INFLUENCE OF SUSPENDED ORGANIC AND ANORGANIC SUBSTANCES IN WATER UPON THE NUMBERS OF BLACKFLY LARVAE (DIPTERA, SIMULIIDAE)

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Abstract. The amount of suspended organic and anorganic substances in water and the species composition and numbers of blackfly larvae were investigated in a 1 km-long sector of a stream in South Bohemia (near the village Purkarec) in 4 biotopes: 1. outlet of an artificial lake, 2. forest stream, 3. transition between forest and meadow sector of the stream and 4. canalized stream flowing across a pasture. The differences in the amount of suspended substances were very low in comparison with the differences in quantitative as well as qualitative composition of the blackfly populations. The species composition in individual sites was determined by the type of biotope and changed markedly within the framework of very short sectors, the species *S. noelleri* predominated in biotope 1, *P. tomosvaryi* in biotope 2, *O. ornata* in biotopes 3 and 4, this species being abundant in the canalized sector of the stream. The food supply always exceeded the actual demand; the quantity of the food supply could not be considered as factor limiting the numbers of blackfly larvae.

The blackfly larvae being filter-feeding insects are able to filter feed on and ingest coloidal particles (Wotton 1976) as well as minor specimens of its own species (Peterson and Davies 1960, Burton 1971). As demonstrated by many authors (e.g. Kurtak 1978, 1979, Merrit et al. 1978, Wotton 1977), blackfly larvae ingest any filter fed material, although the percentile composition of some elements in gut contents do not always agree with the percentile representation of these elements in the food supply investigated in the water samples from the biotope studied (Kurtak 1979). However, on the basis of results obtained by the above mentioned authors, it may be generally presumed that larvae filter-feed on and ingest any material of organic or anorganic origin which they are able to intercept by their cephalic fans.

The goal of the present paper was to ascertain the extent to which the quantity of food supply in the stream can influence the qualitative and mainly quantitative composition of the fauna of pre-imaginal stages of blackflies in small streams.

MATERIAL AND METHODS

In sites described below samples of blackfly larvae and pupae and samples of stream water were collected in the period between May 1982 and July 1983. The collecting dates are given in Tables 1 and 2; the samples were collected always between 11 and 13 hours. In order to obtain quantitatively comparable samples of blackfly larvae and pupae artificial substrates were used, namely unglazed ceramic tiles 10×10 cm large (Lewis and Bennet 1974) similar in colour to the colour of stones in the stream, polyethylene strips 2.5×20 cm in size. The samples were also collected on natural substrates, whose area was carefully measured. Larvae and pupae were collected from these substrates with entomological pincers and in the field were stored in 96 % alcohol. In laboratory the larvae were identified down to species by using Knoz's monographs (1965, 1980), respecting the nomenclatoric changes recorded by Zwick (1974) and Zwick and Crosskey (1980). For each sample a mean number of specimens per dm² of substrate area was calculated.

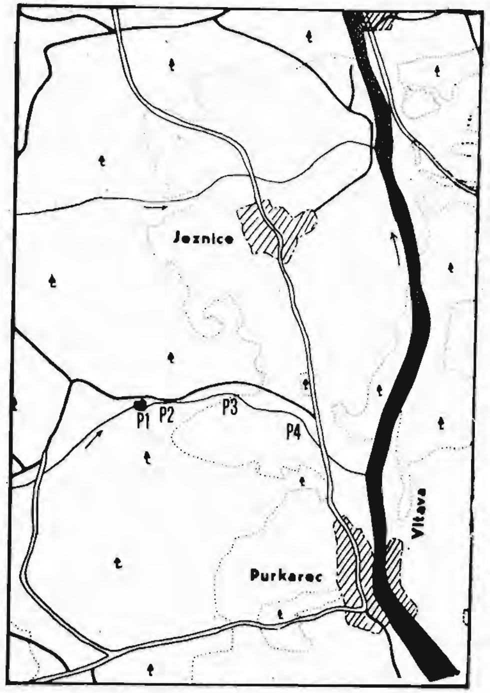

Fig. 1. A chart of locality studied. Different biotopes are indicated as P1—P4.

