Daily and Seasonal Fluctuations of Blood Sucking Activity of Horse-flies in Sapporo, Hokkaido[1)2)]

By

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(*With 7 Text-figures and 6 Tables*)

Horse-flies or the family Tabanidae occupy a distinguished position among various blood sucking insects by the large amount of blood intake at one time, accompanied with terrible pains, which often give a serious nuisance for cattle grazing. Concerning the bionomics and ecology of the Japanese species, a number of papers have so far been published as to particular aspects such as daily activity (Sasakawa *et al.* 1968), phenology (Nagasawa 1967), blood sucking habits (Katô *et al.* 1965), etc. In Hokkaido, however, no precise ecological study of horse-flies has hitherto been made, nevertheless the damage is not much less than in other areas of Japan. Since 1969 the present author has engaged in the studies of tabanid biology in and near Sapporo. In this first report, some observations on the aspects such as faunal make-up, daily activity and phenogy in the area studied are described as a basis for further analysis.

Before going further, the author wishes to express his sincere gratitude to Prof. Mayumi Yamada, Dr. Shoichi F. Sakagami and Mr. Hiromi Fukuda, Zoological Institute, Hokkaido University Sapporo, for their useful guidance in the course of the present study.

Methods

Area of field observations

Most field observations were carried out within the ground of Hokkaido National Agricultural Experiment Station, situated in Tsukisamu at the eastern outskirt of Sapporo, with an altitude of about 100 m. The ground is approximately 11 sq. km. The eastern and southern parts are covered by forests, but the rest is used as field or pastures. Cows and sheep kept by the station graze during summer in numerous pastures within the ground. The observations were made in some pastures only with cows, because sheep were too

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2) Ecological Studies on the family Tabanidae in Hokkaido, I.

sensitive to observe and seldom attacked by horse-flies in the area studied. This lower susceptibility of sheep to horse-flies is also reported by Abe *et al.* (1955). The number of cows was about 200 in 1970. In 1969 observations were made only in pasture No. 36 with one of five herds kept there during the season. In 1970 four pastures, Nos. 22, 24, 29 and 36 were used (cf. Fig. 1). Observations were mainly performed in No. 24, but often in other 3 pastures mentioned and occasionally in other pastures in the area studied, too. No conspicuous difference of tabanid faunal make-up was found among these pastures. The herd composition of cows in these pastures in 1970 are as follows:

No. 24: 1 herd with 5 Holstein hefers (24 months old)

No. 22: 8 herds with 25 Holstein hefers, observations were mainly made on a particular herd with 4 hefers.

No. 29: 1 herd with 20 Holstein adults.

No. 36: 3 herds each with 65 Holstein hefers, 8 Aberdeen Angus hefers (17 months old) and 6 Japanese Short Horn hefers (27 months old), observations were mainly made on the latter two herds.

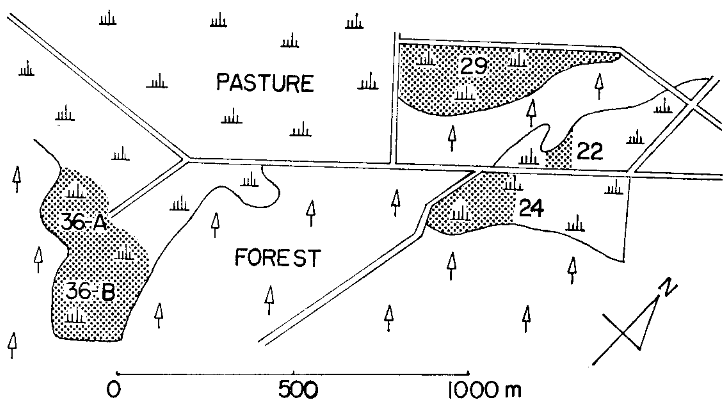

Fig. 1. Area studied. Dotted areas: Pastures for field observations.

The selection of particular cows is essential in the census of horse-flies, especially in case of net collecting. The result is markedly affected by the disposition of individual cows, some ones being relatively indifferent for interference, while some others quite sensitive. Further, the tameness for census practice increases by constant contact and brushing of cows by observer. For this reason, the census was mainly made with one particular herd consisting of five hefers at No. 24, only sporadically at other pastures. The census was made from June 27 to September 19 in 1969, from July 2 to September 9 in 1970, and the sampling of immatures from May 11 to August 15 in 1970. Further details are given in each section of results.

Census method of blood sucking adults

In the present study, the tabanid activity was mostly observed by making census of the number of individuals flying around or staying on the body surface of cows by using two different procedures.

a) *Counting*: In this method the number of attacking flies is rapidly counted by walking around all cows in a herd from a distance of about 0.5～1.0 m. This method is superior to net collecting described below, as it can yield numerous records per hour and can be applied to many cows irrespective of their disposition. The demerits are the difficulty to count all individuals and identify the species at the moment. As to the misidentification, however, the result does not deviate too much from real faunal make-up as shown later (cf. Fig. 3). On the other hand the figures obtained may deviate from the real number of flies present at the start of the census by displacement of same individuals which landed on the opposite body side of the cow in course of counting. To eliminate such possible sources of errors, the counting was made twice at an interval of three minutes. The number of individuals obtained by this procedure are express subsequently as counted number (CN) and recounted number (RN).

b) *Net collecting*: Collecting was made from particular cows by using an insect net, 42 cm. in diameter with 90 cm. long shaft. In most cases three units of collecting were successively made after counting. Each unit was continued for two minutes, which were usually sufficient to catch most individuals on and around the cow. The first unit covers both individulas stayed on the cow and those newly arrived, while the second and third units only newly arrived. The collected number (NN) used below is the sum of these three units. Merits and demerits of net collecting are just opposite to those of counting mentioned above. The error of collecting may be greater by inevitable escapes of some individuals during the procedure. Moreover the number of flies attacking on one cow deviates much more than that attacking the whole herd. Therefore NN is seemingly inferior to CN and RN as a relative index of activity at a given time. Further, the method is greatly affected by the disposition of cows, some ones are quite shy to the operation, making collection virtually impossible. However, collecting is superior to counting for the accurate identification of species and possibility of using collected individuals for estimation of relative age and examination of other internal organs, etc.

