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Geographical Trends in the Abundance of Tabanids in Japan (Diptera, Tabanidae)

Takeshi MATSUMURA

Laboratory of Insect Systematics, National Institute of Agro-Environmental Sciences, Kannondai, Tsukuba, 305 Japan

and

Hirofumi HAYAKAWA

Tohoku National Agricultural Experiment Station, Morioka, 020–01 Japan

Abstract Geographical trends in the relative abundance of Japanese tabanids were analyzed by comparing 44 localities on the Japanese Main Islands. Three major zones were distinguished: (1) Hokkaido dominated by *T. nipponicus* or *Haematopota tristis*, (2) Tohoku and Kanto dominated by *T. nipponicus* or *Hirosia humilis*, and (3) S. W. Honshu along the Japan Sea with a predominance of *T. trigeminus*.

Introduction

The Japanese tabanid fauna was elucidated in two taxonomic revisions, those of TAKAHASI (1962) and MURDOCH and TAKAHASI (1969). By the subsequent addition of several new species, 103 forms including nine subspecies are recorded from Japan according to the checklist by HAYAKAWA (1985).

Reports on localized tabanid fauna by periodical surveys have been documented recently in various areas of Japan. MATSUMURA and ITO (1985) compared qualitatively the total number of tabanid species and their relative abundance at 26 pastures throughout Japan, and presented a preliminary outline of the geographical distribution of Japanese Tabanidae. To have a more accurate picture on the faunistic structure of Japanese tabanids, it is necessary to compare the tabanid assemblages in more localities both quantitatively and qualitatively. In the present study, 44 localities where tabanid assemblages were periodically collected are compared.

Methods

A total of 44 localities were selected from Hokkaido (12), Honshu (28), Shikoku (2) and Kyushu (2). In all these localities periodical surveys were carried out throughout the tabanid active season or at least for the peak months of July and August. The localities are shown in Table 1, together with habitats, altitudes, sampling methods and authorities, and are mapped in Fig. 1.

Habitats were roughly divided into four categories: mountains (M), hills (H), valleys (V) and plains (P). Among sampling methods, net-collection on cattle (S) was the most preferred, followed by CO_2 trapping (T). Counting on cattle (C) was employed only at Wassamu and Tsukisappu and collecting at cow-shed windows (W) only at Kouzu Pasture.

As an estimate for the relative diversity of each local tabanid assemblage, SIMPSON's index of concentration was calculated (SIMPSON 1949, cf. KIMOTO 1976):

$$\Sigma\Pi^2=\sum_{i=1}^{S}\left(\frac{n_i}{N}\right)^2, \qquad 0\leqq\Sigma\Pi^2\leqq 1$$

where N is the total number of individuals sampled and n_i the individual number of species i.. $\Sigma\Pi^2$ approaches 1.0 at higher relative abundance of a particular species

