Notes on the Methods of Belt Transect Census of Butterflies

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(With 3 Text-figures and 6 Tables)

Following a previous report on the faunal makeup and phenology of butterfly assemblage at Jozankei (Yamamoto 1974), the present paper deals with some technical problems to be resolved for an objective apprehension of the local butterfly fauna by adopting the belt census survey, especially: 1) Possible discrepancy of the results due to personal differences among observers, which may, if considerably large, invalidate a comparison of the results obtained. 2) Possible biases caused by different observation time within a day, which may, if considerable, require some adjustments as to standardization for a reliable comparison.

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Methods

The survey area is the same to that reported previously, the roadsides at Jozankei in the suburbs of Sapporo City, the ecological and topographical conditions of which were described in Yamamoto (1974). As in the previous survey, any individuals of any species on the wing or at rest found within 10 m wide of both sides of the road were registered without collecting. Certain species difficult to identify at distance were captured and liberated after identification (*Pieris napi*, *P. melete*, *P. rapae* and some small lycaenid species of the genus *Favonius*). The procedures particular to the present study are:

1) Two observers, Mr. M. Ito and M. Yamamoto[1] registered all observed butterflies by walking the same route, B～C (cf. Yamamoto *op. cit.*), synchronously or with a slight delay, in both cases without communicating for each other. The results were summed up for each subdivision (Ba, Bb, Bc, Bd, Be, Bf and Bg). This census was carried out twice in case of synchronous survey and six times with a slight delay between observers from 10:00～16:40, 20th July, 1973. Some additional remarks on the procedures will be given in respective sections.

2) Six censuses (at 7:30, 9:10, 10:30, 12:30, 14:30 and 16:00) per day were repeated fifteen times from May to September, 1973.

The forms censused are cited by the specific names alone. The details on the faunal makeup is consulted for Yamamoto (*op. cit.*). New additions to the previous result are:

Pieridae *Anthocalis scolymus* (Butler).

Nymphalidae *Limenitis populi jezoensis* Matsumura, *Neptis philyra excellens* Butler, *Nymphalis xanthomelas japonica* (Stichel).

Lycaenidae *Artopoetes pryeri pryeri* (Murray), *Antigius attilia* (Bremer), *Chrysozephyrus aurorinus* (Obertür), *Strymonidia w-album fentoni* (Butler), *Plebejus argus pseudaegon* (Butler), *Everes argiades hellotia* (Ménétriès).

Hesperiidae *Erynnis montanus* (Bremer), *Polytremis pellucida* (Murray).

Results and Discussions

Results are divided into two parts, possible influences of personal difference between observers and of difference due to diurnal rhythm upon the census results. Some related discussions are given in each section.

1. Influence of personal difference between observers

The different results between two given surveys on the quantitative makeup of local butterfly assemblages are regarded as a combined outcome of A). real faunistic difference and B). various factors affecting the survey, for instance, weather conditions, survey schedules, personal difference between observers, etc. The real faunal difference is obtained only by eliminating the influence of the factors enumerated under B. As a step towards this final aim, the influence of personal difference is examined here.

1.1 *Comparison of two censuses made synchronously by two observers*: Table 1 compares the results of synchronous observation obtained by MI and MY. The recorded individual number of each species are shown for each of seven subdivisions, combining two trials.

1.1.1. *Number of species*: MY confirmed 27 species in addition to one

1) Henceforth abbreviated as MI and MY, also to designate census made by them.

unidentified *Argynnis* species while MI 25 species with two unidentified nymphalid ones. Among 28 confirmed species in total, only four species were registered by one of two observers alone, *Harima callipteris*, *Celastrina argiolus* and *Ochlodes venata* by MY and *Neptis philyra* by MI, all were so few in number and found only at one subdivision or two that they must have escaped from discovery. Distance of resemblance (Distance index=DI) between the two different results, A and B, is calculated by the formula,

$$\mathrm{DI} = \sqrt{\frac{\Sigma (f_{iA} - f_{iB})^2}{T}}$$

where f_{iA} and f_{iB} are the value of species i in results A and B, taking either 1 (=presence) or 0 (=absence) and T is total number of species. The numerator is therefore equal to the root of number of species registered only in one of both results. The value of DI ranges from 0 when all species represented in both results to 1 in the absence of any common species. In the present case the value takes 0.378, implying a fairly good similarity between the two results.

1.1.2. *Number of individuals*: The departure between two results as to the individual number registered for each species was evaluated by using Chi-square values. The results were regarded as homogeneous when the value equal to or exceeding $\chi^2=0.148$ (p=0.70, d.f.=1), while heterogeneous equal to or below $\chi^2=3.841$ (p=0.05, d.f.=1). The results were judged as undetermined for the probability range 0.70～0.05, assuming the possible chance fluctutation of personal registration. In total individual numbers, the Chi-square value for two results was 0.4989 ($0.50>p>0.30$, d.f.=1), suggesting no significant difference. Nextly, the departure in individual number for each species was analized by Chi-square value for the species represented by five individuals or more and by comparing the actual recorded number of individuals for the species with less than five individuals. A good homogeneity between two results was recognized in 15 out of 28 species, *Pieris napi*, *P. rapae*, *Colias erate*, *Lethe diana*, *Coenonympha hero*, *Aglais urticae*, *Apatura ilia*, *Araschnia burejana*, *A. levana*, *Polygonia c-album*, *P. vau-album*, *Ladoga camilla*, *Japonica lutea*, *Strymonidia w-album* and *Plebejus argus*, consisting 9 out of 16 medium sized species, 3 out of 5 small ones (*Coenonympha hero*, *Neptis rivularis*, *Araschnia burejana*, *A. levana* and *Bibasis aquilina*) and 3 out of 6 dwarf ones (*Japonica lutea*, *Strymonidia w-album*, *Celastrina argiolus*, *Plebejus argus*, *Thoressa varia* and *Ochlodes venata*).

The homogeneity of distribution along the survey route was examined, though not free from subjective judgement, by comparing the actual individual number among seven subdivisions. A good homogeneity on the distribution pattern among subdivisions was obtained in one large species (*Papilio bianor*), 12 out of 16 medium species, 3 out of 5 small ones and 2 out of 6 dwarf ones. From both distribution pattern and total individual number, it is likely that dwarf butterflies are apt to escape from registration. Exceptionally, two dwarf species with a high

Table 1. Species and recorded individual number for each subdivision of the survey
dividual number is shown by χ^2-values and homogeneity in distribution pattern (#:
fied into four types (L: large, M:

Observer		MY							
Species \ Subdivision	Size	Ba	Bb	Bc	Bd	Be	Bf	Bg	T
Papilio bianor	L					3			3
Aporia crataegi	M	1			1				2
Pieris rapae	M	1	1						2
P. napi	M	5	6	4	2	11	17		45
Colias erate	M	2				2	1		5
Lethe diana	M	2	4	8		2		3	19
Neope goschkevitschii	M		1	1		1			3
Harima callipteris	S			2					2
Coenonympha hero	M					1			1
Aglais urticae	M	6	7	2	1	10	16		42
Apatua ilia	S	5	1	1					7
Araschnia burejana	S		1	2		2	1		6
A. levana	M	1					1		2
Ladoga camilla	M						1		1
Polygonia c-album	M						1		1
P. vau-album	M					2			2
Neptis rivularis	S			1	1	1			3
N. philyra	M								
Argynnis paphia	M		2			1			3
Speyeria aglaia	M		2	1		1			4
Brenthis ino	M		4	1	2	8	8		23
Japonica lutea	D			1	1	1	1		4
Strymonidia w-album	D			1					1
Celastrina argiolus	D			1					1
Plebejus argus	D					1	1		2
Bibasis aquilina	S	1	11	3	5	3	2		25
Thoressa variao	D	6	1	2	1	2	3		15
Ochlodes venata	D		2	1					3
Argynnis sp.			3			2	1		6
Nymphalidae ?									
Total		30	46	32	14	54	54	3	233
p (from $\chi^2_{(1)}$)			> 0.30	> 0.70	> 0.80	> 0.50	> 0.70	> 0.30	

sedentariness, *Japonica lutea* and *Strymonidia w-album*, show both a good homogeneity between two census results. This may increase the chance of registration of the same individuals by both observers but the duplicate registration of the same individuals either by MI or MY is less probable. In large (1), medium (11/16), and small species (3/5) prefering roadsides and open places, too, the chance of duplicate registration by both observers may be high by their conspicuousness, and route censused synchronously by two observers. Similarity between a pair of in- very similar, +: similar, ±: undetermined, —: uneven). Size of each butterfly classi- medium, S: Small, D: dwarf).