Fig. 2. Biotope 1. Spillway dam of the forest lake, site of massive occurrence of *S. noelleri*.

During each visit to the locality studied water samples were collected in individual sites and brought to laboratory in a cool state. Here the amount of suspended substances both organic and anorganic was ascertained, such as the difference between the dry and flame annealed filtrate (Hofman 1965); during underpressure filtration membrane filters Synpor No. 3 were used which intercept particles bigger than 1.5 μm.

The velocity of stream was measured by Raušer's modification of Pittot's tube, pH of water was measured with colorimeter, the water temperature was taken with stem mercury thermometer.

Marginally also some natural enemies of blackfly larvae were investigated. Larvae of various predatory species of caddisflies (Trichoptera), primarily of the species *Hydropsyche angustipennis* (Curtis, 1834), were collected, dissected in laboratory, and head capsules or other body parts of blackfly larvae were searched for in their digestive tracts. In addition, fatbodies of larvae were examined and cysts of microsporidia, spheral sporangia and hyphal corpuscles of the fungus *Coelomycidium simulii*, discernible even in the fixed material were looked for. Simultaneously also the presence of other potential predators was investigated which might have influenced the numbers of blackfly larvae in the locality under study.

Locality studied

Investigations were carried out in the lower reaches of the Rachačka stream, the right tributary of the Vltava river, flowing north of the village Purkarec (district of České Budějovice, Fig. 1). The locality in question was a forest stream whose backed-up waters form a lake at a distance of about 2.5 km from its source. The lake outlet represented biotope 1 (Fig. 2). Biotope 2 (Fig. 3) was situated 100 m downstream, in the sector shaded by tall trees throughout the year; biotope 3 was 500 m downstream from the lake outlet at a site where the stream leaves the forest and intersects a fenced cattle pasture; biotope 4 (Fig. 4) was situated approximately in the centre of this pasture, 1000 m from the lake outlet and about 400 m before the stream empties into the Vltava river. The total sector investigated was 1 km long, its upper part being in full shade of

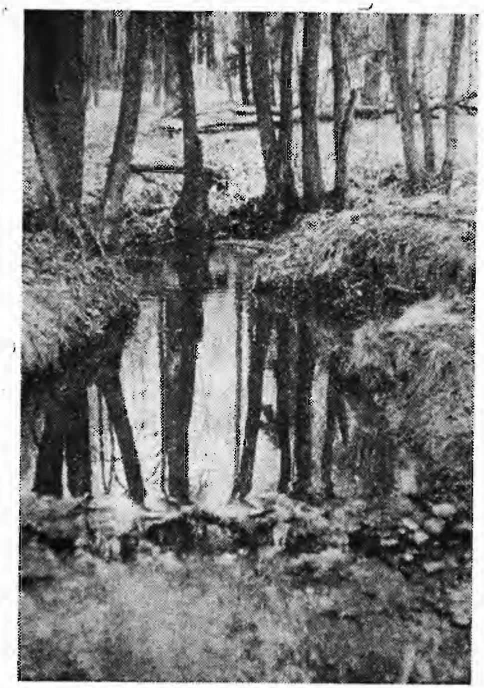

Fig. 3. Biotope 2. Forest sector of the Rachačka stream.

Fig. 4. Biotope 4. Canalized sector of the stream flowing across pasture. Massive breeding place of the species *O. ornata*.

a tall mixed forest the whole day (except for the spillway dam) and the lower part in the open terrain. The studied sector in its upper part (biotopes 1—3) had a natural bed with many meanders and calm waters, with pebble or rocky bottom. The lower part was canalized with a straight bed, its crossection in the shape of trapezium, its banks and bottom paved with stones. The forest sector of the stream had no green water vegetation, but its banks in the open terrain were overgrown with dense grass hanging down in water. The width of the bed in the studied sector varied between 1 and 2 m, the depth often ranged from 5 to 10 cm, the average stream velocity being 65 cm/sec. The pH varied slightly, namely between 5.6 and 6.2.

