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Ecological background and importance of the change of chironomid fauna (Diptera: Chironomidae) in shallow Lake Balaton

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Abstract

The objectives of this research were to record the changes in composition of the open-water, bottom-dwelling chironomid fauna in Lake Balaton between 1978–1984, to examine the causes of these changes, and to discover their significance in the life of the lake.

The spatio-temporal dispersion of larvae is compared with the water and sediment quality of each basin in the lake. It is established that, under present conditions, nutrient status can be regarded as the chief environmental factor.

Studies of population dynamics show that chironomids play a highly important role in preserving sediment quality. Chironomids are an essential element in the organic matter circulation of the lake. They dominate a sub-system that retards water quality degradation, and thus they play a prominent role in the natural prevention of eutrophication.

Introduction

The task of this research, which was carried out between 1978–1984, was to study the qualitative and quantitative composition of the sediment-dwelling chironomid fauna in Lake Balaton. The purpose was to collect basic biological data pertinent to the elaboration of plans for the control of water and sediment quality, and to the preparation of the matter and energy budget of the lake. A presentation of information for the evaluation and prediction of the changes occurring in the quality of water and sediment was also intended. A review of literature on sediment-dwelling organisms, especially chironomids, and a detailed presentation of our investigations, have already been given (Dévai, 1980, 1981, 1984, 1988; Dévai & Moldován, 1983; Dévai *et al.*, 1982, 1983). This paper aims at providing a summarizing evaluation of previous results.

Material and methods

In accordance with the stated objectives and the characteristic gradient of water quality in the lake (Somlyódy *et al.*, 1983), attention was mainly focussed on describing differences along the longitudinal axis of the lake, and on determining the state of the Keszthely-basin, the basin most endangered by water-quality deterioration. Therefore, nine sampling stations (H/1–H/9) were established along a longitudinal axis at the middle part of the bed (Fig. 1). Five more stations

