SUBFOSSIL CHIRONOMIDS FROM 18 LAKES IN SOUTHERN AND NORTHERN FINLAND

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Introduction

Midge and especially chironomid (Diptera: Chironomidae) larvae provide an excellent data source of environmental conditions in aquatic ecosystems, particularly in lakes and ponds, where they live abundantly in the bottom of littoral and pelagic zones. Chironomids are a very diverse midge family, for example Paasivirta (2007) lists over 750 species in Finland. Some species are ecologically sensitive, living only in certain types of waters. Their chitinous head capsules preserve in lake sediments as subfossil remains and have been used to interpret past environmental changes in lakes, e.g. changes in temperature, water depth, salinity, productivity, hypolimnetic oxygen and pH (Walker 2001). Subfossil chironomid analysis has also been used in contemporary ecological studies, as the chironomid assemblage in the topmost sediment layer, if not disturbed, is considered to represent the present chironomid fauna and sampling of the surface sediment is fairly easy and effective. The major disadvantage in subfossil chironomid analysis is the difficulty in identification, because it is often impossible to identify to species or even genus level. However, for example Olander et al. (1999), Larocque et al. (2001) and Nyman et al. (2005) have gathered important information on distribution of chironomids in northern Fennoscandia based on surface sediment samples. Although these studies have led to highly developed chironomid-based palaeotemperature inference models, they are restricted to subarctic regions and do not cover the southern areas of Fennoscandia.

The aim of the present study is to provide data on the distribution of chironomids in southern and northern Finland and to examine whether faunal patterns in distribution exist between these regions. Therefore, 18 lakes in Finland, 11 situated in the southernmost part of the state and 7 in the northernmost part, were studied for their subfossil chironomid fauna. This study presents preliminary results from a wider investigation of chironomid distribution in Finland.

The study area

The 18 lakes were chosen to represent different lake types in southern (60°13’ to 60°26’ N) and northern Finland (69°40’ to 69°53’ N) (Figure 1). Catchment vegetation of the lakes spans from boreal coniferous forests in the south to tundra vegetation in north. The mean annual air temperature varies between 4.5 (south, Helsinki-Vantaa airport) and -2.0 °C (north, Kevo research station), and the mean annual precipitation from 649 mm to 395 mm, respectively. The altitude of the lakes varies from 15 to 404 m a.s.l. and altitude corrected mean July air temperatures were calculated for individual lakes (Laaksonen 1976) (Table 1). The range in mean July air temperature varies from 16.8 in south to 11.0 °C in north. All northern lakes were oligotrophic and their surface areas varied from ca. 20 to 90 ha., whereas southern lakes varied more in their trophic status and were generally smaller (Table 1).

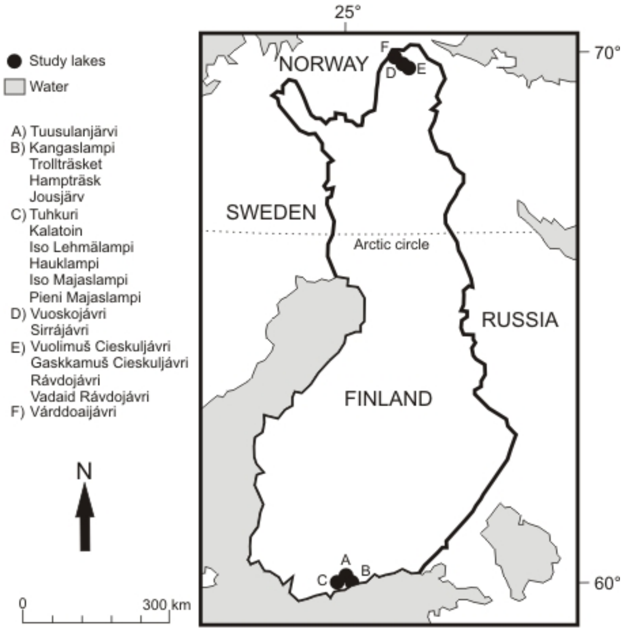

Figure 2. Location of the study sites. Lakes A-C are located in boreal forests, lakes D-E in mountain birch woodland and F in subarctic tundra.

