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Species diversity and distribution of Ostracoda (Crustacea) in mesosaline Lake Bafa (Aegean Region, Turkey)

Selçuk Altınsaçlı**ABSTRACT**

This study was carried out in order to determine Ostracoda fauna of Lake Bafa (Aydın-Muğla, Turkey) and investigate their distribution from 20 sites in February, May, July and September of 1997. The ostracods assemblages comprised a mixture of 14 freshwater and brackish-marine origin species. The most common and abundant species were the brackish-water ostracods *Cyprideis torosa* and *Loxoconcha elliptica*. According to Shannon-Weiner diversity index, it was found that Lake Bafa had a mean diversity value of $H' = 0.85$. The ostracod abundance showed an increase in the warmer period starting from late spring and reached maximum values in May. We analysed the dominance and distribution of ostracod assemblages and their relation to environmental factors (temperature, dissolved oxygen, pH, and salinity) by using classification and ordination techniques. Canonical correspondence analysis (CCA) was used to characterize the relationship between ostracods and the environmental variables. According to the first axis of CCA, we determined salinity to be the most important environmental variable affecting ostracod species distribution. According to Jaccard similarity coefficient (Jaccard Index) analysis results, sampling stations and ostracod species assemblage were clustered into two groups with the non-weighted pair-group method with arithmetic mean based on presence/absence of species. Besides multivariate analysis, Spearman correlation analysis indicated that some species (*Cyprideis torosa*, *Loxoconcha elliptica*, *Cytherois fischeri*, and *Leptocythere lacertosa*) had a positive correlation with salinity, whereas there are strong negative correlations between salinity and other nine species, which are, more related to freshwater environments.

Keywords: Ostracoda, Mesosaline, Ecology, Diversity, Lake Bafa, Turkey.

1. Introduction

The River Büyük Menderes (hereafter RBM) or Great Maender River Graben, a seismically active depositional basin in the North-South extensional tectonic region of western Anatolia, is one of the most important structural elements of the area. During the last 5,500 years at the RBM Graben, the former marine embayment of the Latmian Gulf has been silted up by the progradation of the RBM Delta ^[1]. Thus the ancient sea port cities of Miletos, Myous, Priene and Herakleia became landlocked and the harbours useless, which led to the decline and finally abandonment of these cities ^[1]. Silt carried by the RBM has caused the formation of lagoons, lakes and oxbow lakes. Lakes Bafa, Avşar and Azap are among the best examples of this formation. Lake Avşar is drained by DSI (State Hydraulic Works) and the land obtained by this activity is used as agricultural land. Even though Azap and Bafa lakes are not dried, they have many problems as chemical and agricultural pollution, eutrophication, use of agrochemicals increasing in the lakes basin for cotton, untreated domestic wastewater. In contrast, the catchment area of the lakes has been seen a rapid growth of agricultural activities in recent years and, as a result, dangerous and serious environmental problems have been reported regarding both Lake Bafa and Azap.

A high number of human settlements (three big cities, eight moderate size towns and many villages) are located in the RBM Graben, therefore, surface and ground waters are vital for this region. Groundwater aquifers have been used for years by many villages and towns for domestic use and for irrigation purposes. Extensive farming activities and, consequently, heavy use of fertilizers have caused soil and ground water pollution in the RBM Graben.

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In addition, many thermal springs along the fault-lines provide a good deal of boron, carbonates, sulphates and sulphurs to the streams, worsening the quality of usable water from the RBM [2].

Ostracods are small bivalved crustaceans that can be found in all types of water bodies. The small, calcified, species-specific bivalved carapaces of ostracods are easily fossilized and this feature makes them an excellent tool for Palaeobiological and Palaeoecological studies. Ostracods species give information about salinity, solute composition, temperature, flow conditions and other environmental properties of the water they inhabit. Especially, salinity has a major influence on the distribution of ostracod species. Ostracods are sensitive to changes in environmental factors and useful as indicators of water quality in different water bodies [3, 4, 5, 6]. Many studies have been done about the taxonomy of these organisms, and have given important ecological and taxonomical information about freshwater ostracod species of Europe [7]. Athersuch *et al.* [8] provided ecological and taxonomical information about marine and brackish water ostracod species of Europe. Altınsaçlı and Griffiths [9] and Altınsaçlı [10] presented a checklist of the non-marine Ostracoda fauna from Turkey.

Sediments of the RBM Delta contain a rich fossil assemblage of ostracods where 71 species were identified by Handl *et al.* [11]. Results of this study showed that faunal composition of ostracod species clearly revealed marine, brackish and limnic-fluvial facies. A palynological, microfaunal and sedimentological investigation at Lake Bafa was carried out as a contribution to the environmental history of the lower RBM valley during the later Holocene by Müllenhoff *et al.* [12] and Knipping *et al.* [13].

Only one living ostracod species (*Cyprideis torosa* hereafter CT) had been previously found at Lake Bafa by Sarı *et al.* [14] and its valves were found in lake sediments by Müllenhoff *et al.* [12] and Knipping *et al.* [13]. Besides ostracods, other 12 crustacean species [14, 15, 16, 17, 18] and three bivalvian mollusc species [19] were recorded in the lake.

There is a considerable amount of information on faunistic [14, 15, 16, 17, 19, 18, 20, 21, 22, 23, 24, 25], floristic [26, 27, 28], geographical [2, 29, 30, 31], palaeoecological [1, 11, 12, 32] and ecological [33, 34, 35, 36, 37, 38, 39] aspects of Lake Bafa and its adjacent area. These studies showed that the faunal and environmental traits of Lake Bafa changed significantly in time due to anthropogenic activities. In the present survey, bio-indicator species including ostracods were used to understand the changes affecting the lake. Much of the value of ostracods in environmental monitoring stems from their utilization in a variety of historical and palaeoecological studies.

The main objectives of our study were to establish a detailed temporal record of physicochemical characteristics of Lake Bafa, determining the ostracod species composition of the lake, evaluate the relationship between salinity and species distribution in the lake, and report the ecology, microhabitat distribution, ecological tolerances, and optimum values of individual species. Furthermore, biomonitoring the ostracod fauna of Lake Bafa would help evaluate future changes in the ecological status of the lake. Although the Grand National Assembly of Turkey started legislative activities related to nature protection laws and regulations in the 1980's, studies on wetland conservation only started in 1990's. For a majority of Turkish people, saline lakes, small lakes, swamps and marshes are considered unused fields and a source of mosquitoes. Therefore, many Turkish people regard positively the drainage of wetlands, due to a lack of understanding of the ecological importance of wetlands.

2. Materials and Methods

2.1. Site description

Lake Bafa (37°28'N and 37°32' N longitudes – 27° 22'E and 27° 32'E latitudes), which is situated within the borders of Muğla and Aydın Provinces (South Aegean Region), is located in the South RBM Basin (Figure. 1).

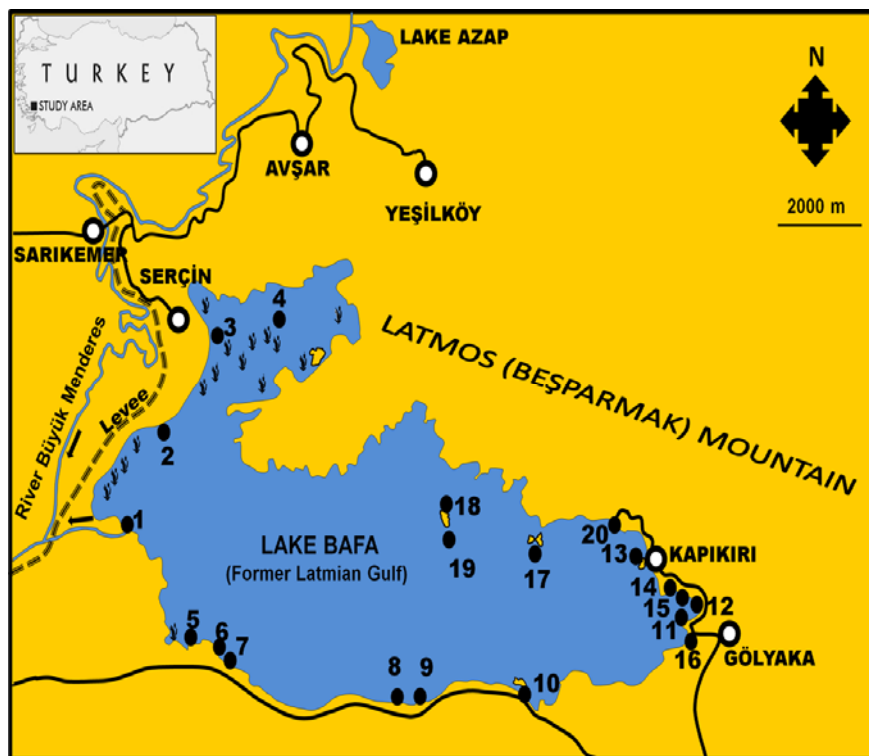


Fig. 1: Location of the Lake Bafa and twenty sampling stations around it.

