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Preliminary Results on Development of a Chironomid-Based Mean July Air Temperature Inference Model for the Turkish Lakes

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Abstract: As a preliminary study, surface sediment recovered from 30 lakes in Turkey was analysed for subfossil chironomid (Insecta: Diptera) remains and incorporated in a chironomid-based inference model for summer surface water temperature. Altitude varies between 4 and 2315 m a.s.l. among the lakes. Gravity corer was used to take surface samples in the deepest location for contemporary training set. To standardise the taxonomic approach, all chironomid samples taken from the Turkish lakes have compared with the European subfossil larvae collection. In total 68 different subfossil chironomids werefound. Detrended correspondence analysis (DCA) of the assemblage data were performed to identify outlying samples. Canonical correspondence analysis (CCA) was used to examine the distribution of chironomid taxa among the lakes and to relate their distributions to measured environmental variables in dataset. Weighted Averaging-Partial Least Squares (WA-PLS) were used to assess the transfer function performance. The statistics of the inference model for summer surface water temperature were analysed as RMSE = 3.03 and $r^2 = 0.60$. These results are expected to become more consistent as the number of lakes. This study is innovative as the first Turkish chironomid-based temperature calibration set and this will offer much potential for work on temperature reconstructions in Turkey.

Key words: Paleolimnology, subfossil chironomids, Diptera, transfer function

Introduction

Palaeotemperature reconstructions provide an important basis for understanding the dynamics and functioning of the climatic system (Heiri *et al.* 2003). It provides a basis for prediction of future changes in the region along with qualitative and quantitative estimations of past climate changes by palaeoenvironmental records (Andreev *et al.* 2004). Potentially one of the most useful sources of palaeoclimatic proxy data is the lake sediment record due to its strong influence of climate upon lakes and their biota (Battarbee 1991, Hoestler 1995) and because of changes in external and internal conditions is recorded chronologically in lake sedimentary deposits (Olander *et al.* 1997).

In recent years, chironomids have increasingly being used as sensitive indicators of past environmental change (Walker 2001, Brooks 2003, Porinchu and MacDonald 2003) among other proxies such as diatoms, cladocerans and pollens due to their several indicator attributes. In order to use chironomids as indicators of past environmental change an accurately identified modern chironomid-based temperature calibration data-set is required. For Europe, chironomid-temperature calibration

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*Corresponding author: mduran@pau.edu.tr data-sets and associated calibration functions are now available from Sweden, Finland, Iceland, Norway, and Switzerland. These data-sets have been used to produce reconstructions of past temperature changes (Heiri *et al.* 2007). In addition, more than 20 Holocene chironomid-based temperature reconstructions have been published from Europe so far (Antonsson *et al.* 2006, Bigler *et al.* 2002, 2003, Heider 2004, Heinrichs *et al.* 2005; Korhola *et al.* 2002, Larocque and Bigler 2004, Luoto *et al.* 2010, Paus *et al.* 2011, Velle *et al.* 2011).

Considering all these palaeolimnological approaches, they have never been used in this role in Turkey before. It is the fundamental element to understand the interactions between palaeoenvironment and climatic variations due to location of Turkey (Akçar and Schlüchter 2005). In order to develop research of this kind in Turkey, it is essential to identify correctly the chironomid species and standardize the taxonomic approach with research elsewhere in Europe. Although many previous studies have used training sets to produce temperature reconstructions from outside the region in which they were developed (Larocque-Tobler 2010, Lang *et al.* 2010a, b, Engels *et al.* 2008, 2010, Larocque and Finsinger 2008, Heiri *et al.* 2007, Langdon *et al.* 2004, Bedford *et al.* 2004, Heiri and Lotter 2003, Caseldine *et al.* 2003, Brooks and Birks 2000, 2001, Brooks and Birks 2000). The results show that although there may be problems when applying a training set outside its region (Holmes *et al.* 2011). On the other hand, the larger environmental gradient covered, along with the increased number of taxa present and increased occurrences of taxa in the combined training set, may allow for more realistic and consistent reconstructions of past temperature from fossil chironomids (Holmes *et al.* 2011). Eventually, developing the Turkish training set will not only be useful for its own region but also for the European calibration set.

In this paper, we present a preliminary results on analysis of the response of chironomid assemblages to environmental gradient in Turkey. It is the very first modern temperature calibration data-set of chironomids to develop quantitative reconstructions of climate. To standardise the taxonomic approach, chironomid samples taken from the Turkish lakes have been compared with the European subfossil larvae. Several factors influencing chironomid assemblages and composition were identified using multivariate analysing techniques. Detrended correspondence analysis (DCA) of the assemblage data were performed to identify outlying samples. Canonical correspondence analysis (CCA) was used to examine the distribution of chironomid taxa among the lakes and to relate their distributions to measured environmental variables in dataset. Weighted Averaging-Partial Least Squares (WA-PLS) were used to assess the transfer function performance. Forward selection, with Monte Carlo permutation tests (499 unrestricted permutations), was used to identify a minimal subset of the remaining predictor variables that could account for a statistically significant amount of variance in the midge data.