Identification of species at field

Thanks to monographic revisions by Takahasi (1962), and Murdoch and Takahasi (1969), the identification of the Japanese tabanid species is now possible without much difficulty. However, various diagnostic characters are not applicable to identify the species at field observations. For this purpose, the author prepared a tentative key for field observation, mainly based upon size, shape, color pattern and behavior (cf. Fig. 2).

1a. Large species, longer than ca. 20 mm. 2
1b. Medium species, ca. 13～17 mm. 3
1c. Small species, less than ca. 12 mm. 7

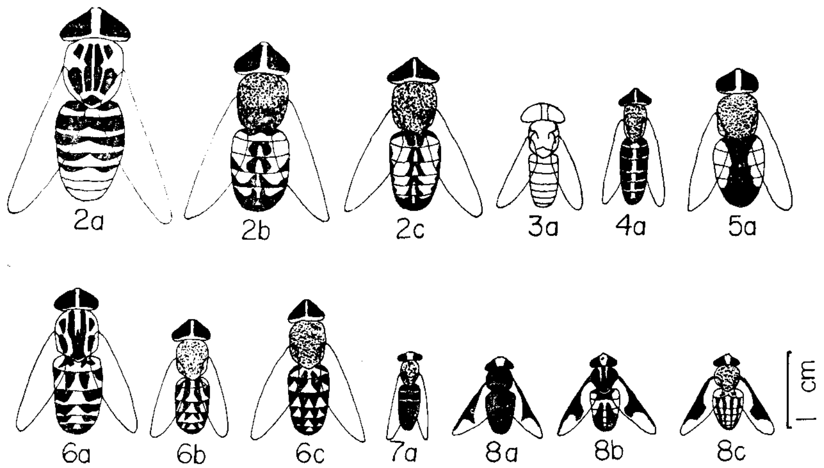

Fig. 2. Schematic figures for identification of species at field.

2a. Largest. Golden yellow. Always staying on back of cow. . .*Tabanus chrysurus* Loew
2b. Second largest. Brownish yellow, seen reddish especially on fly. Mostly staying on back of cow. Eyes widely separated for each other. . .*Tabanus sapporoenus* Shiraki
2c. Brownish. Abdominal stripe with median spots clearer than *sapporoenus*. Eyes narrowly separated. Mostly staying on lateral or ventral side of cow. . . . .*Tabanus rufidens* (Bigot)
3a. Yellow species. Head large. . . . .*Atylotus horvathi* (Szilady)
3b. Differently colored species. 4
4a. Body slender. Brownish yellow with conspicuous narrow yellow stripe on abdomen. . . . .*Tabanus fulvimedioides* Shiraki
4b. Body normal. 5
5a. Gray with conspicuous orange patch on abdomen. . . . .*Hybomitra arpadi* (Szilady)
5b. Grayish with fine white or brown stripe on abdomen. 6
6a. Relatively large. Gray. Abdominal stripe with clear white spots. . . . .*Tabanus trigeminus* Coquillet
6b. Relatively small. Grayish blue. Abdominal stripe with clear blueish white spots. Head large. . . . .*Tabanus kinoshitai* Kôno et Takahasi
6c. Grayish brown. Abdominal brownish stripe obscure. Head normal. . . . .*Tabanus nipponicus* Murdoch et Takahasi
7a. Slender. Wings gray with indistinct marks. . . . .*Haematopota tristis* Bigot
7b. Robust. Wings hyaline with distinct marks. 8
8a. Black. Wings hyaline with clear black marks. . . . .*Chrysops japonicus* Wiedemann
8b. Black with conspicuous yellow abdominal mark. Wings marks black. . . . . *Chrysops suavis* Loew
8c. Brown with conspicuous four black stripes on abdomen. Wings marks brown. . . . .*Chrysops vanderwulpi* (Kröber)

Among these species, the distinction is often subtle because of similarity in size and color pattern in the following three cases: I. *T. rufidens*～*T. sapproenus*, II. *T. nipponicus*～*T. trigeminus*～*T. kinoshitai*, III. *C. suavis*～*C. vanderwulpi*. In case I, uncertain individuals were identified with *T. sapporoenus* when found on the back of the cow, while with *T. rufidens* on other body parts. In case II, all uncertain individuals were identified with *T. nipponicus*. The resulting over-estimation of *T. nipponicus* may not too much affect the result because this species is, as given below (cf. Fig. 3), absolutely dominant in the area studied, occupying more than 70% of tabanid individuals censused. By the same reason all uncertain individuals in case III were identified with *C. suavis* which is much more than *C. vanderwulpi*.

Results

1. Some remarks on the behavior of blood sucking horse-flies

In this first section, some observations on the factors proximately affecting the number of blood sucking horse-flies are enumerated.

1.1. Relation between herd size and number of horse-flies attracted: At observations, there were several herds in different pastures, each composed of four to 20 cows. The relation between herd size and number of attacking horse-flies

Table 1. Relation between herds size and number of attracted hosre-flies

Pasture	No. 22	No. 24	No. 36–A	No. 36–B	No. 29
Number of cows	4	5	6	8	20
Flies per one cow	5.8	5.3	5.0	2.7	2.0
Flies per herd	23.1	26.4	29.9	21.6	39.2
Observed cases	(41)	(183)	(46)	(56)	(23)

is shown in Table 1 by using results of (CN+RN)/2. The figures are the mean number of horse-flies attracted to a cow or a herd at day-time observations 9:00–17:00 from July 21 to August 13 with the number of observed cases in parentheses as shown in Table 1. The number of flies attracted to herd does not increase in parallel to the increase of herd size, resulting in the small number of flies per cows in larger herds. This tendency is commonly observed also in other pastures though the observations are still insufficient to give any definite conclusion.