The lake, formerly a bay of the Aegean Sea, became isolated from the sea as a result of alluvium blockage of the opening of the Latmian (Latmos) Gulf caused by alluvial deposits of the RBM during 50–300 AD ^[17, 29]. The mesosaline Lake Bafa, also known as Lake Çamiçi, is one of the largest coastal lakes in Turkey. Approximately during the last six millennia, the former marine embayment of the Latmian (Latmos) Gulf has been silted up by the progradation of the RBM Delta ^[12]. Due to these processes, Lake Bafa has become a brackish residual lake in the southern part of the former embayment. Lake levels fluctuate every year approximately between 1 and 2 meters. The lake has a maximum depth of 25 meters and surface area of 67-70 km² (7000 ha) ^[20, 23, 40]. At present, its altitude is 3 m a.s.l., however, Göney ^[29] reported its altitude as 10 m a.s.l. The lake area has a Mediterranean climate with hot summers and mild winters. Some small brooks arising

from the surrounding mountains and flooding over the RBM feed the lake with freshwater. The General Directorate of DSI built a stone levee between Lake Bafa and RBM in 1985 and later a canal between RBM and the lake. DSI closes this channel with soil levee in winter and spring seasons, while it opens the channel in autumn. Nowadays, because of the barrier constructed in 1985 to prevent floods in Serçin Village from the RBM, no significant inflow enters the lake from this river. A shallow bay of the lake, referred to as Lake Serçin, is situated in the northwest area of the lake water body, which completely separates from central Lake Bafa during dry periods. Halophilic species *Potamogeton pectinatus* L. is the dominant submerged macrophyte species in the lake. The lake was declared as a Natural Park area in 1994. Some characteristics of the sampling sites and details of the sampling stations of Lake Bafa are shown in Table 1.

Table 1: Lake Bafa sampling stations details and co-ordinates. **DS:** distance from the lakeshore (m). **Depth:** sampling depth (m). **B:** bottom substratum type (**M:** mud with detritus; **MS:** mud and sand with detritus; **SR:** sand and rock with detritus and algae). **V:** vegetation (**G:** shoreline with grass; **L:** *Lemna* sp. on the water surface; **Ph:** shoreline with marshes of *Phragmites* sp. and *Typha* sp.; **O:** shoreline with olive trees; **S:** submerged plants; **T:** shoreline with *Tamarix* sp.). **AF:** accompanying fauna (1: Foraminifera; 2a: Polychaeta; 2b: Oligochaeta; 3: Bivalvia *CG* (Poiret, 1789); 4: Bivalvia *MM* (Locard, 1889); 5: subfossil valves of *Dreissena polymorpha* (Pallas, 1771); 6: Isopoda; 7: Amphipoda; 8: Decapoda; 9: *Chironomus* spp. larvae). Stations numbers as in Fig. 1.

Sta. No.	Location/Region (Remarks)	Longitude E	Latitude N	DS(m)	Depth(m)	B	V	AF
1	Serçin Village, Sakız Dalyanı Region	27°21'63''	37°30'61''	1	1.5	MS	Ph	1, 2a, 3, 4, 6, 7, 9
2	Serçin Village, Sedde Önü Region	27°21'45''	37°31'05''	100	0.2-0.4	MS	-	3,6
3	Serçin Village, Sulama Kanalı Region	27°23'27''	37°32'34''	1	0.4-1.0	M	Ph	6
4	Lake Serçin	27°23'57''	37°32'37''	300	0.2-0.5	MS	-	1,3,4,6
5	Pınarcık Village, Çiftlik Region	27°23'20''	37°29'08''	5	0.5	M	Ph	4,6
6	Pınarcık Village, Kumluk Region	27°23'34''	37°29'05''	3	0.5	SR	O	4
7	Pınarcık Village, Çiftlik Region	27°24'15''	37°29'01''	3	0.5	SR	O	4
8	Çamiçi Village, Ateşler Region	27°25'20''	37°28'27''	3	0.5	SR	O	3,4, 6
9	Çamiçi Village, Ateşler Region	27°26'54''	37°28'33''	3	0.5	SR	O	3,4,5,6
10	Kahvehisar Island, Çeri'nin Yeri Region	27°29'10''	37°28'39''	1	0.4-1.0	MS	S, Ph, O	3,4,5,6,7,8
11	Gölyaka Village, Bademyanı Region	27°32'15''	37°29'26''	1	0.4-0.7	M	Ph, O	3
12	Kapıkırı Village, Otluboğaz Region	27°32'24''	37°29'46''	1	0.4-1.5	M	Ph, T	-
13	Kapıkırı Village, Sandal Taşı Region	27°31'27''	37°30'03''	1	0.4-0.5	MS	Ph, T	2a, 3, 4, 6, 7, 8
14	Kapıkırı Village, Otluboğaz Region	27°32'05''	37°29'44''	5	0.4-0.5	MS	G	1,3,4,5,6,7,8
15	Otluboğaz Reg. (lakeside pool)	27°32'10''	37°29'46''	1	0.3-0.5	M	T, L	-
16	Karadöklük Stream, Gölyaka Village,	27°32'31''	37°29'20''	1	0.4-0.5	MS	Ph, T	-
17	İkizce Island	27°29'26''	37°30'23''	100	13.0	M	-	3,4,5
18	Melekada Island	27°27'57''	37°30'41''	100	22.0	M	-	2a,3,4,5
19	Melekada Island	27°28'00''	37°30'33''	200	24.0	M	-	2b
20	Kapıkırı Village, Yazlık Region	27°30'51''	37°30'31''	100	4.0	MS	-	4,5,6,8

2.2 Data collection

Studies at Lake Bafa involved taking qualitative ostracod samples from the 20 stations throughout year 1997, in winter (22 February), spring (10 May), summer (12 July) and autumn (6 September). In shallow waters (<1 m) ostracods were collected using a plankton net (mesh size = 250 µm). In deeper water, (>1m) ostracods were collected with a custom-built 15 x 15 x 20 cm Ekman-Birge grab sampler. All samples were fixed in the field in 4% formaldehyde. In the laboratory, ostracods were separated from sediment using

four standardized sieves: 2.0, 1.5, 0.5, and 0.25 mm mesh size. Samples were stored in 1:1 70% ethanol: glycerine, and species were identified using both soft parts and carapace-based characters using standard keys ^[7, 8, 41], with systematic nomenclature following Hartmann and Puri ^[42] and Meisch ^[7]. Permanent and temporary soft part preparations were made with Canada balsam and lactophenol. Seasonal Individual numbers of ostracod species are shown Table 2.

Table 2: Individual numbers of ostracod species collected from the 20 stations at Lake Bafa in 1997.

Species and sampling dates	Stations and a number of individuals (n) of each station																			
22.02.1997	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10	St.11	St.12	St.13	St.14	St.15	St.16	St.17	St.18	St.19	St.20
<i>C. angulata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>F. fabaeformis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. pubera</i>	0	0	0	0	0	0	0	0	0	0	0	33	0	0	82	52	0	0	0	0
<i>E. mareotica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
<i>E. lilljeborgi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>E. virens</i>	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0
<i>H. incongruens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0
<i>H. salina</i>	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	11	0	0	0	0
<i>C. vidua</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0
<i>P. variegata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0	0	0	0
<i>C. torosa</i>	23	20	36	58	44	27	46	38	29	36	45	0	32	0	0	0	9	6	0	25
<i>L. lacertosa</i>	9	0	0	0	0	0	7	0	0	0	0	0	13	0	14	0	0	0	0	0
<i>L. elliptica</i>	0	12	13	9	15	12	14	12	14	16	13	0	13	12	0	0	5	0	5	12
<i>C. fischeri</i>	10	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total number of individuals	42	45	49	67	59	39	67	50	43	52	58	49	58	12	96	123	14	6	5	37
10.05.1997	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10	St.11	St.12	St.13	St.14	St.15	St.16	St.17	St.18	St.19	St.20
<i>C. angulata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	18	0	0
<i>F. fabaeformis</i>	0	0	0	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0	0
<i>C. pubera</i>	0	0	0	0	0	0	0	0	0	0	0	22	0	0	70	33	0	0	0	0
<i>E. mareotica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0
<i>E. lilljeborgi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	0	0	0	0	0
<i>E. virens</i>	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0
<i>H. incongruens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	223	0	0	0	0
<i>H. salina</i>	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	53	0	0	0	0
<i>C. vidua</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0
<i>P. variegata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	54	0	0	0	0
<i>C. torosa</i>	181	187	271	297	154	161	176	171	221	165	276	0	154	0	0	0	46	37	0	142
<i>L. lacertosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>L. elliptica</i>	81	97	104	101	111	113	108	107	106	122	0	0	42	107	0	0	12	0	10	98
<i>C. fischeri</i>	13	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total number of individuals	275	301	375	398	265	274	284	278	327	287	276	93	196	107	106	412	58	55	10	240

Table 2: continue

Species and sampling dates	Stations and a number of individuals (n) of each station																			
12.07.1997	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10	St.11	St.12	St.13	St.14	St.15	St.16	St.17	St.18	St.19	St.20
<i>C. angulata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	19	0	0
<i>F. fabaeformis</i>	0	0	0	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0	0
<i>C. pubera</i>	0	0	0	0	0	0	0	0	0	0	0	7	0	0	22	13	0	0	0	0
<i>E. mareotica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
<i>E. lilljeborgi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0
<i>E. virens</i>	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0
<i>H. incongruens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	130	0	0	0	0
<i>H. salina</i>	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	42	0	0	0	0
<i>C. vidua</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0
<i>P. variegata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0
<i>C. torosa</i>	147	159	187	161	144	150	154	149	146	145	191	0	133	0	0	0	18	12	0	135
<i>L. lacertosa</i>	11	0	0	9	13	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0
<i>L. elliptica</i>	0	63	61	60	56	67	65	64	66	83	70	0	35	67	0	0	8	0	6	62
<i>C. fischeri</i>	7	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total number of individuals	165	235	248	230	213	217	219	213	212	228	261	56	168	83	54	238	26	31	6	197
06.09.1997	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10	St.11	St.12	St.13	St.14	St.15	St.16	St.17	St.18	St.19	St.20
<i>C. angulata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>F. fabaeformis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. pubera</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>E. mareotica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0
<i>E. lilljeborgi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>E. virens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>H. incongruens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	0	0	0	0
<i>H. salina</i>	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	22	0	0	0	0
<i>C. vidua</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0
<i>P. variegata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
<i>C. torosa</i>	50	54	88	79	45	49	68	79	58	61	82	0	52	0	0	0	8	5	0	42
<i>L. lacertosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>L. elliptica</i>	0	28	26	23	25	26	23	27	29	32	28	0	0	24	22	0	6	0	4	23
<i>C. fischeri</i>	6	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total number of individuals	56	89	114	102	70	75	91	106	87	93	110	10	52	24	22	114	14	5	4	65