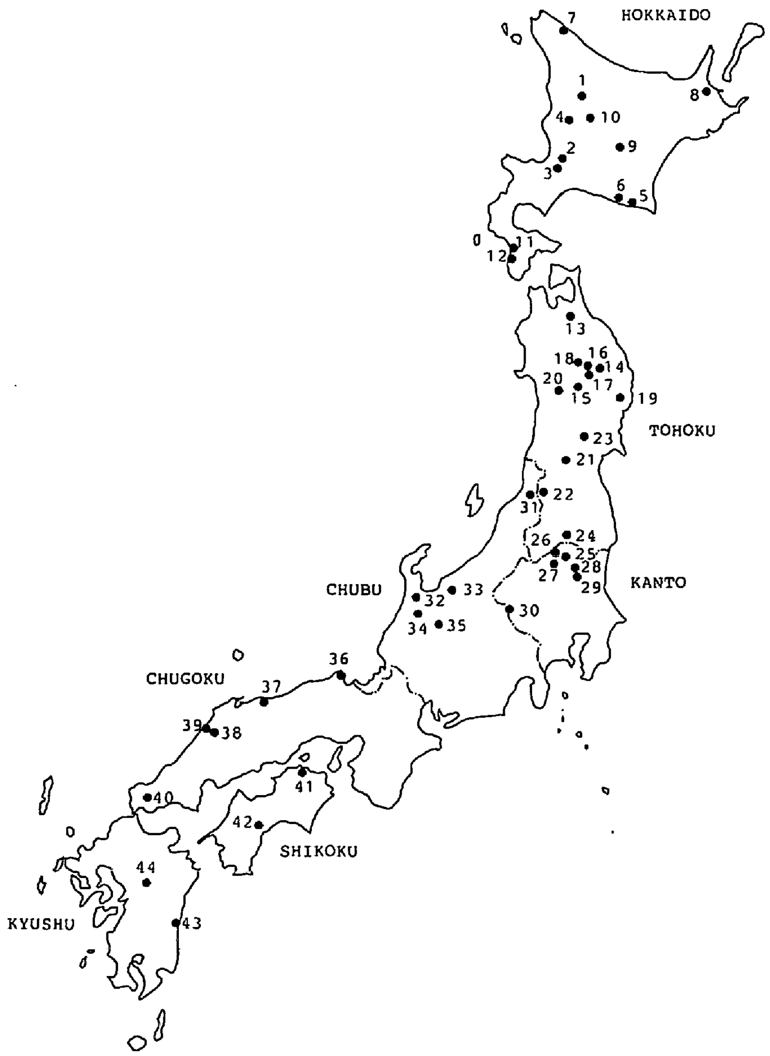

Fig. 1. Map of 44 localities of which local tabanid assemblages were compared.

Table 1. Localities surveyed for tabanid faunas.

No.	Locality (Prefecture)	Latitude (N)	Habitat*	Altitude (m)	Method**	Authority
01	Wassamu (Hokkaido)	44°00′	H	250	T·C	INAOKA *et al.* (1982)
02	Ebetsu (〃)	43°05′	P	50	S	INAOKA and MATSUDA (1983)
03	Tsukisappu (〃)	43°00′	H	100	T·C	INAOKA (1971)
04	Takikawa (〃)	43°35′	H	100	S	SARASHINA and KUDO (1982)
05	Urakawa (〃)	42°15′	V	90	T	HAYAKAWA *et al.* (1988)
06	Shizunai (〃)	42°20′	H	100	T	INAOKA (unpubl.)
07	Hamatonbetsu (〃)	45°10′	P	40	S	SARASHINA and KUDO (1982)
08	Nakashibetsu (〃)	43°30′	H	60	S	〃
09	Shintoku (〃)	43°05′	H	260	S	〃
10	Biei (〃)	43°35′	M	840	S	〃
11	Esashi (〃)	41°52′	M	165	S	〃
12	Kaminokuni (〃)	41°47′	H	160	S	〃
13	Shichinohe (Aomori)	41°42′	H	100	T	HAYAKAWA and MATSUMURA (1975)
14	Sotoyama (Iwate)	39°45′	M	700	T	HAYAKAWA (1975)
15	Sawauchi (〃)	39°32′	M	500	S	HASEGAWA and CHIBA (1970)
16	Takizawa (〃)	39°46′	P	260	S	〃
17	Morioka (〃)	39°44′	P	170	S	HAYAKAWA (1980)
18	Nishine (〃)	39°52′	M	550	S	〃
19	Goyosan (〃)	39°11′	M	500	T	〃
20	Kamioka (Akita)	39°30′	P	40	S	Iwate Pref. Anim. Husb. Exp. St. (1975)
21	16 pastures (Yamagata)	38°–39°	H.P	300–900	S·T	SHIBATA *et al.* (1984)
22	Oguni (〃)	38°00′	V	300	T	NAGASHIMA *et al.* (1972)
23	Kawatabi (Miyagi)	38°45′	M	500	S	KUROSAKI *et al.* (1958)
24	Nishigo (Fukushima)	37°10′	H	600	T	MORIYAMA (1978)
25	Nishinasuno (Tochigi)	36°55′	P	300	S	ITO *et al.* (1982)
26	Hachirogahara (〃)	36°56′	M	900	T	MATSUMURA and ITO (1985)
27	Dojodaira (〃)	36°52′	M	900	S·T	SHIMOZAKI *et al.* (1986)
28	Haga (〃)	36°34′	P	110	S·T	〃
29	Minaminasu (〃)	36°40′	H	170	S·T	〃
30	Kouzu (Gunma)	36°15′	M	1000	W	NAGASAWA (1967)
31	Shibata (Niigata)	37°55′	H	150	S	HAYAKAWA (1986)
32	Inabayama (Toyama)	36°43′	H	300	S	WATANABE *et al.* (1973)
33	Niikawa Pasture (〃)	36°50′	H	200	T	〃
34	Fukumitsu (〃)	36°25′	V	360	T	KAMIMURA *et al.* (1971)
35	Takayama (Gifu)	36°08′	M	1300	S	HUKUSHIMA and TAKADA (1973)
36	Ikari (Kyoto)	35°43′	M	400	T	Kyoto Pref. (1979)
37	Akasaki (Tottori)	35°25′	P	50	S	HAYAKAWA (1981)
38	Sambe (Shimane)	35°29′	M	400	S	HARA and IWATA (1974)
39	Ohda (〃)	35°07′	H	100	S	HAYAKAWA and WATANABE (1980)
40	Mine (Yamaguchi)	34°10′	H	150	S	HAYAKAWA (1981)
41	Miki (Kagawa)	34°17′	P	50	S	YAMAGAMI (1973)
42	Sagawa (Kochi)	33°30′	M	150	S	HAYAKAWA *et al.* (1979)
43	Kawaminami (Miyazaki)	32°15′	P	50	S	HAYAKAWA (1981)
44	Aso (Kumamoto)	32°53′	M	550	S	HAYAKAWA (1981)

