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Limnological Assesment on the Brakish Shallow Liman Lake from Kizilirmak Delta (Turkey)

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Abstract: Liman lake is a part of the Kiziirmak Delta which is one of the most valuable wetland systems in Northern Turkey as a Ramsar site. Liman Lake is a typical brackish lagoon lakewhich is separated from the Black Sea by a narrow sandy barrier. Phyto/zooplankton composition, chlorophyll aand some water quality parameters were investigated in the mixo-oligohaline brackish Liman lake between October 2002 and March 2004. Water temperature, oxygen, Electrical Conductivity (EC), pH and salinity, chemical parameters (K^+, Na^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2-}, HCO_3^- and CO_3^{2-}) and nitrite, nitrate, ammonia and orthophosphate were analyzed. About 35 taxa were distinguished in the zooplankton samples (Rotifera 28, Cladocera 5 and Copepoda 2). *Hexathra oxyuris*, *Keratella quadrata*, *Keratella cohlearis* were the dominant species. A total of 73 species belonging to Cyanobacteria (25), Chlorophyta (23), Bacillariophyta (14), Pyrrophyta (5), Cryptophyta (3) and Euglenophyta (3) were identified. *Chroococcus minutus*, *Merismopedia tenuissima*, *Phormidium tenue*, *Phormidium* sp., *Monoraphidium contortum*, *M. minutum*, *M. pusillum* were perennial dominant species. The chlorophyll a concentration of Liman lake ranged from 5-50 $\mu g L^{-1}$ with a mean value of 19.7 $\mu g L^{-1}$. Based on chlorophyll a results, the trophic level of Liman lake was found in the range of eutrophic level.

Key words: Liman lake, limnology, mixo-oligohaline lake, zooplankton, phytoplankton, Turkey

INTRODUCTION

Coastal ecosystems are ecotonal regions between marine, freshwater and terrestrial habitats and may exhibit properties of these systems as well as unique characteristics of their own. Coastal wetlands are among the most fluctuating and productive ecosystems in the world (Mitsch and Gosselink, 1993). These ecosystems play an important role in coastal defense and wildlife conservation and can act as either sinks or sources of a wide range of substances such as mineral nutrients, organic matter and pollutants. Changes in water regime in coastal wetlands due to human activities have caused serious water quality degradation. Therefore, understanding hydrological function of coastal wetlands is particularly important for conservation and management especially in those coastal wetlands where formerly extensive areas have been reduced by human land use (Puigserver *et al*., 2002).

Kizilirmak Delta is located in the Central Black Sea region of Northern Turkey and covers an area of 50,000 ha that includes 15,000 ha of freshwater marshes and swamps, coastal lagoons and lakes. The Delta is one of the Black Sea's most important coastal wetland complexes with its rich biodiversity and critical habitat for globally endangered bird species (e.g., *Pelicanus crispus*, *Oxyura leucocephala*, *Bronte ruficollis*, *Aynthya nyroca*, *Aquila heliaca*) (Husting and Dijk, 1993). Bird Life International included the area in the Important Bird Areas (IBA) list of Europe (Grimmet and Jones, 1989). It is a national biodiversity hotspot with more than 310 bird species or 75% of all known bird species in Turkey. Birds use the delta for breeding, wintering, nesting and migration in large numbers. Due to these characteristics, the delta has recently been declared a Ramsar site and a Wetland of International Important by the Ministry of Environment in Turkey (Magnin and Yarar, 1997).

People have inhabited the Kizilirmak Delta at least since Chalcolitic and actively changed the ecosystem. The intensive presence of people in the delta since the 1950s became a serious threat and caused degradation to the ecosystem because of urban and agricultural pollution, housing development and coastal erosion. Furthermore, the irrigation channel project was performed to bring residual irrigation water from regional agricultural areas into the lakes or Black Sea in the Western part of the

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delta by State Water Department (DSI, 1986). This project has also caused detrimental effects to the lakes ecosystem and biota because this channel system lead to deep changes in the water regime of delta. It is thought that Liman lake is one of the most to suffer from anthropogenic activities in the delta because of the irrigation channel at the South side of the lake. Construction of irrigation channel was also performed with no ecosystem impact analysis on the deltaincluding Liman lake. Data related to the main biological components of Liman lake were unavailable and effects of drainage channel on the lake ecosystem are completely unknown. The aim of this study is to describe biotic community its function and physical-chemical structure of Liman Lake. These data will be a framework to determine conservation and management strategies of the lake.