1.2. Color hue preference by horse-flies: It was already reported that horse-flies have a particular preference to cows with certain coat hue (Satô *et al.* 1962). The number of flies on each cow was observed in relation to their coat hue from August 6 to 13 by using counting method in three herds. The results are shown in Table 2. The figures are the mean number of flies attracted to each cow at

Table 2. Relation between number of flies attracted and color hue of individual cow

No. 24 (126)	*T. nipponicus*	*T. rufidens*	*A. horvathi*	*C. suavis*	Total
Cow ind. 1	7.4	2.2	0.8	0.3	10.6
2	2.8	0.9	0.4	0.1	4.2
3	2.1	0.4	0.3	0.1	2.9
4	2.9	0.7	0.5	0.2	4.2
5	1.6	0.3	0.2	0.1	2.2
No. 22 (35)					
1	5.3	3.5	0.3	0.2	9.2
2	2.7	1.9	0.3	0.1	5.0
3	1.6	0.7	0.1	0.1	2.5
4	1.5	0.2	0.1	0.0	1.8
No. 36-A(41)					
1	3.4	1.0	0.9	0.6	6.9
2	2.6	1.4	0.6	0.6	5.2
3	2.4	0.8	0.6	0.6	4.4
4	1.2	1.4	0.2	0.4	3.2
5	1.3	0.8	0.3	0.5	3.0
6	1.3	0.4	0.5	0.6	3.1

observations, with the number of observed cases in parentheses. In pastures Nos. 24 and 22, the cows are arranged in the descending order of the increase of white body part. In pasture No. 36-A, all cows were approximately of the same brownish hue. While in Japanese Short Horns in No. 36-A, the number of flies did not differ much among cows with more or less similar hue, in Holstein in other two pastures, the number was distinctly higher on cows entirely black. This tendency was invariably seen in other herds kept in the area studied, showing the preference of horse-flies for black tone or probably for darker objects.

1.3. Body parts preferred by attacking horse-flies: It has also been reported by many authors that horse-flies showed a kind of spatial segregation on the body surface of cow (Katô *et al.* 1965 etc.). For instance, *T. chrysurus* mainly attacks back and *T. nipponicus* does belly and legs. Such differential response was also observed by the present author. Various species are divided into three groups according to their preference:

I. Species attacking back: *T. chrysurus* and *T. sapporoenus*

II. Species attacking lateral sides and belly: *T. rufidens*, *T. fulvimedioides* and *Hy. arpadi*

III. Species attacking belly and legs: all other species.

According to Katô *et al.* (1965), the preference for particular body parts includes intra- and interspecific interference but in the present study this aspect was not quantitatively determined. The preference is so well fixed that the

Table 3. Comparison of the number of flies attracted to cows at standing or lying

Pasture No. 24	*T. nipponicus*	*T. rufidens*	*A. horvathi*	*C. suavis*	Total
Cow ind. 1 standing(102)	8.1	2.5	0.7	0.3	11.6
lying (24)	3.1	0.8	0.8	0.3	4.8
4 standing (95)	2.9	0.6	0.4	0.2	4.0
lying (31)	2.8	0.9	0.7	0.2	4.7

species belonging to group II and III tend to avoid landing on the cows when the latter lie on the ground, resulting in the decrease of individuals on cow both in absolute and relative number, especially at higher densities. Table 3 shows the mean number of *T. nipponicus*, *T. rufidens*, *A. horvathi* and *C. suavis* counted when cows are either standing or lying, with the number of observed cases in postures in the parentheses. The number of flies on cow No. 1 is distinctly higher when she is standing but no such tendency is recognized in cow No. 4. Thus the number of flies on cows clearly depends on the posture of cow when many flies exist, but not so conspicuously when few flies are attracted.

The behavioral preference given above must be kept in mind at daily and seasonal censuses, especially when making some conclusions based upon limited observations. In the present survey, the first two items do not seriously affect the result, because the main census was always made with a particular herd at pasture No. 24. As to the third item, the posture of cows was partly recorded as shown in Fig. 4. But the procedure is still not perfect, requiring further improvement.

2. Faunal make-up in the area studied

The species censused are given in Fig. 3, in the descending order of the result by collecting in 1969 and the percentage ratios of various species by the vertical line on each horizontal bar, the ends of which respectively show upper and lower fiducial limits ($p=0.05$) by the occurrence probability method (Katô *et al.* 1952). The results by different methods and obtained in different years are shown separately. The absolute number of collected and counted individuals are given with figures. The faunal make-up in the area studied is simple. It is markedly skewed by the overwheleming predominance of *T. nipponicus*, followed by *T. rufidens*, *A. horvathi* and *C. suavis*. These four species occupy nearly 93% of the total species censused. The species censused include 41.6% of those from Hokkaido (32 sp. cf. Takahasi 1962). As seen in Fig. 3, the results by counting and collecting do not show significant difference in most species. Exceptions are *T. rufidens*, *T. trigeminus* and *T. kinoshitai*. In these species, it is certain that the difference was caused by the premise described above (the subtle cases I and II, in the key) but in general it is concluded that counting census is fairly effective for the estimation of the relative abundance of species, especially dominant ones except *T. rufidens*.

