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Diversity and Structure of Chironomidae (Diptera) Limnofauna of Lake Uluabat, a Ramsar Site of Turkey, and their Relation to Environmental Variables

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Abstract

Density and species composition of chironomidae larvae fauna from twelve sampling sites of Lake Uluabat (a protected wetland area) were investigated. Monthly sampling was done from August 2004 to July 2005. In addition, simultaneously, physical and chemical parameters of water were measured. 1,812 chironomid larvae were examined and a total of twelve taxa were identified. Chironomid larvae were the third dominant group consisting on average 12.3% of the total zoobenthos density. *Chironomus* (*Camptochironomus*) *tentans* Fabricius 1805 was the most abundant chironomid species contributing with about 66.2% of the total chironomid limnofauna. Dominant species from the lake Uluabat were the following: *Tanypus punctipennis* Meigen, 1818 (12 sites, 12%), *Procladius choreus* (Meigen, 1804) (11 sites, 10.2%), *Cryptochironomus defectus* (Kieffer, 1913) (10 sites, 4%), *Dicrotendipes tritomus* (Kieffer, 1916) (8 sites, 1.6%) and *Microchironomus* sp. (7 sites, 1.8%). Except *Dicrotendipes nervosus* (Stæger 1839) all other species occurred at <4 sites (between 0.04-0.6%). The relationships between the dynamics of the Chironomidae larvae and the limnological variables were supported by the Pearson correlation index According to Pearson correlation between the average number of *Ch.* (*Campt.*) *tentans, Cryptochironomus defectus* and temperature, BOD was directly proportional ($P<0.05$) while *Paratanytarsus lauterborni, Cricotopus* (*Cricotopus*) *flavocinctus, Cricotopus* (*Cricotopus*) *tremulus* was inversely proportional ($P<0.05$).

Keywords: Chironomidae Limnofauna, Lake Uluabat (Apolyont), Turkey.

Türkiye'nin Ramsar Alanlarından biri olan Uluabat Gölü Chironomidae Limnofauna Yapısı, Çeşitliliği ve Çevresel Parametrelerle İlişkisi

Özet

Korunan bir sulak alan olan Uluabat Gölü'nde Ağustos 2004 ile Temmuz 2005 tarihleri arasında aylık periyotlarla 12 istasyondan örneklemeler yapılarak Chironomidae tür çeşitliliği ve yoğunluğu araştırılmıştır. 1.812 örnek incelenmiş ve 12 taksa tespit edilmiş ve Chironomidae larvalarının %12.3'lük ortalama abundansla, göl zoobentozunu oluşturan 3. dominant grup olduğu belirlenmiştir. *Chironomus* (*Camptochironomus*) *tentans* Fabricius 1805, %66,2'lik oranıyla en yaygın chironomid türü olarak tespit edilmiştir. Uluabat Gölü'nün diğer dominant türleri ise; *Tanypus punctipennis* Meigen, 1818 (12 istasyonda, %12 oranı ile), *Procladius choreus* (Meigen, 1804) (11 istasyonda, %10,2), *Cryptochironomus defectus* (Kieffer, 1913) (10 istasyonda, %4), *Dicrotendipes tritomus* (Kieffer, 1916) (8 istasyonda, %1,6) and *Microchironomus* sp. (7 istasyonda, %1,8) şeklindedir. *Dicrotendipes nervosus* (Stæger 1839) haricindeki diğer türler 4 istasyondan daha az sayıda istasyonda tespit edilmiştir (%0,04-0,6). Chironomidae larvaları dağılışı ile limnolojik parametreler arasındaki ilişki Pearson Correlation Analyses (PCA) yöntemi ile incelenmiştir. Buna göre *Ch.* (*Campt.*) *tentans*, *Cryptochironomus defectus* ortalama birey sayısı ile sıcaklık, BOD arasında pozitif bir korelasyon ($P<0,05$); *Paratanytarsus lauterborni, Cricotopus* (*Cricotopus*) *flavocinctus, Cricotopus* (*Cricotopus*) *tremulus* ortalama birey sayısı ile ters bir korelasyon ($P<0,05$) olduğu tespit edilmiştir.

Anahtar Kelimeler: Chironomidae Limnofauna, Uluabat (Apolyont) Gölü, Türkiye.

Introduction

Chironomidae are broadly distributed worldwide and frequently are the most abundant insects in many freshwater ecosystems. Certain species show ecological adaptations, in ecosystems at different trophic levels, to extreme environmental situations related to high temperature, pH, organic matter content in the sediment, and low dissolved oxygen in the water-sediment interface (Armitage *et al*., 1994).

