

EYE-STRIPE COMPOSITION, SEX-RATIOS AND  
MORPHOMETRY OF THE 1949-61 DESERT  
LOCUST POPULATIONS IN INDIA IN RELA-  
TION TO PHASE TRANSFORMATION

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(With 7 Text-figures)

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## I—INTRODUCTION

1. *General*

The Ninth (recorded) Swarming Cycle of the Desert Locust, *Schistocerca gregaria* (Forskål) (Orthoptera: Acrididae) in India (1949–55) started with a sudden increase in locust population density in 1949, a small sample of which, taken from the village Kakko (Bikaner, District, Rajasthan) had a population density of about 18,000 locusts per square mile. This initial or *Kakko Concentration* was analysed morphometrically by Misra (1952). Roonwal (1952) studied the second year of the swarming cycle from a small sample obtained from the *Ajmer Swarm* of 1950. Bhanotar *et al.* (in press) studied the 1954-population. A small sample from a swarm in July 1954 was also studied by Roonwal (1955). Roonwal and Bhanotar (1966) studied the 1955-population which formed last year of this Ninth Cycle. Bhanotar *et al.* (in press) studied samples from populations of the first and second years (1956 and 1957) of the non-swarming period which immediately followed the 1949–55 swarming Cycle and lasted upto 1958. Finally, Roonwal and Bhanotar (1962 and 1966) studied a sample obtained from a *Calcutta Swarm* of 1961 which represented the third year of the Tenth Swarming Cycle in India (1959–63).

Thus, we have now available considerable data on several biologically interesting populations representing various degrees of phase-transformation in the Desert Locust in India. For the 1949–55 cycle we have the *Kakko Concentration* of 1949 which started the initial phase-transformation from *solitaria* to *gregaria* populations; the 1955-population (particularly the last one-third or Group III) during which transformation from *gregaria* to *solitaria* population took place; and the intervening populations of the years 1950, 1954 and the earlier two-thirds of 1955 (Groups I and II); then were studied the representative of the years 1956–57 (of the non-swarming period 1956–58); and finally, another *gregaria* representative (a 1961 swarm) of the swarming period 1959–63.

The phase status of all these populations have now been studied. We may now be able to know the behaviour of the morphometric characters and the ratios in phase-transformation. Similarly, we are in a position to study the behaviour of the eye-stripes (5-8-striped individuals) and the sex-ratios. We may further be able to know which are the more sensitive phase-characters and how they behave in the critical periods of phase-transformation.

2. *Abbreviations used*

Except where otherwise stated, the following abbreviations have been used throughout:—

- O, Width of head at ocular level.
- C, Width of head at genal level.
- P, Length of pronotum.
- H, Height of pronotum.

- M, Width of pronotum at the constriction.  
 E, Length of elytron.  
 W<sub>1</sub>, Restricted width of elytron.  
 F, Length of hind-femur.  
 S.E., Standard error.

6-*greg.*, *greg.* or *Greg.*, typical 6- striped phase *gregaria* individuals.  
 6-*sol.*, 7-*sol.*, ph. *sol.*, typical 6- or 7- striped phase *solitaria* individuals.

6-, 7-, (6) or (7)- striped, 6- or 7- eye-striped.  
 5- 8- striped, 5- or 8- eye-striped.

1954 (Dehra Dun swarm), 6- or 7- striped individuals of 1954-Dehra Dun swarm (Roonwal, 1955).

1954-Gr.I, 1954 Group I populations.

1954-Gr.II, 1954, Group II populations.

1954-Gr.III, 1954 Group III populations.

1955-Gr.I, 1955 Group I populations.

1955-Gr.II, 1955 Group II populations.

1955-Gr.III, 1955 Group III populations.

1956-57 6- or 7- striped individuals of 1956 and 1957 years populations.

1961 (*Calcutta swarm*) or 1961 (*Cal.sw.*) or *Cal.sw.*(6), 6- or 7- striped individuals of 1961 Calcutta swarm.

Gr.I(6) or Gr.I(7), 6- or 7- striped individuals of Group I.