MATERIALS AND METHODS

Water, zooplankton and phytoplankton samples were collected 13 times from October 2002-March 2004 at approximately monthly intervals from three stations of Liman Lake (Fig. 1).

Site description: Liman lake is located on the North West side of Kizilirmak Delta and the coordinates of the lake are between 41°44' North latitude and 35°40' East longitude. The lake has 200 ha surface area with a maximum depth of 3.75 m. It receives residual irrigation water originating from regional agricultural areas via artificial channel on the South side and/or superficial waters. Liman lake is separated from the Black Sea by a narrow sandy barrier on the Northern side. The South, South-West and South-East sections of the lake consist of reed beds (*Phragmites australis*) and there is very thin sandy beach barrier between Black Sea and Northern side of the lake. The bottom in the South and central parts of the lake is covered by submerged vegetation e.g., *Potamogeton perfolitus*, *Potamogeton pectinatus*, *Potamogeton nodosus* and *Chara vulgaris*. Submerged vegetation nearly disappeared at the Northern end of the lake which has deeper and more salty water conditions. Fish population of the lake consists of *Carassius carassius*, *Mugil cephalus*, *Stizostedion lucioperca* and *Cyprinus carpio*.

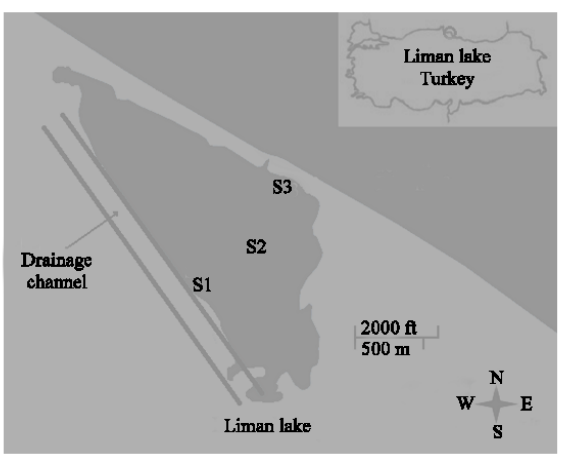

Fig. 1: Map of Liman lake, drainage channel and sampling stations

Analyses of physico chemical variables: During the study period, three sampling stations were selected throughout the lake, one of which (S1) was located at a point of macrophyte colonization and connection point of the lake and irrigation channel discharge, the other (S2) in the central part of the lake and the final one (S3) at the outlet point to the sea (Fig. 1). At every sampling site; temperature, oxygen, conductivity, pH and salinity were measured *in situ* using portable WTW OXI 96 STB/B oxygenmeter, WTW LF 90 conductivitymeter and Orion 230 pH m. For the determination of chemical properties and pigment analyses, 1 L each of surface and bottom water were collected from each of the three stations in a colored bottle with HYDOBIOS water samplerand then water samples were transported to the laboratory and processed immediately. The water samples for nutrient and ion analysis were filtered on Whatman GF/C and samples were stored at +4°C prior to analyses. Chemical parameters (K^+, Na^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2-}, HCO_3^- and CO_3^{2-}) and inorganic nutrients (nitrite, nitrate, ammonia and orthophosphate) were determined with Bionex Ion Chromatography. Filtering appropriate water samples through Whatman GF/C glass fiber filters was carried out to determine chlorophyll a. The pigment extraction was performed with boiling methanol method and measurements were made by a spectrophotometer according to Marker (1994).