Chironomidae larvae play an important ecological role in the bioturbation process at the sediment water interface. In eutrophic environments, they do so in nitrogen remobilization for the primary producers (Fukuhara and Sakamoto, 1988). In aquatic ecosystems, these organisms participate in two webs: (a) by the detritus chain, ingesting organic fragments and associated microorganisms, (b) by the food-web, by eating smaller organisms and being consumed by other insects, alevins, aquatic birds, and benthophagous fishes (Branco *et al*., 1997). Therefore, in lake environments, they are important components needing further study.

Turkey is one of the most important country in the Palearctic Region with important bird areas (IBA) and wetlandand Turkey has 97 Important Bird Areas (IBAs) covering a total of 29,978 km^2 or 4% of the total land area (Magnin and Yarar, 1997). Among them Lake Uluabat (also known as Apolyont) has tectonic origins, and is a large turbid, shallow and eutrophic freshwater lake on the South side of the Sea of Marmara (Magnin and Yarar, 1997). In 1998, Lake Uluabat and its surrounding area were included in the Ramsar List that was established in response to Article 2.1 of the Convention on Wetlands held in Ramsar, Iran in 1971.

Although many researchers have studied Lake Uluabat from faunistic or ecological points of view at different times (such as, Barlas *et al*., 2005; Salihoğlu and Karaer, 2004; Kökmen *et al*., 2007) to date there has been almost no comprehensive study of Chironomidae communities and their relationships with the limnological parameters of Lake Uluabat. The aim of this study is to investigate the relationship between chironomids and the limnological parameters (physical, chemical and microbiological) of Lake Uluabat. Limnological parameters include dissolved oxygen levels, biological oxygen demand, chemical oxygen demand, pH levels, nitrate levels, phosphorus levels, water temperature, fecal coliform and total coliform. These measurements were compared with the abundance and diversity of the chironomid larvae. As there was very little previous information about the zoobenthic species composition in Lake Uluabat this study also contributed to the faunistic knowledge of the lake.

Materials and Methods

Study Area

The shallow and eutrophic Lake Uluabat is located in the western part of Turkey (40°10' N, 28°35' E) at an altitude of 9 m above sea level with a surface area of 156 km^2 (Figure 1) (Magnin and Yarar, 1997). Lake is fed principally by the Mustafakemalpaşa River from the southwest and has its only outlet in the northwest, where it drains into Kocaçay River. Deposits of incoming silt from the Mustafakemalpasa River have formed an inland delta covering an area of 3,747.6 ha that is under agricultural use (Salihoğlu and Karaer, 2004).

The lake's area includes a series of marshes, wetlands and islands, and these contribute substantially to the site's importance as a wintering site for waders and waterfowl, and as a breeding site for species (Magnin and Yarar, 1997). Its rich biodiversity, its location on the migratory bird route, and its vast areas of suitable habitats for many bird species makes the lake important not only for Turkey but also for Europe and the Middle East (Salihoğlu and Karaer, 2004). Furthermore in 1998, Uluabat

