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ORIGINAL ARTICLE

The effect of the abiotic factors on the vital functions of caribou warble flies (*Oedemagena tarandi* L.) in conditions of subarctic tundra

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The existence of the caribou warble flies population during the different phases of their living is determined by the ecological factors. At one phase the controlling factor is the temperature, at other phases it is humidity, insolation, wind power etc. All of these factors influence on the population of this particular type of insects through the related interaction.

Due to this, the studying of combinations of ecological factors totally and systematically influencing on the condition and growth of *O. tarandi* species is the issue of major importance that gives the opportunity to make a long-term forecast of changes in the population of caribou warble flies.

The set of all physical conditions influencing on the researched insects can be related to abiotic factors. We are examining the main of them such as temperature, illumination, wind, soil factors, humidity and rainfall.

Moreover, the climate itself and ever-changing weather conditions have significant influence on the insects.

Keywords: Abiotic factors; caribou warble flies; Yamal; subarctic tundra; reindeers

Introduction

The caribou warble flies parasitize during their larva state on domestic and wild reindeer causing the edemagenesis (Solomakha, 1990).

The starting point in providing any measures against caribou warble flies is the observation on the basis of which the forecast and signaling of the time of appearing caribou warble flies in nature are made. The interactions of ecological factors are complicated and it is problematic to define which of them have the major importance in the caribou warble flies' population existence (Abiotic Factors, 2005). For this reason, we paid our attention to those factors that had obvious influence on the regulation of the caribou warble flies' abundance in different combinations.

The aim of our research consequently is the studying of the influence of the abiotic factors on vital functions of caribou warble flies *Oedemagena tarandi* L.

Materials and methods

The research has been done in 2013-2016 at the reindeer herders' base of the state enterprise "Antipayutinskiy". The territory of its pasturing is based in typical subarctic tundra of Gydanskiy peninsula under the observation of the District Veterinary Laboratory of the Yamal-Nenets Autonomous Region and All-Russian Scientific Research Institute of Veterinary Entomology and Arachnology.

The ecological and phonological basis of the caribou warble flies' viability was researched in environmental conditions of subarctic tundra. The species affiliation of the insects that were caught was defined with the help of the microscope MBS-15 using "The Identifier of the Insects of the European Part of the USSR" by Bey-Biyenko according to the collection of insects approved by All-Russian Scientific Research Institute of Veterinary Entomology and Arachnology.

The diurnal activity rate of the caribou warble flies was measured by the method of K.A.Breev. We counted the insects sitting down during the period of 30 minutes three times a day (at 7 am, at 1 pm and 7 pm), accompanying it by the temperature recording (Celsius), the recording of the relative humidity (%) using the Assman's psychrometer, the recording of wind power (m/s) using the Fuss's anemometer and the recording of the illumination using a luxmeter.

The elaboration of the image of the O. tarandi's seasonal pattern was made on the basis of the entomological counting of the female caribou warble flies attacking the target reindeer during the peak of their diurnal activity determining the calendar beginning and ending of their activity using the method of K.A. Breev.

Results and discussion

The territories of the West Siberian plain which are located to the North of the Arctic Circle relate to tundra areas. The dividing line between two natural areas passes there. The first of them is the north extremity of the continent with the surrounding islands that relates to the Arctic zone and the second is the Ob-Irtysh natural area including subarctic tundra. Tundra features the change of landscapes and a great variety of ecological factors. The ecological factors are the separate elements of natural habitat that affect living organisms.

Each habitat differs its own ecological factors' effect. Inherently, the ecological factors can be divided into abiotic, biotic and anthropogenic. The abiotic factors are the components of inanimate nature that directly or indirectly affect the living organism. They are divided into the certain groups such as climate factors (light, temperature, humidity, wind, atmospheric pressure etc.), geological factors (earthquakes, volcano eruptions, glacial drift, radiation etc.), orographic or terrain factors (terrain elevation, terrain steepness – the rotation angle of the terrain to the horizon, terrain exposure in relation to the parts of the world etc.), edaphic or soil factors (particle size distribution, chemical composition, density, soil structure, pH etc.), hydrological factors (water flows, degree of solinity, water pressure etc.).The abiotic factors can also be divided into physical and chemical.

Temperature. The normal viability of caribou warble flies is possible only within the certain range of temperatures that are specific for this type of insects (Sivkova, Gavrichkin, 2016). The caribou warble flies are proactive only in the period when the daily temperature is higher than 5°C (6-7°C) above zero. Under the condition of 5°C the actively flying insects were not noticed, we met only single limply crawling females. This data was collected in conditions of good illumination during the cloudless days.