Material and Methods

Study area

The 30 natural lakes sampled for this present study were chosen from five regions of Turkey which includes Mediterranean, Aegean, Central Anatolia, Marmara and Black Sea (Fig. 1). The study area spans 810 km long from west to east and 560 km long from south to north. The lakes mostly selected were relatively shallow with the depth 0.7-17 m. Care of this present study was taken in the selection of lakes at different altitudes starting above the sea level. Elevation of the lakes spans from 4 to 2315 m to sample the broadest temperature gradient as possible. Their measured surface-water temperature varied between 12.4 °C and 29.6 °C (Table 1). Lake water salinity varied from 0.0 to saline 7.7 ‰; only three lakes were over 2.0 ‰ which are close to sea side and eleven lakes were between 0.1-0.6 ‰. These values are thought to arise from the structure of the lakebed. Lake water pH varied from quite slightly acid (6.87) to alkaline (9.54) (Table 2). There were no visible signs of anthropogenic pollution directly in the study area, although all lakes sampled are considered to be exposed to human impacts in anyway.

Sampling and laboratory methods

To optimize the integration between taxa living in the littoral and taxa that live in the profundal sediment, samples were collected from the deepest points of the lakes. The deepest point of the lakes was determined by using a Hawkeye Handhelded Sonar Unit® or a sinker when there was intensive water planting on the lakebed. Magellan Explorist 600® global positioning system (GPS) was used to

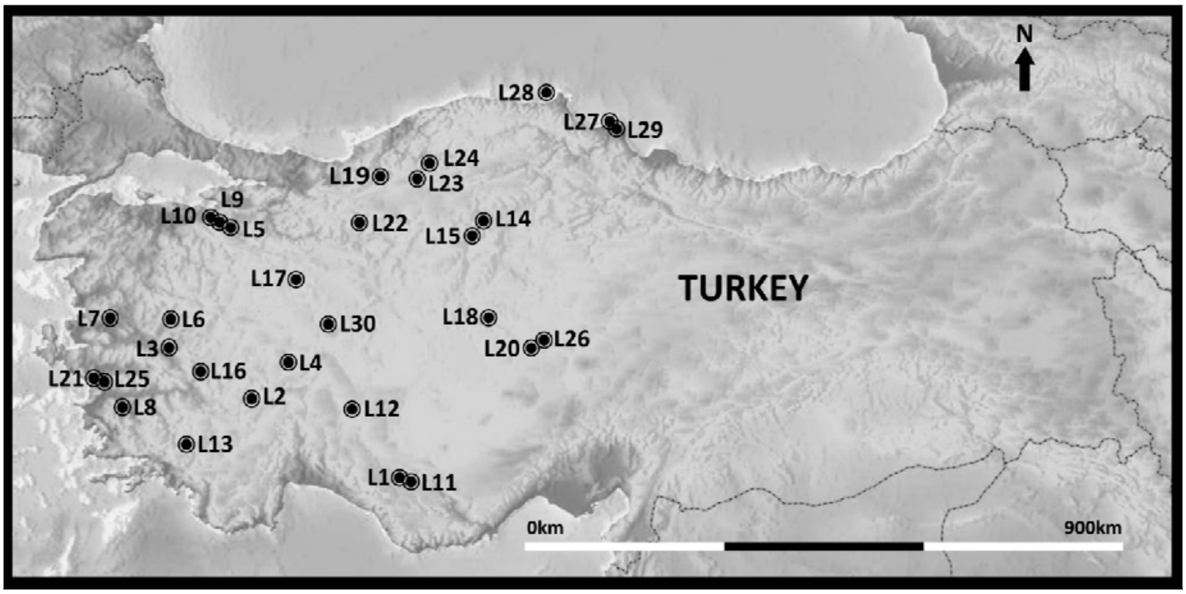

Fig. 1. Location of the 30 lakes selected for the training set.

obtain lake altitudes and coordinates of the deepest point of the lakes. Sediments were collected using a KC Denmark-Kajak Corer® with 50 cm sharpened acrylic tube. This coring process was repeated three times for each lake. The sequences first and second cm taken from top of the surface sediment was stored in commercial zipper plastic bags separately. The sediment samples collected were kept in the fridge (+4 °C) at the laboratory.

Water samples for chemical analysis were collected from the central part of the lakes from 1 m depth with a Ruttner® water sampler. 500 mL water samples were transferred to polyethylene bottles for each lake and stored at +4 °C. Water samples were filtered using Filter-Lab® MFV3 glass microfiber filters before chemical analysis. The glass microfiber filters were kept in -20 °C for further chlorophyll analysis. The physicochemical parameters were taken at the field with portable hand-held instruments. Surface water temperature, dissolved and saturated Oxygen was measured with YSI® 550A calibrated with altitude and salinity concentration of the lake; pH and oxidation reduction potential (ORP) were measured with WTW® ph 330i; Conductivity (standardized to +25 °C), salinity and TDS were measured with WTW® Cond 330i portable instruments. Water transparency (Secchi depth) was measured with Secchi® disk using standard methods. NH_3, Cl^-, NO_2, NO_3, Fe^{+2}, PO_4^{-3}, Mg and Ca concentrations were determined in the laboratory using the Hach-Lange® DR2800 spectrophotometer with its own pre-programmed tests and reagent kits.

