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Influence of Land-based Fish Farm Effluents on the Water Quality of Yanýklar Creek

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ABSTRACT: This study evaluates the influence of Yanýklar Creek on the water quality of Fethiye Gulf. Accordingly, this study demonstrates (i) change in the water quality of Fethiye Gulf from 2006 to 2007; (ii) the water quality classification of the Yanýklar Creek feeding Fethiye Gulf; and (iii) how land-based fish farm influences Yanýklar Creek water quality in a Fethiye-Göcek Specially Protected Area. In this study, the high contribution of nitrite-nitrogen, total phosphate and number of total and fecal coliform of Yanýklar Creek is verified to be due to land-based fish farm located on the creek. Since, ammonium nitrogen, nitrate nitrogen, nitrite nitrogen and total phosphate concentrations and, number of total and fecal coliform were elevated and dissolved oxygen levels dropped at downstream of the fish farm. Water transparency increased except in July and August. Number of total coliform increased except in October and November. The number of total coliform in the gulf also dramatically exceeded the acceptable limit of 1000 CFU/100mL, thereby implicating wastewater inputs to the gulf as the probable source. Overall data suggest that external phosphorus and nitrogen loads to Fethiye Gulf derive mainly from tributary streams impacted by point sources, and land-based trout fish farm.

Key words: Land-based fish farms, Water quality, Nutrients, Fethiye Gulf, Turkey

INTRODUCTION

It is well known that receiving body obtain most 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 sea phosphorus concentration increase. In the recent years fishes are studied in various fields (*Behrouzirad, 2007;* Bhakta and Bandyopadhyay, 2008). Wu (1995) declared that dissolved inorganic forms of nitrogen are rapidly assimilated by algae and thereby help and cause eutrophication and cause significant increases in river's ammonium and organic carbon concentrations downstream of fish farms.

Nitrogen and phosphorus are important waste products of fish farms. Handy and Poxton (1993) stated that ammonia is a major waste product from fish. It is excreted across the gill membranes and in the urine. The primary source of ammonia in aquaculture systems is fish feed and feed composition (Enell 1995). It is further reported by Handy and Poxton (1993) that 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 tanks thus producing pollution in a closed aquatic environment and they are considered to be a point source of pollution, affecting directly the receiving bodies.

Tovar et al. (2000) established the environmental impact of marine aquaculture by estimating the total amount of each compound discharged into the receiving waters as a direct consequence of the culture activities. The two-

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year research study estimated that 9104.57 kg total suspended solids (TSS), 235.40 kg biochemical oxygen demand (BOD), 36.41 kg $N–NH_4^+$, 4.95 kg $N–NO_2^-$, 6.73 kg $N–NO_3^-$ and 2.57 kg $P–PO_4^{3-}$ dissolved in the for each tones of fish cultured. The conceptual model used by Islam (2005) shows that 132.5 kg N and 25.0 kg P are released to the environment for each ton of fish produced; these values are as high as 462.5 kg N and 80.0 kg P when calculated on the basis of dry matter conversion rate instead of usual feed conversion rate.

Ruiz et al. (2001) reported that organic release from fish cages decreases water transparency and increases organic content of sediments in the vicinity of cages. Pawar et al., (2001) stated that fish cage farming generates large amounts of organic waste in the form of unconsumed feed and fecal matter resulting in sediment deterioration. The significant difference between the quality of the sediment in aquaculture and non-aquaculture areas were reported. The sediment underlying the fish cage farms was found to be extremely acidic and sulfidic.Cao et al. (2007) stated that urine and feces from the aquaculture animals can cause high content of ammonia-nitrogen and increase of BOD. Ammonia is reported to be the main nitrogenous waste that is produced by fish via metabolism and is excreted across the gills. In Lake Taihu, freshwater lake in China compared to non-aquaculture areas; ammonia-nitrogen and phosphorous load of this area increased 55 % and 46%, respectively. Homewood et al. (2004) reported that ammonium levels were consistently elevated downstream of the trout farm. Nitrate levels made up to major part of dissolved nitrogen in the river system.

In a monoculture fish farm, the profile of nutrient flow is complex and governed by the metabolism and interactions between various organisms such as fish, phytoplankton and bacteria. Major sources of nutrients are fish excretion and fish feed. In addition, some bacteria degrade the organic detritus in fish farms and release dissolved inorganic nutrients to the water. On the other hand, direct uptake of nutrients is achieved through the activities of nearby algae and bacteria. Ammonia and urea excreted by fish can be readily taken up by phytoplankton or macrophytes, and may stimulate their growth. Lam (1990) indicated that higher nutrient concentrations result in an increase in phytoplankton growth in marine fish culture zones. Eutrophication or algal blooms often occur in such nutrient-enriched environments. Furthermore, high bacterial content in aquaculture waters may significantly deteriorate water quality by lowering the dissolved oxygen and pH (Qian *et al.,* 2001).

