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DETERMINATION OF WATER QUALITY AND EFFECT OF AQUACULTURE FACILITIES IN BAFA LAKE FROM BUYUK MENDERES BASIN OF TURKEY

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ABSTRACT

Bafa Lake is one of the largest Turkish Lagoon lakes in Aegean Region covering a surface area of 50km^2. Because of its water capacity and myriad benefits in aquaculture facility, agricultural activities and tourism. The lake is considered as an important wetland within Buyuk Menderes basin. This study investigate the aquaculture facilities and anthropogenic sources of pollutions and how they affect the water quality of Bafa Lake. The major factors that control the quality of Bafa Lake water are agricultural activities in the basin, domestic and industrial wastes that come from Buyuk Menderes River and its surrounding lake, fisheries and aquaculture facilities. Contaminants located in the Lake are continuously having a negative impact on its water quality during the last three decades. The effect of sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*) cultivation facilities on surface water quality in the Lake were determined. Water samples were taken from five stations between April 2013 and March 2014 from Bafa Lake. Sample were analyzed for water temperature, pH, dissolved oxygen, electrical conductivity, amonium nitrogen, nitrite nitrogen, nitrate nitrogen, and orthophosphate. From result surface water quality was assessed based on the comparison of samples collected near aquaculture stations. For reference, a sample was taken outside the cultivation area and compared with the Water Pollution Registration Act (WPRA) standards. According to the WPRA, surface water quality of the Lake was classified as level II. At the end of analyses, it was revealed that the area where aquaculture activities were intense showed high rate of polution than the other 3 stations as well as the reference station. The results show that, aquaculture activities on sea bream and sea bass have a negative impact in the entire Bafa Lake.

KEYWORDS:
Bafa Lake, Aquaculture, Environmental effects, Water quality, Sea bream, Sea bass

INTRODUCTION

Bafa Lake is a shallow lagoon located in the Buyuk Menderes River Basin from Southeastern part of Aegean Region (Turkey). It is one of the largest coastal shore lake of the Aegean Region. Bafa Lake, also known as Camici Lake is a private wetland which is very important for the livelihood of the people around the area offering several benefits for the economy of the region and the country. The lake constitutes a significant and original ecosystem in terms of conservation of natural resources and biological diversity [1, 2].

Bafa Lake was listed among the 76 most important international wetlands in Turkey [3,4] and it is one of the Turkish most important areas for birds. From 1989 it is a natural protected area and in 1994 was declared a Natural Park [5, 2].

The Lake is characterized by a rich fauna and flora comprising 15 different fish species. Furthermore, the lake has a high fish larvae breeding potential serving as an important reservoir for fisheries [5, 6]. Never the less, after the deviation of water in flow of Buyuk Menderes River due to the creation of several dams along the watercourse, the river start getting affected by several human disturbances mainly due to agricultural activities and domestic pollution. To date, drying and improvement work to acquire new land for agriculture, illegal catch of eggs and juveniles, uncontrolled cutting and burning of reed, fish farming implementation in lagoons, increasing of sedimentation, lack of water management and excessive tourism activity represent the main disturbances for Bafa Lake ecosystem.

Turkey is having 26 major river basins comprising 200 natural lakes, 700 ponds and 794 reservoirs [7]. Conversely, the country hosts 1.263.995 acres of inland water suitable for aquatic production. Aquaculture production in Turkey is an important fishery activity for both sea and inland water. On fish production current information reveals that Turkish inland fresh and marine water are about 52.71% and 47.29% respectively. Total of 1.935 licensed inland fish farms (with a capacity of

245.166 tons) and 418 marine aquaculture facilities (total capacity of 217.166 tons) are currently identified [8].

The Turkish marine aquaculture industry is mostly issued in southwestern Turkey near the Aegean Sea for the last 3 decades [8]. In this area the main fish species are sea bream Sparus aurata L., 1758 and sea bass, Dicentrarchus labrax (L., 1758). With the development of marine fish farming in the Aegean region, three large fish farm facilities for production of fish larval were estabilished in Bafa Lake.

In 1959, the National Water Supply directorate has conducted fishery works in dam lakes, which resulted in limnological analyses of 183 dam lakes and 12 natural lakes [9]. For commercial reasons, there are approximately 255 fish species of different culture in eight fish farming stations around Turkey. 178 dam lakes, 320 ponds, 12 natural lakes, and reservoirs belonging to other institutions are found in turkey. 45.585 tons of aquatic products by cultivation was produced in 2004. However, only 20% of this (9.117 tons) is from inland water production. In these lakes, approximately 110 cage cultivation projects with a total capacity of 6.617 tons have been implemented, 15% of which comprises the total inland water cultivation (44.115 tons) [9].

Sea bream, sea bass, European ell, *Anguilla anguilla* (L., 1758), gibelcarp, *Carassius gibelio* (Bloch, 1782), Thinlip grey mullet, *Liza ramada* (Risso, 1827) and Flathead grey mullet, *Mugil cephalus* (L., 1758) have a great potential in Bafa Lake in terms of economic importance.

A study on 17 water bodies of fish species and mean value of measured environmental variable (pH, EC, DO, Temperature) of South Aegean region was given by Ozdemir et al. [10].

Distruption of lake and sea sediment around aquaculture facilities (fish cages) is one of the most widely documented effect of fish farming. These changes are demonstrated through disturbances of sediment in diffirent level as an accumulation of phosphorus, nitrogen compounds and organic carbon [11].

Because of the significant capability for fishery production of Bafa Lake, maintenance of water quality of the lake is fundamental. The aim of this study was to assess the water quality status of Bafa Lake and evaluate the potential impacts of fish farming activities on water quality.