Physical and chemical major variables (water temperature, pH, dissolved oxygen and salinity) were measured seasonally at all sampling sites. Temperature, salinity, pH and dissolved oxygen (hereafter DO) were measured both in the surface and bottom waters (only in deep stations). pH was measured with a pH meter model of WTW in situ. The Mohr-Knudsen method [43] was used to measure salinity values from 1997 to 1999 and the Winkler method [44] for DO in 1997. Salinity was measured with a WTW model conductivity meter 330 SET and 340i multimeter during the period from 2000 to 2012 in situ. The results are shown in Table 3. Also, salinity of surface water was measured with a WTW model conductivity meter 330 SET and 340i multimeter during the period from 2000 to 2013 in situ. Global position (latitude and longitude) of sampling stations were recorded with a hand-held Lawrence model GPS.

Table 3: Seasonally measured physicochemical variables of the 20 stations of Lake Bafa in 1997. Abbreviations together with their units show that are Winter (W; 22.02.1997), Spring (SP; 10.05.1997), Summer (SM; 12.07.1997), Autumn (AU; 06.09.1997), water temperature (Temp, °C), DO (mg/L) pH, salinity (Sal, ‰), maximum (Max), minimum (Min) and standard deviations for mean values.

Station No	W	SP	SM	AU	Mean	W	SP	SM	AU	Mean	W	SP	SM	AU	Mean	W	SP	SM	AU	Mean
	DO	DO	DO	DO		Sal	Sal	Sal	Sal		pH	pH	pH	pH		Temp	Temp	Temp	Temp	
1	11,2	11,3	9,8	9,8	10,5±0,8	8,7	7,3	11,5	12,7	10,05±2,48	8,2	7,9	8,3	8,4	8,2±0,2	12	21	28	27	22±7
2	10,7	11,2	9,8	9,8	10,4±0,7	11,2	8,2	11,2	13,2	10,95±2,06	7,9	7,5	8,1	8,2	7,925±0,31	12	21	28	27	22±7
3	9,8	10,8	8,8	8,8	9,55±0,96	9,7	8,1	10,8	12,2	10,2±1,7	7,6	7,1	7,8	7,9	7,6±0,4	12	21	28	27	22±7
4	10,2	10,3	8,6	8,5	9,4±1	11,5	9,1	10,3	14,8	11,43±2,45	8,2	7,9	8,1	8,3	8,125±0,171	12	21	28	27	22±7
5	9,2	10,2	8,8	8,8	9,25±0,66	9,8	8,3	13,2	12,2	10,88±2,23	7,5	7	7,5	7,8	7,45±0,33	12	21	28	28	22,25±7,59
6	12,1	13,2	10,4	9,8	11,4±1,6	10,7	8,2	11,2	12,8	10,73±1,91	7,5	7,1	7,7	7,8	7,525±0,31	12	21	28	27	22±7
7	10,2	11,3	8,7	8,3	9,63±1,38	10,5	8,3	11,3	12,8	10,73±1,88	8,2	7,8	7,8	8,3	8,025±0,263	12	21	28	26	21,75±7,14
8	8,3	9,8	7,8	7,7	8,4±1,0	9,5	8,1	9,8	10,8	9,55±1,11	7,5	6,9	8,2	7,8	7,6±0,5	12	21	28	27	22±7
9	8,5	10,2	8,1	7,8	8,65±1,07	10,4	7,9	11,3	12,8	10,6±2,1	8,3	7,9	7,6	8,8	8,15±0,52	12	21	28	27	22±7
10	11,2	12,3	9,8	9,7	10,8±1,2	10,5	7,8	11,4	12,2	10,48±1,91	8,1	8	7,9	7,8	7,95±0,13	12	21	28	27	22±7
11	9,7	11,7	8,8	8,7	9,73±1,39	11,2	8,1	12,1	13,3	11,3±2,4	7,9	7,2	7,5	8,6	7,8±0,6	12	21	28	27	22±7
12	14	14,3	11,8	10,8	12,7±1,7	1	0,9	0,9	1,8	1,15±0,44	6,4	6,7	7,5	7,8	7,1±0,7	12	21	28	27	22±7
13	8,9	9,8	7,8	7,7	8,55±0,99	11,2	8,2	9,8	10,8	10±1	8,2	7,8	8	7,8	7,95±0,19	12	21	28	27	22±7
14	9	11	8,1	7,9	9±1	9,6	8,1	9,7	10,5	9,475±1,001	8,4	7,9	6,7	8,4	7,85±0,8	12	21	28	27	22±7
15	12,8	13,7	9,9	9,8	11,6±2	1,2	0,9	1,2	1,8	1,275±0,377	7,9	7,9	7,1	6,8	7,425±0,562	12	21	28	27	22±7
16	13,2	12,3	11,2	10,8	11,9±1,1	1	0,8	0,9	0,9	0,9±0,01	7,9	7,9	7,2	7,2	7,55±0,4	12	21	28	27	22±7
17	11,2	11,9	10,1	9,8	10,8±1	11,2	8,1	11,7	13,3	11,08±2,18	8,2	7,3	7,3	7,9	7,675±0,45	12	21	28	26	21,75±7,14
18	11,3	13,2	10,2	9,7	11,1±1,6	11,3	8,2	12	12,4	10,98±1,91	8,1	7,2	7,5	7,8	7,65±0,39	12	21	28	27	22±7
19	12,3	13,7	9,8	9,7	11,4±2	9,7	7,7	11,7	13,8	10,73±2,62	8,3	7,4	8,2	8,6	8,125±0,512	12	21	28	27	22±7
20	9,8	10,7	8,2	7,9	9,15±1,33	10,8	7,8	10,8	12,7	10,53±2,03	7,9	7,1	8,1	7,9	7,75±0,44	12	21	28	27	22±7
Mean	10,68±1,61	11,6±1,4	9,33±1,13	9,09±1,00	10,2±1,2	9,035±3,514	7,005±2,667	9,64±3,82	10,9±4,25	9,151±3,505	7,91±0,45	7,475±0,419	7,71±0,42	7,995±0,475	7,771±0,29	12±0	21±0	28±0	26,95±0,39	21,99±0,1
Max	14	14,3	11,8	10,8	12,7±1,7	11,5	9,1	13,2	14,8	12,15±2,44	8,4	8	8,3	8,8	8,4±0,3	12	21	28	28	22,25±7,59
Min	8,3	9,8	7,8	7,7	8,4±1,0	1	0,8	0,9	0,9	0,9±0,1	6,4	6,7	6,7	6,8	6,6±0,2	12	21	28	26	21,75±7,14

Qualitative ostracods samples were taken seasonally during one year (i.e. seasons of spring, summer, autumn and winter in 1997). Seasonal distributions of ostracod species, maximum and minimum ranges of some physiochemical variables in the lake water and

frequency rate of species presence of Lake Bafa are shown in Table 4. Living Ostracoda species database of seasonal samples from the 20 stations of Lake Bafa.

Table 4: Seasonal distributions of ostracod species, maximum and minimum ranges of some physiochemical variables and frequency rate of species presence of Lake Bafa. Symbol of frequency is shown “F” and the all abbreviations are mentioned before.

Species	Spring (S _n)	Summer (S _n)	Autumn (S _n)	Winter (S _n)	pH Min- Max	DO (mg/L) Min-Max	Salinity (‰) Min- Max	Temp. (°C) Min-Max	Station Number	F (%)	Sediment Type
CA	22	22	-	-	7.2-8.1	9.7-13.2	0.8-12.4	12.0-28.0	16, 18	10	Mud. Sandy Mud
FF	23	23	-	-	6.4-7.8	10.8-14.3	0.9-1.8	12.0-28.0	12	5	Mud
CP	125	42	-	167	6.4-7.9	9.8-14.3	0.9-1.8	12.0-28.0	12, 15, 16	15	Mud. Sandy Mud
EM	15	10	5	2	7.2-7.9	10.8-13.2	0.8-1.0	12.0-28.0	16	5	Sandy Mud
EL	36	32	-	-	6.8-7.9	9.8-13.7	0.9-1.8	12.0-28.0	15	5	Mud
EV	16	13	-	12	6.4-7.8	10.8-14.3	0.9-1.8	12.0-28.0	12	5	Sandy Mud
HI	223	130	70	20	7.2-7.9	10.8-13.2	0.8-1.0	12.0-28.0	16	5	Sandy Mud
HS	85	55	32	15	6.4-7.9	10.8-14.3	0.9-1.0	12.0-28.0	12, 16	10	Mud. Sandy Mud
CV	30	25	7	5	7.2-7.9	10.8-13.2	0.8-1.0	12.0-28.0	16	5	Sandy Mud
PV	54	15	10	33	7.2-7.9	10.8-13.2	0.8-1.0	12.0-28.0	16	5	Sandy Mud
CT	2639	2031	820	474	8.8-6.9	7.7-13.2	7.3-14.8	12.0-28.0	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 17, 18, 20	75	Mud. Sandy Mud, Stone
LL	-	49	-	43	8.4-7.0	7.9-11.3	7.3-14.8	12.0-28.0	1, 4, 5, 7, 13, 14, 15	35	Sandy Mud
LE	1319	833	346	177	8.8-6.9	7.7-13.2	7.7-14.8	12.0-28.0	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 17, 19, 20	85	Mud. Sandy Mud, Stone
CF	30	20	13	23	7.5-8.2	9.8-11.2	8.2-13.2	12.0-28.0	1, 2	10	Sandy Mud

Secchi disc transparency values were measured 85 cm in July 1997, 120 cm in October 1997, 230 cm in February 1997 and 175 cm in May 1997 at the deep stations of 17, 18 and 19.