The primary purpose of the current environmental monitoring of fish farms is to meet the goals of surface water quality. Furthermore, nutrient accounting could be used to provide incentives for farmers to reduce their emissions and to increase their efficiency of resource utilization through improved awareness and management practices.The objectives of the present study are to elucidate the relationships of stream water quality with land based fish farms and to identify the major sources of nitrogen, phosphorus, total and fecal coliform contributing to Fethiye Gulf's contamination. Accordingly, this study demonstrates (i) change in the water quality of Fethiye Gulf from 2006 to 2007; (ii) the water quality classification of the Yanýklar Creek feeding Fethiye Gulf; and (iii) how land-based fish farm influences Yanýklar Creek water quality in a Fethiye-Göcek Specially Protected Area.

As a result of increasing environmental awareness and public concern about the conservation of the historical (ruins belonging to Hellenistic and Roman Ages), floral (endemic *Liquidambar orientalis*) and faunal richness (sea turtles) of the area, the Cabinet of Ministers designated the area surrounding Fethiye-Göcek and declared as "Fethiye-Göcek Specially Protected Area" in 1988. The Authority for the Protection of Special Areas (APSA) was established to protect the gulf's environmental values, and to take all measures necessary to reverse the existing environmental degradation of the gulf's surrounding area; to prepare appropriate development plans and to revise and approve existing developments at all scales of development plans.

MATERIALS & METHODS

Five sampling points were selected and monitored for 2 years. Two of them were chosen to establish the effect of trout fish farm on the water quality of Yanýklar Creek namely F1 (before fish farm) and F2 (after fish farm). Two other sampling points were chosen to determine the water quality of Yanýklar Creek (sampling point F3) and Fethiye Gulf (sampling point F4) (Fig. 1).Water samples were collected from the surface of Fethiye Gulf and Yanýklar Creek and covered to prevent exposure to direct sunlight, stored in ice and analyzed in the laboratory within 24 hr. Standard methods, equipments and method of measurement used in analysis are presented in (Table 1).

RESULTS & DISCUSSION

The results of two projects (APSA 2006; APSA 2007) were examined to investigate the present status of, and the monthly (April, May, June, July, August, September, October, November, December) and yearly (2006-2007) changes in, the water quality of the Fethiye Gulf. The data are combined in Tables 2 for easy comparison.Gulf's water quality was examined in terms of dissolved oxygen (DO), pH, water transparency and number of total coliform. The parameters in question were measured at sampling station F4 that is located in the Fethiye Gulf (Fig. 1). and are graphically represented in (Fig. 2).

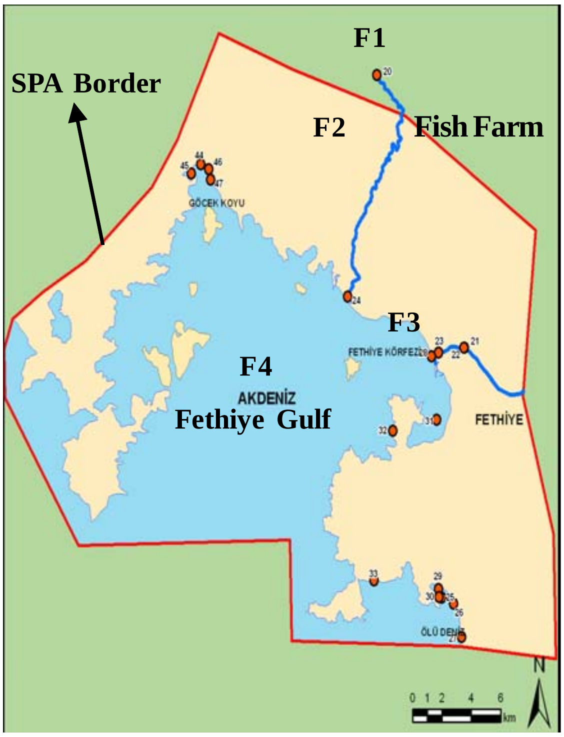

Fig. 1. Fethiye Gulf and its vicinity (APSA, 2007)

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 phosphate	DRLANGE – XION 500 Spectrophotometer	TS ISO 8466-1:1997 TS EN ISO 10304-2:1997	Spectrophotometric
Fecal Coliform	SARTORIUS Vacuum Filter KNF Vacuum Pump	TS EN ISO 9308-1:2004	Membrane Filtration
Total Coliform	SARTORIUS Vacuum Filter KNF Vacuum Pump	TS EN ISO 9308-1: 2004	Membrane Filtration
Water Transparency	Secchi Disk	Method of Secchi Disk	Secchi Disk