Table 1. Location, climate and other characteristics of the examined lakes.

Lake	Latitude (°N)	Longitude (°E)	Altitude (m a.s.l.)	MeanTJul (°C)	Area (ha)	Trophic status	Vegetation zones*
Varddoaijavri	69.53	26.31	404.0	11.01	28.5	oligotrophic	Ba
Vadaid Ravdojavri	69.40	27.13	301.0	11.59	92.2	oligotrophic	MBW
Gaskkamus Cieskuljavri	69.43	27.07	282.6	11.70	15.0	oligotrophic	MBW
Ravdojavri	69.40	27.12	275.8	11.74	62.3	oligotrophic	MBW
Vuolimus Cieskuljavri	69.44	27.05	269.4	11.77	45.7	oligotrophic	MBW
Sirrajavri	69.45	26.53	208.0	12.12	18.2	oligotrophic	MBW
Vuoskojavri	69.44	26.56	145.0	12.48	19.2	oligotrophic	MBW
Pieni Majaslampi	60.19	24.35	97.3	16.35	1.1	oligotrophic	SPB
Iso Majaslampi	60.19	24.35	92.7	16.37	6.3	oligotrophic	SPB
Iso Lehmälampi	60.20	24.36	91.7	16.38	5.1	oligotrophic	SPB
Kalatoin	60.20	24.37	89.5	16.39	0.9	dystrophic	SPB
Hauklampi	60.18	24.36	75.7	16.47	2.7	oligotrophic	SPB
Tuhkuri	60.20	24.38	73.7	16.48	13.7	oligotrophic	SPB
Jousjärv	60.20	25.11	37.3	16.69	0.5	dystrophic	SPB
Tuusulanjärvi	60.26	25.03	37.8	16.69	600.0	eutrophic	SPB
Trollträsket	60.20	25.09	24.0	16.77	1.3	mesotophic	SPB
Hampträsk	60.17	25.15	20.3	16.79	3.8	mesotophic	SPB
Kangaslampi	60.13	25.08	14.6	16.82	1.4	eutrophic	SPB

*Ba = barren tundra, MBW = mountain birch woodland, SPB = spruce, pine and birch forest.

Materials and methods

The surface sediment samples were obtained with a Limnos gravity corer between February and April in 2005. The sediment samples for subfossil chironomid analysis were prepared using standard methods described in Hofmann (1986) and Walker (2001). A minimum of 100 chironomid head capsules were identified from each sample. The identification was based mainly on Wiederholm (1983). Heiri et al. (2004) was used to identify the Tanytarsini, Sæther (1975, 1976) and Walker et al. (1992) for some of the Orthocladiinae and Rieradevall & Brooks (2001) for the Tanypodinae larvae. The WWW Field Guide to subfossil Midges (Walker 2007) was also very helpful. The nomenclature follows the above mentioned literature.

Detrended correspondence analysis (DCA) was performed using the program CANOCO, version 4.52 (ter Braak 2003) to explore patterns in the distribution of the chironomid taxa in Finland. The DCA was run with detrending by segments, square-root-transformation of species abundances and down weighting of rare species. DCA is an indirect ordination method that summarizes the variation of the species assemblages along the DCA axes.

Results and discussion

From the sediments of the 18 lakes, a total of 2310 chironomid head capsules were counted and identified to genus or species level. In all, 66 taxa were identified; 40 Chironominae (23 Chironomini, 16 Tanytarsini, 1 Pseudochironomini), 22 Orthocladiinae, 3 Tanypodinae and 1 Diamesinae. The most common chironomid taxa (Figure 2, Table 2) were *Tanytarsus* undif. (mean abundance in the lakes 7.8%) and *Psectrocladius sordidellus* type (7.7%). *Ablabesmyia monilis* type (6.8%), *Monopsectrocladius calcaratus* type (6.4%) and *Procladius* (6.3%) were also common. *Monopsectrocladius calcaratus* type, *Ablabesmyia monilis* type, *Dicrotendipes pulsus* type, *Tanytarsus* undif. and *Procladius* occurred in 17 lakes (Table 2) while none of the taxa occurred in all lakes. The most evenly distributed taxa in the lakes, with high effective number of occurrences (Hill's N2), were *Ablabesmyia monilis* type (13.1), *Dicrotendipes pulsus* type (11.7) and *Psectrocladius sordidellus* type (11.0) (Table 2).

