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Studies on the Seasonal Variation of Population Structure in *Drosophila*, II. The Effect of Altitude on Seasonal Activity of *Drosophila*, with a Note on the Monthly Numerical Variation of Species¹⁾

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(With 8 Text-figures and 2 Tables)

In the previous paper (Wakahama 1962), the author reported the seasonal activity of *Drosophila* and allied forms on Mt. Dakesan, Shimane Pref., with reference to the fluctuation for the total population. The fluctuation in relation to the total population size was found to be bimodal in type, with two peaks in spring and autumn: *D. bizonata*, *D. lutea* and *D. subtilis* displayed two peaks, one in spring and the other in autumn, while *D. angularis* and *D. immigrans* showed a single peak, the former in autumn and the latter in summer. It was reported that there were some species which showed an altitudinal difference in seasonal activity. The effect of altitude on seasonal activity should therefore be considered in relation to the fluctuation for population structure in *Drosophila*. Previously correlation between distribution and altitude was studied in several species of *Drosophila* by Takada (1954, 1958), Kurokawa (1956) and Heed (1957), but the altitudinal difference of seasonal variation of population structure has remained without consideration.

The present report deals with the relation of altitude to the seasonal activity of *Drosophila* (part I), with a note on the monthly numerical variation of species, observed on Mt. Dakesan during a period from April to November, 1961 (part II).

It is the author's pleasant duty to express his gratefulness to Professor Sajiro Makino for reading through this manuscript with important advice. His sincere thanks are also due to Dr. Toyohi Okada for identification of the species, and to Dr. Eizi Momma for his special guidance.

Part I. Altitudinal difference on seasonal activity of *Drosophila*

Method of collection: For details of collection method, refer to the author's previous paper (Wakahama 1962). Out of 16 traps used, 6 were set up along the foot of Mt. Dakesan at the 100 m level (Sta. I), 5 along the 100 to 200 m level (Sta. II), and the remaining 5 from 200 to the summit of the mountain (Sta. III).

Results

In this collection, a total of 9958 specimens was obtained; among them 4416 specimens represented by 37 species were obtained in Sta. I, 3008 specimens includ-

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ing 24 species in Sta. II, and 2534 specimens comprise in 30 species in Sta. III (Table 1).

In Sta's. I and II, the seasonal activity of the flies was found to be of a typical bimodal type, with two peaks in spring and autumn, whereas a single summer peak was found in Sta. III.

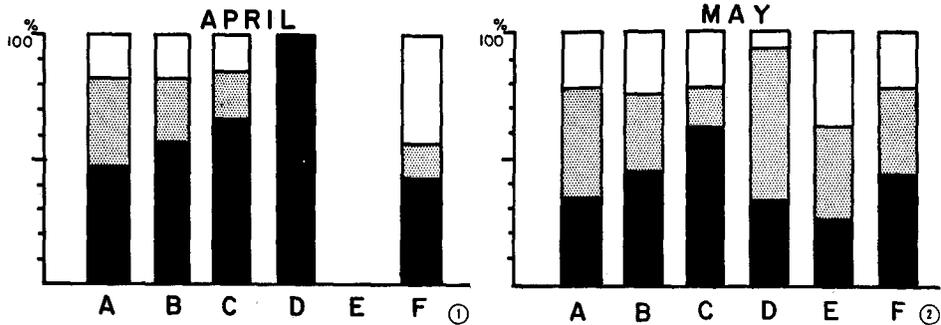
Table 1. Monthly collection records of dominant species of *Drosophila* observed at three stations on Mt. Dakesan, from April to November (1961).