ISO: International Organization for Standardization

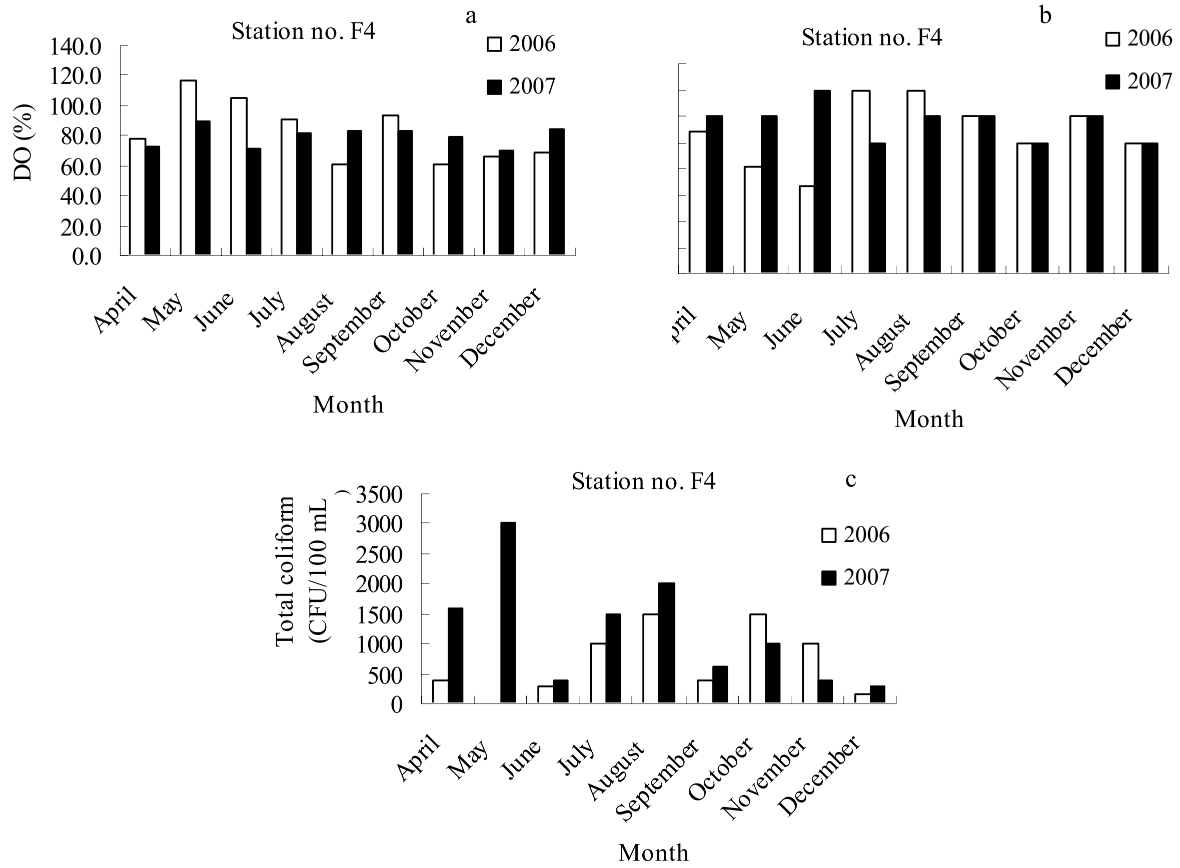

Fig. 2. Change in dissolved oxygen (a), water transparency (b) and total coliform (c) for 2006 and 2007 in Fethiye Gulf

As an essential element for almost all aquatic life, the concentration of DO in a sea provides a broad indication of its water quality. In Turkey, the acceptable DO percentage (within the context of bathing water quality) for seas designated as protected areas and/or used for recreational purposes is >80 % (Turkish Bathing Water Quality Regulation (TBWQR 2006)). As noted in Table 2, the DO value in the Fethiye Gulf were below this limit on many dates, including April 2006 and 2007 (77.7 and 72.2 %, respectively), June 2007 (71.6 %), August 2006 (61 %), October 2006 and 2007 (61.4 and 78.8 %, respectively), November 2006 and 2007 (66.2 and 69.5 %, respectively), and December 2006 (68.9%) at sampling site F4.The DO value has decreased from 2006 to 2007, in April, May, June, July and September and it was well below the standard value of 80 % in April, October and November (Figure 2a) both in 2006 and 2007.

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. In Turkey, the acceptable water transparency for seas designated as protected areas and/or used for recreational purposes is > 2m (TBWQR 2006). As noted in (Table 2), the water transparency in the Fethiye Gulf was below only in June 2006 (1.65 m).Water transparency had decreased from 2006 to 2007 only in July and August and there was no change in September, October, November and December (Fig. 2b).

