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Water quality and impacts of pollution sources for Eymir and Mogan Lakes (Turkey)

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Abstract

Mogan and Eymir Lakes are two shallow lakes, interconnected hydrologically in the close vicinity of Ankara, Turkey. A total of 245 km^2 of the total 971.4 km^2 watershed is under environmental protection status as ''Gölbaşı Specially Protected Area''. Potential impacts from extensive agriculture, recreation, incomplete infrastructure and other human activities, such as residential settlements, are discussed with reference to previous and more recent pollution monitoring. Six monitoring stations enabling follow-up of previous work were selected in this study. These were on the creeks feeding the lake systems. Generally, summer months showed heavier pollution loads, with Eymir Lake concentrating the pollutants due to flow from Mogan Lake. When compared with the 1995 study; COD, total-P, Kjeldahl-N in the six stations were close or slightly decreased in the present study. Suspended solids significantly decreased; possibly due to erosion control measures and decreased domestic wastewater. The improvement in the pollution state of the lakes is attributed to the construction of a sewage system going around Mogan Lake and collecting wastewater discharges and restrictions to urban settlement development around the lakes brought by the 1/25000 land use plan controlling further impact from residential developments within the protected area boundaries. The study, while addressing water quality and interactions due to human activities in shallow lakes, also discusses problems associated with human impacts in protected areas with the aim of presenting a complicated case study.

Keywords: Water quality; Mogan Lake; Eymir Lake; Lake pollution; Impact

1. Introduction

In recent years, there has been considerable research on nutrient dynamics, pollution control (and abatement) of lake water bodies. The value and importance of freshwater resources necessitates that they be well managed ecologically for meeting water quality standards. Along this line work continues in the field on: identifying general properties, ecosystem characteristics, human impacts and utility of empirical models for resource management (Cooke et al., 1993; Li and Yang, 1995; Moss et al., 1996; Havens et al., 2001; Havens and Schelske, 2001; Timchenko et al., 2000).

Eymir and Mogan Lakes were chosen in this study since they are heavily influenced by human actions leading to domestic, agricultural and partially industrial pollution sources and they are in the close vicinity of Ankara (capital city of Turkey). The two lakes are interconnected hydrologically with a flow from South (Mogan Lake) to North (Eymir Lake). They are also a major recreation area serving metropolitan Ankara area. In recent years, there has been discussion concerning the eutrophication state of the lakes and several basic studies (including monitoring) have been carried out (MTA (General Directorate of Mineral Research and Exploration), 1992; DSİ (The General Directorate of State Hydraulic Works), 1993; ASKİ (Ankara Water and Sewage Management Authority), 1995; ÖÇKK (The Authority for the Protection of Special Areas), 1998; EİEİ (Electrical and Survey Works General Directorate), 2001). Both lakes were taken under legal environmental protection status in 1990 by a decree of the Turkish Cabinet of Ministers and hence became a ''Specially Protected Area'' (SPA).

Major land use in the common watershed of the two lakes is extensive agriculture. A 1/25000 scale land use

