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Anna HILLBRICHT-ILKOWSKA

THE EFFECT OF THE FREQUENCY OF SAMPLING ON THE PICTURE OF THE OCCURRENCE AND DYNAMICS OF PLANKTON ROTIFERS*

It was found that the "customary" system of taking plankton samples (every 14 days) caused, in comparison with sampling every 3–5 days – a fundamental distortion of the picture of the dynamics and species composition of littoral and euplankton rotifers. The degree of such distortion depends on the frequency and periodicity of the occurrence of particular species.

The occurrence and variations in abundance of plankton most often form the subject of ecological research on this group and the basis of all synthetic studies of water ecosystems. It is therefore essential to obtain an exact picture, faithfully reflecting the zooplankton variations in nature.

Plankton rotifers, like the majority of plankton organisms, are characterized by generally considerable variations in abundance, often rapid and short-lived, caused by sudden, sharp increase in the numbers of the species. This variability is as a rule greater in rotifers, as small and very fecund organisms, than in crustaceans – the larger, more slowly reproducing elements of zooplankton.

The character of such variations in abundance makes it necessary to establish how frequently samples should correctly be taken. This question is in general treated optionally and depends more on the time at the research worker's disposal than on the character of the subject under study. In research on the

* From the Institute of Ecology, Polish Academy of Sciences, Warszawa.

seasonal dynamics of zooplankton, both in larger and smaller bodies of water, sampling is not as a rule done more frequently than every 10–14 days, this period being treated as representing to an equal degree the variations of rotifers and crustaceans, and even of phytoplankton – that is, organisms with an ever shorter life cycle. As shown by Spodniewska (1964), however, such "customary" sampling is responsible for very significant distortion of the picture of the abundance and dynamics of plankton algae.

The aim of the present study is to compare the picture of variations in the abundance and species composition of plankton rotifers obtained by means of quantitative samples taken "according to custom" – that is, approximately every 14 days, with the picture of these variations obtained from samples taken from 3–4 times more often, that is, every 3–5 days.

The investigations were made on ponds, which, as being ephemeral, fertile and fairly shallow bodies of water, are characterized by generally considerable variations in their plankton.

I. AREA AND METHODS

Use was made in the present study of certain results obtained from long-term investigations of plankton rotifers in recently-constructed ponds kept filled for four months each year (from mid-June to mid-October). These ponds were of uniform construction, 0.20 ha in area and up to 1.5 m in depth, and formed a compact group in which each pond had its own separate intake and outlet.

For the purposes of the present study a certain number of ponds were chosen and divided into two groups: in one (12 ponds) samples were taken approximately every 14 days (twice a month), which made 8–10 times during the growing season of the pond, and in the second group (9 ponds) samples were taken every 3–5 days, that is, 3–4 times more often, giving a frequency of 33–40 times during the growing season. Each sample consisted of 20 litres of water taken by means of a 1-litre Patalas type apparatus, taking each of the litres from different parts in the pond.

Comparison of the picture of the dynamics and species composition of the rotifers was made between: 1) ponds examined frequently (i.e. every 3–5 days), and less often (every 14 days), and also 2) among the ponds examined every 3–5 days – taking results obtained from all the samples taken, and results obtained from every 3rd sample, the frequency of sampling of which corresponded to two-weekly intervals of time and to the dates on which samples were simultaneously taken from the ponds examined every 14 days.

The groups of ponds chosen for comparison, examined in 1959 and 1960, were stocked with different fish stocks. It was not, however, found (Hillbricht-Ilkowska 1964) that the fish stock affected the number and composition of

rotifer species or that it was subject to variations in any particular direction during the study period. All the ponds belong to the given variant of sampling frequency were therefore treated jointly in the comparison of species composition, regardless of their fish stock and the study year, but in the case of comparison of variations in abundance and for other purposes (discussed later in the text) comparison was made between pairs of ponds examined at the same time and stocked with similar fish stocks. The only difference in such cases was the frequency with which samples were taken.