Niemi and 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 water. 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 in the sea, reduce its water

Table 2. Water quality of Fethiye Gulf (Sampling Station F4)

Month	April		May		June		July		August		September		October		November		December	
Year	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
pH	7.01	7.83	7.96	7.91	8.24	8.20	8.0	8.08	7.89	7.95	7.98	8.01	8.15	7.18	8.42	7.95	8.01	8.17
DO (%)	77.7	72.2	117.3	89.9	104.5	71.6	90.7	81.1	61.0	82.4	93.8	83.4	61.4	78.8	66.2	69.5	68.9	84.3
Water transparency (m)	2.7	3.0	2.05	3.0	1.65	3.5	3.5	2.5	3.5	3.0	3.0	3.0	2.5	2.5	3.0	3.0	2.5	2.5
Total Coliform (CFU/100ml)	400	1600	16	3000	300	400	1000	1500	1500	2000	400	600	1500	1000	1000	400	150	300

quality, and cause sickness in wildlife using sea as a water source.Table 2 reveals that the total coliform number exceeded the limit (1000 CFU/100mL) defined in the TBWQR for most sampling dates, dramatically in some cases, indicating wastewater inputs were reaching the gulf. Exceptions for this trend were April 2006 (400 CFU/100mL), May 2006 (16 CFU/100mL), June 2006 and 2007 (300 and 400, respectively), September 2006 and 2007 (400 and 600 CFU/100mL, respectively), October 2007 (1000 CFU/100mL), November 2006 and 2007 (1000 and 400 CFU/100mL, respectively) and December 2006 and 2007 (150 and 300 CFU/100mL, respectively) at sampling site F4.As noted in Figure 2c number of total coliform in Fethiye Gulf increased from 2006 to 2007. Exceptions for this trend were October and November.

The water quality of creeks in the Turkish Water Pollution Control Regulation (TWPCR) is designated in four major classes, as follows:
1-Class I- high-quality water (used as drinking water supply after disinfection, used for recreational activities, and for fish (trout) production).
2-Class II: less-polluted water (used for drinking water supply after treatment process, for recreational activities, fish production (other than trout), and for irrigation in compliance with TWPCR irrigation standards).
3-Class III: polluted water (used for industrial water supply, other than food and textile industry, but not for irrigation).
4-Class IV: very polluted water (not used for irrigation; used for industrial water supply)..

Water quality in the Yanýklar Creek to Fethiye Gulf was evaluated on the basis of its DO, NH_4-N, NO_3-N, NO_2-N, and TP concentrations, the number of total and fecal coliform in 2007 at sampling station F3 (Fig.1).Dissolved oxygen concentration ranged from 7.1 to 9.14 mg/L (Table 3)Table 3. Water quality of Yanýklar Creek reaching Fethiye Gulf (Sampling Station F3), indicating Class I and II water quality in Yanýklar Creek in 2006 (the DO concentration indicating Class I water quality is >8 mg/L and Class II water quality is 6-8 mg/L (TWPCR 2004)). Two measurements out of nine indicate Class II water quality (April (7.1 mg/L) and November (7.76 mg/L)). In 2007 based on nine measurements, DO concentration varied from 7.16 mg/L to 10.55 mg/L indicating Class I and II water quality in the creek. Three measurements out of nine designate Class II water quality (June (7.7 mg/L), October (7.16 mg/L) and November (7.54 mg/L)). The data in (Fig.3-a) indicates that DO concentration in Yanýklar Creek decreases from 2006 to 2007. Exceptions for this trend were April, May, July and December.

Based on nine measurements, the NH_4-N concentration ranged from 0.015 mg/L to 0.179 mg/L in 2006 and 0.013 to 0.085 mg/L in 2007 (Table 3). The creek's water quality was Class I (0-0.2 mg/L) for all measurements (TWPCR 2004). The data in (Fig. 3-b) indicate that NH_4-N concentration in Yanýklar Creek decreased from 2006 to 2007. Exceptions for this trend were June, July and August.Based on nine measurements, the NO_2-N concentration ranged from 0.016 mg/L to 0.064 mg/L in 2006 (Table 3). These values place

Table 3. Water quality of Yanıklar Creek reaching Fethiye Gulf (Sampling Station F3)

Month	April		May		June		July		August		September		October		November		December	
Year	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Temp. (^oC)	20.5	18	18.5	20	20.2	20.8	24.2	22.8	24.1	23	22.1	24	19	21.6	15.5	15	15	13
pH	7.1	8.54	8.12	8.57	8.46	8.35	8.29	8.27	8.53	8.29	8.62	8.38	9.14	8.08	8.5	8.41	8.29	8.2
DO(mg/L)	7.1	8.92	8.19	10.55	9.51	7.7	8.52	9.52	8.8	8.81	9.8	9.15	8.01	7.16	7.76	7.54	8.02	8.58
NH_4-N (mg/L)	0.045	0.013	0.015	0.015	0.016	0.042	0.015	0.045	0.022	0.056	0.021	0.015	0.016	0.015	0.179	0.085	0.078	0.015
NO_2-N (mg/L)	0.029	0.006	0.025	0.018	0.03	0.019	0.016	0.018	0.022	0.021	0.022	0.019	0.02	0.033	0.06	0.018	0.064	0.017
NO_3-N (mg/L)	0.771	1.07	0.824	0.243	1.02	0.23	1.07	0.23	1.04	0.301	1.15	0.324	1.28	1.09	1.24	1.88	1.14	0.23
TP(mg/L)	0.027	0.009	0.465	0.013	0.007	0.01	0.01	0.019	0.021	0.016	0.01	0.011	0.006	0.014	0.071	0.018	0.062	0.08
Fecal Coliform (CFU /100mL)	5	10	80	5	48	100	300	200	50	200	500	200	64	500	40	100	6	300
Total Coliform (CFU /100mL)	1000	1000	500	2500	900	2100	1800	2500	1600	3000	3000	2400	1500	2800	1500	400	800	2800