* M, Mountain; H, Hill; V, Valley; P, Plain

** S, Net-collection on cattle; T, Trapping baited with CO_2; C, Counting on cattle; W, Collecting at windows within a cow-shed.

while approaching 0.0 when the community lacks conspicuously predominant species.

Because the sampling methods, frequency and total time of collecting differed among localities, the tabanid assemblages of any two localities were compared with KIMOTO's modification of MORISITA's index which measures similarity between communities. It allows comparison between communities where total numbers of individuals are quite different (KIMOTO, 1967, cf. KIMOTO, 1976):

$$C\pi = \frac{2\sum_{i=1}^{S} n_{1i} \cdot n_{2i}}{(\Sigma\Pi_1^2 + \Sigma\Pi_2^2)N_1 \cdot N_2}, \qquad 0 \leqq C\pi \leqq 1$$

where N_1 and N_2 are the total number of individuals collected in localities 1 and 2 respecitively, and n_{1i} and n_{2i} are the individual number of species i collected in localites 1 and 2. $\Sigma\Pi_1^2$ and $\Sigma\Pi_2^2$ are Simpson's indices of concentration for both localities which approaches 1.0 when the species composition is similar in the two localities. Based upon KIMOTO's index, a matrix was drawn comparing the 44 localities surveyed.

Results

Table 2 shows the total numbers of both species and individuals, Simpson's index of concentration and the pre-dominant species of each locality. The total number of species was richest in Sawauchi (36 spp.), followed by Sotoyama (32 spp.), and Shichinohe and Kouzu (both 29 spp.). On the contrary, it was poorest in Aso (4 spp.), and Akasaki and Miki (both 6 spp.). It is impossible to compare the total number of collected individuals among areas due to the differences in sampling methods and total time spent.

By means of SIMPSON's index of concentration, we can estimate aspects of the species composition of each locality. The remarkably high values in Fukumitsu (0.954) and Oguni (0.816) are the result of outbursts of *Hirosia iyoensis* which absolutely surpassed other species, as did *Haematopota tristis* in Hamatonbetsu (0.941). The areas with lower index values, lowest in Goyosan (0.139), have complicated tabanid fauna showing the coexistence of many species.