Chironomid analysis

Subsamples taken from the stored sediment were processed to collect a minimum 50 head capsule for each lake. The number of collected head capsules varied according to the amount and type of the sediment. The amount of the wet sediment varied between 1.56 – 20.1 g to reach minimum 50 head capsules. The weight of each wet subsamples taken was measured with Precisa® XB 220 A. The standard preparation technique (Brooks *et al.* 2007) was used to disaggregating sediment and pick out the head capsules. Head capsules were mounted on slides in Euparal®. Identification of the chironomid head capsules was mainly based on Brooks *et al.* (2007). The description of Wiederholm (1983) was also used. Vallenduuk *et al.* (1997) and Webb & Scholl (1985) were also used to identify head capsules of genus *Chironomus* because of different mandible and mentum conditions referred in Brooks *et al.* (2007). Cephalic setation was mostly used to identify the subfamily Tanypodinae that based on Rieradevall, Brooks (2001) because of they were often fragmented. *Cricotopus flavocinctus* type was identified by using (Simpson *et al.* 1983). A taxon of *Tanytarsus* type was conferred as *Tanytarsus* cf. *gracilentus* because of different mentum and mandible conditions as distinct from *Tanytarsus gracilentus* morphotype

Table 1. Environmental and limnological data for 30 lakes.

Lake ID	Latitude (metric)	Longitude (metric)	Altitude (m)	Mean July Air_Tmp (°C)	Lake Tmp (°C)	Lake Depth (cm)	Secchi Depth (cm)
L1	36.93	32.17	2037.00	12.00	11.80	70.00	25.00
L2	37.73	29.49	1250.00	22.22	12.40	430.00	250.00
L3	38.31	28.02	1050.00	21.81	12.80	410.00	200.00
L4	38.22	29.89	835.00	24.71	14.10	440.00	440.00
L5	40.07	29.22	2216.00	12.00	15.20	1000.00	10.00
L6	38.62	28.03	73.00	28.29	15.40	380.00	240.00
L7	38.55	27.12	817.00	22.88	17.15	760.00	66.00
L8	37.61	27.66	491.00	25.84	17.50	760.00	220.00
L9	40.07	29.23	2315.00	11.41	17.80	80.00	80.00
L10	40.07	29.22	2290.00	11.56	18.20	410.00	410.00
L11	36.93	32.20	2064.00	16.30	19.90	900.00	400.00
L12	37.81	31.50	1123.00	22.97	21.10	770.00	77.00
L13	37.09	28.85	1904.00	18.30	21.10	70.00	70.00
L14	39.76	32.78	977.00	22.80	21.36	440.00	140.00
L15	39.82	32.83	972.00	23.00	22.10	580.00	280.00
L16	38.05	28.77	1165.00	22.73	22.10	200.00	140.00
L17	39.10	30.43	1150.00	21.00	23.00	550.00	110.00
L18	39.24	32.92	1193.00	22.50	23.00	150.00	150.00
L19	40.79	32.16	1319.00	16.18	23.10	670.00	280.00
L20	38.39	34.36	1173.00	22.06	23.40	380.00	63.00
L21	37.98	27.30	4.00	28.10	24.80	550.00	80.00
L22	40.35	31.92	1423.00	15.56	24.80	650.00	148.00
L23	40.83	32.43	1232.00	16.71	24.90	600.00	410.00
L24	40.84	32.44	1222.00	16.77	25.20	320.00	250.00
L25	37.99	27.31	10.00	28.10	25.40	300.00	50.00
L26	38.40	34.37	1184.00	22.00	26.10	340.00	53.00
L27	41.58	36.06	1.00	23.22	27.50	120.00	25.00
L28	42.01	34.91	12.00	22.63	28.00	800.00	90.00
L29	41.56	36.06	1.00	23.22	28.60	130.00	70.00
L30	38.64	31.14	967.00	22.20	29.60	160.00	20.00

referred in Brooks *et al.* (2007). The state of the all chironomid remains rarely allowed identify to species, and mostly to the generic level.

Data analysis

All the ordinations were performed using R (2011) and the vegan package (Oksanen *et al.* 2012). All taxon data were presented as percent abundances and were square-root transformed prior to further analysis. DCA was performed to explore principal patterns in the distribution of chironomid assemblage data. CCA was used to examine the distribution of chironomid taxa among the sampling sites and to relate their distributions to measured environmental variables in dataset. The significance of the full CCA model was also checked. Number of constraints was reduced by using forward selection based on the Akaike's information criterion (Aic) to find important environmental variables. AIC is a penalized goodness of fit measure. Increasing the number of explanatory variables has the effect of reducing the constraints on the ordination. Forward selected variables were tested for significance by permutation tests (199 unrestricted permutations). Variables were taken to be significant where $P \leq 0.05$.