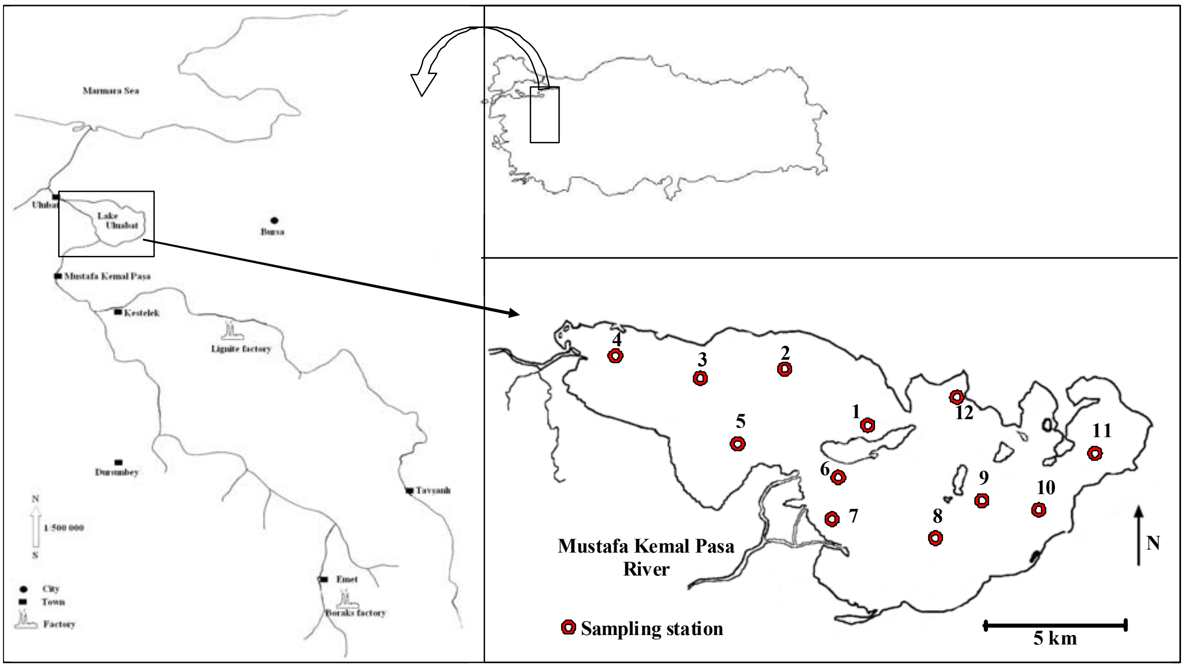

Figure 1. Catchment basin of lake Uluabat and sampling stations.

Lake and its surrounding area were included in the Ramsar List that was established in response to Article 2.1 of the Convention on Wetlands held in Ramsar, Iran in 1971. The lake is currently considered to show a typical eutrophication character. Domestic and industrial waste discharges affect water quality.

Water and benthos samples were collected as monthly periods from August 2004 to July 2005 at 12 sampling stations in Uluabat Lake and sampling was made from:

Station 1: Depth= 2 m, no macrophyte, the structure of bottom consists of mud, coordinate; 40°10'45″N-28°35'42″E, elevation 6 m; Station 2: Depth= 2.4 m, no macrophyte, the structure of bottom consists of mud, coordinate; 40°12'02″N-28°33'51″E, elevation 5 m.; Station 3: Depth= 1.7, bottom has mud and this location has reedbed, coordinate; 40°11'55″N-28°31'09″E, elevation 4 m; Station 4: Mouth of Uluabat River with reedbed, depth=1.8 m, bottom of this location has mud, coordinate; 40°12'08″N-28°28'26″E, elevation 4 m; Station 5: Depth= 1.2 m, bottom has mud and this location has reedbed, coordinate; 40°11'08″N-28°30'15″E, elevation 6 m.; Station 6: Depth= 1m, the structure of bottom consists of mud and fine sand, Reedbed and submerged macrophytes, coordinate; 40°09'58 N-28°34'10″ E, elevation 4 m; Station 7: Depth = 2.2 m, no macrophyte, Its bottom has only mud, coordinate; 40°08'20″ N-28°35'11″ E, elevation 5 m; Station 8: Depth= 2.5 m, bottom of this location has mud, sand, fine sand, reedbed, coordinate; 40°08'09″N-28°38'43″E, elevation 4 m; Station 9: Depth= 1.1 m, Bottom has mud, reedbed, coordinate; 40°09'26″N-28°38'31″E, elevation 5 m.; Station 10: Depth= 1.4 m, no macrophyte, the structure of bottom consists of fine sand and mud, coordinate; 40°08'31″N-28°40'21″E, elevation 6 m; Station 11: Depth= 1 m, Its bottom has fine sand and mud and this location has abundant reedbed, coordinate; 40°10'23″N-28°42'54″E, elevation 4 m; Station 12: Depth=0.6 m, the structure of bottom consists of fine sand and mud and emerged and submerged macrophytes and white water-lily were abundant at this station, coordinate; 40°11'36″N-28°38'12″E, elevation 6 m.

Limnological Parameters

The water samples were analyzed in the laboratory for biochemical parameters included the dissolved oxygen (mg/L) biochemical oxygen demand (mg/L) and chemical oxygen demand (mg/L). The pH and temparature were measured in the field using water quality checker (TOA WQC 22A). The water samples were analyzed in the laboratory for phosphate-phosphorus, nitrite-nitrogen and nitrate-nitrogen (PO_3^-, NO_2–N, NO_3–N). The biological parameters studied include fecal coliform, total coliform and zoobenthos. Samples were taken in two replicas with a Ekman dredge (with a coverage of 0.025 m^2) between November 2005 and July 2006, as monthly. The bottom samples were washed *in situ* using a 200 µm mesh size, the material was preserved in 4% formalin, in the laboratory all samples were removed from the debris, sorted under a stereoscope and transfered to 70% ethanol after they were identified to family, ordo or clasis level. The identification of the larvae was done using Cranston (1982), Fittkau and Roback (1983) and Şahin (1991).