Comparison of top-ranked species also showed some local characteristics. *Tabanus nipponicus* exceedingly dominated 16 localities of Hokkaido, Tohoku and Kanto Districts, and was fairly high-ranking at eight other localities in these three districts. *T. trigeminus* was the most dominant species in nine localities mainly along the coast of the Japan Sea in Honshu, *Hi. humilis* dominated in seven localities in Tohoku and Kanto, *Ha. tristis* in three localities in Hokkaido, and *Hi. iyoensis* in two localities in Honshu.

Table 3 shows the means of the number of species and Simpson's indices in respective districts. The mean number of species decreases in the order of

Table 2. Number of species and individuals collected, and predominant species of tabanid fauna at various localities.

No.	Locality	Total No. of species	Total No. of individuals	Simpson's index	Relative abundance*
01	Wassamu	12	2,264	0.261	TN>TG>(TC)
02	Ebetsu	13	2,708	0.511	TN>TR
03	Tsukisappu	13	11,584	0.549	TN>TR>AH
04	Takikawa	14	24,008	0.579	TN>TK
05	Urakawa	18	2,709	0.360	TN>TC>(TT)
06	Shizunai	19	4,663	0.287	TN>TC>(TT)
07	Hamatonbetsu	9	757	0.941	HAT
08	Nakashibetsu	8	430	0.462	HAT>TN
09	Shintoku	9	478	0.730	TN
10	Biei	15	256	0.169	HAT>TC
11	Esashi	13	434	0.177	TN>TR>CJ
12	Kaminokuni	12	334	0.309	TN>TR>(TF)
13	Shichinohe	29	3,023	0.326	TN>HH>(TF)
14	Sotoyama	32	2,557	0.381	HH>TN
15	Sawauchi	36	1,351	0.164	HH>TG>TS>TC>TN
16	Takizawa	14	761	0.259	TN>HH>AH
17	Morioka	27	1,450	0.265	TN>HH>TF
18	Nishine	27	631	0.229	HH>HJ
19	Goyosan	20	1,465	0.139	HH>TN>HS
20	Kamioka	24	1,304	0.242	TN>AH>TG
21	Yamagata	21	3,507	0.222	TG>TC>TR
22	Oguni	24	3,903	0.816	HI
23	Kawatabi	14	537	0.413	TC>TG
24	Nishigo	9	90	0.439	HH>TN=TC
25	Nishinasuno	12	2,264	0.492	TN>AB
26	Hachirogahara	20	3,802	0.574	TN>(TC)>(TR)
27	Dojodaira	13	1,589	0.399	TN>HH>TR
28	Haga	12	543	0.180	HH>AB>TK>TN
29	Minaminasu	10	173	0.198	TG>TN>TK>TR
30	Kouzu	29	4,562	0.215	HH>HAR>TN
31	Shibata	10	458	0.360	TG>TT>(TK)
32	Inabayama	10	1,196	0.363	TG>TC
33	Arakawa	7	655	0.722	TG>(TR)>(TT)
34	Fukumitsu	10	10,004	0.954	HI
35	Takayama	14	161	0.303	TG>HH>TC
36	Ikari	20	10,550	0.458	TG
37	Akasaki	6	19	0.230	TF>AB
38	Sambe	19	3,908	0.184	AB>TG>TK
39	Ohda	19	756	0.225	TG>AB>TC
40	Mine	13	206	0.247	TW>AB
41	Miki	6	65	0.725	AH>TT
42	Sagawa	10	69	0.388	CJ>AB
43	Kawaminami	8	43	0.236	TC>TG>TT=TR
44	Aso	4	21	0.492	AB>TT

* The dominant species representing more than 10% of total individual number are cited, and those less than 10% are shown in parentheses.

AB, *Atylotus bivittateinus*; AH, *At. horvathi*; CJ, *Chrysops japonicus*; HAR, *Haematopota rufipennis*; HAT, *Ha. tristis*; HH, *Hirosia humilis*; HI, *Hi. iyoensis*; HS, *Hybomitra jersey*; TC, *Tabanus chrysurus*; TF, *T. fulvimedioides*; TG, *T. trigeminus*; TK, *T. kinoshitai*; TN, *T. nipponicus*; TR, *T. rufidens*; TT, *T. trigonus*; TW, *T. taiwanus*; TS, *T. sapporoenus*.