The C2 version 1.4 (Juggins 2003) was use

Table 2. Physico-chemical data for 30 lakes.

Lake ID	satO_2 (%)	disO_2 (mg/l)	pH	Sal (mg/l)	TDS (mg/l)	Cond (mg/l)	NH_3 (mg/l)	Cl (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)	Fe (mg/l)	PO_4 (mg/l)	Mg (mg/l)	Ca (mg/l)
L1	97.60	7.96	9.51	0.00	111.00	147.70	0.36	0.10	0.02	1.10	0.02	0.10	3.00	0.14
L2	53.00	5.74	7.61	0.10	643.00	796.00	0.04	3.20	0.00	0.50	0.65	0.22	0.33	1.82
L3	114.60	11.93	8.75	0.00	248.00	306.00	0.07	6.30	0.00	0.80	0.05	0.47	0.95	0.18
L4	29.40	2.79	8.55	0.00	298.00	371.00	0.01	15.40	0.00	0.50	0.15	0.72	1.47	0.46
L5	79.00	7.86	7.70	0.00	66.00	87.90	0.02	23.20	0.02	1.00	0.15	0.47	2.89	0.00
L6	89.60	8.95	8.70	0.00	457.00	565.00	0.10	4.10	0.00	0.80	0.04	0.35	0.00	2.20
L7	128.90	12.41	8.71	0.00	198.00	245.00	0.53	0.10	0.013	0.60	0.02	0.91	2.29	0.26
L8	68.00	6.48	7.69	0.00	181.00	224.00	0.09	0.70	0.02	0.20	0.02	0.26	2.11	0.00
L9	78.90	7.74	8.39	0.00	51.00	67.30	0.01	14.40	0.01	0.60	0.10	0.27	3.28	0.00
L10	93.00	8.97	8.88	0.00	73.00	95.90	0.00	19.80	0.01	0.50	0.25	0.50	3.37	0.00
L11	89.10	8.14	8.23	0.00	142.00	175.00	0.00	0.10	0.00	0.70	0.01	1.57	2.48	0.25
L12	75.20	6.65	8.27	0.00	328.00	396.00	0.05	1.80	0.00	0.80	0.24	0.34	0.72	0.14
L13	110.40	9.59	8.96	0.00	84.00	107.30	0.01	1.20	0.04	0.40	0.00	0.13	1.81	6.64
L14	66.10	5.82	8.22	0.60	1262.00	1558.00	0.11	33.60	0.02	0.40	0.03	0.24	0.81	0.00
L15	98.80	8.63	8.31	0.60	1253.00	1547.00	0.04	16.70	0.00	0.30	0.01	4.11	0.00	2.47
L16	100.40	8.59	9.30	0.00	126.00	161.30	0.30	2.70	0.00	0.70	0.04	0.68	0.00	6.54
L17	81.00	6.94	7.83	0.00	182.00	225.00	0.71	0.00	0.00	1.10	0.02	2.42	1.69	0.00
L18	119.00	9.71	9.10	0.50	1149.00	1385.00	0.35	12.40	0.00	0.40	0.27	0.38	1.21	0.00
L19	50.00	4.25	7.81	0.40	988.00	1190.00	0.23	3.90	0.00	0.70	0.13	1.54	0.25	0.51
L20	161.00	14.00	6.87	0.10	553.00	665.00	0.55	93.20	0.03	1.20	0.04	0.36	1.27	0.36
L21	114.50	9.44	8.18	5.20	7000.00	92800.00	0.36	150.70	0.009	0.50	0.08	2.23	0.52	0.00
L22	91.50	7.72	8.68	0.00	84.00	1021.00	0.45	0.10	0.00	0.80	0.17	0.45	2.99	0.06
L23	82.90	6.80	8.09	0.00	423.00	509.00	0.16	12.10	0.00	0.70	0.10	1.20	1.06	2.20
L24	75.60	6.07	7.90	0.00	487.00	590.00	0.14	19.40	0.00	0.10	0.25	1.23	2.11	0.70
L25	99.90	8.18	8.14	2.10	2673.00	4030.00	0.04	4.40	0.00	0.40	0.02	1.93	0.00	0.27
L26	210.00	17.55	7.43	0.10	510.00	670.00	0.99	11.90	0.00	0.70	0.06	0.35	0.31	0.29
L27	196.00	15.50	9.54	0.50	1136.00	1369.00	0.93	1.30	0.00	0.90	0.61	0.37	0.16	0.33
L28	166.20	13.06	9.19	7.70	2000.00	13130.00	1.99	61.90	0.00	0.30	0.06	0.62	0.00	1.58
L29	37.10	3.16	7.51	0.20	688.00	831.00	0.43	36.90	0.08	0.70	0.08	0.47	1.37	1.24
L30	144.20	11.80	8.95	0.20	644.00	795.00	0.86	0.30	0.00	2.10	0.02	4.34	0.21	1.91

to develop chironomid transfer function for July-air temperature. Weighted Averaging-Partial Least Squares (WA-PLS) were used to assess the transfer function performance.