2.3. Statistical analysis

The (log₂) Shannon-Weaver diversity index (H') [45], was calculated for each sample based on number of individuals of each ostracod species found. Binary (presence-absence) data was used to show relationships among species using the Jaccard similarity coefficient and non-weighted pair group mean averages (hereafter UPGMA) analysis provided by the program Multivariate Statistical Package Version 3.1 [46].

Canonical Correspondence Analysis (hereafter CCA), a gradient analysis technique, was used to examine the relationship between environmental variables and species [46, 47, 48, 49]. In the ordination procedure, 4 physicochemical variables of pH, DO, water salinity and air temperature were used.

Correlations between species and environmental variables were analysed with two-tailed nonparametric Spearman Correlation analysis performed with SPSS 10.0 software program [50]. Significant results were determined at 0.01 and/or 0.05 critical levels.

3. Results

During the 1997 sampling periods, 10191 individuals belonging to 11 genera and 14 taxa were collected from the 20 stations (See Table 2). A list of the 14 ostracod taxa and individual numbers of ostracod species collected from the study area is given in Table 2. Physical and chemical data are provided in Table 3. Secchi disc

transparency values were measured 85 cm in July 1997, 120 cm in October 1997, 230 cm in February 1997 and 175 cm in May 1997 at the deep stations of 17, 18 and 19. Water temperature showed seasonal pattern with maxima 28 °C during the summer months and minima 12 °C during the winter. Salinity in the lake was at its maximum in summer and autumn months while the lowest values recorded in the winter and spring months and pH values did not change seasonally in the lake (See Table 3). DO level at the station 18 was measured at 9.7-13.2 mg/L in the surface waters and 1.5–2 mg/L at 22 m depth.

During the study, a total of 10191 ostracod specimens belonging to 14 species from the 20 stations were identified. The most common species at Lake Bafa was the brackish water species *Loxoconcha elliptica* (LE) Brady, 1868 (17 sites, 85%), followed by *Cyprideis torosa* (CT) (Jones, 1850) (15 sites, 75%), *Leptocythere lacertosa* (LL) (Hirschmann, 1912) (7 sites, 35%), *Cypris pubera* (CP) O.F. Müller, 1776 (3 sites, 15%), *Candona angulata* (CA) G.W. Müller, 1900 (2 sites, 10%), *Heterocypris salina* (HS) (Brady, 1868) (2 sites, 10%), *Cytherois fischeri* (CF) (Sars, 1866;) (2 sites, 10%). The remaining species were found only in 1 site: *Fabaeformiscandona fabaeformis* (FF) (Fischer 1851), *Eucypris mareotica* (EM) (Fischer, 1855), *Eucypris lilljeborgi* (EL) (G.W. Müller, 1900), *Eucypris virens* (EV) (Jurine, 1820), *Heterocypris incongruens* (HI) (Ramdohr, 1808), *Cypridopsis vidua* (CV) (O.F. Müller, 1776) and *Potamocypris variegata* (PV) (Brady & Norman,

1889). The most abundant species at Lake Bafa was the brackish water species *CT* (5964 specimens, 58.5 %) followed by *LE* (2675 specimens, 26.3 %), *HI* (443 specimens, 4.35%), *CP* (334 specimens, 3.28%), *HS* (187 specimens, 1,8 %) and *PV* (112 specimens, 1,1%). The total abundance of the remaining species was always below 100 individuals (<1%).

Based on species occurrences, two main groups resulted from cluster analysis (see Figure 2). The first group includes four

brackish water species (*CT*, *LE*, *LL* and *CF*) and one freshwater species (*EL*). The second group includes nine species, three of them are cosmopolitan species that tolerate slightly saline environments (*EV*, *CV* and *HI*), one species (*PV*) clearly prefer freshwater habitats, three species (*CA*, *HS* and *EM*) of this group have very good tolerance of saline environments, and another two species (*CP* and *FF*) can be adapted to slightly saline conditions. Abbreviations for each species are given in Table 4.

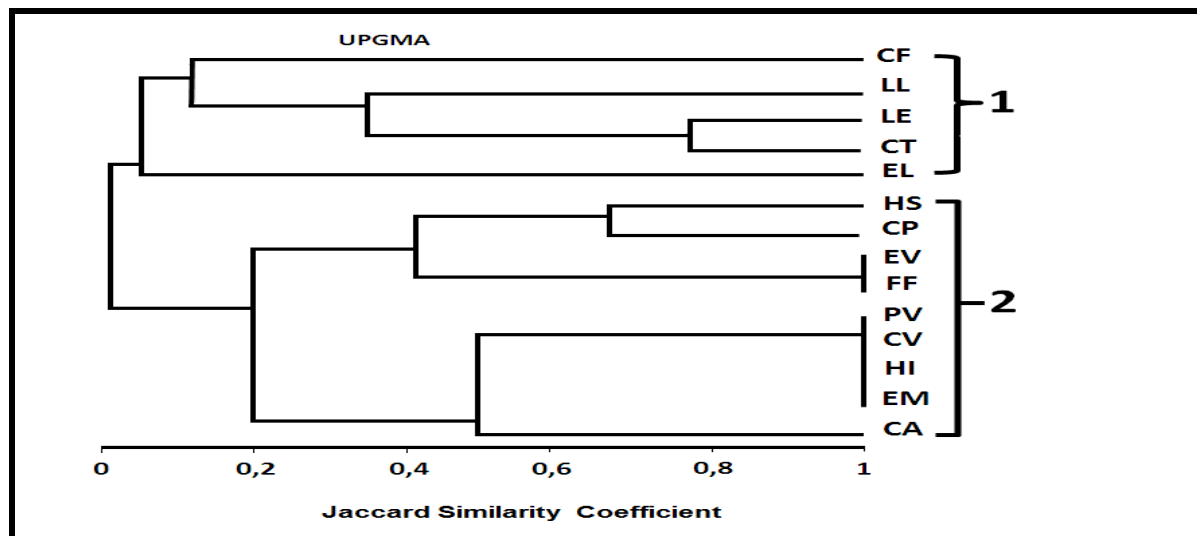


Fig 2: Dendrogram resulting from UPGMA clustering (using Jaccard index) of 14 ostracod species from Lake Bafa. Two main species groups (1 and 2) are shown in the figure.

Dendrogram provided from binary (presence/absence) data along with Jaccard similarity index (coefficient) shows the results of UPGMA for the relationships among the 20 stations (Figure 3). Based on their occurrence, two main groups are clustered. The first group includes brackish (oligosaline) station water stations of 12, 15 and 16). Freshwater species were determined from these

stations. Although these conditions are mesosaline conditions are well tolerated by some freshwater species like the 18th station. Therefore, the station 18 has been included in the first group. Second group includes completely brackish (mesosaline) water (from 1 to 11, 13, 14, 17, 19 and 20). And typically ostracods species were found these stations.

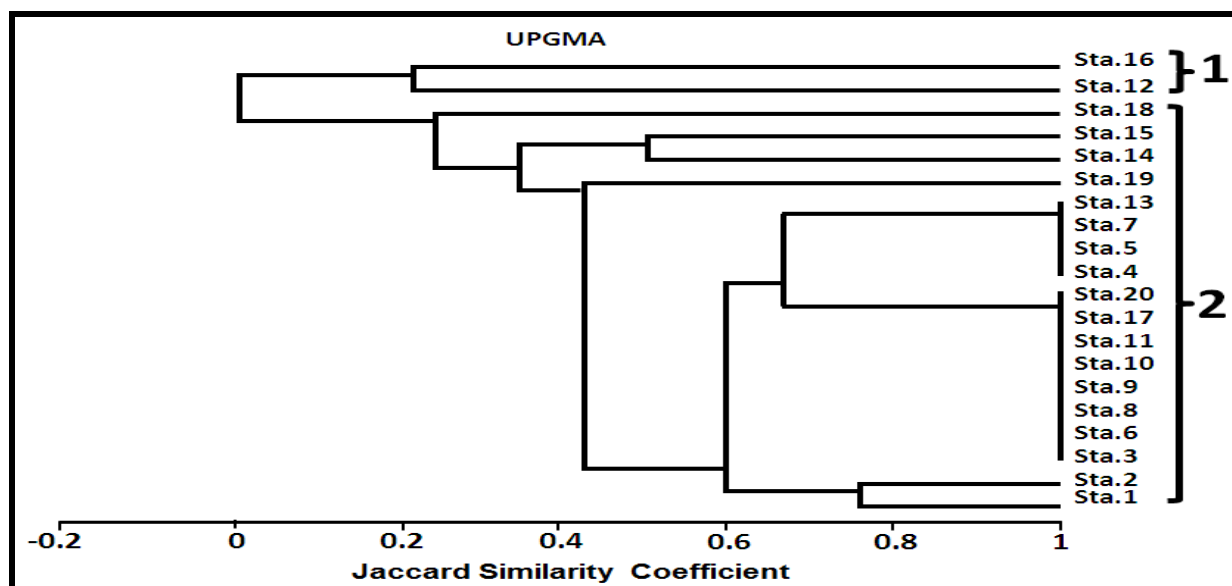


Fig 3: UPGMA dendrogram of sampling stations and from Lake Bafa based on ostracod species presence (Jaccard index).