II. NUMBER AND COMPOSITION OF THE ROTIFER SPECIES

The difference in frequency of sampling will produce a different degree of distortion in the results obtained depending on the character of the occurrence of the species themselves. On this account distinction has been made in this study between: littoral rotifers occurring relatively seldom and scantily (a few individuals per litre) and in species numbers varying from several to thirteen in each pond, and euplankton rotifers – at least about several-twenty species in each pond, frequently and numerously, and periodically in very large numbers[1].

Samples taken the "customary" way (every 14 days) showed that only part

Comparison of the number of rotifers species caught by frequent and infrequent sampling

Tab. I

Ponds examined every:		Littoral species			Euplankton species		
		no. of species		percent of no. of species*	no. of species		percent of no. of species*
		mean	range		mean	range	
3–5 days, on the basis of:	all the samples taken	8.1	3–13	–	19.1	17–23	–
	selected samples (every 3rd sample), corresponding to 14-day periods	3.0	0–7	38	12.7	9–16	66
14 days		4.3	0–7	53	11.2	6–14	58

*Found in less frequently taken samples from the number found in samples taken more frequently.

[1] A list and more detailed information on the occurrence of species in these two groups is given in another study (Hillbricht-Ilkowska 1964).

of the species occurred in comparison with the species composition obtained by means of more frequent sampling (Tab. I). This part is relatively smaller (38–53% – Tab. I) in the case of littoral rotifers – species occurring sporadically and not commonly, than in the case of euplankton rotifers (58–66% – Tab. I)–species generally more frequent and common. Nevertheless in this latter case also the distortion obtained in the number of species found must be considered as fairly considerable.

The distortion of the species composition obtained by means of less frequently taken samples is also illustrated by comparison of the species composition of different pairs of ponds (see "Area and methods"), from which one pond was more frequently and the other less frequently sampled, and comparison of the species composition within one pond, but obtained on the basis of all the samples taken every 3–5 days and of samples taken (every 3rd sample) corresponding to the 14-day time intervals. Thus in the case of littoral rotifers, the total number of which is small (Tab. I) ponds compared in this way often fail to yield even one species in common (or 1–2), while in the case of euplankton rotifers at least half of the species found are common to all the ponds compared[2].

The following conclusions can be drawn from the above analysis: 1) "customary" sampling introduces significant distortions into the number and composition obtained of the species which are capable of leading to erroneous conclusions as to the supposedly separate character of the habitats compared, and 2) this distortion is relatively greater in the case of sporadic, rarely-occurring species than in that of frequently-occurring species.

This justifies the statement that species varying as to their frequency of occurrence in a given period are passed over, to a greater or lesser degree, when samples are taken infrequently.

In order to illustrate this point all the species of rotifers found in three chosen ponds from which samples were taken every 3–5 days, were divided into three classes of frequency of occurrence: those found in under 10% of all the samples taken during the growing season, those occurring in from 11–20% and in over 21% of all the samples (Fig. 1).

One hundred percent of the most frequent species, both littoral and

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[2] Detailed analysis of the similarity of the species composition of euplankton rotifers on the basis of the Marczewski-Steinhaus (1959) index: $S = \frac{w}{a + b - w} \cdot 100$ (where a – number of species found in one group, b – number of species found in the second group, w – number of species common to both) revealed a similarity of about 50% (range 35–72%) for a large number of pairs of compared ponds with different frequency of sampling, and about 60% (range 53–84%) for the species composition within one pond, on the basis of all samples taken every 3–5 days and samples corresponding to the 14-day time intervals.

euplankton, the frequency of occurrence of which during the growing season is over 21%, are caught when samples are taken every two weeks, and in their case the "customary" frequency of sampling does not distort the completeness of the species composition (Fig. 1). A high percentage, sometimes as much as 100%, of the less frequent species (11–20%) is also caught. Attention must, however, be drawn to the fact, apparently astonishing, that a similar or even smaller percentage of the euplankton species in this class of frequency of occurrence than that of the littoral species, is generally caught (for instance as