Table 1. Some limnological parameters of Lake Uluabat in the period of investigations from August 2004 to July 2005

	Limnological Parameters											
Months/ Stations	DO (mg/L)	BOD (mg/L)	COD (mg/L)	WT (ºC)	pH	NO_2-N (mg/L)	NO_3-N (mg/L)	NH_3-N (mg/L)	PO_4^{-3} (mg/L)	Fecal coliform	Total coliform	Number of taxa
Aug.04	6.5	16.3	41.2	23.9	8.5	0.051	0.298	0.623	0.951	11	68	7
Sep. 04	5.4	13	39.1	23.1	8.2	0.075	0.788	0.153	0.493	9	102	6
Oct. 04	7.4	5.5	27.4	18.3	8.3	0.018	1.838	0.026	0.477	147	463	6
Nov. 04	9.3	3.5	27.7	12	8	0.041	1.533	0.138	0.466	237	301	12
Mar.05	6.4	10.8	45.6	13.4	8.8	0.036	1.147	0.128	0.323	387	970	6
Apr. 05	7.5	6.6	73.4	19.1	8.3	0.048	0.833	0.114	0.331	466	593	3
May. 05	7	7.1	70.8	22.5	8.3	0.028	0.708	0.083	0.148	213	1748	7
Jun. 05	7.5	7.6	78.3	23	8.4	0.045	1.167	0.285	0.331	75	1235	6
Jul. 05	6.3	18.2	66.4	25.7	8.8	0.044	0.617	0.463	0.302	132	1393	5
Stations												
1st	8.5	15.4	62.3	20.4	8.5	0.036	0.531	0.400	0.369	4	302	6
2nd	8.6	7.6	48.5	20	8.5	0.046	0.762	0.174	0.302	5	72	7
3rd	9.3	7.4	47.8	19.5	8.4	0.068	1.077	0.157	0.570	0	171	4
4th	7.7	7.7	60.6	19.5	8.4	0.027	1.111	0.239	0.378	0	233	7
5th	9.2	7.8	56.3	19.7	8.5	0.052	1.012	0.128	0.281	1	99	7
6th	8.3	7.6	34.6	19.6	8.3	0.053	0.944	0.182	0.527	1113	2344	6
7th	7.5	8.1	51.6	20	8.3	0.036	1.103	0.202	0.314	110	741	5
8th	7.4	7.1	51.9	19.8	8.4	0.038	1.238	0.302	0.355	5	224	4
9th	7.7	14.6	41.6	21	8.4	0.051	0.749	0.222	0.532	123	335	4
10th	7.4	11.9	63	20.4	8.4	0.039	1.199	0.201	0.475	38	237	4
11nd	6.1	15.2	47.2	21.5	8.5	0.040	1.139	0.311	0.574	805	4146	4
12th	5.4	6	73.6	18.8	8.4	0.021	1.074	0.114	0.306	18	286	10

Some limnological parameters of Lake Uluabat in the period of investigations were shown in Table 1.

Numerical Analysis

Shannon-Wiener species diversity index and Bray-Curtis similarity index were applied to analyze taxa statistically (log base 10 was not applied to the data). Also the Pearson Correlation index was used to determine whether there were any correlation between the limnological parameters and number of individuals or not.