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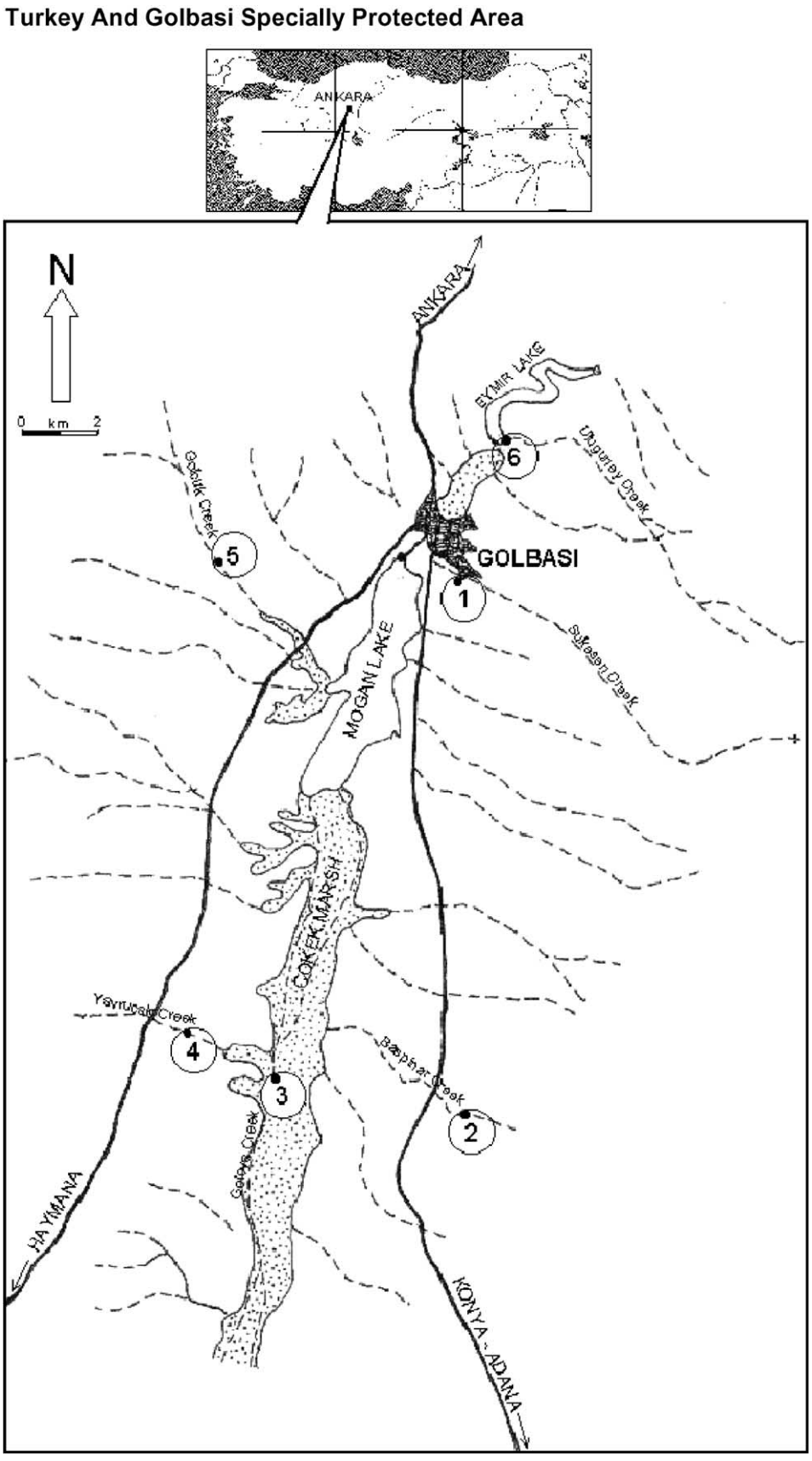

Fig. 1. Map of Turkey showing the location of the study area, Gölbaşı Specially Protected Area and all sampling stations.

Table 1
General features of the two lakes and watersheds

Attribute	Eymir Lake	Mogan Lake
Origin recession	Lateral	Lateral
Latitude	39.28 N	39.53 N
Longitude	32.30 E	33.00 E
Average elevation of watershed (m)	1110 for both lakes	
Lake area (km^2)	1.25	5.43
Mean depth (m)	2.5	2.8
Maximal depth (m)	–	3.97
Lake volume ($\times 10^6$ m^3)	3.88	11.63
Watershed area (km^2)	925.4 + 46	925.4
Human population (of Gölbaşı)	1997 General census total 49,526: Gölbaşı center 30,795; villages 18,731	

plan was endorsed by the ÖÇKK in 1992 (ÖÇKK, 1992). At present, untreated waste from portions of the Gölbaşı town and its environs plus non-point agricultural pollution and runoff are discharged into both lakes.

The objectives of this study were: (1) To have an overall picture of the environmental impacts of pollutants and human actions on Eymir and Mogan Lakes; (2) pollution loads and water quality determination; (3) comparison of present data with previous published data; (4) discussion of the Eymir and Mogan Lakes case in terms of human impact on the environment with a view of providing good insight for future management of similar freshwater resources.