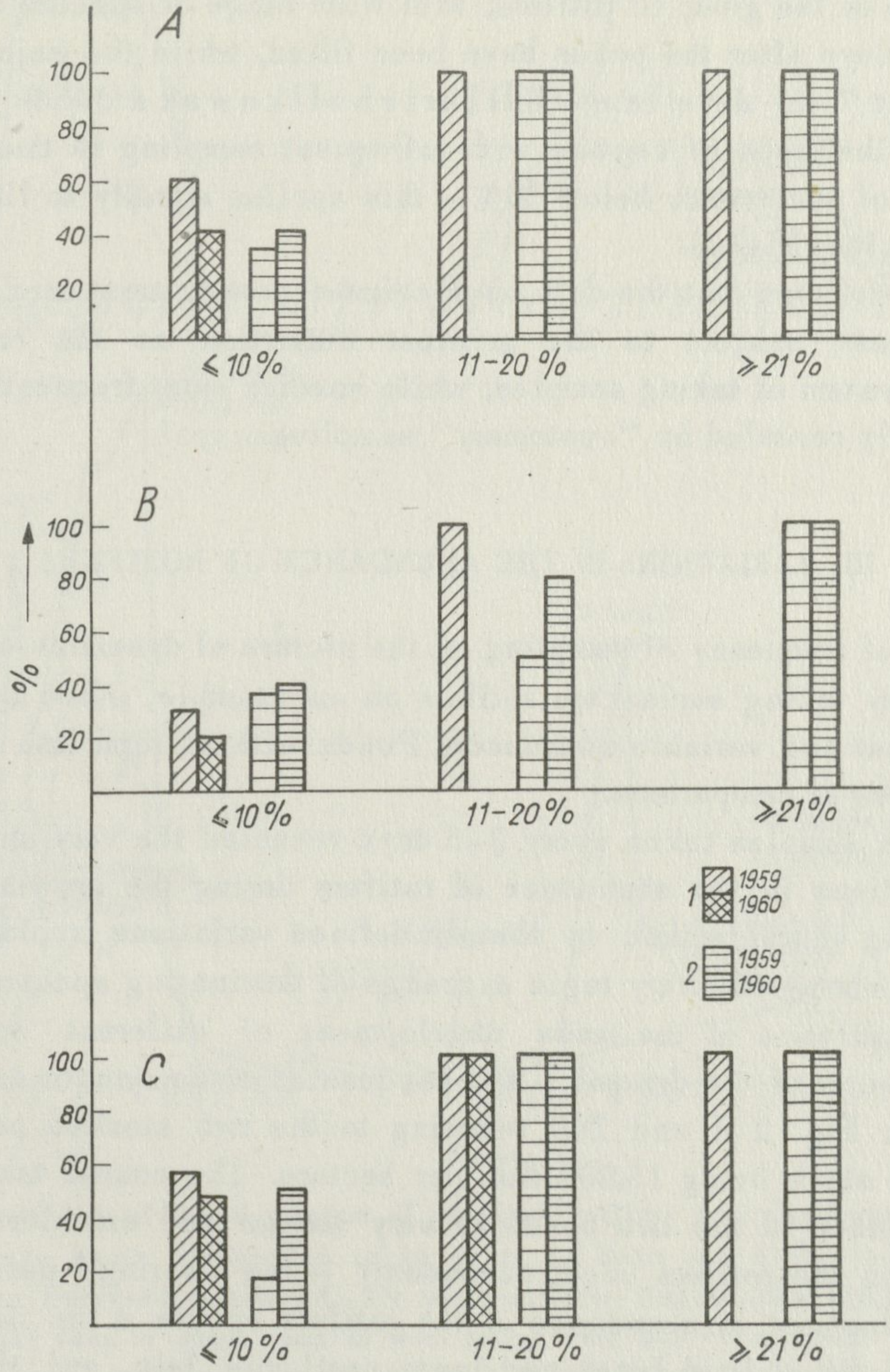

Fig. 1. Number of species of rotifers in each class of frequency of occurrence (explanation in text), found in samples taken every 14 days, as a percentage of the number of samples found in samples taken every 3–5 days, for three selected ponds (*A*, *B*, *C*) and for the two study years