Sampling and analyses of plankton: Zooplankton and phytoplankton samples were taken periodically at each station using plankton nets with 30 and 55 μm mesh size and identifications were keyed to species level by reference to Koste (1978), Pennak (1978), Negrea (1983), Kiefer (1952, 1955), Ettl (1983), Prescott (1973), Popovski and Pfiester (1990). Quantitative analyses of zooplankton groups were counted under a Nikon light microscope and densities were expressed as number organism per cubic meter. For quantitative and qualitative analyses of phytoplanktoninverted and a phase-contrast microscope was used.

RESULTS AND DISCUSSION

Physical and chemical characteristics of water: Due to its special geographic position, Liman lake has some

Table 1: Average values and variations of physico-chemical variables recorded at Liman Lake *(mg L^{-1}) **(g L^{-1})

Months	Tem (°C)	pH	D.O.*	S%	Ca*	Mg*	Na*	K*	Cl*	SO_4*	HCO_3*	CO_3*	NH_4**	NO_3**	NO_2**	Chl a**
October 02	17.4	7.89	6.97	3.15	78	124	926	37	1670	510	124	37	0	0	0	13.15
November	11.3	8.71	8.65	2.52	43	102	910	34	1422	344	155	14	18	0	0	6.81
February 03	5.7	8.42	8.38	2.63	69	105	1037	47	1716	356	221	18	0	734	39	16.68
April	9.1	8.53	9.27	3.36	15	120	1152	40	2021	477	249	32	45	905	23	24.16
May	18.6	8.55	6.87	4.06	77	165	1126	38	1961	377	214	36	104	0	20	34.30
June	22.7	8.85	7.50	3.93	65	154	1035	35	1616	381	157	40	9	0	0	21.47
July	22.7	8.62	6.45	2.95	58	103	659	21	1120	354	160	28	0	0	16	12.22
August	24.1	8.80	6.75	2.51	63	104	616	20	924	369	131	32	1698	0	209	8.35
October	17.9	8.75	8.58	1.96	62	91	506	17	729	301	159	28	741	0	0	18.32
November	12.6	8.14	7.87	2.46	86	119	740	27	1196	281	209	20	2143	0	0	5.58
December	7.3	8.66	9.05	2.99	94	163	1104	39	1737	429	229	37	3677	0	69	3.88
February 04	7.8	8.61	9.38	2.36	86	135	811	29	1410	314	254	43	17853	0	59	41.46
March	5.8	8.82	9.77	2.27	79	127	784	29	1432	306	308	41	19145	0	0	49.77

different properties in terms of hydrological and ecological process than other lakes in the Kizilirmak Delta. Its exceptional status is a result of entrance seawater, freshwater and nearby agricultural activities. The presence of freshwater and sea water input causes a progressive accumulation of salts, total nutrients and organic contents in the lake.

Seasonal fluctuations in the physical and chemical variables of the Liman Lake are shown in Table 1. Liman lake is very shallow until its central area (<1.5 m) but beyond this site, a deeper water column is established (maximum depth 3.75 m) (Fig. 2). Seasonal depth changes are primarily related to water inputs/penetrations from the drainage channel or the sea. Liman lake is a typically brackish water ecosystem due to the mixture of sea water and fresh water in the lake (Remane and Schlieper, 1971). The water level in the lake was mainly controlled by direct freshwater discharge from the drainage channel which flows diffusely in the Southern portions. During the dry period when the lake water level dropped, seawater penetrated the lake by the surface or underground. Transparency was variable in the lake during the study period. It was highest at station 1 because the bottom was entirely covered by the submerged plant e.g. *Potamogeton perfolitus*, *Potamogeton pectinatus*, *Potamogeton nodosus* and *Chara vulgaris* (Fig. 2). Secchi depth decreased with algal blooms in the lakebut this was not a single factor influence to transparency. Light regime in the lake (especially at station 2 and 3) was also under the control of wind mixture leading suspension of silt and detritus in the water column.