Gr.II(6) or Gr.II(7), 6- or 7- striped individuals of Group II.

Gr.III(6) or Gr.III(7), 6- or 7- striped individuals of Group III.

1949-*Kakko Conc.* or *Inl. Conc.*, Initial concentration of locusts Kakko village (Rajasthan, India) in 1949 (Misra, 1952).

1950-*Ajm. sw.*, or *Ajm.*(6), Ajmer Swarm population of 1950 (Roonwal and Misra, 1952).

### 3. *Acknowledgement*

I am grateful to Dr. M. L. Roonwal, Vice-Chancellor, University of Jodhpur, Jodhpur, Rajasthan and formerly, Director, Zoological Survey of India, Calcutta, for his valuable suggestions and guidance. Thanks are due to Director, Zoological Survey of India, for giving all laboratory facilities.

## II—EYE-STRIPES AND SEX-RATIOS

### 1. *Eye-stripes*

(a) *Eye-stripes composition (1949-61)*.—The number of eye-stripes varies from 5-8, and the composition (percentage) of such individuals in

various populations is as given below:—

Years	% of individual in each type $\pm$ S.E.			
	5-striped	6-striped	7-striped	8-striped.
1949	0.4 (1 ex.)	94.0 $\pm$ 1.4	5.6 $\pm$ 1.4	0
1950	0	93.00	7.00	0
1954 (Dehra Dun swarm)	0	99.9	0.1	0
1954-Gr.I	0	85.14 $\pm$ 4.13	14.86 $\pm$ 4.14	0
1954-Gr.II	0	99.77 $\pm$ 0.13	0.23 $\pm$ 0.14	0
1954-Gr.III	0	97.84 $\pm$ 0.69	2.16 $\pm$ 0.69	0
1955-Gr.I	0	93.0 $\pm$ 4	7.0 $\pm$ 4	0
1955-Gr.II	0.20 $\pm$ 0.3 (2 exs.)	98.6 $\pm$ 0.3	1.2 $\pm$ 0.3	0
1955-Gr.III	0	56.0 $\pm$ 4	42.7 $\pm$ 4	1.3 $\pm$ 4 (2 exs.)
1956-57	0	60.0 $\pm$ 5	40.0 $\pm$ 5	0
1961 (Calcutta swarm)	0	100.00	0	0

(b) *Discussion.*—No eye-stripe data is available for the non-swarmling period 1947-48. However, Roonwal (1954, p. 507) mentioned the common occurrence of 7-striped forms; but no 8-striped forms were reported. During the ninth swarming cycle in India (1949-55), all the four types (*viz.*, 5- to 8-striped) forms occurred. The 5- and 8-striped forms are of a rare occurrence in nature. We may now discuss the position regarding each type of eye.

(i) *5-eye-stripes:* Roonwal (1954) placed the 5-striped forms with solitaria population, but left its position open.

In the 1949-55 Cycle, Misra (1952) found a single 5-striped form in the initial *Kakko Concentration* of 1949, a period when phase-transformation took place. Later on, from the last year of this cycle (1955), particularly Group II, Roonwal and Bhanotar (1966) found two 5-striped forms, and correlated its appearance with the most critical period of the Desert Locust plague, when the equilibrium in the morphometric characters and ratios appears to be most disturbed. Still, its basic origin and phase-status remain problematic. For the present we may associate the occurrence of 5-striped forms with the critical period when the phase is being transformed (*vide*, discussion in Roonwal, in press).

(ii) *6-eye-stripes:* As viewed against Roonwal's First Hypothesis (1945), the populations of the years 1949-55 (swarming cycle), behaved in a set pattern. Right from the initial *Kakko concentration* of 1949, the "above 80 percent rule for 6-striped forms was strictly maintained by the populations (indicating a swarming or *gregaria* tendency) upto August, 1955 (ranges of means 85.14  $\pm$  4.13 to 99.9%). In the 1954-gr.I population, the proportion of 6-striped forms (85.14  $\pm$  4.13%) came down somewhat, but still remained above 80%. In the critical

1955-Gr.III population (September-December), a sudden transformation to *solitaria* phase took place. The proportion of 6-striped forms fell far below 80%, coming down to  $56.0 \pm 4\%$  along with a corresponding increase in the proportion of 7-striped forms ( $44.0 \pm 4\%$ ). This declined ratio was maintained by the succeeding population of the years 1956 and 1957 (6-striped,  $60.0 \pm 5\%$ ). In the *Calcutta Swarm* of 1961, representing the third year of the tenth swarming cycle (1959-63), the percentage of 6-striped forms arose to 100% and 7-striped forms were completely absent.