Species		Month								
		April	May	June	July	August	September	October	November	Total
<i>D. bizonata</i>	Sta. I	30	39	39	7	40	32	542	839	1568
	Sta. II	23	51	39	15	42	50	238	507	965
	Sta. III	11	24	24	17	27	38	82	170	393
<i>D. lutea</i>	Sta. I	16	235	184	26	12	21	296	339	1129
	Sta. II	7	163	132	40	38	28	97	47	552
	Sta. III	5	129	192	160	118	31	43	24	702
<i>D. subtilis</i>	Sta. I	21	110	185	22	9	65	219	60	691
	Sta. II	6	31	87	25	32	67	281	121	650
	Sta. III	5	37	48	46	83	67	87	32	405
<i>D. angularis</i>	Sta. I	3	6	13	0	0	1	209	130	362
	Sta. II	0	11	12	0	5	0	218	103	349
	Sta. III	0	1	4	4	5	1	41	68	124
<i>D. immigrans</i>	Sta. I	0	2	14	15	0	0	5	40	76
	Sta. II	0	3	23	62	5	0	0	2	95
	Sta. III	0	3	74	248	116	2	1	5	449
<i>D. rufa</i>	Sta. I	3	6	21	8	18	9	15	2	82
	Sta. II	1	5	26	5	36	21	3	1	98
	Sta. III	3	3	19	42	83	30	4	0	184
Others	Sta. I	11	31	43	11	33	105	190	84	508
	Sta. II	10	24	27	12	23	105	64	40	302
	Sta. III	0	31	42	23	29	115	26	11	277
Total	Sta. I	84	429	499	89	112	233	1476	1494	4416
	Sta. II	41	288	346	159	181	271	901	821	3008
	Sta. III	24	228	403	540	461	284	284	310	2534

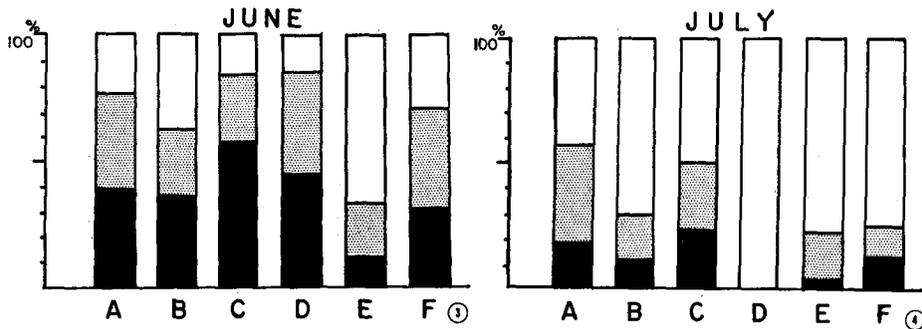
Among the species observed, *D. bizonata* and *D. angularis* showed a monomodal activity in all stations here considered. The former showed peak in November in the three stations, while the latter displayed a peak in October in Sta's. I and II, and in November in Sta. III. *Drosophila lutea* and *D. subtilis* furnished a bimodal curve in Sta's. I and II, with two peaks in spring and autumn, whereas in Sta. III, the former showed a monomodal activity exhibiting a peak in spring, though the latter was indefinite in activity type. *Drosophila immigrans* and *D. rufa* showed dominancy only in Sta. III; they displayed a monomodal activity peak, the former in July and the latter in August.

The dominant species collected in each station were highly variable by month.

In April, *D. bizonata*, *D. subtilis*, *D. lutea* and *D. histrioides* were the dominant species in Sta. I. Among them, only *D. bizonata* was dominant in Sta's. II and III. In May, *D. bizonata*, *D. lutea* and *D. subtilis* were found as the dominant species in all stations, and *D. auraria* was added to the dominant group in Sta. II.



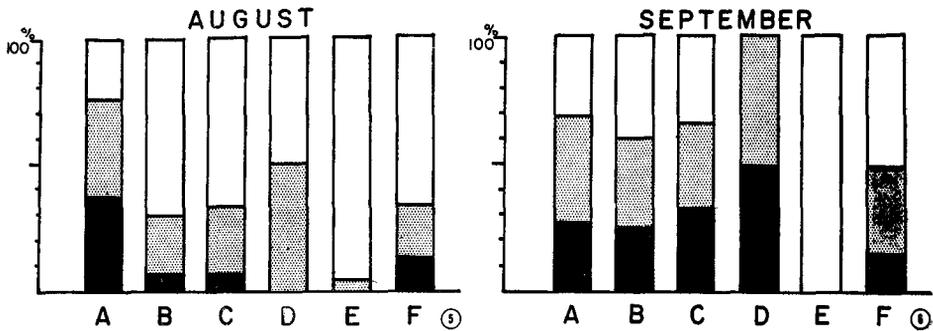
Figs. 1-2. Bar graphs showing seasonal differences on dispersal frequency of dominant species. A, *D. bizonata*. B; *D. lutea*. C; *D. subtilis*. D; *D. angularis*. E; *D. immigrans*. F; *D. rufa*. Black bars showing the frequency of each species in Sta. I, dotted bars that of in Sta. II, and white bars that of in Sta. III. Fig. 1; April. Fig. 2; May.



