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Circadian activity rhythm of blood-sucking midges (*Diptera simuliidae*) in different natural and climatic subzones of the South of Tyumen Region

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Blood-sucking midges of the family Simuliidae - small two-winged insects belonging to the suborder nematocerans (Diptera: Nematocera). Midges are one of the most important components of blood-sucking Diptera of the gnats' complex. Simuliidae are widespread in all landscape and geographical zones of the Russian Federation, and in foreign countries the ecology has been poorly studied so far, but great attention is being paid to the study of human disease vectors. The aim of the study was to study the circadian activity rhythm of blood-sucking midges (Diptera Simuliidae) in different natural and climatic subzones of the South of Tyumen Region. The censuses of blood-sucking midges was performed by standard methods. The circadian activity rhythm of blood-sucking midges (Diptera Simuliidae) depends on the species composition, attack, weather features, climatic conditions.

In all landscape and climatic zones of the region under study, blood-sucking midges have two population numbers increase. Midges are diurnal fliers, they are not active at night. According to V.P. Chernyshev's (1996) circadian activity types, midges are only active at certain time of day, remain active for a long period of time and their activity is associated with transitional conditions. That is, the circadian activity of midges is of morning-evening-type.

Registrations conducted in the open area and in the forest, showed a different pattern in their ratio. The fact of alternating population numbers increase of blood-sucking midges activity in the subzones in the evening from 18 to 23 o'clock and in the morning has been established. The midges flight begins from 5 to 9 o'clock. Midges fly and attack, under favourable conditions, around the clock, with two distinct increase in activity - in the mornings and evenings. The midges are less active during the day and at night. The decrease in activity during the day is caused by a strong wind (above 3 m/sec., with gusts of up to 8 m/sec.), high illuminance (45000 lux), rarely high temperatures. At night, the limiting factor is the low temperature (6-7 °C). In addition, the circadian activity of midges depends on the biological characteristics of species. For example, the most photophilous species in our studies was B. maculatus, and Sch. pusilla and p. Simulium midges are timed to the morning and evening time.

The species diversity in the open area and under the forest canopy is the same. During the period of maximum activity, which is in the mornings and evenings, the highest activity of midges is seen in the open area. Mass species in both stations is Byssodon maculatus.

Currently, the studies of the midges fauna is relevant. Owing to global warming, scientists are assuming that the most flexible species of blood-sucking arthropods can move to the Northern regions, which will have a direct impact on the epidemiology and epizootiology of vector-borne diseases.

Keywords: Circadian activity rhythm; blood-sucking midges; natural and climatic subzones; Tyumen Region

Introduction

The study of ecology of blood-sucking midges (Diptera Simuliidae) is of great practical significance to development of effective methods for regulating the number, populations and to protecting people and animals from them.

The circadian activity rhythm of blood-sucking midges (Diptera Simuliidae) depends on the species composition, attack, weather features, climatic conditions.

The available literature, both Russian and foreign, has no complete picture of analytical studies on the circadian activity rhythm of blood-sucking midges (Diptera Simuliidae), since the studies were carried out in the 60-80 years of the last century. According to V.P. Chernyshev's (1996) circadian activity types, midges are only active at certain time of day, remain active for a long period of time and their activity is associated with transitional conditions. That is, the circadian activity of midges is of morning-evening-type. However, when the temperature is comfortable, the increase in activity before sunset at the end of the day often continues as crepuscular. Circadian activity rhythm of midges, that can only fly, is due to change of illuminance. In addition, the increase in circadian activity in the morning or evening, crepuscular times in gravid females, as V.B. Chernyshev points out, is because they are in search of blood. It is well known that in the evening air turbulence decreases, and its humidity increases that favorably affects the olfaction. Thus, the type of circadian rhythm and confinement to an open area provide, through a combination of visual and olfactory stimuli, a faster host finding. The most important limiting factor is the wind speed of 15 m/s and the temperature of less than 200C . (Freeden & Masan, 1991; el Bashir, ELJack & Hadi, 1976, Fiodorova; 2018).

The study of the circadian activity rhythm of blood-sucking midges will help to determine the month, year and hour of the day during which the pathogen will be transmitted. Most of the foreign literature focuses on the study of human onchocerciasis vectors (Grillet et al., 2005, Oforka et al., 2019). Blood-sucking midges are found everywhere, significantly inconvenience the lives of humans and animals, and are carriers of infectious and invasive diseases (Adler, 2016; Ader et al., 2016a; Low et. al., 2016b; Tokaoka et al., 2014 a; Tokaoka et al., 2014 b; Tokaoka et al., 2014 e; Goddan et al., 2018; Koala et al., 2019).

The main determinants of high number of insects of the gnats' complex are fair weather conditions for their reproduction and existence in combination with an abundance of breeding and habitat of adults, as well as the presence of a sufficient number of homoiotherm organisms -a source of engorgement.

