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STUDIES ON THE INCIDENCE OF MOSQUITOES IN THE FOOD OF *TETRAGNATHA MONTANA* SIMON AND ITS FOOD ACTIVITY IN THE NATURAL HABITAT

The food of spider, *Tetragnatha montana* Simon, was gathered from its webs in alder forest (*Alnion glutinosae* union). A high percentage of it formed mosquitoes. The influence of abundance and activity of mosquitoes in the habitat on their abundance in the food of *T. montana* was studied. A correlation was found between occurrence, abundance and activity of this spider and those of mosquitoes which is an evidence of adaptation of predator to this type of prey.

From the beginning of June to the beginning of August 1967, webs of *T. montana* were searched, the feeding behaviour of this spider preying on mosquitoes was observed, and the abundance of mosquitoes in a natural habitat was studied. This spider species was found to occur abundantly in alder forest (*Alnion glutinosae* union) habitats of the Kampinos Forest. Its predation on mosquitoes has been studied experimentally (field experiments) in this environment since 1965 (Łuczak, Dąbrowska-Prot 1966, Dąbrowska-Prot, Łuczak, Tarwid 1966, Łuczak, Dąbrowska-Prot 1968).

The authors were interested in: finding out whether mosquitoes are preyed upon by this species in the natural habitat, mosquito incidence in the spider diet, and correlations of occurrence, abundance and activity of this spider

and of mosquitoes, these correlations being an evidence of adaptation of the predator to the prey of this type.

Studies were carried out in a *Salici-Franguletum* strip, about 40 m long, on the border of alder forest (*Alnion glutinosae* union). This area, about 400 m^2 of surface, was a suitable environment for populations of both the predator and mosquitoes.

Observations were carried out at 05, 08, 11, 16 and 19, depending on a thorough survey of 25 webs of *T. montana* females; the webs of the same individuals were often surveyed subsequently during the same day. The first observation described relations in the early morning, next three observations those in the day-time, and the last one – those in the evening. From 3rd June to 19th July, 69 observations were carried out (25 webs in each), and from 26th July to 7th August – the period of decreasing adult population of the spider – 14 observations involved surveying of 139 webs. A total of 1,864 webs of *T. montana* were surveyed and 595 individuals of prey were collected (besides aphids and tiny *Diptera*) among which 65% were mosquitoes. During each observation, the position of spider was recorded (on web or on a plant nearby), its posture, indicating activity or inactivity, the fact of feeding in the moment of observation, and the number of prey in the webs. The mosquitoes that were found in webs were identified to species, whereas other prey was classified to larger taxonomic groups. In addition, the abundance of mosquitoes that were in flight at a given moment of observation was studied by using a bait method (10 min. capture). These data allowed to define the influence of both the changes in 24 hour activity of mosquitoes and the seasonal decrease in their abundance on the incidence of mosquitoes in the food of *T. montana*.