Average water temperature was characterized with a seasonal cycle by a minimum of 5.7°C (February, 2003) and a maximum of 24.1°C (August, 2003). Thermal homogeneity was established in the water column during the study period and the circulation pattern was polymictic. Water column was always well oxygenated due to efficient vertical and horizontal mixture. Dissolved oxygen varied between 6.45 (July, 2003) and 9.77 mg L^{-1}

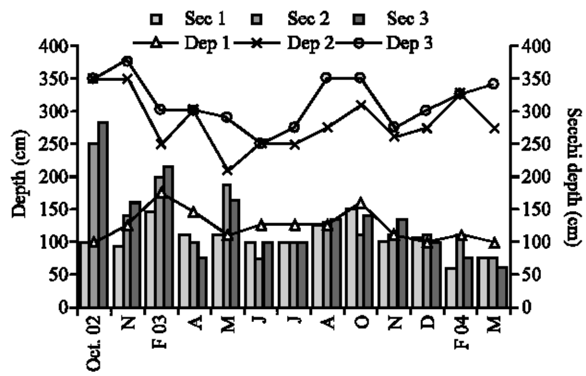

Fig. 2: Seasonal variations in depth and secchi depth (cm) at stations 1, 2 and 3

(March, 2004). In coastal lagoons, vertical gradient of salinity can contribute to creation of anoxic zones in the deeper part of water column (Lucena *et al*., 2002). In contrast to many coastal lagoons, water column in Liman lake always remained well oxygenated. Relatively high pH values corresponded to water mass influenced by seawater under oxygenated conditions. The water was alkaline and in most cases, pH was recorded as over 8.

Due to large surface and shallow depth, atmospheric oxygen infusion was achieved constantly and anoxic condition was prevented by this process. As a consequence, the factors affecting the oxygen concentration in the water column were the efficient vertical mixture, shallow depth and dense submerged vegetation.

Electrical conductivity of the lake displayed seasonal and spatial variations with the minimum (1930 μS cm^{-1}) and the maximum (7530 μS cm^{-1}) values observed in November 2003 and May 2003, respectively (Fig. 3). Electrical conductivity in Liman lake was fairly high as expected from a brackish water mass (Lucena *et al*., 2002). In contrast to other lagoon lakes in the Kizilirmak Delta (Demirkalp *et al*., 2004), chemical stratification in

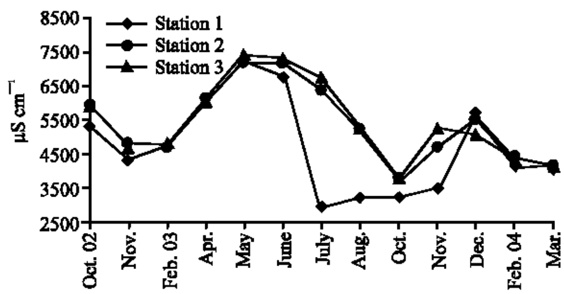

Fig. 3: Seasonal variations in conductivity ($\mu S\ cm^{-1}$)

Liman Lake was distinguished according to hydrological conditions. For example; evident vertical differentiations of electrical conductivity were observed at S1 in August and in the whole lake in November 2003 period and maximum amplitude was determined as 3220 $\mu S\ cm^{-1}$. However, its shallow depth and local wind action did not allow permanent stratification of the water column due to its continuous mixture. On the other hand, horizontal electrical conductivity variations were constantly dependant on inputs of sea water or freshwater. Due to large fresh water charges, conductivity was fairly low at S1 in the October-November 2002 and June-October 2003 periods (Fig. 3).

