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Emergence patterns of chironomids in Keszthely-basin of Lake Balaton (Hungary)

(Diptera, Chironomidae)

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Abstract

The author tries to give a general idea of the characteristic features and patterns of the emergence of chironomids relying upon two series of examinations of a long period between March 11 and October 18, 1980 as well as between March 15 and August 31, 1983, which were performed on the Keszthely shoreline of the biggest shallow lake of Europe, Lake Balaton. Relying upon the comparative analysis and computer processing of the data set of the daily observations as well as that of 53 and 147 samples of pupal exuviae collected in 1980 and 1983, respectively, the author presents the characteristic emergence types and states the main emergence periods. He analyses in detail the essential changes which occurred in the taxonomic composition of samples of pupal exuviae between 1980 and 1983.

Introduction

One of the decisive and obviously the most spectacular moments of the life of chironomids is their emergence. Moreover, this process has an outstanding significance also in the settling dynamics and matter circulation of water bodies (Dévai et al. 1979, Dévai 1980a, 1980b). Thus it is understandable that the rough and regular interventions performed in the environs of water bodies as e. g. mosquito extermination by aeroplane or helicopter inevitably raise the question how the chironomids are en dangered.

In the case of Lake Balaton there was another important viewpoint to be said for the fact that mosquito extermination should follow the emergence dynamics and swarming peculiarities of chironomids. It is well-known that land-fauna exterminated in consequence of mosquito extermination is relatively soon supplemented from the neighbouring regions due to the so-called vacuum-effect (Sáringer et al. 1984). However, at insects flying out of water, especially in the case if extermination covers the predominant part of the shoreline (as e. g. in the case of Lake Balaton as well), the decrease of individual number can be so drastic among the animals generally assembling here that the population sustains permanent loss through it and the standing mass can decrease to 10 or 20 % of the original number. This condition of risk especially exists in the case of Lake Balaton, the peculiar chironomid fauna of which rests first of all on self-revival since the fauna practically cannot or can only be slightly supplemented from the neighbouring regions failing water bodies of a similar type and size.

Accordingly it was justified from several viewpoints to investigate the emergence dynamics of the chironomid fauna of Lake Balaton thoroughly. In my present paper I wish to give a survey about the results of our investigations of emergence performed in 1980 and 1983.

According to the reports of the majority of papers (see e. g. Palmén 1958, 1962, Danks 1971, Stahl 1975, Lindegaard & Jónasson 1979, Butler 1980) the emergence of chironomid adults from the pupal-exuviae and at the same time their emergence from the water bodies occur in periods characteristic of the different species and they do not show more than little temporal shift in the subsequent years. The emergence can be generally observed once or maximum two or three times a year and on these occasions the animals emerge in great mass. At the same time certain experiences in the field (e. g. Hein & Schmulbach 1972, Jonsson & Sandlund 1975, Ali et al. 1983, 1985) or laboratory experiments (e. g. Danks 1978) refer to the fact that the emergence period of certain species can be significantly long-drawn and during this long period several generations can emerge. According to the data up to now the emergence was synchronized with one of the abiotic environmental factors or the joint effect of two of them. Such factors can be e. g. water temperature, light conditions, air pressure or ebb and flow (Lenz 1962, Palmén 1962, Danks 1971, 1978, Hein & Schmulbach 1972, Hashimoto 1975, Heimbach 1978, Bagge et al. 1980).

Material and Method

Our examinations were performed on the biggest shallow lake of Central Europe, Lake Balaton (its detailed characterization see in papers by Bíró 1984, and Dévai et al. 1984). Our main sample area out of the regions of the lake with different water qualities was the Keszthely-basin mostly endangered by the accelerated eutrophication of recent years.

A series of observations during a period of 236 days was performed on the shoreline of Lake Balaton at Keszthely in 1980 in order to examine the emergence in a pragmatical way. The regular surveys were performed on the pier of the harbour of Keszthely each day from March 11 to October 28. This point of the shoreline was proved to be convenient from several viewpoints: the pier projects far into the open water of the lake (to a distance of 200 m), at its end the water depth is already near the average (about 2 m) and no reeds of a large extension can be found at the pier (in a district of approximately 500 m). In this way this site of observation and sampling was suitable to reflect satisfactorily the conditions of the open water of almost the whole Keszthely-basin. The second series of examinations of 170 days was performed in the same place from March 15 to August 31, 1983.