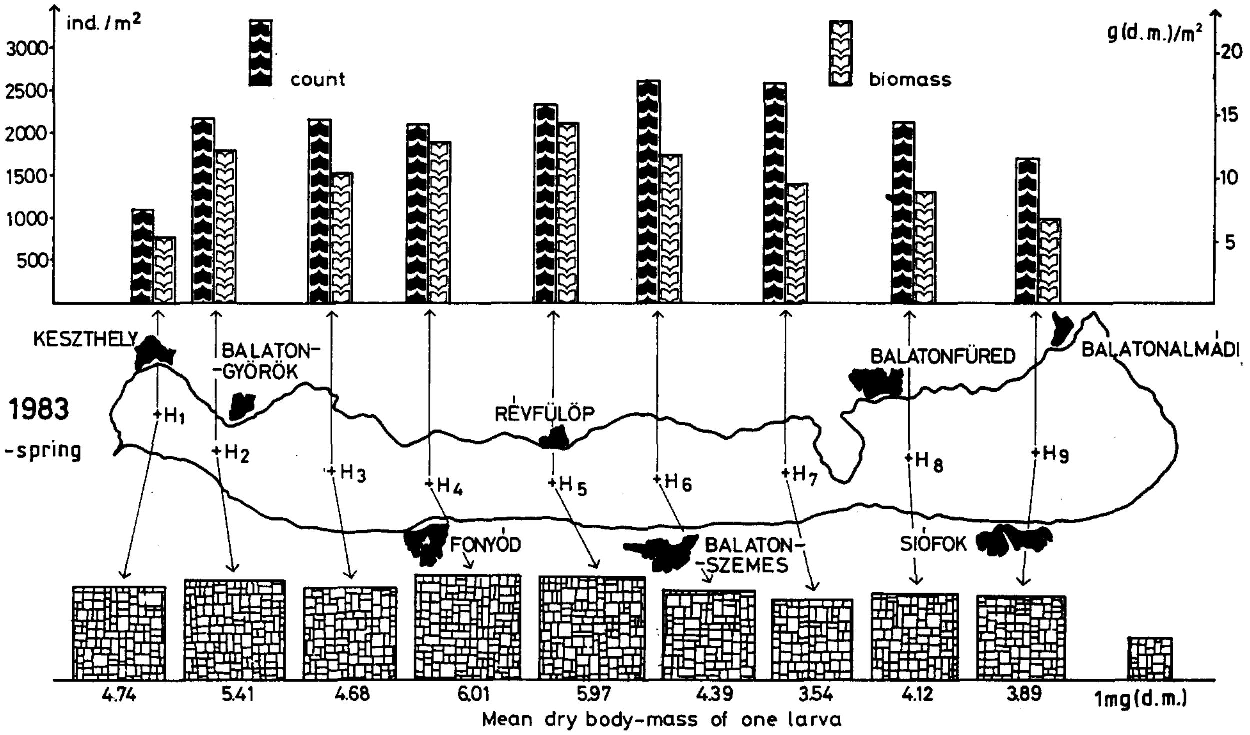

Fig. 1. Average larval count, biomass and mean body mass values of chironomids in Lake Balaton, spring 1983.

(K/1–K/5) were established in the Keszthely-basin; two of these were in its centre and three near-shore (Fig. 5). The characterization of Lake Balaton, and sampling and processing methods, have been described in detail(Dévai, 1984; Heim *et al.*, 1984; Tóth *et al.*, 1986).

Results and discussion

Composition and change of the chironomid fauna

In 1978, numbers of open-water, sediment-dwelling chironomid larvae in Lake Balaton increased from SW to NE, whereas biomass values decreased. This situation was caused by differences in the species composition. In the Keszthely- and Szigliget-basins (Fig. 6) there were relatively high proportions of large-bodied *Chironomus* species, whereas in the Central- and Northeastern-basins *Procladius* and *Tanypus* species, and representatives of small-bodied Chironominae taxa, dominated (Dévai *et al.*, 1982; Dévai, 1984).

Our data were compared with the water quality of Lake Balaton and other similar shallow lakes in Hungary; also with the conclusions of typifying surveys found in the literature (Thienemann, 1954; Brundin, 1958; Stahl, 1966, 1969; Saether, 1975, 1979, 1980; Carter, 1976, 1977, 1978; Wiederholm & Eriksson, 1979; Kajak, 1980; Kansanen & Aho, 1981). Thus, the *Chironomus-Procladius* community of the Keszthely- and the Szigliget-basins indicated moderately eutrophic conditions, at least at the beginning of the study, whereas the dominance of *Procladius* observed between 1978–1982 in the Northeastern-basin reflected oligotrophic or perhaps oligo-mesotrophic conditions.

Five sediment factors were examined to determine the causes of the characteristic spatial pattern of the chironomid fauna in the lake. These factors were: (1) heavy metals (As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn), (2) chlorinated hydrocarbons (aldrin, dieldrin, alpha-, beta-, gamma-, delta-HCH, heptachlor, pp'-DDE, pp'-DDT, op'-TDE, pp'-TDE), (3) organic carbon content, (4) elemental sulphur content and (5) redox dynamics.

Neither the qualitative nor the quantitative occurrence of heavy metals and chlorinated hydrocarbons, singly or together, were related to the spatial pattern of the chironomid communities (Dévai, 1984).

However, the organic carbon content of the sediment was related to the occurrence of chironomid biomass and numbers along the longitudinal axis of the lake. Thus, the nutrient content of the substratum measured as organic carbon content, i.e. the quantitative and qualitative composition of the detritus, can be regarded as an important environmental factor (Dévai, 1984).

Examination of the taxonomic composition of the recent and subfossil chironomid fauna proved that the spatial differences observed during 1978 in the sediment-dwelling chironomid fauna are secondary, i.e. are consequences of eutrophication, which differs in degree in different basins. The composition of the chironomid fauna also reflects this and is continuously changing in the Keszthely-basin without signs of returning to the former situation. Starting in 1978, the basin was more and more characterized by a chironomid community of stagnant backwaters, well-fertilized fish ponds, and basins of open-air sewage-treatment plants. Unfortunately, this transformation of the fauna in 1978 could be considered rather advanced in the Szigliget-basin too, and signs of the changes were already detectable in other areas of the lake at that time (Dévai & Moldován, 1983; Dévai, 1984). Data from the autumn of 1982 and from 1983 indicate that a similar process has started in the Central-basin and, perhaps, also in the Northeastern-basin. By the autumn of 1982, the faunal composition observed in 1978 had changed (Dévai, 1984). Numbers and biomass were evening-up in such a way that Lake Balaton, over practically its whole length, became similar to the state of the Keszthely-basin. Numbers, biomass and species composition of the chironomid fauna remained similar during the spring of 1983 (Fig. 1), although by the beginning of autumn important changes occurred (Figs. 2, 3). The numbers of larvae, especially in the Central- and the Northeastern-basins, decreased, and the proportion of *Procladius* species increased greatly. However, conditions did not return completely to those we found in 1978.