RESULTS

a) Species composition and blackfly abundance

In the four biotopes mentioned above more than 200 000 larvae and pupae of blackflies were collected. A total of 7 species were identified as follows: *Prosimulium tomosvaryi* (Enderlein, 1921), *Eusimulium augustipes* (Edwards, 1915) (syn. *E. securiforme* Rubzov, 1956), *E. vernum* (Macquart, 1826) (syn. *E. latipes* auct. nec (Meigen, 1804)), *Odagmia ornata* (Meigen, 1818), *O. monticola* (Friederichs, 1920), *O. variegata* (Meigen, 1818) and *Simulium noelleri* Friederichs, 1920 (syn. *S. argyreatum* auct. nec Meigen, 1838). The species composition of the fauna in individual biotopes and the number of species per 1 dm^2 of the substrate area ascertained during the individual collecting, are given in Table 1.

The material collected in biotope 1 consists of two groups, the first group representing the samples collected at the lake spillway dam where only *S. noelleri* was found

Table 1. Species composition and number of larvae of individual species converted to 1 dm² of area of investigated substrate in different biotopes

Site No. / Date	1 a		1 b						
	P.t.	S.n.	P.t.	E.v.	E.a.	O.o.	O.m.	S.n.	Σ
12. 5.		2	0.7	0.3				0.1	1.1
			0	0.8					0.8
18. 5.		19.4						0.1	0.1
	0.2	0.2							0
28. 6.		1,800				34		1,698	1,732
		2,734				0		767	767
7. 7.		21,200						88	88
		700						28	28
14. 7.		5,025						1.4	1.4
		1,551						6.2	6.2
21. 7.		1,825				0		1.8	1.8
		1,275				0.2		0.6	0.8
3. 8.		21,850			1			12	13
		1,150			0			0	0
11. 8.		29,200			0.1			5	5.1
		1,500			0			0	0
1. 9.		9,950			0.2	2	0.2	3.6	6
		850			0	0	0	2.2	2.2
6. 10.		—						—	—
23. 11.		—						—	—
11. 1.		—	32.2					—	32.2
			0						0
23. 3.		—	6.4	0.4				—	6.8
			0	0					0
20. 4.		14	2.2	0.8				0.3	3.3
		0	1.4	0.2				0	1.5
16. 5.		43						0.5	0.5
		0						1.5	1.5
4. 7.		3,480						—	
		420							

P.t. — *Prisimulium tomosvaryi*, S.n. — *Simulium noelleri*, E.v. — *Eusimulium vernum*, E.a. — *Eusimulium angustipes*, O.o. — *Odagmia ornata*, O.m. — *Odagmia monticola*, O.v. — *Odagmia variegata*

Table 1. (Continued)