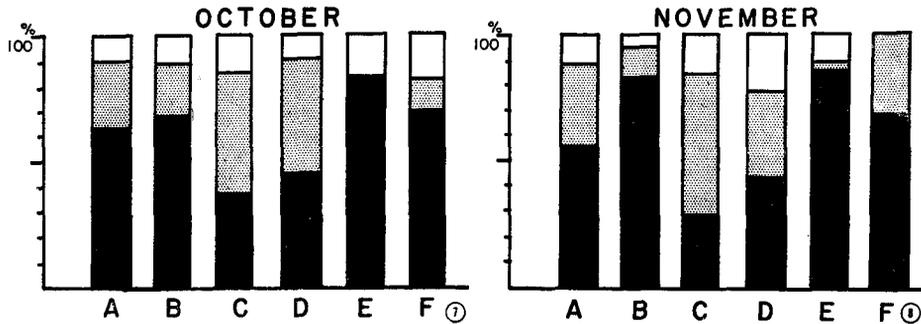
Figs. 3-4. See notes the legends for Figures 1-2. Fig. 3; June. Fig. 4; July.

In June, *D. bizonata*, *D. subtilis* and *D. lutea* showed dominance in all stations; further, *D. immigrans* in Sta's. II and III, *D. rufa* in Sta. II, and *D. auraria* in Sta. III were dominant members, respectively. In July, *D. lutea*, *D. subtilis* and *D. immigrans* were found as members of the dominant group in all stations. *Drosophila bizonata* showed dominance in Sta's. I and II, and *D. rufa* in Sta. III. In August, *D. bizonata*, *D. rufa*, *D. lutea* and *D. subtilis* were dominant in all stations, while *D. coracina* and *D. auraria* were the dominant species in Sta. I, *D. sternopleuralis* in

Sta. II, and *D. immigrans* in Sta. III. In September, *D. subtilis*, *D. bizonata*, *D. lacertosa* and *D. lutea* were found to be dominant members in all stations, while *D. sordidula* was dominant in Sta. I, *D. suzukii* in Sta. II, and *D. rufa* and *D. sternopleuralis* in Sta's. II and III. In October and November, *D. bizonata*, *D. lutea* and *D. angularis* showed dominancy in all stations. *Drosophila subtilis* was the dominant species in all stations in October, while in Sta's. II and III in November.



Figs. 5-6. See notes the legends for Figures 1-2. Fig. 5; August. Fig. 6; September.



Figs. 7-8. See notes the legends for Figures 1-2. Fig. 7; October. Fig. 8; November.

Discussion

Ohba (1956) and Paik (1958) stated that in *Drosophila* different patterns of seasonal activity may occur according to different altitudes in a certain locality. The results of the present survey indicate that a considerable difference is observed in seasonal activity of *Drosophila* according to the difference of altitude. As shown in Figures 1-8, *D. bizonata* was obtained abundantly in Sta. I in April, October and November, in Sta. II in May, June, August and September, and in Sta. III in July.

Drosophila lutea furnished a large number in collections of Sta. I in April, May, October and November, and in Sta. III in the other four months. *Drosophila subtilis* showed dominance in Sta. I in April, May and June, in Sta. II October and November, and in Sta. III in July and August. This species showed in September a uniform frequency in occurrence in all stations. *Drosophila angularis* showed a small number of individuals in collection during the period from April to September, while it furnished a large number in October and November in Sta's. I and II. *Drosophila immigrans* and *D. rufa* showed a high dominance in Sta. III in summer.

In the light of the above findings, it is evident that most species of *Drosophila* are abundant in number on the foot and midway up Mt. Dakesan in spring and autumn seasons, while on the summit they are abundant in summer time.

Part II. Monthly numerical variation of species

The method and stations (Sta's. I-III) of collection were described in detail in the author's previous paper (Wakahama 1962).

Results

A total number of species collected in this survey is 42, as shown in Table 2. Among them, 8 species appeared in April and 7 species were collected in Sta. I, 6 species in Sta. II and 4 species in Sta. III. *Drosophila lutea*, *D. rufa*, *D. bizonata* and *D. subtilis* were found in the three stations and *Amiota variegata* and *D. angularis* were collected in Sta. I, while *D. melanogaster* in Sta. II. *Drosophila histrioides* was obtained in Sta's. I and II.