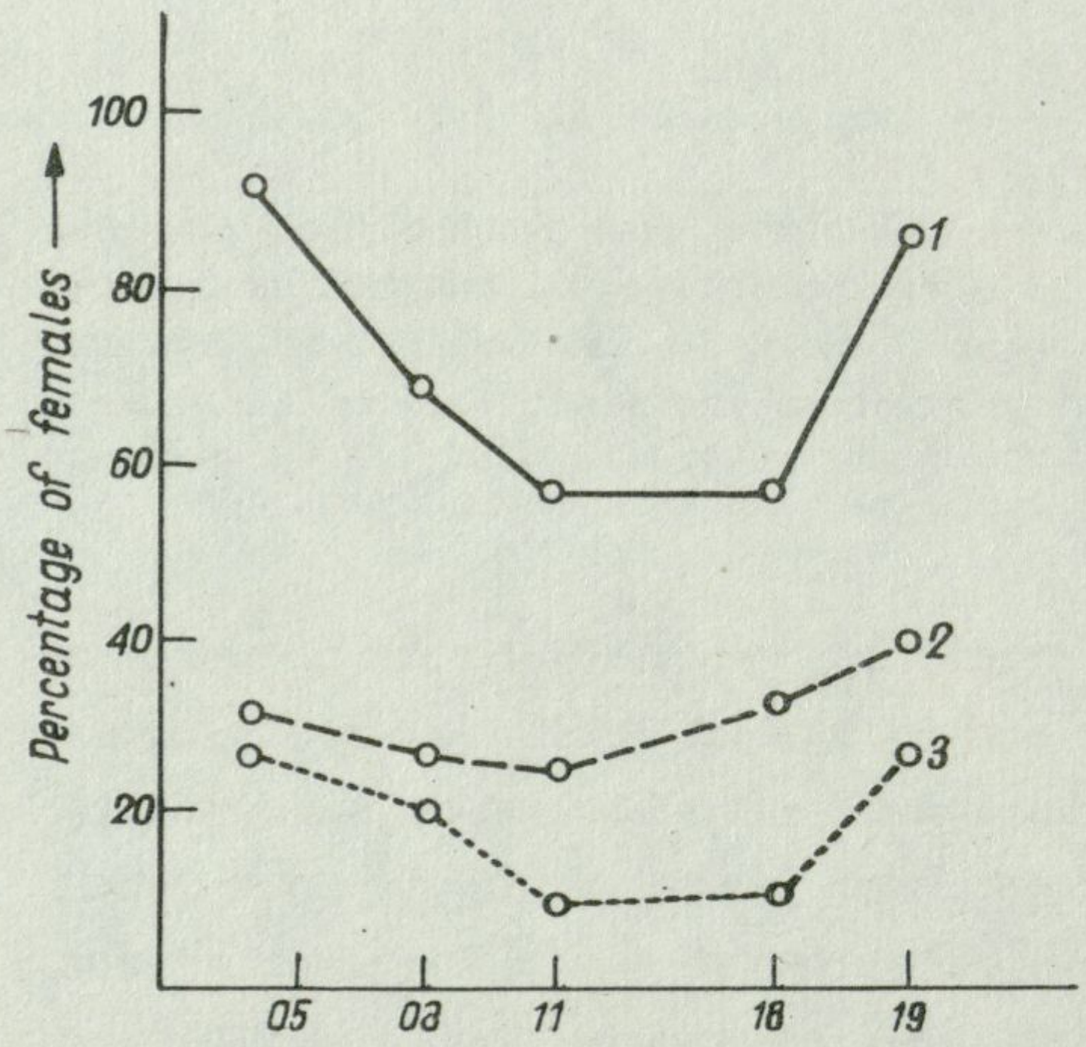

Fig. 1. Food activity of *Tetragnatha montana* and rate of catching the prey in webs, measured at different time of the day

1 – females sitting on the webs, *2* – webs with prey, *3* – females that were feeding during the observation

RESULTS

Feeding activity of spiders was examined at the above given hours. It was characterized by the ration of spiders sitting on webs (active) to those sitting inactively on plants, in the vicinity of webs, and also by the number of spiders which were actually feeding out of those found in

a sample of natural population (25 webs of *T. montana*). The highest percentage of active spiders (85–91%) was found at 05 and 19, the percentage of feeding spiders (26%) was also highest at these hours (Fig. 1). The catchability of webs, as defined by per cent of "full" webs, i.e., each web charged with at least one prey, was also highest in the early morning and in the evening.

Incidence of different items of food* in the *T. montana* webs
(data from 3rd June to 19th July)

Tab. I

Type of prey	Numbers of all prey caught	Per cent in the spider food	Number of all prey caught	Per cent in the spider food
	June, 25 observations with 25 webs in each observation		July, 31 observations with 25 webs in each observation	
Culicidae	191	74	172	62
Diptera small and average	25	10	30	11
Diptera large	9	3.5	17	6
Coleoptera			8	3
Aphididae			6**	2
Heteroptera	3	1.2	1	
Araneida (*T. montana*)			2	2
Homoptera			1	
unidentified remnants	30	11.3	40	14
Total	258	100	277	100

* Except for numerous aphids and tiny *Diptera* which in general do not form the spider food although they were caught in webs.

** Only those individuals which were eaten by *T. montana* were included.

In June, mosquitoes formed 74% of all prey captured in spider webs (excluding winged aphids which were usually not eaten by *T. montana*), in July – 62%. Other items of *T. montana* diet besides remnants whose identification was not possible and which formed about 10% of all prey, consisted mostly of different size *Diptera*, inconsiderable numbers of *Heteroptera*, small *Coleoptera*, *Homoptera*, and two males of *T. montana* (Tab. I). From 23rd June to 16th July, winged aphids were observed to be caught numerously in webs, but apart from sporadical (five) cases when they have been devoured, the spiders paid no attention to them. It seems that *T. montana* can feed on aphids but they are not its appropriate food and perhaps these are only starved individuals which venture to feed upon them. Similar was found for tiny *Diptera* as the spider food.