Table 2. Chironomid occurrences, Hill's N2 diversity index, maximum and mean percentages and calculated optimum temperatures based on the 18 study lakes.

	Occurrences	Hill's N2	Maximum	Mean	Opt. temp. (°C)
Micropsectra radialis type	1	1.0	4.1	0.2	11.01
Hydrobaenus pilipes type	2	2.0	0.7	0.1	11.37
Heterotrissocladius brundini type	6	3.6	10.8	1.4	11.42
Tanytarsus lugens type	10	7.2	10.1	2.5	11.6
Thienemannimyia	5	4.6	1.4	0.2	11.68
Sergentia coracina type	7	5.9	8.4	2.0	11.69
Zalutschia tatrica type	4	3.0	3.5	0.4	11.75
Heterotrissocladius grimshawi type	5	4.0	5.2	1.0	11.90
Parakiefferiella nigra	2	1.5	2.6	0.2	11.90
Cricotopus pulchripes type	6	4.9	4.7	1.0	11.93
Micropsectra insignilobus type	9	4.2	19.8	3.2	11.97
Protanypus	1	1.0	2.6	0.1	12.12
Corynocera ambigua	7	4.0	15.4	2.3	12.29
Stempellinella	1	1.0	0.7	0.0	12.48
Cricotopus (I.) sp.	4	2.5	5.0	0.5	12.53

	Occurrences	Hill's N2	Maximum	Mean	Opt. temp. (°C)
Constempellina brevicosta	5	2.3	5.1	0.5	12.85
Paratanytarsus austriacus type	2	1.4	3.6	0.2	13.14
Paratanytarsus undif.	14	8.7	16.2	4.1	13.25
Micropsectra bidentata type	7	4.0	4.3	0.5	13.52
Monopsectrocladius calcaratus type	13	6.2	36.8	6.4	13.55
Microtendipes pedellus type	13	7.9	7.9	2.2	13.68
Paratanytarsus penicillatus type	8	6.5	5.0	1.2	13.81
Cricotopus (I.) sylvestris type	15	9.6	5.8	1.4	14.06
Pagastiella orophila	8	6.0	2.7	0.5	14.13
Heterotrissocladius marcidus type	6	3.8	6.8	0.9	14.14
Paracladopelma	2	2.0	0.9	0.1	14.31
Cricotopus undif.	10	7.7	5.4	1.3	14.46
Psectrocladius sordidellus type	17	11.0	26.0	7.7	14.71
Cladotanytarsus mancus type	9	4.3	11.3	1.5	14.77
Phaenopsectra flavipes type	7	6.2	1.9	0.5	14.87
Zalutschia zalutschicola	10	7.9	6.0	1.9	14.87
Ablabesmyia monilis type	17	13.1	15.6	6.8	14.95
Dicrotendipes pulsus type	17	11.7	12.1	3.9	14.96
Heterotanytarsus apicalis type	6	3.7	9.9	1.6	15.22
Psectrocladius (Mesopsectrocladius)	4	2.9	2.6	0.3	15.27
Cryptochironomus	2	1.8	1.6	0.1	15.37
Polypedilum nubeculosum type	12	9.5	3.1	1.0	15.63
Tanytarsus undif.	17	7.4	41.9	7.8	15.64
Procladius	17	6.4	38.6	6.3	15.67
Psectrocladius (Allopsectrocladius)	12	4.3	25.0	3.5	15.74
Cladopelma viridulum type	13	6.5	7.7	1.3	15.91
Pseudochironomus prasinatus type	5	4.2	2.9	0.5	16.06
Tanytarsus pallidicornis type	13	7.3	12.4	3.0	16.07
Tanytarsus chinyensis type	6	2.7	7.3	0.7	16.31
Chironomus anthracinus type	11	6.5	13.6	2.9	16.31
Limnophyes	6	3.6	8.7	1.3	16.34
Paratendipes albimanus type	1	1.0	5.8	0.3	16.39
Corynoneura lobata type	5	1.6	29.7	2.1	16.39
Chironomus plumosus type	11	3.9	19.7	2.5	16.41
Lauterborniella agrayloides type	5	4.6	2.3	0.4	16.54
Corynoneura scutellata type	5	3.0	5.8	0.6	16.56
Nanocladius (N.) rectinervis type	4	3.0	3.0	0.4	16.56