The caribou warble flies become active if the temperature is 14°C above zero. If the temperature is 15-16°C above zero their abundance is increasing very quickly. The massive appearance of the insects was recorded when the temperature rose to 23-28°C above zero.

The upper limit of their activity was recorded when the temperature rose to 33°C above zero that is proved by the curve of the diurnal activity of the caribou warble flies (Figure 1). During the hot days the curve always has one peak.

In the subarctic region the highest temperatures in June and July usually are within the limits of 28-35°C above zero. The indicator of the upper limit during the midday in conditions of 33°C above zero is the great decline of the caribou warble flies' attacks and there is also the decline of the curve of their diurnal activity that illustrates the fact that higher temperatures than 33°C above zero cause the thermal inhibition of the caribou warble flies.

The temperature 31-32°C above zero in conditions of dry weather can also decline the number of the attacking females, but the sharp drop of the curve of their diurnal activity according to our observation does not happen.

In general, Oedemagena tarandi L. represents a group enduring the high rate of thermophilicity (maintaining normal viability in conditions of high temperatures) (Hadwen, 1926; Kurkela, & Käänte, 2010).

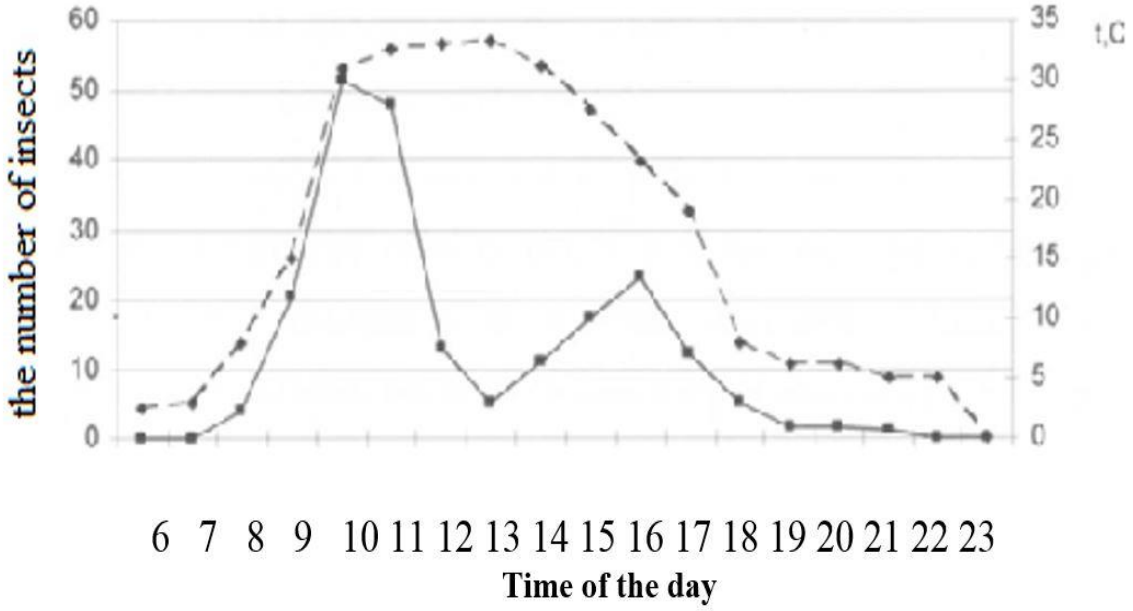

Figure 1. The spread of the caribou warble flies in a temperature scale at different times of the day. —■— the number of insects,

— - — - the temperature.

The high daily temperature remains during 1-2 hours and then at about 2 pm it starts to drop. The number of the caribou warble flies continues to increase and reaches its peak at the midday, but not at 1 or 2 pm, that is earlier than the temperature maximum. This shift of the peak of the diurnal activity curve can be explained by the response of the insects

caused by the physiological thrill of the most optimal temperature (20-25°C) and the increase of the temperature of the caribou warble flies' bodies during their flight.

Illumination

In conditions of the subarctic tundra the increase of the luminous intensity (more than 40000-50000 lux) contributes to the great increase of the caribou warble flies' activity. The lower limit of the illumination that stops the insects' activity hesitated within the temperature optimum (18-21°C) from 950 to 1100 lux, in conditions of 16-18°C from 1100 to 1530 lux, in conditions of 13-15°C from 1530 to 2600 lux. In these conditions we noticed only single insects.

