SPIXIANA	Supplement 14	7–15	München, 15. Juli 1988	ISSN 0177–7424

Changes in the profundal Chironomidae of Lake Mälaren during 17 years

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Abstract

The profundal benthos of Lake Mälaren was sampled in September/October each from 1970 and onwards. Considerable fluctuations in population densities of the most abundant taxa occurred. In many cases the temporal patterns were similar between stations, indicating common causal mechanisms. The role of food, climatic conditions and biotic interactions is discussed.

Introduction

Lake Mälaren is the third in size of Sweden's lakes. The lake serves as a water supply to Stockholm and other surrounding communities, supports a significant fishery and is used for various recreational activities among the population of 1.1 million within its drainage area.

Limnological monitoring of Lake Mälaren and its main tributaries has been performed since 1966. Studies of the bottom fauna were started in 1969. Sampling network and methods have been the same since 1970. Earlier results were reported in Wiederholm (1974, 1978). In the present paper I describe the changes that have taken place among the major taxa of profundal Chironomidae and discuss the importance of trophic conditions and other factors to these changes.

Methods and material

Five Ekman samples (15×15×30 cm) were taken in September/October each year from 19 stations throughout the lake. Eight of these stations, representing the major subareas of the lake, are discussed here (Fig. 1). The sediments were washed through a 0.6 mm net and preserved in 70 % ethanol in the field. The samples were stained using Bengal Rose, sorted under microscope and the animals identified to species or genus (Chironomidae and others) or higher taxonomic level (Oligochaeta, Hydracarina). Data were stored and treated with the use of codes in Maitland (1977) (amended by myself and co-workers), Uppsala University's computer (SAS, own programmes) and PC:s (statistics and diagrammes in this paper).

The chemical and biological conditions in Lake Mälaren are described in detail by Willen (1984). The lake is composed of several more or less isolated basins. The western and northern parts are the most eutrophic, with considerable variation within and between years in phytoplankton biomasses and water chemistry. The central basins are deeper, somewhat colder and more homogenous temporally.

Results

General

The profundal Chironomidae of Lake Mälaren was predominated for the most part by seven taxa. *Chironomus anthracinus* Zett., *C. plumosus* L. and *Procladius* spp. dominated in the western and