The successful social and economic development of the territories is closely linked to the preservation of epizootic and epidemiological welfare of the territories on a number of particularly dangerous widespread diseases. The intensity of epizootic process is affected by temperature and other climatic factors.

The change in regional fauna involving the boundaries shifting of species ranges can be explained both by anthropogenic transformation of landscapes and by the secular dynamics of regional climate. It is assumed that the range expansion is related to these two factors, united by microclimatic conditions corresponding to the environmental standard of species (Carla et al., 2016). The linkages between climate change and the range expansion of some insects to the North is real both now and in the near future and in some cases monitored. Insects can overwinter in areas where previously could not survive the cold season.

The capacity of insects to travel great distances is particularly important in spreading of vector-borne diseases. Midges are able to fly tens of kilometers.

An effective way to address issues related to the implementation of the system for ensuring epizootic and epidemiological welfare, involves annual monitoring of species composition and numbers of insects vectors of dangerous diseases.

The aim of the study was to study the circadian activity rhythm of blood-sucking midges (Diptera, Simuliidae) in different natural and climatic subzones of the South of Tyumen Region.

Materials and methods

The work was performed in the climatic subzones of the south of the Tyumen Region (Western Siberia, 1963; Tarasenkoff, 1964; Atlas of the Tyumen Region, 1971) in 2015-2018.

Observations were carried out according to the existing method. We used an entomological net with removable sacks for collecting and recording adults (Rasnitsyn & Kosovskikh, 1979). The net in the form of a cone was made of a mill gas with a mesh size of 0.2 mm. At the top of the cone, a hole with a diameter of 5 cm was left, which was reinforced with two wire rings sewn to the surface of the cone at the top at a distance of 1 cm from each other. At the base of the cone, a hole with a diameter of 30 cm was reinforced with a wire hoop equipped with a wooden handle. The depth of the bag was 60 cm, the handle was 40-50 cm long. A removable bag 6 cm in diameter, 12 cm long, made of nylon fabric, was secured between the ringlets on the top of the net with the help of a clothesline stitched at its edge. Before each bag was placed a label. After accounting, the bag was removed, tied and placed in a stain with ether vapor.

The stain is a glass jar with a capacity of 0.75 l, at the bottom of which is placed a layer of pieces of rubber, impregnated with ether, chloroform, or their mixture. Top rubber cover cardboard circle, which separates it from the camera for insects and serves to absorb excess moisture. The top of the bank is tightly closed with a screw cap, placed in a white coarse calico bag, sewn along its volume. At the time of the survey the researcher hangs it on himself. Collected insects for storage laid out on wadded mattresses or placed in 70% alcohol.

Accounting for the number of attacking midges was carried out by catching them around "themselves" with the help of an entomological net. Each count represents 10 double sweeps (“figure eight”) in ten replications. The intensity of the attack or the index of abundance (AI) recorded on the account of average and maximum indicators. Standing in one place, we held a net with a straight hand in one direction at the level of the head and chest, and in the other direction - at the level of the knees. Each repetition was performed at a new place, when moving along a certain route (transect) approximately at equal distances (10-15 m). This method of accounting for the transect is used in plant protection to account for pests on a specific area (Lyubishchev, 1958).

Daily activity was studied in two stations on the open site and in the forest. During the summer season of 2015, censuses were conducted on June 27-28 and July 27-28, in 2016 - June 23-24 and July 27-28, in 2017 - June 30 - July 1 and July 15-16, in 2018 - June 30 - July 1. The interval between the accounts was two hours. Each account consisted of 5 replicates.

During all the surveys, meteorological data were recorded: temperature and relative air humidity, light intensity, wind speed, and various weather events were recorded (rain, dew, cloudiness, etc.).

For the qualitative and quantitative assessment of the population of bloodsucking midges, an abundance index (AI) and a domination index (ID) were used (Beklemishev, 1961, 1970). When determining the degree of abundance, the A.I. scale was used. Bakanova (1987), according to which mass species or dominants (ID 50-100%), numerous subdominants (ID 15-49.9%), small (ID 5-14.9%) and rare (ID up to 5%).

Results

The circadian activity rhythm of midges in all natural and climatic subzones (zones) of the south of region was studied in two stations: in the forest and in the open area.

The circadian activity in the subzone of southern taiga was studied in 2015. During the summer season, we conducted two registrations of the circadian activity rhythm: 27-28th of June and 27-28th of July (Table 1).

Table 1. A daily rhythm of activity of blood-sicking midges in a subband of the southern taiga in 2015.