Relying upon our earlier experiences collections of pupal exuviae proved to be the most suitable for establishing the frequency and intensity of emergence. Therefore parallel with the observations on the occasions of great emergences we also took samples of pupal exuviae from the floating material accumulated along the pier. From this viewpoint the choice of the sample area was very favourable since the peculiar flow conditions of the Keszthely-basin (Györke et al. 1980) ensured with the greatest possibility that the pupal exuviae material characteristic of the total water surface could drift together.

For the sampling of pupal exuviae we used a sack-like "skimming-net" of our planning. The samples were preserved in 70% ethylalcohol in of 50–200 ml cubic capacity depending on the quantity of the collected material. The pupal exuviae were selected and counted by means of a stereomicroscope of Technival type and of Zeiss (GDR) make. In order to unify the processing permanent preparations were made from the pupal exuviae of different type for an identifying and comparative collection (Schlee 1966).

On the occasions of great emergences several hundred or sometimes several thousand pupal exuviae could often be found in the samples. For their processing the application of the following method seemed to be expedient. After a careful shaking a certain number of pupal exuviae was taken out of the sample with Leonhard forceps, the genera occurring in it were determined and the number of their pupal exuviae was in the percentage of all the counted ones. We had only two obligations regarding the quantity taken out of the sample. One of them was that the number of examined exuviae should be above 100 and the other was that any additional pieces taken out were also counted. The first obligation ensured that the obtained quantities should reflect roughly the proportions in the whole sample. And by counting all the pupal exuviae taken out we avoided the mistake of conscious choice.

Relying upon our literary studies and our field experiences we chose factors from the system of factors being able to influence the emergence and their detailed analysis was expected to result in the knowledge of phenomena and processes producing and synchronizing the emergence. The factors investigated were the following: the real daily mean value, maximum and minimum of the air temperature; the sum of the daily radiation and the duration of sunshine; the daily most frequent direction of wind; the real daily most frequent direction of wind; the real daily mean value of the wind speed as well as the extent of its daily fluctuation; the real daily mean value of the air pressure and the extent of its fluctuation; the daily mean value of the air humidity; the daily sums of the evaporation and precipitation; the value of the morning and evening water temperature; the strength of waviness in the morning and in the evening; the values of the air temperature, wind direction, wind speed and air humidity measured at 7 p. m. These factors were measured partly by ourselves and partly the data of the Keszthely Synoptic Station of the National Meteorological Service as well as those of the Research Institute of the Atmosphere Physics were utilized by us, for the conveyance of which data we express our thanks.

The nearly 10 thousands data were fixed on a magnetic band and processed by the Robotron (GDR) computer of R 55 M type of the Computing Centre of the L. Kossuth University. The evaluation of the data was performed by means of the hierarchical cluster analysis programme functioning on the basis of Euclidean distances as well as the stepwise discriminance analysis programme of BMDP. In order to increase the certainty of the processing, we took notice first of all of the great emergence cases (indicated with double or triple motive on Figure 1) or we drew into the processing only those of the emergences of less intensity (indicated with one motive) which could be identified regionally or could be delimited from one another temporarily with proper certainty.