$\chi^2_{(1)}$	Homogeneity in distribution pattern	MI							
		Ba	Bb	Bc	Bd	Be	Bf	Bg	T
	+					2			2
	+				1				1
	⧺	1	1						2
0.103 p>0.70	+	4	6	4	4	11	13		42
	⧺	2				2	1		5
	⧺	1	4	8		2	1	3	19
	—			2		1		1	4
	—								
	⧺					1			1
0.012 p>0.90	⧺	6	5	2	1	9	18		41
	⧺	5	1	1					7
	+	1	2	1		1	1		6
	—	2							2
	⧺						1		1
	⧺						1		1
	⧺					2			2
	+			1	1	1		2	5
	—		1						1
	+		1			1			2
	—			1	1				2
0.320 p>0.50	—		4	3		9	11		27
	⧺			1	1	1	1		4
	⧺			1					1
	—								
	—	1					1		2
0.556 p>0.30	—	3	9		3	3	2		20
0.615 p>0.30	—	4	2	3	1	1			11
	—								
			2	1		2			5
				1		1			2
0.499 p>0.30		30	38	30	13	50	51	6	218

the chance of duplicate registration by each of MI or MY may increase a little but, judging from their flight habits, not so seriously as to invalidate the results. In medium butterflies, *Neope goschkevitschii, Harima callipteris, Neptis philyra, Speyeria aglaia* and *Brenthis ino,* all showing a higher heterogeneity between MI and MY are characterized by fluttering and resting at forest edges.

Among small species, *Bibasis aquilina* showed a considerable heterogeneity indubitably due to the habit of absorbing water gregariously and flying away with a high speed at disturbance. Consequently, in spite of its preference for roadsides or open areas, this species is difficult to be counted correctly. It is inferred that the larger species prefering roadsides or open areas are easier to find than the smaller and forest edge species.

The total numbers of individuals between two results were compared by Chi-square values for each species and for each subdivision. The individual numbers for each of nine species and other species combined are extracted from Table 1 as follows:

	MI	MY		MI	MY
Pieris napi	42	45	*Thoressa varia*	11	15
Aglais urticae	41	42	*Apatura ilia*	7	7
Brenthis ino	27	23	*Araschnia burejana*	6	6
Bibasis aquilina	20	25	*Argynnis* sp.	5	6
Lethe diana	19	19	Other species combined	40	45

In all these species Chi-square value falls over the range $p>0.99$ ($\chi^2=1.494$, d.f.$=9$) suggesting a high homogeneity of the species composition between two surveys. The rank sequence of predominant species is in MY 1. *Pieris napi*, 2. *Aglais urticae*, 3. *Bibasis aquilina*, 4. *Berenthis ino*, 5. *Lethe diana*, 6. *Thoressa varia* and in MI 1. *Pieris napi*, 2. *Aglais urticae*, 3. *Brenthis ino*, 4. *Bibasis aquilina*, 5. *Lethe diana*, 6. *Thoressa varia*. Although the ranks of *Bibasis aquilina* and *Brenthis ino* are reversed, the homogeneity is certainly more than a mere chance coincidence.

The number of individuals for each subdivision is arranged in the rank sequence as follows:

Rank sequence	1	2	3	4	5	6	7
MY	54(Bf)	54(Be)	46(Bb)	32(Bc)	30(Ba)	14(Bd)	3(Bg)
MI	51(Bf)	50(Be)	38(Bb)	30(Bc)	30(Ba)	13(Bd)	4(Bg)

The value ($=0.6124$, $p>0.99$, d.f.$=6$) supports a high homogeneity in the distribution pattern of the individual number between two census results. A complete rank correspondence is observed between the distribution pattern of individual number counted by two observers. Thus a high homogeneity between two data was confirmed except a slight decrease of the individual number in MI as follows:

Relation of the individual number	number of species
MY=MI	13
MY<MI	5
MY>MI	12

1.2. *Comparison of two censuses made by two observers with a slight time lag*: The present section deals with the comparison of two censuses, in which MI made five minutes later after MY by the following reason. The census route included the Gorge Hoheikyo, being famous by sightseeing and visited by many people, especially at week ends. Consequently, it was often noticed that visitors walking ahead of MY unwillingly disturbed butterflies activities. If the influence caused by visitors is kept for a long time to give a considerable change upon the activity, some correction of the number of recorded individuals is necessary for the censuses made on such a day. For this purpose, six censuses were made with a time lag of five minutes from 11:40 to 16:40, 20th, July, 1973 and the results were given in Table 2, summing up six censuses.

1.2.1. *Number of species*: MY recorded 33 species with two unidentified species, while MI 30 species and three unidentified ones. The number of species recorded only in one of two censuses was five, *Papilio machaon, Coenonympha hero, Nymphalis xanthomelas, Neptis philyra* and *Everes argiades*, in all of which only one or two individuals were recorded at only one or two subdivisions. Distance index, 0.454, suggests a high similarity between two census results.

1.2.2. *Number of individuals*: As to the total number of individuals (MY= 632, MI=563) the two results were heterogeneous for each other ($\chi^2=3.984$, $p<0.05$, d.f.=1). But from the distribution pattern of total individual number for each species and for each subdivision, together with rank similarity for each species and for each subdivision, a null hypothesis of heterogeneity is rejected by the following five reasons: 1) For each species, Chi-square value fell within the range $0.20>p>0.10$. 2) The following high ranked species are common to both censuses: *Bibasis aquilina, Pieris napi, Aglais urticae, Brenthis ino* and *Lethe diana*. 3) The rank sequence of subsivisions in the individual number is fairly similar between two censues except for reversal between first and second rank as follows:

Rank	1	2	3	4	5	6	7
MY	Bb	Be	Bc	Bf	Ba	Bd	Bg
MI	Be	Bb	Bc	Bf	Ba	Bd	Bg

4) A high heterogeneity of a single species, *Bibasis aquilina*, is likely to be responsible for the heterogeneity in total individual number, for the latter becomes not heterogenous ($\chi^2=0.656$, $0.50>p>0.30$, d.f.=1) when the individual number of the above mentioned species was estimated as 140.5 on average. In fact, Chi-square value for *Bibasis aquilina* falls within the range $0.01>p>0.001$, though the range is $p>0.05$ in the other species. 5) In total number of individuals, the heterogeneity of two out of six censuses is accepted by Chi-square value, while that of the other four is rejected.