Time of day, hours	Air temperature, °C	Relative air humidity, %	Illumination, lx.	The number of midges in the account					
				On the open place				In the forest on the person	
				On the person		On the calf in the herd			
				Average	Maximum	Average	Maximum	Average	Maximum
June 27-28									
7	16	86	8600	208.8	256	18.4	35	190	255
9	19.6	78	53000	85	121	7.2	13	160.6	197
11	21.8	72	51000	29.6	46	2	3	68.4	91
13	22.2	68	38000	55	90	5.2	7	76	107
15	23.6	33	53000	6.4	10	4.6	9	0	0
17	23.7	48	46000	18.8	37	1.2	5	57.2	60
19	23.2	47	8500	39	76	2.8	5	61	71
21	21	70	940	170.2	190	26	37	146.6	174
23	15.6	94	20	234.4	296	42.2	65	54.2	145
1	14.4	88	0	1.8	5	1	3	0	0
3	13	98	0	0	0	0.6	1	2.4	12
5	12.6	95	70	181.2	231	22.8	42	140.2	199
Total:				1030.2	1358	134	225	956.6	1311
July 27-28									
7	16.8	97	37000	1.6	5	0.6	2	9.4	18
9	22.4	74	53000	3.2	8	1	3	5.6	8
11	23.6	81	61000	2.4	4	0.2	1	8.2	12
13	26.1	40	53000	1	2	0	0	3.8	6
15	30	48	47000	1.2	3	0	0	4.4	10
17	24.4	69	8900	4.6	11	0	0	15.6	33
19	25	72	700	1.8	2	0	0	3.4	7
21	22.2	90	30	6.8	10	1.4	3	11.2	15
23	18	100, fog	0	0.8	2	1.4	4	0.4	1
1	16	100, fog	0	0	0	0	0	0	0
3	13.6	96, fog	410	0	0	0.2	1	0	0
5	13.8	97, fog		0	0	0	0	1.4	3
Total:				23.4	47	4.8	14	63.4	113

In both selected stations (open area and forest), midges flight begins at dawn and ends at nightfall, with two peaks of activity. During the first registration in June, the number of midges was high: in the open area, an average of 1030 individuals were caught per registration, and in the forest - 957 individuals. The greatest number of midges attacking in the open space was seen in the evening at 21 and 23 o'clock and in the morning at 5 and 7 o'clock, having amounted to 181-209 and 170 -234 individuals per registration respectively, that is, both peaks were almost equal in number. At night at 1-3 o'clock, there were

no midges or some separate individuals were encountered. During the day, the number of midges has remained relatively low, ranging from 6.4 to 85 individuals per registration.

Under the forest canopy, midges attack activity peaked a little earlier - at 21 o'clock (146.6 individuals per registration), and in the morning, lengthened from 5 to 9 o'clock (from 140.2 to 190 individuals per registration). At night, they were seldom encountered. During the day, the number of midges in the forest was higher than in the open area. However, during the period of highest circadian activity, the number of midges was higher in the open area. In general, the number of midges caught in the forest and in the open area during the day was almost the same.

The maximum number in the open space on a calf in the herd was also noted at 21-23 and 5-7 o'clock, when 18.4-22.8 and 26-42 individuals were caught per registration, respectively. During this daily registration, the weather conditions have been following: air temperature from 12.6° to 23.7°C, illuminance from 20 to 53000 lux and relative humidity from 33 to 98%. The minimum number of midges during the day was seen at a temperature of 23.6°C, relative humidity of 33% and illuminance of 53000 lux. In the morning at a temperature of 12.6-16°C, relative humidity of 86-95% and illuminance of 70-8600 lux, there was a peak activity.

The second daily registration at the end of July was conducted with a low number of midges. In total, 23.4 individuals were caught in this registration in the open area, and in the forest - 63.4 individuals. In the forest, the number during the day was higher than in the open area, and amounted to 0.4-11.2 individuals against 0.8-6.8 individuals per registration. The increase in number was seen at 17 and 23 o'clock. On calves, single individuals attack was noted in the open area, with a maximum of 1.4 individuals per registration. In this registration, Simuliidae flight was recorded at air temperature of 13.6° to 30°C, at illuminance of 30-61000 lux and the relative humidity of 49-100 %. In the morning, midges flight in this registration was hindered by fog, and in the afternoon, by a very high temperature in the open area, whence midges migrated to the forest, where the air temperature is lower.

According to the two daily registrations, the number of midges on calves in the herd in the open area was low and was lower than in a single person by 5-8 times. This may be because midges prefer to attack sites like dewlap and abdomen (Demyanchenko, 1957a; Rubtsov, 1962; Veselkin, 2006), which makes it difficult to collect them when conducting registration in the herd when the animal is not isolated. Comparative censuses with nets, performed by K.N. Beltyukova and G.A. Arkhipova (1967) in Perm Region showed that during the same time a single animal is attacked 4.6 times more than a person. Thus, in the southern taiga during periods of high number of midges in the circadian rhythm there are two increases in the attacking activity-in the evening at 21-23 o'clock and in the morning at 5-7 o'clock. They almost do not attack at night. During the day, the number of midges is low and is subject to significant fluctuations, which can be a result of abiotic factors (wind, precipitation) impact, as well as the behavior of these insects. According to S.P. Rasnitsyn and A.N. Bikunov (1979), the unevenness of midges catching with a net indicates that they attack their prey unevenly (by group). This phenomenon is also seen in horseflies (Rasnitsyn, 1963).