MATERIALS AND METHODS

The Study Area. Bafa Lake is located between 37° 30'' N latitude and 27° 25'' E longitude (Figure 1), and covered a total of 229 km land area;

Buyuk Menderes River passes through Bafa Lake by silt which is carried by running water from Gulf of Agean Sea that split at the shore. Bafa Lake, is a lagoon lake located in the southwestern part of Turkey, having boundaries with Aydin and Mugla provinces and covered an area of about 70 km^2 with 10 m sea level with maximum depth of 21 m. this wetlands is among the A category. For a long time the lake is mainly fed by Buyuk Menderes River, (average rainfall of about 545 mm). Additional streams flow into the lake are from Besparmak Mountains. Ilbır Mountains is found at the south of Bafa Lake; from the north is Besparmak Mountain. There are five island around Bafa lake monastery and castle Defense Island, Ikiz Island, Menet Island, Kapıkırı Island and Kahve Hisar Island [12].

The bay, known as the arm of the Agean Sea is formed from the silt carried by running water coming from Buyuk Menderes Rıver. Bafa Lake was form in M.S. 1500 when the lake lost it connection to the sea. During Hellenistic era (B.C. 323) the lake has been dominated by marine conditions (4). The weather around the lake during winter is temperate and rainy while in summer is dry and hot like the Mediterranean climate [13].

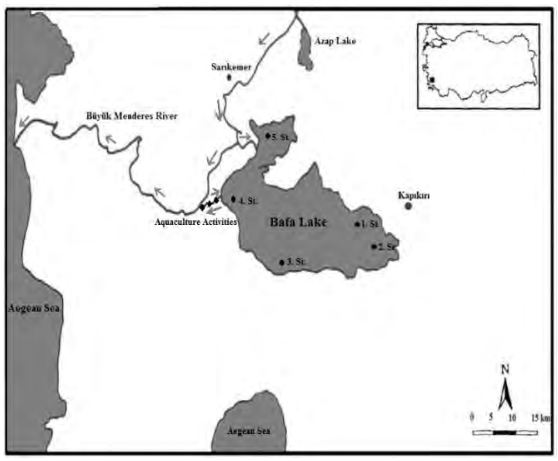

FIGURE 1
Study Area of Bafa Lake.

Sampling Method. Water samples were collected from 5 stations. A reference station (called station 5) as selected at the mixing point of Bafa lake and Buyuk Menderes River. This area is close to the main freshwater input. The begining of summer water coming to the lake is totally closed for supply of cotton fields, because of this the water level in the lake decrease in summer.

A second station (called station 4) was selected near the larval fish production area close to Buyuk Menderes River in flow and 3 fish production conduit area. The water used for aquaculture production is taking from 40-50 m debt. The water used for production is then release from pond.

The other 3 stations (stations 1, 2 and 3) were selected from different coordinate of the lake.

Samplings were carried monthly between April 2013 and March 2014. From every sampling station.

Temperature, salinity, pH, electric conductivity and dissolved oxygen (DO) (mg/L) were measured directly on the field by means of MultiProb (YSI 556 MPS). Sample of water was collected at 20 cm below the surface in a 1 liter pre-cleaned plastic container (Niskin bottles).

The samples were immediately transfered to the laboratory. The water samples are filtered by 0.45 µm pore size membrane filters and arranged in separate aliquot. All samples were stored at 4 °C until analysis.

Analytical procedure. The anions (ammonium nitrogen, nitrite nitrogen, nitrate nitrogen and orthophosphate) was analyzed by spectrophotometry, using a Hach Lange Dr3900 UVVIS Spectrophotometer (Table 1).

Water parameters was measured in the laboratory by SM standard method [14]: Ammonium nitrogen by Phenate method, SM 4500-NH_3-F; Nitrite nitrogen by Colorimetric method, SM 4500-NO_2-B; Nitrate nitrogen by Hydrazine reduction method, SM 4500-NO_3-H and Orthophosphate by Stannous chloride method, SM 4500-PD.

TABLE 1
Inland water quality criteria according to WPCR.

Water Quality Parameters	Water Quality Classes			
	I	II	III	IV
Temperature (°C)	25	25	30	>30
pH	6.5-8.5	6.5-8.5	6.0-9.0	6.0-9.0
Dissolved oxygen (mg/L)	8	6	3	<3
Ammonium nitrogen (mg/L)	0.2	1.0	2.0	>2.0
Nitrite nitrogen (mg/L)	0.002	0.01	0.05	>0.05
Nitrate nitrogen (mg/L)	5	10	20	>20
Ortho phosphate phosphorus (mg/L)	0,02	0,16	0,65	>0,65

The quality criteria of inland water resources according to relevant categories of the Water Pollution Category Registration (WPCR) are shown in Table 1 [15, 16].

Statistical Analysis. For each parameter the mean monthly value for every station was calculated and the annual trend were analyzed.

Sperman's rho test was used to assess the correlation among the parameters. The analysis Variance (ANOVA) followed by the post-hoc Turkey test was to assess the differences between the values of the measured parameters among stations. A value of $P<0.05$ was chosen for significance.

RESULTS

The average, minimum and maximum ranges of water qualities parameters in Bafa Lake were given below together. The results of ANOVA and post-hoc Tukey test (Table 2). The mean value of temperature and orthophosphate did not differ in the stations ($P<0.05$). The mean value of electrical conductivity, salinity and nitrite measured in station 4 (close to aquaculture facilities) resulted significantly different ($P<0.05$) from the other 4 stations. Moreover the value of pH, DO and ammonium resulted significantly different ($p<0.05$) just between station 4 and station 5 (reference station). The mean values of nitrate nitrogen of station 4 were significantly different from stations 1 and 2.

Water temperature. The mean of water temperatures were 22.90; 22.30; 22.20; 22.40 and 21.20 °C at stations 1, 2, 3, 4 and 5, respectively. Lowest temperature (8.90 °C) was seen in December at station 5 whereas the highest temperature (31.30 °C) was measured at August in station 4. From one year study period, the mean water temperature was 22.21 °C (Table 2; Fig. 2).