Table 3. Number of species and Simpson's index of tabanid fauna in respective districts, shown by mean values with SD.

District	No. of areas	No. of species	Simpson's index
Hokkaido	12	12.9±3.4	0.445±0.232
Tohoku	12	23.1±7.9	0.325±0.181
Kanto	6	16.0±7.2	0.343±0.169
Chubu	5	10.2±2.5	0.540±0.285
Kinki·Chugoku	5	15.4±5.9	0.269±0.108
Kyushu·Shikoku	4	7.0±2.6	0.460±0.205
Mean		15.5±7.6	0.390±0.210

Tohoku > Kanto > Kinki·Chugoku > Hokkaido > Chubu > Kyushu·Shikoku, whereas the mean of Simpson's indices increases in the order of Kinki·Chugoku < Tohoku < Kanto < Hokkaido < Kyushu·Shikoku < Chubu. These two orders show

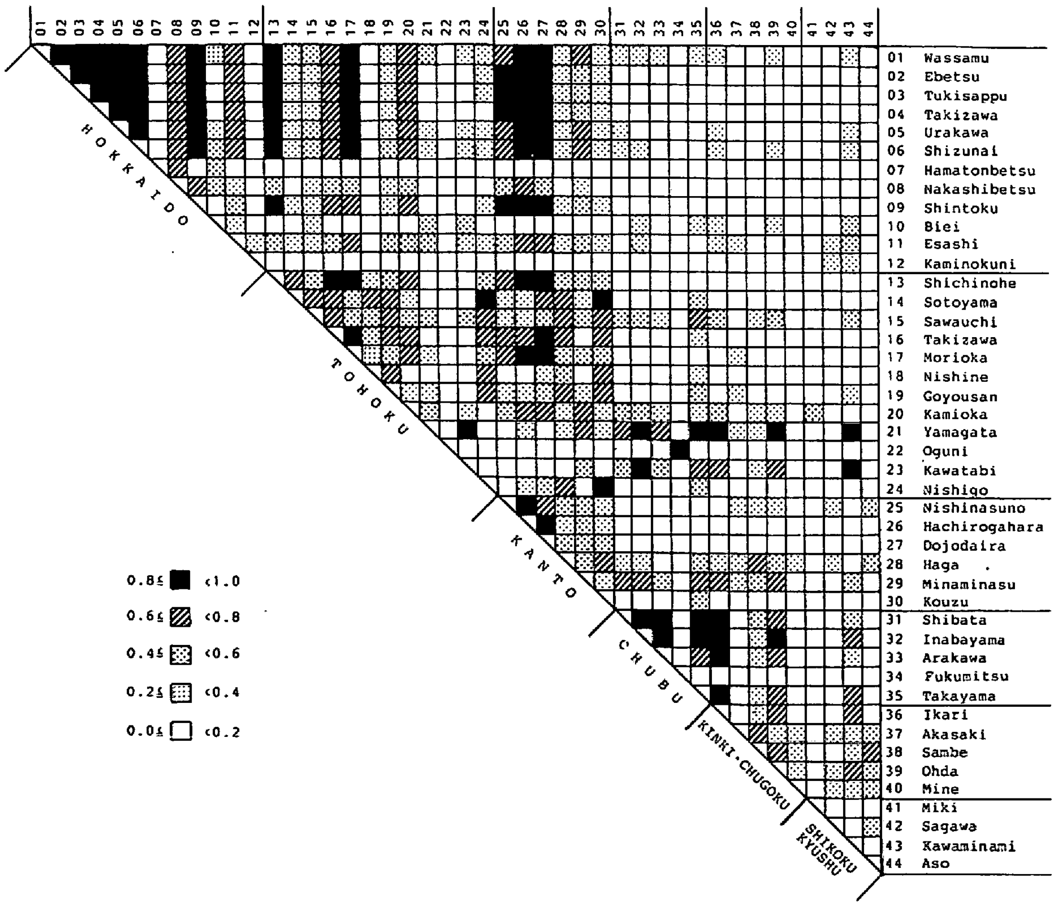

Fig. 2. Matrix of KIMOTO's index measuring similarity among tabanid assemblages of 44 localities in Japan.