The circadian activity rhythm of midges in the subzone of small-leaved aspen and birch forests was studied in 2017-2018. During the summer season of 2017, two registrations of the circadian activity rhythm were conducted: June 30 - July 1 and July 15-16. Data are presented in Table 2.

Table 2. A daily rhythm of activity of blood-sicking midges in a subband of the small-leaved aspen and birch woods in 2017.

Time of day, hours	Air temperature, °C	Relative air humidity, %	Speed of wind, m/s	Illumination lx.	Number of midges for 10 waves				3-minute accounts	
					On the open place		In the forest		On the open place	In the forest
					Average	Maximum	Average	Maximum		
30 June -1 July										
7	17	74	quietly	7000	124.4	140	16.4	39	650	102
9	20	72	0.5	47000	34.2	53	9.4	18	101	27
11	23.2	59	1.5	53000	10.6	16	21	26	117	69
13	25.2	56	1.4	56000	10	15	5.6	12	50	32
15	26	35	2.5	62000	7.8	12	15.6	20	116	77
17	27	33	0.9	57000	8.6	10	15	18	58	193
19	26.4	39	0.3	41000	14.8	28	15.2	26	150	158
21	24	55	quietly	5600	104.8	200	10.2	15	90	89
23	18	81	quietly	20	40.8	77	3.8	6	320	26
1	14	95. fog	quietly	0	0	1	0.2	1	1	2
3	13.2	100. fog	quietly	0	0.2	1	0.8	2	1	0
5	13.1	99. fog	quietly	90	22.6	37	0	0	260	4
Total:					379	590	113.	183	1914	779

							2			
7	19.1	91	quietly	7900	8.2	14	1	4	56	6
9	23.4	53	quietly	47000	10.2	15	0.2	1	132	1
11	26	51	0.66	54000	6.4	11	0.4	2	104	5
13	28	37	1.2	56000	4.2	7	1.8	3	157	6
15	28.8	40	1.83	56000	5.8	9	2.8	5	144	10
17	28.8	40	1.71	56000	6.8	18	3	8	180	13
19	28.4	47	0.25	46000	5.6	14	1.2	3	110	5
21	26	54	quietly	5800	4.6	7	1	2	84	2
23	19.4	79	quietly	5	1.4	4	0.4	2	21	0
1	18	85	quietly	0	0	0	0.2	1	0	0
3	16.8	95	quietly	0	0	0	0	0	0	0
5	15.2	92	quietly	78	1.6	4	0	0	11	0
Total:					54.8	98	12	31	999	48

As this table shows, during the first registration, a total of 379 midges were caught in the open area and 113 in the forest. Bloodsuckers begin to attack in the open area at 5 o'clock in the morning and end in the evening at 23 o'clock. Midges are rare at night. The peak attacking activity in the open area was noted at 21 and 7 o'clock when 104.8 and 124.2 individuals were caught per registration respectively. During daylight, the number was decreasing significantly, reaching its minimum at 15-17 o'clock at maximum illuminance (57-62 thous. lux), maximum air temperature (26-27 °C) and minimum relative humidity (33-35%). In the forest, the midges began to attack at 7 o'clock. During the day, it was subject to significant fluctuations, varying from 9 to 21 individuals per registration, so the periods of their maximum activity could not be determined. However, a trend towards increase of the number in the forest as it decreases in the open area can be observed. In general, in the forest, the number was 3 times lower.

During this daily registration, the air temperature was from 13.1 to 27 °C, illuminance from 20 to 62000 lux and relative humidity from 33 to 100%. It should be noted that the high (up to 100%) relative humidity and fog in the morning postponed warming and beginning of flight activity. The second registration was conducted with a lower number: 54.8 individuals were caught in the open area, and 12 individuals in the forest. Relatively equal activity of midges in the open area and under the forest canopy was seen throughout the day, having amounted to 4.2 - 10.2 and 0.2-2.8 individuals per registration respectively. Flight activity was seen from 5-7 to 23 o'clock with almost no activity at night. In this registration, the midges attacked at air temperature of 15.2 to 28.8 °C, illuminance from 5 to 56,000 lux and relative humidity from 37 to 95%.

During the daily registration of Simuliidae in this subzone, we recorded an attack of 5 species (Table 3). Throughout the day, one species of Byssodon maculatus dominated. Schoenbaueria pusilla also flew all day, but its number was increasing in the morning and evening. Midges of the genus Simulium are timed to the morning and evening hours. At this time, the greatest diversity of their species composition was noted.