Yanýklar Creek in the Class III (0.01-0.05 mg/L) for seven measurements and Class IV (> 0.05 mg/L) for two measurements (TWPCR 2004). NO_2-N concentration varied from 0.006 mg/L and 0.033 mg/L in 2007 (Table 3). These values place the creek in the Class I (0-0.002 mg/L) for one measurement and Class III for eight measurements. The data in (Fig. 3-c) all indicate that NO_2-N concentration in Yanýklar Creek decreased from 2006 to 2007 except July and October.Based on nine measurements, the NO_3-N concentration ranged from 0.771 mg/L to 1.28 mg/L in 2006 and 0.23 mg/L to 1.88 mg/L in 2007 (Table 3). The creek's water quality was Class I (0-5 mg/L) for all measurements (TWPCR 2004). The data in (Fig. 3-d) all indicate that NO_3-N concentration in Yanýklar Creek decreased from 2006 to 2007 except April and November.

The TP concentrations ranged from 0.006 to 0.465 mg/L in 2006 (Table 3), based on nine measurements. These values place Yanýklar Creek in the Class I (<0.02 mg/L) water quality designation for five measurements, Class II (0.02-0.16 mg/L) for three measurements and Class III (0.16-0.65 mg/L) for one measurement (TWPCR 2004). In 2007, TP concentrations varied from 0.009 to 0.08 mg/L. The creek was in a Class I designation for eight measurements and Class II for one measurement. The data in (Fig. 3-e) designate that TP concentration in Yanýklar Creek decreased from 2006 to 2007 except June, July, October and December.

The number of fecal coliform ranged from 5 to 500 CFU/100mL (Table 3), indicating Class I water quality for two measurements, Class II for five measurements and Class III for two measurements in 2006 (the Class I limit for fecal coliform is 0-10 CFU/100 mL, the Class II limit is 10-200 CFU/100mL and the Class III limit is 200-2000 CFU/100mL; TWPCR 2004). Based on nine measurements in 2007, the number of fecal coliform varied from 5 to 500 CFU/100mL. These numbers place Yanýklar Creek in the Class I water quality designation for two measurements, Class II for five measurements and Class III for two measurements. The data in (Fig. 3-f) indicate that the fecal coliform number increased from 2006 to 2007. Exceptions for this trend were May, July and September.

The number of total coliform ranged from 500 to 3000 CFU/100mL in 2006 and 400 to 3000 CFU/100mL in 2007 (Table 3), indicating Class II water quality for all measurements (the Class II limit for total coliform is 100-20000 CFU/100 mL; TWPCR 2004). The data in (Fig. 3-g) designate that the total coliform number increased from 2006 to 2007. Exceptions for this trend were September and November. Based on these comparisons, it is clear that there is significant influence of Yanýklar Creek on Fethiye Gulf's water quality in terms of nitrite-nitrogen, total phosphate, and number of fecal coliform.

The high contribution of nitrite-nitrogen, total phosphate and number of fecal coliform of Yanýklar Creek is considered to be due to land-based fish farm located on the creek. In order to confirm this thought, the effect of fish farm was further investigated.The results of Monitoring of Water Quality in Specially Protected Areas Project (APSA, 2007) was examined to investigate the effect of land-based trout fish farm, and the monthly (April, May, June, July, August, September, October, November, December) and yearly (2007) changes in, the water quality of the Yanýklar Creek draining into Fethiye Gulf. The data are combined in (Table 4), for easy comparison.Water temperature, pH, DO, NH_4-N, NO_3-N, NO_2-N, TP, fecal coliform and total coliform were measured at sampling stations F1 (before fish farm) and F2 (after fish farm) that are located on the Yanýklar Creek (Fig. 1).

Graphical representation of the effect of land-based fish farm on the water quality of Yan klar Creek in terms of nutrient, organic and microbiologic parameters in 2007 are presented in (Fig. 4).Dissolved Oxygen concentration ranged from 7.87 to 9.45 mg/L (Table 4), indicating Class I water quality for eight measurements and Class II water quality for one measurement before fish farm in 2007 (the DO concentration indicating Class I and Class II water quality is >8 mg/L and 6-8 mg/L, respectively; TWPCR 2004). After fish farm, DO concentration varied from 7.76 mg/L to 9.49 mg/L. These values place Yan klar Creek in the Class I for six measurements and Class II for three measurements. The data in (Fig. 4-a) indicate that the DO concentration decreased after fish farm except May and July.Based on nine