In conditions of the highest illumination the luminous intensity hesitated within the limits of 70000-98000 lux. When the sun hid in the clouds the extent of the illumination was dependent on the extent of cloudiness. In conditions of cloudiness of 4/10 of the horizon (on the 30th of July) the luminous intensity of the direct sunlight equaled to 49000 lux and in the shade it equaled to 23000 lux. In conditions of cloudiness of 5/10 of the horizon (on the 14th of August) at 12 am the luminous intensity equaled to 36000 lux and in the shade to 15000 lux. In conditions of cloudiness of 7/10 of the horizon at 6 pm the luminous intensity equaled to 10000—6000 lux respectively. In conditions of cloudiness of 10/10 of the horizon the luminous intensity equaled to 2000 lux.

The caribou warble flies were numerous and intrusive during the most sunny hours (Nilssen, Anderson, 1986), (Figure 2). The highest degree of their optimum was recorded in conditions of 93000 lux with the temperature of 31°C. With the onset of cloudiness the number of attacking imago insects sharply declined (in 15-20 minutes after the sky was covered with clouds). With the disappearance of clouds the number of flying and attacking insects increased very fast.

The comparative counting of the insects produced the following results: on the 15th of July during the 30 minutes we caught 31 females of the caribou warble flies attaching the target reindeer at 9 am, 44 females at 11 am, 21 females at 1 pm, and 12 females at 5 pm. On the 3rd of August we caught 8 females of the caribou warble flies attaching the target reindeer at 9 am, 24 females at 11 am, 13 females at 1 pm, and 33 females at 5 pm.

The counting of the insects during the hours of changing of the luminous intensity in conditions of different extent of cloudiness showed that the caribou warble flies have the sensitivity to the lowering of the illumination. In conditions of cloudiness the decline of the abundance of the flying and attacking insects was recorded. Moreover, on cloudy days the insects became less aggressive and more timid.

The simultaneous influence of warmth and light in their exact combination and within the certain quantitative limit does not counteract the special character of each factor's effect. According to our observations the earliest activity of single female insects started on different days in conditions of the same illumination, but at different time (from 6 to 9 am) and it always happened if there was the least minimum required temperature (>10°C).

The length of daylight and ever-changing cloudiness during the season of the caribou warble flies' activity create the conditions of their living even during the moist summers, but it sharply decreases the period of their massive activity (2013, 2015).

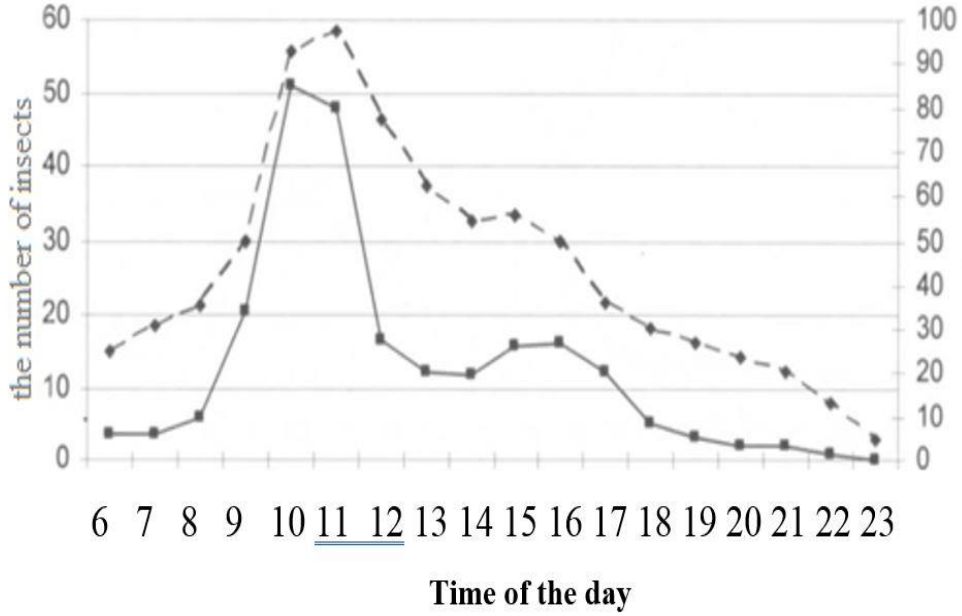

Figure 2. The spread of the caribou warble flies in conditions of changing the luminous intensity at different times of the day. —■— the number of insects —♦— - illumination, lux.

Consequently, it can be considered accurate (p=0.05) that the pivotal role in the caribou warble flies' viability is not only the air temperature, but also the solar radiation.