Data input and screening

From chironomid taxa expressed as relative abundances (% total chironomid), only the chironomid taxa that achieved $\geq 2\%$ abundance in at least two sites were included in the ordination axes (Table 3). By this process 41 taxa were met this requirement. Variables with an inflation factor ≥ 20 were also eliminated from the environmental data, and the CCA was re-run until all remaining variables had values of < 20. The sites were defined as an outlier if leverage diagnostics in CCA showed a sample to have an environmental variable with extreme influence (>8X). Following this criteria L21, L25 and L28 were eliminated from the data screening. After data eliminations 27 sites, 12 environmental variables and 41 chironomid taxa were used in the ordination analysis.

Results

Faunistic Description

A total 2802 chironomid subfossil from 68 taxa was examined (Table 3). 11 from Tanypodinae, 21 from Chironomini, 11 from Tanytarsinii, 24 from

Table 3. List of chironomid taxa, total number of head capsules found in the surface sediment, percentage of the total fauna, the number of occurences and N2 values of only the chironomid taxa that achieved ≥ 2% abundance in at least two sites.

Taxon	Total number	Percentage of the total fauna	Occurrences	N2
Tanypodinae				
Ablabesmyia monilis type (Johannsen)	114	4.07	11	3.97
Conchapelopia type (Fittkau)	1	0.04	1	
Krenopelopia type (Fittkau)	2	0.07	1	
Labrundinia longipalpis type (Fittkau)	13	0.46	2	1.73
Macropelopia type (Thienemann)	2	0.07	1	
Monopelopia type (Fittkau)	4	0.14	2	1.64
Procladius choreus type (Skuse)	123	4.39	20	12.78
Tanypus II type (Meigen)	9	0.32	3	2.36
Tanypus type (Meigen)	3	0.11	1	
Thienemannimyia type (Fittkau)	1	0.04	1	
Zavrelimyia type (Fittkau)	2	0.07	1	
Chironomini				
Chironomus anthracinus type (Meigen)	100	3.57	20	13.31
Chironomus plumosus type (Meigen)	220	7.85	26	16.29
Cladopelma laccophila type (Kieffer)	25	0.89	9	5.66
Cladopelma lateralis type (Kieffer)	21	0.75	3	1.24
Cryptochironomus type (Kieffer)	9	0.32	3	2.02
Dicrotendipes nervosus type (Kieffer)	159	5.67	12	2.29
Dicrotendipes notatus type (Kieffer)	8	0.29	3	1.77
Endochironomus albipennis type (Kieffer)	24	0.86	5	3.84
Endochironomus tendens type (Kieffer)	14	0.50	5	3.69
Glyptotendipes pallens type (Kieffer)	128	4.57	16	3.75
Glyptotendipes barbipes type (Kieffer)	5	0.18	1	
Kiefferulus tendipediformis type (Goetghebuer)	1	0.04	1	
Microchironomus type (Kieffer)	44	1.57	10	4.5
Parachironomus sp. (Lenz)	18	0.64	2	1.39
Parachironomus varus type (Lenz)	8	0.29	7	6.62
Paratendipes mudisquama type (Kieffer)	1	0.04	1	
Polypedilum nubeculosum type (Kieffer)	30	1.07	9	4.04
Polypedilum nubifer type (Kieffer)	11	0.39	5	2.43
Polypedilum sordens type (Kieffer)	22	0.79	8	4.43
Stictochironomus rosenschoeldi type (Kieffer)	4	0.14	2	2
Zavreliella type (Kieffer)	9	0.32	2	1.96
Tanytarsini				
Apsectrotanypus trifascipennis type (Zetterstedt)	4	0.14	1	
Cladotanytarsus mancus type 2 (Kieffer)	79	2.82	7	3.54
Micropsectra concrata type (Kieffer)	3	0.11	2	1.86
Micropsectra insignilobus type (Kieffer)	2	0.07	2	2
Micropsectra type A (Kieffer)	7	0.25	2	1.67

Table 3. Continued.