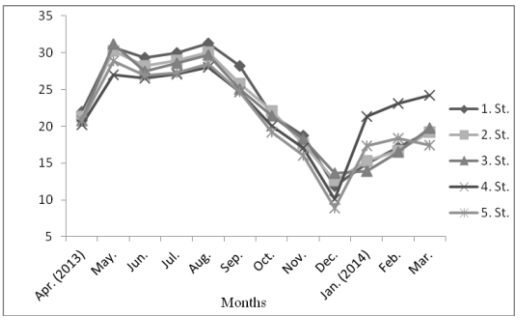

FIGURE 2
Monthly water temperature (˚C) all station in the Bafa Lake.

According to the data found on Bafa Lake it indicate that no thermal pollution was involved. According to WPCR the water quality can be classified as class level 1.

pH. The pH values of all stations in Bafa Lake changed between 6.95 and 9.35. The average pH was detected as 8, 26. The annual mean pH value for the stations are given below. Station 1, 8.20; station 2, 8.26; station 3, 8.29; station 4, 7.77; station 5, 8.76 (Table 2; Fig. 3).

According to these value, the Lake water is neutral and slightly basic and reflects the geological features of the lake surrounding area. According to WPCR the water quality of the Lake in terms of pH is classified as class level I (Table 1).

TABLE 2
Physical-Chemical values of water sample from the selected 5 stations of Bafa Lake.

Parameters	Unit	1.Station Mean (Range)	2.Station Mean (Range)	3.Station Mean (Range)	4 Station Mean (Range)	5.Station (1) Mean (Range)
Temperature	°C	22,90[a] (11,90-31,30)	22,30[a] (12,60-30,30)	22,20[a] (13,60-31,20)	21,40[a] (10,10-28,00)	21,20[a] (8,90-28,90)
pH	-	8,20[a] (7,77-8,70)	8,26[a] (7,66-9,23)	8,29[a] (7,67-9,35)	7,77[b] (6,95-8,66)	8,76[c] (7,76-9,35)
Dissolved oxygen	mg L^{-1}	7,35[a] (2,88-9,80)	7,51[a] (5,30-9,20)	7,58[a] (5,30-9,60)	6,34[b] (3,15-12,06)	8,84[c] (6,20-12,46)
Electrical conductivity	mS cm^{-1}	18,44[a] (10,27-21,53)	18,17[a] (10,71-20,07)	18,15[a] (10,41-19,94)	30,52[b] (19,22-47,49)	19,14[a] (12,93-46,88)
Salinity	‰	11,08[a] (5,85-12,87)	10,91[a] (6,09-11,95)	11,19[a] (5,94-11,55)	21,95[b] (11,46-30,91)	9,62[a] (2,92-12,90)
Ammonium nitrogen	mg L^{-1}	1,02[a] (0,76-1,20)	1,02[a] (0,61-1,20)	0,97[a] (0,84-1,20)	1,11[b] (0,91-1,24)	0,91[c] (0,50-1,16)
Nitrite	mg L^{-1}	0,01[a] (0,01-0,01)	0,01[a] (0,01-0,06)	0,01[a] (0,01-0,03)	0,16[b] (0,01-0,81)	0,03[a] (0,01-0,17)
Nitrate	mg L^{-1}	2,16[a] (0,80-3,06)	2,07[b] (0,20-3,40)	2,77[c] (2,10-3,50)	3,40[d] (2,20-4,90)	3,16[c] (2,20-3,80)
Ortophosphate	mg L^{-1}	0,24[a] (0,05-0,56)	0,17[a] (0,05-0,44)	0,21[a] (0,05-0,61)	0,23[a] (0,05-0,48)	0,19[a] (0,05-0,41)

(1) Reference station -Mean with common superscripts in the same row are not significantly different at Tukey test (P>0.05).

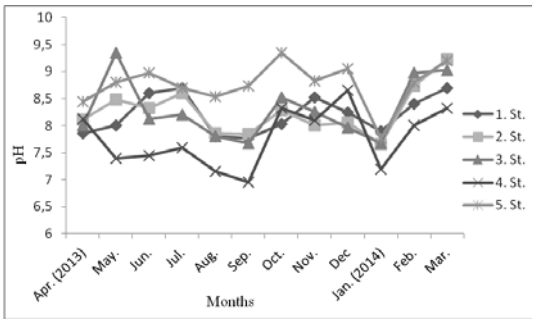

FIGURE 3
Monthly pH values in the 5 selected stations.

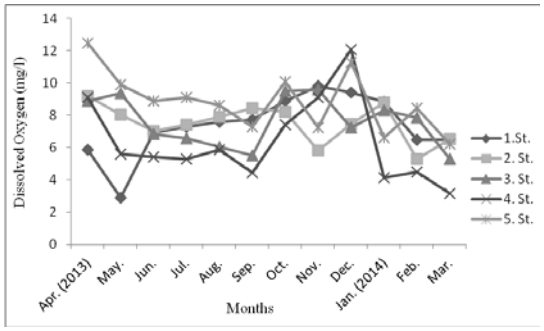

FIGURE 4
Mean amount of dissolved oxygen (mg/L) in the 5 stations of Bafa Lake.

Dissolved oxygen. Average dissolved oxygen value of the station was determined as follow; station 1, 7.35 mg/L; station 2, 7. mg/L; station 3, 7.58 mg/L; station 4, 6.34 mg/L and station 5, 8.84. Minimum value was seen in May at station 1 (2.88 mg/L), whereas the maximum was in 12.46 mg/L in April at station 5 (Table 2; Fig. 4).

The dissolved oxygen average value of all stations for 12 month was 7.53 mg/L. Dissolved oxygen was found to be lower in summer. Decreased water temperature results for increased suitability of oxygen levels. The amount of dissolved oxygen in the water depends on the water temperature, atmospheric pressure, mineral concentrations and water pollution level. The mean Dissolved oxygen was between 6.34 and 12.46 mg/L at all stations. This is classified as class level II according to WPCR (Table 1).