In this case distribution pattern for subdivisions can not be compared, for a five minutes interval allows the butterflies to return the first subdivision concerned after once displaced to other subdivisions. From Chi-square value, a considerable heterogeneity is recognized in *Ypthima argus, Aglais urticae, Polygonia c-album, Japonica lutea, Plebejus argus* and *Bibasis aquilina*. If a five minutes interval is assumed to be too short for a conspicuous change of faunistic composition, a heterogeneity occuring in the data should be attributed to the disturbance caused by a person walking ahead, suggested by a tendency of decrease of individual

Table 2. Species and recorded individual number for each subdivision of the survey

Observer		MY							
Species \ Subdivision	Size	Ba	Bb	Bc	Bd	Be	Bf	Bg	T
Parnassius stubbendorfii	M			1		1			2
Papilio machaon	L	1							1
P. bianor		1							1
Aporia crataegi			1	2		1	2		6
Pieris rapae			2	1					3
P. melete	M								
P. napi		3	11	19	11	41	21	1	107
Colias erate			4		3	3	1		11
Lethe diana		1	19	24	2	7	1	4	58
Ypthima argus	S	1	3	1		1	1		7
Neope goshkevitschii			3	8			1		12
Harima callipteris		1	7	3					11
Coenonympha hero						1			1
Aglais urticae		7	19	5	4	21	20	2	78
Apatura ilia		7	1		1	3	1		13
Araschnia burejana			3	1		5			9
Polygonia c-album				2		3	3		8
P. vau-album									
Neptis rivularis					2	3	3		8
N. philyra				1		1			2
Nymphalis xanthomelas	M		1						1
Inachis io	M	1	1			1	2		5
Ladoga camilla						1	2		3
Argynnis paphia			1			1			2
Speyeria aglaia				3					3
Brenthis ino			4	7	2	27	21	1	62
Japonica lutea		1	2	2	1		1	1	8
Artopoetes pryeri	D			3					3
Plebejus argus						4	2		6
Everes argiades		1							1
Chrysozephyrus aurorinus	D					1			1
Bibasis aquilina		11	91	18	10	22	8	1	161
Thoressa varia		2	6	1		5	1		15
Ochlodes venata		4	5		1	2			12
Argynnis sp.			1	3	1	1			6
Nymphalidae ?									
Favonius sp.			1	1					2
Lycaenidae ?						2		1	3
Total		42	186	106	38	158	91	11	632
p (from $\chi^2_{(1)}$)		∨ 0.70	∧ 0.01	∨ 0.70	∨ 0.50	∨ 0.20		∧ 0.05	

number in MI as composed with the data in **1.1.2.**. Disturbance caused by preceding observer results either in decrease (e.g. *Bibasis aquilina*) or in increase (e.g. *Ypthima argus*) of the individual number.

route censused by two observers with a slight time lag. Other explanations as in Table 1.

$\chi^2_{(1)}$	Homogeneity in distribution pattern	MI							
		Ba	Bb	Bc	Bd	Be	Bf	Bg	T
	+			1					1
	−								
	−			2					2
0.400 p>0.30	−					2	1	1	4
	+		2						2
	−					1			1
0.395 p>0.50	++	2	8	20	9	34	16	9	98
1.690 p>0.10	−	4	4		3	4	3		18
0.295 p>0.50	±	3	24	23	2	4	4	4	64
1.800 p>0.10	−	4	3	1	2	2	1		13
0.182 p>0.50	−		2	4	1	1	2		10
0.043 p>0.80	+		8	3			1		12
	−								
2.800 p>0.05	+	4	16	2	3	14	21	1	61
0.040 p>0.80	+	8	2		1		1		12
1.000 p>0.30	±		3	3		2		2	10
2.273 p>0.10	−		1	1			1		3
	−					1			1
0.053 p>0.80	++			1	1	4	4		10
	−								
	−								
	+					1	1		2
	−			2			1		3
	±			1					1
	−				1	1	2		4
0.008 p>0.90	+		5	01	1	24	19	4	63
2.273 p>0.10	±		1	1	1				3
	−			2	1	3			6
1.471 p>0.20	−	1		3		6	1		11
	−								
	++					1			1
5.982 p>0.05	+	9	47	21	7	27	8	1	120
1.000 p>0.30	+	1	1	1		5	2		10
0.429 p>0.50	−	1	8						9
		1					1	1	3
		1					1		2
								2	2
								1	1
3.984 p<0.05		39	135	102	33	137	91	26	563

1.3.. *Influence caused by capture*: The Gorge Hôheikyo is familiar to the butterfly collectors. But most of them catch relatively rare species such as *Coenonympha hero, Scolytantides orion, Papilio macckii*, etc. so that affect little the total

Table 3. Species and recorded individual number for each subdivision (A, B

Observer		MY				$\chi^2_{(1)}$
Species \ Subdivision	Size	A	B	C	T	
Papilio machon				2	2	
Pieris napi		16	12	10	38	1.210 $p>0.20$
P. melete		3	4	2	9	0.600 $p>0.50$
Lethe diana		3	8		11	0.615 $p>0.30$
Neope goschkevitschii			2		2	
Harima callipteris		6	17	6	29	0.148 $p>0.70$
Sasakia charonda	L			1	1	
Araschnia burejana		1	1		2	
Neptis rivularis				5	5	
Artopoetes pryeri			1		1	
Araragi enthea	D		1		1	
Chrysozephyrus smaragdinus	D			1	1	
Everes argiades		4	3	4	11	0.167 $p>0.50$
Bibasis aquilina						
Ochlodes venata			1		1	3.571 $p>0.05$
Polytremis pellucida	S			1	1	
Argynnis sp.				1	1	
Total		33	50	33	116	0.159 $p>0.50$
p (from $\chi^2_{(1)}$)		$>$ 0.20	$>$ 0.30	$>$ 0.10		

faunistic composition. On the other hand, school boys collect not only rare species but also common ones in summer vacation, thus possibly affecting the census result to some extent. The experiment was carried out by MI and MY at a mountain road about 400 m long (subdivisions, A, B and C) on the Mt. Moiwa, 7 km south of Sapporo City on 2nd August, 1973, for the purpose of estimating the influence caused by catching. The sum of the individual number counted in four trials from 12:50 to 14:00 is shown in Table 3, together with the number of individuals caught with a net (42 cm in diameter). MY counted each individual and collected it as far as possible. Five minutes later MI censused along same route. In four censuses the ratio of captured individuals to total recorded individuals was 32.4%, 32.1%, 38.8% and 34.8%, respectively, suggesting a high stability. Contrary to the expectation, neutrality or even increase of individual number was observed except for some rare species. Neutrality in the individual number was probably caused by the abundance of the species concerned, while increase as observed in *Harima callipteris*, *Lethe diana* and *Ochlodes venata* might suggest an increased flight activity after capturing, which stimulated to drive out the butterflies so far resting undersides of leaves or absorbing tree sap as in Satyridae. What has been mentioned above suggests that the reliable estimation of the individual number is not obtained by the belt census method for Satyridae and some other species with and C) of the survey route censused or collected by two observers (cf. Table 1).

Homogeneity in distribution pattern	MI				Collected species			
	A	B	C	T	A	B	C	T
–							1	1
+	13	9	7	29	7	8	2	17
+	2	3	1	6	1	2	2	5
–	12	3		15	1	1		2
–								
+	12	17	3	32	1	5	3	9
–								
++	1	1		2		1		1
–		1	3	4				
–								
–						1		1
–	1			1			1	1
±	3	3	7	13			2	2
–			1	1				
–		6		6				
–							1	1
			1	1				
	44	43	23	110	10	18	12	40

the habit of swarming at damp areas to absorb water. But this preliminary sruvey is still premature to give the reliable estimation of the individual number.