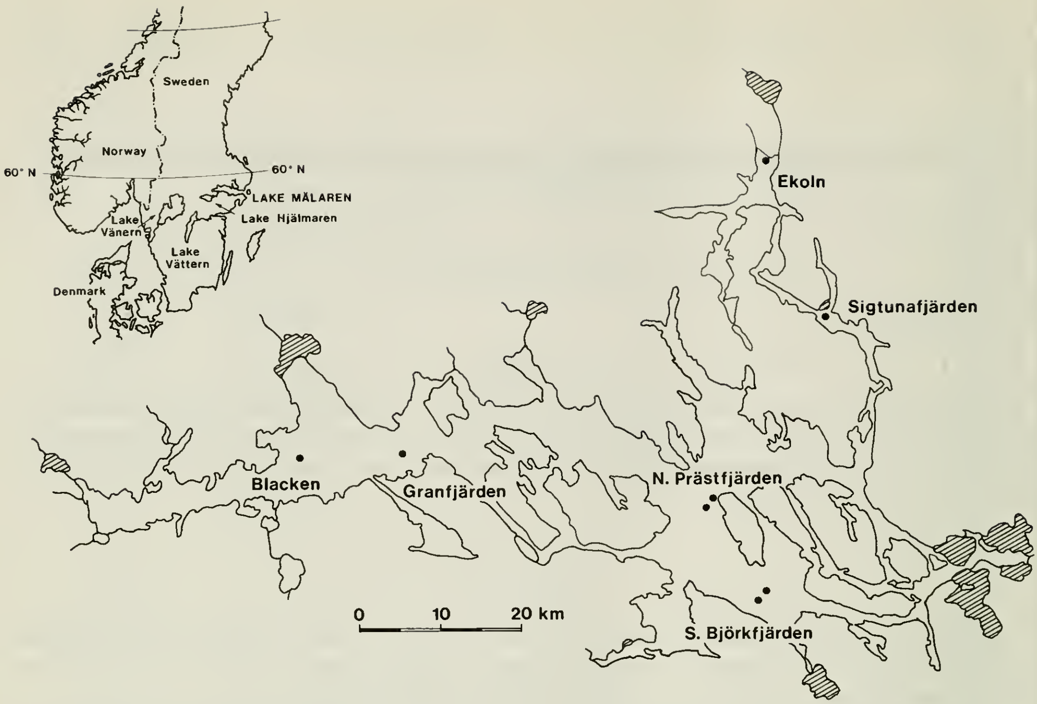

Fig. 1. Lake Mälaren with sampling stations.

northern basins (Blacken, Granfjärden, Ekoln and Sigtunafjärden in Fig. 1). *C. neocorax* Wülker & Butler occurred in western Lake Mälaren. *Micropsectra* spp., *Tanytarsus* spp. and *Procladius* spp. dominated in the central part of the lake, where *Chironomus* was absent. *Sergentia coracina* and *Stictochironomus* spp. were also part of the fauna of the central basins but in lower numbers than the other taxa.

It has not been possible to identify all larval material to species. Imagines of *Micropsectra* caught by hand-net at the central basins were identified as *M. insignilobus* Kieffer by Säwedal (1976). Several species of *Tanytarsus* and *Procladius* have been found and at least two species of *Stictochironomus*, one of which was *S. rosenschoeldi* (Zett.), have been reported to occur in hand-netted material (Wiederholm 1974). *Chironomus* larvae of the *salinarius* type from western Lake Mälaren were described as *C. neocorax* by Wülker & Butler (1983) and none of the other species with this larval type are likely to occur in the lake. The identity of *C. plumosus* and *C. anthracinus* has not been established from chromosome identifications, but these species are the most likely ones to occur in great numbers at the depth that has been sampled here, viz 15 m (cf. Lindeberg & Wiederholm 1979).

Considerable temporal variation in numbers have been noted for most groups of benthic organisms during the study period. Oligochaeta and Chironomidae decreased in numbers at most stations throughout the period. *Chaoborus flavicans* became more abundant during later years (station Blacken in Fig. 2). Crustaceans occurred in high numbers in the central part of the lake during some few years (station N. Prästfjärden in Fig. 2).

Chironomus anthracinus

C. anthracinus occurred in particularly high numbers in Blacken and Sigtunafjärden during the first part of the period (Fig. 3). The species then decreased at all stations and population density was rather low throughout the 1980's. Considerable variation occurred between individual years, and the corre-