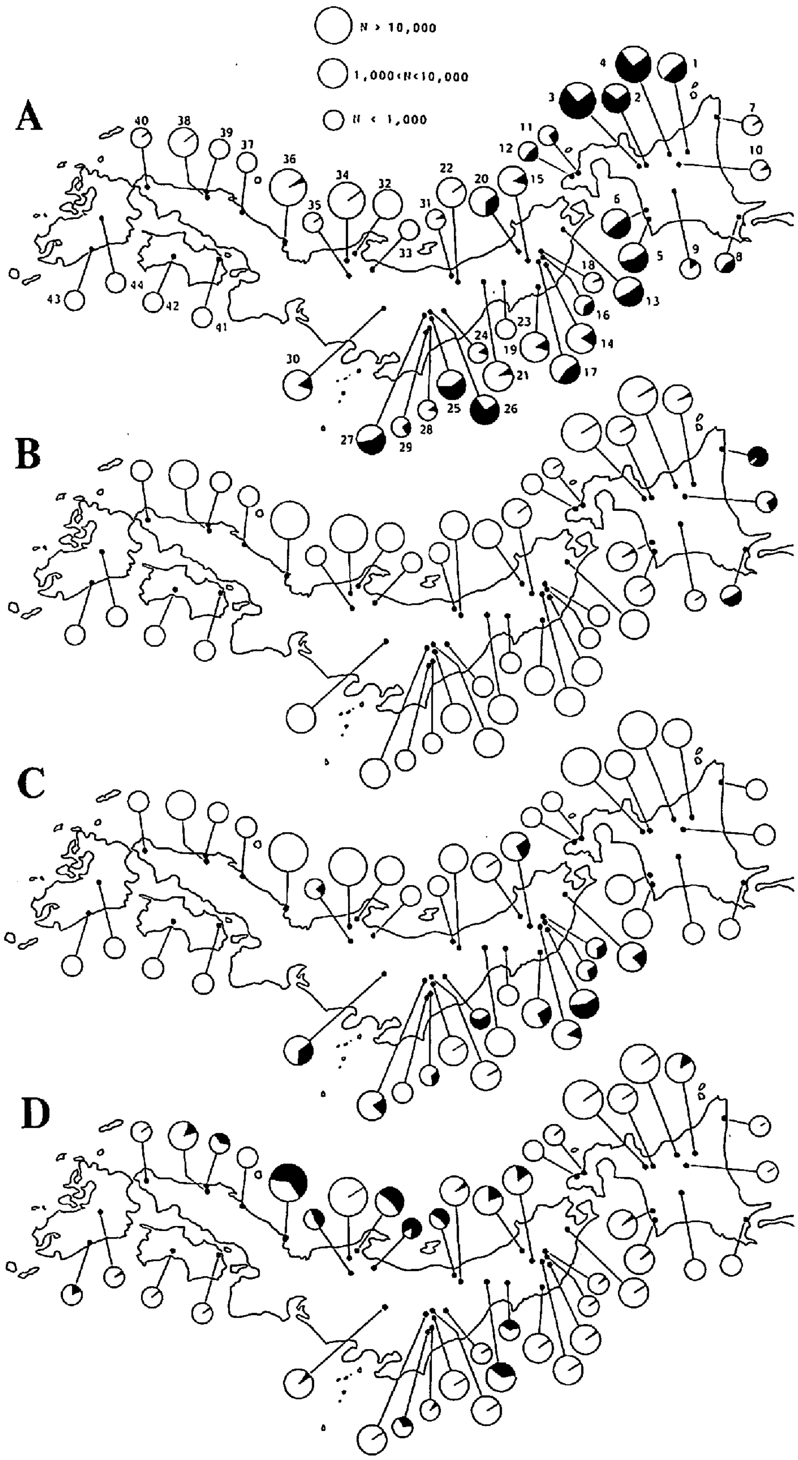

Fig. 3. Relative abundance of four tabanid species at various localities. A: *Tabanus nipponicus*, B: *Haematopota tristis*, C: *Hirosia humilis*, D: *Tabanus trigeminus*. Numerals represent local numbers in Table 1 and Fig. 1.

that Tohoku district is the richest biofaunistically, followed by Kinki·Chugoku, Kanto, Hokkaido, Chubu and Kyushu·Shikoku.