On the basis of these facts it can be established that it is the utilizable nutrient content of the sediment that enabled the mass occurrence of *Chironomus balatonicus*, the dominant species of the open-water sediment (cf. Warwick, 1975; Cole & Weigmann, 1983). Relying upon the latest examinations, the critical limiting value of organic carbon content is about 12 g kg^{-1} (dry matter). For the biomass and permanent occurrence of *C. balatonicus* larvae, however, the constant presence of about 15 g organic carbon content kg^{-1} (dry matter) seems to be needed (Dévai *et al.*, 1983). The parallel changes that we found between 1978–1983 in the composition of the chironomid fauna and in the organic carbon content, and moreover the striking coincidence between predicted trends (cf. Dévai, 1984) and the subsequent investigation results, supported this idea (Fig. 4).

These results were confirmed by the spatio-temporal changes of the contents of easily mobilizable iron and manganese, organic carbon, elemental sulphur and of redox potential values. During the last few years, the amount of decaying organic matter has increased in the sediment of Lake Balaton. At the same time destructing and decomposing processes have considerably accelerated. Such changes in the sediment of the lake are connected with the acceleration of eutrophication. A change is predicted in which the oxygen conditions become degraded, as a result of progressively stronger decay processes, and will cause a complete change in the fauna. This is proved by the fact that the sediment of the Keszthely-basin already has a sapropelic, slightly mineralized organic content, and in the case of destructing processes, anaerobic pathways have a greater and greater predominance.

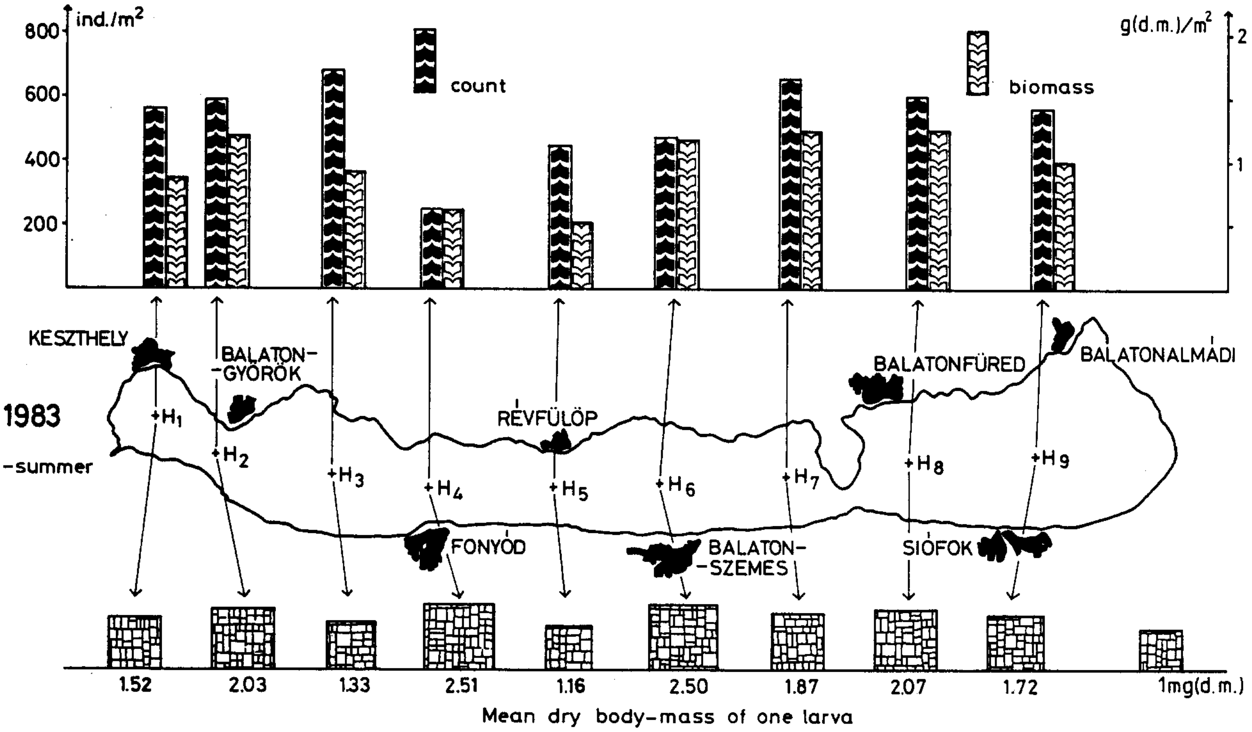

Fig. 2. Average larval count, biomass and mean body mass values of chironomids in Lake Balaton, summer 1983.