Results

Chironomidae Species Richness and Diversity

The zoobenthic invertebrate fauna of Lake Uluabat mainly consisted of Oligochaeta (35.6%), Nematoda (27.7%), and Gastropoda (10.7%). The chironomid community comprised 12.3% of the total zoobenthic fauna and it was the third dominant macroinvertebrate group in the studied lakes during the study period. Other organisms were found sporadically and in insignificant amount. Oligochaeta community structure of the lake was examined as in detail by Kökmen *et al*. (2007). In the present investigation, 12 species of Chironomidae were identified, three species belonging to Tanypodinae, two species belonging to Orthocladiinae, six species belonging to Chironomini and only one species belonging to Tanytarsinini (Table 2). The total number of identifed taxa varied between four and ten among sampling sites. Distribution of Chironomidae larvae (average number of individual) and dominant species in Lake Uluabat between August 2004-July 2005 is shown in Table 2. A monthly abundance of the total Chironomidae in the 12 sampling stations showed considerable fluctuations during the study period ranging from 0 (Station 3, June 2005) to 101 individuals (Station 8, October 2004). In addition, the average number of individuals of Chironomidae at 12 sampling stations was significantly different from each other (P≤0.05). The highest average number of chironomid observed at stations 8th and 9th were 43 and 28 individuals, respectively. And the lowest number of individual observed at stations 11th and 4th were 3 and 8 individuals, respectively. Of Chironomidae the subfamily Chironominae (tribe: Chironomini) was found in the greatest number. The genus *Chironomus* was represented mainly by *Ch. (Camptoc.) tentans* Fabricius 1805, (12 sites, 66.2%) and the highest individual number of this species was found at Station 8 (October 2004, 101 ind.). The second most important chironomid was the *Tanypus punctipennis* Meigen, 1818 (12 sites, 12%) followed by *Procladius choreus* (Meigen, 1804) (11 sites, 10.2%), *Cryptochironomus defectus* (Kieffer, 1913) (10 sites, 4%), *Dicrotendipes tritomus* (Kieffer, 1916) (8 sites, 1.6%) and *Microchironomus* sp. (7 sites, 1.8%). Except *Dicrotendipes nervosus* (Stæger, 1839) all other species occurred at <4 sites (between 0.04-0.6%). During each sampling, the minimum chironomid species (<4) was found at stations 3rd, 8th-11th. On the other hand, the maximum number of species (10) was usually observed at station 12th where the vegetation was densely.

The lowest number of taxa was found in lake

Table 2. Distribution of Chironomidae larvae (average number of individual) and percent composition occurring in Lake Uluabat between August 2004-July 2005 (number in parantheses indicates their proportion in %)

	Tanypodinae			Orthocladiinae		Chironominae						Tanytarsini
Taxa	*Tanypus kraatzi*	*Tanypus punctipennis*	*Procladius choreus*	*Cricotopus (Crictopus) tremulus*	*Cricotopus (Crictopus) flavocinctus*	*Cryptochironomus defectus*	*Ch. (Camptoch) tentans*	*Microchironomus* sp.	*Polypedilum nubeculosum*	*Dicrotendipes nervosus*	*Dicrotendipes tritomus*	*Paratanytarsus lauterborni*
1	-	2 (10.4)	2 (13.7)	-	-	3 (14.6)	13 (56.7)	1 (1.8)	-	-	1 (2.9)	-
2	1 (0.5)	1 (4.7)	2 (12)	-	-	1 (0.6)	19 (80.5)	1 (0.8)	-	-	1 (0.9)	-
3	-	1 (6.1)	2 (13.3)	-	-	-	12 (78.7)	-	-	-	1 (1.8)	-
4	-	2 (21)	1 (6.3)	-	-	1 (6)	4 (56.5)	1 (3.6)	-	1 (4.5)	1 (2.1)	-
5	-	1 (1.5)	2 (26)	-	-	1(0.9)	5 (59.7)	1 (6.5)	-	1 (0.9)	1 (4.4)	-
6	-	5(32.5)	1 (11.7)	-	-	1 (4.7)	9 (46.3)	1 (3.9)	-	-	1 (0.8)	-
7	-	3 (29)	2 (6.5)	-	-	1 (4.4)	15 (57.9)	1 (2.2)	-	-	-	-
8	-	1 (1.4)	-	-	-	1 (1.2)	42 (95.7)	-	-	-	1 (1.7)	-
9	-	1 (2.2)	1 (2.2)	-	-	1 (3.4)	29 (92.2)	-	-	-	-	-
10	-	1 (0.6)	2 (11.5)	-	-	1 (8.3)	20 (79.6)	-	-	-	-	-
11	-	2 (20)	2 (20)	-	-	-	1 (53.3)	-	-	1(6.6)	-	-
12	-	4 (21)	-	1 (1.2)	2 (5.1)	2 (3.9)	5 (39)	1 (1.9)	2 (4.1)	3(13.5)	2 (5.9)	2(4.4)
General (as%)	0.04	12.5	10.3	0.07	0.4	4	66.3	1.8	0.3	2.1	1.7	0.6

stations 3rd, 8th, 9th, 10th and 11th (except satation 3rd, other satations were located at the east of the lake) whereas the highest number of taxa was found at station 12th (Figure 1). Generally, species richness and diversity were significantly higher at this staion than the others. Important differences between the sampling stations was the vegetation. High diversity and taxonomic richness of the station 12 may be partly due to their rich vegetation (especially reedbed) and substrate types.