Salinity. Salinity value ranged between 2.92 to 30.91‰. Highest salinity value was found at station 4 in September, lowest salinity value was in February at station 5 (Fig. 5). The average salinity in all stations was 12.95‰.

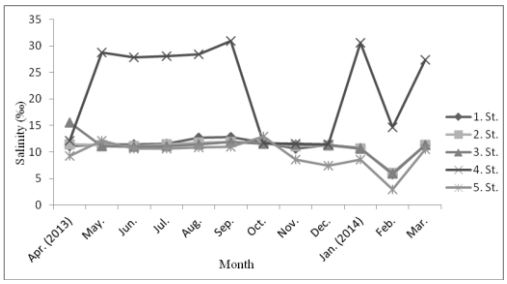

FIGURE 5
Salinity changes (‰) in the 5 stations of Bafa Lake.

Electrical conductivity. Electric conductivity change between 10.27-47.49 mS/cm. Lowest value was 10.27 mS/cm in February from station 1, highest value was 47.49 mS/cm in September from station 4 (Fig. 6). The annual mean electrical conductivity value was 20.89 mS/cm.

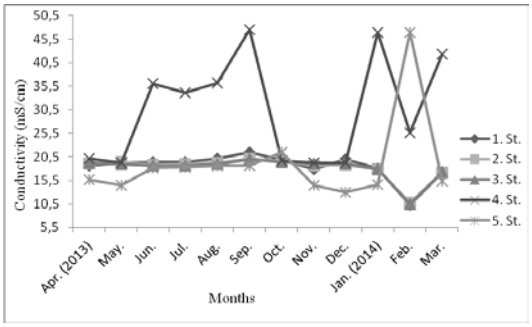

FIGURE 6
Electrical conductivity changes (mS/cm) according to stations.

Ammonium nitrogen (NH_4-N mg/L). Ammonia nitrogen values varies between 0.5-1 and 24 mg/L. The average ammonia nitrogen value from stations are as follows: Station 1, 1.02 mg/L; station 2, 1.02 mg/L; station 3, 0.97 mg/L; station 4, 1.11 mg/L; station 5, 0.91 mg/L (Fig. 7).

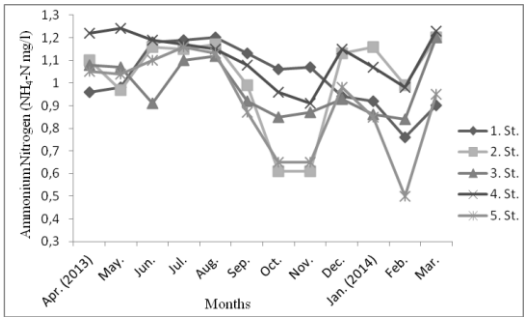

FIGURE 7
Ammonium nitrogen (mg/L) value in Bafa Lake.

Annual ammonium value was 1.01 mg/L. According to Anonymous (2008), this is clasified as class level III (Table 1).

Nitrite nitrogen (NO_2-N mg/L). Nitrite nitrogen values change between 0.01-0.81 mg/L. Average value according to stations are as follows; station 1, 0.01 mg/L; station 2, 0.02 mg/L; station 3, 0.01 mg/L; station 4, 0.18 mg/L; station 5, 0.03 mg/L. According to analysis, the highest level of nitrite nitrogen is (NO_2-N). This found in station 4 with the value of 0.81 in July (Fig. 8).

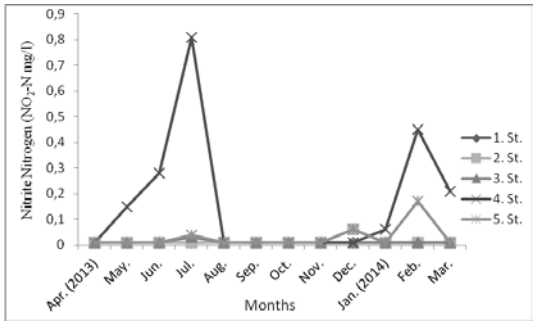

FIGURE 8
Distribution of nitrite levels (mg/L) from all stations in Bafa Lake.

The average nitrite nitrogen concentration of the water samples was 0.05 mg/L, which indicates that the water quality in the Lake is classified as class level III (WPCR).

Nitrate nitrogen (NO_3-N mg/L). Changes in nitrate nitrogen from all stations were found between 0.2-4.9 mg/L. The average nitrate nitrogen concentrations were 2.16 mg/L for station 1; 2.07 mg/L for station 2; 2.77 mg/L for station 3; 3.40 mg/L for station 4 and 3,16 mg/L for station 5 (Fig. 9).

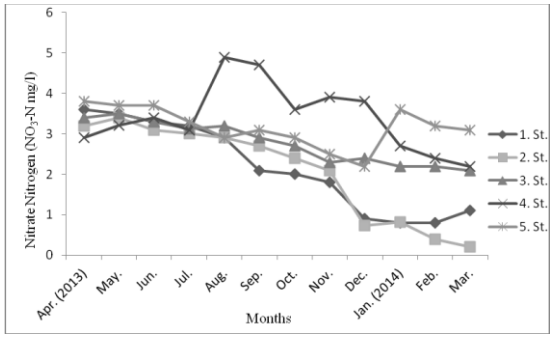

FIGURE 9
Nitrate nitrogen change (mg/L) according to stations.

Ortho-phosphate (PO_4-P mg/L). Orthophosphate phosphorus (PO_4-P) change between 0.05-0.61 mg/L. Average value from stations are; 0.24 in station 1; station 2, 0.17 mg/L; station 3, 0.21mg/L; 0.23 mg/L in station 4; 0.19 mg/L in station 5. The highest annual value of ortho-phosphate was seen at station 3 in March 0, 61 mg/L whereas minimum value was 0, 05 mg/L which was seen in all stations during the summer (Fig. 10).