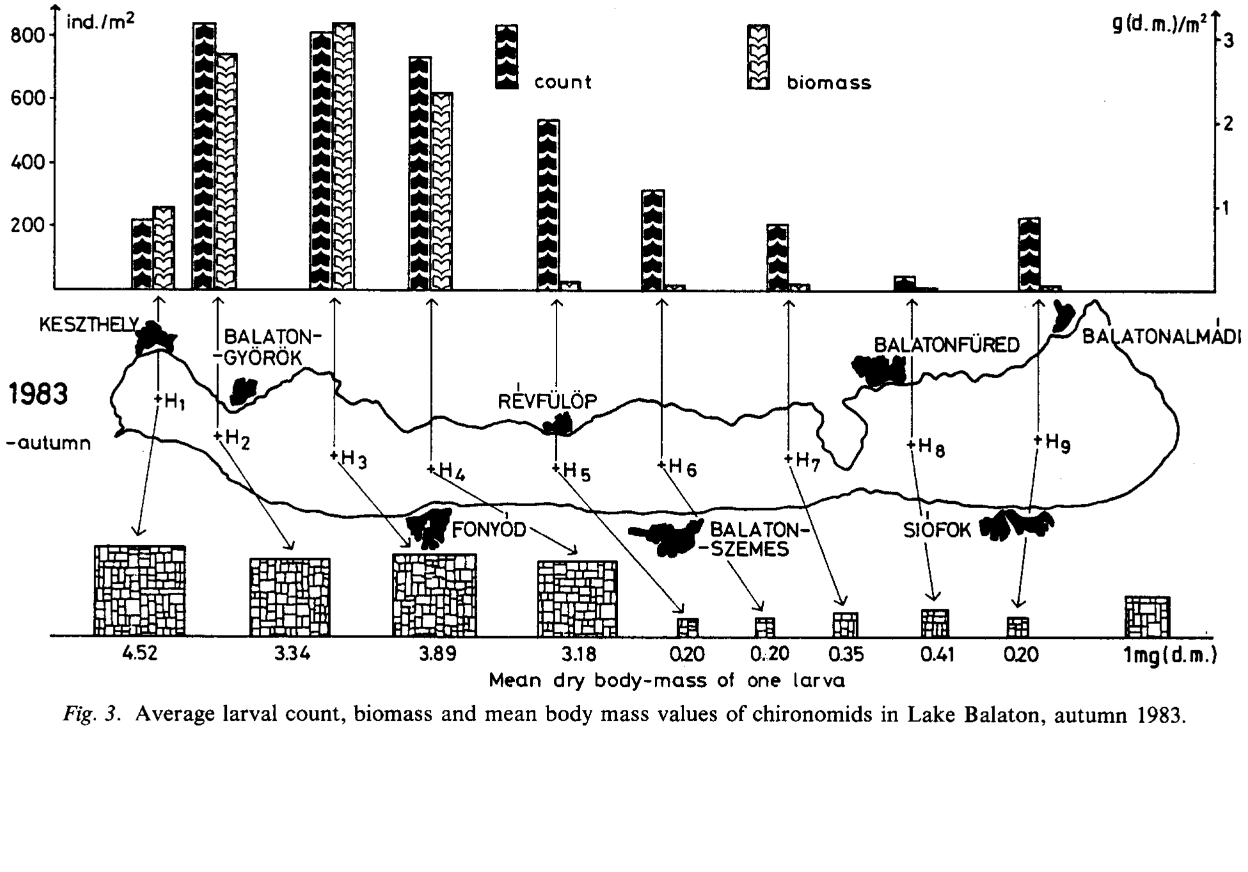

Fig. 3. Average larval count, biomass and mean body mass values of chironomids in Lake Balaton, autumn 1983.