The occurrence of mosquitoes in the diet of *T. montana* is shown in Figure 2. In the early morning (05–06), mosquitoes formed the highest percentage (about 80%) in the diet of *T. montana*.

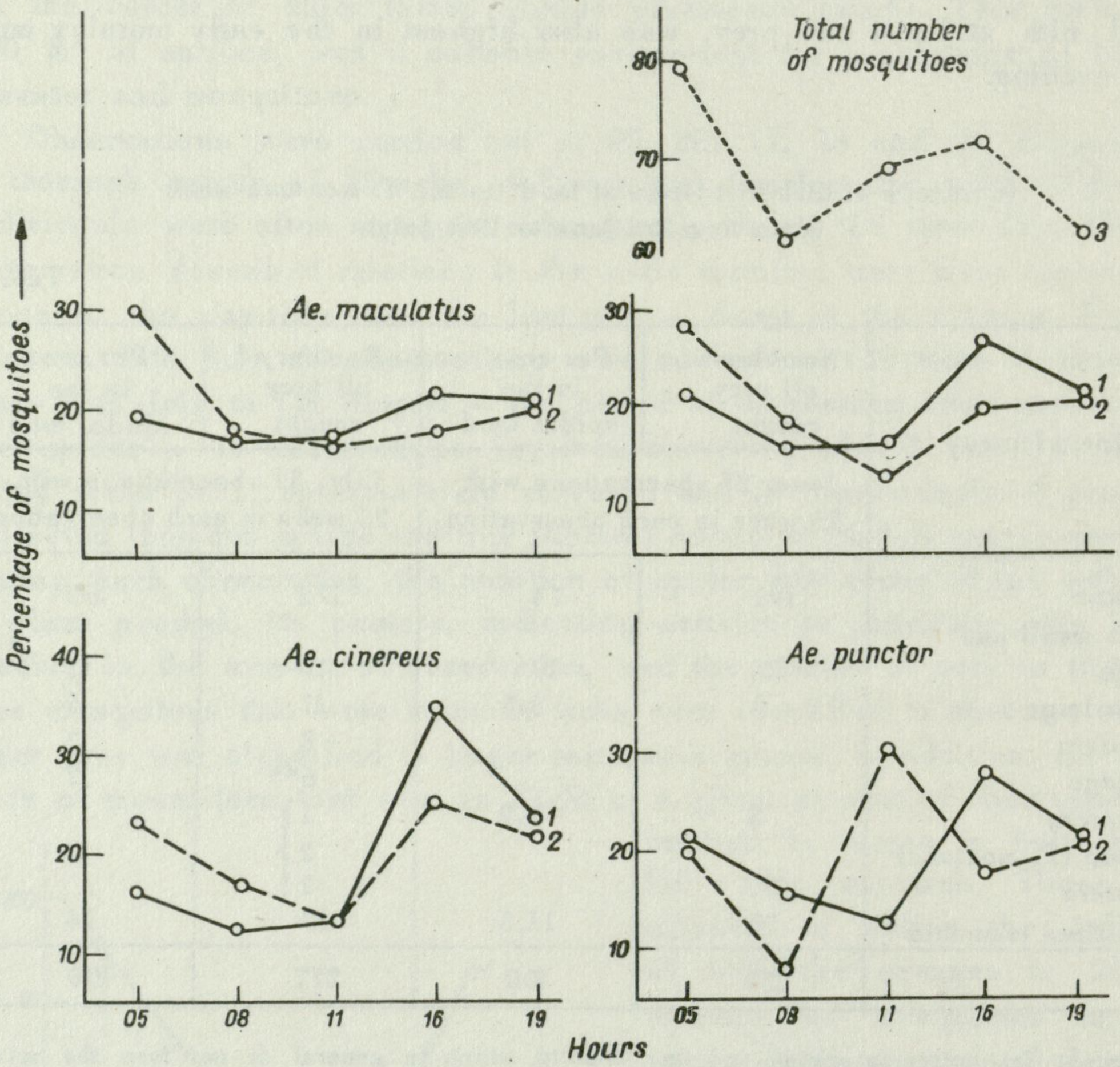

Fig. 2. Percentage of different mosquito species in environment (*1*) and in *T. montana* food (*2*) at different times of the day. Incidence of mosquitoes in the whole spider food in the webs (*3*)