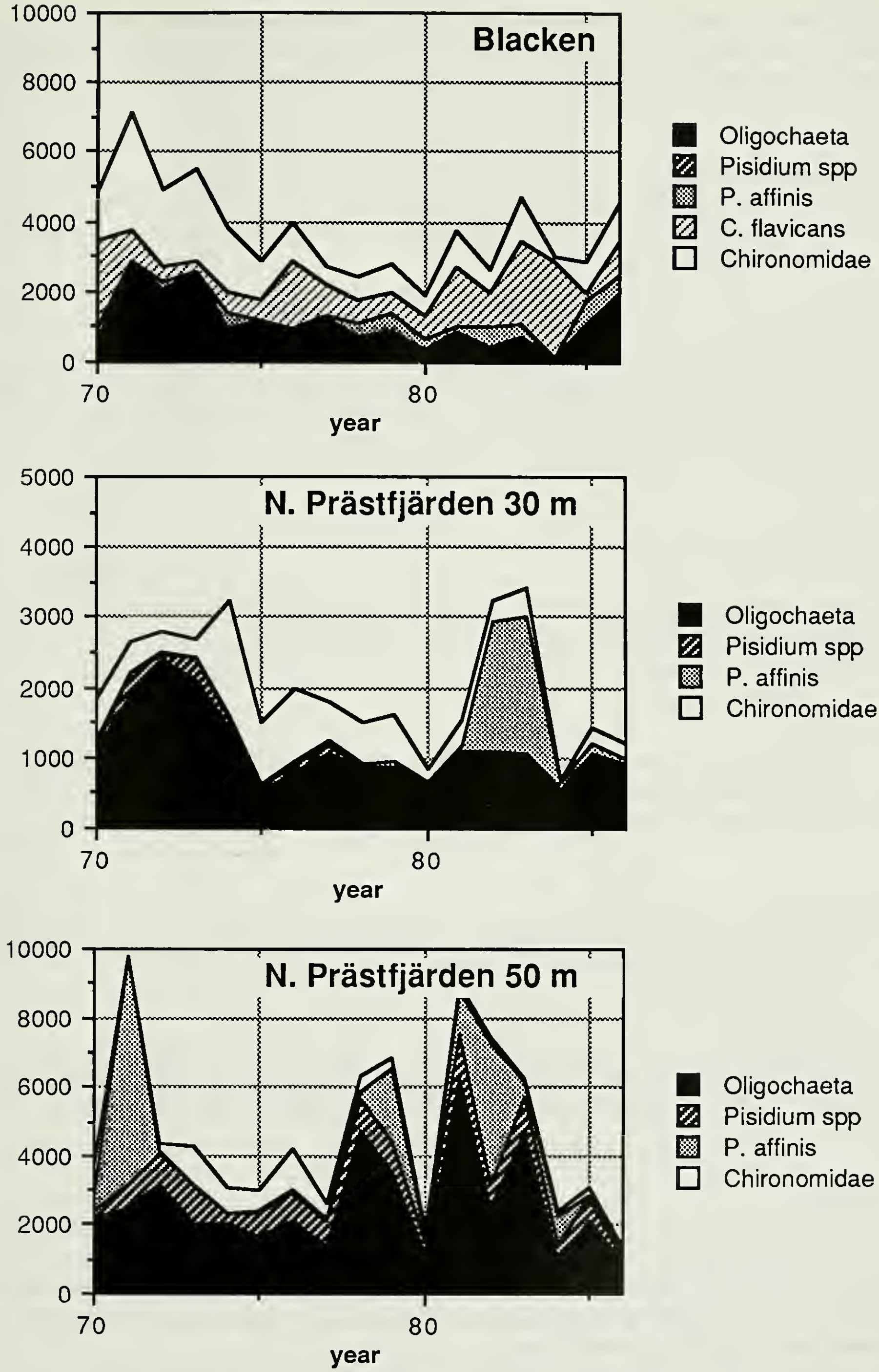

Fig. 2. Occurrence of major groups of benthic organisms 1970–1986 (ind. m^{-2}) in western (stn. Blacken) and central Lake Mälaren (stn. N. Prästfjärden).

lation coefficients between the various data sets for single years were low, except between Blacken and Sigtunafjärden. The general pattern of development was quite similar at all stations, however, as appears from the figures and the correlation coefficients for running means (Fig. 3, Table 1).

C. plumosus

C. plumosus fluctuated in numbers at most stations without any clear general trend or correlation between stations (Fig. 3, Table 1). High numbers occurred in Ekoln during the first part of the study period, but the population density decreased strongly at the end of the 1970's and remained low throughout the remainder of the study period.

C. neocorax

This species has a rather uneven distribution within Lake Mälaren. Similar to the other *Chironomus* species it is absent from the central basins, and it occurs in high numbers only in some of the moderately eutrophic western basins. Of the stations dealt with here, only Granfjärden had high population densities of *C. neocorax,* and there was no clear temporal pattern or correlation between stations (Fig. 3, Table 1).

Micropsectra spp.