1 – littoral species, *2* – euplankton species

in pond *B* – Fig. 1). This must be explained by the distinctly periodical character of the occurrence of certain euplankton species. Littoral species with this frequency of occurrence, occur ih small numbers only and that infrequently, but over the whole of the growing period of the ponds, so that there are chances of their being caught even when samples are taken every two weeks, while the occurrence of euplankton species not frequently occurring is so limited in time that it generally comes within the limits of a smaller periods between successive samples, that is, every two weeks. This applies in particular to the spring period, when the whole of the group of rotifers, with wide range of species composition, appears a few days after the ponds have been filled, while the majority of them disappear about 7–10 days later (Hillbricht-Ilkowska 1964). The lowest percentage of likelihood of capture with infrequent sampling is that of species with frequency of occurrence below 10% – this applies equally to littoral and to euplankton species (Fig. 1).

It therefore follows that the data on species occurring most rarely in a given habitat are those subject to the greatest distortion as the result of the "customary" system of taking samples, while species most frequently occurring are satisfactorily revealed by "customary" sampling.

III. VARIATIONS IN THE ABUNDANCE OF ROTIFERS

The effect of frequency of sampling on the picture of dynamics obtained will be illustrated by taking euplankton rotifers as an example, since they occur in sufficiently great and variable abundance. Ponds with uniform fish stocks were used for purposes of comparison.

Quantitative samples taken every 3–5 days revealed the very uneven course taken by variations in the abundance of rotifers during the growing season of the ponds, being characterized by sharply defined variations (rapid increase or reduction in numbers) and very rapid exchange of dominating species due to the successive occurrence of the mass development of different species. This particular character of the dynamics and succession of dominants are illustrated by curves 1 in Fig. 2 *A* and 2 *B* referring to the two stocked ponds chosen, density of fish stock being 15,000 fish per hectare. The course taken by variations in abundance in the two ponds is very similar and exhibits two distinct periods in which the rotifers occur numerously – the "spring" period in which the rapid development in abundance of the rotifers occurs a few days after the pond has been filled (mid-June) and lasts until mid July, and the "summer-autumn" period – in which the rotifers occur numerously from the end of August to the end of the growing season in the pond (mid-October). In addition in one of the ponds (Fig. 2 *B*) a slight and short-lived increase in the abundance of rotifers was observed at the beginning of August. Apart from these two basic

