eutrophic category, respectively. TN/TP ratios suggest Uzungöl Lake can be considered to be P limited and the TN/TP ratio is generally always greater than 12 (57 out of 61 measurement). WQI for Uzungöl Lake has found to be slightly improved from "POOR WQI" to "MARGINAL WQI" from 2006 to 2011. Nutrient loading calculations showed significant effect of land-based fish farms.

There is moderate influence of Haldizen Creek on Uzungöl Lake's water quality in terms of ammonium–nitrogen, total phosphate, and the number of total and fecal coliforms. It has been determined that the water quality of Haldizen Creek after fish farming became even worse at the outlet of Uzungöl Lake in terms of nitrite–nitrogen concentration and fecal coliform number.

After years of nutrient accumulation in the lagoon, one of the reasons for lagoon eutrophication seems to be the release of phosphorus from bottom sediments into the water column which is further enhanced in the summer period by the limited flushing that recycles nutrients in the water.

Protective measures and actions should be taken in order to improve the Lake's water quality, these could/should include;

- Investigation of rainwater's and groundwater's nutrient, organic and inorganic content which may enter the lake since these sources are believed to cause insignificant external inputs when compared to river inputs. High water tables in the watershed enable nitrogen-enriched groundwater to degrade water quality in the creeks and eventually in Uzungöl Lake.
- Application of best management practices in the agricultural parts of the drainage area should be investigated towards further reduction or total elimination of nutrients loadings to the lagoon. Unauthorized agricultural land use should be curtailed, and the usage of fertilizers and pesticides should be better controlled.
- Best practices should also be applied in the drainage area for further sediment supply and control, to prevent continuing reduction of the lagoon volume and depth in the long run. Soil-erosion control projects should be developed and implemented within the Uzungöl Lake drainage basin as soon as possible.
- Operational problems associated with wastewater treatment plant should be solved since amount of wastewater is increasing thereby affecting

wild life.

- Garbage collection should be conducted on time and the problem of increased plastics (especially from nylon bags), as well as battery pollution should be addressed.
- Fish (Trout) farming uses river water as input and releases its effluent almost invariably to the river. Therefore, emission requirements need to meet the quality objectives of the surface waters concerned, so that nutrient concentrations do not exceed the predefined standards. Unfortunately, there are no limit or emission standards for land-based fish farms under Turkish Regulations. Current regulations only set standards for fish farms located in the sea. Its content should comprise the emission standards for land-based fish farms. Wastewater treatment system should be built for fish farm wastewaters.
- Wetland systems should be constructed in order to provide efficient water quality improvement, to avoid biodiversity loss, to reduce nutrient loading into rivers, to prevent flood, to provide nursery habitat for juvenile fish that support commercial fisheries.
- Taking into account the wealth of natural and cultural values in Uzungöl SEPA, there is a need to inform the public and promote their awareness regarding the use and protection of forests, the value and preservation of ecological values, and the protection of Uzungöl Lake. For this purpose, priority should be given to training and educating local people, administrators and civil employees as well as informing visitors to the region. Workers (especially) in agriculture, tourism, commercial and other sectors, women in rural areas, children and youth and visitors to the region can be chosen as target groups.
-

Acknowledgements

The author is grateful to Özlem AKSOY, ÇINAR Mühendislik Müşavirlik ve Proje Hizmetleri and ALKA İnşaat Çevre San. Tic. Ltd. Şti for providing the water quality data used in this study.

Disclaimer

Any opinions, findings, conclusions, or recommendations expressed herein are those of the author and do not necessarily reflect the view of Environmental Protection Agency for Special Areas.

Received at: 16. 10. 2012
Revised at: 21. 06. 2013
Accepted for publication at: 28. 06. 2013
Published online at: 03. 07. 2013

REFERENCES

Atasoy, M., 2010. *Monitoring land use changes in tourism centers with GIS: Uzungöl Case Study*", Scientific Research and Essays, 5(8), 790-798.

Camargo, J.A., & Alonso, A., 2006. *Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: a global assessment*. Environment International 32, 831–849.

Camargo, J.A., Alonso, A. & de la Puente, M., 2004. *Multimetric assessment of nutrient enrichment in impounded rivers based on benthic macroinvertebrates*. Environmental Monitoring and Assessment 96, 233–249.

Carlson, R.E, 1977. *A Trophic State Index for Lakes.* Limnology and Oceanography 22(2), 361-369.

EPASA, 2006, 2007, 2008. 2009, 2010 and 2011(b). *"Project of Monitoring of water quality in Special Environmental Protection Areas".* Technical Report prepared by ÇINAR Mühendislik Müşavirlik ve Proje Hizmetleri, and ALKA İnşaat Çevre San. Tic. Ltd. Şti, to the Environmental Protection Agency for Special Areas (in Turkish).

EPASA, 2011(a). "Project of Terrestrial Biological Diversity of Uzungöl Special Environmental Protection Area", Report prepared by TAKVA to the Environmental Protection Agency for Special Areas (in Turkish).

Grayson, R.B., Gippel, C.J., Finlayson, B.L. & Hart, B.T., 1997. *Catchment-wide impacts on water quality: The use of snapshot sampling during stable flow*. Journal of Hydrology, 199, 121–134.

Handy, R.D., & Poxton, M.G., 1993. *Nitrogen pollution in mariculture: Toxicity and excretion of nitrogenous compounds by marine fish.* Reviews in Fish Biology and Fisheries, 3, 205–241.

Niemi, M. & Taipalinen, I., 1982. *Faecal indicator bacteria at fish farms.* Hydrobiologia, 86, 171–175.

TWPCR (2004). *Water Pollution Control Regulation (in Turkish), prepared by Ministry of Environment and Forest.* Official Journal, *25*(687), 18–76.

Wright, C.R., Saffran, K.A., Anderson, A.-M., Neilson, R.D., MacAlpine, N.D. & Cooke, S.E., 1999. *A Water Quality Index for Agricultural Streams in Alberta: The Alberta Agricultural Water Quality Index (AAWQI).* Prepared for the Alberta Environmentally Sustainable Agriculture Program (AESA). Published by Alberta Agriculture, Food and Rural Development. Edmonton, AB. 35 pp

Wu, R.S.S., 1995. *The environmental impact of marine fish culture: Towards a sustainable future.* Marine Pollution Bulletin, 31, 159–166.