Table 3. Confinedness of different types of midges by the time of day in a subband of the small-leaved aspen and birch woods in 2017 (on accounts by two methods).

	Quantity of the caught individuals in											
Look	7 h	9 h	11 h	13 h	15 h	17 h	19 h	21 h	23 h	1 h	3 h	5 h
Byssodon maculatus Meigen	689	444	410	344	440	445	600	549	222	6	-	150
Schoenbaueria pusilla Fries	344	44	16	5	41	166	7	195	205	-	6	96
Odagmia ornate Meigen	27	-	-	-	-	-	-	-	-	-	-	-
Simulium longipalpae Beltucova	-	-	-	-	13	-	-	-	35	-	-	-
Sim.sp.	291	28	7	-	13	-	-	124	51	-	-	-
In total individuals	1351	516	433	349	507	611	607	868	513	6	6	246
Kinds	3	2	2	2	3	2	2	2	3	1	1	2

During the summer season of 2018, one registration of the circadian activity rhythm was conducted - June 30-July 1 with a high number of midges. On average, 1000 individuals were caught in the open area, and 62 individuals in the forest per registration. Table 4 shows that the number of midges in the open area throughout the day from 9 to 21 o'clock was at a high level, varying from 53 to 230 individuals per registration. At night, midges were absent or rare. In addition, at night, individuals

of only a mass species of Byssodon maculatus were encountered. The decline in activity at 13 o'clock was due to thunderstorms coming and a wind got up to 2.5 m/s. The greatest number of midges in both stations was at 9-11 and 17-19 o'clock, with a maximum of 168.4 and 230.2 individuals per registration in the open area, respectively. It should be noted that this registration of circadian activity was conducted in cooler weather than all previous ones. During the day, the temperature went only up to 22 °C. The midges were encountered at a temperature of 13.2 °C. The maximum activity was observed at 19.8-22 °C, that is, this temperature level did not have a negative impact on the midges activity. In this registration, the maximum circadian activity shifted from morning to later hours, and from afternoon to earlier hours, due to the negative impact of low air temperature at 7 (14.8 °C) and 23 (16 °C) o'clock. During daytime, the number of individuals decreased to 53 due to the cloud, temperature decrease and increase of wind up to 2.5 m/s. After a light rain, the number of midges increased to 94.2 individuals.

The study of circadian rhythm of midges this season recorded an attack of 7 species (table 5). The peak of species diversity was recorded at 9 and 19 o'clock, at this time, 4 species of midges attacked. Throughout the day, midges of the two most numerous species - Byssodon maculatus, Schoenbaueria pusilla - were active. At the same time, Sch. pusilla was the most numerous at 19-21 o'clock at a temperature of 20-22 °C. Rare species were encountered only in the morning and evening.

In the 2016 season, we conducted two registrations of the circadian activity rhythm in the forest-steppe zone: 23-24th of June and 27-28th of July (table 6). And during the first registration, the number of midges was relatively low, and during the second one - extremely low. In total, 68.6 individuals were collected in the open area during registrations, and 71 individuals and 3.8 and 5.6 individuals were collected in the forest respectively. The midges attacked only in daylight between 5-23 o'clock. During the day, there were fluctuations in the number, that peaked when illuminance was reduced. For example, on June 23, the drop in illuminance from 57000 lux at 11 o'clock to 5800 lux at 15 o'clock with overcast conditions after a little rain caused an increase in the number of midges in the forest from 3.6 to 22.8 individuals and from 0.4 to 21.0 individuals in the open area per registration. Moreover, there was an increase in midges activity in the evening at 21 o'clock at illuminance of 650 lux and air temperature of 18.2 °C, and in the morning at 5 o'clock at illuminance of 49 lux and temperature of 14 °C. In doing so, the morning increase was much lower than the evening one, which can be explained by the low temperature at high relative humidity.

It should also be noted that during the number increase in the evening and in the morning, there were more midges in the open area than in the forest. However, during daylight, the number of midges in the forest and in the open area was almost the same, and amounted to 7.89 ± 2.56 and 6.29 ± 2.58 individuals per registration, respectively (difference is unreliable).

During the registrations in July, the number of midges was very low, but even with these registrations, the illuminance reduction to 4000 lux at 17 o'clock and to 4200 lux at 21 o'clock was accompanied by some increase in the number.

Thus, in the forest-steppe zone, there were midges attack during daylight hours. Their activity increases in the evening at 21 o'clock and in the morning at 5 o'clock, and the evening maximum number is slightly higher than the morning one, due to weather conditions. The midges flight was at air temperature of 11.6 to 22 °C, relative humidity of 56 to 94% and illuminance of 25 to 57 thousand lux.