2. Diurnal activity

Each butterfly species possesses the characteristic pattern of diurnal activity. When the census was made for a particular species alone, the survey could be made at the time of its highest activity. But dealing with an assemblage consisting of the species of various diurnal rhythms, a compromise between labor economy and efficiency must be sought. The diurnal activity of all species at Jozankei is classified into five types as follows, together with the species belonging to each type.

a) Unimodal type with a morning peak

7:30 *Strymonidia w-album*

9:10 *Parnassius stubbendorfii*, *Papilio machaon*, *Pieris rapae*, *Colias erate**, *Erebia niphonica*, *Coenonympha hero*, *Araschnia levana*, *Vanessa indica*, *Argyronome laodice*, *Scolytantides orion*, *Ahlbergia ferrea*, *Lycaena phlaeas**, *Celastrina sugitanii*, *Artopoetes pryeri*, *Favonius orientalis*, *Chrysozephyrus aurorinus*, *Bibasis aquilina*, *Thoressa varia* and *Erynnis montanus*.

10:30 *Anthocaris scolymus*, *Pieris napi**, *P. melete*, *Coenonympha hero*, *Apatura ilia*, *Araschnia burejana**, *Neptis philyra*, *Nymphalis xanthomelas*, *Brenthis ino*, *Argyronome ruslana*, *Argynnis paphia*, *Speyeria aglaia*, *Fabriciana adippe*, *Scolytantides orion*, *Thymelicus sylvaticus* and *Polytremis pellucida*.

b) Unimodal type with an afternoon peak

12:30 *Papilio mecilentus*, *Ypthima argus*, *Limenitis populi*, *Nymphalis antiopa*, *Aglais urticae*, *Inachis io*, *Argynnis anadyomene*, *Everes argiades*, *Plebejus argus* and *Neozephyrus taxila*.

14:30 *Aporia crataegi*, *Polygonia c-album* and *Ochlodes venata*.

16:00 *Polygonia vau-album*, *Kaniska canace* and *Shirozua jonasi*.

c) Bimodal type with a morning (9:10～12:30) and an afternoon peak (14:30～16:00): *Papilio maackii*, *Ninguta schrenckii*, *Neptis rivularis* and *Ladoga camilla*.

d) Bim odal type with a higher morning peak (7:30～9:10) and a low evening peak (16:00～17:15), or so-called crepuscular type. Although the censuses in dawn and dusk are required (Akiyama et al. 1969), the next species belong in all probability to this type: *Lethe diana**, *Neope goschkevitschii*, *Celastrina argiolus*, *Japonica lutea*, *Ussuriana stigiana* and *Favonius* spp.

e) Erratic type: *Papilio bianor* without clear diurnal rhythm. *Harima callipteris** fluctuating erratically during daytime.

The asterisked species, *Pieris napi*, *Colias erate*, *Lethe diana*, *Harima callipteris*, *Araschnia burejana*, *Lycaena phlaeas* and *Celastrina sugitanii*, change the diurnal activity according to seasons. In *Pieris napi* the diurnal activity showed a unimodal tendency with a morning peak at start and end of its phenology in May and from late July to September (the summer type), while with an afternoon peak in June (the spring type). *Colias erate* showed a weak unimodal activity with an afternoon peak in June (the spring type), but a typical unimodality with a morning peak was observed from July onwards (the summer type). The diurnal activity of *Araschnia burejana* fluctuated as follows: A unimodality with a morning peak in early June, with an afternoon peak in late June, a morning peak type in July and, again an afternoon one in August. *Lethe diana* and *Harima callipteris* showed a typical bimodality in July, but a unimodality with a midday peak in August and September. The spring type of *Lycaena phlaeas* possessed the diurnal activity of a weak unimodality with a morning peak (9:10～10:30) in late August on. In *Celastrina sugitanii* a weak unimodality with an afternoon peak was observed in May, while with a morning peak in June.

If the diurnal activity pattern is similar in all species, a single census at the time of the highest activity is sufficient to apprehend the faunal makeup. As each species shows its own pattern, theoretically, the census must be carried out as many times as the number of activity patterns, that is, four censuses, two in the morning, approximately at 7:00 and 10:00 and the other two, in the afternoon, at 14:00 and 16:30. Considering the distance to be traversed for these censuses, 16 km (the length of survey route =4 km) in the present case, a full day survey is required for such work. A compromise between accuracy of the result and the time available for an average observer is discussed in the following subsection.

2.1. *A single census per day*: Table 4 shows the number of individuals registered for each species in each of six censuses, summing up the data for 15 days.

Table 4. Species and recorded individual number censused six times per day. Rank by individual number in each census is given in parentheses.

Species \ Census time	7:30	9:10	10:30	12:30	14:30	16:00	Total
Parnassius stubbendorfii	5(19)	26(13)	22(12)	17(14)	9(18)	4(21)	83(15)
Papilio machaon	15(10)	43(6)	43(7)	30(8)	21(8)	6(18)	158(9)
P. macilentus			1	2			3
P. maackii	3(21)	14(16)	9(20)	10(19)	13(12)	8(16)	57(19)
P. binaor	7(16)	5(29)	7(24)	7(22)	6(25)	5(19)	37(26)
Aporia crataegi	3(21)	7(27)	5(30)	6(26)	10(17)	4(21)	35(27)
Anthocalis scolymus	2	1	2	1	1		7
Pieris napi	63(2)	207(2)	331(1)	289(1)	223(1)	137(1)	1,250(1)
P. melete	1(29)	3(31)	11(18)	5(30)	3(29)	4(21)	27(29)
P. rapae	67(1)	241(1)	212(2)	172(2)	138(2)	65(2)	895(2)
Colias erate	43(5)	134(3)	99(3)	102(3)	114(3)	25(5)	517(3)
Ypthima argus	3(21)	5(29)	6(28)	12(17)	11(15)	8(16)	45(25)
Erebia niphonica		3	1				4
Coenonympha hero		1	1				2
Lethe diana	53(3)	51(4)	22(12)	26(10)	32(7)	37(3)	221(5)
Harima callipteris	16(8)	26(13)	11(18)	17(14)	12(13)	18(8)	100(14)
Neope goschkevitschii	13(12)	10(22)	7(24)	6(27)	9(18)	11(14)	56(20)
Ninguta schrenckii	1	4	2		2	1	10
Apatura ilia	3(21)	11(19)	16(16)	8(22)	7(23)	2(28)	47(23)
Limenitis populi				1			1
Ladoga camilla	2	1	3		4	1	11
Neptis philyra	1	2	4	1	2	1	11
N. rivularis	2(28)	8(24)	5(30)	5(31)	9(18)	3(25)	32(28)
Araschnia burejana	16(8)	45(5)	46(6)	22(11)	19(11)	15(10)	163(8)
A. levana		5	5	2	3	1	16
Polygonia c-album	1(30)	11(19)	9(20)	10(19)	22(8)	21(6)	74(16)
P. vau-album	1(30)	8(24)	8(22)	7(24)	11(15)	11(14)	46(24)
Vanessa indica	1	1					2
Nymphalis xanthomelas	1	4	4	3		2	14
N. antiopa		2	4	4	2	1	13
Inachis io	12(13)	13(17)	42(8)	67(5)	41(5)	21(6)	196(6)
Kaniska canace		2	1	2	2	5	12
Aglais urticae	21(7)	40(8)	63(4)	78(4)	50(4)	33(4)	285(4)
Fabriciana adippe	3	3	7	6			19
Argyronome laodice		3					3
A. ruslana		5	10	5	4		24
Argynnis paphia	4(20)	9(23)	17(14)	15(16)	4(26)	2(28)	51(21)
A. anadyomene				1			1
Speyeria aglaia	6(18)	12(18)	14(17)	11(18)	4(26)	2(28)	49(22)
Brenthis ino	14(11)	32(10)	51(5)	42(6)	20(10)	13(11)	172(8)
Artopoetes pryeri	1	2				1	4
Antigius attilia			1				1
Japonica lutea	44(4)	31(12)	7(24)	7(22)	7(23)	12(12)	108(13)
Shirozua jonasi				1	1	2	4
Ussuriana stygiana	2	3			1		6
Neozephyrus taxila	1	1		4	1	1	8
Chrysozephyrus aurorinus		3					3
Favonius orientalis			1				1