The anions equilibrium of Liman Lake was determined as $Cl^{-}>SO_4^{2-}>HCO_3^{-}>CO_3^{2-}$ (Table 1). During the study period, chloride concentrations ranged between 729 (October, 2003) and 2021 mg L^{-1} (April, 2003) and sulfate was recorded between 281 (November, 2003) and 510 mg L^{-1} (October, 2002). Inorganic carbon was mainly in the form of bicarbonate with a minimum and maximum value of 124 and 308 mg L^{-1}, respectively. Major cations followed the trend of $NA^{+}>Mg^{2+}>Ca^{2+}>K^{+}$. The minimum and maximum concentrations were as follows for sodium 506 and 1152 mg L^{-1} for magnesium 91 and 165 mg L^{-1}, for calcium 43 and 148 mg L^{-1} for potassium 17 and 47 mg L^{-1}. The anion and the cation equilibrium of Liman Lake showed remarkable differences to alkaline fresh waters and displayed more resemblance to seawater (Wetzel, 1983). Because of sodium and chloride dominance, Liman lake was characterized as sodium chloride type brackish water (Hammer, 1986). The salinity of the lake was determined as between 1.96 and 4.06% and this range belonged to mixo-oligohaline brackish water according to the Venice System (Remane and Schlieper, 1971; Bulger *et al.*, 1993).

During the study period, dissolved ammonia of Liman lake was at a negligible level until August 2003. However, ammonia concentrations attained extreme dangerous levels after this month. Ammonia was recorded as 17.8 in February 2004 and 19.15 mg L^{-1} in March 2004. Whereas nitrite and nitrate were found in trace amounts, nitrate was recorded only in 2 months and displayed small seasonal fluctuations. The low dissolved oxidized inorganic nitrogen and the high ammonia concentration may be an indication of intense mineralization nitrogenous matter in Liman lake (Comin *et al.*, 1997). Dissolved Inorganic Nitrogen (DIN) variables allowed two periods with different chemical characteristics to be distinguished. The first period, represented between October 2002 and July 2003 had low value for DIN (nitrite, nitrate and ammonia). The second period (after July, 2003) was characterized with extreme nitrogen loading mainly in the form of ammonia (Table1). On the other hand, highest level of ammonia were detected at S1 ($p<0.05$). It is known that dissolved inorganic nitrogen is usually related to water inputs, either marine or freshwater, whereas phosphorus depends more on the internal recycling process (e.g., release from sediment, mineralization of organic matter) as a common feature in most coastal lagoons (Lucena *et al.*, 2002; Perez-Ruzafa *et al.*, 2002; Serrano *et al.*, 2004). In Liman lake, the freshwater inputs determined the entries of the dissolved inorganic nitrogen into the lagoon. It is clear that ammonia input was related to freshwater discharges because the high nutrient values were determined simultaneously with the lowest conductivity condition in the lake. Large freshwater discharge in the direction of S1 was probably responsible for elevation of ammonia. Quantity of freshwater flowing from the Southern drainage channel into the lake displayed an increase after the State Department of Water (DSI) expanded the width of drainage channel in July. This drainage channel also caused DIN to increase in the water column to bring fertile waters especially in fertilization period (February-March 2004) in surrounding agriculture areas. Ammonia level of second period was found at dangerous level according to OECD criteria (OECD, 1982).

Another distinctive feature of Liman lake was the formation of orthophosphate compound. Orthophosphate concentration probably remained below the detection limit in the lake. As a general rule, excessive sulfate concentration causes phosphorus releases from the lake sediment (Derry *et al.*, 2003). Considering this process, moderate orthophosphate concentration might be expected to exist in the water column containing quite high sulfate in Liman lake. Orthophosphate might probably follow three major processes in Liman lake: Phosphorus was likely to be precipitated as calcium or magnesium phosphate in the lake; excessive alkaline conditions might favour the precipitation of phosphate in the lake (Wetzel, 1983); another considerable factor might be dense submerged vegetation causing the depletion of orthophosphate in the water column.