Large numbers of *Micropsectra* were found during only a few years (Fig. 3). Distinct peaks occurred at all stations between 1973 and 1976 and the running means of the 30 and 50 m depths in both N. Prästfjärden and S. Björkfjärden were strongly correlated (Table 1). The overall occurrence of *Micropsectra* was low throughout the 1980's.

Tanytarsus spp.

The occurrence of *Tanytarsus* was similar to that of *Micropsectra* (Fig. 3). Peaks occurred at all stations in 1974 and 1976, and very low numbers were found after 1979. The data sets from the various stations were strongly correlated (Table 1).

Sergentia coracina

This species was rare or absent most years, but distinct peaks occurred in 1976 or 1977 in three out of four stations in the central part of Lake Mälaren (Fig. 3).

Stictochironomus spp.

Stictochironomus (not shown in figure or table) had its main occurrence in 1976–79, i. e. somewhat after the peaks of *Micropsectra* and *Tanytarsus.* Significant numbers were found only in N. Prästfjärden.

Procladius spp.

Two peaks occurred at the 30 m stations in central Lake Mälaren – one around 1976 and the other one in 1982–83 (Fig. 3). The running means from these stations were strongly correlated (Table 1). At 50 m depth in N. Prästfjärden the second peak was much less pronounced, but the general pattern was similar. The 50 m station in S. Björkfjärden showed much less variation, but the highest numbers occurred in the first part of the study period.

In the western and northern basins temporal variation was seemingly greater, without much similarity between stations (Fig. 3, Table 1). A general tendency to decreasing abundances may be noted, however.

The occurrence of *Procladius* was similar to that of *Micropsectra* and *Tanytarsus*. Running means of *Procladius* were strongly correlated to those of *Micropsectra* (r = 0.91–0.97) (not shown in table) at the 30 m stations, though less so at the 50 m stations (r = 0.17–0.38). There was also a positive correlation with running means of *Tanytarsus* or *Tanytarsus* plus *Micropsectra* (r = 0.65–0.91) at the 30 m stations, though again this trend was weaker at the greater depth.

Discussion

Considerable variation occurred between years. However, for most taxa trends or regular patterns of variation are clearly discernible. In many cases the similarity between stations, as indicated by high correlation coefficients between the data sets, indicates a common causal mechanism for the observed variation. For example, the high numbers of *Micropsectra*, *Tanytarsus*, *S. coracina* and *Stictochironomus* at most stations in central Lake Mälaren during the mid–1970's would seem to have a common reason. Decreasing numbers of *C. anthracinus* were common to the stations of western and northern Lake Mälaren and one may suspect a common structuring factor here also. The numbers of *Procladius* were strongly correlated at stations in the central part of the lake, but not at the western and northern stations, and this may indicate that different factors are predominating. No pattern could be seen in the numbers of *C. plumosus* and *C. neocorax,* except for the marked decrease of the former species at station Ekoln.

Food, weather conditions and biotic factors are important determinants acting independently or collectively in governing population density. Improved sewage treatment in all major communities around the lake has brought about a 50 % reduction of the phosphorus loading on Lake Mälaren since the middle of the 1960's. The occurrence of a series of dry years up to 1976 added to this and the total phosphorus loading decreased to less than half of its maximum during the last 20 years. Evidently as a result of this, the excessive blooms of bluegreen algae in the western and northern parts of the lake decreased in intensity and duration (Willen 1987). Small species of algae (e. g. flagellates) became more common and the number of species increased. The average total biomass of algae did not decrease to any great extent, however, except for the most eutrophic parts of the lake.

The significance of these changes to the bottom fauna is not immediately clear. Both quantitative and qualitative changes in profundal food supply may have resulted. Because many of the small, non-colonial species of algae are more effective producers than large, colonial species, there is reason to believe that the total planktonic primary production per unit area is about the same as before or even higher. Measurements to support this conclusion are lacking, however. One might assume that a greater proportion of the phytoplankton is metabolized in the water column when small and mobile forms are more predominant. Bluegreens such as *Anabaena* are also metabolized in the water phase (Fallon & Brock 1980), but others sink and decompose on the lake bottom. This may result in increased sediment oxygen demand, but the increased microbial production favours many invertebrates that tolerate low oxygen levels. Among these are several species of Oligochaeta. Hence the reduced numbers of Oligochaeta in many parts of Lake Mälaren (cf. Fig. 2, station Blacken) may therefore be understood as reflecting a reduced nutrient flow through bacteria and sediments, resulting from the reduced occurrence of bluegreen algae.