Site No. / Date	2						3					4			
	P.t.	E.v.	E.a.	O.o.	S.n.	Σ	P.t.	E.v.	O.o.	O.v.	Σ	P.t.	E.a.	O.o.	Σ
12. 5.	1.3	36			2.3	39.5	4.5	4			8.5	1.4		4.2	5.6
	0	0.5			0	0.5	1.8	0.3			2.0	0		4.4	4.4
18. 5.	1.8	6.2			0.2	8.1	1.2	0.2			1.4	0.1		0.6	0.7
	0	0.2			0	0.2	0.2	0			0.2	0		2.4	2.4
28. 6.	—					—			1.2		1.2			277.5	277.5
									0.8		0.8			299.5	299.5
7. 7.	—					—			8.6		8.6			161.8	161.8
									0.2		0.2			30.0	30.0
14. 7.	—					—			23.2		23.2			363.4	363.4
									0.2		0.2			10	10
21. 7.	—					—			25.9		25.9			832.5	832.5
									0.2		0.2			25.3	25.3
3. 8.			0			0			52	0.3	52.3			324	324
			0.1			0.1			0.3	0	0.3			0	0
11. 8.				0.1	0	0.1			125.3		125.3			364	364
				0	0	0			4.3		4.3			0	0
1. 9.				0.6		0.6			20.3		20.3			200	200
				0.2		0.2			4.3		4.3			0	0
6. 10.	—					—	—				—			108	108
23. 11.	1					1	0.1				0.1	4		25.5	29.5
	0					0	0				0	0		0	0
11. 1.	42.5					42.5	0.4				0.4	50	40	920	1,010
	0					0	0				0	0	0	0	0
23. 3.	24	0.2				24.2	9.2				9.2	6	4	74	84
	0	0				0	0				0	0	0	6	6
20. 4.	6.6	0.3		0		6.9	9.2				9.2			46	46
	0.3	0		0.1		0.4	0.1				0.1			20	20
16. 5.		0			0	0	0				0			23	23
		1			3	4	0.4				0.4			17	17
4. 7.			0.1	0.1		0.2	—				—		6	32	38
			0.1	0		0.1							0	0	0

(except one sample). In similar biotopes this species occurred in very high density. Larvae formed clusters which covered about 50 % of the total area of the dam. The second group of samples was collected in sites within 20 m downstream from the dam and contained 6 species. The blackfly populations in these sites were much less numerous, but revealed the highest species variety (Shanon's index), namely in the period of abatement of the overwintering populations and the build up of the dominant *S. noelleri*. In the samples collected in biotope 2 five species were identified and the blackfly populations there were least numerous, the larvae being rarely encountered. The species *P. tomosvaryi* reached the highest density here, while larvae and pupae of *S. noelleri* were sporadically found. This species was not encountered in biotopes 3 and 4, where *O. ornata* was predominant, whose populations were very high in biotope 4 throughout the period studied. Biotope 4 was the only one, where blackfly larvae and pupae were always found.

Table 2. Water temperatures measured during individual collections in different biotopes

Site No / Date	1	2	3	4
	°C	°C	°C	°C
12. 5.	9.2	9.4	10	14.2
18.5.	14	14	14.8	18
28. 6.				
7. 7.	17.2	17	15.6	16.8
14. 7.	20.2	19.3	17.6	22.4
21. 7.	18.2	17.9	18	25.8
3. 8.	18.3	17.9	17.2	20.9
11. 8.	17.4	17.1	17.0	21.3
1. 9.	14.5	14.4	14.5	15.8
6. 10.	11.5	11.4	11.4	11.5
23. 11.	2.3	2.3	2.3	3.4
11. 1.	2.5	3	3.5	4
23. 3.	4.5	3.4	3.6	5.5
20. 4.	8.5	8.8	9	10.5
16. 5.	14.5	15	15	15.5
4. 7.	17	17	16.5	19

Throughout the studied section of the stream the blackflies were concentrated in those microbiotopes where the stream water flowed at a minimum rate of 40 cm/sec. In sites where the rate was lower, no larvae were found or occurred there only rarely.

b) Quantity of suspended particles in water

The results of studies on suspended organic and anorganic substances in water are depicted in the graph (Fig. 5), where the values are given in mg per 1 liter for all samples collected. The time behaviour of changes of these values was similar in all biotopes; the highest values were regularly obtained in biotope 1 (lake outlet), the lowest values of organic substances in biotope 3 (forest-meadow-transition), the lower and relatively stable values of anorganic substances were ascertained in biotope 4 in sites, where the stream was partly overgrown with high vegetation. Sixteen water samples were collected at 20-minute intervals in biotope 4 on 1 November 1982. The

individual samples did not differ from one another more than ± 1 mg/l in both values traced. (This measurement was not depicted in the graph, but did not deviate essentially from its course).