Wind. In conditions of subarctic tundra this factor is more relevant than in forest tundra where the caribou warble flies do not decrease their activity in the open areas even if the wind power is 7-8 metres per hour. (Boykov, 1999; Sizikov, 2005).

In subarctic tundra when the weather is hot and the wind power is 5 m/s the number of flying insects sharply decreases, especially in the large open areas where wind is quite strong at midday and the activity of the insects at noon is lower than in the morning or afternoon.

If the air temperature drops to 9-12°C above zero and the wind power is 6-8 m/s, the caribou warble flies' activity in the open areas decreases to single insects. In ravines in the same conditions the insects continue being active, but their attacks on the animals is not intensive - only 2-3 insects per the half an hour. When the wind power is 6 m/s the caribou warble flies fly closer to the ground surface (up to 40 ± 10 cm). When the air temperature is 19-21°C above zero and the wind power is 8-9 m/s the number of flying insects decreases to 5-9 specimens. In the same temperature conditions and the wind power of 1 m/s during half an hour the number of attacking female insects reached 10-13 specimens per one reindeer.

Strong wind, low illumination level and low air temperature both have the inhibiting effect on the caribou warble flies. When the air temperature is about 15-16°C above zero and the illumination in about 2500 lux, the insects' reaction to the wind factor that reaches 4-5 m/s increases (the number of female caribou warble flies equalized 1 insect per half an hour).

The inhibiting effect of wind increases not only by low, but also high air temperatures. The decline of the insects attacking reindeer was recorded with the wind of 5 m/s and air temperature of 30-31°C above zero, but their number does not decline in the same wind conditions, but with the air temperature of 25-30°C above zero. In the first case, during half an hour we caught 23 attacking insects and in the second case about 40 specimens.

Consequently, in conditions of both low and high air temperatures the average wind power (6-8 m/s) become a significant reason of the decline or even the ending of the caribou warble flies' activity.

Soil factors and humidity. Seeking the favourable environment the caribou warble flies' larvae move in the topsoil both vertically and horizontally (Bursell, 1974). The horizontal migrations are usually performed by larvae from the places with less favourable conditions of humidity. Knowing the larvae migrations direction we can fight them more effectively (Dobrovolskiy, 1965).

In connection with the fact that the part of *O. tarandi* L.'s life (the stage of larva of the 3rd age and the pupa stage) depends on the soil microclimate, we made the experiments devoted to the detecting of the most favourable conditions needed for the forming and development of the caribou warble flies' pupae.

For this purpose we made the laying of the larvae at the prepupa stage into the keepnets which bottoms were paved with the soil from the place where the larvae were collected. Then we recorded the period when the larvae became pupae following the experiment with the recording of the soil temperature.

In total we laid 136 larvae at the 3rd stage of their development and 105 of them became pupae. Our observations showed that the duration of their development at the pupa stage hesitates from 50 to 98 days, 71.5 ± 2.7 days on average (Table 1).

Table 1. Development of chrysalis of *Oedemagena tarandi* L. in cages under various conditions of a bookmark.

Conditions of laying of larvae	**Date of experience**	**The larvae of stage III are incorporated into the experiment**	**Pupated**	**Duration of development of pupae, days**			**The pupae died**		**Brood imago**		**Soil temperature during the development of pupae**		
				min	max	M ± m	Ex.	%	Ex.	%	min	max	average
Snow, moss	1.05	21	20	98			19	95	1	5	-15	24	3
Snow, thawed turf	5.05	28	25	71	89	80 ± 1.6	12	48	13	52	-6	33	13.5
Thawed turf	10.05	10	10	50	75	62 ± 2.9	1	10	9	90	-5	25	10
Moss, thawed turf	18.05	12	10	67	84	75 ± 1.7	2	20	8	80	-1	24	11.5
Sand	24.05	10	7	65	81	73	5	71	2	28	0	26	13
Turf	12.05	9	8	60	81	71.1 ± 3.0	0	0	8	100	-3	25	11
Wet silt	28.05	15	0	-	-	-	-	-	-	-	-	-	-
Moss, sand, turf	25.05	25	25	58	79	67.4 ± 1.9	11	44	14	56	1	28	14.5
Total		130	105	50	98	71.5 ± 2.7	50	48	55	52	-15	33	10.9

The shortest period of their development was recorded in conditions of the soil temperature of 10-14,5°C above zero.

The soil substrate where a pupa lies must not be too wet. Pupae and larvae at the 3rd stage die when they are in the hydromorphic soil (in the hydromorphic sludge soil their deaths amounted 100%). This phenomenon was mostly recorded among the larvae becoming pupae in the territory of Gydanskaya plain.