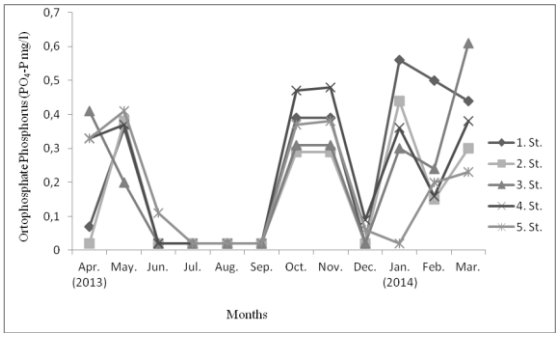

FIGURE 10
Orthophosphate phosphorus value (mg/L) Bafa Lake according to stations.

Statistical analysis. According to the Spearman's rho test, negative correlation was observed between the temperature values and dissolved oxygen values. In addition, there was a positive correlation between the water temperature values and pH, electrical conductivity and orthophosphate.

There was no significant relationship between

pH and electrical conductivity values or between nitrite and orthophosphate value but there was a positive correlation between nitrite nitrogen, nitrate nitrogen, and orthophosphate.

DISCUSSION

The mean water temperature was 22.21 °C, according to WPCR (Table 1) the water characteristic was classified as class level I. The water quallity is suitable for Aquaculture and fish cultivation for sea bream (*S. aurata*) and sea bass (*D. labrax*). Water temperature is an important climatic factor, it increases biological activities and oxygen saturation [17]. In this study, the temperatures of all stations together with reference station did not vary significantly ($P>0.05$).

In Pisciculture, the nutrient content used for the growth can make water more acidic. with this it can cause the death of fishes. Contrariwise when water pH is high, ammonium and nitrogen compounds have adverse effects. Fish can live in optimum pH value between 6.5 and 8.5 [18, 19]. However, in this study the value of pH, indicates that growing of sea bream and sea bass is appropriate [9, 20]. However, the pH values of aquaculture facility and reference station were different considerably ($P<0.05$).

The amount of dissolved oxygen decreases in water when the concentration of salt increases [21]. Increase in salt level in the Bafa Lake occurred as result of flood prevention to Buyuk Menderes in the year 1988. After the start of aquaculture, salt water was produced by drilling. After the use of this salt water it is then released to the lake and this increased the amount of salt in the lake. For sea bass and sea bream cultivation, amount dissolved oxygen need to be higher than 5.00 mg L^{-1} [19]. Finding the mean dissolved oxygen in water is 7.53 mg L^{-1}. Dissolved oxygen is classified as level II class according to the WPCR.

In station II, the minimum dissolved oxygen value is 2.88 mg L^{-1} in early summer. Because of the high nutrient accumulation and the beginning of eutrification phenomena in this part of lake. The sources of nutrient was seen to be much more from animal breeding and also from other nutrient imminent as a result of flow accumulation from Buyuk Menderes (Station 1 and 2). In May and June, station 1 and 2 surface water turn into green and dense of a Dinoflagellate, *Noctiluca scintillans* [6]. In this period some fish species are seen died. This situation shows that its possible station 1 and 2 are affected by the terrestrial environment and Aquaculture activities.

Intensive aquaculture activity perform in station 4, especially during the spring and summer period indicate dissolved oxygen value was below 6 mg L^{-1} and the mean value of all years to be around 6.34 mg L^{-1}. With this value it shows that the water is affected by aquaculture in the area. The results of ANOVA showing that the mean DO of station 4 was significantly lower than the reference station 5.

From recent research pertaining average salinity of the lake Yılgor [22] it reported a salinity of 14.07‰. While Yabanli et al. [23] reported a value of 16.2‰. From more older studies, Turgutcan [24], Artuz [25], Geldiay et al. [26], Yaramaz et al. [27], Kasperek [12], Cirik et al. [3] studies from recent history shows the salinity values are seen to be more lower (Table 3).

From our studies in Bafa Lake, the mean value of salinity in station 4 resulted significantly higher ($P<0.05$) than the other stations. This is becasue the water in the station was obtained by drilling and due to intensive fish farming activities that is left to overflow to the lake. Flow of water from the channel to the lake when there is low rain fall and flow of water from aquaculture activity channel increase the water lake salinity to about 30-35‰.

Changes in electrical conductivity of ions in water, the total concentration and mobility valence depends on the change of temperature [20, 28]. Decrease in electrical conductivity, means a reduction of total dissolved solids content [29]. Conductivity values shows to be parallel with the increase of ambient temperature and salinity level. The high level of electrical conductivity observed in the lagoon lake is an indicator of high salt content. The maximum electrical conductivity value was observed in station 4 and this value was significantly different than those of other stations. In parallel with this case the station showed the highest salinity values. The mean electrical conductivity value obtained in this study was 20.89 mS/cm. Other studies conducted in Bafa Lake, shows that average electrical values are from Balik and Ustaoglu [30] 7.66 mS/cm; Sari et al. [31] 7.66 mS/cm; Ozturk et al. [32] 14.06 mS/cm; Kazanci et al. [1] 22,2 mS/cm and Hepsogutlu [29] 23.1 mS/cm (Table 3).