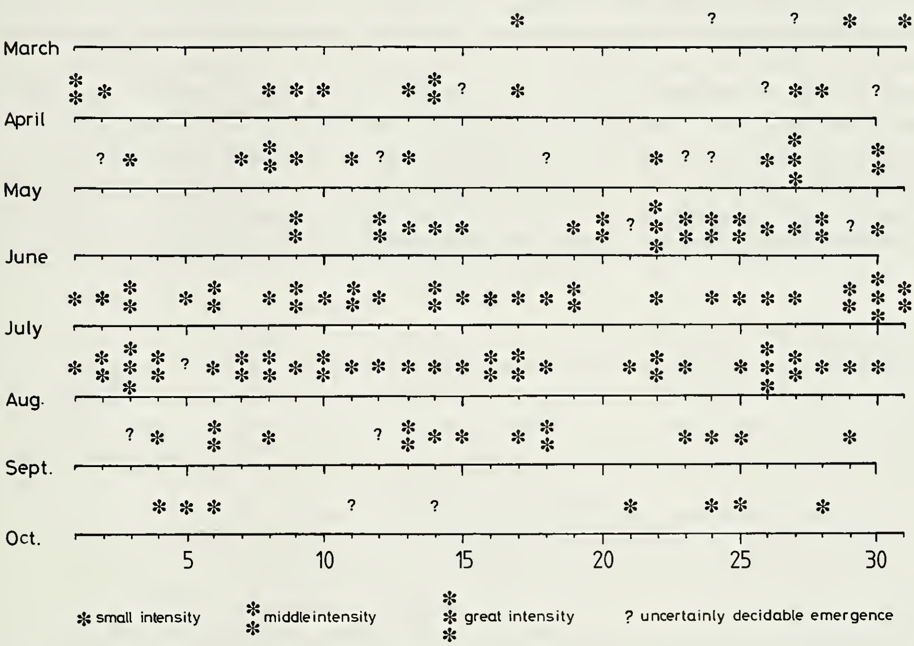


Fig. 1. Emergences in 1980 and their intensities on the basis of pupal exuviae collections.

Results and Discussion

Although the processing procedure detailed above, could not bring absolutely exact results, it made the present opinions about the emergence dynamics and the change in taxonomic composition of the chironomids of Lake Balaton more exact even in its first approach to a great extent. On the basis of our field experiences and the results of our evaluation we can draw the following main statements.

The emergence dynamics of the chironomids in Lake Balaton is almost unprecedented considering both the long-drawn period of the emergence and the frequency of the emergences. According to our observations in 1980 the period of emergence lasted from the middle of March until the end of October (Fig. 1). From May to September emergence was observed on an average every second day, it was even of middle intensity every fifth day. The main emergence periods were May 26–27, June 20–25, July 29-August 4 and August 25–27.

In 1983 the emergence was considered to be even more uniform, disregarding some small interruptions it lasted almost continuously. Emergence cases of great intensity were observed on 5 occasions: April 11–18, June 25-July 3, July 30-August 2, August 21–26 and September 12–18. Regarding the mass of the emergence the first emergence case was specially striking. It is definitely worth mentioning that during nearly the whole month of May emergence of medium strength went on and no doubt it was entirely at least as significant as any other very strong emergence lasting for a short time. As a result of our observations performed on the whole territory of the Lake Balaton in 1980–1985 we can state that significant differences can be experienced in the frequency and strength of the small emergence cases along the total shoreline of Lake Balaton. However, according to the experiences up to now the great emergence cases are never limited to a smaller region or any basin but they go on simultaneously on the whole surface of the lake.

Comparing the results of the observations performed in 1980 and 1983 it can be seen that emergence cases became definitely more frequent by 1983. It manifested itself in not only the number but also the strength of the emergence cases. The most conspicuous sign of it was that mass emergence cases also increased, namely with two peaks in the middle of April and in the middle of September. In the same periods of 1980 we observed only medium emergence. The change can be obviously explained with the significant increase of the food supply and the change in the species composition (Devai et al. 1984). The earlier peak at the end of May – due to similar causes – changed into an emergence period of middle strength lasting almost continuously in May, which well can be brought into correlations with the results of larval investigations (Devai 1985). However, the three great summer emergence