Limnological Parameters

The variations of the limnological parameters are represented in Table 1 and the highest DO concentrations were recorded in cooler months, the temperature of the sampling stations reflected the seasonal changes and ranged from 11.2°C to 27.3°C. It is known that DO concentrations inversely related to water temperature. DO concentrations is probably that level of decomposer activity versus photosynthetic activity was also a contributing factor in the seasonal changes observed in DO concentrations. pH of the water varied between 7.8 and 9.1.

Water quality regulations in Turkey divide inland waters into four classes. Class I refers to clean water that can be used for domestic purposes after simple disinfection, for recreational purposes or for irrigation. Class II refers to fairly clean water that can be used as domestic water after treatment, for recreational purposes or for fishing, farming, etc. Class III includes polluted water, which can only be used as industrial water after treatment. Class IV refers to heavily polluted water that should not be used at all (Turkish Standards, 2004). When the water quality was evaluated for nutrients, the values of NO_3–N was found at first quality level, NO_2–N was generally found at third-fourth quality level, NH_4–N was found at second quality level, PO_4^{-3}–P was found at third quality level. BOD was found at second or third quality level (except station 12) while DO was found at first or second quality level. COD was found at first or second quality level (except station 12) generally. The maximum Fc level was found at station 11.

Numerical Analysis

According to the Shannon-Wiener index, the species diversity in lake was found as 0.73 at average, station 12 and November were determined to have the highest diversity while station 3 and April 2005 were determined to have the lowest diversity. According to Bray-Curtis similarity index, stations 2-10, 4-12 and 1-7-3 are the most similar to each other while stations 8 and 9 are the most different for the dynamics of chironomid larvae (both the numbers and species) in Lake Uluabat (Figure 2).

With regard to the Pearson correlation index between the average number of Chironomid species and the paramaters, the relation between the number of *Ch.* (*Camptoch.*) *tentans, Cryptochironomus defectus* and temperature ($P<0.05$, $r=+0.634$ and $r=+0.652$ respectively) was directly proportional while the relation between the number of some taxa, *Paratanytarsus lauterborni* (Kieffer 1909), *Cricotopus* (*Cricotopus*) *flavocinctus* (Kieffer 1924), *Cricotopus* (*Cricotopus*) *tremulus* (Linnaeus 1758) was inversely proportional ($P<0.05$, $r=-0.650$). In addition, between the average number of *Ch.* (*Campt.*) *tentans, Cryptochironomus defectus* and DO was inversely proportional ($P<0.05$, $r=-0.673$ and $r=-0.650$, respectively).

Disscussion

Chironomidae Species Community

Present study shown that zoobenthic fauna of Lake Uluabat was dominated by three group invertebrates, Oligochaeta, Nematoda and

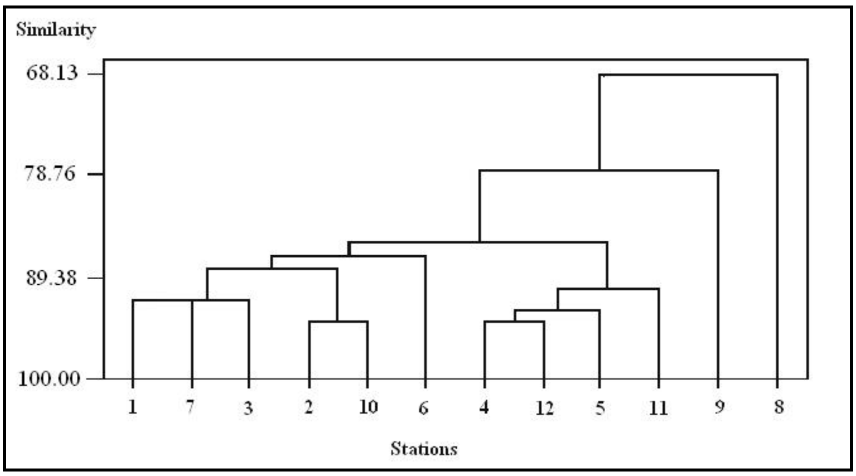

Figure 2. The dendrogram of similarity of the stations in lake Uluabat with respect to Chironomidae species.