During the daily registrations, 4 species of midges were registered in the forest steppe (table 7). The species diversity peaked at 7 o'clock, at 15 and 17 o'clock. Two of the most numerous species flew during the daylight hours. The peak number of B. maculatus was seen at 13 o'clock before the rain and at 21 o'clock, and Sch. pusilla-at 15 o'clock after the rain. Boopthora erythrocephala flight during the day was uneven with activity peak at 15 o'clock after the rain.

Daily registrations allowed to analyze the confinement of different species of midges to stations in the open area and in the forest. For example, in the subzone of small-leaved aspen and birch forests, the species diversity of midges caught in the daily registrations was almost the same both in the open area and under the forest canopy, but the ratio of species differed slightly (table 8). 6 species attacked in the open area and 5 species in the forest, except for a rare species.

In the forest-steppe zone, species composition of attacking midges in the open area and in the forest was the same, and the ratio of species by the dominance index was very similar (table 9).

The results obtained show that the attacking activity of blood-sucking midges is observed both in the open area and in the forest. Species diversity in both stations is the same. During the period of maximum activity, which is in the mornings and evenings, the highest number is seen in the open area. During the day, with the suppressive effect of high temperature and illuminance, as well as low relative humidity, the number of attacking midges increases in the forest.

Thus, the study of circadian activity rhythm of blood-sucking midges showed its dependence on weather conditions: temperature, illuminance, relative humidity and wind speed. Their activity period is limited to daylight hours, that is, they are diurnal insects. They fly from 5 to 23 o'clock. There are two number increases in their circadian activity: in the morning from 5 to 7-9 o'clock and in the evening from 19 to 23 o'clock, during daylight hours, the number of midges decreases. The circadian activity is, by its nature, of morning-evening-type (Chernyshev, 1996).

During the daily registrations, midges activity was observed at temperatures from 11.6 to 30 °C, relative humidity from 33 to 100%, illuminance from 20 up to 62000 lux and a wind speed of up to 2.5 m/s. All these factors have a different effect on the midges activity, but it can be difficult to identify the determining one, since they act together. As V.B. Chernyshev (1996) notes, according to the environmental law of the minimum, the impact of the factor affects the more, the further its value from the optimum and, if the registrations were during the time when the factor was at the optimal level, its impact will not be obvious and it might be classified as insignificant.

In the period of high numbers during the season, when the air temperature is favorable for the midges flight, a factor limiting circadian activity is low illuminance (less than 20 lux), that is, the nightfall. When the temperature drops at night and air gets warm in the morning, the main determining factor is the temperature. Moreover, the combination of high temperatures (above 25 °C) during daylight hours, high illuminance (of more than 50 thousand lux) and low relative humidity (33-35%) have

a negative impact on the midges activity. According to the registration of 2018, the optimum temperature for the midges flight is 18-22 °C, at which there was a high level of activity throughout the day. The increase in cloudiness during the day and the drop in illuminance to 6-8 thousand lux at a favorable temperature contribute to an increase in flight activity. Wind speed of 2.5 m/s suppresses midges activity.

In addition, the circadian activity of midges depends on the biological characteristics of species. For example, the most photophilous species in our studies was B. maculatus, and Sch. pusilla and p. Simulium midges are timed to the morning and evening time.

Table 4. The daily rhythm of activity of bloodsucking midges in the subzone of small-leaved aspen - birch forests in 2018 (30. VI - 1. VII).

Time of day, hours	Air temperature, °C	Relative air humidity, %	Wind speed, м/с	Illumination lx.	The number of midges in account			
					On the open place		In the forest	
					Average	Maximum	Average	Maximum
7	14.8	95	quietly	6000	53.4	80	6.6	9
9	19.8	66	quietly	8500	168.4	216	10.6	18
11	21	56	quietly	42000	134.6	216	16	27
13	18.6	66	2.5	6500	53	106	5.2	8
15	19.6	70	quietly	47000	94.2	122	5.2	8/
17	22	54	1.23	53000	230.2	380	4.8	8
19	22	53	quietly	35000	144.6	380	11	20
21	20.4	66	quietly	4800	94.8	127	1.6	3
23	16	92	quietly	18	19.2	30	0.2	1
1	14	96	quietly	0	0.4	1	0.4	2
3	13.8	99	quietly	0	0.4	2	0	0
5	13.2	92	quietly	63	7.4	34	0.6	3
Total:					1000.6	1694	62.2	99

Table 5. Confinedness of different types of midges by the time of day in a subband of the small-leaved aspen and birch woods in 2018 (on accounts by two methods).

Look	Quantity of the caught individuals in											
	7 h	9 h	11 h	13 h	15 h	17 h	19 h	21 h	23 h	1 h	3 h	5 h
Byssodon maculatus	253	850	743	260	478	1173	632	344	97	4	2	40
Schoenbaueria pusilla	45	30	10	31	19	2	132	138	-	-	-	-
Simulium reptans	-	-	-	-	-	-	2	-	-	-	-	-
Boophthora erytrocephala	2	-	-	-	-	-	-	-	-	-	-	-
Argentisimulium noelleri	-	12	-	-	-	-	-	-	-	-	-	-
In total individuals	300	892	753	291	197	1175	766	482	97	4	2	40
Kinds	3	3	2	2	2	2	3	2	1	1	1	1

Table 6. A daily rhythm of activity of blood-sicking midges in a forest-steppe zone in 2016.