	Occurrences	Hill's N2	Maximum	Mean	Opt. temp. (°C)
Tanytarsus mendax type	7	6.4	6.8	1.8	16.57
Microchironomus tener type	1	1.0	11.0	0.6	16.69
Endochironomus impar type	2	1.9	1.6	0.1	16.69
Endochironomus albipennis type	3	2.4	3.4	0.4	16.74
Orthocladius sp.	3	2.7	4.0	0.5	16.75
Einfeldia pagana type	3	2.5	6.8	0.7	16.75
Rheotanytarsus	5	3.6	4.3	0.6	16.76
Polypedilum sordens type	3	1.9	3.4	0.3	16.76
Mesocricotopus thienemannii	1	1.0	1.5	0.1	16.79
Glyptotendipes pallens type	4	2.3	10.3	0.9	16.79
Omisus caledonicus	1	1.0	0.9	0.0	16.82
Parachironomus varus type	1	1.0	3.4	0.2	16.82
Endochironomus tendens type	1	1.0	0.9	0.0	16.82
Kiefferulus tendipediformis type	1	1.0	1.7	0.1	16.82

Several chironomid taxa occurred mainly in the northern lakes, whereas many were found only from southern sites (Figure 2). Some taxa, e.g. *Psectrocladius sordidellus* type and *Ablabesmyia monilis* type were found abundantly in both northern and southern lakes (Figure 2). *Micropsectra radialis* type occurred only in Várddoaijávri (Figure 2, Table 2), which is the coldest of the lakes, located in the subarctic tundra of the northernmost Finland. Also *Heterotrissocladius brundini* type and *Paratanytarsus* undif., were at their highest abundance in Várddoaijávri. *Paratanytarsus* undif. occurred also in all mountain birch woodland lakes and in some boreal forest lakes. A clear northern distribution with preference to mountain birch woodland lakes (Table 1), was observed for *Tanytarsus lugens* type, *Thienemannimyia*, *Sergentia coracina* type, *Zalutschia tatrica* type, *Heterotrissocladius grimshawi* type, *Parakiefferiella nigra, Cricotopus pulchripes* type, *Micropsectra insignilobus* type, *Protanypus, Corynocera ambigua, Cricotopus (I.)* sp., *Constempellina brevicosta* and *Paratanytarsus austriacus* type. A southern distribution was observed for many taxa (Figure 2). *Polypedilum sordens* type, *Rheotanytarsus, Orthocladius* sp., *Endochironomus impar* type, *Tanytarsus mendax* type, *Nanocladius (N.) rectinervis* type, *Corynoneura scutellata* type, *Lauterborniella agrayloides* type, *Corynoneura lobata* type, *Paratendipes albimanus* type, *Limnophyes, Tanytarsus chinyensis* type, *T. pallidicornis* type, *Pseudochironomus prasinatus* type, *Cladopelma viridulum* type and *Psectrocladius (Allopsectrocladius)* occurred mainly in southern lakes, which are situated in the boreal forest vegetation zone. *Glyptotendipes pallens* type, *Einfeldia pagana* type, *Endochironomus albipennis* type, *Microchironomus tener* type and *Chironomus plumosus* type also had southern occurrences, and they showed further preference for nutrient rich lakes (Figure 2, Table 1). Also *Chironomus anthracinus* type and *Procladius* had their maximum abundances in southern, nutrient-rich lakes. The general results of the distribution of chironomids in the present study seem to agree with other studies (e.g. Brodersen and Quinlan 2006; Brooks 2006).