Little information is available on food utilization of aquatic insects – certain types of ingested matter are probably of little value, whereas small amounts of other material may be critical (Lambertini & Moore 1984). *C. anthracinus* and *C. plumosus* are both detrivores, but algae sometimes make up a considerable part of the gut content (Jónasson 1972, Lambertini & Moore 1974). Johnson (1985) concluded that *C. anthracinus* is more of a deposit feeder, ingesting particulate matter scraped from the recently deposited surface sediments, whereas *C. plumosus* is a filter feeder with the nutritional quality of ingested matter depending primarily on pelagic inputs. This would explain the decreasing num-

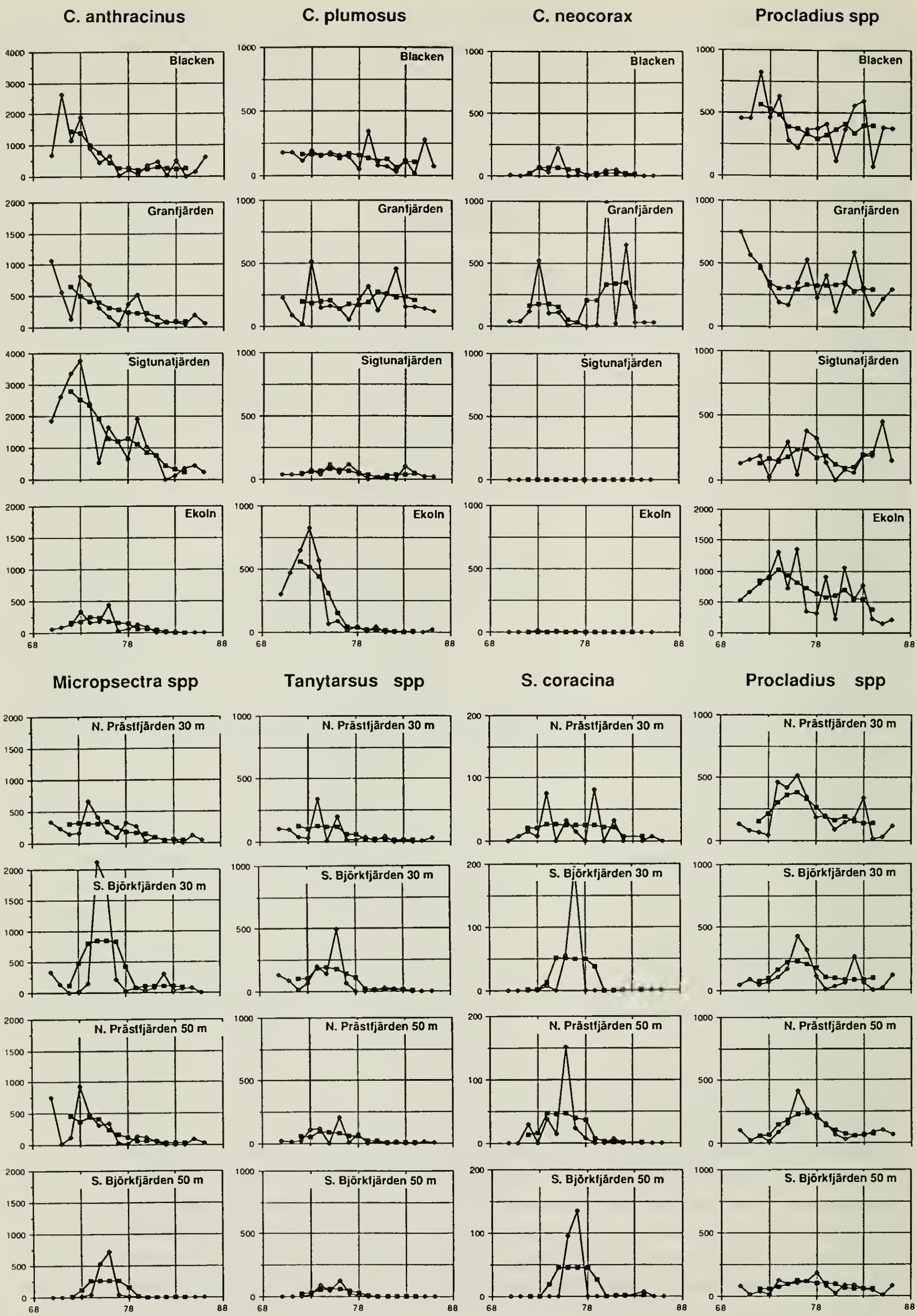

Fig. 3. Occurrence of major profundal Chironomidae 1970–1986; yearly and 5 yr running means (ind. m^{-2}). Please observe differences in scales.

bers of *C. anthracinus* if, as argued above, one accepts that the changes in phytoplankton species composition has increased the relative importance of the pelagic metabolism relative to that of the benthic one.

The decrease of *C. plumosus* at station Ekoln is probably more of a local change than part of a general pattern. Hypereutrophic conditions occurred at this station before effective sewage treatment was installed in the nearby city of Uppsala, and *C. plumosus* endured this better than *C. anthracinus*. It is surprising, however, that both species have decreased to virtual extinction during later years.

Contrary to the other species dealt with here, *Procladius* spp. are predominantly carnivorous, although algae and detritus may also be found in their gut content (Tarwid 1969, Baker & McLachlan 1979). Oligochaetes, other chironomid larvae and small benthic crustaceans are the preferred prey. Data on the ocurrence of crustaceans are not available. There was a positive correlation between the running means of *Procladius* spp. and those of Oligochaeta at two of the four stations in western and northern Lake Mälaren. The correlation was negative and very weak at the central stations, where *Micropsectra* and *Tanytarsus* were better correlated with *Procladius*. This may indicate that the fluctuations in numbers of *Procladius* depended on fluctuations of their prey organisms, but it may also indicate that some of these taxa responded to some other factor that led to a common temporal pattern (cf. below).