Time of day, hours	Air temperature , °C	Relative air humidity, %	Wind speed, м/с	Illumination lx.	Number of midges in account				3-minute accounts	
					On the open place		In the forest		On the open place	In the forest
					Average	Maximum	Average	Maximum		
June 23-24										
7	11.6	94	quietly	9500	2.2	6	3	6	13	9
9	17.8	72	quietly	50000	5.4	10	5.6	14	28	7
11	21.2	58	quietly	57000	0.4	1	3.6	4	7	5
13	22	56	quietly	6200	7	13	6.6	17	77	16
15	18.6	72	quietly*)	5800	21	33	22.8	44	146	46

17	19.4	68	quietly	7500	4.6	7	7.2	10	21	35
19	18.8	56	quietly	4500	3.4	6	6.2	16	46	9
21	18.2	66	quietly	650	14.6	25	8	17	133	12
23	16.2	79	quietly	25	2.6	4	1	3	9	0
1	15	85	quietly	0	0	0	0	0	0	0
3	13.8	88	quietly	0	0	0	1.2	6	0	0
5	14	90	quietly	49	7.4	13	5.8	10	53	17
Total:					68.6	118	71	147	533	156
July 27-28										
7	15.2	82	5	5000	0	0	0.2	1	0	0
9	17	81	3.5	25000	0.6	3	0.2	1	0	4
11	17.8	84	2.3	8000	0	0	0.4	1	3	1
13	15.8	68	4	55000	0.4	2	0.6	3	2	0
15	17.2	68	4.1	9500	0	0	0.2	1	0	11
17	19	69	4.3	4000	0.4	2	2.2	4	24	3
19	19.8	72	3.6	48000	0.4	1	0.6	1	4	3
21	17.8	68	quietly	4200	1.4	3	0.4	1	19	3
23	15	68	quietly	2	0.2	1	0	0	1	0
1	16	73	quietly	0	0.2	1	0.4	1	0	3
3	16	64	quietly	0	0	0	0	0	0	0
5	14.2	82	quietly	20	0.2	1	0.4	1	0	0
Total:					3.8	14	5.6	15	53	28

Note: *) Cloud, after a rain

Table 7. Confinedness of different types of midges by the time of day in a forest-steppe zone in 2016 (on accounts by two methods).

Look	**Quantity of the caught individuals in**											
	7 h	9 h	11 h	13 h	15 h	17 h	19 h	21 h	23 h	1 h	3 h	5 h
Byssodon maculatus	15	78	35	166	58	82	95	255	29	6	2	132
Boophthora erythrocephala	10	-	1	-	126	34	-	-	-	-	2	-
Schoenbaueria pusilla	12	20	2	-	235	36	20	34	-	-	2	7
Odagmia ornata	12	-	-	2	4	3	-	-	-	-	-	-
In total individuals	49	94	38	168	423	155	115	289	29	6	6	139
Kinds	4	2	3	2	4	4	2	2	1	1	3	2

Table 8. Confinedness of different types of midges to various biotopes in a subband of the small-leaved aspen and birch woods (on daily accounts).

Look	**It is brought together all individuals**	**From them**			
		On the open place		**Under a canopy of the wood**	
		Quantity	**ID%**	**Quantity**	**ID %**
Byssodon maculatus	8890	7515	82.1	1375	80.2
Schoenbaueria pusilla	1826	1510	16.4	316	18.4
Sim. longipalpe	139	118	1128	21	1.22
Argentisimulium noelleri	11	9	0.09	2	0.11
Total:	10886	9152	100	1714	100

Table 9. Confinedness of different types of midges to various biotopes in conditions to a forest-steppe zone (on daily accounts).

Look	**It is brought together all individuals**	**From them**			
		On the open place		**Under a canopy of the wood**	
		Quantity	**ID%**	**Quantity**	**ID%**
Byssodon maculatus	957	610	58.29	356	62.79
Schoenbaueria pusilla	442	310	30.07	1323	23.28

Boophthora erythrocephala	174	102	9.89	72	12.7
Odagmia ornata	25	18	1.75	7	1.23
Total:	1598	1031	100	567	100

The environmental conditions of the South of Tyumen Region favor the mass production of blood-sucking Diptera of the gnats' complex, where they are widespread and cause significant damage to agriculture.