Table 2: Zooplankton and phytoplankton taxa found in Liman lake

Phytoplankton	Phytoplankton	Zooplankton
Cyanobacteria		**Rotifera**
Anabaena circinalis	*Monoraphidium pusillum*	*Brachionus angularis*
Aphanothece clathrata	*Oocystis apiculata*	*Brachionus calyciflorus*
Aphanezomenon flos-aquae	*Oocystis elliptica*	*Brachionus plicatilis*
Chroococcus minor	*Oocystis eremosphaeria*	*Brachionus quadridentatus*
Chroococcus minutus	*Oocystis naegeli*	*Brachionus urceolaris*
Chroococcus turgidus	*Oocystis pusilla*	*Colurella adritica*
Chroococcus varius	*Scenedesmus bijuga*	*Colurella colurus*
Gloeocapsa sp.	*Scenedesmus quadricauda*	*Euchlanis dilalata*
Gloeothece subtilis	*Tetraedron muticum*	*Filinia longiseta*
Gloeothece sp.	*Tetraedron minimum*	*Filinia terminalis*
Gomphosphaeria aponina	**Bacillariophyta**	*Hexathra oxyuris*
Hapalosiphon fountinalis	*Cyclotella* sp.	*Keratella cochlearis*
Hapalosiphon inrticatus	*Stephanodiscus astrea*	*Keratella quadrata*
Merismopedia tenuissima	*Achnanthes* sp.	*Keratella tropica*
Microcystis aeruginosa	*Amphora linearis*	*Lecane bulla*
Microcystis geminata	*Amphora ovalis*	*Lecane closterocerca*
Nostoc coeruleum	*Amphora* sp.	*Lecane luna*
Phormidium tenue	*Cymatopleura solea*	*Lepadella patella*
Phormidium sp.	*Cymbelle prostrata*	*Notholcha acuminata*
Snowella lacustris	*Gomphonema olivaceum*	*Notholcha squamula*
Snowella sp.	*Navicula* sp.	*Philodina megalotrocha*
Spirulina maior	*Nitzschia palea*	*Polyathra dolichoptera*
Spirulina sp.	*Nitzschia* sp.	*Polyathra vulgaris*
Tolypothrix sp.	*Rhoicosphaenia curvata*	*Synchaeta pectinata*
Woronichinia sp.	*Synedra* sp.	*Synchaeta* sp.
Chlorophyta	**Pyrrophyta**	*Trichocerca longiseta*
Ankistrodesmus falcatus	Gymnodinium hippocastanum	*Trichocerca stylata*
Ankyra judayi	*Gymnodinium* sp.	*Trichotria pocillum*
Ankyra setigera	*Peridinium cinctum*	**Cladocera**
Botryococcus braunii	*Peridinium* sp	*Alona rectangula*
Closterium acutum	*Wolozynskia pseudopalustris*	*Alonella excisa*
Closteriopsis acicularis	**Cryptophyta**	*Chydorus sphaericus*
Closteriopsis longissima	*Cryptomonas erosa*	*Pleopsis* sp.
Cosmarium abbreviatum	*Cryptomonas ovata*	*Pleuroxus trigonellus*
Cosmarium fontigenum	*Rhodomonas lacustris*	**Copepoda**
Dactylococcopsis raphioides	**Euglenophyta**	*Calanipeda aquaedulcis*
Euastrum insulare	*Euglena* sp.	*Mesochra aestuarii*
Monoraphidium contortum	*Lepocinilis* sp.	
Monoraphidium minutum	*Phacus* sp.	

The complexity of natural ecosystems requires the use of number variables for water quality assessment. Nutrients and chlorophyll a content of the water are considered as the most significant parameters in eutrophication studies since they represent the general trends of enrichment of the water systems and can be easily recorded in monitoring programs. Based on chlorophyll a results, the trophic level of Liman Lake was found in the range of eutrophic level (OECD, 1982; Wetzel, 1983).

The chlorophyll a concentration of Liman lake ranged from 5 to 50 μg L^{-1} with a mean value of 19.7 μg L^{-1} (Table 1). These values were quite below the range measured in Cernek lake (4.12-541.5 μg L^{-1}) which was characterized as oligohaline brackish water in the Kizilirmak Delta (Demirkalp *et al*., 2004). Highest values were observed in February and March 2004 periods when ammonia level was found at extreme level. In this regard, it is possible to state eutrophication process in the lake accelerated due to nearby agricultural activities.