Table 4. (Continued)

species \ Census time	7:30	9:10	10:30	12:30	14:30	16:00	Total
Strymonidia w-album	2						2
Ahlbergia ferrea	4	6	2	4	1		17
Lycaena phlaeas	12(13)	38(9)	30(10)	30(8)	12(13)	1(32)	123(11)
Scolytantides orion	2(28)	7(27)	7(24)	6(27)	2(31)	2(28)	26(32)
Plebejus argus	3(27)	2(32)	4(32)	10(21)	4(28)	4(24)	27(29)
Celastrina argiolus	1	2			1	3	7
C. sugitanii	3(21)	8(24)	6(28)	6(27)	1(32)	3(25)	27(29)
Everes argiades	3(21)	11(19)	17(14)	20(13)	9(18)	3(25)	63(18)
Erynnis monthanus		1	1				2
Bibasis aquilina	11(15)	32(10)	8(22)	7(24)	3(29)	12(13)	73(17)
Thymelicus sylvaticus		1	2				3
Ochlodes venata	22(6)	19(15)	24(11)	31(7)	38(6)	16(9)	150(10)
Thoressa varia	7(16)	42(7)	33(9)	21(12)	9(18)	5(19)	117(12)
Polytremis pellucida	1		2	1	5	1	10
(*Favonius* spp.)	10	4			4	1	19
Total	502	1, 207	1, 245	1, 141	902	534	5, 532

2.1.1. *Number of species and individuals*: The highest number of species, 54, was observed in census 9:10, followed by 10:30 (50 species), 12:30 (48), 7:30 (46) and 14:30, 16:00 (45). As to the number of individuals, the order was 10:30> 9:10>12:30>14:30>16:00>7:30. The census with the highest number both of species and individuals, that is, indicating the highest value of the community prosperity index $=T\beta$ (Morisita 1964), was favoured to represent the faunal richness. The census 9:10 ($T\beta$=12,987.3) satisfies this condition, followed by 10: 30 (10,652.2), 12:30 (10,493.8), 14:30 (8,082.4), 7:30 (6,304.7) and 16:00 (5,370.2).

2.1.2. *Similarity*: The sum (C_t) of the results of six censuses ($C_1 \sim C_6$) is tentatively regarded as the best approximation to the real faunal makeup. Then, the harmonity index to compare the similarity between C_j ($j=1\sim 6$) and C_t and Spearman's coefficient of rank correlation were calculated to specify the C_j most useful to represent the faunal makeup. The harmonity index (HI) is obtained from

$$HI=\frac{2\Sigma n_{1i}n_{2i}}{(\pi_1^2+\pi_2^2)N_1N_2}$$

where N=total individual number, n_i=individual number of species i, $\pi_1^2=\Sigma n_i^2/N_1^2$, $\pi_2^2=\Sigma n_i^2/N_2^2$, N_1, N_2=respectively total individual number of assemblage I and II, and n_{1i} or n_{2i}=individual number of species i found in the assemblage I or II. The value of HI ranges from 1.0 (same faunal makeup) to 0.0 (complete difference). The calculated values between C_j and C_t are:

C_j	7:30	9:10	10:30	12:30	14:30	16:00
HI	0.873	0.958	0.985	0.988	0.986	0.959

According to the values of *HI* which was similar from 9:10∼16:00, especially 10:30∼14:30, all censuses except 7:30 are fairly effective to show the faunal makeup.

Spearman's coefficient of rank correlation is formulated

$$1-\frac{6\Sigma(x_i-y_i)^2}{n(n^2-1)}$$

where n=number of species, x_i, y_i=rank of species i in assemblage x and y, respectively. The same ranked species in one assemblage are conveniently adjusted. For instance, the 8th species in census 7:30 is represented by *Araschnia burejana* and *Harima callipteris*. From the rank order in total assemblage (C_t) (Table 4), *Araschnia burejana* was regarded as the 8th species and *Harima callipteris* as the 9th one. The calculated values of coefficient are:

7:30	9:10	10:30	12:30	14:30	16:00
0.86	0.93	0.89	0.92	0.85	0.76

From both harmonity index and Spearman's coefficient which was very similar from 9:10∼12:30, a good similarity between C_j and C_t is seen in census 12:30, followed by 9:10 and 10:30.

The judgement obtained by community prosperity index ($T\beta$), harmonity index (*HI*) and Spearman's coefficient of rank correlation (*S*) is summarized below (⧺: highly effective, +: effective, —: not effective), together with the number of species with the maximum number of individuals registered in C_j (species with the same individual number are duplicated):

	7:30	9:10	10:30	12:30	14:30	16:00
$T\beta$	−	⧺	+	+	−	−
HI	−	+	⧺	⧺	⧺	+
S	+	⧺	+	⧺	+	−
No. species	7	23	22	11	11	3

Three censuses, 7:30, 14:30 and 16:00, are rejected as unsuitable, leaving three, 9:10, 10:30 and 12:30 as effective. The conclusion coincides with a well known experience by butterfly lovers who mostly practice collecting from 9:00∼12:00.

2.2. *Two censuses per day*: Following the preceding subsection, efficiency of the case of two censuses per day is discussed.

2.2.1. *Number of species and individuals*: The number of species registered in the combination of two given censuses C_j+C_j' and individuals of species registered not in this combination but in C_t, are shown as follows:

	7:30	9:10	10:30	12:30	14:30	16:00
7:30		11	12	15	24	48
9:10	56		8	4	9	9
10:30	56	58		27	26	16
12:30	55	59	55		29	19
14:30	51	56	53	51		49
16:00	50	56	53	53	48	

Number of species (mean=54)

Number of individuals

Two pairs 9:10+12:30 and 9:10+10:30 cover respectively 93.5% and 95.2% of the total species number, regarded as the best combination to gain as many as possible number of species.

2.2.2. *Harmonity index*: Harmonity index is also useful here to evaluate the similarity between the assemblage C_j+C_j' and the total assemblage C_t as arranged as follows:

(C_j+C_j')	: C_t	*HI*	(C_j+C_j')	: C_t	*HI*
(7:30+ 9:10)		0.959	(9:10+16:00)		0.990
(+10:30)		0.997	(10:30+12:30)		0.989
(+12:30)		0.994	(+14:30)		0.992
(+14:30)		0.987	(+16:00)		0.989
(+16:00)		0.957	(12:30+14:30)		0.991
(9:10+10:30)		0.992	(+16:00)		0.989
(+12:30)		0.996	(14:30+16:00)		0.958
(+14:30)		0.992			

The combined assemblage C_j+C_j' is closer to C_t than C_j or C_j', for instance, the values of *HI* between C_t and 7:30+10:30 or 9:10+12:30 or 7:30+12:30 are higher than those between any C_j and C_t (cf. p. 106). The results mentioned above lead to the proposition that the censuses carried out twice per day should be started at about 9:00 and about noon.