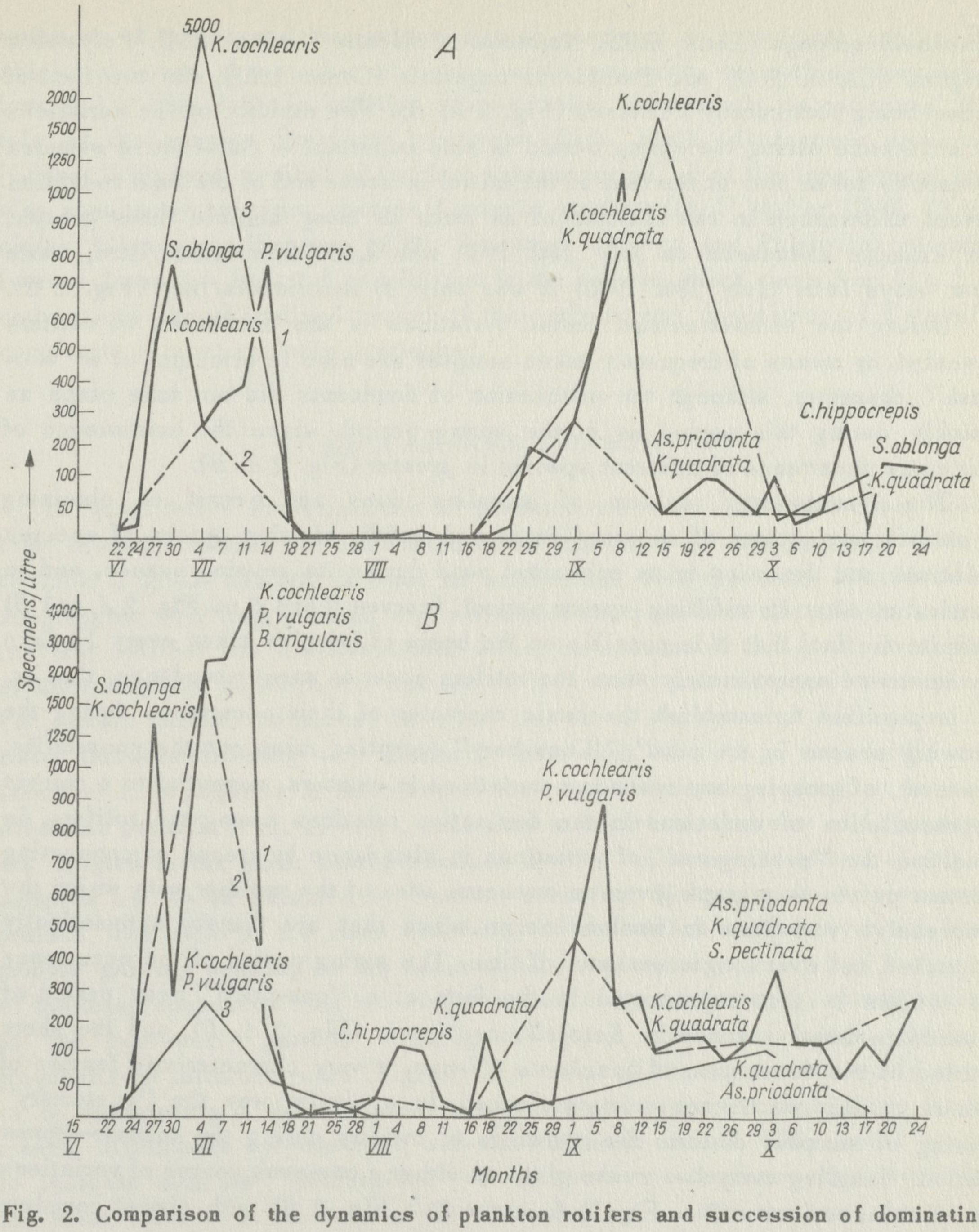

Fig. 2. Comparison of the dynamics of plankton rotifers and succession of dominating species, on the basis of samples taken every 14 days and every 3–5 days, using as examples two selected ponds (*A*, *B*) with uniform fish stocks (15,000 fish/hectare) *1* – data for the pond in which samples were taken every 3–5 days; results of all samples, *2* – as above, results for samples (every 3rd sample) corresponding to 14-day periods, *3* – data for the pond in which samples were taken every 14 days

"peaks" in numbers numerous secondary "decreases" and "increases" in numbers are also observed. For instance the "two-peak" character of the spring peak period is due to the successive mass development of several species:

Synchaeta oblonga (Ehrb. 1832), *Keratella cochlearis* (Gosse 1851). *Polyarthra vulgaris* (Carlin 1943) and *Brachionus angularis* (Gosse 1851), the two first of these being particularly numerous (Fig. 2 *A*, *B*). The rapidity of the variations in abundance during the spring period is also important – consecutive samples frequently taken both at the time of the initial increase and of the final reduction reveal differences in the numbers of as much as many hundred times greater, for example abundance on July 14th 1960 was 4,500 individuals/litre, while four days later (July 18th 1960) it was only 30 individuals/litre (Fig. 2 *B*).

During the summer-autumn period variations in the abundance of rotifers revealed by means of frequently taken samples are also in principle of a "two-peak" character, although the succession of dominants did not take place as quickly during this period as in the spring period, since the persistence of numerous occurrence of different species is greater (Fig. 2 *A*, *B*).