Seasonal changes in diversity of species at stations are shown in Table 5 and figure 4. According to the Shannon-Weaver diversity index, freshwater input stations (oligosaline or slightly saline) have a rich diversity. The salinity of Lake Bafa was a limiting factor for ten species as determined in this study.

Stations	22.02.1997			10.05.1997			12.07.1997			06.09.1997		
	S	n	H (S) index	S	n	H (S) index	S	n	H (S) index	S	n	H (S) index
Sta. 1	3	42	1.44	3	275	1.12	3	165	0.60	2	56	0.49
Sta. 2	3	45	1.55	3	301	1.19	3	235	1.12	3	89	1.25
Sta. 3	2	49	0.83	2	375	0.85	2	248	0.80	2	114	0.77
Sta. 4	2	67	0.57	2	398	0.82	3	230	1.05	2	102	0.77
Sta. 5	2	59	0.82	2	265	0.98	3	213	1.13	2	70	0.94
Sta. 6	2	39	0.89	2	274	0.98	2	217	0.89	2	75	0.93
Sta. 7	3	67	1.18	2	284	0.96	2	219	0.88	2	91	0.82
Sta. 8	2	50	0.80	2	278	0.96	2	213	0.88	2	106	0.82
Sta. 9	2	43	0.91	2	327	0.91	2	212	0.89	2	87	0.92
Sta. 10	2	52	0.89	2	287	0.98	2	228	0.95	2	93	0.93
Sta. 11	2	58	0.77	1	276	0.00	2	261	0.84	2	110	0.82
Sta. 12	3	49	1.18	4	93	1.96	4	56	1.88	1	10	0.00
Sta. 13	3	58	1.44	2	196	0.75	2	168	0.74	1	52	0.00
Sta. 14	1	12	0.00	1	107	0.00	2	83	0.71	1	24	0.00
Sta. 15	2	96	0.60	2	106	0.92	2	54	0.98	1	22	0.00
Sta. 16	6	123	2.06	7	412	2.05	7	238	2.01	5	114	1.64
Sta. 17	2	14	0.94	2	58	0.74	2	26	0.89	2	14	0.99
Sta. 18	1	6	0.00	2	55	0.91	2	31	0.96	1	5	0.00
Sta. 19	1	5	0.00	1	10	0.00	1	6	0.00	1	4	0.00
Sta. 20	2	37	0.91	2	240	0.98	2	197	0.90	2	65	0.94

Table 5: Seasonal changes in ostracod species diversity for each sampling station. Abbreviations: total number of species (S), the total number of individuals (n) and species diversity (Shannon-Weaver index H(s)).

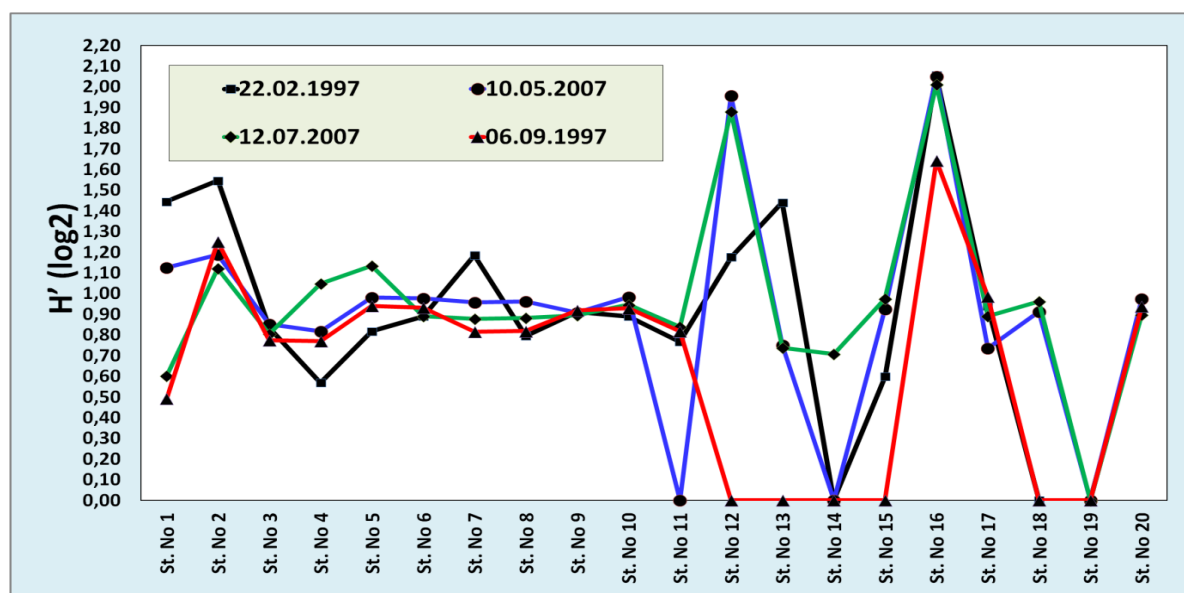


Fig. 4: Time series of Shannon-Weaver diversity index

According to results of the Shannon-Weaver diversity index, freshwater input stations (oligosaline or slightly saline) have a rich diversity according to the mesosaline stations at Lake Bafa (see Table 5 and Figure 4). The highest diversity was found in the station 16 (H' value of 2.06). The salinity rate of Lake Bafa was a

life-limiting factor for ten species (CA, FF, CP, EM, EL, EV, HI, HS, CV and PV) as determined in this study.

Spearman rank correlation matrix for four environmental variables and fourteen ostracod species are shown Table 6.

Table 6: Spearman correlation between four environmental variables and species analyzed. Numbers indicate strong correlations (*p<0.05, **p<0.01). Abbreviations are the same in Tables 2 and 4.

	DO	Salinity	pH	Temp.	CA	FF	CP	EM	EL	EV	HI	HS	CV	PV	CT	LL	LE	CF
DO	1																	
Salinity	-0,620**	1																
pH	-0,374**	0,510**	1															
Temp.	-0,408**	0,154	-0,033	1														
CA	0,172	-0,024	-0,149	0,074	1													
FF	0,280*	-0,350**	-0,225*	0,063	-0,030	1												
CP	0,492**	-0,631**	-0,115	-0,212	-0,004	0,116	1											
EM	0,188	-0,425**	-0,081	0,048	0,150	-0,031	0,252*	1										
EL	0,168	-0,343**	-0,083	0,058	-0,030	-0,026	0,484**	-0,031	1									
EV	0,386**	-0,426**	-0,372**	-0,043	-0,037	0,856**	0,223*	-0,038	-0,031	1								
HI	0,183	-0,413**	-0,074	0,048	0,15	-0,030	0,245*	0,998**	-0,030	-0,037	1							
HS	0,329**	-0,585**	-0,215	0,058	0,115	0,371**	0,303**	0,885**	-0,043	0,348**	0,878**	1						
CV	0,188	-0,419**	-0,082	0,047	0,154	-0,031	0,258*	0,990**	-0,030	-0,037	0,981**	0,881**	1					
PV	0,248*	-0,425**	-0,011	-0,066	0,118	-0,031	0,391**	0,864**	-0,031	-0,038	0,865**	0,759**	0,842**	1				
CT	-0,172	0,213	-0,065	0,228*	-0,132	-0,155	-0,282*	-0,187	-0,154	-0,189	-0,181	-0,259*	-0,184	-0,187	1			
LL	-0,087	0,017	0,017	-0,074	-0,061	-0,052	0,188	-0,062	-0,052	-0,063	-0,061	-0,087	-0,062	-0,063	-0,044	1		
LE	-0,112	0,125	-0,161	0,195	-0,170	-0,145	-0,265*	-0,175	-0,145	-0,177	-0,170	-0,243*	-0,173	-0,176	0,745**	-0,045	1	
CF	0,080	0,072	0,136	-0,042	-0,059	-0,050	-0,092	-0,061	-0,050	-0,061	-0,059	-0,084	-0,060	-0,061	0,160	0,070	0,099	1

The results show two strong negative correlations between DO and salinity ($p<0.01$) and between temperature ($p<0.01$) and pH ($p<0.01$) and also a strong positive correlation between salinity and pH (0.510). Some strong negative correlations are shown among salinity and *CP*, *HP*, *EP*, *PV*, *EM*, *CV*, *HI*, *FF*, *EL* and *CA*. Although the last three species show the weak correlations than the others. The correlations were positive among salinity and *CT*, *LE*, *CF* and *LL* (see Table 6). The results of Spearman correlation analysis show a strong positive correlation between *HI* and *EM* ($p<0.01$). Strong positive correlations are shown between typical

brackish species *CT* and *LE* ($P<0.01$) (see Table 6).

According to results of Spearman correlation analysis four positive relationships are shown among salinity and in the distribution of four typical mesohalophilic brackish-marine species (*CT*, *LL*, *LE* and *CF*), and some strong negative relationships are shown among salinity and eight non-marine halophilic freshwater species (*CA*, *FF*, *CP*, *EM*, *EV*, *HI*, *HS* and *CV*) and two freshwater species (*EL* and *PV*) (see Table 6). In our study CCA analysis showed that the distribution patterns of Ostracoda species assemblages are strongly related with the environment in Figure 5 and Table 7.