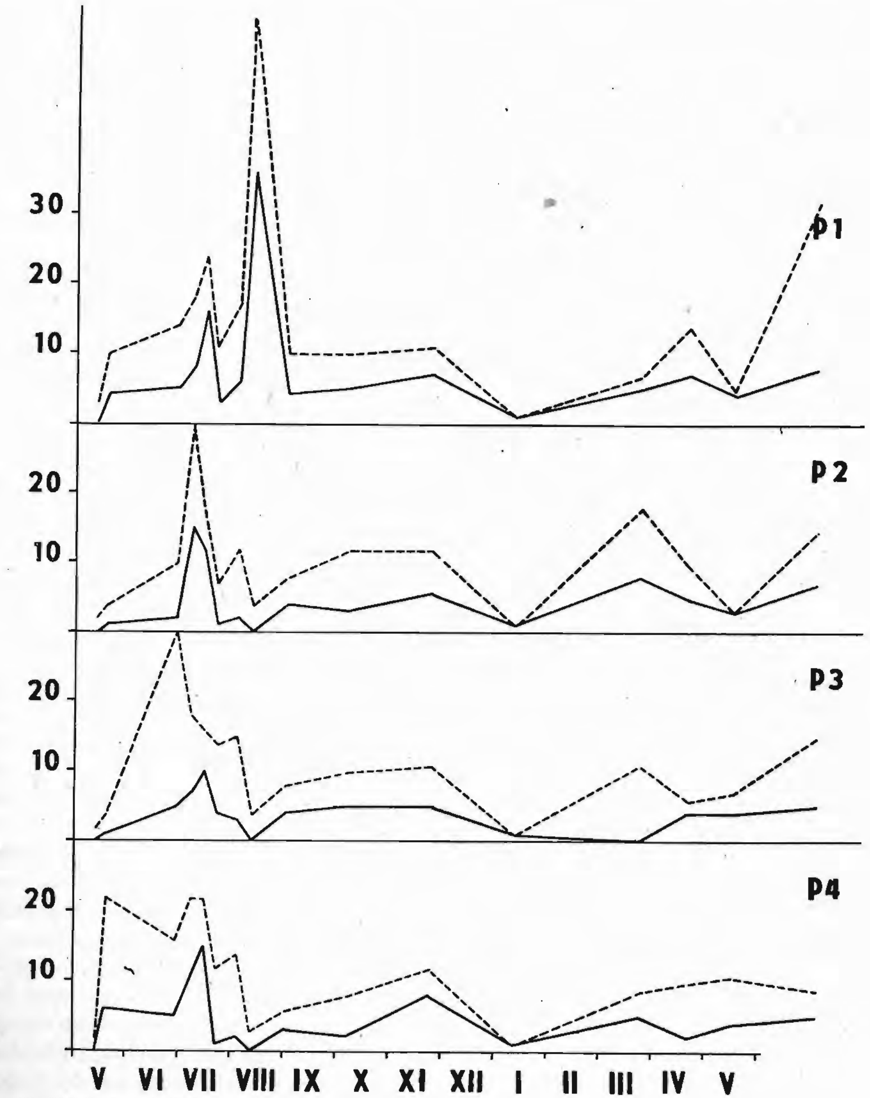

Fig. 5. Amount of suspended particles (mg/l) found in different biotopes (P1—P4) during individual collections (Roman digits indicate months). Solid line = organic substances, broken line = anorganic substances.

c) Natural enemies of blackfly larvae

The results obtained in the investigation of pathogens and predators of blackfly larvae showed that the latter did not influence the population numbers in the locality studied in any significant way.

The *S. noelleri* colonies contained abundant larvae of *Limnophora riparia* (Fallén 1824) (Diptera, Muscidae), which are, according to hitherto observations, the most frequent insect predators of this species throughout the territory of Czechoslovakia. The blackfly remains were found only sporadically in the digestive tract of caddisflies. A detailed information is presented in the paper by Kuralová and Olejníček (1985). Evidently ill blackfly larvae were found only in fragmentary low percentages; *Ceolomycidium simulii* as well as microsporidia could not be considered as factors influencing the differences in the numbers of blackfly populations in individual biotopes.