Taxon	**Total number**	**Percentage of the total fauna**	**Occurrences**	**N2**
Microtendipes pedellus type (Kieffer)	1	0.04	1	
Paratanytarsus penicillatus (Thienemann & Bause)	207	7.39	18	8.44
Tanytarsus cf *gracilentus* type (van der Wulp)	112	4.00	3	2.38
Tanytarsus mendax type (van der Wulp)	137	4.89	10	5.55
Tanytarsus pallidicornis type (van der Wulp)	43	1.53	2	1.05
Tanytarsus pallidicornis type 2 (van der Wulp)	11	0.39	2	1.21
Orthocladiniinae				
Chaetocladius piger type (Kieffer)	2	0.07	1	
Chaetocladius type (Kieffer)	1	0.04	1	
Corynoneura arctica type (Winnertz)	26	0.93	12	7.44
Corynoneura edwardsi type (Winnertz)	73	2.61	7	2.04
Corynoneura lobata type (Winnertz)	3	0.11	1	
Cricotopus bicinctus type (van der Wulp)	2	0.07	2	2
Cricotopus cylindraceus type (van der Wulp)	13	0.46	5	2.45
Cricotopus flavocinctus (van der Wulp)	200	7.14	11	4.19
Cricotopus intersectus type (van der Wulp)	67	2.39	14	9.11
Cricotopus laricomalis type (van der Wulp)	304	10.85	20	7.28
Cricotopus obnixus type (van der Wulp)	1	0.04	1	
Limnophyes type (Eaton)	1	0.04	1	
Metriocnemus eurynotus type (van der Wulp)	1	0.04	1	
Orthocladius trigonolabis type (van der Wulp)	1	0.04	1	
Orthocladius type I (van der Wulp)	1	0.04	1	
Parakiefferiella bathophila type (Thienemann)	2	0.07	2	2
Psectrocladius limbatellus type (Kieffer)	12	0.43	1	
Psectrocladius psilopterus type (Kieffer)	2	0.07	1	
Psectrocladius sordidellus type (Kieffer)	340	12.13	19	9.33
Pseudorthocladius sp. (Goetghebuer)	1	0.04	1	
Pseudosmittia type (Goetghebuer)	3	0.11	1	
Smittia type (Holmgren)	1	0.04	1	
Tvetenia calvescens type (Kieffer)	1	0.04	1	
Zalutchia type (Lipina)	2	0.07	1	
Diamesiane				
Diamesa type (Meigen)	1	0.04	1	

Orthocladiini and 1 from Diamesinae was founded in this study. The highest total number of head capsules found in the surface sediments was 340 (*Psectrocladius sordidellus* type). The percentage of the total fauna of *P. sordidellus* and its number of occurrences and N2-values was 12.13%, 19 and 9.33 respectively. The most common was *Chironomus plumosus* group (220, 7.6%, 26 lakes). The highest N2-value (16.29) was belonging to *C. plumosus* group too. *Procladius choreus* type (123, 4.39%, 20 lakes), *Chironomus anthracinus* (100, 3.57%, 20 lakes), and *Paratanytarsus penicillatus* type (207, 7.39%, 18 lakes) were the next most common taxa in our study.

Ordinations

Ordination analyses included 41 non-rare taxa, 27 sampling sites and 12 explanatory variables. The lengths of axis were founded as 4.11, 2.77, 2.93 and 2.86 for DCA1, DCA 2, DCA 3 and DCA 4 axis respectively by the function decorana in Vegan package. Eigen values of the first two DCA axes are $\lambda_1 = 0.59$ and $\lambda_2 = 0.40$. Accordingly, CCA was applied for the further numerical analysis. To use as many constraints as possible has the effect of reducing the constraints on the ordination. Thus, the variance inflation factors and significance for each variable were calculated to represent how significant the constraints are. Total 7 significant ($P \leq 0.05$) environmental variables (altitude, july-air temperature, latitude, lake temperature, NH_3, Conductivity and Magnesium) were selected by using forwards selection based on AIC and after this process the full CCA model was found significant ($P \leq 0.05$) (Table 3). The eigen values for the first two CCA axes are 0.51 and 0.37 respectively while the total inertia is 4.47 (constrained = 1.65, unconstrained = 2.82). The first two CCA axes accounted for 53.03% (30,6%, 22.43%) of the variance in the weighted averages of the chironomids (Fig. 2). Altitude and Mg variables have a significant positive correlation with the CCA 1 axis while July-air temperature, lake temperature, NH_3 and Conductivity have a significant negative correlation. Latitude has a significant positive correlation with the CCA 2 axis. We are able to say the left lower quadrant of CCA ordination graph include taxa that they prefer the warmer and lower latitudes (*Dicrotendipes nervosus*, *Cricotopus bicinctus*, *Tanytarsus pallidicornis*). The left top quadrant is representing the warmer and higher latitudes. *Labrundinia longipalpis*, *Cricotopus flavocinctus*, *Endochironomus albipennis* and *Ablabesymia monilis* are located in this quadrant. *Cladopelma lateralis* has a significant positive correlation with the altitude and CCA 2 axis. *Tanytarsus* cf. *gracilentus* is almost completely separated from the other taxa. It is the taxa typical of the coldest sites.