The data on consumption rate of mosquitoes by females of *T. montana* involved about 20 observations which depended on pushing the insects into the webs and watching the complete process of sucking out the prey. In order to avoid distractive effect of additional prey individuals, these observations were made when natural prey infrequently got into the webs of this spider. It appeared that one individual of *T. montana* could feed on one mosquito for 2.5 hrs, but already after one hour it was impossible to identify the prey which have been shaped by then in a compact food pellet. Since the main observations were made at least at 3-hr intervals it ensured that these were new individuals of mosquitoes which were found in the webs at each next

Numbers (averages) and per cent incidence of mosquito species in the habitat and in *T. montana* food

Tab. II

Species	*Aedes maculatus* Meig.	*Aedes cinereus* Meig.	*Aedes punctor* Kirby	*Aedes communis* De Geer	*Aedes annulipes* Meig.	*Aedes excrucians* Walk.	*Aedes vexans* Meig.	*Theobaldia annulata* Schr.	*Aedes flavescens* Müller	*Mansonia richiardii* Fic.
Numbers in the habitat	45.2	17.9	9.8	4.8	2.0	1.3	0.2	0.08	0.06	
Per cent incidence in the habitat	55.6	21.6	12.0	6.3	2.5	1.6	0.24	0.10	0.05	
Numbers in spider food	3.2	0.9	0.2	0.01	0.05	0.01				0.01
Per cent incidence in spider food	73.8	19.4	4.5	0.45	1.0	0.45				0.4

observation. Large *Diptera* (e.g. *Tipula* sp.) were sometimes recorded for the same web throughout one day of observations.

From the comparison of data on abundance of particular species of mosquitoes in the field and in the food of *T. montana* (Tab. II), it was found that the main prey of this spider consisted of species which were most numerous in the habitat: *Aedes maculatus* Meig., *Aedes cinereus* Meig., and *Aedes punctor* Kirby. Less numerous species were only seldom found in webs of *T. montana*, and below some level of their abundance in the habitat they did not get at all into the webs. The proportions among 3 most numerous species found in the food of *T. montana* deviated somewhat from those among the mosquito fauna of the habitat. The incidence of dominant species on webs was higher than that in the habitat, but the percentage of the remaining two species on webs of *T. montana* were lower than those in the mosquito fauna. In the habitat, *Aedes maculatus* was about 2.5 times more numerous than *Ae. cinereus* and about 4.5 times more numerous than *Ae. punctor*; in the food of *T. montana*, *Ae. maculatus* was about 4 times more numerous than *Ae. cinereus* and about 17 times more numerous than *Ae. punctor*.

Other observations concerned the seasonal changes in numbers of mosquitoes in the habitat and their influence on the composition of *T. montana* food (Tab. III). In the season of their occurrence, three periods have been distinguished which differed in abundance of mosquitoes in the habitat. In period *I*, average numbers of mosquitoes amounted to 112 individuals per 10 min. of baiting, in period *II* – 71 individuals, and in period *III* – 27.5 individuals. It was found that during the whole season the most numerous species in the habitat formed the majority of mosquitoes which were caught in spider webs. Below a certain level of abundance of species in the habitat (about 10 individuals caught during 10 min.) they were not found in the webs of *T. montana*. Throughout the whole period of investigation, in spite of decreasing numbers of mosquitoes, the percentage of dominant species in the spider food was considerably higher than that in the mosquito fauna of the natural environment and the percentage of accessory species was considerably lower than that in the habitat (Tab. III). This very interesting observation needs, however, further, detailed studies.

Nevertheless, the observed seasonal decrease in numbers of particular species of mosquitoes caught in spider webs was not proportional to the corresponding decrease observed in the habitat. The abundance of *Ae. maculatus* in the habitat decreased by about two times during period *II*, and about 5.2 times in period *III* as compared with that in period *I*. On the other hand, its abundance in the spider food was similar for periods *I* and *II*, but in period *III* it showed 4-fold decrease. *Ae. cinereus* did not reveal any changes in its numbers both in the habitat and in the webs of *T. montana* during the first two periods, but in period *III* its numbers decreased by half in the habitat,

Per cent incidence of mosquito species in the habitat and in the *T. montana* food during three different periods of the season