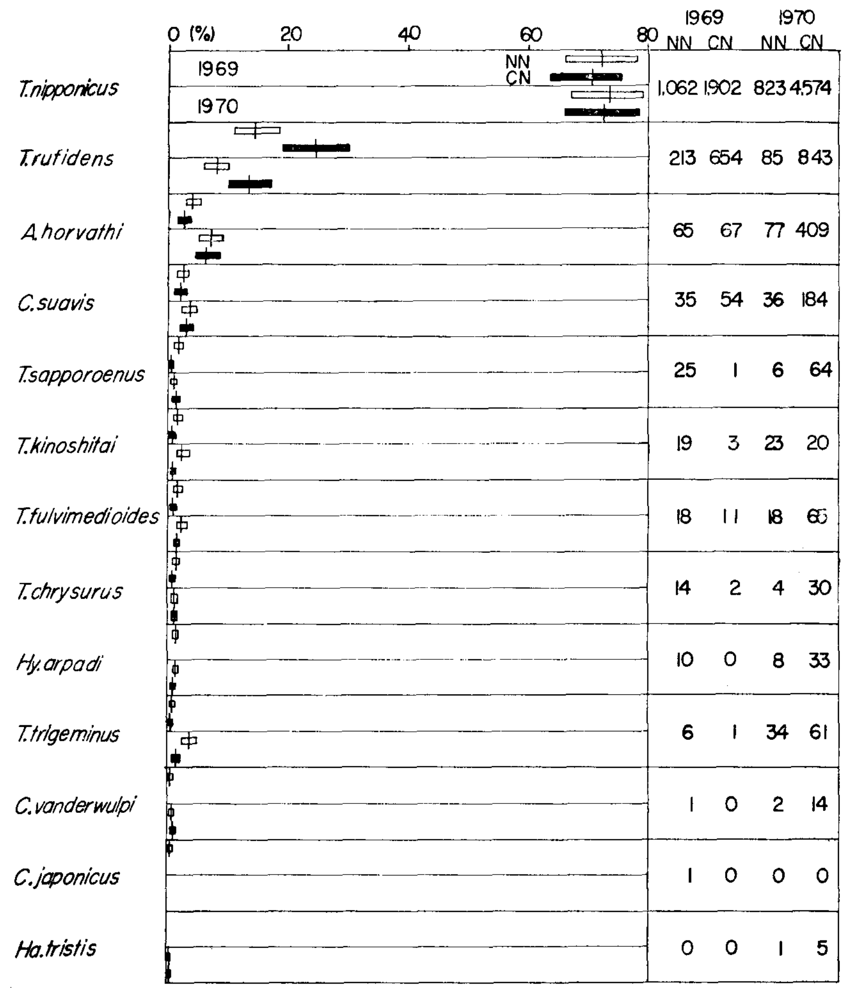

Fig. 3. Faunal make-up in the area studied in 1969 and 1970.

3. Daily activity

The accurate understanding of diurnal activity pattern is a prerequisite for ecological studies of any animals. Even a local faunal list cannot be made completely without some knowledge on the daily activity pattern of various species.

Before describing the results obtained, the previous contributions made with Japanese species are briefly reviewed. Two types of activity pattern, unimodal and bimodal, are so far recorded. There are some discrepancies among authors: *T. trigeminus* is unimodal after Ôtsuru *et al.* (1956), Harakawa *et al.* (1956) and Hukushima (1963), while bimodal after Ôtsuru *et al.* (1965) and Sasakawa *et al.* (1968). *T. iyoensis* is unimodal after Kono *et al.* (1940), while bimodal after Ôtsuru *et al.* (1965). *T. nipponicus* is unimodal after Hayakawa (pers. comm.), while bimodal after Shimizu *et al.* (1966).

Obviously various causes must contribute to the realization of such discrepancies, but the difference of seasonal and climatic conditions at observation may be regarded as one of the principal factors concerned. Keeping this assumption in mind, the author observed daily activity in relation to climatic conditions, especially air temperature and radiation. The results are presented in Table 4 and Figs. 4 and 5. Some explanatios on the procedures are preceeded: 1) Although the observations were made in four pastures, only the results obtained from pasture No. 24 taken in 1970 was referred to. 2) Air temperature was measured hourly by a bar thermometer placed at pasture No. 24 avoiding direct sunbeams. Radiation was cited from the measurements taken at Meteological Laboratory of Hokkaido National Agricultural Experiment Station. 3) Census was made by counting and collecting, both one to four times per hour, but only the results by counting was used because it is superior to the other to show the activity at a given time. 4) Data obtained from July 15 to August 15 was summed up in Table 5 to show the general tendency of daily activity, but such summation can obscure different sequences by particular weather condition. Therefore the sequence on particular day or days clustered for similar weather conditions, are shown in Fig. 4 concerning *T. nipponicus*, the most dominant species, as follows: mid July (clustered July 15~17), late July (July 22, 24~26, 28~30), August 8, 9 and 11, while all observations at each period are plotted in Fig. 5. 5) The figures expressed as daily activity are the mean hourly value of (CN+RN)/2. Difference between CN and RN was negligible in general.

As seen in Table 4, most species are active during daytime so that certain level of illumination must be indispensable to release blood sucking activity. As exceptions to this rule, *C. vanderwulpi* is active only under twilight and the similar tendency is seen though less remarkably in *C. suavis* and *Ha. tristis*. Daily activity pattern of most species seems to be unimodal with plateau like sequence as far as the result given in the table is concerned. But the summarized data do not always yield exact conclusion. Therefore various instances of different sequence shown in Fig. 4 concerning *T. nipponicus* are described below in relation to climatic factors.

a) Mid July in Fig. 4–1 and 5–1. The temperature was so low (maximum temperature 21.0°C, 23.8°C, 22.0°C respectively) that only a few flies were active. On July 18, the temperature rose remarkably (max. temp. 27.2°C), resulting in an increased activity though not mentioned in Fig. 4. This fact suggests that adult flies were ready to exert their activity, only inhibited by low temperature until July 18. Under such situation, the activity curves take a typical unimodal form, with the peak at the time of the maximum temperature, and the relation between activity and thermal condition becomes linear as shown in Fig. 5–1.