2. Materials and methods

2.1. Study area

Eymir and Mogan Lakes are located 25 km from the city center of Ankara with a total watershed area of 971.4 km^2. The two lakes are shallow (average depth ~ 2.5 m) and hydrologically interconnected (Fig. 1). A total of 245 km^2 of the total watershed area has been declared "Specially Protected Area" and taken under environmental protection status as mentioned above. The climate in the study area is continental, winter months are cold and rainy, summers are hot and dry. Rainwater regime is semi-arid. General features of Mogan and Eymir Lakes and watersheds are given in Table 1.

2.2. Sampling and study sites

Six sampling stations were selected: 5 of them were creeks feeding Mogan Lake (1: Sukesen Creek; 2: Başpınar Creek; 3: Gölova Creek; 4: Yavrucak Creek; 5: Gölcük Creek); the sixth station (Eymir–Mogan connection; 6: Mogan Canal) has been reported to carry the heaviest pollution load (ASKİ, 1995). Locations of the sampling stations are depicted in Fig. 1.

2.3. Analytical water quality procedures

Field and laboratory measurement of selected water quality parameters were made on three dates (July 1999, October 1999 and February 2000) at all six sampling stations. Temperature (Temp.) and dissolved oxygen (DO) were measured using Wissenschaftlich-Technische-Werkstätlen (WTW, Weilheim, Germany) field apparatus. Conductivity measurements were made using a Hanna portable conductivity meter. Calibration of meters and probes were made according to manufacturers' instructions. Laboratory samples were stored on ice at 4 °C until transport for analysis. Total phosphates (Total P), Kjeldahl-N, suspended solids (SS) and chemical oxygen demand (COD) values were determined in the Ankara Metropolitan Municipality Laboratory (ASKİ) using standard methods. For microbiological determinations a Sartorius semi-quantitative coliform bacteria system was used. Nutrient loading data were calculated as flow times concentration. Flow data were determined by Electrical and Survey Works General Directorate of Turkey (EİEİ, 2001) based on 2 years of data. The said Institute has been collecting such data since 1994. Our sampling

Table 2
Water quality data collected and pollution loads from six stations in the Gölbaşı area (July 1999)

Reference stations	Parameter												
	Temp. (°C)	Conductivity (μmhos/cm)	DO (mg/l)	COD		Kjeldahl-N		Total P		SS		Total coliforms/ 100 ml	Flow rate (m^3/s)
				(mg/l)	(kg/day)	(mg/l)	(kg/day)	(mg/l)	(kg/day)	(mg/l)	(kg/day)		
Sukesen Creek	24.0	763	10.8	39	6.739	2.96	0.511	0.35	0.605	< 10	1.728	5556	0.002
Başpınar Creek	19.8	990	4.7	36	6.22	2.81	0.486	0.22	0.038	108	18.662	8889	0.002
Gölova Creek	25.1	1600	8.5	67	0	12.95	0	0.21	0	23	0	3334	No flow
Yavrucak Creek	22.1	532	7.6	44	106.44	4.65	11.249	0.27	0.653	190	459.648	7779	0.028
Gölcük Creek	27.7	732	6.9	113	78.869	3.43	2.667	1.0	7.776	747	580.867	9×10^5	0.009
Mogan Canal	23.5	1323	4.7	0.111	95.904	12.95	11.189	1.60	1.382	10	8.64	2×10^5	0.01

Table 3
Water quality data collected and pollution loads from six stations in the Gölbaşı area (October 1999)

Reference stations	Parameter												
	Temp. (°C)	Conductivity (μmhos/cm)	DO (mg/l)	COD		Kjeldahl-N		Total P		SS		Total coliforms/ 100 ml	Flow rate (m^3/s)
				(mg/l)	(kg/day)	(mg/l)	(kg/day)	(mg/l)	(kg/day)	(mg/l)	(kg/day)		
Sukesen Creek	12.4	608	11.5	14	3.629	7.3	1.892	0.07	0.0181	18	4.666	823	0.003
Başpınar Creek	10.6	830	6.5	76	157.594	7.2	14.93	0.66	1.369	227	470.707	1438	0.024
Gölova Creek	10.2	1971	7.1	48	12.442	9.4	2.436	0.04	0.010	7	1.814	178	0.003
Yavrucak Creek	9.6	513	9.9	48	116.122	9.4	22.74	0.7	1.693	85	205.632	495	0.028
Gölcük Creek	9.6	709	10.4	38	9.850	9.4	2.436	0.13	0.0337	166	43.027	334	0.003
Mogan Canal	11.9	1937	1.3	57	0	9.0	0	1.5	0	7	0	134	No flow

stations were also the flow measurement stations of EİEİ.