Zooplankton and phytoplankton composition: Liman lake was quite rich in phytoplankton and zooplankton. About 35 taxa were distinguished in the zooplankton samples. The most represented groups were Rotifera, Cladocera and Copepoda with 28, 5 and 2 taxa, respectively (Table 2). In temperate zones, seasonal variations of zooplankton communities are usually explained with PEG-model (Sommer *et al*., 1986). According to this model, such a succession from small to large zooplankton occurs from spring to early summer. However, it is difficult explain seasonal variations in the zooplankton community according to this model in Liman lake as they have quickly changeable and specific hydrological conditions. Freshwater or sea water input, mixture degree in the water column, stratification and environmental variables such as salinity, temperature leads to spatial and seasonal zooplankton heterogeneity in lagoon lakes (Joyce *et al*., 2005). Thus it can be distinguished that zooplankton community show variations in lagoon lakes of the

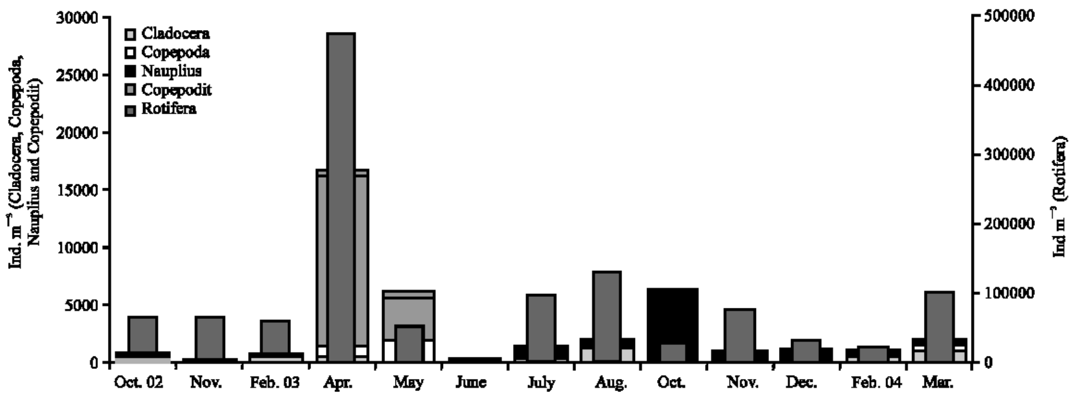

Fig. 4: Monthly variations in zooplankton abundance

Kizilirmak Delta. Although Rotifera was found to be dominant in the lakes of the Kizilirmak Delta, zooplankton community of Liman displayed evident differences in comparison to Cernek and Balik lake where Copepoda and Cladocera significantly contributed to zooplankton (Gunduz, 1991a, b; Demirkalp *et al.*, 2004). Lower contribution of Copepoda and Cladocera to zooplankton in Liman lake may be related to more hyperhaline conditions in the lake (Fig. 4). Species composition of Liman Lake is typical for brackish lakes and dominant species such as *Hexathra oxyuris*, *Keratella quadrata and Keratella cohlearis* are very euryhaline and adapted to high salinity fluctuations (Ramdani *et al.*, 2001). *Brachionus angularis*, *Trichocerca stylata*, *Polyathra* sp. ve *Syncaeta* sp. have widespread distribution in freshwaters biotopesbut these species successfully adapted to the brackish water of Liman lake. Copepod *Calanipeda aquaedulcis* ve *Mesochra aestuari* are characterized as euryhaline and euthermal species. Although calanoid *Calanipeda aquaedulcis* is related with more oligotrophic conditions (Boix *et al.*, 2005) it was only found in 3 sampling periods (February-May 2003) in Liman lake when chlorophyll a was approximately over 20 μg L^{-1}.