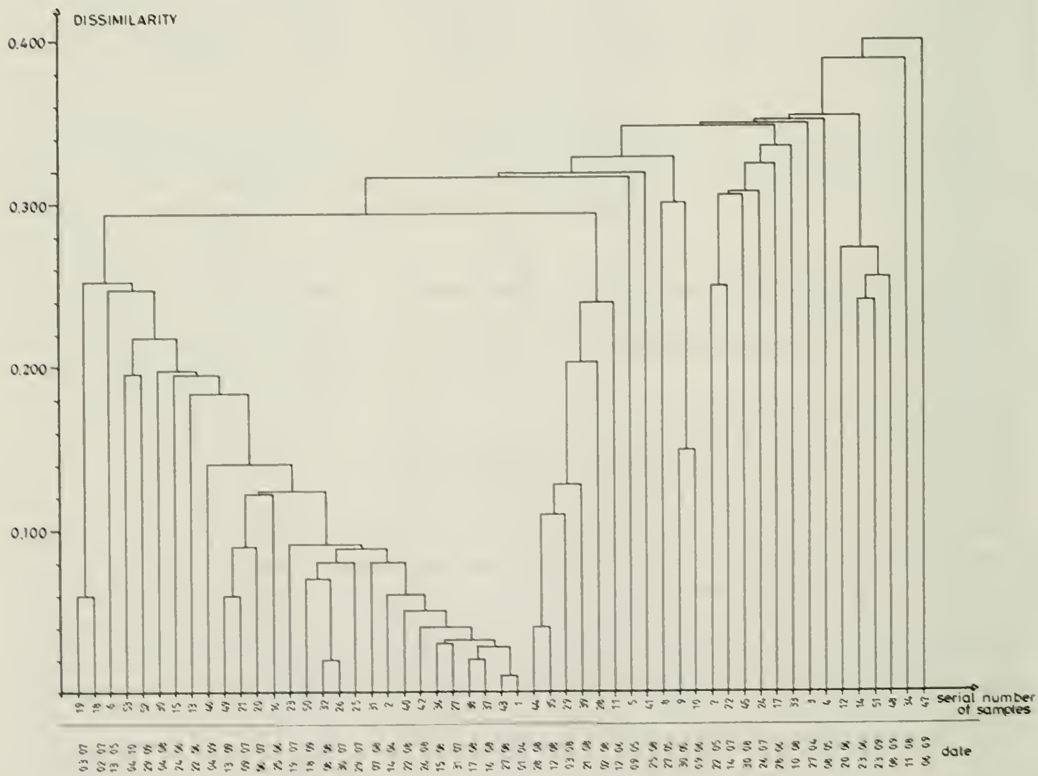


Fig. 2. Dendrogram of pupal exuviae samples collected on occasions of important emergences in 1980.

periods remained the same, disregarding a shift of some days due to the actual change in weather conditions.

The field experiences showed that mass emergences mainly occurred at sudden change of temperature and they seemed to be characterized roughly with the changes of meteorological factors. This hypothesis was supported by the observations that mass emergence often followed the red storm signals, however, they did not occur if wave activity was permanently strong and especially if combing waves were observed.

Accordingly, when making an effort to understand the effects inducing or at least promoting the emergence we analysed the examined meteorological factors successively and compared them at first separately and later in different combinations to the emergence pattern. Naturally, in the latter case we took into consideration that between the factual occurrence and the observation of emergence there were significant temporal differences, depending upon the actual weather conditions (first of all wind conditions) amounted to at least 2–3 hours, generally 6–10 hours but sometimes even 12–24 hours.

We did not get an unambiguous and comprehensive relationship in any case, not even the discriminance analyses brought satisfactory results. We only succeeded in establishing that groupings made on the basis of empirical facts and the discriminance function may correspond each other in an acceptable way (in approximately 70–75 % of all the cases) if we consider the values of the daily radiation and the average air temperature or those of the water temperature in the morning. However, this relationship weakens if we take notice that for example the emergence of the *Chironomus balatonicus*, the most abundant and frequent chironomid species occurred at the values of the water temperature between 10–28°C alike.

Relying upon all these findings we drew the conclusion that in the future we have to put the main stress on the examination of the relationship of emergence and front situations since the separate study of individual meteorological factors does not reflect properly the change in the weather conditions caused by the different meteorological fronts (Kiss 1959). At the same time the results obtained called our attention to the fact that in the peculiar weather conditions of Carpathian basin that are characteristic of the environs of Lake Balaton, it is hardly probable that the start or stop of the emergence can be attributed to only one or 2–3 factors as well. It can be rather postulated that the emergence dynamics of the chironomids do not depend upon the change of a certain meteorological element but upon the joint effect of several, often a series of factors, they can be practically interpreted as the resultant of them; naturally with the exception of extreme cases. However, by means of demonstrating the regularities still observable in the emergences as well as elucidating their causes we see the possibility of predicting mass emergences both in region and in time and so of successfully promoting the prevention of the permanent damage of fauna.

