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Midge fauna development in acidified lakes in northern Europe

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Analyses of stratigraphical sedimentary remains of aquatic midges (Chironomidae, Chaoboridae and Ceratopogonidae) revealed pronounced faunal changes attributable to acidification in north European lakes from about 1850 and onwards. Increased lake acidification during this century generally caused a reduction of midge fauna stability, diversity, productivity and survival rate. The similarity of chironomid species composition between lakes increased. Changes in chironomid species composition also revealed that oligotrophication is a typical feature of acidified lakes.

Introduction

The recent acidification of lakes has exerted profound effects on aquatic fauna, the most obvious consequences being decreased animal diversity and elimination of several species, especially among fish, snails, mussels, crustaceans and mayflies (Oekland & Oekland 1986). Only a few groups of insects seem to be increasing in numbers in greatly acidified lakes, for example, water beetles (Coleoptera), water boatmen (Corixidae) and damselflies (Agrionidae) (Oekland & Oekland 1986).

The main objective of this paper is to outline important effects of acidification on aquatic midges in north European lakes, with special emphasis on chironomids.

The present study is based on analyses of remains of midge larvae (Chironomidae, Chaoboridae and Ceratopogonidae) in sediment cores from three strongly acidified lakes in Scotland (Round Loch of Glenhead), Norway (Verevatn) and Sweden (Lilla Öresjön), and two moderately acidified lakes in Scotland (Loch Tinker and Loch Chon). Locations, site characteristics and chemical data for these lakes are described by Battarbee & Renberg (this symposium).

Methods

Laboratory and taxonomic methods employed for analyses of aquatic midges are described by Brodin (1990). The Shannon Wiener index was used to calculate temporal changes in species diversity (Southwood 1971). Temporal changes in faunal stability were calculated by using the ps index described by Whittaker (1972).

Midge productivity was calculated by using the number of fourth instar larvae per cubic centimetre and the sediment accumulation rate. Calculations of survival rate were based on the relative proportion of fourth larval instars. Calculations of lake trophic conditions were based on the trophic preference and dominance of different chironomid species (Brodin 1990).

Core chronologies used were derived from ^{210}Pb dates for each site (Appleby *et al.*, this symposium; El-Daoushy, this symposium).

Results

Despite differences in catchment characteristics of the sites studied, a close agreement in the trends of the different midge fauna parameters was observed (figure 1 and table 1). Consequently, the midge faunal development was divided into four phases defined by major differences in the character of the midge fauna.

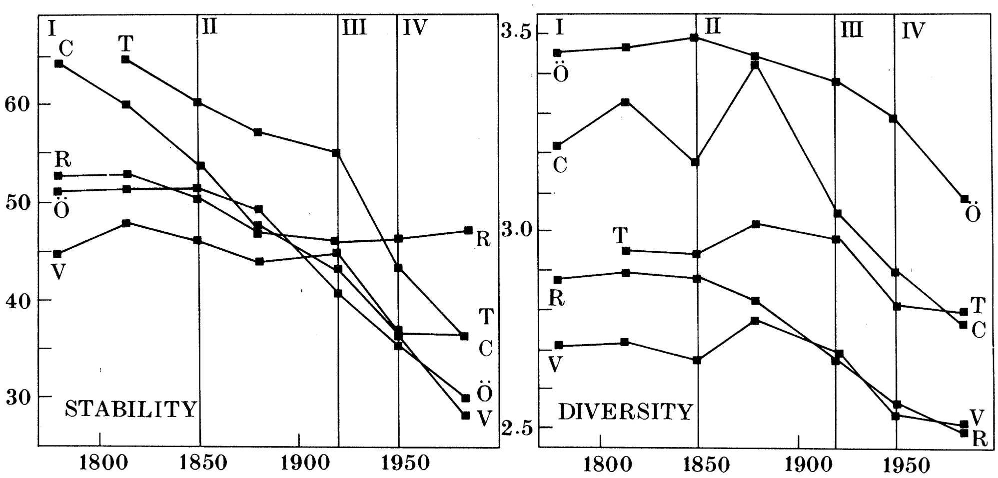

Figure 1. Temporal development of midge fauna stability and diversity in Loch Chon (C), Lilla Öresjön (Ö), Round Loch of Glenhead (R), Loch Tinker (T) and Verevatn (V). Midge faunal phases (I–IV), showing varying degrees of lake acidification are outlined (cf. text).

Table 1. Midge productivity, survival rate and lake trophic level during different midge faunal phases (cf. text). Phase I, *ca.* 1780–1850: phase II, *ca.* 1850–1920; phase III, *ca.* 1920–1950; phase IV, *ca.* 1950–1985. Diatom inferred pH for midge faunal phases is given in parentheses. Diatom data were obtained from Kreiser *et al.* (this symposium), Jones *et al.* (this symposium), Berge *et al.* (this symposium) and Renberg *et al.* (this symposium).