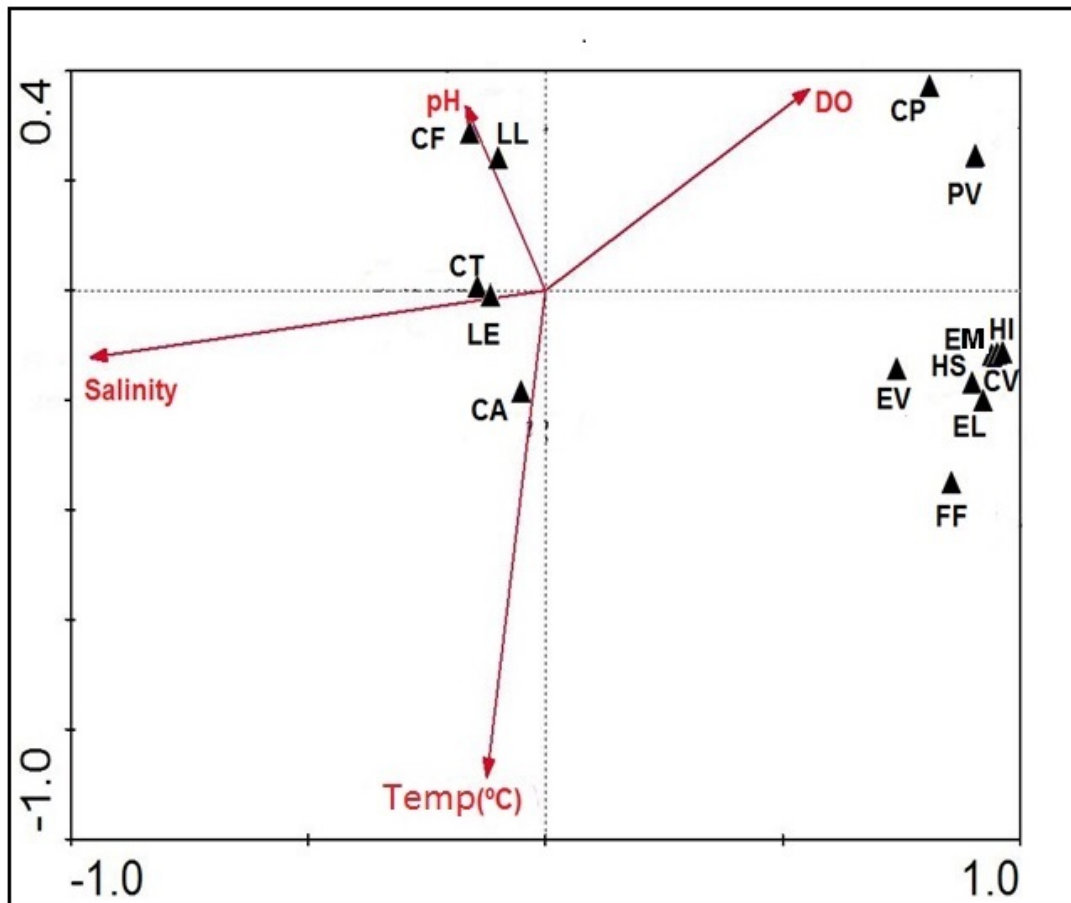


Fig. 5: CCA diagram, showing the relationships between four environmental variables and 14 ostracod species. The environmental variables are represented by arrows and abbreviations are the same meaning in the text and tables.

Table 7: Main results from the CCA analysis.

Axes	1	2	3	4	Total inertia
Eigenvalues:	0.798	0.058	0.041	0.010	3.328
Species-environment correlations:	0.901	0.418	0.294	0.235	
Cumulative percentage variance of species data of species-environment relation:					
Sum of all eigenvalues:	24.0	25.7	27.0	27.3	3.328
Sum of all canonical eigenvalues	88.0	94.3	98.9	100.0	0.907

Water salinity and temperature were statistically significant ($p < 0.01$) in explaining variation in the distribution of ostracod assemblages. Canonical analysis of the presented calibration dataset revealed salinity as the main environmental variable which controls ostracod distribution in the studied lake. The species of *CT*, *LE*, *CF*, *LL* and *CA* are located near the center in the Figure 5.

But the relation seems to be high salinity on the negative side of the first ordination axes in CCA diagram. According to CCA results, positions of the other species on the CCA diagram indicate a strongly negative interaction between them and salinity. The salinity has changed in time of from 1957 to 2012 years at Lake Bafa that is shown in the Figure 6.

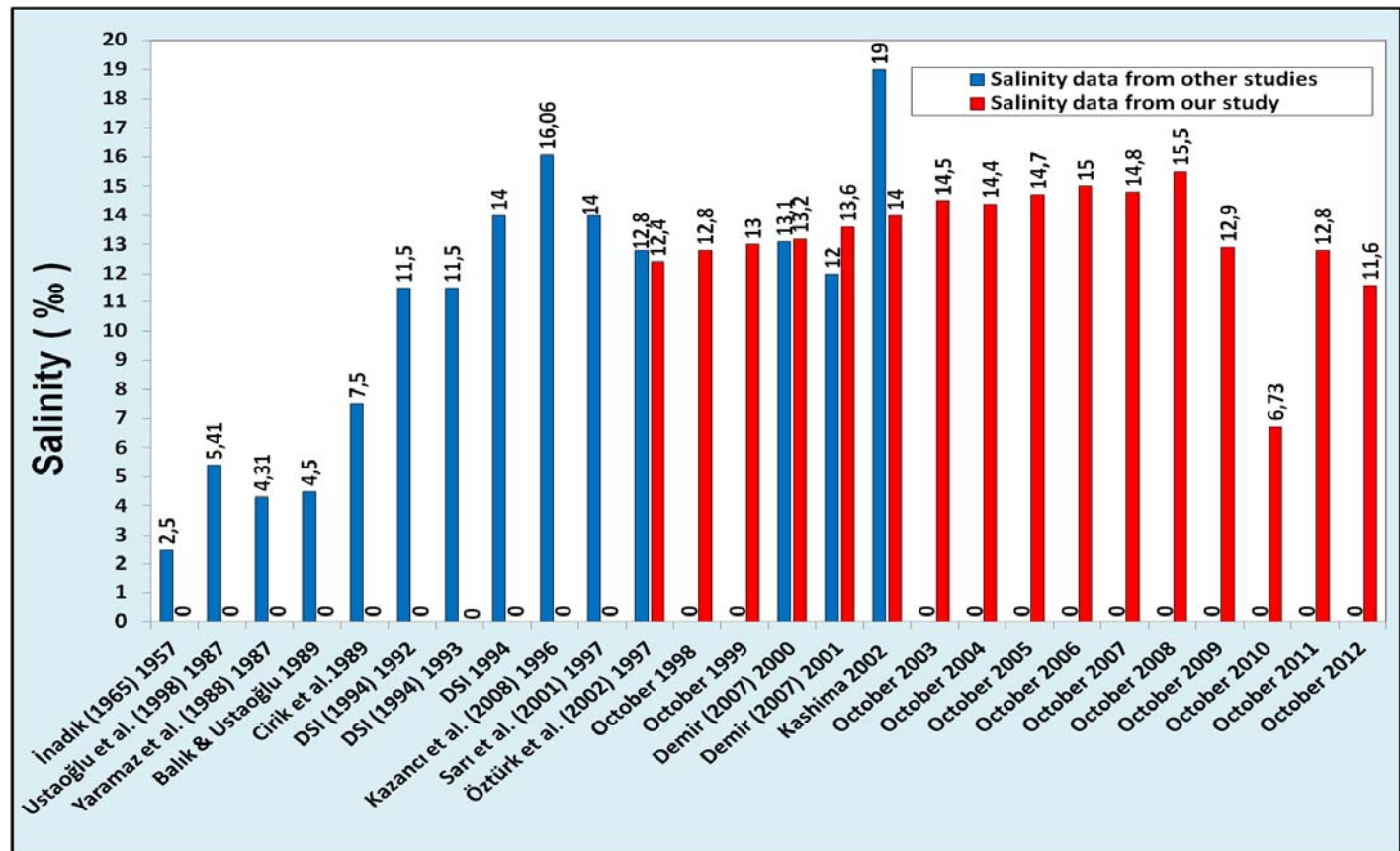


Fig. 6: Time-series of historical salinity levels of the Lake Bafa (1957–2012). The salinity rate changes in time at Lake Bafa.

The salinity measurements from this study together with other studies have shown that the salinity has increased at Lake Bafa in the time. Limnological research report of DSI [40] on Lake Bafa includes salinity measurements results belonging to 1993 and 1994 years.

4. Discussion

In this study four ostracod species (*LL*, *CF*, *CT* and *LE*) from the total number of 14 were found inhabit brackish water conditions, such as estuaries and lagoons. However, the other ten species were found in fresh and slightly saline water, as expected from the literature [7]. The most common species at Lake Bafa were the brackish water species of *LE*, *CT* and *LL*. The main reason for these species being prevalent in the lake is that these halophilic species can easily tolerate the brackish water habitats of the lake. Especially, the mesosaline northern, southern and western parts of the lake contain suitable habitats for these species. *LE*, *CT*, *CF* and *LL* have been recorded in previous studies from different lagoons [10, 51; 52 53; 54; 55, 56].

In water with low salinity (<5 ‰) *CT* valves have often nodes [57, 58, 59; 60]. *CT* is regarded as ecophenotypical forms of a single species [7], the smooth specimens (*Cyprideis torosa* forma *littoralis*) and

noded specimens (*Cyprideis torosa* forma *torosa*). Smooth specimens (*Cyprideis torosa* forma *littoralis*) of *CT* outnumber from noded specimens were found in Lake Bafa. In addition to the established transfer function, the affinity of noded specimens of *CT* to oligohaline and slightly mesohaline water bodies is once more confirmed.