At the samples of 1980 in the percentage distribution of exuviae belonging to different genera two main groups could be separated on the basis of the results of both comparative analyses and cluster analysis (Fig. 2). In one of them the *Chironomus* exuviae dominated, their proportion was mainly above 70 % but it always exceeded 50 %, except one sample. Four separate subgroups occurred within this group. It was characteristic of the first subgroup that *Chironomus* exuviae represented 85–98 % of all the exuviae (samples 1–31). In the other samples the remaining proportion (15–55 %) in addition to the *Chironomus* exuviae was represented by mainly *Procladius* exuviae in the second group (samples 25–50), by *Tanypus* exuviae in the third group (samples 16–49) and by *Cricotopus* exuviae and those belonging to other Chironominae taxa in the fourth group (samples 46–19). The samples being present within this group constitute the most significant proportion, approximately 53 % of all the examined samples.

The other great group shows a much more colourful picture than the previous one and far more subgroups could be separated within it mainly relying upon the exuviae belonging to genera occurring in greater proportions. On such a basis four subgroups could be recognised with more or less certainty.

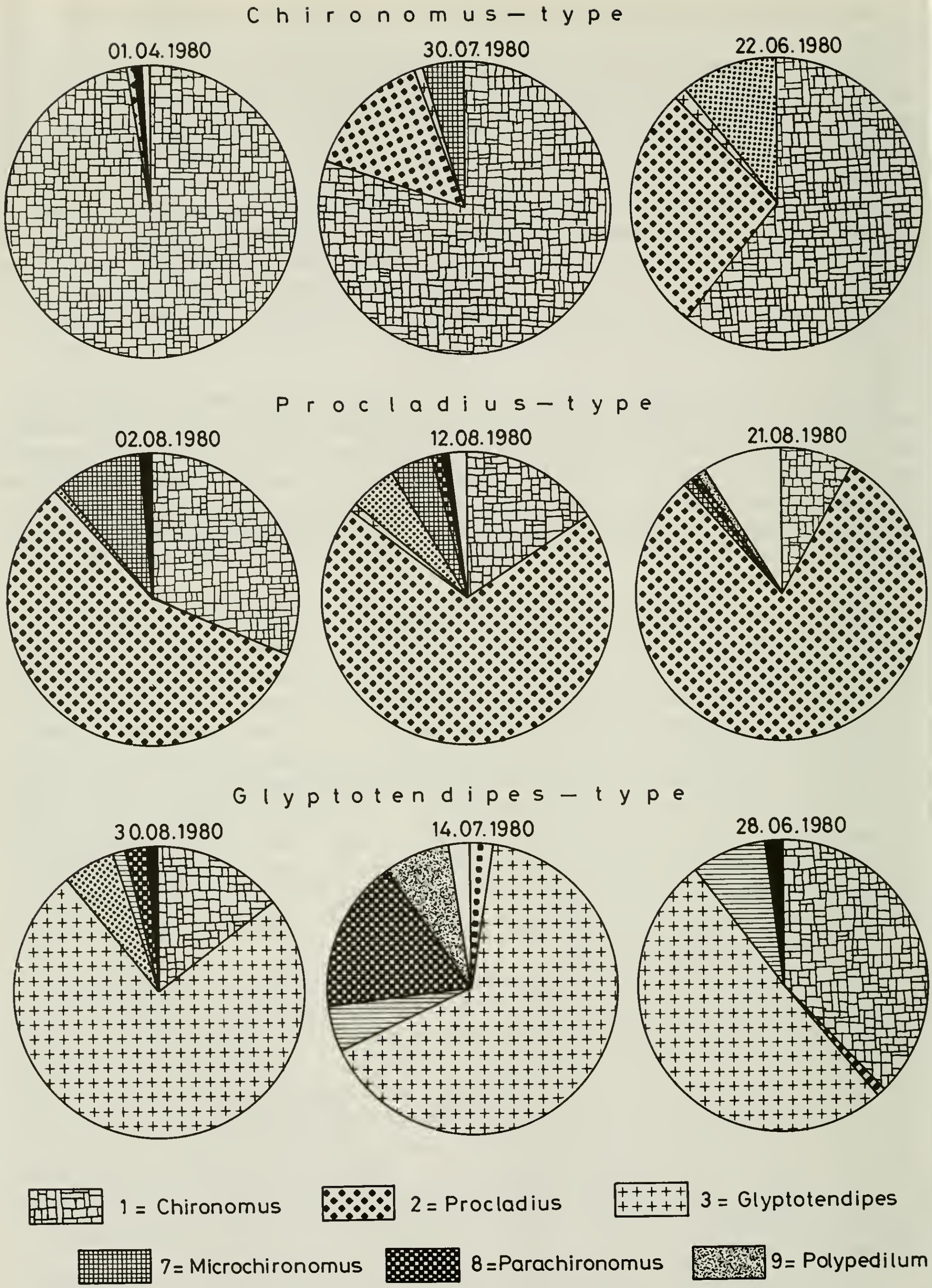
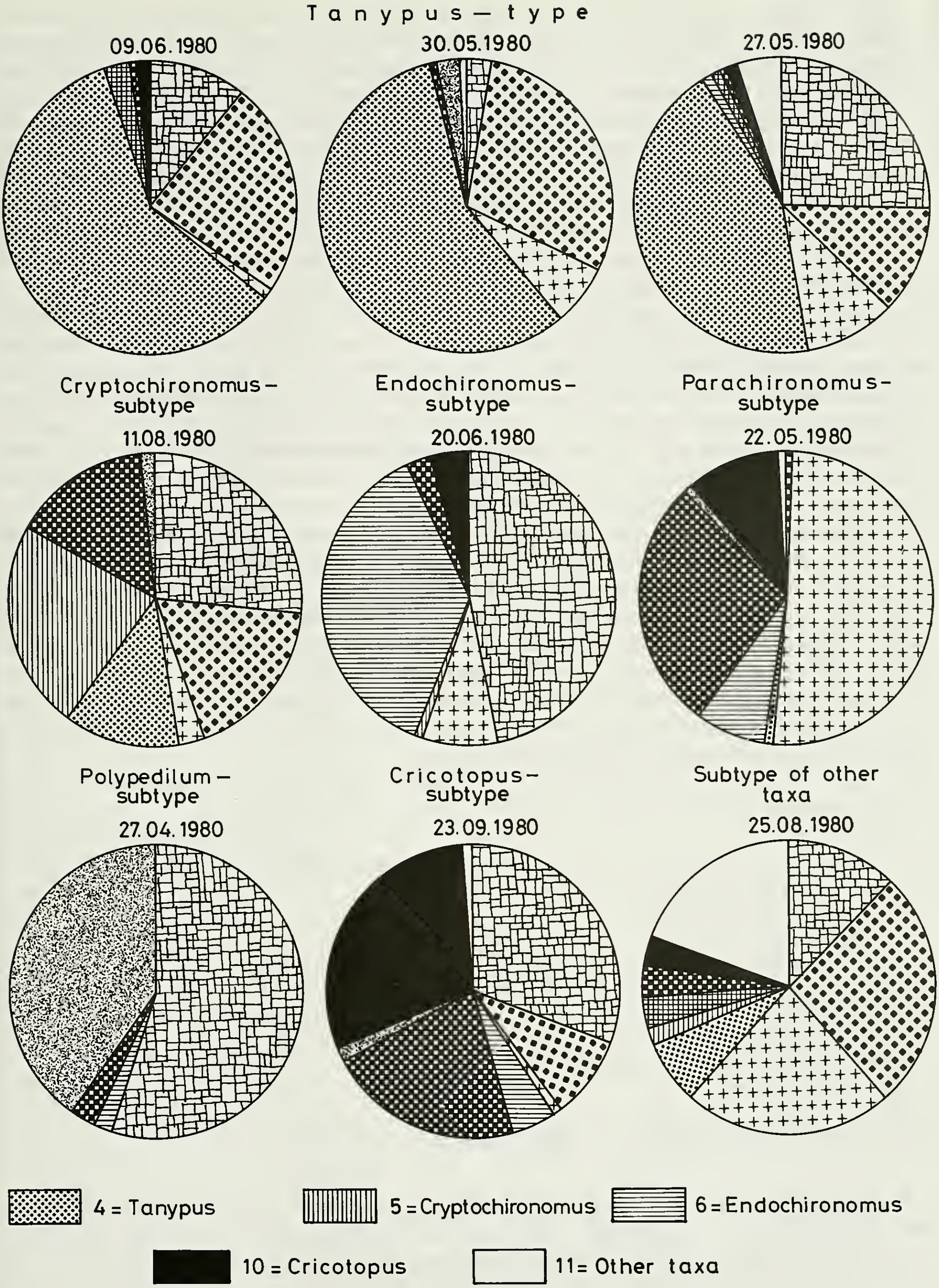