Table 4. General tendency of tabanid daily activity shown by relative

species \ time	5:00	6:00	7:00	8:00	9:00	10:00	11:00
T. nipponicus	25	51	41	79	83	96	100
T. rufidens	5	9	36	42	35	45	58
A. horvathi	0	0	10	15	60	85	100
C. suavis	0	0	10	30	20	60	40
T. fulvimedioides	0	75	50	75	75	25	25
T. kinoshitai	0	0	0	47	27	27	100
T. trigeminus	0	0	3	6	69	31	86
T. sapporoenus	14	7	17	77	57	31	71
T. chrysurus	0	53	21	43	9	0	21
H. arpadi	0	100	40	28	32	56	20
C. vanderwulpi	0	0	0	0	0	0	0
H. tritis	0	0	0	0	0	0	0
Total	21	43	43	72	76	89	97
No. of observed cases	(4)	(4)	(10)	(15)	(25)	(28)	(20)

b) Late July in Fig. 4–2 and 5–2. The highest annual temperatures were recorded (max. temp. 29.5–32.2°C). It is interesting to know the possible inhibition of such highest temperature upon tabanid activity, which might lead to the appearance of a bimodal curve. The daily activity, however, does not suggest any such inhibition, showing a plateau like sequence with no distinct peak. Flies attacked cows very actively under such high thermal condition. As seen in the figures the highest activity of *T. nipponicus* was seen at the temperature higher than 28°C. The effect of radiation seems positive within the range observed.

c) August 8, 9 and 11 in Fig. 4–3～5 and 5–3. On these three days activity pattern was different from that of late July, rather forming a bimodal curve with a slight decrease at maximum temperature. But the peak at morning was not so distinct that the highest activity was recorded at evening. The decreases at 15:00 on August 8 and 16:00 on August 9 were certainly caused by the fact that the cows observed took the lying posture. Relation between activity and temperature as well as radiation was also different from that of late July. While attacks by flies were inactive in late July when temperature was lower than 28°C, most attacks were found 24～27°C in early August, less intensively but still frequently at 22–24°C. Radiation may negatively affect tabanid activity in high thermal condition. On the other days with relatively low temperature in August, the daily activity curves formed a plateau like unimodality with an indistinct peak at the maximum temperature.

4. Phenology of blood sucking activity

Phenology or seasonal change of blood sucking activity was observed in 1969 from June 27 to September 19, covering 21 days with irregular intervals by number of flies to the maximum number attracted (=100)

12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	Total
98	88	89	97	77	76	32	25	4504
62	24	100	44	44	45	25	0	722
95	80	100	50	70	55	10	5	368
40	60	60	80	100	60	90	50	297
75	50	100	25	75	50	50	0	113
93	80	27	80	27	60	40	0	22
20	54	37	77	100	60	34	0	52
60	43	71	23	49	34	100	57	60
15	81	53	32	47	32	100	0	48
44	92	68	60	35	0	24	40	31
0	0	0	0	43	15	45	100	13
33	0	33	0	0	0	100	0	5
96	82	100	90	80	74	39	22	6235
(28)	(26)	(24)	(26)	(23)	(34)	(17)	(10)	—

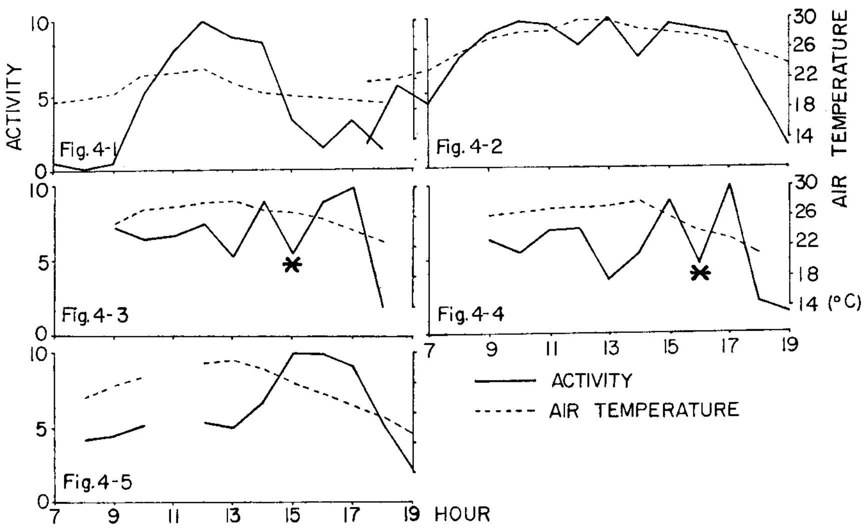

Fig. 4. Daily activity of *T. nipponicus*.
* Decrease of the number of flies due to lying of cows.

collecting flies from a particular cow grazing at pasture No. 36, and in 1970 from July 2 to September 9 on 32 days by counting flies staying on five particular cows in pasture No. 24. From these data the phenological sequence of all tabanid in the area studied is shown in Fig. 6 with the recognition of several life cycle types

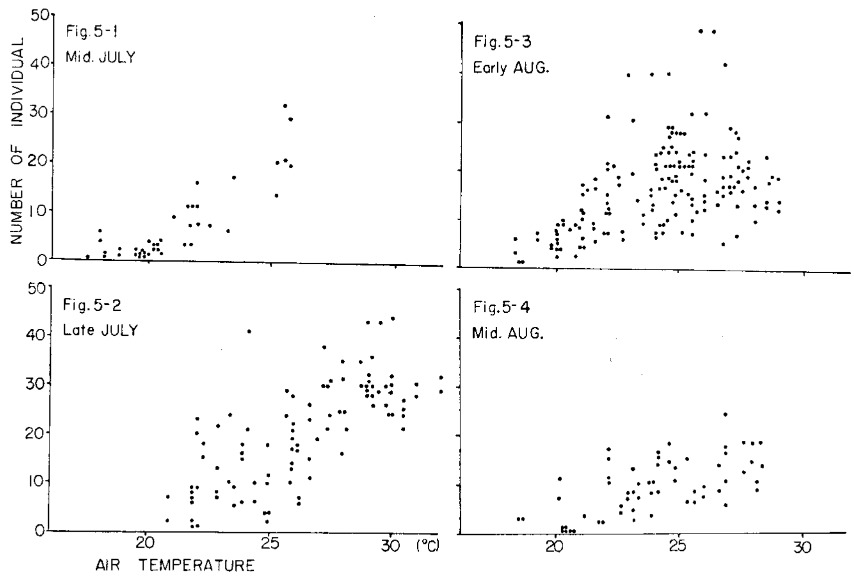

Fig. 5. Relation between activity and temperature.