Chironomidae that is typical of many freshwater systems and they have been known as tolerant organisms. Some species of them are sensitive to specific forms of pollution and exact species are quite tolerant, such as *Ch.* (*Camptoch*.) *tentans*, *Cryptochironomus defectus*. Large numbers of pollution-tolerant chironomids are often indicative of poor water quality (characterized by low dissolved oxygen and high nutrient concentrations). Chironomid species diversity and their sensitivity to eutrophic conditions were used to create trophic status classifications of lakes (Langdon *et al*., 2006).

Our result indicated that Chironomidae fauna of Lake Uluabat consists mainly of taxa with wide ecological tolerances and extensive geographical ranges. The chironomids were mainly represented by *Ch*. (*Camptoc*.) *tentans* and it was the only species obtain regularly from all stations during the study and it also occurred in large numbers (Stations 8, 9, 10 and 11 as 95.7%, 92.7%, 79.6%, 53.35%, respectively (Table 2). This species is frequently referred to in the literature as being positive indicators of organic pollution. By contrast, especially Orthocladiinae members, *Cricotopus* (*Cricotopus*) *tremulus* and *Cricotopus* (*Cricotopus*) *flavocinctus*, were not detected at those stations. These two species were found only in one station (12^{th}) associated with aquatic plants, like found in other study (Brodersen *et al*., 2001). Tanytarsini has correspondingly been reported as sensitive taxa (Clements and Cherry, 1988; Clements *et al*., 1992). In the present study, only Tanytarsini species was found at sampling site 12. The species richness of chironomids was generally low especially at sites 3, 8, 9, 10, and 11 where there is organic pollution reported by Filik-İscen *et al*. (2008). Physiological adjustment is shown in several species of Chironomidae. It has been found by various workers that some red Chironomidae containing erythrocruorin ("haemoglobin") can exist in the complete absence of dissolved oxygen for 30 to 120 days. The presence of *Ch.* (*Camptoc*.) *tentans* and *Cryptochironomus defectus* their high abundance may be interpreted as an indication of organic pollution. Some genera of Chironomidae such as *Procladius*, *Tanypus*, and *Chironomus* spp. have worldwide distributions and commonly occur in freshwater lakes (Wiederholm, 1983; Walker *et al*., 1985; Mousavi, 2002). *Tanypus punctipennis* and except stations 8 and 12, *Procladius choreus*, were the two Tanypodin species that are common in the study area (Table 2). *Chironomus* spp. and particularly *Procladius* and *Tanypus* have been reported as tolerant (Hare and Shooner, 1995), our results supported this knowledge. In addition, some *Chironomus* spp. larvae found presented deformities on mouth parts (especially at mentum which included various types of asymmetry, missing teeth or extra teeth). The mouthpart deformities in the *Chironomus* spp. community ranged from 3% to 8%. According to literature data; the occurrence of midge deformities is reportedly less than 1% in nonimpacted or preindustrialization communities (Wiederholm 1984; Warwick *et al*., 1987). Background levels have been estimated at 3% to 4% (Dickman *et al*., 1992), and investigators have suggested that frequency of deformities in the range of 5–25% or greater is generally associated with moderate to severe contamination (Wiederholm 1984; Warwick *et al*., 1987). Several studies have shown the relationship between the occurrence of structural deformities in Chironomidae larvae and degraded environmental conditions, resulting from contamination by heavy herbicides, metals and insecticides, deformities have been used in environmental impact evaluation studies on freshwater ecosystems and suggested as a biological parameter to be included in long-term water-quality monitoring programs (Callisto *et al*., 2000). Based on these criteria, deformities in *Chironomus* spp. from Lake Uluabat indicate that sediments from would be classified as “moderately contaminated”.

Finally, we can conclude from our results three commonly occurring taxa, *Procladius choreus, Tanypus punctipennis* and *Ch.* (*Camptoc*.) *tentans* appeared to be indicators of the pollution. Saether (1979) indicated that in Nearctic and Palearctic lakes show that at least 15 characteristic chironomid species communities can be delineated, 6 in each of the oligotrophic and the eutropbic ranges. According to his key, Lake Uluabat is λ-eutrophic.