Fig. 3. Different types of emergence patterns in 1980 on the basis of pupal exuviae collections.


Tanypus – type
09.06.1980
30.05.1980
27.05.1980
Cryptochironomus-subtype
11.08.1980
Endochironomus-subtype
20.06.1980
Parachironomus-subtype
22.05.1980
Polypedilum-subtype
27.04.1980
Cricotopus-subtype
23.09.1980
Subtype of other taxa
25.08.1980
4 = Tanypus
5 = Cryptochironomus
6 = Endochironomus
10 = Cricotopus
11 = Other taxa

In the first one the relatively high percentage (between 43–81%) of *Procladius* exuviae (samples 11–44), in the second one that of *Tanypus* exuviae (samples 8–10), in the third one that of *Glyptotendipes* exuviae (samples 7–33) and the smaller quantity of *Chironomus* exuviae (in the majority of cases under 25%) in all the three could be considered as a separative feature. These subgroups represent 11%, 6% and 11% of all the examined samples, respectively. The other samples drawn in the fourth group are of very varied composition. In fact this constitutes an independent subgroup because of its separation from the former ones. The samples grouped here in addition to the *Chironomus* exuviae of the proportion mainly above 30% either contain exuviae that belong to some genera not mentioned in the foregoing in a proportion of approximately 30% or their composition according to genera shows a very varied picture. These cases constitute about 19% of all the examined samples. The circle diagrams shown in Figure 3 illustrate some of the typical cases of these emergence patterns.

The summarized evaluation of the frequency of occurrence of pupal exuviae belonging to genera that were detectable in a significant amount was performed in two different ways from the data of the 53 selected samples. On the one hand we examined in what proportion the pupal exuviae were present by genera compared to the total amount of counted pupal exuviae. For the genus *Chironomus* this value was 51%, for *Procladius* it was 15%, for *Glyptotendipes* it was 11% and for *Tanypus* it was 7% i. e. these genera constituted 84% of all the pupal exuviae. Altogether only 16% was the proportion of the other genera under the frequency limit of 5% *(Cryptochironomus, Endochironomus, Microchironomus, Parachironomus, Polypedilum, Cricotopus).*

Somewhat different picture was obtained if the frequency of occurrence was evaluated only on the basis of presence and absence independently of quantitative results. Although the order of the first four species did not change since among the pupal exuviae found in the samples *Chironomus* occurred in 96% of the cases, *Procladius* occurred in 79%, *Glyptotendipes* occurred in 75% and *Tanypus* occurred in 60% of all cases. However, in this summarizing the presence of pupal exuviae belonging to other genera was also significant since they occurred in 96% of the samples.

An opportunity presented itself for an even more comprehensive evaluation by combining the two procedures i. e. by establishing the presence or absence above or under certain quantitative limits. The following results were achieved by this method:

The percentage frequency of occurrence	At				
	A	B	C	D	E
	genera (in %)				
In case of a quantity above 75%	32	4	0	0	0
In case of a quantity above 50%	53	11	9	4	4
In case of a quantity above 25%	76	21	13	8	28
In case of a quantity above 10%	87	36	25	25	47
In case of a quantity above 5%	92	49	34	34	68
In case of a quantity under 5%	4	30	41	26	28
The frequency of the cases when the pupal exuviae belonging to the given genus did not occur in the sample	4	21	25	40	4

(A =*Chironomus,* B =*Procladius,* C = *Glyptotendipes,* D = *Tanypus,* E = Other taxa)

It can be seen from the data that already in 1980 the *Chironomus* exuviae could be considered as most significant not only regarding the number of occasions but also quantitatively since they proved to be absolute dominant in more than half of the examined cases and they were the determinants of type (in an amount of above 25%) in more than three-quarters of them. The *Procladius* exuviae could be considered to a much less extent but still unambiguously characteristic as regards both the frequency of occurrence and the quantitative conditions.