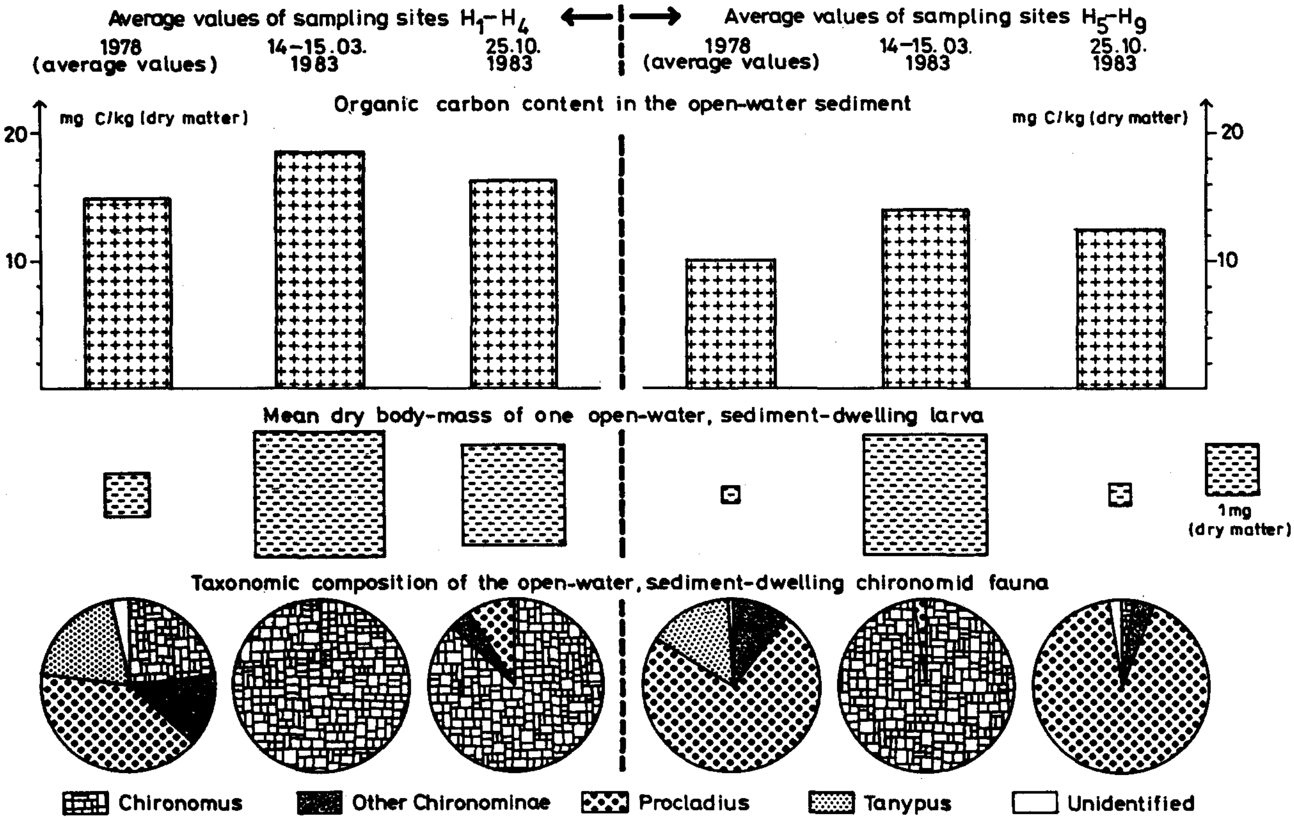

Fig. 4. Relationship between organic carbon content and chironomid faunal composition in Lake Balaton.

This unusually quick and considerable change required that population-dynamics of the sediment-dwelling chironomids be studied in connection with their role in the organic matter circulation of the lake. Using data collected over a period of several years in the Keszthely-basin, a phenological pattern, as shown by the 1983 data, was observed (Fig. 5). Highest numbers of larvae were observed at the beginning of April. This relatively high number continuously decreased until the last third of May. Numbers then increased, but only reached 60% of the maximum counts in spring. This increase stopped in the last third of June and from then, until the middle of July, the numbers of larvae decreased considerably. A new increase was observed again until the end of July, but in the first half of August numbers decreased even more than earlier. Numbers increased again in the second half of August, and remained at the same level between the end of August and the middle of September. Of the four consecutive peaks, the first was strikingly high, whereas the other three seemed almost the same, although some decrease occurred approaching autumn. After the middle of September, the numbers of larvae drastically decreased in a few days to the lowest level of 1983. Their numbers then gradually began to increase until the middle of November. However, this increase was very slow, and numbers reached only one quarter of their value at the beginning of the year. On the basis of experiences of several years, we may consider this trend as characteristic of Lake Balaton, at least of the areas and periods that have great food abundance.