Tab. III

Period	Observations	*Ae. maculatus*	*Ae. cinereus*	*Ae. punctor*	*Ae. communis*	*Ae. annulipes*	*Ae. excrucians*	*Ae. vexans*	*Ae. flavescens*	*M. richiardii*	*Th. annulata*
I 8. VI–23. VI	in the habitat	58.6	16.9	10.9	9.1	3.0	1.3				0.13
	in the food	72.8	15.7	9.8	0.8	0.8					
II 5. VII–19. VII	in the habitat	52.4	25.9	14.8	2.4	1.8	2.0	0.6	0.1		
	in the food	73.3	22.8	0.6		1.3	1.3	1.3		1.3	
III 26. VII–7. VIII	in the habitat	49.2	36.1	10.6			2.9	1.1			
	in the food	92.3	7.7								

and 10 times in the spider webs. *Ae. punctor*, similarly to *Ae. cinereus*, has maintained its level of abundance in the habitat for the first two periods, but in period *III* its numbers decreased 5 times. The decrease in its abundance in the spider webs occurred much sharper: this species was caught in webs 7 times less in period *II* than in period *I*, and in period *III* it was not observed in the webs.

From the above data it can be said that the structure of the mosquito fauna in the habitat have some reflection in the spider food, although the most abundant species is being caught by spiders more intensively than one would expect it from its abundance in the environment. The less numerous species are less intensely reduced by spiders, resulting in lower numbers caught in the webs than it could be predicted from their proportion in the mosquito fauna in the habitat.

The effect of 24 hour activity of mosquitoes on their numbers in the spider webs was also studied (Fig. 2). The course of the curves in the diagram depicting the total numbers of mosquitoes captured in the habitat and found in webs at different hours of a day points to a dependence between these two values. The increase in numbers of active mosquitoes in the habitat has brought about an increase of mosquito numbers found in the webs. This dependence was observed throughout the study period (Fig. 3). In the two most abundant species, the day-time decrease in numbers of active individuals in the undergrowth resulted in analogous decrease of their percentage in the food of *T. montana*, and the increase in their activity in the evening was reflected by increased numbers of this prey in the webs. The behaviour of *Ae. punctor* did not follow this rule. In the morning (08) and in the noon, its percentage in the webs was observed to decrease together with decreasing activity in the habitat; on the other hand, the further increase of its numbers in the webs preceded the increase in its evening activity in the habitat. It is possible that the activity of this species in the vegetation layer where the webs were spread out was increasing earlier than in the upper layers of the undergrowth, which could escape observer's attention. This supposition is reinforced by the fact that after the period of minimum daily activity this species is known to become first active in the forest undergrowth (Dąbrowska-Prot 1959a).

The seasonal occurrences of matured individuals of *T. montana* and those of mosquitoes were found to coincide. In the study area, reduction of spiders (perceptible for the observer) occured between 19th and 26th of July. On 19th July it was easy to find 25 webs of this spider there, but from 26th July on, this number of spiders has never been found at one observation. In this period, simultaneous decrease in numbers of mosquitoes was observed in the evironment examined. Thus, seasonal decrease in numbers of mosquitoes was correlated with the abrupt decrease of adult population of *T. montana* in this area.

It was found that 24-hr activities of predator and its prey revealed also time coincidence. *T. montana* became active when the mosquitoes were leaving their resting places and beginning their intense penetration of the undergrowth layer (19–20). Then the numbers of prey captured in the webs were increasing. The highest catches in webs were observed at 05–06, accompanied by the highest percentage of active spiders. This was the time when mosquitoes, compelled by less and less favourable conditions of microclimate in higher layers of the forest and in the open area, aggregated again in the undergrowth (Dąbrowska-Prot 1959a, 1959b).