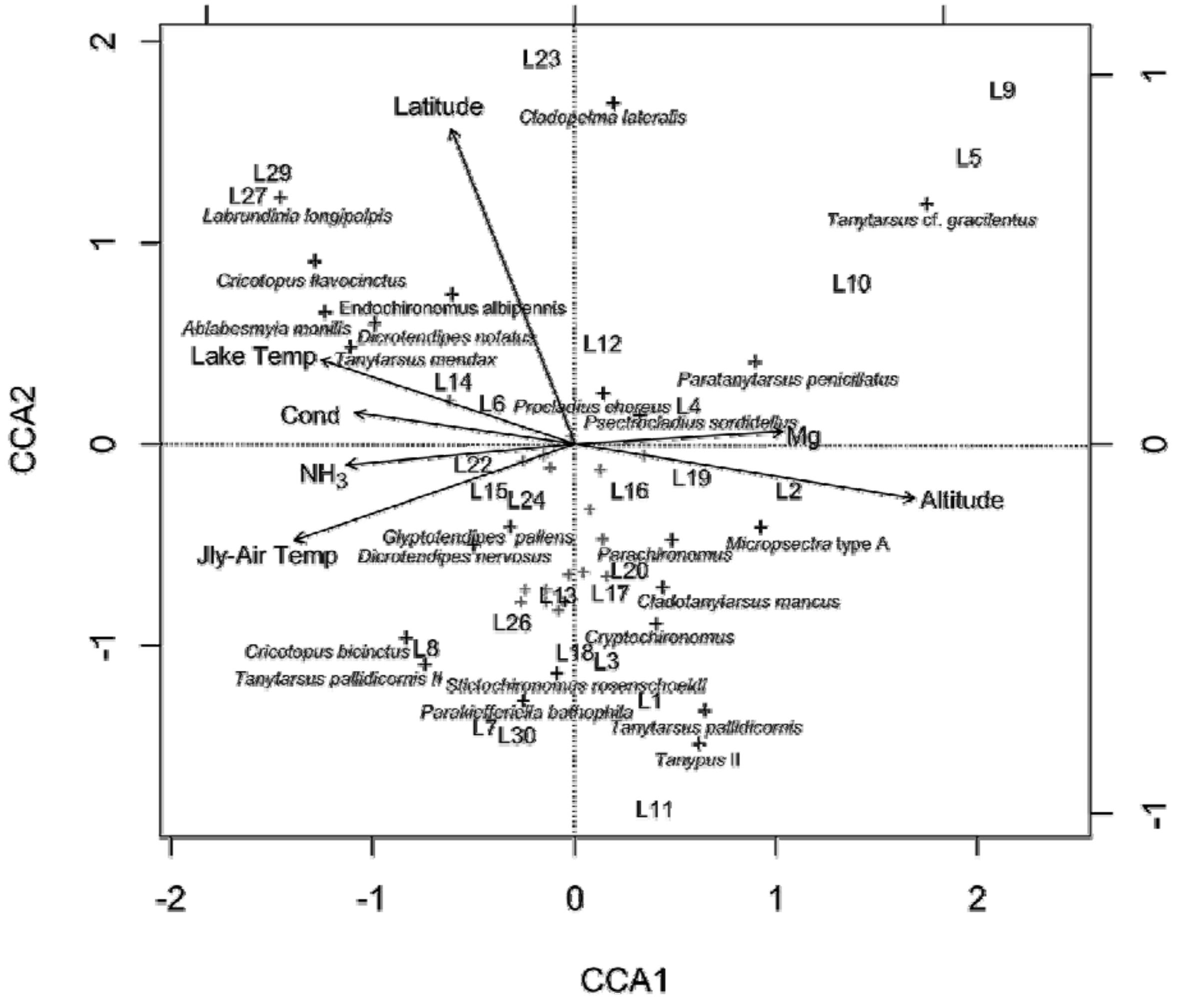

Fig. 2. Ordination diagram based on an explanatory canonical correspondence analysis (CCA).

Transfer Function

The mean July air temperature was the second strongest variable as determined by forward selection. WA-PLS model was used to assess the transfer function performance. For the WA-PLS mean July-air temperature model predicted versus observed values for mean July-air temperature is shown in Fig. 3. The model performance is calculated as RMSE = 3.03 and $r^2 = 0.60$. The stratigraphic diagram of the midges (Hill's N2 > 2.0) according to mean July air temperature is given in the Fig. 4.

Discussion

In this present study, *Psectrocladius sordidellus* type with the highest total number of head capsules found in the surface sediments is common and of often abundant in lake sediments (Brooks *et al.* 2007). They are usually associated with temperate lakes (lake temperature 11.8 – 29.6 °C). *Chironomus plumosus* group was found as the most common in the lakes. *C. plumosus* group has been mentioned often as a lake group, occurring more scarcely in small water bodies (Langton 1991). The most sensitive taxon to temperature was found as *Tanytarsus* cf. *gracilentus.* This taxon was conferred as *Tanytarsus* cf. *gracilentus* because of different mentum and mandible conditions as distinct from *Tanytarsus gracilentus* morphotype referred in Brooks *et al*. (2007). This taxon was only found in three glacial mountain lakes (L5, L9, L10) at 11.4, 11.6, 12.0 °C mean July-air temperature respectively.

Forwards selection in CCA indicated that seven environmental variables (altitude, mean July air temperature, latitude, lake temperature, NH_3, conductivity, Magnesium) explained significant proportion of the chironomid distribution. The most significant environmental variable was found as altitude ($P < 0.005$). The samples taken from the wide range of altitude (4 – 2315 m) might have an effect on this dispersion. The difference between the significant environmental variables (1.65) and the total variance (4.47) indicates that the distribution of chironomid taxa is also affected by additional factors (unconstrained = 2.82) not included in the ordination. We suggest that organic content of the sediment, predators (e.g., presence of fish), sources of food and unpredictable climatic variations might contribute the dispersion of the chironomid taxa.