Micropsectra, Tanytarsus, Sergentia coracina and *Stictochironomus* had their maximum occurrence during the mid–1970's. All are presumably browsers or filter feeders and typical inhabitants of the mesotrophic or moderately oligotrophic lake types as characterized by Brundin (1956). They were characteristic members of the profundal chironomid communities in the central part of Lake Mälaren throughout the study period dealt with here, but high population densities occurred only during a few years. It seems unlikely that this pattern would have been due to a directional change toward more mesotrophic or oligotrophic conditions that would have presented optimal conditions during these years only. Thus underlying factors with a more stochastic variation should be sought to explain the occurrence of these taxa. Weather conditions coincident with emergence may be one such factor. Calm and warm weather should be favourable to swarming, egg-laying, and hence the recruitment of young larvae, particularly in species with a short and well synchronized flight period. Phenological data is scarce, however, and the available information indicates rather long or even several flight periods. Imagines of *M. insignilobus* are common in May and June at the central basins of Lake Mälaren (Wiederholm 1974). *Stictochironomus rosenschoeldi* and another species of *Stictochironomus* occur in June and July. Records of adult *Sergentia coracina* from southern and central Sweden include late June and September (Brundin 1949); no adults have been found from Lake Mälaren. If one assumes that the 4th instar larvae found in September–October were born in the early summer the same year, weather conditions in May and June should be important. Weather records show that these months were particularly warm in 1976, with 230 day degrees above the average for 1970–85 and nearly 350 day degrees above the minimum during the period, which occurred in 1982. *Micropsectra, Tanytarsus* and *Sergentia coracina* had population peaks in 1976 at some stations. Peaks did occur in other years also, however, when temperatures were below average (e. g. 1985). Nevertheless it is still possible that the peaks in larval abundance that occurred during these years were related to weather conditions, but more detailed life history information is needed to support this conjecture.