Figure 2 shows the similarity matrix of all localities studied, composed using KIMOTO's index which measures similarity. Obviously the value tends to be higher between localities within the same district, especially in Hokkaido and Chubu.

In Hokkaido, seven localities (Wassamu, Ebetsu, Tsukisappu, Takikawa, Urakawa, Shizunai and Shintoku) in which *T. nipponicus* predominated were highly similar to one another, while three localities (Hamatonbetsu, Biei and Kaminokuni) differed from one another and also from other areas. It is in-

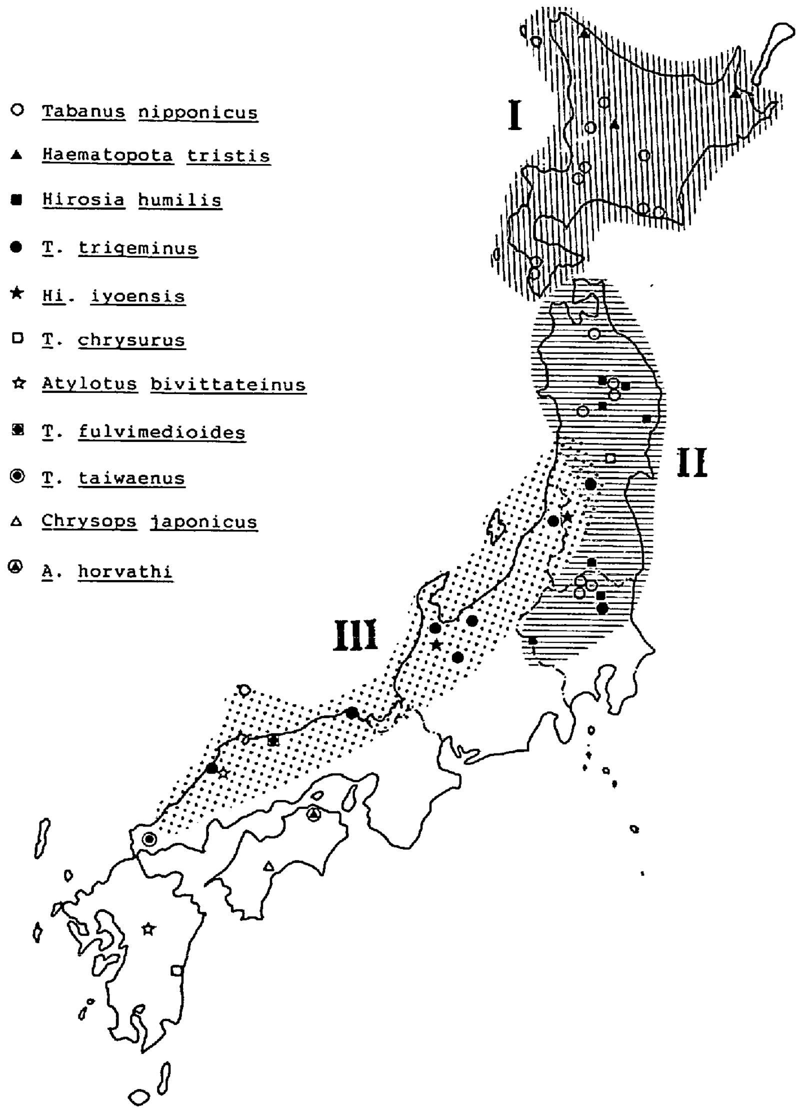

Fig. 4. Top-ranked species at 44 localities and three zones dominated by (I) *T. nipponicus* or *Ha. tristis*, (II) *T. nipponicus* or *Hi. humilis*, and (III) *T. trigeminus*.