as follows:

A: Earliest species (appearance: June) with a shrot active period. ....*C. japonicus* and *Hy. arpadi*

B: Early species (appearance: early July) with a long active period. ....*T. nipponicus* and *C. suavis*

C_1: Middle species (appearance: mid July) with a shrot active period. ....*T. chrysurus*

C_2: Middle species (appearance: mid July) with long active period. ....*T. kinoshitai, T. trigeminus, T. sapporoenus* and *A. horvathi*

D_1: Late species (appearance: late July) with a short active period. ....*C. vanderwulpi* and *Ha. tristis*

D_2: Late species (appearance: late July) with a long active period. ....*T. rufidens* and *T. fulvimedioides*

As to *T. nipponicus,* seasonal change of age composition is shown in Table 5. The fresh individuals are naturally more abundant in earlier periods but it is noteworthy that some fresh or relatively fresh ones are found in early and even in late August, suggesting a continuous emergence of a small portion of adults during the active period. This is also confirmed from the sampling of immatures. The sampling records in Table 6 show that pupation and emergence begin in mid June and late June respectively and pupal exuviae are predominant in August. Nevertheless some old larvae are found in August, favoring the assumption held above.

In 1969 each collecting trial was continued for six minutes and in average

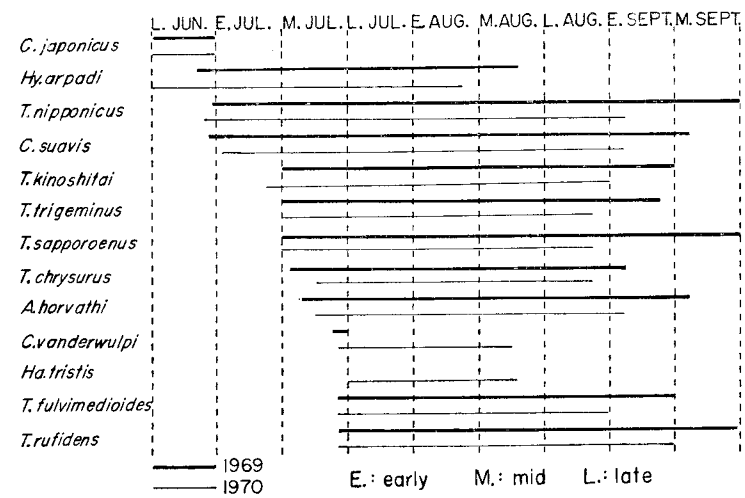

Fig. 6. Phenological sequence of all tabanid species in the area studied.

Table 5. Seasonal change of percentage age composition of *T. nipponicus*

Season	Age class				Total of examined individuals
	I	II	III	IV	
Late July	51.9	33.2	10.0	4.9	289
Early Aug.	33.7	30.1	26.4	9.8	757
Late Aug.	46.5	32.1	14.3	7.1	28

Table 6. Phenological sequence of immature stages

Season	Young Larva	Old Larva	Pupa	Pupal Exuvia	Sampled Number
Mid May	6	9	—	—	10
Late May	—	1	—	—	5
Early June	2	7	—	—	9
Mid June	5	6	3	—	28
Late June	6	3	4	1	25
Mid July	—	3	2	2	10
Mid Aug.	—	1	—	12	25

two trials were made per hour, but the data obtained include deviations caused by inadequate sampling procedure so that they cannot be used for precise estimation. In 1970 counting was made one to four times per hour, usually but not always continued from 9:00 to 18:00. The deviation due to difference of observed hours

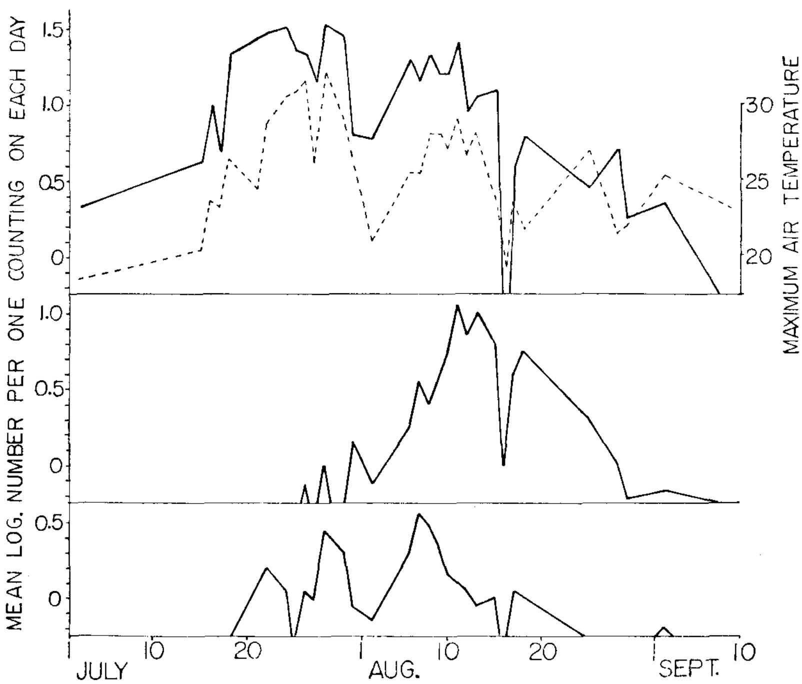

Fig. 7. Seasonal change of blood sucking activity of *T. nipponicus T. rufidens* and *A. horvathi*.