Between 5000 and 10000 ind. m^{-2}, occasionally as much as 20000 ind. m^{-2}, of *Pontoporiea affinis* may be found at 50 m depth at station S. Björkfjärden (Wiederholm unpubl.). The physical disturbance by such numbers of crustaceans should have a negative influence on the sessile, tube-living and rather fragile larvae of *Tanytarsus* and *Micropsectra,* and a strong negative correlation did occur between running means of *P. affinis* and the two chironomid taxa ($r = -0.85$ and -0.91, respectively). Hence, the absence of large numbers of *P. affinis* might be a prerequisite for *Tanytarsus* and *Micropsectra* to occur in reasonably large populations densities even during years when weather conditions and other circumstances were favourable to recruitment of young.

C. anthracinus

	Blacken	Granfj.	Sigtunafj.	Ekoln
Blacken		0.48/0.91	0.72/0.92	0.39/0.63
Granfj.	0.08/-0.51		0.60/0.98	0.34/0.78
Sigtunafj.	0.01/0.61	-0.22/-0.77		0.60/0.83
Ekoln	0.17/0.60	0.12/-0.32	0.08/0.51	

C. plumosus

C. neocorax

	Blacken	Granfj.	Sigtunafj.	Ekoln
Blacken		0.15/-0.47	-/-	0.11/0.71
Granfj.	0.46/0.60		-/-	0.21/-0.43
Sigtunafj.	-0.04/-0.28	-0.11/-0.27		-/-
Ekoln	0.34/0.55	0.08/0.26	-0.43/-0.07	

Procladius spp

Micropsectra spp

	N. Prästfj. 30	S. Björkfj. 30	N. Prästfj. 50	S. Björkfj. 50
N. Prästfj. 30		0.30/0.76	0.47/0.89	0.25/0.75
S. Björkfj. 30	0.68/0.89		0.20/0.59	0.95/0.99
N. Prästfj. 50	0.67/0.92	0.80/0.98		0.19/0.57
S. Björkfj. 50	0.75/0.85	0.92/0.99	0.82/0.97	

Tanytarsus spp

Sergentia coracina

	N. Prästfj. 30	S. Björkfj. 30	N. Prästfj. 50	S. Björkfj. 50
N. Prästfj. 30		0.05/0.59	0.28/0.64	0.06/0.60
S. Björkfj. 30	0.67/0.97		0.32/0.75	0.94/0.99
N. Prästfj. 50	0.65/0.87	0.73/0.94		0.60/0.82
S. Björkfj. 50	0.60/0.75	0.46/0.80	0.53/0.91	

Procladius spp

Table 1. Correlations between stations for the dominant chironomid species; yearly data/5 yr running means.

The deep profundal of temperate lakes is sometimes thought of as a zone of stable environmental conditions with little variation in population densities and community composition. The studies reported here are not the first to demonstrate that considerable fluctuations do occur (cf. Jónasson 1972, Holopainen & Jónasson 1983). Few time series exist, however, that describe long-term variation in profundal Chironomidae. Observations from such series may be used to formulate hypotheses on the role of abiotic factors, food, competition and predation to variation in population density and community structure. In particular, long series of field observations are the only practical way to assess the significance of climatic varation to population densities of profundal Chironomidae. To understand the role of biotic interactions, more information is needed, in particular, on life histories of Chironomidae and how these are linked to seasonal variation of phytoplankton production and deposition of organic matter on lake bottoms.

Acknowledgements

Lars Eriksson identified and counted the Chironomidae. Richard Johnson read the manuscript.

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