In addition, Langdon *et al*. (2006) showed that twelve lakes with high total phosphorus levels tended to have a relatively high abundance of *Chironomus plumosus*-type and *Cricotopus sylvestris* type, with more mid-range total phosphorus lakes being predominated by *Procladius* and *Polypedilum nubeculosum*-type. It is known that, total phosphorus incorporates the total of all filterable and particulate phosphorus forms and its high level show organic pollution (Peters, 1986). If an excess of phosphate enters the waterway; algae and aquatic plants will grow rapidly, choke up the waterway and use up large amounts of oxygen. This condition is known as eutrophication. According to the findings of Dalkıran *et al*. (2006), they emphasize that high nutrient loads, joining the lake Uluabat from the Mustafakemalpaşa stream, the Azatlı drainage channel, and some companies near the lakeshore, have increased the external pollution load and have changed the trophic status of the lake. Our results supported this data.

Limnological Parameters

In the recent publication, water quality of Uluabat Lake was evaluated according to both Turkish Standards (2004), and cluster analysis, principle component analysis and factor analysis on principle components Filik–İşcen *et al*. (2008). They reported that the Mustafa Kemal Paşa River carried high loads of coliform, nitrates and phosphates. The lake is exposed to sewage and wastewater from streams, with sewage outlets, urban wastewater, and agricultural runoff all contributing to the current condition of the sources contaminating the lake. Kökmen *et al*. (2007) indicated that Uluabat Lake is generally polluted by organic wastes. In addition, In an earlier study (Barlas *et al*., 2005) it was found that heavy metal residues (Fe, Mn, Cu, Zn, Cr, Pb, Ni, and Co) in the Uluabat Lake water were lower than the maximum allowable levels in drinking water established by WHO (2006).

BOD level classifies in Turkey ranges from 4 (first quality) to over 20 mg/L (fourth quality) (Turkish Standards, 2004). Filik-İscen *et al*. (2008) reported that BOD is defined as the amount of oxygen required by aerobic microorganisms to oxidize organic matter to a stable inorganic form and they determined that highest BOD levels were found in the eastern part of the lake included stations 8, 9, 10 and 11 where the lowest number of Chironomid taxa was found in. In addition they indicated that these high values of BOD may be positively correlated with the increase of discharge from streams into the Lake.

As can be seen Table 1, the maximum total and fecal coliform were found in stations 6 and 11. In general, total and fecal coliform are commonly used as indicators of bacteriological quality of the water. Bacterial groups indicate the contamination process occurring in aquatic environments. The maximum ammonium concentrations were found at Stations 1, 4, 6, 8 and 11 where the center of the population companies are located, and domestic and industrial effluents flow into the lake. As the most representative variations, those observed for DO, BOD and nutrients, especially for ammonium and coliform, which as is well known, is indicative of recent pollution, can be mentioned.

Numerical Analysis

Although a wetland often host considerable biodiversity and endemism, the results from this study indicate that Chironomidae richness and diversity of Lake Uluabat were low but number of individual was high (as we mentioned above that the Chironomid species diversity in lake was found as 0.73). Furthermore, euryoic species, such as *Ch.* (*Camptoc.*) *tentans* and *Cryptochironomus defectus* distributed in the lake are generally widespread. Shannon-Wiener diversity index also supports this result.

Finally, Lake Uluabat is shallow lake where littoral areas are large and has a large catchments. Increased organic fluxes from the surrounding catchments will lead to increased sedimentation of organic detritus, causing species favouring more minerogenic substrates to suffer. Also, the whole of lake will ultimately be affected by receiving more organic material through increased allochthonous inputs of organic matter and increased primary production.

Excellent water quality conditions are often characterized by relatively low densities and high species diversity. As we mentioned above the benthic macroinvertebrate community in Lake Uluabat is dominated by Oligochaeta, Nematoda and Chironomidae. Generally, species richness and diversity were higher in the littoral site whereas the abundance and takson richness of chironomid larvae was lower at the east of the lake where organic pollution has. Irrigation, sewage system, variable flow rate, uncontrollable anthropogenic deposits etc. affect the quality of water Lake Uluabat. This situation may affect the food chain. Aquatic organisms rely upon the great diversity of aquatic habitats and resources for food, materials and breeding grounds. The structure of invertebrate fauna in the lake may change with effects of environmental variables. Lake Uluabat can be considered as polluted, with higher impact of pollution. The results obtained in this research showed that eutrophication in the Lake Uluabat has influenced the structure of the chironomid community (prevalence of detritivorous organisms, such as *Chironomus* spp.), resulting in high individual number and low taxonomic diversity. We also need to do further taxonomic studies in the lake in order to obtain better qualitative information (especially species biodiversity) that allow us to compare our results with other studies.

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