(iii) *7-eye-stripes*: The presence of 7-striped forms in all the studied populations of the Ninth Swarming Cycle (1949-55), may indicate the mildness of this Cycle. But the sudden abundance of 7-striped forms ( $44.0 \pm 4\%$ ) in the 1955-Gr.III population (September-December) show an abrupt disturbance in the hitherto stable condition of the eye-stripe composition. This eye-stripe shift in the last generation of the 1955-population corresponds to the complete break down of the Cycle, as seen from the study of the immediately succeeding populations of the years 1956 and 1957.

(iv) *8-eye-stripes*: The earlier record of the occurrence of 8-striped forms was reported in India during the non-swarmling period 1932-39, particularly in the years 1936-38. Roonwal (1954, p. 504) associated this form with the "extreme development of the *solitaria* period". In the 1949-55 Swarming Cycle, 8-striped forms were reported only in the last part of 1955 (Gr.III) population when two such individuals were found.

(v) *Asymmetry in eye-stripes*: Usually the number of eye-stripes in an individual are symmetrical *i.e.*, both eyes has the same number of stripes. But in the middle period of 1955 (Gr.II), an asymmetrical individual occurred (Bhanotar, 1959). While the right eye had 8-stripes the left eye only 7. The phase significance of this asymmetry is problematic—probably it has none.

Thus, the important and significant role of eye-stripes composition in determining the phase nature of a population is established, and the data give further support to Roonwal's (1945) First Hypothesis.

(b) *Discussion*.—Except for three 5-striped individuals (1♂, 2♀♀) and two 8-striped ones (both females), the sexes in the remaining individuals of the 1949-55 cycle were associated with 6- and 7-striped forms only.

As viewed against Roonwal's (1945) Second hypothesis, during the swarming period, in all the population—groups from July 1949 to August, 1955, in the 6- eye-striped category, the proportion of sexes remained almost equal (range 45-56%), indicating a *gregaria* characteristic of the desert locust population, where the sex-ratio is typically 50:50. However, this stability of the sex-ratio was found to be disturbed in the 1955-Gr.III population (September-December 1955). Where the sex-ratio in the 6-striped category was ♂84±4: ♀16±4. This predominance of males over females showed a *solitaria* facies of the population. In the 7-striped category of the same population, the proportion of females was higher (♂33±5: ♀67±5), thereby further indicating the *solitaria* characteristic of the population.

The trend of the sex-ratio as found in the 1955-Gr. III population was maintained by the immediately succeeding population of the years 1956 and 1957, where the ratio in 6-striped category was  $\sigma^75 \pm 6$ :  $\text{♀}25 \pm 6$  and in the 7-striped category  $\sigma^38 \pm 8$ :  $\text{♀}62 \pm 8$ .

In the 1961-population (*Calcutta swarm*) the sex-ratio was almost equal ( $\sigma^49.23 \pm 6.20$ :  $\text{♀}50.77 \pm 6.20$ ), indicating the *gregaria* nature of this population.