Ammonium should be less than 1 mg/l in clean water [18]. NH_4-N, which is the waste material of aquatic organisms, may be absorbed by organisms. Non-toxic ammonium depending on temperature and high pH (>8, 5) could transform into ammonia and become toxic for fish and other aquatic organisms [33, 34]. The mean Ammonium nitrogen samples taken from stations changed between 0.91 (V. station) to 1.11 mg L^{-1} (IV. Station) and the values obtained in these two stations are significantly different. The highest ammonium value was seen in station V at 1, 24 mg L^{-1}. The occurrence of high ammonia in Bafa Lake is considered to be from organic waste and sluice channel that carries water waste used for aquaculture, illegal fishing and fuel pollution. The lowest ammonium value was found in February at 0.50 mg L^{-1} in Reference station (V). The average annual value of ammonium was determined to be 1.01 mg L^{-1}. According to Anonim [9] value it is considered to be classified as level II.

The nitrite nitrogen of the water samples is an intermediate product of biological oxidation of ammonium to nitrate. The concentration of nitrite in natural lake water is generally low. However, the concentrations can increase in areas in which organic pollution is considered high and oxygen levels are low [35].

Nitrite, a compound of Nitrogen, cannot be found in natural water due to it's toxicity to aquatic organisms. Highest value was found in July, while the lowest value was found in all station except for few months. The annual value of NO_2-N in Bafa Lake is 0.05 mg L^{-1}. The highest value of NO_2-N was seen at station IV and this value resulted significantly different than those of the other stations. The reasons for this value to be this high is because of organic pollution that comes from the Aquaculture activity area. Furthermore from the lake connecting to Menderes River Lake, the entrance of organic remains and nitrogenous fertilizer shows increase in pollution. In accordance with the value reported by Anonimous [16], the average annual value in terms of nitrite nitrogen in all selected stations was within the class level III (Table 1). From previous study done in Bafa Lake by Hepsogutlu [27] showed a mean value of NO_2-N of 0.06 mg/L (Table 3).

Regarding the Nitrate nitrogen (NO_3-N), the minimum nitrate nitrogen concentration was 0.20 mg/L in March at station I, while the maximum value was 4.90 mg L^{-1} in August at station IV. Because of the waste product coming from Menderes channel and organic agricultural waste, the highest value was seen in station IV. Hydrological systems and sources of pollution can effect some variable characteristics regarding ammonium and nitrate in reservoirs and rivers [36].

According to WPCR, the average annual value of nitrate was about 2.71 mg/L, with this value it is classified to be level I. Nitrate nitrogen levels increased with sea bream and sea bass farming activities. According to the WPCR, 5.0 mg/L Nitrate nitrogen are suitable for sea bass and sea bream cultivation.

Dissolved organic phosphorus or suspended organic phosphorus found in natural water and the total average of phosphorus content in most lakes is between 0.01-0.03 mg/L.

The main source of phosphate is ortho-phosphate. Average orthophosphate phosphorus (PO_4-P) at stations in Bafa Lake was determined to be 0.214 mg/L. The highest orthophosphate value was seen in station III around 0.61 mg/L in August. In terms of orthophosphate phosphorus Bafa Lake is classified to be class level II [37].

When aquatic organisms die, high amount of this organisms join the orthophosphate phosphorus. Increase in agricultural, domestic and organic waste result in producing unwanted algae blooms in lake and also become reason for eutrophication [38]. The highest averages orthophosphate phosphorus in Bafa Lake was due to intensive domestic and animal waste in station I (0.24 mg/L); Aquaculture activities was in station IV (0.23 mg/L). Lowest value was found in reference station (0.19 mg/L) and 2. Station (0, 17 mg/L). If total phosphorus is less than 10 µg/L the lake is considered to be Oligotrophic, if it is 10-20 µg/L Mesotrophic, and if it is greater than 20 µg/L, it is considered to be Eutrophic [39].

According to WPCR, water containing 0.02 mg/L total phosphorus is classified to be at class level I and is suitable for fishery. Phosphorus level higher than 0.30 mg/L is a signal of pollution. The total phosphorus concentration in natural waters depends on the morphometry of basin, the chemical content of the region, and the existence of organic substances and organic metabolism in the water [18].

The orthophosphate concentrations at the aquaculture facility station and reference station did not differ significantly ($P>0.05$).

From channel connecting Bafa Lake and station 4 for producing sea bass and sea bream larvae. Total surface areas of the Lake and the aquaculture facilities is approximately 60.000.000 m^2 and 20.000 m^2.

TABLE 3
Water physico-chemical values from other studies accomplished in Bafa Lake.

Reference	Temperature (T, °C)	Salinity (‰)	pH	Conductivity (mS/cm)	Dissolved Oxygen (mg/l)
Balik and Ustaoglu [30]	27.3	4.47	8.31	7.66	9.79
Cirik et al. [3]	28.0	7.5	7.0	-	6.0
Sari et al. [31]	26.0	14.04	7.7	14.06	8.0
Ozturk et al. [32]	26.0	14.0	7.7	-	8.0
Koc [40]	23.0	23.0	7.7	-	4.7-6.5
Kazanci et al. [1]	27.0	-	7.6	22.2	7.0
Yabanli et al. [23]	23.0	16.2	7.7	25.3	5.5
Erdogan [41]	21.2-23.4	-	7.97-8.17	1.9-25.2	4.45-9.59
Hepsogutlu [29]	27.9	14.0	8.3	23.1	6.1
This study	22.21	12.95	8.26	20.88	7.52

TABLE 4
Water physicochemical values from other studies accomplished in Bafa Lake.

Locality (References)	T (°C)	Sal. (‰)	pH	EC (mS/cm)	DO (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	PO_4-P (mg/l)
Topcam D. Lake [42]	19.1	0.25	7.93	0.133	7.63	0.28	0.83	0.008
Uluabat Lake [26]	18.05	4.40	8.31	5.53	7.99	-	0.21	0.13
Egirdir Lake [43]	26.24	-	8.93	0.41	6.00	0.07	2.17	0.45
Koycegiz Lake [44]	20.72	1.89	8.64	3.65	7.30	0.012	1.50	0.11
Bereket D. Lake [45]	15.42	-	7.93	0.71	6.76	1.17	6.45	0.91
This Study	22.21	12.95	8.26	20.88	7.52	0.04	2.10	0.19

The water quality parameters in the Bafa Lake was compared with other studies where there is no fish cultivation except Bereket Dam Lake (Table 4). Generally, the concentrations of nitrite nitrogen, nitrate nitrogen and orthophosphate reported for other lentic waters were not significantly different than those found in this study. Only in Bereket Dam the values were higher because of intensive Aquaculture activities (Table 4).