3. Results

Results of water quality parameter analyses of six selected stations from the Mogan and Eymir Lakes catchment area are depicted in Tables 2–4 together with total pollution loads of point sources with their seasonal changes. Average pollution loads from point sources are given in Table 5.

Parameters are calculated individually as follows.

COD: Gölova Creek had the highest COD load among the point sources feeding Mogan Lake: 57.29 kg/day. Yavrucak Creek follows Gölova Creek with 40.07 kg/day. The lowest was Sukesen Creek with 2.1 kg/day. COD load changed seasonally for five stations, except Yavrucak.

SS: Yavrucak Creek had the highest SS load: 172.98 kg/day. Başpınar and Gölcük Creeks follow Yavrucak. The lowest SS load was seen at Sukesen Creek as 2.57 kg/day. This creek has been rehabilitated by the State Hydraulic Works General Directorate just before the measurements were made: A concrete trapezoidal channel was constructed along 1230 m of Sukesen Creek for flood control. Seasonal variation did not show a definite trend in five stations, except Sukesen Creek. In Sukesen, SS increased steadily from July to October then to February.

Total P: The highest total phosphates were monitored with the aim of following eutrophication process closely. Gölcük Creek was the highest with a load of 0.96 kg/day. Mogan Canal was the second highest with 0.66 kg/day. The loads were lower in February, except for Mogan Canal and Başpınar Creek. In addition Gölcük Creek had the higest load in July.

Kjeldahl-N: Mogan Canal had the highest load: 15.02 kg/day. Sukesen Creek was the lowest 0.36 kg/day. Seasonal variaton was again inconsistent. Mogan Canal received the highest load in February. Sukesen, Başpınar and Yavrucak had the higest loads in October.

DO: Mogan Canal had the lowest DO content; < 5 mg/l. Pollution is concentrated and magnified. (ASKİ, 1995, p. 240). In other stations February had the highest DO content as expected from the converse relationship of water temperature versus DO content.

Conductivity: Conductivity values were consistent throughout the study period. The highest values were recorded at Gölova Creek and Mogan Canal; average 1810 and 1642 μmhos/cm, respectively.

Total Coliforms: As expected, total coliform counts were low in October and February and very high in July. In February, four stations did not have any countable colonies except for Sukesen Creek and Mogan Canal. Bacteriological

Table 4
Water quality data collected and pollution loads from six stations in the Gölbaşı area (February 2000)

Reference stations	Parameter												
	Temp. (°C)	Conductivity (μmhos/cm)	DO (mg/l)	COD		Kjeldahl-N		Total P		SS		Total coliforms/100 ml	Flow rate (m^3/s)
				(mg/l)	(kg/day)	(mg/l)	(kg/day)	(mg/l)	(kg/day)	(mg/l)	(kg/day)		
Sukesen Creek	6.4	554	13.4	8	6.912	0.672	0.581	< 0.01	0.00864	17	14.688	2000	0.01
Başpınar Creek	2.5	672	12.2	36	62.208	2.8	4.838	0.165	0.285	105	181.44	1140	0.02
Gölova Creek	0.9	1860	16.3	64	458.425	1.12	8.032	0.094	0.674	51	365.731	140	0.083
Yavrucak Creek	0	452	13.2	12	106.790	1.008	8.570	0.106	0.943	85	756.432	1100	0.103
Gölcük Creek	1.3	528	14.7	< 10	4.32	2.6	1.123	0.10	0.043	19	8.208	110	0.005
Mogan Canal	2.5	1665	4.7	11	184.378	6.7	112.303	0.24	4.023	< 10	167.616	40,000	0.194

Table 5
Average pollution loads from point sources feeding Mogan Lake (1999–2000)

Station	Av. COD[a] (kg/day)	Av. Total P (kg/day)	Av. SS (kg/day)	Av. Kjeldahl-N (kg/day)
Sukesen Creek	2.100	0.077	2.565	0.363
Başpınar Creek	27.494	0.206	81.615	2.464
Gölova Creek	57.290	0.083	44.718	1.274
Yavrucak Creek	40.071	0.400	172.975	5.227
Gölcük Creek	11.320	0.955	76.906	0.757
Mogan Canal	34.101	0.658	21.444	15.024

[a] Av. : average.

pollution was highest in Gölcük Creek and Mogan Canal in the summer months.