These results indicated that a detailed analysis of emergence dynamics would be valuable, because the emergence period at Lake Balaton is so extended (from mid-March to early October) and emergences are very frequent within the period; they occur every second day, on average, and are of moderate intensity on every fifth day from May to September (cf. Dévai, 1988).

This peculiar form of emergence dynamics demanded the determination of the time of mass emergences and the degree of synchronization in 1983, simultaneously with examinations of larvae. The emergence in 1983 was similar to earlier years, and was almost continuous. Emergence of high intensity was observed five times: between 11–18 April, 25 June–03 July, 30 July–2 August, 11–16 August, and 12–18 September. The first emergence was the greatest. In May, emergence was of average intensity for almost the whole month, and the sum of individual emergences during this period was similar to high but short emergences during other periods. The two great emergences in the period 30 July – 16 August must be considered only one, which was interrupted by the unusual, quick and unfavourable change in the weather. Moreover, emergences, at least the stronger ones, occurred at the same time over the whole area of the lake.

It is useful to compare the results of larval collections with the emergence observations. Figure 5 shows that the changes in emergence intensity can easily be brought into relation with changes in larval counts. The main emergence periods almost always overlap the same types of sections on the hypothetical curve. Great emergences come after the periods that show the highest numbers of larvae in the given period of time, and then numbers of larvae usually decrease quickly and considerably.

Chironomids in the circulation of organic matter

Detailed analysis of the spatio-temporal dispersion of larvae, and the emergence dynamics of