The "customary" system of sampling does not permit of obtaining a satisfactory picture of so complicated and rapidly altering system of species relations and dynamics in an ephemeral pond during its growing season, and in particular, after its refilling (spring period), (curves 2 and 3 on Fig. 2 *A* and *B*) despite the fact that it is possible on the basis of samples taken every 14 days to determine approximately when the rotifers occur in great abundance, that is, it is possible to establish the basic character of their occurrence during the growing season in the pond[3]. "Customary" sampling rules out the possibility, however, of grasping any secondary variations in numbers, essential to a correct representation of variations in the domination relations among the rotifers. In addition the "evening-out" of variations in abundance by means of connecting distant points on a graph gives an erroneous idea of the rapidity with which the successive variations in numbers occur, since they are thereby automatically stretched out over longer sections of time. The spring period of the occurrence of rotifers is thus represented in the form of a "one-peak" peak period of abundance mainly caused by *Keratella cochlearis* (Fig. 2 *A*, *B*), and the short period of the domination of *Synchaeta oblonga*, a very characteristic feature of ponds refilled each year – is overlooked. In a similar way the "customary" taking of samples distorts the dynamics of rotifers during the summer-autumn period. Sampling every two weeks gives us either a one-peak course of variations in abundance (curve 2 – Fig. 2 *A*, curve 3 – Fig. 2 *B*) with almost complete

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[3] Assuming of course that the first sample taken during the growing season forms the starting point for both variants of frequency of sampling – consideration of how the picture of dynamics alters when the same frequency of sampling is adhered to but the first sample is taken at different times has been omitted in the present study. It must, however, be held that if the first sample is taken not a few days, but two weeks, after the pond has been filled, the spring peak period of rotifers – a phenomenon very characteristic of ponds refilled each year (Braginskij 1957) – is almost completely passed over.

omission of the second late-autumn rise in numbers, or a two-peak course, in which, however, the number of peaks would appear to be entirely fortuitous (curve 2 – Fig. 2 *B*). In addition samples taken infrequently do not reveal the role of the species *Synchaeta pectinata* (Ehrb. 1832), *Asplanchna priodonta* (Gosse 1850), very typical of the late autumn period, or of the less typical but also abundantly occurring species *Keratella quadrata* (O. F. Müller 1786), *Conochilus hippocrepis* (Schrank 1830), *Synchaeta oblonga* and *Polyarthra vulgaris* (curves 2 and 3 – Fig. 2 *A* and *B*), and in the pond to which curve 3 on Fig. 2 *B* corresponds the short-lived period of the early-autumn domination of *Keratella cochlearis* is most probably overlooked.

IV. MEAN ABUNDANCE OF ROTIFERS

In quantitative investigations of plankton its mean abundance over fairly long intervals of time are often used as an indication of the abundance characterizing a given habitat. It must be emphasised that the mean abundance of zooplankton over long periods, e.g. periods of one year or of the growing season (several months) has a conventional value, on account of the great variability of their numbers, of which the courses of dynamics described provide examples. For certain definite purposes, however, i.e. for a very general description of water habitats differing very distinctly from each other (e.g. very fertile and infertile) it is possible to make use of the mean abundance of plankton for considerable periods. It is, however, necessary to ascertain what sort of differences are created in the mean values obtained by the "customary" system of taking samples and those obtained by frequent sampling. With this aim in view comparison was made of the mean abundance of euplankton rotifers over the four-months growing season, on the basis of all samples taken every 3–5 days and of the mean abundance from selected samples (every third sample) corresponding to the two-weekly periods – using the group of several ponds examined frequently in different years (Fig. 3). The result of the comparison would seem to be astonishing – the two mean values are relatively similar, i.e. no fundamental differences are observed between the mean values. This would appear to indicate that the "evening-out" of variations in abundance by calculating the mean value – in the case of frequent sampling – is of the same degree as the "evening-out" of variations in abundance when samples are taken infrequently. To put it differently the distortion introduced into an estimate of the abundance of zooplankton when samples are taken sporadically "adds" very little to the distortion which is automatically created when an estimate of abundance is based on a mean value, even when such a mean is calculated from quantitative samples taken very frequently.