4. Discussion

4.1. Total coliforms

Total coliform counts in water bodies is an important parameter for checking possible sewage contamination (Elmund et al., 1999). Measurements in July showed that total coliform counts increased considerably during the summer months. More specifically, the 9×10^5 colonies/100 ml in Gölcük Creek and 2×10^5 colonies/100 ml in Mogan Canal are clear evidence of domestic wastewater contamination in the two creeks. The October and February measurements showed only Başpınar and Yavrucak Creeks (1438 and 1140 colonies/100 ml, respectively) to exceed the allowable 1000 colonies/100 ml level of the Turkish Environmental Legistation (SSKY, Su Kirliliği Kontrol Yönetmeliği: Water Pollution Control Regulation, 1988). Başpınar Creek is not located in a residential area, nor does it have any major point pollution sources except for a poultry-processing facility (Tipo Tavukçuluk). The high values in coliform counts most probably arise from untreated wastewater discharges to Başpınar Creek from time to time even though the facility does have a biological treatment plant. As depicted in Tables 2–4, flow rates of creeks in the summer months decrease; leading to more concentrated pollution loads.

4.2. Dissolved oxygen

DO levels were acceptable in all stations except for Başpınar Creek and Mogan Canal. The February measurement in Başpınar Creek increased to 12.2 mg/l as expected; in Mogan Canal DO levels were consistently low. It must be concluded that Mogan Canal is not suitable to support fish life in terms of DO levels.

4.3. Conductivity

No seasonally significant changes were observed in any of the stations. Measurements showed lower than 2000 μmhos/cm levels even in the highest measured stations of Mogan Canal and Başpınar Creek and may be suitable for use as irrigation water. Conductivity has long been used as an important parameter in deciding whether water resources are suitable for irrigation water or not. Accordingly, the studied water sources are placed in Class III water (potable water) pursuant to Turkish Environmental Legislation (SKKYT, 1991).

4.4. Chemical oxygen demand

The highest COD is carried to Mogan Lake via Gölova Creek (57.29 kg/day). Possible cause of this high value could be the illegal discharge of slaughterhouse waste to this creek by the Gölbaşı Municipality. The minimum determined COD level in Sukesen Creek could be due to the rehabilitation works carried out for flood control.

Examination of the seasonal changes in COD loads showed insignificant changes in Sukesen and Yavrucak Creeks; other creeks and Mogan Canal showed a general increase in COD in the winter months. This is an indication of increased organic loads due to increased household wastewater or slaughterhouse waste discharges.

4.5. Suspended solids

As can be seen in Table 5, the maximum SS pollution loads comes from Yavrucak Creek with an average load of 172.98 kg/day and the follower comes with a load which is less than the half of it, Başpınar Creek (81.62 kg/day). The reason for such a high amount of SS from Yavrucak Creek would possibly originate from the erosion coming from the immediate vicinity. Because areas near this creek are barren, unforested land, therefore, the adverse effects of surface runoff may cause increase in SS levels.

When seasonal variation is examined; SS increases in winter months because of increase in household wastewater. These homes are more populated in the winter months, some households leave town for vacation during the summer months. The only exception being Gölcük Creek, SS load is very high in July. This may originate from the cooperative houses used in summer months discharging their domestic wastes to Gölcük Creek, and these houses are not used in winter months.

Sukesen Creek has the lowest SS load as in the case of other observed parameters since it is rehabilitated.

4.6. Total phosphates

The high total P levels in the Gölcük Creek environs could possibly result from agricultural fertilizer runoff reaching surface waters by rain darinage or irrigation return reaching Gölcük Creek. The second highest level found in Mogan Canal could be due to the closely located Police Academy and TEK (Turkish Electric and Power Authority) public housing wastewater and detergent dis-

charges to this canal. Both facilities have treatment plants but most probably they are not operated routinely and properly. This situation finally pollutes Eymir Lake since it receives almost all its pollution load from the Mogan Canal.