2.3. *Relation between number of species or individuals and frequency of censuses*: From the result in **2.2.2.**, it arises a question how the combined result approaches that of C_t, when the census was carried out three times or more. This question is discussed only in terms of species and individual number. In Fig. 1 the mean number of species unrecorded in the censuses concerned (though recorded in C_t) and of individuals of these species recoded in other censuses are plotted against census frequency. The mean number of unrecorded species decreases curvilinearly with increased census frequency, while the mean individual number of these species hyperbolically. Increased census frequency is more effective to increase the number of species than that of individuals. The estimates for the number of species inhabiting the surveyed area based upon the result in C_t was calculated by using the Preston's log normal, adopting the procedure developed by Nagasawa (1948) (Fig. 2, $\chi^2=13.676$, $0.98>p>0.95$, d.f.=25). The number of

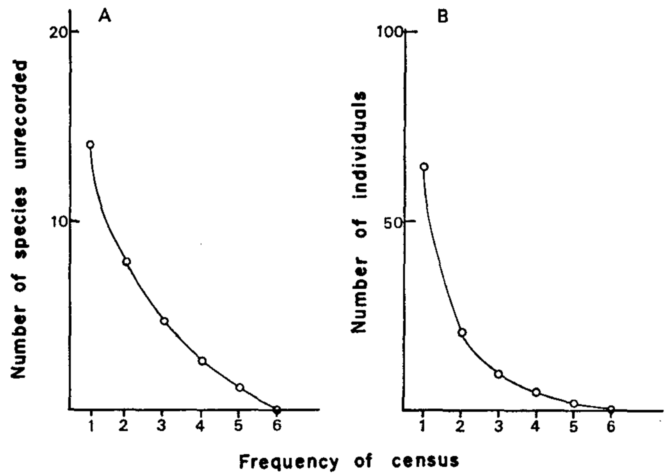

Fig. 1. Relation between species (A) or individual (B) numbers and census frequency.

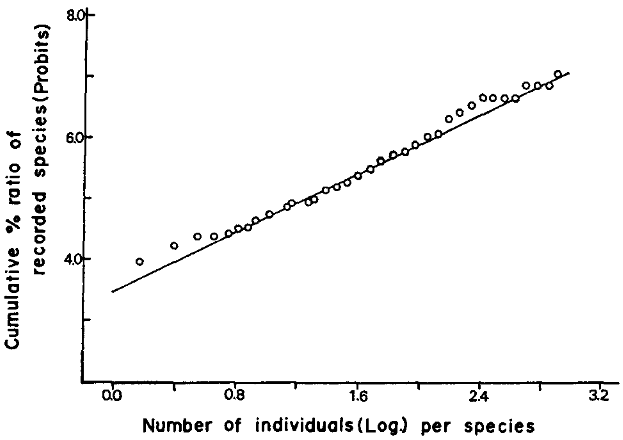

Fig. 2. Relation between number of species and individuals.

unrecorded species was calculated as 1.70, to some extent comparable with the number of species observed in 1973 out of the routine census, which are *Wagimo signatus*, *Favonius cognatus*, *Araragi enthea* and *Sasakia charonda*. Among them only two species, *Wagimo signatus* and *Araragi enthea* were regarded as unrecorded in the routine census, probably for *Favonius cognatus* was included among observed *Favonius* spp. and *Sasakia charonda* was an accidental migrant from the neighboring habitat, Mt. Hakken where it is residential.

2.4. *Correction of the number of individuals*: The previous sections clarified that the individual number obtained from the belt census method was biased more or less by factor B (see Section **1**), especially significantly by the difference among diurnal rhythms of species concerned. But most surveys using this census method have been carried out once or twice per day, ignoring the diurnal rhythm. This is inevitable by the limit of time available for each observer and the condition must remain unsolved for most instances for the future. For this reason it is convenient to estimate the unbiased individual number (=individual number showing relative abundance unbiased as to diurnal activity) obtained by six censuses made throughout daytime by correcting the individual number obtained from one census per day. Although the available data are insufficient to be treated statistically, the estimation for the correction of individual number is provisionally attempted. For this purpose, the number of individuals of a given species counted in each census was converted to the percentage ratio to the total number of the species by six censuses combined and arranged in descending order, taking *Pieris napi* as an example as follows:

Rank	1	2	3	4	5	6
Census	10:30	12:30	14:30	9:10	16:00	7:30
No. individuals	331	289	223	207	137	63
%	26.5	23.1	17.8	16.6	11.0	5.0

The same procedure was applied for all species as shown in Table 5. From the fact that some species show a similar fluctuation pattern as to the relation among the percentage ratios, five types of the change of percentage ratios were distinguished. The percentage ratio for each census was modified by trial and error in order to approximate the change of cumulative ratio to the pattern as similar as the normal distribution with the help of probability paper (Fig. 3). The corrected percentage ratio is shown as below:

Rank of census	1	2	3	4	5	6	Total
Type							
A	27.5	22.5	17.5	15.0	10.0	7.5	100.0
B	35.0	25.0	20.0	10.0	5.0	5.0	100.0
C	40.0	20.0	15.0	12.5	7.5	5.0	100.0
D	50.0	25.0	15.0	10.0			100.0
E	100.0						

Symbols A~E are inscribed before the species names in Table 5 except *Papilio bianor*.

All pierid species except *Pieris melete* belong to A, while the majority of so-called *Zephyrus* group, to C or D. Obviously most species represented by 10 individuals or less belong to C or D. On the other hand, most species with over 100 individuals are classified into A. Based upon these types, the unbiased individual number (UIN) of each species can be estimated as follows: $UIN = INC_j / Cp_j$ where INC_j is the individual number in C_j and Cp_j, the corrected percentage

Table 5. Percentage ratio of individual number in each species for particular census in relation to the combined individual number obtained by six censuses per day. Symbols A～E show the types of percentage ratio flucutation among censuses.