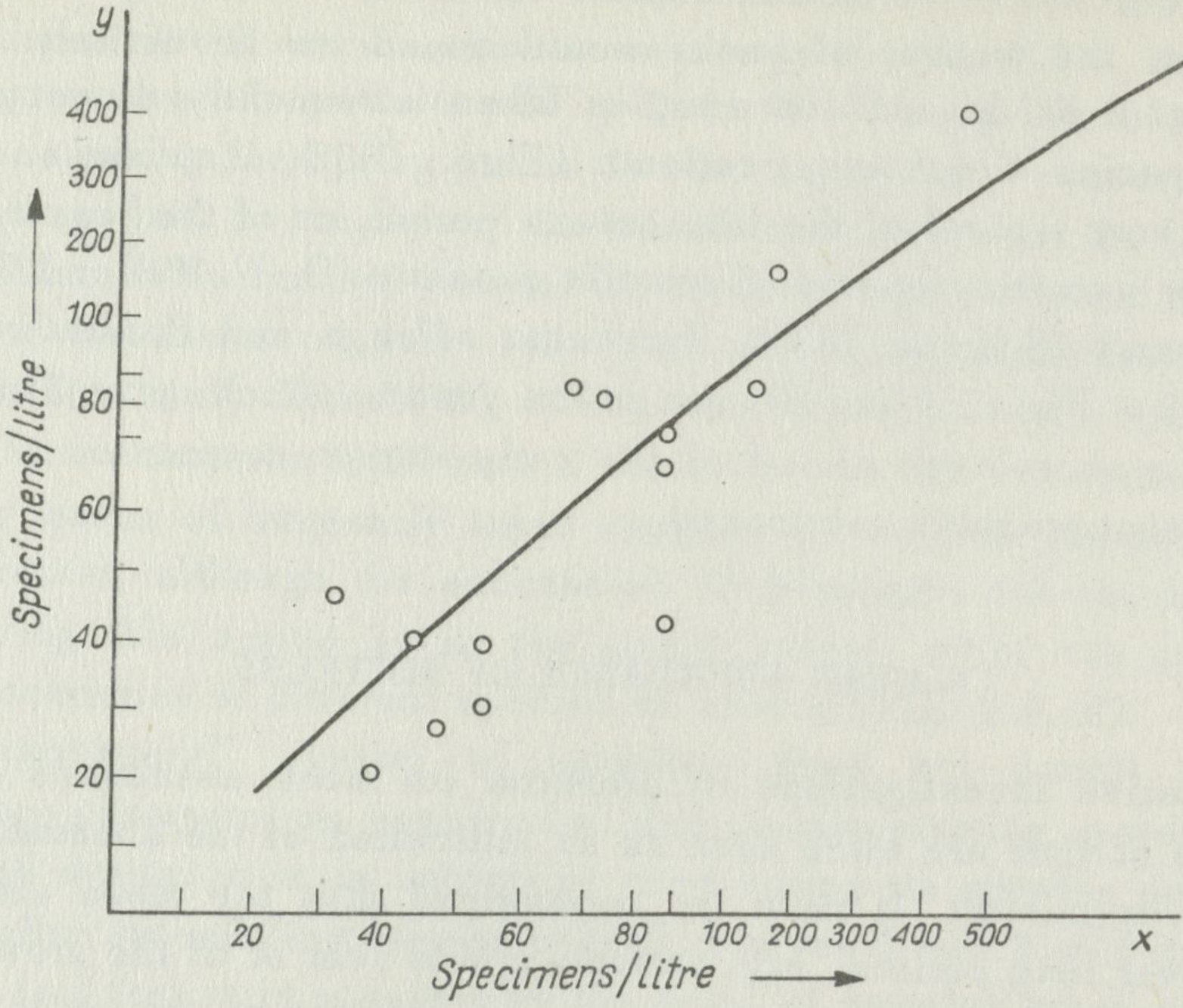

Fig. 3. Comparison of the mean abundance of euplankton rotifers on the basis of samples taken every 3–5 days (y) and of samples (every 3rd sample) corresponding to 14-day intervals (x) for the group of ponds frequently sampled

V. CONCLUSIONS

1. When quantitative samples are taken every 14 days significant distortion takes place in the picture of the number and composition of the species found in comparison with their composition obtained from samples taken 3–4 times more frequently. In the case of littoral species about half the species, and in that of euplankton rotifers about 30–40%, are never caught at all. The species which fail to be caught belong chiefly to species occurring least frequently during the growing season in the pond (in about 10% of all the samples taken).