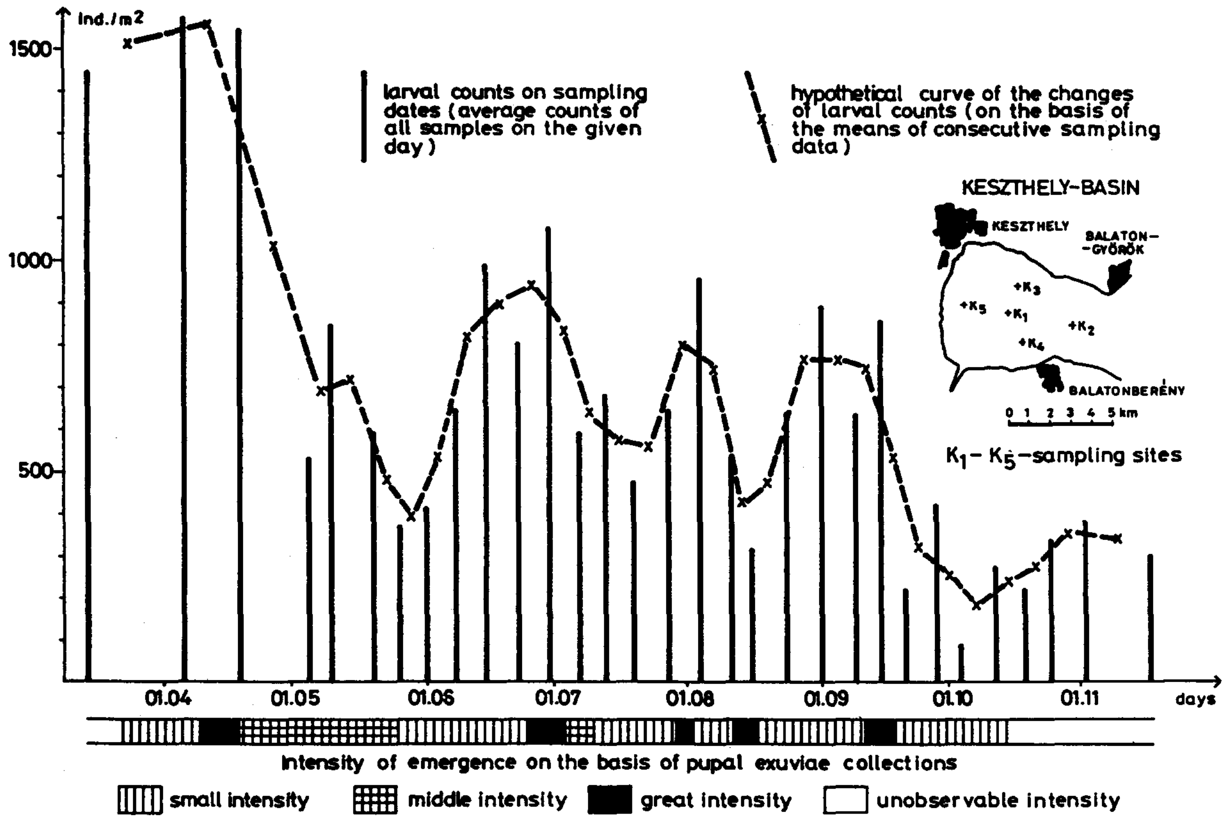

Fig. 5. The changes of larval chironomid counts and intensity of emergence in the Keszthely-basin in 1983.

adults, supported the opinion that chironomid numbers, biomass and production are significant components for the matter and energy budgets and for water quality control of the lake. For example, in 1983 there were an average of 6×10^{11} larvae, calculated for the whole area of the lake; in March, which had the greatest abundance of food, the number was more than double this value (14.5×10^{11}). The biomass values were also staggering. Their yearly average calculated for the whole lake was 2400 tons, but the maximum value in March reached 8100 tons.

This enormous chironomid population deserves attention because natural purification of waters depends largely on the dynamics of biogenic matter circulation and energy flow (bioactivity) of the water-bodies, primarily on the activity of heterotrophic organisms, among which emerging insects are of great importance (Dévai, 1980).

Detritus-feeding larvae play a direct role in the elimination of decayable and putrefiable organic matter, the amount of which is increasing in the sediment because of eutrophication. Although the organic content of the bodies of chironomid larvae is negligible as compared to the amount of organic matter in the sediment (the ratio is on average only 0.1%), the quantity of sediment these larvae circulate is considerable (relying on Entz's results in 1964, it is $0.5–1.5 \text{ g m}^{-2} \text{ day}^{-1}$, using the average individual density of the lake). Because most of the sediment is composed of detritus, chironomid larvae circulate about 2–3% of the organic compounds of the upper sediment-layer during the year. During digestion the larvae expose one part of the organic matter and make it available for bacterial destruction, whereas another part is utilized in the course of their existence and growth. The importance of predatory larvae, which are abundant, must also be considered. By entering into newer and higher levels of the food-chain, the proportion of metabolism used for existence is steadily increased. Due to these processes, the activity of chironomids contributes considerably to the breakdown of organic matter under natural conditions.

It was probable that the food abundance between the autumn of 1982 and the spring of 1983, at least in the Northeastern- and Central-basins, would not remain permanent. This was because the sudden and excessive increase in chironomid population would probably 'consume' the utilizable nutrient content, and some chironomid species (e.g. *Chironomus balatonicus*) would be temporarily eliminated from these areas. Paleolimnological study of the sediment in the Northeastern-basin verified that there have already been events of this type in the history of the lake (Dévai & Moldován, 1983).

The results obtained in the summer and autumn of 1983 firmly supported this supposition (Figs. 2–4). The question is, when will this – so far – temporary change become constant, i.e. turn into an irreversible process, which will unfortunately restrict the possibilities of treatment. The Keszthely-basin is already in a critical state and the Szigliget-basin is taking this direction. Increasing warning signs indicate that the break-up of natural matter-circulation dynamics of the sediment has already begun in the Central- and also in the Northeastern-basin.

Sediment-dwelling larvae are of great importance in the constant reworking and concomittent aeration of the sediment. With this activity, the larvae contribute to the preservation of aerobic conditions, i.e. to the maintenance of the 'healthy' matter circulation and energy-flow dynamics of the lake.

The amount of organic matter released from the lake by emerging chironomids seems most important in forming water and sediment qualities.

The organic matter released by emergence was not negligible in 1978 either, but in 1983 it was considerable (Fig. 6): about 6300 tons during the first series of emergence, i.e. chironomids removed approximately 3300 tons of organic carbon, 700 tons of nitrogen and 60 tons of phosphorus from the lake. Because there are four emergences in a year on the whole area of the lake, during one vegetation season, chironomids release almost two-thirds of the yearly available phosphorus-loading (i.e. about 100 tons of P).