A total of 73 taxa belonging to 6 divisio were found in the phytoplankton (Table 2). Cyanobacteria contributed the highest number of species (25), followed by Chlorophyta (23), Bacillariophyta (14), Pyrrophyta (5), Chrysophyta (3) and Euglenophyta (3). The phytoplankton community in Liman lake was composed of cosmopolite, alkaliphil, saline, brackish and freshwater algal species. In temperate zones it is known that algae blooms are expected in spring and autumn (Macedo *et al.*, 2001). While Cyanobacteria dominated during the summer months, the species belonging to Chlorophyta showed maximum in autumn and autumn

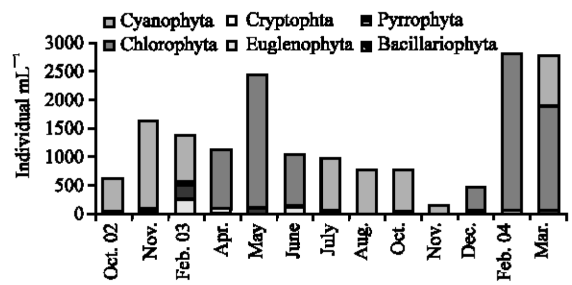

Fig. 5: Monthly variations in phytoplankton abundance

months in Liman lake (Fig. 5). *Chroococcus minutus*, *Merismopedia tenuissima*, *Phormidium tenue*, *Phormidium* sp., *Monoraphidium contortum*, *M. minutum*, *M. pusillum* were perennial dominant species in Liman lake. Phytoplankton community of Liman Lake was composed of fresh, brackish or sea water origin species. For example *Aphanezomenon flos-aquae, Anabaena circinalis*, *Chroococcus minutus*, *Microcystis aeruginosa*, *Oocystis* sp., *Euglena* sp., *Cyclotella* sp., *Synedra* sp., *Peridinium* sp. and *Wolozynskia pseudopalustris* were freshwater origin species (Hutchinson, 1967). *Phormodium*, *Spriluna*, *Merismopedia*, *Scenodesmus* sp. were euryhaline freshawater species. On the other hand *Cyclotella* sp., *Amphora ovalis* ve *Gomphonema olivaceum* have also been described as brackish or halophyte species (Remane and Schliper, 1971).

CONCLUSION

Coastal lagoons, resembling Liman lake have peculiar structural and functional characteristics as a consequence of their position between land and sea. Generally they present large spatial and temporal changes in their environmental and biological variables caused by land influence, shallow depth and strong wind action (Barnes, 1980). Drainage channel in the South side (S1) of Liman lake could have caused serious nutrient loading in the water column because strong wind action and shallow depth profile lead to easy diffusion of nutrients from S1 throughout the lake. Moreover it must also be recognized that excessive loading of ammonia may potentially pose a threat to ecological values of Liman lake due to alkaline structure of the lake. As general rule ammonia in water is present primarily as NH_4^+ and undissociated NH_4OH, the latter has highly toxic effects on many organisms, especially fish (Trussel, 1972).

The proportions of these compounds are dependent on the dissociation dynamics which are governed by pH. When pH>8, ratios of NH_4OH display an important increase in the water column (Wetzel, 1983). Therefore, excessive ammonia loading can be detrimental for ecosystem in Liman lake. According to many studies, a direct correlation is found between alkalinity and photosynthetic activity (Sreenivasan, 1964) and high bicarbonate (>100 mgL^{-1} $^{-}HCO_3^{-}$) may support high productivity. Although Liman Lake has eutrophic conditionsinsufficient orthophosphate profile in the water column was possibly restricted to primary production, because phosphorus plays a major role in biological metabolism and in comparison to other macronutrients required by biota, commonly is the first element to limit biological productivity (Wetzel, 1983).

Preliminary analysis in Liman Lake revealed that the most destructive human practice involves hydrology. Urgent and important conservation concerns are: irrigation and drainage channel projects planned and executed by the State Water Departmentand; agricultural practices that cause loading in the drainage channel. These factors have lead to negative environmental impacts on the lake.

RECOMMENDATIONS

It is suggested that strategies necessary for the conservation of the lake ecosystem should be developed and a specific water quality objective should be designed for the lake to restrict discharges of waste from the catchments area.

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