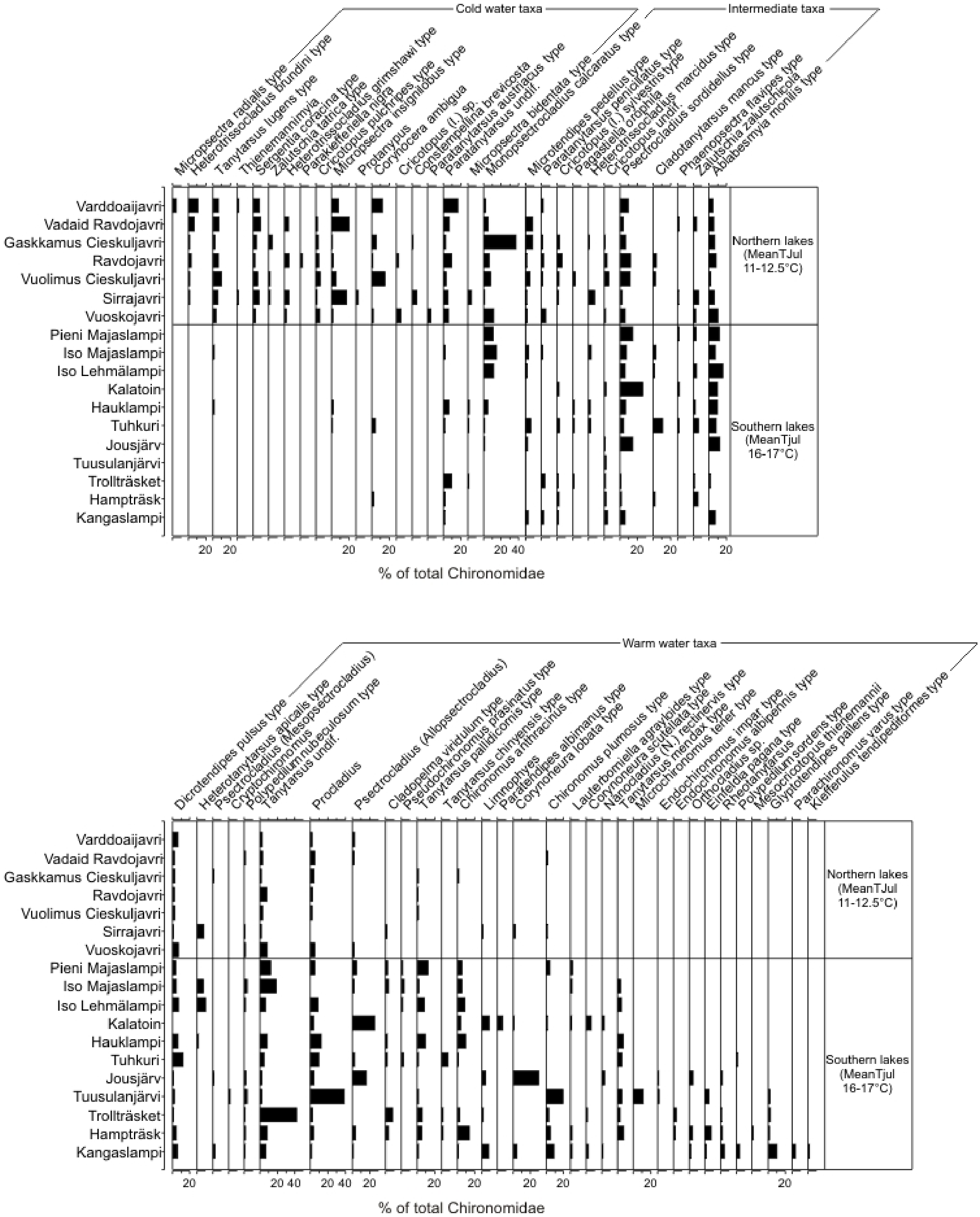

Figure 3. Distribution of the most common Chironomidae. The taxa are ordered based on their optimum temperatures from the coldest (left) to the warmest (right) and the lakes are ordered based on their mean July air temperatures from the coldest (top) to the warmest (bottom).