may be small in daytime species but rather high in twilight species because observations were occasionally not made in early morning and late afternoon. For this reason the seasonal change of blood sucking activity is shown only with three dominant daytime species, *T. nipponicus, T. rufidens* and *A. horvathi,* by using the maen log. value of CN and RN obtained during 9:00～17:00 on each day. The fluctuations of these three species are given in Fig. 7 together with the maximum air temperature on each observed day at pasture No. 24. The seasonal sequence of blood sucking activity has the peak at late July, early August and mid August in *T. nipponicus, A. horvathi* and *T. rufiedns* respectively, in parallel to change of daily temperature. The effect of temperature is so remarkable that seasonal change of activity should always be compared with the temperature in each period

Discussion

Comparing faunal make-up in the area studied with the results obtained in Honshû, *T. trigeminus* is dominant in many areas in Honshû (Harakawa *et al.* 1956, Ôtsuru *et al.* 1965, Hukushima 1963 and Sasakawa *et al.* 1968 etc.) and *T. iyoensis* or *T. humilis* often abundant locally (Ôtsuru *et al.* 1956, Nagasawa 1967 etc.). *T. nipponicus*, the top ranked species in Sapporo, is abundant in northern areas of Honshû (Hasegawa *et al.* 1970 etc.), while replaced by *T. trigeminus* in central and southern Honshû though both are sympatric throughout Japan. The result obtained by Takahasi (pers. comm. 1940) in and near Sapporo was very similar to that of the present study. Namely, the dominant species are completely same and all species collected by him are represented in the present study. Therefore it is assumed that the faunal make-up in and near Sapporo did not much alter qualitatively for about 30 years, in spite of ever increasing urbanization of the city of Sapporo.

Concerning the daily activity pattern of horse-flies, as recognized from the results described above, attack to grazing cattle are most active at midday hours in the area studied. This activity pattern seems to be governed at least in part by climatic conditions, especially by temperature. Some previous contributions to the influence of climatic factors upon tabanid activity are cited here in relation to the results obtained in the present study. According to Sasakawa *et al.* (1968), *T. trigeminus*, *T. chrysurus* and *T. trigonus* are most active at temperature of 25～26°C, and illumination 7,000～9,000 lux, decreasing rapidly 27°C and 10,000 lux respectively, showing a bimodal curve with peak at 8:00–9:00 and 15:00–18:00. According to Hayakawa (pers. comm.), the optimum thermal range of most species including *T. nipponicus*, *T. rufidens* and *A. horvathi* are 25～26°C. Kurosaki *et al.* (1958) stress the inhibition of activity by strong wind while underestimate the effect of temperature. The results obtained in the present paper deviate from these metioned above in some aspects and suggest that the relation is not so simple as stated previously. The relation between activity and thermal condition opposed diametrically between July and August. The high temperature inhibition was not observed in July, even under 30°C, while conspicuous in August, with the optimum range of 24～27°C. It is not easy to find causes realized such difference but some possible explanations are given briefly: 1) At first it is pointed out that the air temperature in late July was nearly always higher than 27°C, the value recorded as the optimum in August, which was observed only in early morning and late evening. In these hours horse-flies are still or already inactive, limited by the conditions other than temperature, probably illumination. Obviously this fact alone cannot explain the result but may not be ignored in combination with the following two possibilities. 2) Another explanation relates to the adaptation to particular thermal ranges. The appearance of maximum temperature, say, 30°C may affected differently when flies are adapted to the range of 22°C or 27°C. If such would be the cases, obtained thermal records must be interpreted not only in absolute values but also in relative values. 3) As a third possibility, the difference of activity due to physiological conditions, for instance, aging, is suggested. For this purpose the author sorted the specimens collected in different periods according to their relative age, as follows:

Class I. Both wings and body hairs intact.

Class II. One wing slightly worn and some hairs lost.
Class III. One wing heavily worn or both wings slightly worn. Hairs considerably lost.
Class VI. Both wings heavily worn and hairs mostly lost.

The percentage ratio of individuals of *T. nipponicus* corresponding to these classes is shown in Table 5. The number of individuals examined is still insuffcient but the prevalence of younger flies in July must relate higher motivation for blood sucking and stronger tolerance to high temperature.

Any of these possibilities cannot explain the fact sufficiently but these and any other possibilities must be kept in mind for further analysis of tabanid daily activity which is probably not so statically determined by absolute values of one or more environmental factors. The presence of these possiblities can also be regarded as a warning to the premature assertion of uni- or bimodality in daily activity, based upon the observations made in a limited period or careless summation of results obtained under different situations.

Finally, the daily activity pattern and influence of some climatic factors in the area studied is summarized: After sunrise flies rapidly increase as temperature increases, reaching the maximum level at 9:00 in mid summer. The level is kept in most species till 17:00. The sequence forms an indistinct unimodality or rather a plateau with fluctuation. The clear peak is relatively rare, found at or near noon on relatively cool days. Activity of most species rapidly decreases when temperature lowers to 22°C and ceases nearly completely at 16°C. The high temperature inhibition is occasionally observed at temperature higher than 27°C. It is difficult to separate the effect of radiation from that of temperature, but on cloudy days, flies are less active than on fine days even if air temperature does not differ. The gentle breeze does not affect much the activity but wind stronger than moderate breeze disturbs the flight activity so that the number on and around cows is always small under strong wind.