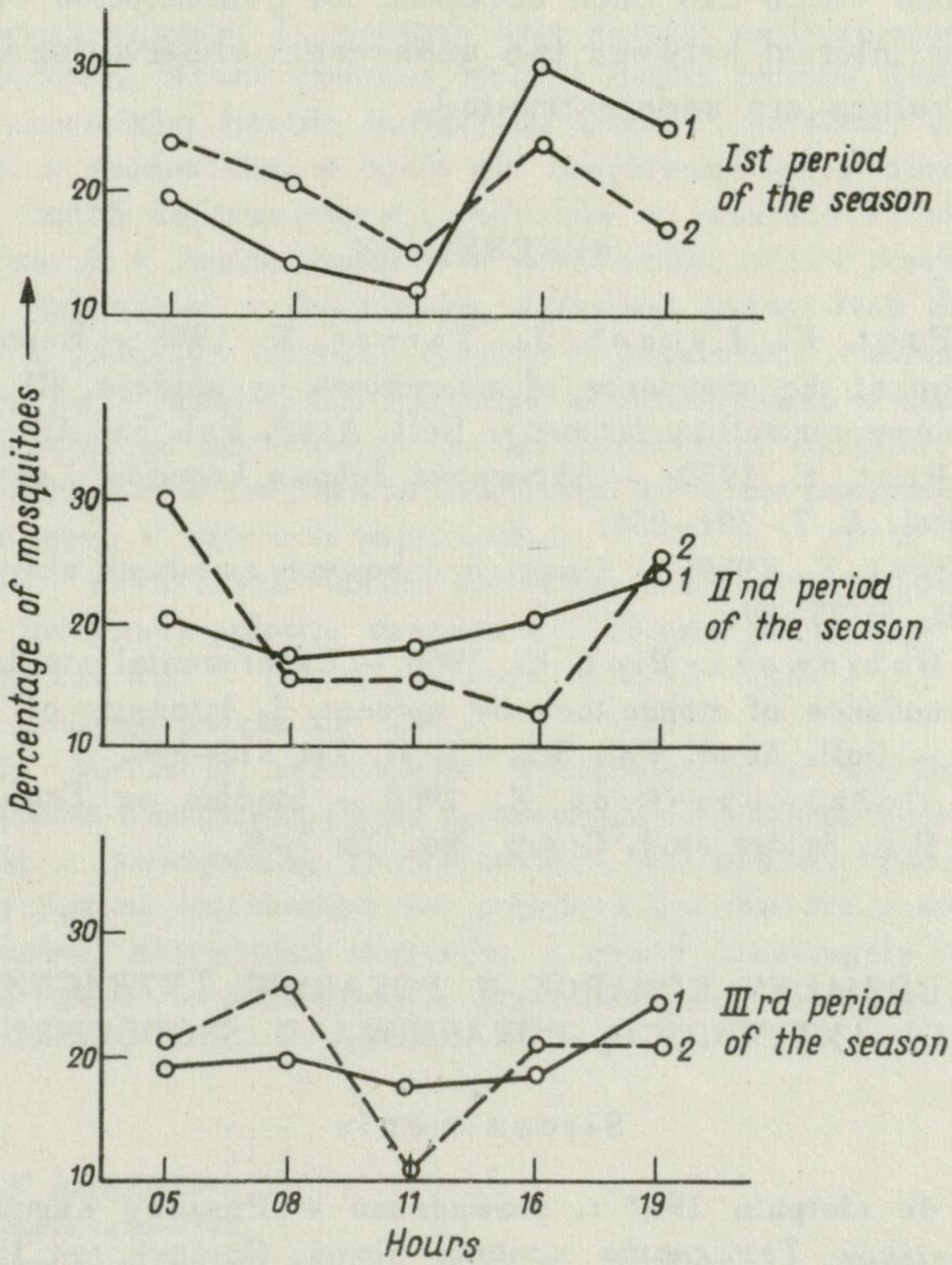

Fig. 3. Percentage of mosquito species in the habitat (*1*) and in the *T. montana* food (*2*) at different times of the day and season. Periods of the season as in Table III

From the present data, one can be tempted to calculate tentative average numbers of mosquitoes caught by spiders. Taking into account the fact that the changes in numbers of active mosquitoes in the undergrowth during the day-time are similar to those in night (Dąbrowska-Prot 1959a), and the fact that the number of mosquitoes caught in the webs depends on 24-hr activity

cycle of mosquitoes, one can calculate the average number of mosquitoes caught by one spider within 24 hrs. One can do this from the observations performed 5 times during the day by doubling the results obtained during these day-time observations. It was calculated that during the first half of June the average number of mosquitoes consumed per spider of *T. montana* during 24 hrs amounted to 3.7 individuals, in the second half of June it amounted to 1.9 individuals, in the first half of July – to 1.7, and in the second half of July – 0.6. Taking into consideration the fact that some of the food collected from the webs remained unidetified (10% of total) and that some part of it still consisted of mosquitoes, and also the fact that this was maximum time which has been accepted for consumption of one mosquito by a spider (3-hr interval between two subsequent observations), it is certain that the above values are underestimated.