The DCA ordination diagram (Figure 3) indicates that the samples (i.e. lakes) are clearly clustered into several groups according to their chironomid fauna. The scores for the southern and northern lakes are distinctly different from each other; the southern lakes having low or intermediate values for DCA axis 1 and northern lakes having high values. The northern lakes had very similar scores along both DCA axes suggesting that their chironomid assemblages were very similar. There was also clustering among the southern lakes. The meso-eutrophic southern lakes had rather low values along both DCA axis and the most eutrophic lake (Tuusulanjärvi) had distinctly low values for both axes. The dystrophic, macrophyte-rich lakes had highest scores for the DCA axis 2 values and low axis 1 values and the oligotrophic southern lakes had scores in the center of the ordination diagram.

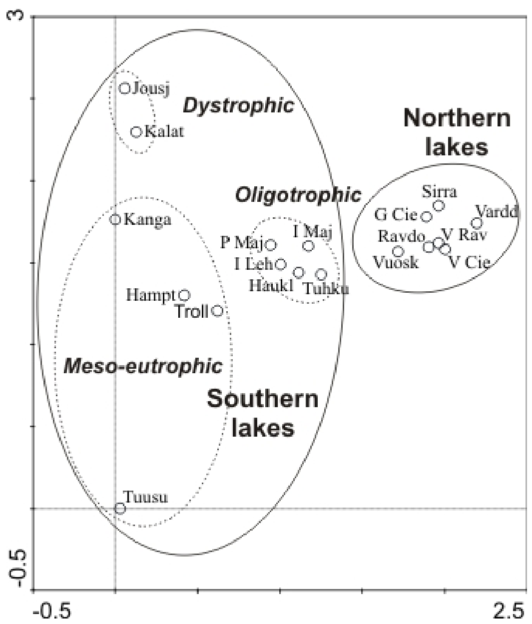

Figure 4. Figure 3. DCA plot for samples based on the chironomid assemblages in the 18 lakes.

According to the current results, it appears that the occurrences of some chironomid taxa are restricted to either southern or northern lakes and some were found in both regions (Figure 2). This suggests that faunal patterns exist in distribution of chironomids in Finland. It is possible that climatic factors are behind this geographical distribution of chironomids, since climate differs considerably between southern and northern Finland (Table 1) and temperature is known to affect the occurrence of chironomids (Brooks 2006). Because such differences in distribution were found, optimum temperatures, based on lake specific July air temperatures (meanTJul) were calculated for each taxon (Table 2) and the chironomids were grouped to cold, intermediate and warm water inhabitants (Figure 2). However, it is likely that many other chemical, physical or ecological factors besides climate affect their distribution and are influencing these faunal patterns. For example the northern lakes in the present study were much larger than the southern ones and this may be one contributing factor causing the differences in northern and southern chironomid assemblages. Olander et al. (1999) found the organic content of the sediment (measured as loss on ignition: LOI) and lake water temperature to be the key factors and Nyman *et al.* (2005) showed that LOI, total organic carbon (TOC), pH and lake specific July air temperature were the most significant factors affecting chironomid distributions in western Finnish Lapland. Larocque *et al.* (2001) concluded that mean July air temperature, LOI and maximum lake depth were the most important environmental variables in subarctic northern Sweden. The present study provided data only on chironomids in southern and northern lakes and therefore presents no information on distribution in the geographical region in between. For more detailed information on distribution patterns of chironomids more research is needed from a wider spatial range.

Conclusions

The southern lakes were generally dissimilar in their chironomid assemblages compared to northern lakes, and furthermore showed some clear faunal patterns. Chironomid assemblages were similar within the 5 oligotrophic lakes, 2 dystrophic lakes and 4 meso-eutrophic lakes (Figure 3). It is probable that the limnological diversity in lake ecosystems in southern Finland, e.g. variation in the trophic status, water color and macrophyte-cover, provided suitable habitats for different chironomid taxa, resulting in different faunal assemblages in certain types of lakes and that similar conditions does not exist in northern Finland.

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