CA prefers slightly saline water and it is commonly seen in brackish coastal ponds, ditches and river mouths with a salinity of 0.2-14 ‰ [7]. *CA* was found in oligosaline (0.8-1‰) water of Karadöklük Stream. The physicochemical conditions of Karadöklük Stream are suitable for supporting this species. However, only carapaces of this species were found in salinity range between 7.2 and 12.4 ‰ (mesosaline water) in depths of 22 m of Melek Island coast at the station 18. Bivalvian mollusc species *Mytilaster marioni* Locard, 1889, living forms of chironomid larvae and a polychaetan (*Nereis* sp.) species were found together with *CA* at the station 18.

FF was reported at a maximum of 8.1 ‰ in the salinity range. *FF* was found only in oligosaline water (0.9-1.8‰) of the station 12 which was well agrees with the results reported by Vesper [61].

CP was found in freshwater during spring, summer and winter seasons. This species is frequently seen in the spring season. Lake

Bafa Region has rainy and cool weather conditions during winter season. Therefore, *CP* has dense population in winter. Stephanides [62] reported that it had a maximum salinity range of 5 ‰. But in this study it was only found in oligosaline water (0.9-1.8‰) in Lake Bafa in spite of the incidence of *CP* with preference for brackish waters and also inhabiting pure freshwaters.

CA, *HS*, *HI* and *CV* were generally reported by many researcher in freshwater, but *CA*, *HI*, *HS*, *HI* and *CV* were reported that had salinity ranges (‰) of 7.5-12.4 [7], 1-20 [63], 1-20 [7] and 8 [64] in oligo-mesohaline waters, respectively. Therefore, *CA*, *HS*, *HI* and *CV* can easily become adapted to mesosaline waters which are seen at Lake Bafa.

FF, *CP*, *EL*, *EV* and *PV* were detected in oligosaline waters of Lake Bafa. *FF*, *CP*, *EL*, *EV* and *PV* previously preferred freshwater condition, whereas they were also reported in oligo-mesosaline water bodies [7, 61, 62, 64]. *EL* was found in oligosaline waters (0.9-1.8 ‰) of Lake Bafa. No salinity tolerance of *EL* has been reported.

CT like *EM* is well adapted to brackish and hypersaline water. *EM* (synonym of *Eucypris inflata*) was reported in both saline and pure freshwater by Bronshtein [41] and it clearly prefers high salinity and Na-Cl dominated waters [65]. *CT*, *LL* and *CF* were commonly reported in brackish water of coastal lagoons [8].

LE is known from Pontocaspian and the Boreo-Mediterranean region [8]. *LL* is a typical brackish water species [8]. In addition, this species was found in Lake Bafa in a salinity range between 8-18.2 ‰. Meanwhile, *CT* and *LE* were commonly found at Lake Bafa in a salinity range between 2.5 –13‰.

Brackish-fresh water gastropod species *Potamopyrgus jenkinsi* (Smith, 1889) was found at the stations of 1, 2, 4, 8, 9, 10, 11, 13, 17 and 18. *Potamopyrgus jenkinsi* are highly eurybiontic (highly tolerant to drying and variations in oxygen concentration and salinity) [66]. The bivalvian mollusc species *Cerastoderma glaucum* (hereafter *CG*; Poiret, 1789) was found at the 10 stations mentioned above. The lagoon cockle *CG* is distributed in the Mediterranean Sea and the eastern Atlantic where it inhabits the sandy and muddy bottoms of the upper sublittoral zone in coastal areas and particularly various types of transitional water ecosystems such as estuaries, lagoons, salt marshes and saltworks [67]. *CG* is found in the soft sediments of lagoons and estuaries. Adults usually burrow in soft shallow sediments. Another bivalvian mollusc species *Mytilaster marioni* (Locard, 1889) was found at the stations of 1, 4, 5, 6, 7, 8, 9, 10, 13, 14, 17, 18 and 20. *MM* was accepted as euryhaline species [68]. We found many subfossil valves of the *CG* and *Potamopyrgus jenkinsi*. Living individuals of the species have been rarely found in the present study. Pérès & Picard [68] reported that this species was a characteristic species of euryhaline and eurytherm lagoonal biocenosis in coastal lakes and estuaries, and it occurs in mesosaline and hyposaline coastal lakes. *MM* is the most common and dominant molluscs of the lake and living individuals of this mollusc species are much more seen than in other mollusc's species in Lake Bafa.

CF was found at the stations of 1 and 2 during all seasonal sampling. It was found in waters that had salinity range of 8–31.1 ‰ in the lake.

Both *CT* and *LE* are typical brackish water species and their dominance in this lake that this indicates the increasing salinity trend at Lake Bafa. There were commonly and abundantly these species in the lake. Because Lake Bafa shows typical lagoon characteristics with its measured salinity range. And these species are typical brackish water forms and euryhaline species. The

occurrence of *CT*, *LE* and *CF* in this lake was not surprising given their presence in coastal brackish waters of Turkey [10].

Salinity and temperature have been suggested as primary factors constraining ostracod ecology and distribution [60]. The most important environmental gradients in the studied sites within Lake Bafa were highly related to salinity according to the CCA results in Table 7 (axis 1). The salinity measurements absolutely indicate that the salinity increased at Lake Bafa from 1992 to 2008. According to these findings the salinity of Lake Bafa has increased rapidly in a short time. In some years sufficient water was not given to the lake from the RBM by DSI. And in dry periods of these years the salinity gradually increased by evaporation. These salinity changes might have strongly affected the distribution and composition of ostracods, other fauna and local informants in the lake. In this way, according to local fishermen, the population of Ulubat fish (*Acanthobrama mirabilis* Ladiges, 1960) collapsed in 1987, so as the freshwater turtles and decapods. Similarly, the population of zebra mussel (*Dreissena polymorpha* Pallas, 1771) collapsed in 1989. *D. polymorpha* colonizes lakes, rivers and brackish lagoons. Recently, the species has only been found in sub-fossilized valves in the sediments of Lake Bafa. The populations of freshwater turtles and crabs also collapsed in 1987. Although some fishermen claim that Blue Crab (*Callinectes sapidus* Rathbun, 1896) lived in the lake, in this study, this species was not found to be present in the lake. The population of common carp fish (*Cyprinus carpio* Linnaeus 1758) only lives in the water channel connecting the lake to the RBM. The survival of marine fish species, which escapes into the lake coupled with the death of slightly brackish water algae, indicates that the salinity of Lake Bafa is increasing.

Seriously declines in the eel (*Anguilla anguilla* Linnaeus, 1758) population was confirmed by Local fishermen. The increased salinities have resulted in the death of algae (*Cladophora* sp.) that this is only tolerated low salinities. As the algae decomposes bacterial levels in the water increase. Thus, oxygen concentration depletes. Many small species of fishes find refuge towards predators in the algae habitat. Therefore, the loss of this habitat has resulted in the loss of many species depending on the algae. Usually, in the summer months the DSI opens a channel to allow the input of freshwater from the RBM into Lake Bafa. However, in the year 2000 this canal remained close leading to further increases in the salinity. In 2000, the salinity level was measured at approximately 18.2‰. The salinity is at present an environmental variable showing seasonal stability for a large section of the lake; hence, halophilic and euryhaline species *CT* and *LE* have a widespread distribution in the lake. *CT* and *LE* have shown wide tolerance limits for physicochemical variables such as salinity, temperature, DO and pH. Therefore, these two species are common and dominant at Lake Bafa.

The shallow north western section (called Lake Serçin) of Lake Bafa has a high salinity due to evaporation in summer and autumn months. Salinities were measured at 31.1‰ (almost as saline as seawater) in this part of the lake in the summer and autumn of 1998. The cause of increase in the salinity rate was evaporation. Therefore, Lake Bafa can be categorized as a mixohaline water body. A large part of the lake is now mesosaline (5-20 ‰) and some parts of lake are even polysaline (20-30 ‰) or eusaline (30-40‰) during summer and autumn, as Lake Serçin.

RBM is a heavy polluted river. DSI opened the outlet canal of Lake Bafa in autumns of 2001 and 2002, and polluted waters of the RBM flowed to Lake Bafa. Therefore, a dense algal bloom was clearly observed by Altınışağı (unpublished data) in the lake waters

in autumn of 2001 and 2002. And in the meantime light green colour waters of the lake are changed into reddish brown. Unfortunately, the natural balance of Lake Bafa has been extensively damaged by anthropogenic effects, eutrophication being at present a major problem causing high fish mortalities in certain periods. Before RBM alluvium deposits separated Lake Bafa from the Aegean Sea, the ancient Latmian Bay had a salinity rate range of 28-38‰ as in the Aegean Sea. The researcher determined a test borehole that contained ground water with salinity of 28.4‰ at a depth of 30–40m. In the present study, a water sample was determined at salinity of 28.4‰, taken from a depth of 20-30 m of the borehole used by marine fish farms. The evidence from this saline borehole water confirmed the theory that Lake Bafa was a part of the former Latmian Bay. On the other hand, these measured salinity rates can be considered as a sign of the seawater intrusion to ground waters of Söke coastal plain.

Either ground waters belonging to the former Latmian Gulf or probably waters of Aegean Sea can reach to permeable alluvial layers of the RBM Basin and to ground waters by way filtration. Also alluvial layers of the RBM Basin are suitable for groundwater storage. Data from borehole water samples indicate that ground waters are at risk of salinisation due to the seawater intrusion.