2. In the case of littoral species, which generally belong to species occurring sporadically and scantily, the composition obtained, based on samples taken every 14 days, often differs fundamentally from the composition obtained from the same pond by means of samples taken more frequently. In the case of euplankton rotifers about half the species are common to both compositions.

3. Despite the fact that when samples are taken every 14 days a curve of dynamics is obtained which represents fundamental variations in the abundance of rotifers during the growing season in the pond – this curve does not in fact give the true succession of dominating species, the rate of variations in numbers nor the times of maximum abundances. Variations in abundance and

relations between species during the period following the spring refilling of the pond are subject to particular distortion.

4. The mean abundance of euplankton rotifers for the growing season of the pond is not subject to particular distortion as the result of samples being taken infrequently. It would seem that this is due to the "evening-out" of variations in abundance caused to an equal degree by infrequent sampling and by the fact itself of calculating the mean from greatly varying values.

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WPŁYW CZĘSTOŚCI POBIERANIA PRÓB NA OBRAZ WYSTĘPOWANIA I DYNAMIKI WROTKÓW PLANKTONOWYCH

Streszczenie

Badania przeprowadzono na kilkunastu jednakowych stawach o powierzchni 0,20 ha i głębokości 1,5 m, zalewanych na okres czterech miesięcy (od połowy czerwca – do połowy października). W części stawów pobierano próby ilościowe (o objętości 20 litrów) co 14 dni, w części zaś – co 3–4 dni.

Porównanie obrazu dynamiki i składu gatunkowego wrotków przeprowadzono pomiędzy:

1. stawami badanymi często (co 3–5 dni) i rzadziej (co 14 dni),
2. w obrębie stawów badanych co 3–5 dni, biorąc za podstawę wyniki uzyskane z wszystkich pobranych prób oraz z prób co trzecich, których częstość pobrania odpowiadała dwutygodniowym odstępom czasu oraz datom, w których równocześnie pobierano próby ze stawów badanych co 14 dni.

Stwierdzono, że:

1. Przy pobieraniu prób ilościowych co 14 dni następują istotne odkształcenia w obrazie liczby i zestawie stwierdzonych gatunków, w porównaniu z ich zestawem otrzymanym na podstawie prób branych 3–4 razy częściej. Nie wyłapuje się około połowy gatunków wrotków litoralowych oraz około 30–40% gatunków wrotków euplanktonowych (tab. I). Niewyłapane gatunki wrotków należą głównie do gatunków o najmniejszej częstości występowania w okresie wegetacji zbiornika (w około 10% wszystkich pobranych prób) (fig. 1).

2. Zestaw otrzymany na podstawie prób branych co 14 dni różni się nieraz zasadniczo, w przypadku gatunków litoralowych, które należą ogólnie do gatunków sporadycznie i nielicznie występujących, od zestawu otrzymanego z tego samego stawu, na podstawie prób branych częściej. Prawie połowa gatunków, w przypadku wrotków euplanktonowych, jest wspólna dla obu zestawów.

3. Mimo, że przy pobieraniu prób co 14 dni otrzymuje się krzywą dynamiki, reprezentującą zasadnicze zmiany liczebności wrotków w okresie wegetacji stawu, to jednak krzywa ta nie oddaje rzeczywistego następstwa gatunków dominujących, tempa zmian liczebności oraz momentów maksymalnej liczebności wrotków (fig. 2). Szczególnemu zniekształceniu ulega obraz zmian liczebności i stosunków między gatunkami w okresie wiosennego odnowienia zbiornika (fig. 2).

4. W wyniku nieczęstego pobierania prób nie ulega szczególnym zmianon obraz przeciętnej liczebności wrotków euplanktonowych w okresie wegetacji stawu (fig. 3). Wydaje się, że jest to wynikiem "wyrównywania" zmian liczebności przez nieczęste pobieranie prób i przez sam fakt wyciągania średniej z silnie zmiennych wartości.

AUTHOR'S ADDRESS:
Dr. Anna Hillbricht-Ilkowska
Institute of Ecology,
Polish Academy of Sciences,
Warszawa, ul. Nowy Świat 72,
Poland.