teresting that two localities in Tohoku (Shichinohe and Morioka) and three localities in Kanto (Nishinasuno, Hachirogahara and Dojodaira) resembled, to a remarkable degree, the above seven localities in Hokkaido, due to the predominance of *T. nipponicus*. Five areas in Chubu resembled one another, all dominated by *T. trigeminus*. Yamagata as well as Kawatabi in Tohoku were very similar to some areas in southwestern Japan such as Inabayama, Takayama, Ikari, Ohda and Kawaminami in the abundance of *T. trigeminus* and *T. chrysurus*. Oguni and Fukumitsu closely resembled each other but differed from all other localities. Both areas are located in mountainous valleys and dominated by *Hi. iyoensis*, a species well known for its sporadic outbursts.

Figure 3 shows the relative abundance of four important species in the tabanid assemblages of various localities. The geographical predominance of each species is obvious: *T. nipponicus* in Hokkaido, Tohoku and Kanto (A), *Ha. tristis* in eastern Hokkaido (B), *Hi. humilis* in Tohoku and Kanto (C), and *T. trigeminus* in southwestern Honshu (D).

Discussion

From Fig. 4, which shows the dominant species at each locality, the geographical trends of the predominant tabanid species in the main islands of Japan can be visualized with the differentiation of three zones: (1) Hokkaido, dominated by *T. nipponicus* or *Ha. tristis*, (2) Tohoku and Kanto, dominated by *T. nipponicus* or *Hi. humilis*, and (3) southwestern Honshu mainly along the Japan Sea including the southwestern part of Tohoku, predominated by *T. trigeminus*. The local abundance of certain species was not shown in Kyushu and Shikoku. The data of other areas in southern Japan are still insufficient, especially in the Pacific coast of S. Honshu and Nansei Islands, requiring further surveys in the future.

Inaoka (1975) suggested that the tabanid assemblage in Hokkaido is gradually changing due to the progress of ruralization from the forest-eurytopic species complex dominated by *Ha. tristis* to the openland-eurytopic species complex dominated by *T. nipponicus*. *Ha. tristis* is autogenous but *T. nipponicus* is anautogenous (Hayakawa, 1980). *Ha. tristis* must have been abundant in Hokkaido in former times. It is conceivable that increased blood-sucking resources accelerated a gradual displacement of autogenous species by anautogenous ones, with the introduction of domestic animals and advanced ruralization.

Hi. humilis is anautogenous (Hayakawa, 1980), and could be regarded as a forest species as the larva inhabits the forest floor. In the mountains of northern Honshu, *Hi. humilis* must have prospered with the development of pastures, as did *T. nipponicus* in the plains with the introduction of domestic animals. However, it is difficult to specify the original occupant species in Tohoku and Kanto.

Predominance of *T. nipponicus* in western Hokkaido and of *Ha. tristis* in eastern Hokkaido must be caused by a difference in cold resistance and ambient factors between both species. Overwintering larvae in the soil may be protected from the coldness by thick snow cover in the former area, while those in the latter may be exposed to severe freezing by thin snow cover. Three predominant species in northern Japan, *T. nipponicus, Ha. tristis* and *Hi. humilis*, are terrestrial as larvae. On the other hand, southwestern Honshu with a predominance of *T. trigeminus*, whose larva is hydrophilous, is characterized by an abundant quantity of precipitation in the way of moist and thick snow cover in winter. The relationship between biogeography and over wintering habits of tabanids is a interesting problem.

The number of tabanid species was highest in the localities of Tohoku District while less in Kyushu and Shikoku. Species composition reflects the larval habitats in and near the localities surveyed. The richness of tabanid fauna in Tohoku seems to rely upon more diverse and complicated habitats surrounding the pastures of this district, like marshs, streams, ponds, forests, valleys and mountains.

The bionomics and ecology of important tabanid species must be clarified extensively in the future.

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