The r^2 (0.60) of the temperature model developed is a little bit low. In addition, the model performance gave us adequate results to compare the distribution of chironomid assemblage data according mean July air temperature. The next step in the present study is to enlarge the database by adding further sampling sites and new significant environmental variables in our data set. This study is innovative as the first Turkish chironomid-based temperature calibration set and this will offer much potential for work on temperature reconstructions in Turkey. Furthermore, to standardise the taxonomic approach, chironomid samples taken from Turkish lakes have been compared with the European subfossil larvae. We respect that confidince is going to increase with the number of lakes.

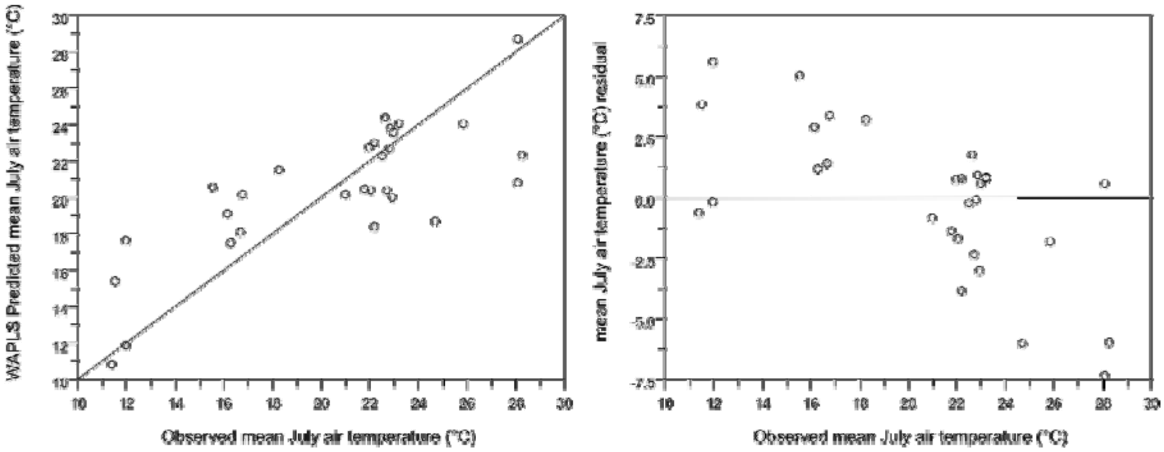

Fig. 3. Mean July air temperature model predicted versus observed values for mean July air temperature (left) and residuals of predicted varsus observed mean July air temperature (right).

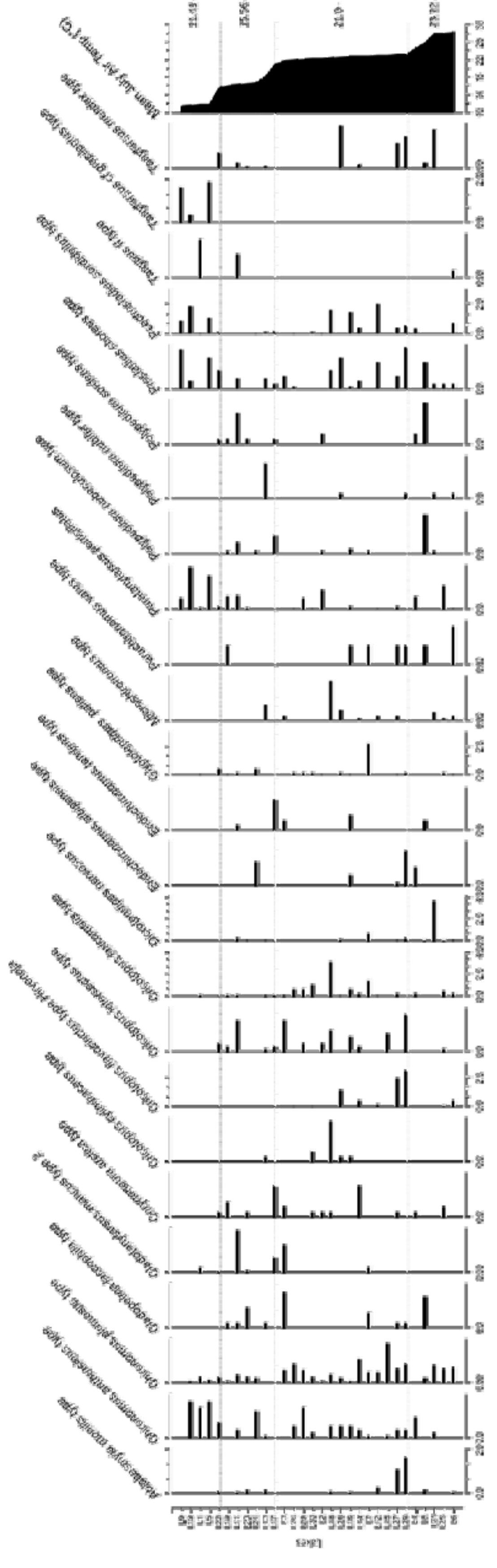

Fig. 4. Chironomid percentage diagram for the Turkish training set, with taxa ranked by mean July air temperature.

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