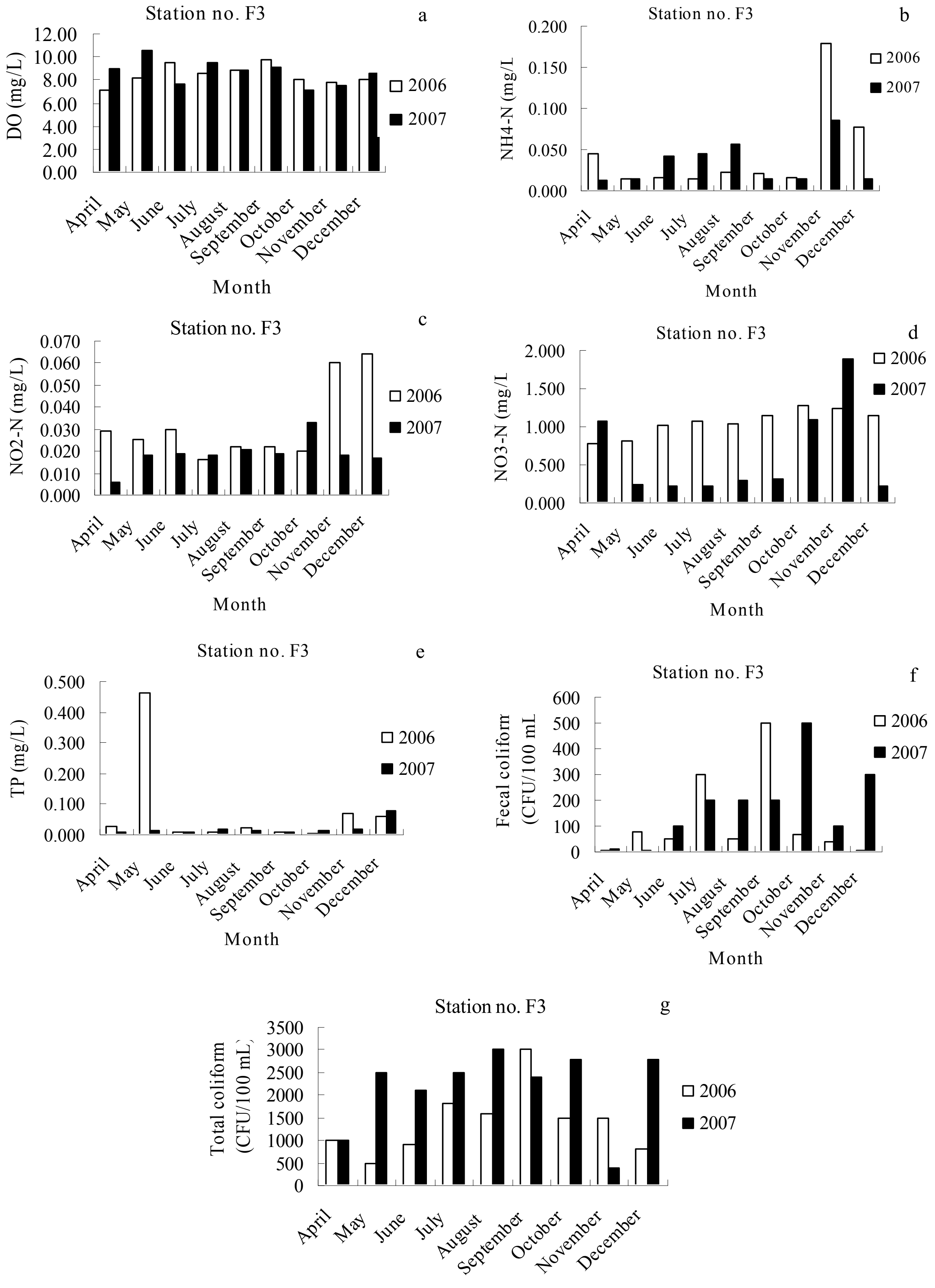

Fig. 3. Dissolved oxygen (a), ammonium-nitrogen (b), nitrite-nitrogen (c), nitrate-nitrogen (d), total phosphate (e), fecal coliform (f) and total coliform (g) for 2006 and 2007 in Yanýklar Creek

Table 4. Effect of land-based fish farm on the water quality of Yanȷklar Creek (2007)