The active season of horse-flies in the area studied begings in June by the appearance of *C. japonicus* and flies increase remarkably in late July to early August with the highest number of species and individuals. The end of active period of most species was distinctly earlier in 1970. Naturally the length of active period may be determined by the interaction of many factors so that the conspicuous difference between the two years is not sufficiently explained. But rapid decrease of flies in 1970 might partly be explained by the high thermal condition during active period, (in 1969 summer temperature was remarkably lower than in 1970, especially in August), which released more intense blood sucking activity and resulting earlier consumption. In addition the possible influence of a typhoon passed through Sapporo on August 16, 1970 is not excluded as to the earlier cessation of activity in this year.

The whole activity of a given population cannot be clarified by the observation on blood sucking activity alone. In the present study, however, increase of blood sucking of *T. nipponicus* is nearly sychronized with the emergence of pupae. On the other hand, the presence of some fresh individuals and old larvae throughout the active blood sucking period suggests that a continuous supply of some newly emergence adults, though the peak of emergence is in mid or late July.

Summary

Some bionomic observations were made on horse-flies at pastures in Hokkaido National Agricultural Experiment Station in 1969 (from June 27 to September 19) and 1970 (from April 24 to September 9). The results are summarized as follows:

1. Thirteen species were recorded in the area studied. Among them, *Tabanus nipponicus* Murdoch et Takahasi was absolutely dominant, occupying 72% of total individuals censused. *Tabanus rufidens* (Bigot) (11%), *Atylotus horvathi* (Szilady) (4%) and *Chrysops suavis* Loew (2%) were also abundant, while other species were recorded only sporadically.

2. Daily blood sucking activity was rather unimodal in most species even on hottest days, though probable inhibition by high temperature and bimodality was occasionally observed in August. The responses to temperature and radiation were quite complicated so that the higher limits of the optimum ranges were difficult to determine. All species were completely inactive below 16°C.

3. The tabanid blood sucking in the area studied begins in June by the appearance of *Chrysops japonicus* Wiedemann and *Hybomitra arpadi* (Szilady) and ceases in mid September by the disappearance of *T. nipponicus* with the peak in late July both in species and individuals. According to the observation in 1970, pupation and emergence of *T. nipponicus* begin in mid June and late June respectively.

References

Abe, N., Murai, S. & T. Ishikawa 1955. Studies on the control of the blood-sucking insects attacking to the domestic animals in the alpine region (1). Especially on the distribution, condition of the occurrence and activities of the blood-sucking insects. Yamagata Norin Gakkaihô **8**: 23–33. (In Japanese with English summary).

Harakawa, T. & T. Yajima 1956. Study of tabanid flies attacking cows and their phenology. Chikusan no Kenkyû **10**: 591–593. (In Japanese).

Hasegawa, T. & T. Chiba 1970. The fauna and the seasonal occurrence of tabanids attacking cattle in Iwate Prefecture. Report from the Iwate-Ken Agricultural Experiment Station **14**: 125–141. (In Japanese with English summary).

Hukushima, S. 1963. Tabanid flies at Iwai farm in Gifu Prefecture. Nihon Kontyû Gakkai Tôkai Shibuhô **15**: 7–11. (In Japanese).

Kato, M., Matsuda, T. & Z. Yamasita 1952. Associative ecology of insects formed in the paddy field cultivated by various planting forms. Sci. Rep. Tôhoku Univ. IV. Biol. **19**: 291–301.

———, ———, Nakamura, K. & K. Chiba 1965. Ecological studies on blood sucking insects on grazing cattles. Sôchi Sôgô Kenkyû, Tôhoku University, Sendai 45–64. (In Japanese).

Kôno, H. & H. Takahasi 1940. Study of horse-flies bothered the construction of railway in Oshima penninsula. Jap. J. Appl. Zool. **12**: 21–29. (In Japanese).

Kurosaki, Z., Tamate, H. & S. Iizumi 1958. On the relationship between grazing habits and vegetation of grassland. Part 5. Grazing habits and blood sucking insects. Sci. Rep. RITU. **10**: 213–223. (In Japanese with Engilish summary).

Murdoch, W. P. & H. Takahasi 1969. The female Tabanidae of Japan, Korea and Manchuria. Mem. Ent. Soc. Washington. **6**: 1–230.

Nagasawa, S. 1967. Seasonal prevalence of horse-flies attacking cattles. Jap. J. Sanit. Zool. **18**: 259–268. (In Japanese with English summary).

Ôtsuru, M. & Y. Saito 1956. Some observations of Tabanidae in Niigata Prefecture. *Ibid.* **7**: 63–68. (In Japanese with English summary).

———, ———, Ômori, Y., Saito, S., Mizuno, S. & H. Abe 1965. The breeding places and some habits of the mountainous tabanid flies (Diptera: Tabanidae). *Ibid.* **16**: 123–132. (In Japanese with English summary).

Sasakawa, M., Yoshida, A., Oibe, A. & K. Nagano 1968. Study on bionomics and control of horse-flies attacking the grazing cattle (1). Diurnal biting activity and habitat segregation of the horse-flies. Jap. J. Appl. Ent. Zool. **12**: 181–188. (In Japanese with English summary).

Satô, M., Ono, Y., Yanagawa, S. & The Nenoshiroishi Agr. Co-op. 1962. Studies on the ectoparasites on grazing cattle. Part I. Bloodsucking insects attacking cattle grazed in the pasture of the Nenoshiroishi Agricultural Cooperation. (1). Sci. Rep. Miyagi Agr. Coll. **10**: 68–72. (In Japanese with English summary).

Shimizu, A., Kurashima, H., Shinohara, S., Asakawa, F., Yamaguchi, Y. & G. Kiso 1966. Ecological studies of horse-flies (Tabanidae Diptera) in the Karuizawa Highland (2). On the seasonal prevalence of the adult horse-fly from Karuizawa (Nagano Prefecture). Karuizawa Kyôiku Iinkai 62p. (In Japanese with English summary).

Takahasi, H. 1962. Fauna Japonica Tabanidae (Insecta: Diptera). Tôkyô Electrical Engineering College press. Tôkyô 143p. and 12 plates.