Type	Species \ Rank	1	2	3	4	5	6	T
B	*Parnassius stubbendorfii*	31.4	26.5	20.5	10.8	6.0	4.8	100.0
A	*Papilio machaon*	27.2	27.2	20.0	13.3	9.5	3.8	
D	*P. macilentus*	66.7	33.3					
A	*P. maackii*	24.6	22.8	17.5	15.8	14.0	5.3	
?	*P. bianor*	18.9	18.9	18.9	16.3	13.5	13.5	
A	*Aporia crataegi*	28.6	20.0	17.1	14.3	11.4	8.6	
A	*Anthocalis scolymus*	28.6	28.5	14.3	14.3	14.3		
A	*Pieris napi*	26.5	23.1	17.8	16.6	11.0	5.0	
C	*P. melete*	40.8	18.5	14.3	11.1	11.1	3.7	
A	*P. rapae*	26.9	23.7	19.2	15.4	7.5	7.3	
A	*Colias erate*	25.9	22.1	19.7	19.2	8.3	4.8	
A	*Ypthima argus*	26.7	24.4	17.8	13.3	11.1	6.7	
D	*Erebia niphonica*	75.0	25.0					
D	*Coenonympha hero*	50.0	50.0					
A	*Lethe diana*	24.0	23.0	16.7	14.5	11.8	10.0	
A	*Harima callipteris*	26.0	18.0	17.0	16.0	12.0	11.0	
A	*Neope goschkevitschii*	23.2	19.6	17.9	16.1	12.5	10.7	
C	*Ninguta schrenckii*	40.0	20.0	20.0	10.0	10.0		
B	*Apatura ilia*	34.0	23.4	17.0	14.9	6.4	4.3	
A	*Limenitis populi*	100.0						
A	*Ladoga camilla*	36.3	27.3	18.2	9.1	9.1		
B	*Neptis philyra*	36.3	18.2	18.2	9.1	9.1	9.1	
A	*N. rivularis*	28.1	25.0	15.6	15.6	9.4	6.3	
A	*Araschnia burejana*	28.2	27.6	13.5	11.7	9.8	9.2	
B	*A. levana*	31.3	31.3	18.8	12.5	6.3		
A	*Polygonia c-album*	29.6	28.4	14.9	13.5	12.2	1.4	
A	*P. vau-album*	23.9	23.9	17.4	17.4	15.2	2.2	
D	*Vanessa indica*	50.0	50.0					
A	*Nymphalis xanthomelas*	28.6	28.6	21.4	14.3	7.1		
B	*N. antiopa*	30.8	30.7	15.4	15.4	7.7		
B	*Inachis io*	34.2	21.4	20.9	10.1	6.6	6.1	
C	*Kaniska canace*	41.6	16.7	16.7	16.7	8.3		
A	*Aglais urticae*	27.4	22.1	17.5	14.0	11.6	7.4	
B	*Fabriciana adippe*	36.8	31.6	15.8	15.8			
E	*Argyronome laodice*	100,0						
C	*A. ruslana*	41.7	20.8	26.8	16.7			
B	*Argynnis paphia*	33.4	29.4	17.7	7.8	7.8	3.9	
E	*A. anadyomene*	100.0						
B	*Speyeria aglaia*	28.5	24.5	22.5	12.2	8.2	4.1	
A	*Brenthis ino*	29.7	24.4	18.6	11.6	8.1	7.6	
D	*Artopoetes pryeri*	50.0	25.0	25.0				
E	*Antigius attilia*	100.0						
C	*Japonica lutea*	40.7	28.7	11.1	6.5	6.5	6.5	
D	*Shirozua jonasi*	50.0	25.0	25.0				
D	*Ussuriana stygiana*	50.0	33.3	16.7				
D	*Neozephyrus taxila*	50.0	12.5	12.5	12.5	12.5		

Table 5. (Continued)

Type	Species \ Rank	1	2	3	4	5	6	T
E	*Chrysozephyrus aurorinus*	100.0						
E	*Favonius orientalis*	100.0						
E	*Strymonidia w-album*	100.0						
B	*Ahlbergia ferrea*	35.3	23.5	23.5	11.8	5.9		
B	*Lycaena phlaeas*	30.8	24.4	24.4	9.8	9.8	0.8	
B	*Scolytantides orion*	26.9	26.9	23.1	7.7	7.7	7.7	
B	*Plebejus argus*	37.1	14.8	14.8	14.8	11.1	7.4	
D	*Celastrina argiolus*	42.8	28.6	14.3	14.3			
A	*C. sugitanii*	29.2	22.2	22.2	11.1	11.1	3.7	
B	*Everes argiades*	31.7	26.9	17.5	14.3	4.8	4.8	
D	*Erynnis monthanus*	50.0	50.0					
C	*Bibasis aquilina*	43.8	16.4	15.1	11.0	9.6	4.1	
D	*Thymelicus sylvaticus*	66.7	33.3					
A	*Ochlodes venata*	25.2	20.7	16.0	14.7	12.7	10.7	
B	*Thoressa varia*	35.8	28.2	18.0	7.7	6.0	4.3	
D	*Polytremis pellucida*	50.0	20.0	10.0	10.0	10.0		

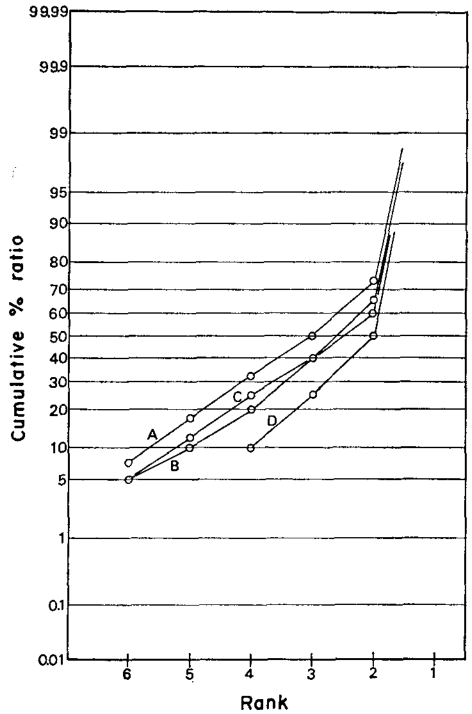

Fig. 3. Cumulative percentage ratio occupied by the top ranked census plotted on probability paper. Further explanations in text.

Table 6. Three individual numbers, INC_3, UIN and INC_t for each species. Further explanation in text.

Species	INC_3(%)	Rank (%)	UIN (%)	INC_t (%)
Parnassius stubbendorfii	22(1.77)	2(25.0)	88(1.56)	83(1.50)
Papilio machaon	43(3.45)	1(27.5)	156(2.76)	158(2.86)
P. macilentus	1(0.08)	2(25.0)	4(0.07)	3(0.05)
P. maackii	9(0.72)	4(15.0)	60(1.06)	57(1.03)
P. bianor	7(0.56)	1	?	37(0.67)
Aporia crataegi	5(0.40)	4(15.0)	33(0.58)	35(0.63)
Anthocalis scolymus	2(0.16)	1(27.5)	7(0.12)	7(0.13)
Pieris napi	331(26.59)	1(27.5)	1,204(21.33)	1,250(22.60)
P. melete	11(0.88)	1(40.0)	28(0.50)	27(0.49)
P. rapae	212(17.03)	2(22.5)	942(16.69)	895(16.18)
Colias erate	99(7.95)	4(15.0)	660(11.69)	517(9.35)
Ypthima argus	6(0.48)	4(15.0)	40(0.71)	45(0.81)
Erebia niphonica	1(0.08)	2(25.0)	4(0.07)	4(0.07)
Coenonympha hero	1(0.08)	1(50.0)	2(0.04)	2(0.04)
Lethe diana	22(1.77)	6(7.5)	293(5.19)	221(4.00)
Harima callipteris	11(0.88)	6(7.5)	147(2.60)	100(1.81)
Neope goschkevitschii	7(0.56)	5(10.0)	70(1.24)	56(1.01)
Ninguta schrenckii	2(0.16)	2(20.0)	10(0.18)	10(0.18)
Apatura ilia	16(1.29)	1(35.0)	46(0.81)	47(0.85)
Limenitis populi	0		0	1(0.02)
Ladoga camilla	3(0.24)	2(25.0)	12(0.21)	11(0.20)
Neptis philyra	4(0.32)	1(35.0)	11(0.19)	11(0.20)
N. rivularis	5(0.40)	3(17.5)	29(0.51)	32(0.58)
Araschnia burejana	46(3.69)	1(27.5)	167(1.96)	163(2.65)
A. levana	5(0.40)	1(35.0)	14(0.25)	16(0.29)
Polygonia c-album	9(0.72)	5(10.0)	90(1.59)	74(1.34)
P. vau-album	8(0.64)	3(17.5)	46(0.81)	46(0.83)
Vanessa indica	0		0	2(0.04)
Nymphalis xanthomelas	4(0.32)	1(27.5)	15(0.27)	14(0.25)
N. antiopa	4(0.32)	1(35.0)	11(0.19)	13(0.24)
Inachis io	42(3.37)	2(25.0)	168(2.98)	196(3.54)
Kaniska canace	1(0.08)	5(7.5)	13(0.23)	12(0.22)
Aglais urticae	63(5.06)	2(22.5)	280(4.96)	285(5.15)
Fabriciana adippe	7(0.56)	1(35.0)	20(0.35)	19(0.34)
Argyronome laodice	0		0	3(0.05)
A. ruslana	10(0.80)	1(40.0)	25(0.44)	24(0.43)
Argynnis paphia	17(1.37)	1(35.0)	49(0.87)	51(0.92)
A. anadyomene	0		0	1(0.02)
Speyeria aglaia	14(1.12)	1(35.0)	40(0.71)	49(0.89)
Brenthis ino	51(4.10)	1(27.5)	185(3.28)	172(3.11)
Artopoetes pryeri	0		0	4(0.07)
Antigius attilia	1(0.08)	1(100.0)	1(0.02)	1(0.02)
Japonica lutea	7(0.56)	4(12.5)	56(0.99)	108(1.95)
Shirozua jonasi	0		0	4(0.07)
Ussuriana stygiana	0		0	6(0.11)
Neozephyrus taxila	0		0	8(0.14)
Chrysozephyrus aurorinus	0		0	3(0.05)
Favonius orientalis	1(0.08)	1(100.0)	1(0.02)	1(0.02)
Strymonidia w-album	0		0	2(0.04)