Month	April		May		June		July		August		September		October		November		December	
Year	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2
Temp. (^oC)	16.3	16.5	17.7	20.5	16.6	18.6	18	21	19	22	19	21	17.3	20	14	14.5	13	13
pH	8.61	8.32	8.45	8.73	8.51	8.51	8.54	8.29	8.21	8.39	8.16	8.13	8.56	8.12	8.26	8.33	8.31	8.28
DO(mg/L)	7.87	7.76	9.21	9.49	8.33	8.29	8.41	8.78	9.11	8.96	9.45	8.88	9.32	7.84	8.44	7.81	9.16	8.99
NH_4-N (mg/L)	0.014	0.193	0.015	0.164	0.03	0.041	0.015	0.093	0.043	0.37	0.047	0.045	0.015	0.34	0.204	0.346	0.015	0.015
NO_2-N (mg/L)	0.008	0.034	0.015	0.08	0.01	0.048	0.005	0.062	0.017	0.156	0.016	0.018	0.023	0.067	0.024	0.035	0.017	0.017
NO_3-N (mg/L)	0.376	0.703	0.23	0.23	0.23	0.23	0.23	0.23	0.104	0.181	0.073	0.23	0.23	0.971	0.317	0.625	0.49	0.24
TP(mg/L)	0.124	0.249	0.006	0.096	0.01	0.043	0.014	0.067	0.014	0.08	0.016	0.013	0.012	0.105	0.025	0.031	0.088	0.025
Fecal Coliform (CFU/100 mL)	0	6	0	21	0	4	45	900	0	0	0	150	6	300	50	150	100	300
Total Coliform (CFU/100 mL)	100	600	200	2400	50	600	1700	3000	500	2900	30	2200	200	2100	800	2200	1600	3000

F1 : Yanȷklar Creek before land-based fish farm
F2 : Yanȷklar Creek after land-based fish farm

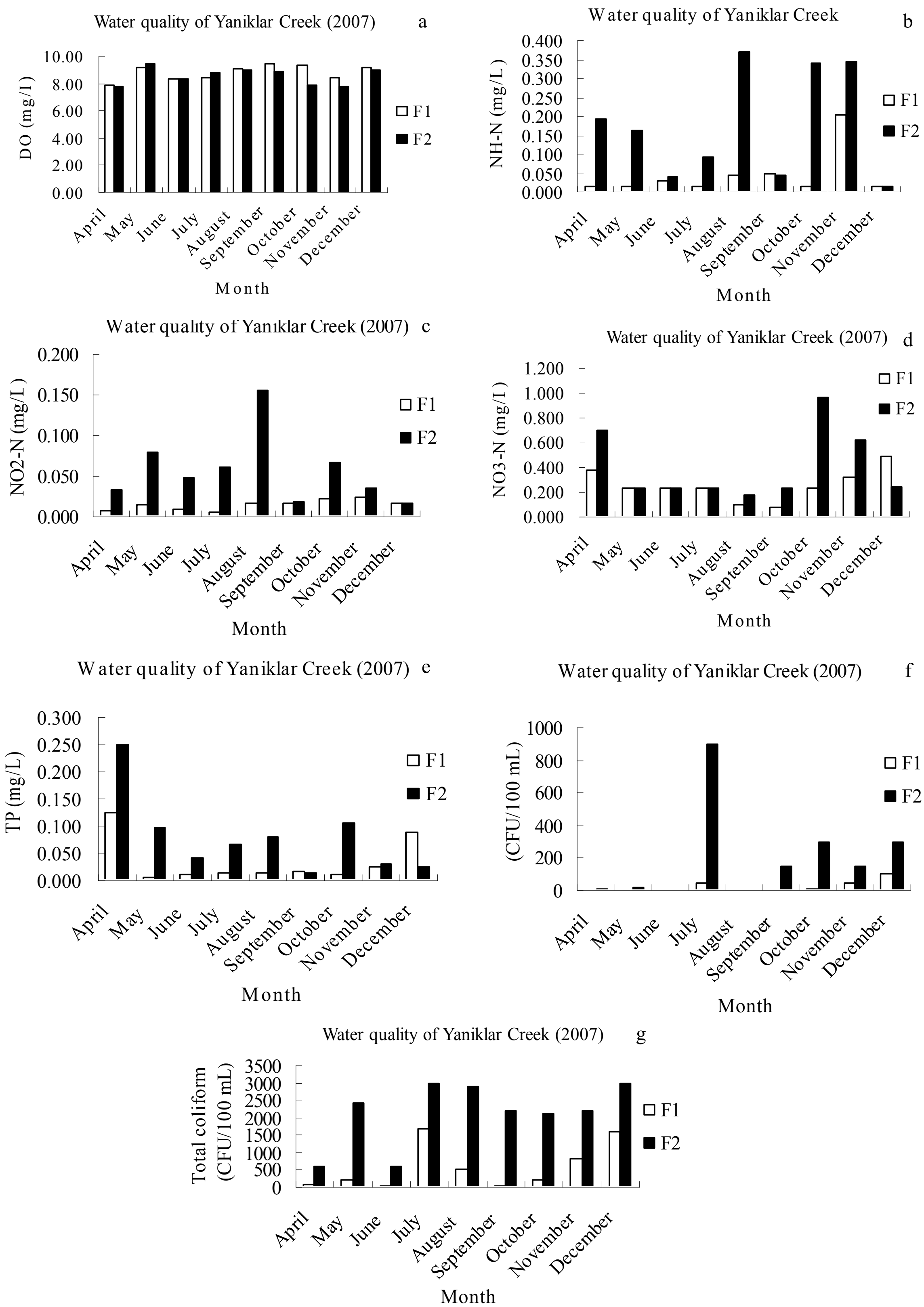

Fig. 4. Change in dissolved oxygen (a), ammonium-nitrogen (b), nitrite-nitrogen (c), nitrate-nitrogen (d), total phosphate (e), fecal coliform (f) and total coliform (g) before (F1) and after (F2) fish farm