Seventy one ostracod species (62 marine, 5 brackish and 4 freshwater) in Holocene sediments of the RBM delta plain were reported by Handl *et al.* [11]. Among these, *CT* was reported as the dominant ostracod species in this palaeogeographical study by Handl *et al.* [11]. The same species was reported in sediments of Lake Bafa by Akçer [37]. This two views can be argued that about the presence of the *CT*, *LE*, *LL*, *CF*, *CG* and *MM* in Lake Bafa. These species can be to come to Lake Bafa in the near past or only *LL* and *CF* can be recently to come to the Lake. Subfossil shells of *CT*, *LE* and *CG* are widespread up to 25 cm thick in the lake sediments. Lake sediments contain dense dead assemblages of *CT* and *LE*, together with foraminiferal species (*Haynesina* sp., *Ammonia beccari*). And mollusc *Ammonia beccari* (Cushman 1926) can tolerate salinities of up to 50‰, low oxygen for several days and low and high temperatures (0-35°C) [69]. However, *LL* and *CF* species were not seen in the top sediment layer of the lake. Therefore, it can be stated that these two species recently came into this water body. Many marine and brackish water species were transferred through a man-made channel connecting the lake to RBM.

Recently, salinity increase, lack of oxygen, hypoxic waters, anthropogenic pollution and insufficient water sources are bringing about very serious environmental problems at Lake Bafa. If the competent institutions of the state do not take necessary precautions, these negative events will be increasingly continuing in future. The sedimentological and palynological investigation of Müllenhoff *et al.* [12] has already proved human impacts (strong morphodynamic and palaeogeographical changes) on the natural ecosystem of Lake Bafa.

According to provided measurement results at the station 18 in 2008, the surface water temperature of the lake decreased in the deeper parts of the lake. The temperature difference between surface water and deep water was 11 °C. Although the amount of DO was high in surface waters of the lake, this ratio was low (0.7 mg/L) in deep waters of the lake. The measured low oxygen values of bottom waters of the lake indicate that is dominated by anoxic and anaerobic conditions in bottom waters of lake from time to time.

According to observations of the local scuba divers, there is very

low visibility at the bottom of the lake. Divers said that they saw a layer of particles (shape-shifting, sometimes thick) in the bottom of lake, and good visibility conditions of winter period.

Around Lake Bafa is an important olive and olive oil production area. The little olive oil factories in the Pınarcık and Çamiçi town also produce a toxic wastewater which is known as “black water” among the public. This toxic water is discharged to a little creek that flows to Lake Bafa

A fish breeding (*Sparus aurata*, L. 1758 and *Dicentrarchus labrax* L. 1758) facility was established by the private sector in the southwest of the lake. This facility is obtaining water from an artesian well 35 meters deep which provides necessary waters for fish breeding. The salinity level of this artesian well water was measured at 29 ‰. This salinity and depth of the artesian wells show that sea water is entering this region or that this groundwater at this depth contains salinity rates of 29 ‰ in both the past and present. Hakyemez *et al.* [70] found that the coastline of the Aegean Sea reached to the Aydın Province.

Previously there did not exist in the lake halophilic species *Prorocentrum micans* Ehrenberg 1833, *Prorocentrum minimum* (Pavillard, 1916) Schiller, 1931 and *Nodularia spumigena* Mertens ex Bornet & Flahault, 1886 was recorded as a new species in the lake [28, 34]. *N. spumigena* (Cyanobacteria) is a frequently encountered phytoplankton species in the brackish waters and seas. According to information obtained from local fishermen, River BM water (nutrient-rich and containing organic wastes) is drained into lake from a canal every year by DSI; following this, firstly, the light green colour waters of the lake are turned into a brownish red, followed by the death of fish. According to fishermen, all of these events occur 10-15 days after the DSI process. This situation has been observed by us at Lake Bafa. A typical algal bloom is formed by *P. micans*. After this event, a bad smell is noticeable at the lake. Lake Bafa uses oxygen for decomposition process, and as a result of this process there is a lack of oxygen (Anoxic) and such a situation can kill macro organisms such as fish.

Administrative originated problems are an important cause of environmental problems of the lake. A portion of the lake is located within the boundaries of Söke District which has a high level of agricultural income; the other part of the lake is located within the boundaries of Milas District which contains relatively poorer less productive agricultural areas. Residents in the center of Söke Town and its villages don't need to derive commercial incomes provided from Lake Bafa. In contrast, there are income requirements to be fulfilled from fishing and tourism activities of the villagers residing in settlements (Kapıkırı, Gölyaka, Çamiçi and Pınarcık) within Milas boundaries. Saline waters of Lake Bafa cannot be used for irrigational purposes. The overflow waters of Lake Bafa flow into the RBM. Farmers demanded DSI should construct a levee for the non-salinization of the RBM, which is really significant for the agriculture, thus preventing the flow of the waters of Lake Bafa into the RBM. Upon such a demand, a stone levee was constructed between Lake Bafa and the RBM. Economic income losses of fishermen were uncalculated at the planning stage of the levee, and this project was a disaster for fishermen and Lake Bafa. The objective of this ecological disaster project is not protecting Lake Bafa from which polluted waters of the RBM, contrarily, prevent entry of salty waters of Lake Bafa into RBM (water used for irrigation of cotton fields).

Waters of RBM contain fertilizers, pesticides, particles and wastes precipitated to the bottom of the rubber dam when it was built by DSI, and these waters have been passed into the lake. Despite such

a process, lake salinity was measured 13.4‰ in October 2009, 6.7‰ in October 2010 and 12.8‰ in October 2011.

In addition, according to Demir *et al.* [71], temperatures will increase and rainfall will decrease 30-40% in the Aegean Region during the coming decades, and losses of water will increase with evaporation [71]. According to a report prepared by the University of Dokuz Eylül [72], the temperature will increase by 1.2 °C around Lake Bafa by the year 2030. Within this climate change framework, the largest feeding source of Lake Bafa and the RBM that feeds it, as a result of reduced rainfall in the region will have lower water levels. Consequently, waters of the RBM will be used by the farmers for agricultural irrigation waters more intensely than at present. In such a case, the DSI will not drain fresh water of RBM to Lake Bafa, and due to the scarcity of freshwater input and evaporation increasing; the salinity in the lake will severely increase in the future, provoking drastic changes in the ecosystem. Halophilic and halotolerant species living in the lake may die in large masses when freshwater of the RBM given into Lake Bafa by DSI ceases. Due to the lack of oxygen major organic mass accumulated in parts of the lake bottom will not sufficiently decompose by anaerobic bacteria, and it will be able to occur a permanent anoxic environment in the lake bottom. In such a case, the majority of animals who die due to rapidly decreasing salinity will accumulate on the bottom layer of the lake, which already contains little oxygen. Hydrogen sulphurs (H₂S) may occur in anoxic conditions at the bottom of the lake, this gas from time to time reaches to the surface layer from the bottom layer and it can kill many organisms including fishes in the lake. Köyceğiz Lake can be given as an example of this situation [73], because, fish species deaths have been reported in the Lake Köyceğiz due to hydrogen sulphurs [73]. According to Carlson's Trophic State Index [74], Secchi depth values show that the lake is classified as eutrophic. A filamentous green algae species is not widespread in autumn (November) and winter months whereas it is widespread in the summer and first months of autumn months (September and October). This filamentous green algae species has been transported to the lake shore and shallow parts of the lake by the water waves. Accumulated algae in the shallow areas of the lake start to decay. Therefore, a bad smell occurs in the lake and it's around.

One plan can be presented to the competent authority for protection of ecological balance at Lake Bafa. This project may be needed to be considered as a solution against salinity increase and oxygen deficiency by DSI. This proposal is the following: A canal should be built slightly below sea level between Lake Bafa and the Aegean Sea. The lake water must flow to Aegean Sea through this canal in winter; sea water should flow in to the lake when Lake water level decreases in the summer. The result of such an arrangement would be that, after a certain period, Lake Bafa will turn into a typical stable coastal lagoon. The water level of the lake will not decrease, and the continuous water circulation will occur in the lake. For these reasons there will not be a problem in terms of oxygen deficiency in the lake. Some marine fish species will enter the lake for reproduction, so fishing will come to again be an important economic activity for Lake Bafa.

The data obtained in this study and previous surveys suggest that anthropogenic activities are directly or indirectly responsible for the formation of environmental problems in the lake. A proper management plan for this reason is urgently needed to attenuate the effects of salinization and eutrophication and to restore the lake biodiversity.

The new data from this study on Ostracoda in Lake Bafa with a very small number of previous records provided information mostly on common taxa with high tolerance for various ecological conditions.

5. Conclusions

Finally, we are summarized our findings on Ostracoda fauna of Lake Bafa as follows:

- 1-We collected 10191 ostracod specimens from the 20 stations in Lake Bafa and identified them into 14 species.
- 2-Four ostracod species (*CF*, *CT*, *LE*, *LL*) of the total 14 were found inhabit brackish water conditions. However, the other ten species (*CA*, *CP*, *CV*, *EL*, *EM*, *EV*, *FF*, *HI*, *HS*, *PV*) were found in fresh and slightly saline water.
- 3-We determined that the salinity was the most important environmental variable affecting ostracod species distribution.
- 4-Five species of *CF*, *CT*, *EL*, *LE*, *LL* and nine species of *CA*, *CP*, *CV*, *EM*, *EV*, *FF*, *HI*, *HS*, 5- *PV* have positive and strong negative correlations with the salinity, respectively.
- 6-Sampling stations and ostracod species assemblage were clustered into two groups.
- 7- The ostracod abundance increases in warm period from late spring to May. Its maximum abundance seems in May.
- 8-We found Lake Bafa's mean diversity of 0.85.

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