Among 17 species which were secured in May, *Mycodrosophila splendida*, *D. lutea*, *D. auraria*, *D. rufa*, *D. angularis*, *D. bizonata*, *D. immigrans* and *D. subtilis* were collected in the three stations. *Drosophila histrioides* was collected in Sta's. II and III, while *D. lacertosa* in Sta's. I and III. *Drosophila busckii*, *D. pengi*, *D. virilis* and one undistinguished specimen were collected in Sta. I, *D. bifasciata* and *D. melanogaster* in Sta. II, and *D. histrio* in Sta. III. Compared the data of May with those of April, it is evident that *Mycod. splendida*, *D. busckii*, *D. immigrans*, *D. virilis*, *D. pengi*, *D. lacertosa* and one undistinguished specimen appeared newly in Sta. I, while *D. histrioides* was not obtained in this station. *Mycodrosophila splendida*, *D. bifasciata*, *D. auraria*, *D. angularis* and *D. immigrans* were new members in Sta. II. *Mycodrosophila splendida*, *D. histrioides*, *D. auraria*, *D. histrio*, *D. immigrans* and *D. lacertosa* were found newly in Sta. III.

In June, 18 species were collected; amongst them 15 species were obtained in Sta. I, 11 species in Sta. II and 13 species in Sta. III. In these members, *D. histrioides*, *D. coracina*, *D. lutea*, *D. auraria*, *D. angularis*, *D. bizonata*, *D. strenopleurialis*, *D. immigrans* and *D. subtilis* appeared in the three stations. *Drosophila suzukii* was collected in Sta's. I and III. *Amiota variegata*, *Parascaptomyza pallida*, *D. sordidula* and *D. lacertosa* were secured in Sta. I. *Drosophila pengi*

Table 2. Altitudinal distribution of the number of species observed on Mt. Dakesan, during from April to November, 1961.

Month	April	May	June	July	August	September	October	November
No. of total species collected	8	17	18	16	18	21	36	19
No. of species common to all stations	4	8	10	9	8	12	13	10
No. of species collected in Sta. I	7 (2)	12 (4)	15 (4)	12 (2)	9 (1)	15 (1)	31 (11)	18 (6)
No. of species collected in Sta. II	6 (1)	11 (2)	11 (1)	10 (0)	13 (2)	15 (0)	16 (3)	13 (1)
No. of species collected in Sta. III	4 (0)	11 (1)	13 (2)	14 (3)	15 (4)	19 (4)	15 (2)	10 (0)
No. of species common to Sta's. I and II	1	0	0	0	0	1	3	2
No. of species common to Sta's. I and III	0	1	1	1	0	1	4	0
No. of species common to Sta's. II and III	0	1	0	1	3	2	0	0

* The numerals in the parentheses denote the number of species characteristic to that station.

and *D. bifasciata* were seen in Sta. II, while *D. melanogaster* in Sta. III. In comparison of population structure in June with those of May, it was found that *A. variegata*, *P. pallida*, *D. histrioides*, *D. coracina*, *D. suzukii*, *D. sternopleuralis* and *D. sordidula* appeared newly in Sta. I, whereas *Mycod. splendida*, *D. busckii*, *D. pengi*, *D. virilis* and one undistinguished specimen were not collected in this station. In Sta. II, *D. coracina*, *D. sternopleuralis* and *D. pengi* were added as new members, and *Mycod. splendida*, *D. bifasciata* and *D. melanogaster* were not observed in this station. *Drosophila coracina*, *D. bifasciata*, *D. suzukii*, *D. melanogaster* and *D. sternopleuralis* were newly found and *Mycod. splendida*, *D. histrio* and *D. lacertosa* were not collected in Sta. III.

In July, 16 species were obtained; among them 12 species were observed in Sta. I, 10 species in Sta. II and 14 species in Sta. III. In these species, *D. suzukii*, *D. lutea*, *D. auraria*, *D. rufa*, *D. bizonata*, *D. immigrans*, *D. subtilis*, *D. histrioides* and *D. virilis* were collected in the three stations. *Drosophila sternopleuralis* was collected in Sta's. I and III, while *D. busckii* in Sta's. II and III. *Amiota variegata* and *D. melanogaster* were obtained in Sta. I, whereas *Microdrosophila* like sp., *D. quadrivittata* and *D. angularis* were observed in Sta. III. In this month, *D. virilis* and *D. melanogaster* were new members in Sta. I. and *P. pallida*, *D. coracina*, *D. angularis*, *D. sordidula* and *D. lacertosa* were not collected in this station. In Sta. II, *D. busckii*, *D. suzukii* and *D. virilis* were added as new members, while *D.*

coracina, *D. angularis*, *D. sternopleuralis* and *D. pengi* did not appear in this station. In Sta. III, *Microdrosophila* like sp., *D. quadrivittata*, *D. busckii* and *D. virilis* were newly found, whereas *D. coracina*, *D. bifasciata* and *D. melanogaster* were not collected in this station.