It can be explained by the fact that humid soil tightly adheres to larvae bodies and the resumption of water rich in oxygen goes slower, so the larvae breathing becomes harder and they die because of the lack of oxygen (Gilyarov, 1949).

If the soil substrate is too dry, the pupae also do not develop. The humidity of the habitat consists of the relative humidity of the air right above the surface of soil (75-80% and more) and moderate soil humidity. Thus, the death of larvae grown in the sandy areas amounted to 71%.

The deviations of relative air humidity especially to its shortage as well as temperature deviations lead to the slowing of the larvae development, their torpor, hibernation and diapauses. The famous researcher of the insects' cold-endurance R.S. Ushatinskaya (1957) pointed out that at first the diapauses appeared as a simple slowing of insects' metabolic activity under the influence of the lack of water. The effect of this factor is always connected to the temperature factor.

We researched the effect of the air relative humidity on the imago caribou warble flies during their activity (from the 3rd decade of June to the 1st decade of September). The level of air humidity of the researched area at different periods of the season and days vary to the large extent (65-100%). There is an inverse relationship between the air humidity and air temperature: the higher temperature is the lower relative air humidity is.

During the summer time the air humidity by the big reservoirs such as the Parisento lake, the Niischanto lake and others equaled 75 ± 1.2% and far from them it equaled 64 ± 0.9%.

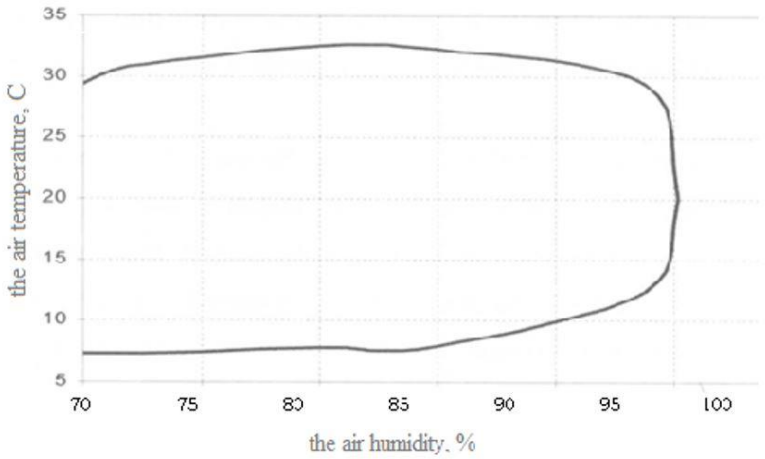

Figure 3. The thermohydrogram of imago caribou warble flies in conditions of subarctic tundra in 2013-2016.

Observing these factors during 2013-2016 (Figure 3) we did not record the definite relationships between the changes of the air humidity and the number of attaching caribou warble flies.

Seeming synchronicity of enhancing the level of relative air humidity and the number of insects does not reflect the dependence of the activity and attacking of the caribou warble flies on the changes of air humidity. Studying the effect of this factor on the insects' activity we found out that in conditions of the air humidity of 95% (t=12-13°C) there is no flying insects. Although, we do not have reasons to confirm that air humidity within the researched limits (95%) has absolutely no influence on the development and behaviour of the caribou warble flies. It is known that the higher the insects' activity under the effect of the stimulating factors is the quicker the metabolic processes and other systems go.

The insects' breathing processes are connected to the intensity of evaporation and water balance itself (Vinogradskaya, 1959). Consequently, the hesitations of air humidity within the 65-94% do not significantly influence on the insects' activity and this factor in subarctic tundra can be referred according to A.S. Monchandskiy (1958) to non-essential.

Conclusion

In the favourable conditions the diurnal activity of imago caribou warble flies starts at 6 am and in the peak of the favourable conditions at 9-12 am. The ending of the insects' attacks happens at 9-11 pm. During the sunny days (in July and August) their attacks start in conditions of the air temperature of 8-10°C above zero and during the cloudy days they start attacking with the temperature of 15-17°C above zero.

The low level of their activity (2-3 specimens that were caught) was recorded during the cloudy days in conditions of the air temperature of 9°C above zero. The crucial role in the life of the caribou warble flies presents not only air temperature, but also solar radiation. Both in conditions of low and high temperatures the wind power of 6-8 m/s becomes a significant cause of the ending of the insects' activity. The air humidity within the researched limits (under 95%) does not affect the activity and behaviour of the caribou warble flies.

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