DISCUSSION

While the qualitative differences between individual biotopes, as far as the food supply is concerned, can be regarded as insignificant (except for the sample collected on 11 August 1982), the differences in the species composition and particularly in the number of blackfly specimens are outstanding. These differences are the more distinct due to the fact that only the stream section 1 km long, without tributaries, was involved. Extraordinary strong colonies of *S. noelleri* occurred only on the stone-built spillway dam which was leaking all over. The blackfly colonies formed clusters covering about one half of the dam area, while in the sites only a few meters below the dam the populations of blackfly larvae were much less numerous. The water samples at biotope 1 were collected about 2 m below the lake dam. Thus, the possibility that lower values ascertained at biotope 2, would be due to the filtration activity of *S. noelleri* colony on the lake dam, could be ruled out.

At biotope 2 the populations were least numerous. Kurtak (1979), who has studied similar problems, reports that fallen leaves constitute a considerable part of organic mater in forest streams and that these sectors are also much poorer in diatoms. Ladle and Hansford (1981) mention diatoms as the most important component of the blackflies food, but admit that in other species than those used by them or in other regions the situation may be different.

The density of the populations studied changed considerably in places where the stream leaves the forest. Its unshaded sector extending practically as far as the confluence with the river, was characterized by high density of *O. ornata* populations, regularly distributed all over the stream sector flowing in the open terrain. The canalized sections of small streams flowing across pastures, become sources of overpopulation of this species. This fact may be responsible for the deaths of cattle bitten by blackflies (Minář and Kubec 1968 etc.). While in biotope 3 abundant *O. ornata* larvae were collected on tiles and stones as well as polyethylene strips, in biotope 4 they were found primarily on polyethylene strips and vegetation leaves. Carlson et al. (1977) who studied factors influencing the numbers of blackfly larvae inhabiting lake outlets in Sweden, report that plankton produced in the lakes does not essentially influence the quantity of blackflies too much. Merrit et al. (1982) surmise that temperature exerts a greater influence on the speed of development than food availability. The presence of individual species is determined primarily by the type of biotope and the fact, that the same stream is involved in a very short sector, apparently plays a small role here.

This applies mainly to *S. noelleri* species whose populations occur in a regular high density in biotopes such as dams and outlets of artificial or natural lakes. The colonies of larvae and masses of overwintering eggs apparently act as inhibitors to oviposition by other species. In other similar localities in southern Bohemia, after the lake has been emptied and the spillway dam and outlet bed are dried up, these biotopes may be colonized by other species (*O. ornata*, *E. angustipes*, *Boophthora erythrocephala* for a short period in the winter after the lake has been refilled again. If this does not happen, the lake outlets, at sites immediately below or very close to the lake, are either free from blackfly larvae, or population density of other species is very low there, similarly as in the locality studied by us. Analogous situation is described by Wotton (1982) at the outlet of a Finnish lake.

Because the stream studied, from its outflow from the lake as far as the biotope 3 is a typical forest stream, the species usually abundant below the lake in the open terrain (Olejníček 1984), or were either their population density was very low. If we compare the values of water temperature measured in individual biotopes (Table 2), we see that the biotopes with partial sunlight (i.e. lake outlet and the stream flowing across meadow) reveal rather high values. In addition, the direct sunlight probably determines the formation of some microorganisms suitable as food for larvae. The two factors undoubtedly contribute to the faster development of larvae in these biotopes.

Our data obtained on the abundance of blackfly larvae are contrary to the data obtained by some other authors. E. g. Sheldon and Oswood (1977), while studying blackflies at the outflow from Lake Placid (Montana, USA), found a continuous decrease of larval numbers downstream. This fact is apparently due to a rather different type of stream, its distinctly larger dimensions and lesser changes of its character. However, the mentioned authors (in contrast to their initial supposition) did not record any quantitative decrease of food supply whichwould be directly dependent on the numbers of larvae. Likewise, it could not be anticipated on the basis of results obtained in the studies on natural enemies of larvae that they might somehow influence the blackfly populations in the locality under study.