In August, 18 species were collected, 9 species out of which were found in Sta. I, 13 species in Sta. II and 15 species in Sta. III. In these species, *D. histrioides*, *D. coracina*, *D. lutea*, *D. auraria*, *D. rufa*, *D. bizonata*, *D. sternopleuralis* and *D. subtilis* were collected in the three stations, and *D. melanogaster*, *D. angularis* and *D. immigrans* were obtained in Sta's. II and III. *Scaptomyza graminum* was collected only in Sta. I. *Leucophenga argentosa* and *L. ornatipennis* were found in Sta. II, while *A. variegata*, *Mycod. splendida*, *D. suzukii* and *D. lacertosa* were obtained in Sta. III. In comparison with the members obtained in the former month, *S. graminum* and *D. coracina* were new members in Sta. I, while *A. variegata*, *D. suzukii*, *D. melanogaster*, *D. immigrans* and *D. virilis* did not appear in this station. In Sta. II, *L. argentosa*, *L. ornatipennis*, *D. coracina*, *D. melanogaster*, *D. angularis* and *D. sternopleuralis* were found as new members, whereas *D. busckii*, *D. suzukii* and *D. virilis* were not collected. In Sta. III, *A. variegata*, *Mycod. splendida*, *D. coracina*, *D. melanogaster* and *D. lacertosa* newly appeared, whereas *Microd. sp.*, *D. quadrivittata*, *D. busckii* and *D. virilis* were not collected in this station in this month.

In September, 21 species were collected, 15 species of which were obtained in Sta. I, 15 species in Sta. II and 19 species in Sta. III. Among them, *A. variegata*, *D. suzukii*, *D. lutea*, *D. melanogaster*, *D. auraria*, *D. rufa*, *D. bizonata*, *D. sternopleuralis*, *D. subtilis*, *D. virilis*, *D. sordidula* and *D. lacertosa* were collected in the three stations. *Drosophila pengi* was obtained in Sta's. I and II, *D. histrioides* and *D. brachynephros* in Sta's. II and III, and *D. angularis* in Sta's. I and III. *Drosophila coracina* was collected only in Sta. I, while *A. magna*, *D. alboralis*, *D. immigrans* and *D. virgata* were gathered in Sta. III. Compared the data of this month with those of August, it is apparent that *A. variegata*, *D. suzukii*, *D. melanogaster*, *D. angularis*, *D. pengi*, *D. virilis*, *D. sordidula* and *D. lacertosa* were new members in Sta. I, while *S. graminum* and *D. histrioides* did not appear in this station. In Sta. II, *A. variegata*, *D. suzukii*, *D. brachynephros*, *D. pengi*, *D. virilis*, *D. sordidula* and *D. lacertosa* appeared as new members in this station. On the other hand, *L. argentosa*, *L. ornatipennis*, *D. coracina*, *D. angularis* and *D. immigrans* were not collected in this station. In Sta. III, *A. magna*, *D. alboralis*, *D. brachynephros*, *D. virgata*, *D. virilis* and *D. sordidula* consisted of new members in this station, whereas *Mycod. splendida* and *D. coracina* were not obtained in this station.

In October, 36 species were collected and among of them, 31 species were found in Sta. I, 16 species in Sta. II, and 15 species in Sta. III. In these species, *D. coracina*, *D. suzukii*, *D. lutea*, *D. melanogaster*, *D. rufa*, *D. angularis*, *D. bizonata*, *D. sternopleuralis*, *D. pengi* and *D. subtilis* were collected in three stations.