Table 6. (Continued)

Species	INC_3 (%)	Rank (%)	UIN (%)	INC_t (%)
Ahlbergia ferrea	2(0.16)	4(10.0)	20(0.35)	17(0.31)
Lycaena phlaeas	30(2.41)	2(25.0)	120(2.13)	123(2.22)
Scolytantides orion	7(0.56)	1(35.0)	20(0.35)	26(0.47)
Plebejus argus	4(0.32)	2(25.9)	16(0.28)	27(0.49)
Celastrina argiolus	0		0	7(0.13)
C. sugitanii	6(0.48)	2(22.5)	27(0.48)	27(0.49)
Everes argiades	17(1.37)	2(25.0)	68(1.20)	63(1.14)
Erynnis monthanus	1(0.08)	1(50.0)	2(0.04)	2(0.04)
Bibasis aquilina	8(0.64)	4(12.5)	64(1.13)	73(1.32)
Thymelicus sylvacticus	2(0.16)	1(50.0)	4(0.07)	3(0.05)
Ochlodes venata	24(1.93)	3(17.5)	137(2.43)	150(2.71)
Thoressa varia	33(2.65)	2(25.0)	132(2.34)	117(2.12)
Polytremis pellucida	2(0.16)	2(25.0)	8(0.14)	10(0.18)
Total	1,245(100.00)		5,645(100.00)	5,531(100.00)

ratio determined both by the type and rank of census j. UIN of all species obtained at Jozankei, taking 10:30 census (C_3) as an example is given in Table 6, together with the individual number in C_t ($=INC_t$). As to the percentage ratio (parentheses in Table 6), comparisons between INC_3 and INC_t or UIN and INC_t lead to the conclusion that UIN approximates more to INC_t than INC_3 in most species except six ones, *Colias erate, Inachis jio, Aglais urticae, Scolytantides orion, Plebejus argus* and *Polytremis pellucida.*

Concluding Remarks

The belt census method has first been developed in the field of ornithology and subsequently applied to apprehend the quantitative faunal makeup of some animals with a high locomotive activity. This method is superior to the capture method in that various types of environment can be included on the way of the census route and also that it is suitable to make the faunal list with some quantitaive estimation of component species less laboriously. But we cannot analyze quantitatively the data obtained unless some technical demerits are resolved, the following four items of which are particularly important.

1) A belt censused must be a representative of the wider surrounding area, that is, the environmental composition of a census route must be proportional to that of the wider area including the route.

2) The observers must sufficiently be qualified for the identification of the species without capturing and different observers must approximately be equal in their average and differential abilities of identification.

3) Conspicuous and active species are likely to be overestimated more abundantly than inconspicuous and inactive ones even if of the same or lower

density.

4) In connection with 3), the individual number of a given species must be compared only with that of another species showing the same diurnal rhythm and habitat preference.

Some comments on the solution of these problems are itemized below.

1) Census should be carried out at the habitat involving both forest and openland of approximately equal extent. The result obtained from the census must receive a proper correction of the individual number, according to ratios of various habitats in the wider area including the census area. This problem was untouched in the present paper.

2) As shown in Section **1**, the personal difference does not affect much the result when the ability of discovery and identification does not much different among observers. But the qualification of observers requires further considerations. Obviously, only the persons which have some experience to discriminate various species without capturing are qualified as observers. But the discriminating ability is complicate, varying among persons in average ability, that is, an observer A is much expert than B in all taxonomic groups as well as in differential ability, or, an observer A′ may discriminate group X much expertly than Y while another observer B′ may behave oppositely. In the present study such refined comparison was not undertaken.

3) and 4) These phenomena are likely to occur in some groups, particularly in Satyridae (e.g. *Lethe diana*). The correction of individual numbers such as presented in Section **2. 4.** is required in order to avoid over- or underestimation of the real relative abundance. In the present paper, partial solutions were attempted for the personal difference and diurnal rhythm. But further improvement is necessary to approximate the obtained result to the real relative abundance.

Summary

In order to find tentative solutions for some questions arising as to the belt census method for butterflies, some special censuses were performed. Main results are:

1) The result from census in the same route at the same time by two observers clarified that the personal difference did not affect much the result as far as they possessed approximately the similar ability of identifying the species.

2) Disturbance caused by a fore-going person was not significant for most butterflies except some species with the habit of resting or absorbing water on the census road such as *Aglais urticae* and *Bibasis aquilina.*

3) Within the limit of the procedure adopted, the capture of butterflies did not markedly decrease the individual number except rare species, and even an increase of the number observed in some species (e.g. *Lethe diana*).

4) The recorded butterfly species showed specific diurnal rhythms, being classified into five types (two unimodal types, two bimodal types and an erratic

type.).

5) One census during 9:00∼12:00 or two censuses started at about 9:00 and about noon are more reliable to apprehend the real faunal makeup, when the execution of more censuses (e. g. two in the morning and two in the afternoon) are circumstantially difficult.

6) For all species the correction of individual number obtained from one census per day was proposed, with which we could infer the real relative abundance with a higher likelihood.

References

Akiyama, Y., Sekiguchi, T. and N. Koyama 1969. Fluttering activity of lycaenid butterfly, *Japonica saepestriata* (Hewiston). New Entomologist **18**: 1–17. (In Japanese with English summary).

Morisita, M. 1967. The seasonal distribution of the butterflies in the suburbs of Kyoto. 95–132 (In Japanese). In M. Morisita and T. Kira (ed)'s. Natural History-Ecological studies. VI+497pp. Chûo Kôron Co. Tokyo.

Nagasawa, S. 1969. Fisher's logarithmic series and truncated discrete lognormal proposed by Preston for expressing the relation between number of species and number of individuals in insects. Seibutsu-Kyozai (Materials for Biological Education) **6**: 1–17. (In Japanese).

Yamamoto, M. 1974. A butterfly phenology at Jozankei (Sapporo), Northern Japan. J. Fac. Sci. Hokkaido Univ. VI, Zool. **19**: 465–473.