	productivity (ind. × 10^{-3}, m^{-2} a^{-1})				survival rate (%)				lake trophic level (> 3.5 = oligotrophic) (< 3.5 = ultraoligotrophic)			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Loch Chon	11.9 (6.2)	9.7 (6.2)	8.6 (6.0)	6.4 (5.7)	37.4	47.2	33.9	19.2	3.7	4.2	3.1	3.1
Lilla Öresjön	8.4 (6.0)	7.7 (6.0)	6.3 (5.7)	3.8 (4.6)	44.4	45.3	40.2	32.5	3.8	3.7	4.0	3.6
Round Loch of Glenhead	10.6 (5.5)	9.8 (5.0)	5.2 (4.7)	4.1 (4.7)	50.1	47.2	42.4	43.6	4.2	3.8	3.5	3.4
Loch Tinker	12.4 (6.2)	12.9 (6.0)	7.8 (5.7)	4.6 (5.7)	40.9	42.1	39.9	31.1	3.8	4.3	3.8	3.5
Verevatn	2.7 (5.0)	3.9 (4.7)	3.6 (4.7)	1.6 (4.5)	39.7	40.7	34.6	17.6	4.1	4.2	3.6	3.5

Faunal stability decreased distinctly in Loch Chon during phase I (*ca.* 1780–1850). Otherwise no major changes in midge fauna of the lakes studied occurred. Diversity and productivity was comparatively high, as was the survival rate. During phase II (*ca.* 1850–1920) all the lakes experienced decreases in stability and diversity decreased in Loch Chon, Round Loch of Glenhead and Lilla Öresjön.

Apart from stability in Round Loch of Glenhead, all lakes experienced decreases in midge fauna stability, diversity, productivity and survival rate during phase III (*ca.* 1920–1950). Changes in chironomid species' composition during this period also show oligotrophication. During phase IV, from about 1950 and onwards, the midge fauna of the lakes experienced a further decline in stability, diversity, productivity and survival rate, and continued lake oligotrophication. An increased in similarity of species composition between lakes also occurred (Brodin 1990).

Ceratopogonids decreased in relative numbers during phase IV and were not found in any of the lakes after 1975. Otherwise, ceratopogonids, chaoborids and chironomids occurred in largely unchanged relative numbers throughout the phases. The chironomids comprised 78–100 % of the midge fauna in the lakes. Chaoborids and ceratopogonids each comprised 0–8 %.

Discussion

The sites studied represent a range of acidified lakes in northern Europe. The similarity in trends of midge fauna parameters between sites allows the generalization to be made that acidified northwest European lakes have experienced gradual but continuous decreases in midge diversity, productivity and survival potential.

The main changes in the midge faunas show a close temporal correlation with periods of decreasing pH in the studied lakes, as inferred from diatoms. It is also clear that the most dramatic changes in the midge faunas occurred when pH was estimated to have dropped to levels below 5.0–5.5, at least during certain seasons of the year (Brodin 1990). These changes may be explained by decreased environmental stability as well as increased pH fluctuations (Dickson 1983), increased concentrations of toxic aluminium (Baker & Schofield 1982) and profound changes in the composition of microorganisms and algae that serve as important food items for aquatic midges (Anderson 1987).

Some authors have suggested that oligotrophication is a typical feature of acidified lakes (see, for example, Persson & Broberg (1985)). This view is supported by the changes in the chironomid species composition of the lakes in this study. However, it could be argued that the increased oligotrophic character of the chironomid fauna was mainly an effect of the harsh environmental conditions in the lakes rather than the trophic level. Yet the chironomid fauna of these lakes is very similar to that of non-acidified lakes with low trophic levels (Thienemann 1954; Saether 1979). Thus lake trophic level seems to be a more decisive factor governing chironomid species composition in acidified lakes than is lake pH.

Of the midge families studied, only ceratopogonids have experienced distinct decreases in relative numbers in inverse proportion to increasing lake acidification, a decline that may be attributed to oligotrophication (Thienemann 1954).

Chaoborids have generally been reported to be favoured in acidified lakes, in both absolute and relative numbers (Oekland & Oekland 1986). This is not confirmed by the present study where chaoborids as a whole showed no marked changes in relative numbers and a definite decrease in absolute numbers.

References

Andersson, G. 1987 Effects of acidification on aquatic organisms. *Nordic Council of Ministers, Envir. Rep.* **1987:5**, 94–123.

Baker, J. P. & Schofield, C. P. 1982 Aluminium toxicity to fish in acidic waters. *Wat. Air Soil Pollut.* **31**, 289–309.

Brodin, Y.-W. 1990 Non-biting midges (Diptera, Chironomidae) as indicators of past and present trends in lake acidification in Northern Europe. *Nat. Swedish Environ. Prot. Board Rep.* (In the press.)

Dickson, W. 1983 Water acidification – effects and counter measures: summary document. *Nat. Swedish Environ. Prot. Board Rep.* **1636**, 267–273.

Oekland, J. & Oekland, K. A. 1986 The effects of acid deposition on benthic animals in lakes and streams. *Experientia* **42**, 471–486.

Persson, O. & Broberg, O. 1985 Nutrient concentrations in the acidified lake Gårdsjön: the role of transport and retension of phosphorous, nitrogen and DOC in watershed and lake. *Ecol. bull.* **37**, 176–192.

Saether, O. A. 1979 Chironomid communities as water quality indicators. *Holarctic Ecol.* **2**, 65–74.

Southwood, T. R. E. 1971 *Ecological methods with particular reference to the study of insect populations*, pp. 1–391. London: Methuen & Co.

Thienemann, A. 1954 *Chironomus. Die Binnengew.* **20**, 1–834. Stuttgart: Schweizerbart'sche Verlag.

Whittaker, R. H. 1972 Evolution and measurement of species diversity. *Taxon* **21**, 213–251.