The absolute population density of blackfly larvae was highest in the lower part of the stream (biotope 4), because relatively abundant larval populations colonize a long sector here, in contrast to the small sector colonized by the otherwise very abundant population of *S. noelleri*. The quantity of the food supply, however, was not distinctly higher than in the preceding biotopes, especially if compared with biotope 1, it was rather the other way round. The results obtained justify the presumption that neither species composition nor population density are determined by the quantity of food supply, but that they could be rather influenced by its quality, or other factors, such as sunlight, water temperature in different biotopes, or the presence of suitable substrates for larval attachment. (Natural enemies probably play only a small role). It cannot be ruled out, however, that the population density may be influenced by the food component which is minimal and whose quantity may also vary distinctly depending on various factors.

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ВЛИЯНИЕ СУСПЕНДИРОВАННЫХ ОРГАНИЧЕСКИХ И АНОРГАНИЧЕСКИХ ВЕЩЕСТВ В ВОДЕ НА ЧИСЛЕННОСТЬ ЛИЧИНОК МОШЕК (*DIPTERA, SIMULIIDAE*)

Й. Олейничек

Резюме. На участке ручья, длиной 1 км, в южной Чехии (недалеко от села Пуркарец) исследовали количество суспендированных органических и анорганических веществ в воде, и видовой состав и численность личинок мошек на 4 биотопах: 1. сток из пруда, 2. лесной ручей, 3. переход между лесным и луговым участком ручья и 4. регулированный ручей, проходящий через пастбище. Разницы в количестве суспендированных веществ были ничтожны по сравнению с разницами в количественной и качественной структуре популяций мошек. Видовой состав в отдельных стациях определялся типом биотопа и резко менялся даже в рамках очень коротких участков; в биотопе 1 выразительно преобладал вид *S. noelleri*, в биотопе 2 — *P. tomosvaryi*, в биотопах 3 и 4 имел преимущество вид *O. ornata*, который особенно в регулированном участке ручья встречался в многочисленных популяциях. Пищевой запас всегда превышал настоящие требования, количество снабжения питательными веществами нельзя было считать фактором, ограничивающим численность личиночных популяций мошек.

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W. Peters, W. H. G. Richards (Eds.): Antimalarial drugs. II. Current antimalarials and new drug developments. *Springer Verlag, Berlin-Heidelberg-New York-Tokyo, 1984, 150 Figs., 520 pp., Price DM 390, US $ 145,50.*

This volume has four areas of topics divided into 16 chapters, compiled by 22 authors. At first, current antimalarials are discussed: 4-aminoquinolines, quinine and related substances, 8-aminoquinolines, sulphonamides and sulphones, dehydrofolate reductase inhibitors proguanil and pyrimethamine. Next, there is information about new methods used in the research of drugs, about the effect of drug combinations, about depository preparations with prolonged effect, which can be particularly applied in prophylaxis of malaria; use of incorporations of drugs in polymeres and other carriers, of insoluble salts and other techniques.

On the basis of the results obtained in the latest development of antimalarials the following substances with the effect of quinine are applied: quinolinmethanols, phenantron methanols and pyridine methanols; a special note should be made of mefloquine. Also discussed are 8-aminoquinolines, 4-aminoquinolines, triazines and other dehydropholate reductase inhibitors and last but not least antibiotics affecting malarial plasmodia, such as clindamycin.

The last chapter deals with the prevention of drug resistance which is quickly spreading to different geographic regions and extremely complicates the situation. Drug combinations are most effective here.

The two volumes of antimalarial drugs present a comprehensive information about the current state of pharmacotherapy of malaria. It is a vital problem for public health in the world, carefully monitored by the World Health Organisation. Each chapter has been compiled by a specialist in the form of a comprehensive scientific study provided with tables, graphs, photographs or structural patterns, including complete references to periodical literature. All this information will be useful to parasitologists, pharmacologists, infectologists and tropicologists.

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