We got pictures fairly similar to each other with the exuviae belonging to the *Glyptotendipes* and *Tanypus* genera, which occurred as the determinants of type in a part of the cases and as absolute dominants in some cases. However, all together they did not prove to be more significant than *Procladius* itself. The difference between them was first of all that the *Glyptotendipes* exuviae were present more times in great (above 50 and 25 %) and small (under 5 %) amounts than *Tanypus* exuviae, however, the latter were more frequently absent in the samples.

The total amount of exuviae belonging to nearly 8—10 other genera could not be considered as negligible in spite of the fact that they have individually never proved to be absolute dominants, they occurred as the determinants of type in only 6 cases even the number of the cases when they were separately detectable in an amount above 10 % was only 18.

At last, relying upon the data of 1980 we wished to see whether the differences in the distribution according to genera corresponded to any temporal emergence pattern. Unfortunately relying upon the processed samples, satisfactory answer cannot be given to this question. We could state with a more or less certainty all in all that *Chironomus* dominance could be demonstrated continuously while a proportion exceeding the average was observed for *Procladius* exuviae first of all from the end of May to the middle of June and in August, for *Tanypus* exuviae mainly in June and in the first half of September and for *Glyptotendipes* exuviae in the middle of May, at the end and beginning of June as well as after that on several occasions during certain shorter periods (e. g. about July 14, 26, August 10, 25, 30, September 8). The samples in which the representatives of the other genera were present in a significant amount, sporadically originated from the whole emergence period but the samples collected in May and September seem to be at least relatively somewhat more frequent among them.

If we compare the data of the series of samples from 1983 to the results of 1980, the following important differences come out. In the percentage summarizing according to the amount of pupal exuviae the proportion of *Chironomus* exuviae strikingly increased (by 16 %) and that of the *Procladius, Glyptotendipes* and *Tanypus* exuviae significantly decreased (by 4—6 %). The proportion of the exuviae belonging to other genera did not change significantly (only decreased by 2 %). These shifts of the proportion totally coincide with the experiences of larval examinations (Dévai 1985).

The examination of the frequency of occurrence on the basis of presence and absence brought somewhat different results compared to the foregoing. A decrease was experienced only for *Glyptotendipes* exuviae and it was only slight (altogether 7 %). With the exception of that a rise could be established in the case of all the genera.

The following data obtained by combining these two methods let us conclude to the real relations most of all.

The percentage frequency of occurrence	At A	B	C genera (in %)	D	E
In case of an amount above 75 %	29	0	0	0	0
In case of an amount above 50 %	90	0	0	0	0
In case of an amount above 25 %	100	1	1	0	7
In case of an amount above 10 %	100	57	10	5	65
In case of an amount above 5 %	100	88	30	28	90
In case of an amount under 5 %	0	11	38	54	10
The frequency of the cases when the pupal exuviae belonging to a given genus did not occur in the sample	0	1	32	18	0

(A = *Chironomus*, B = *Procladius*, C = *Glyptotendipes*, D = *Tanypus*, E = Other taxa)

These results unambiguously show the almost absolute dominance of *Chironomus* exuviae and the significant depression, of the proportion of all other genera. For example it is characteristic that in

1983 in the case of the Keszthely basin we did not find an example of the *Procladius* dominance reminding of the picture of the original fauna in Lake Balaton and still detectable on some occasions in 1980. The tendencies recognized here support our ideas which we formed of the transformation of the sediment-dwelling chironomid fauna of Lake Balaton and of the cases and trends of the resulted changes (Dévai 1985).

When we wanted to determine the emergence periods for the quantitatively significant genera on the basis of the samples taken continuously in 1983, maybe we got into an even more difficult situation than in the case of sporadically taken samples of 1980. Namely these data really give evidence of the fact that emergence lasts almost continuously for the representatives of almost all the genera. Although the strength of emergence changes and it can decrease on several occasions for periods of some days or at most one or two weeks, however, it only rarely ceases entirely on these dates.

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