The seasonal increases in Total P levels in winter months in Mogan Exit and Başpınar Creek can be attributed to increased residential population in the winter. An additional source could be Tipo poultry facility at times when its treatment plant is shut off. High levels in Gölcük Creek in the summer months are due to agricultural activities. Total phosphate levels in this study (Tables 2, 3 and 4) were generally found to be higher than the eutrophication values in the Turkish Environmental Legislation (SSKY, 1988, Table 2 in the Regulation).

4.7. Kjeldahl-nitrogen

The highest loads were found in Mogan Canal.

When the results of the pollution in 6 stations in the present study are compared with the results of the study in 1995 (ASKİ, 1995); the SS loads are significantly reduced. Although the exact reason for this recovery is not known, our proposed comments are as follows (personal communication with ÖÇKK):

- Decreased erosion due to completion of contruction works on the Gölbaşı portion of the beltway highway (going around Metropolitan Ankara) and of cooperative housing near the creeks leading to less sediment loads,
- Installation of the sewage system of the Gölbaşı town center settlements has been completed and activated.

With respect to total phosphorous loads, significant reductions were found, except for Gölcük Creek, where increase was considerable. This can be explained with household wastes being connected to the sewage system. COD loads did not vary considerably, except for Gölova Creek (almost a 50% reduction). The reason for the reduction in Gölova is presently unknown.

Lau and Lane (2002) studied water quality parameters and ecological characteristics of Barton Broad, a shallow lake system in the UK similar to Mogan and Eymir Lakes, by evaluating a period of 11 years from 1983 to 1993 and concluded as follows: (a) trophic inter-relationships in eutrophic lakes are strongly related to temporal heterogeneity; (b) seasonality was identified as an important variable affecting lake eutrophication; (c) it is difficult to restore a eutrophic lake solely by nutrient reduction; (d) the complexity of environmental factors involved neccesitates long-term time-series data for an understanding of interacting variables and lake ecosystem behavior. The Broad became increasingly eutrophic in association with increased human activities in the catchment area, including enhanced nutrient runoff due to agricultural intensification and a large tourist industry. Our work shows many similarities with the work of Lau and Lane; however, here, more effort is put into the study of water quality of freshwater resources feeding a shallow lake system consisting of hydrologically interconnected two lakes and its consequences on environmental situation in an ecosystem with abiotic and biotic processes.

5. Conclusion

In general, the most polluted creeks were; Yavrucak, Gölcük Creeks and Mogan Canal. Seasonal changes showed heavier pollution loads in the summer months both due to lower flow rates in the monitored stations and heavier landuse, human activities and agricultural activities. Recreation activities may surmount these.

Mogan and Eymir Lakes are interconnected through the Mogan Canal (Fig. 1, map) and water flow is from Mogan Lake to Eymir Lake. This flow direction is because Mogan Lake is at a higher altitude than Eymir Lake. If this was not the case, Eymir Lake could not carry such heavy pollution loads. Evidently it is receiving the pollution through the flow from Mogan Lake. Eymir Lake and its surrounding lands are the property of Middle East Technical University (METU). There are no settlements except for several simple university housing used as residences by the lake maintenance staff. The university carries out such activities as rowing and sailing courses and water research.

In general, the COD, Total P, Kjeldahl-N levels in the six sampling stations were either close to levels reported by the ASKİ report carried out in 1995 or slightly decreased. This shows moderate environmental impact. At least pollution loads did not worsen within the 5–6 years between the period of the two studies.

Possible explanations for this situation are:

- Direct discharges from households, other domestic sources (restaurants located around Mogan Lake) and recreation activities (from the recreational areas on the Mogan coastline) are now collected by the sewage system going around Mogan Lake and pumped to the pumping station in İmrahor, in the vicinity. However, on rare occasions when there are operational problems in the system, the collected sewage is discharged to Eymir Lake.
- Restrictions to urban settlement development around the lakes and within the boundaries of the Gölbaşı SPA. The 1/25000 land use and environmental management plans (ÖÇKK, 1992) controlled further impact from residential developments.
- SS were significantly decreased since 1995. Possible reasons could be better erosion control and completed highway and cooperative housing construction works in the area and decreased domestic wastewater, which is collected by the sewage system mentioned above.

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