measurements, the NH_4-N concentration ranged from 0.014 mg/L to 0.204 mg/L in 2007 (Table 4). The creek's water quality was Class I (0-0.2 mg/L) for eight measurements and Class II (0.2-1 mg/L) for one measurement before fish farm (TWPCR 2004). NH_4-N concentration varied from 0.015 mg/L to 0.37 mg/L after fish farm in 2007. These values place Yanýklar Creek in the Class I water quality designation for six measurements and Class II for three measurements. The data in (Fig.4-b) show that NH_4-N concentration drastically increased after fish farm for all sampling dates.Based on nine measurements, the NO_2-N concentration ranged from 0.005 mg/L to 0.01 mg/L before fish farm in 2007 (Table 4). The creek's water quality was Class II (0.002-0.01 mg/L) for three measurements and Class III (0.01-0.05 mg/L) for six measurements before fish farm (TWPCR 2004). It varied from 0.017 mg/L to 0.156 mg/L after fish farm. These values place Yanýklar Creek in the Class III water quality designation for five measurements and Class IV (>0.05 mg/L) for four measurements after fish farm. The data in (Fig.4-c) show that NO_2-N concentration considerably increased after fish farm for all sampling dates.

Based on nine measurements, the NO_3-N concentration ranged from 0.073 mg/L to 0.49 mg/L and from 0.181 to 0.971 mg/L before and after fish farm, respectively (Table 4). The creek's water quality was Class I (0-5 mg/L) for all sampling dates before and after fish farm. Although water quality class doesn't change before and after fish farm, it is clear from (Fig.4-d) that NO_3-N concentration increased after fish farm except December 2007.The TP concentrations ranged from 0.006 to 0.124 mg/L in 2007 (Table 4), based on nine measurements. These values place Yanýklar Creek in the Class I (<0.02 mg/L) water quality designation for seven measurements and Class II (0.02-0.16 mg/L) for two measurements before fish farm (TWPCR 2004). It varied from 0.013 to 0.249 mg/L after fish farm. The creek was in a Class I (<0.02 mg/L) for one measurement, Class II (0.02-0.16 mg/L) for seven measurements and Class III (0.16-0.65 mg/L) for one measurement. The data in (Fig. 4-e) all indicate that TP concentration drastically increased after fish farm except December 2007.

Before fish farm, the number of fecal coliform ranged from 0 to 100 (Table 4), indicating Class I water quality for six measurements (the Class I limit for fecal coliform is 0-10 CFU/100 mL) and Class II for three measurements (the Class II limit for fecal coliform is 10-200 CFU/100 mL). The fecal coliform numbers ranged from 4 to 900 indicating Class I water quality for three measurements, Class II for three measurements and Class III (the Class III limit for fecal coliform is 200-2000 CFU/100 mL; TWPCR 2004) for three measurements after fish farm. The data in (Fig.4-f) indicates that the Yanýklar Creek's fecal coliform number drastically increased after fish farm.

The number of total coliform before fish farm ranged from 30 to 1700 CFU/100mL (Table 4) and indicates Class I water quality for three measurements and Class II for six measurements (the Class I and Class II limit for total coliform is 0-100 and 10-20000 CFU/100 mL, respectively; TWPCR 2004). The total coliform numbers ranged from 600 to 3000 indicating Class II water quality for all measurements and (Fig.4-g) revealed that number of total coliform considerably increased after fish farm.

CONCLUSIONS

This study illustrated that the DO concentration in Fethiye Gulf decreased from 2006 to 2007 except in August, October, November and December. Moreover, water transparency increased except in July and August. Number of total coliform increased except in October and November. The number of total coliform in the gulf also dramatically exceeded the acceptable limit of 1000 CFU/100mL, thereby implicating wastewater inputs to the gulf as the probable source. The high contribution of nitrite-nitrogen, total phosphate and number of total and fecal coliform of Yanýklar Creek is verified to be due to land-based fish farm located on the creek. Since, ammonium nitrogen, nitrate nitrogen, nitrite nitrogen and total phosphate concentrations and, number of total and fecal coliform were elevated and dissolved oxygen levels dropped at downstream of the fish farm.

Decrease in dissolved oxygen and increase in nutrients are generally found in the water column around fish farms. Overall data suggest that external phosphorus and nitrogen loads to Fethiye Gulf derive mainly from tributary streams impacted by point sources, and land-based trout fish farm.Fish 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 of concern, so that nutrient concentrations do not exceed the predefined standards. Unfortunately, there is no limit set for emission standards for land-based fish farms. Current regulation set standards only for fish farms located in the sea. Its content should comprise the emission standards for land-based fish farms. Land-based fish farm located on Yanýklar Creek should construct treatment plant as soon as possible.

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