The daily registrations found that the period of circadian activity of midges is limited to daylight hours from 5 to 23 o'clock. In the circadian rhythm there were two increases in the number, timed to the morning (at 5-7 or 7-9 o'clock) and evening (at 21-23 or 19-21 o'clock). During the day, the number of midges was significantly reduced, which was caused by high temperature (25-30 °C), high illuminance (of more than 50 thousand lux) and low relative humidity (33-35%). Precipitation and wind speed of 2.5 m/s and more limit the activity of midges.

Registrations conducted in the open area and in the forest, showed a different pattern in their ratio. For example, during the morning and evening peak of activity, the number of midges in the open area was higher than in the forest, and in the daytime, in most cases, on the contrary. For example, in 2015, during the day in the forest, midges were caught 2.6 times more than in the open area at an air temperature reaching 30 °C, which indicates the suppressive effect of high temperature and therefore the midges preferred the forest. In 2018, the number of midges in the open area was 16 times higher than in the forest likely due to the favorable air temperature, which varied from 18.6 to 22 °C. In the morning, the midges activity in the forest began at a later time.

The results of the abiotic factors impact on the midges activity, obtained in the present study, agree with the data of other studiers (Demyanchenko, 1957; Patrusheva, 1963; Patrusheva, 1963a; Dariychuk, 1967; Boldarueva, 1979, 1980; Maltsev, 2001; Vasilevich, etc., 2004; Isakaev, 2007). The temperature and illuminance, as well as relative humidity and wind speed have the greatest effect on midges activity.

The most optimum conditions for the midges attack, as L.V. Boldarueva (1980) notes, are promoted by illuminance from 1000 to 45000 lux and air temperature 13-22 °C, in doing so, the temperature above 25 °C is the thermal suppression zone. At optimum values of these indicators, the effect of relative humidity was not noted, and when they were not within the normal range, the humidity content of 37-60 and 100% caused a decrease in the midges activity. According to K.N. Beltyukova (1953) and A.N. Berzina (1953), high intensity of daylight illumination limits the midges activity, and when it is dropped to 4-6 thousand lux, it significantly increases. The relation of midges to temperature and illuminance depends on the biological characteristics of species. For example, V.D. Patrusheva (1963, 1967) points out that B. maculatus attacks mainly during the day and the illuminance of 100 thousand lux does not suppress it and only the temperature above 28 °C slightly reduces its activity. For Sch. pusilla midges optimum temperature is 7-28 °C, illuminance of 1000-30000 lux, and for S. longipalpe 7-16 °C and 100-500 lux respectively, and therefore they are most active in the morning and evening.

According to many studiers, the wind speed has a great effect on the number of attacking midges. Wind speed of 1-1.5 m/s does not prevent midges from flying, 2 m/s-reduces the number, and above 2 m/s - prevents them from flying or completely stops them (Demyanchenko, 1957; Andreev, 1966; Boldarueva, 1980; Vasilevich, etc., 2004, etc., Bashir et al., 1976, Wolfe et al., 1960, Jonathan R. Davis et al., 1994, Ishii et al., 2008, Vilma Jonusaite et al., 2002). However, our studies have shown that at wind speeds up to 4 m/s, single individuals were caught in separate registrations.

In determining the type of circadian activity, we assumed that V.B. Chernyshev (1996) distinguishes 12 types of insect activity distribution during the day. Our study conducted the registration of circadian activity rhythm of gravid females at the first stage of the gonotrophic cycle (seeking a host and attack). Midges are diurnal fliers, they are not active at night. According to V.P. Chernyshev's (1996) circadian activity types, midges are only active at certain time of day, remain active for a long period of time and their activity is associated with transitional conditions. That is, the circadian activity of midges is of morning-evening-type. However, when the temperature is comfortable, the increase in activity before sunset at the end of the day often continues as crepuscular. Circadian activity rhythm of midges, that can only fly, is due to change of illuminance. In addition, the increase in circadian activity in the morning or evening, crepuscular times in gravid females, as V.B. Chernyshev points out, is because they are in search of blood. It is well known that in the evening air turbulence decreases, and its humidity increases that favorably affects the olfaction. Thus, the type of circadian rhythm and confinement to an open area provide, through a combination of visual and olfactory stimuli, a faster host finding.

Conclusions

The circadian activity of midges is of morning-evening-type. It is limited to daylight hours, is long-lasting with two number increase under transitional conditions, that is, in the morning from 5 to 7-9 o'clock and in the evening from 19 to 23 o'clock. At a temperature favorable for the flight, the factor limiting circadian activity is low illuminance, and at cold nightfall-air temperature. Midges fly at a temperature of 11.6 to 30 °C, and the optimum temperature is 18-22°C. The attack activity of blood-sucking midges is seen both in the open area and in the forest. Species diversity in both stations is the same. During the period of maximum activity, which is in the mornings and evenings, the highest number is seen in the open area. During the day, with the suppressive effect of high temperature and illuminance, as well as low relative humidity, the number of attacking midges increases in the forest.

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