Drosophila auraria, *D. brachynephros* and *D. sordidula* were obtained in Sta's. I and II, while *D. sexvittata*, *D. unispina* and *D. immigrans* were seen in Sta's. I and III. *Amiota variegata*, *L. magnipalpis*, *L. concilia*, *L. angusta*, *Mycod. splendida*, *P. pallida*, *S. graminum*. *D. alboralis*, *D. quadrivittata*, *D. pulchrella*, *D. ficusphila*, *D. nigromaculata*, *D. testacea*, *D. grandis* and *D. virgata* were found only in Sta. I., *L. ornatipennis*, *D. bifasciata* and *D. virilis* in Sta. II, and *D. histrioides* and *D. lacertosa* in Sta. III. In this month, *L. magnipalpis*, *L. concilia*, *L. angusta*, *Mycod. splendida*, *P. pallida*, *S. graminum*, *D. alboralis*, *D. sexvittata*, *D. quadrivittata*, *D. pulchrella*, *D. ficusphila*, *D. brachynephros*, *D. unispina*, *D. nigromaculata*, *D. testacea*, *D. grandis*, *D. immigrans* and *D. virgata* were added as new members in Sta. I, while *D. virilis* and *D. lacertosa* were not obtained in this station. In Sta. II, *L. ornatipennis*, *D. coracina*, *D. bifasciata* and *D. angularis* were new members in this station, whereas *A. variegata*, *D. histrioides* and *D. lacertosa* did not appear in Sta. II. In Sta. III, *D. sexvittata*, *D. coracina*, *D. unispina*, *D. histrio* and *D. pengi* were newly found in this station, while *A. variegata*, *A. magna*, *D. alboralis*, *D. auraria*, *D. brachynephros*, *D. virgata*, *D. virilis* and *D. sordidula* were not seen in this station.

In November, 18 species were found of which 18 species were collected in Sta. I, 13 species in Sta. II and 10 species in Sta. III. In these species, *D. suzukii*, *D. lutea*, *D. melanogaster*, *D. ficusphila*, *D. brachynephros*, *D. angularis*, *D. bizonata*, *D. sternopleuralis*, *D. immigrans* and *D. subtilis* were collected in the three stations. *Drosophila coracina* and *D. rufa* were obtained in Sta's. I and II. *Leucophenga argentosa*, *D. histrioides*, *D. busckii*, *D. auraria*, *D. histrio* and *D. virgata* were collected only in Sta. I, while *D. sordidula* was seen in Sta. II. In comparison the data of this month with those of the former month, *L. argentosa*, *D. histrioides*, *D. busckii* and *D. histrio* were newly found in Sta. I, while *A. variegata*, *L. angusta*, *L. magnipalpis*, *L. concilia*, *Mycod. splendida*, *P. pallida*, *S. graminum*, *D. alboralis*, *D. sexvittata*, *D. quadrivittata*, *D. pulchrella*, *D. nigromaculata*, *D. testacea*, *D. grandis*, *D. pengi*, *D. virilis* and *D. sordidula* did not appear in this station. In Sta. II, *D. ficusphila* and *D. immigrans* were new members in this station. On the other hand, *L. ornatipennis*, *D. bifasciata*, *D. auraria*, *D. pengi* and *D. virilis* were not collected in this station. In Sta. III, *D. ficusphila* and *D. brachynephros* were newly observed in this station, while *D. sexvittata*, *D. histrioides*, *D. coracina*, *D. rufa*, *D. unispina*, *D. pengi*, *D. virgata* and *D. lacertosa* were not collected in this station.

Discussion

Ohba (1956) stated that the monthly population structure in Asakawa forest consisted of 6 to 14 species. The results of the present survey indicate that 10 or more species consist of a monthly population structure, and that the highest collection record with 31 species was obtained in Sta. I in October. Heed (1957)

pointed out that in *Drosophila* population of El Salvador most species showed a definite favor to either a highland or lowland. Based on the data obtained in this survey it seems to the author that, 50 per cent or more of collected species may be members of both habitats.

It was shown in Part I that dominant species of *Drosophila* are abundant in number on the foot and midway of Mt. Dakesan in spring and autumn seasons, while on the summit in summer time. The results of the present study indicate that there is a related feature also with respect of species number: the number of species collected was abundant on the foot and midway of the mountain in spring and autumn seasons, but on the summit in summer.

Summary

The altitudinal difference in seasonal variation of population structure in *Drosophila* was studied on the basis of data obtained during a period from April to November, 1961, on Mt. Dakesan, Shimane Prefecture, with particular regard to the relation of altitude to seasonal activity of some drosophilid flies. Data on the monthly numerical variation of species were given additionally.

Part I: It was shown that a considerable difference occurred in seasonal activity of *Drosophila* according to the difference of altitude. Generally, *Drosophila* flies were abundant in spring and autumn on the foot and midway of the ascent, while in summer they were abundant on summit.

Part II: It was observed that the number of species collected in this survey was abundant on the foot and midway of the mountain in spring and autumn seasons, while on the summit in summer.

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