Currently several problems and threats affect Bafa Lake. Today, the wetlands in Turkey, are threatened mainly by the following activities; draining of wetlands (for agricultural utilization, etc.), prevention of natural water flows to wetlands by dam constructions, urban development on wetlands and surroundings (urban/industrial utilization), chemical contamination due the industrial and household wastes, introduction of exotic species, unsustainable hunting/fishing/plant picking.

CONCLUSIONS

No changes in surface water quality was observed in reference station.

Aquaculture activities seem to affect the entire Lake. Clear definition of the receiving environment will facilitate implementation of legal and technical measures to sustain and preserve development and prevent water pollution.

As a result of agricultural activity and industrialization Bafa Lake surface water have highly encountered pollution. Especially in the area where aquaculture activity takes place the water quality is very low. Land usage related to pollution covers the entire lake.

Some of the fundamental strategies pertaining water quality problems that provide solution for the water quality improvement are treatment of pollution, safe ussage of waste water, preventing the pollution and lastly restoration and protection of ecosystem.

Reducing the pollution in domestic and industry by the introduction of water treatment systems and using this treatment system in reducing pollution coming from industry and also with effective agreement taking by Decision Makers of the Buyuk Menderes Basin. The problem in Bafa Lake have been into consideration and will be under the same criteria with that of the European Union.

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REFERENCES

[1] Kazancı, N., Girgin, S. and Dugel, M. (2008) Research on the limnology of Bafa Lake in south-western Turkey and climate change impacts. Review of Hydrobiology 2, 207-223.

[2] Anonymous, (2007) RAMSAR, Integrating wetland conservation and wise use into river basin management, Handbook, 7. River Basin Management, Ramsar Handbooks for the Wise Use of Wetlands 3.rd edition.

[3] Cirik, S., Metin, C. and Cirik, S. (1989) Planctonic Algae and Seasonal Change in Bafa Lake (in Turkish), Çukurova Üniv. 5. Bil.ve Tekn. Çev. Kong. Tebl. pp. 604-613, Adana.

[4] Mullenhoff, M., Handl, M., Knipping, M., Bruckner, H. (2004). The Evolution of Bafa Lake (Western Turkey); Sedimentological, microfaunal and Palynological results. Geographie der Meere und Küsten Coastline Reports 1, 55-66.

[5] Magnin, G. and Yarar, M. (1997) Important Birds Areas in Turkey (in Turkish), Dogal Hayati Koruma Dernegi (WWF, Turkey), Istanbul.

[6] Sasi, H. and Demir, H. (2016) Investigation of Fish Fauna and Bio-Ecological Characteristics of Some Economical Fish Populations in Bafa Lake (Mugla-Aydin), Turkey (in Turkish), Mugla Sitki Kocman Universitesi, BAP Projesi No. 13/41, pp. 145, Mugla, Turkey.

[7] Kazanci, N. and Dugel, M. (2000) An Evaluation of the Water Quality of Yuvarlakçay Stream in the Köyceğiz-Dalyan Protected Area, SW Turkey. Turk. J. Zool 24, 69-80.