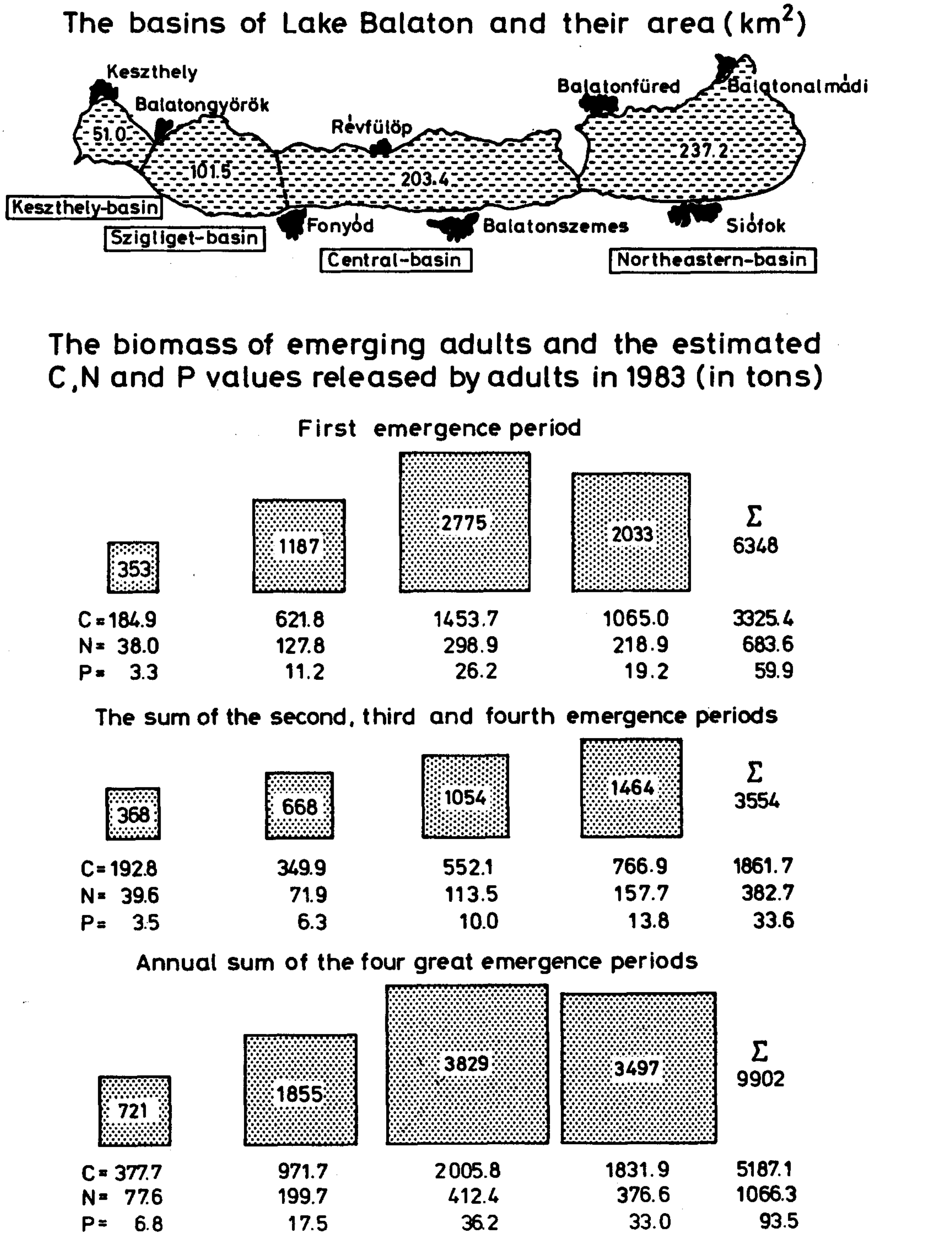

Fig. 6. Contribution of emerging chironomid adults to the organic matter circulation of Lake Balaton and its four basins

From all these considerations it follows that chironomids are important in the factor-system which counterbalances the increase in trophic status under natural conditions. Investigations of effect-dynamics have shown that natural water systems, by way of self-regulating and self-controlling processes, can maintain their state on a supra-individual level, too, despite external effects (perturbations). However, self-directing processes, which are present in natural ecological systems and manifest in homeostasis, can only partly (i.e. within the ranges of the given state of water and sediment qualities) prevent changes of unfavourable direction. Lake Balaton is very close to this critical state. If the best opportunities are provided for the processes (mainly biological) that oppose water quality deterioration in natural ways, serious impairments can be avoided and even gradual improvement can be expected.

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