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BADANIA NAD UDZIAŁEM KOMARÓW W POKARMIE *TETRAGNATHA MONTANA* SIMON ORAZ JEJ AKTYWNOŚCIĄ POKARMOWĄ W ŚRODOWISKU NATURALNYM

Streszczenie

Od czerwca do sierpnia 1967 r. prowadzono w Puszczy Kampinoskiej badania nad pokarmem pająków *Tetragnatha montana* Simon. Gatunek ten licznie występuje w olsach, które są także dogodnym środowiskiem dla komarów.

Autorom chodziło o stwierdzenie, czy komary stanowią w środowisku naturalnym ofiary tego gatunku i zbadanie ich udziału ilościowego w pokarmie pająka.

Przeglądy sieci prowadzono kilka razy w ciągu dnia: o godz. 5^{00}, 8^{00}, 11^{00}, 16^{00}, 19^{00}. Za każdym razem przeglądano 25 sieci samic *T. montana*. Pierwsza obserwacja charakteryzowała stosunki wczesnoranne, trzy następne stosunki dzienne, ostatnia – stosunki wieczorne. Ogółem przejrzano 1864 sieci *T. montana* i zebrano 595 ofiar (poza mszycami i bardzo drobnymi *Diptera*), wśród których 65% stanowiły komary.

Ponadto metodą przynętową (10-minutowy połów) badano liczebność aktywnych komarów w środowisku. Dane te pozwoliły na ustalenie wpływu zmian aktywności

dobowej komarów oraz sezonowego spadku ich liczebności w środowisku na ich udział w pokarmie *T. montana*.

W wyniku badań stwierdzono:

1. Najwięcej pająków (od 85 do 91%) siedziało na sieciach (aktywne pokarmowo) o godz. 5^{00} i 19^{00}; w tych porach dnia odżywiał się także największy procent (26%) obserwowanych pająków. Łowność sieci, określona procentem sieci „pełnych" tzn. z co najmniej jedną złowioną ofiarą, była również największa wcześnie rano i w godzinach wieczornych.

2. W zebranym z sieci pokarmie pająków komary stanowiły w czerwcu 74% a w lipcu 62% całości pokarmu.

3. Komary stanowiły największy procent (ok. 80%) ofiar pająków w godzinach wczesnorannych – 5^{00}.

4. Podstawowymi ofiarami *T. montana* były gatunki najliczniejsze w środowisku: *Aedes maculatus* Meig., *Aedes cinereus* Meig. i *Aedes punctor* Kirby. Gatunki mniej liczne tylko w niewielkiej liczbie trafiały do sieci *T. montana*, a poniżej pewnego progu liczebności w środowisku, w ogóle nie znajdowano ich w sieciach.

5. Proporcje trzech najliczniejszych gatunków w pokarmie *T. montana* odbiegały nieco od ich proporcji w faunie komarów w środowisku; udział dominanta w pokarmie był większy niż jego udział w środowisku, natomiast pozostałych dwóch najliczniejszych gatunków i gatunków akcesorycznych w pokarmie *T. montana* był mniejszy niż w faunie komarów w środowisku. Zjawisko to obserwowano w ciągu całego okresu badań mimo postępującego sezonowego spadku liczebności komarów.

6. Wzrost liczebności w środowisku aktywnych komarów powodował wzrost liczby komarów znajdowanych w sieciach pajęczych.

7. Na podstawie uzyskanych danych obliczono średnią rację pokarmową pająków. Wynosiła ona w pierwszej połowie czerwca 3,7 komara na jednego pająka na dobę, w drugiej połowie czerwca – 1,9, w pierwszej połowie lipca – 1,7 a w końcu lipca – 0,6 komara na jednego pająka na dobę.

8. Stwierdzono korelację sezonowego występowania w środowisku dojrzałych osobników *T. montana* i komarów. Okres maksymalnej liczebności komarów w środowisku pokrywał się z maksymalną liczebnością i aktywnością pokarmową populacji pająka; sezonowy spadek liczebności obu populacji był również z sobą zsynchronizowany. Cykle dobowej aktywności drapieżcy i ofiary przebiegały również podobnie. Zdaniem autorów może to świadczyć o przystosowaniu się pająka *T. montana* do tego typu ofiar.

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