[8] TurkStat (2013) Turkish Statical Institute, Statical Yearbook, Ankara.
[9] Anonymous (2004) DIE statistics, temporary result. Ankara.
[10] Ozdemir, N., Tarkan, A.S., Ağdamar, S., Top, N. and Karakuş, U. (2015) Ecological requirements and distribution of native and introduced freshwater fishes in a Mediterranean-type basin (Muğla, SW Turkey). Fresen. Environ. Bull. 24, 3-13.
[11] Matijevic, S., Kuspilic, G. and Baric, A. (2006) Impact of a fish farm on physical and chemical properties of sediment and water column in the middle Adriatic Sea. Fresen. Environ. Bull. 15(9), 1058-1063.
[12] Kasparek, M. (1988) Bafasee, Natur und Geschichte in der Türkishen Agais. Heidelberg, pp. 174, Germany.
[13] Knipping, M., Mullenhoff, M., Bruckner, H. (2008) Human induced landscape changes around Bafa Lake (western Turkey). Veget Hist Archaeobot 17, 365-380.
[14] APHA AWW, AWEF, (2012) Standard methods for the examination of water and wastewater. 21st ed. American Public Health Association, pp. 1268, Washington D.C., the USA.
[15] Barlas, M. (1995) Criteria of evaluation of biological and chemical pollutions of streams, eastern Anatolia Region (in Turkish), I. and II. Aquaculture Symposium Book, pp. 465-479, Erzurum.
[16] Anonymous (2008) Water pollution control regulations. 13 February 2008 date and 26786 number the official newspaper, Ministry of Environment and Forests, Ankara.
[17] Sinanmıs, A.D.A. and Senes, S. (2004). Ataturk Dam Lake formed by pollution load of the production of Trout Lake. Ekoloji Bulletin 13(53), 1-9.
[18] Tanyolac, J. (1993) Limnology (in Turkish), Hatiboglu Yayınevi, pp. 261, Ankara.
[19] Alpbaz, A. (2005) Aquaculture farming (in Turkish), Alp Publications, pp. 548, İzmir.
[20] Anonymous (1984) Result on Etute Report Beymelek Lagoon (in Turkish), TKB Su Ürünleri Daire Başkanlığı, Antalya Su Ürünl. Müd. Proje Rapor No 1, pp. 78, Antalya.
[21] Tas, B. (2006) Investigation of Derbent Dam Lake (Samsun) water quality. Ekoloji Bull 16, 61, 6-15.
[22] Yilgor, S. (2012) Investigation of Heavy metal Pollution in Sediments from Lake Bafa (in Turkish). Doktora Tezi, Dokuz Eylül Üniversitesi, Fen Bilimleri Enstitüsü, pp. 64, Izmir.
[23] Yabanli, M., Turk, N., Tenekecioglu, E. V. and Uludag, R. (2011) A Research for massive Fish deaths in Bafa Lake (Turkey) (in Turkish). SAU. Fen Bilimleri Dergisi 15, 1, 36-40.
[24] Turgutcan, B. (1957) Bafa Lake, Fish and Fisheries (in Turkish). Balıkçılık Mecmuası 5.11, 19-22.
[25] Artuz, M.I. (1958) Investigation of Fisheries in Bafa Lake (in Turkish). Balık ve Balıkcılık 6 (1), 2-9.
[26] Geldiay, R., Kocatas, A. and Katagan, T., (1977) Peracarida ve Eucarida (Crustacea, Malacostraca) of Bafa Lake (in Turkish). Ege Üniversitesi Fen Fak. Dergisi Seri B, 1(4), 311-318.
[27] Yaramaz, O., Balik, S. and Ustaoglu, M.R., (1988) Etude des paramètres physico-chimiques et des sels nutritifs dans le lac de Bafa (Aydin, Turquie). Rapp. Comm. Int. Mer. Médit 31(2), 76.
[28] Katip, A. and Karaer, F. (2011) Uluabat Gölü su kalitesinin Türk mevzuatına ve uluslararası kriterlere göre değerlendirilmesi (in Turkish). Uludağ Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi 16(2), 25-34.
[29] Hepsogutlu, D. (2012). Macrobentic Organisms and Physicochemical Parameters of Bafa Lake (in Turkish), Yüksek Lisans Tezi, Dokuz Eylül Üniversitesi, pp. 71, İzmir.
[30] Balik, S. and Ustaoglu, M.R. (1989) Investigation of the bio-ecological and Economic Aspects of chub (*Acanthobrama mirabilis* Ladiges, 1960) in Bafa Lake (in Turkish). Doğa Tu Zooloji Dergisi 13, 3, 141-174.
[31] Sari, H., Balık, S., Bilecenoglu, M. and Ture, G., (1999) Recent changes in the fish fauna of Lake Bafa, Aegean region of Turkey. Zoology in the Middle East 18, 67-76.
[32] Ozturk, B., Poutiers, J.M., Sarı, H.M. and Ozbek, M. (2002) on the occurrence of *Mytilaster marioni* (Locard, 1889) (Mollusca; Bivalvia; Mytilidae) in Bafa Lake (Turkey), with a redescription of the species. Hydrobiologia 485 (1-3), 123-131.
[33] Emerson, K., Russo, R.C., Lund, R.E. and Thurston, R.V. (1975) aqueous ammonia equilibrium calculations: effect of pH and temperature. J. Fish. Res. Board Can 32, 2379-2383.
[34] Unlu, A., Coban, F. and Tunc, M. (2008) Investigation of Lake Hazar Water Quality According to Physical and Iorganic Chemical Parameters (in Turkish). Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi 23(1), 119-127.
[35] Egemen, O. and Sunlu, U. (1999) Book on Water Quality (in Turkish), Ege Üniversitesi Yayınevi, pp. 153, İzmir.
[36] Gurzau, A.E., Popovici, E., Pintea, A., Popa, O., Pop, C. and Dumitrascu, I. (2010) Quality of surface water sources from Central Transylvanian area as a possible problem for Human Security and Public Health. Carpathian

Journal of Earth and Environmental Sciences 5, 2, 119-126.
[37] Klee, O. (1991) Angewandte Hydrobiologie: Trinkwasser–Abwasser-Gewasserschutz, Georg Thieme Verlag, pp. 272, Stuttgart, Germany.
[38] Imamoğlu, O. (2000) Investigation of Phsyco-Chemical and Bıological (Bentic Macroinvertebrates) in Dipsiz ve Cine Streams (Muğla-Aydın), (in Turkish), Yüksek Lisans Tezi, Mugla Universitesi, pp. 125, Muğla, Turkey.
[39] Thoman, R.V. and Mueller, J.A. (1987). Principle of surface water quality modelling and control, Harper and Row Publishers, New York.
[40] Koc, C. **(**2008) the effects of the environment and ecology projects on lake management and water quality. Springer Science, Business Media B.V., Environ Monit Assess 146, 397-409.
[41] Erdogan S. (2011) A Chemical reaction to a physical impact: Lake Bafa wetland ecosystem (Turkey) case. Ankara Üniversitesi Çevrebilimleri Dergisi 3(1), 1-8.
[42] Sasi, H. (2002) Investigation of fish fauna and bio-ecological characteristics of some economical fish populations in Topcam Dam Lake, Aydin, Turkey (in Turkish), Doktora Tezi, Ege Universitesi, pp. 159, Bornova, İzmir.
[43] Sener, S., Davraz, A. and Karaguzel, R. (2013) Evaluating the anthropogenic and geologic impacts on water quality of the Egirdir Lake, Turkey. Environ. Earth Sci 1-19, DOI 10.1007/s12665-013-2296-0
[44] Sasi, H. and Akman, M. **(**2011) Determination of water quality and macrobentic in Köyceğiz Lake in South-western of Turkey (in Turkish), Mugla University, BAP Projesi No. 09/47, pp. 133, Muğla.
[45] Ozdemir, N., Demirak, A. and Keskin, F. (2014) Quality of water used during cage cultivation of rainbow trout (*Oncorhynchus mykiss*) in Bereket HES IV Dam Lake (Mugla, Turkey). Environ. Monit. Assess 186, 8463-8472.

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