## 2. Sex-ratios

(a) *Sex-ratios (1949-61)*.—The sex-ratios in the various populations of the period 1949-61 are as given below:—

Years	Sex-ratio (%)			
	6- eye-striped		7- eye-striped	
	Male	Female	Male	Female
1949	$54 \pm 3$	$46 \pm 3$	$20 \pm 10$	$80 \pm 10$
1950	71.43	25.87	(1 ex.)	—
1954 (Dehra Dun Swarm)	48.8	51.2	—	(1 ex.)
1954-Gr. I	$50.79 \pm 6.30$	$49.21 \pm 6.30$	$27.27 \pm 13.45$	$72.73 \pm 13.43$
1954-Gr. II	$54.54 \pm 1.39$	$45.46 \pm 1.39$	0	0
1954-Gr. III	$50.66 \pm 2.35$	$49.34 \pm 2.35$	$70.00 \pm 14.49$	$30.00 \pm 14.49$
1955-Gr. I	$56 \pm 7$	$44 \pm 7$	100	0
1955-Gr. I	$47.52 \pm 2$	$52.5 \pm 2$	$9 \pm 9$	$91 \pm 9$
1955-Gr. III	$84 \pm 4$	$16 \pm 4$	$33 \pm 5$	$67 \pm 5$
1956-57	$75 \pm 6$	$25 \pm 6$	$38 \pm 8$	$62 \pm 8$
1961 ( <i>Cal. Sw.</i> )	$49.23 \pm 6.20$	$50.77 \pm 6.20$	0	0
<i>Typical ph. gregaria</i> (Roonwal's Hypotheses)	50	50	0	0
<i>Typical ph. solitaria</i> (Roonwal's Hypotheses)	60	40	35	65

## III—MORPHOMETRIC CHARACTERS

(Text-figs. 1-4)

### 1. General

For comparisons among the various populations, only the following morphometric characters are taken into account. For the others, (namely, the length of eye (A), width of eye (B), and maximum (K) and minimum (L) width of mesosternal interspace, the data is either lacking or meagre.

1. Width of head at ocular level (O).
2. Width of head at genal level (C).
3. Length of pronotum (P).
4. Height of pronotum (H).
5. Width of pronotum at the constriction (M).
6. Length of elytron (E).
7. Restricted width of elytron ( $W_1$ ).
8. Length of hind-femur (F).

These characters are discussed below with respect to their phase-association in relation to sex- and eye-stripe categories, to determine their trend in the swarming and non-swarming populations.

2. *Width of head at ocular level (O)*

(a) *Mean values.*—The mean values (mm.) of O in the available populations for swarming and non-swarming periods (1949–61) are as follows:—

<i>Populations (and eye-stripes)</i>	<i>Mean width (mm.) S. ± E.</i>		
	<i>Males</i>	<i>Females</i>	
1954-Gr.I(6)	6.40 ± 0.07	6.81 ± 0.13	
1954-Gr.II(6)	6.44 ± 0.01	6.76 ± 0.01	
1954-Gr.III(6)	6.41 ± 0.02	6.68 ± 0.02	
1954-Gr.I(7)	6.60 ± 0.50	7.00 ± 0.06	
1954-Gr.II(7)	—	7.00 ± 0.22	
1954-G.III(7)	6.33 ± 0.12	7.05 ± 0.07	
1955-Gr.I(6)	6.30 ± 0.05	6.71 ± 0.07	
1955-Gr.II(6)	6.40 ± 0.01	6.79 ± 0.01	
1955-Gr.III(6)	6.24 ± 0.025	6.75 ± 0.013	
1955-Gr.I(7)	6.27 ± 0.09	—	
1955-Gr.II(7)	6.10	6.94 ± 0.10	
<i>Ph.</i> {	Gr.III(7)	6.46 ± 0.05	7.14 ± 0.05
	1956-57 (6)	6.13 ± 0.032	6.72 ± 0.076
	<i>sol.</i> { 1956-57 (7)	6.42 ± 0.059	7.04 ± 0.063

(b) *Discussion.*—Data for only four years (1954–57) are available. Of these, the populations of the periods 1954-Grs. I–III and 1955-Grs. I and II are *gregaria* in nature and the 1955-Gr. III and 1956-57 populations are *solitaria*.

For each eye-stripe and sex-group, the mean values are significantly higher in phase *gregaria* populations than in *solitaria* ones, and this is particularly evident in males, females are less phase-sensitive.

Generally, in each eye-stripe and phase-group, the values in females are significantly higher than in males and 6-striped individuals are significantly smaller than 7-striped ones.

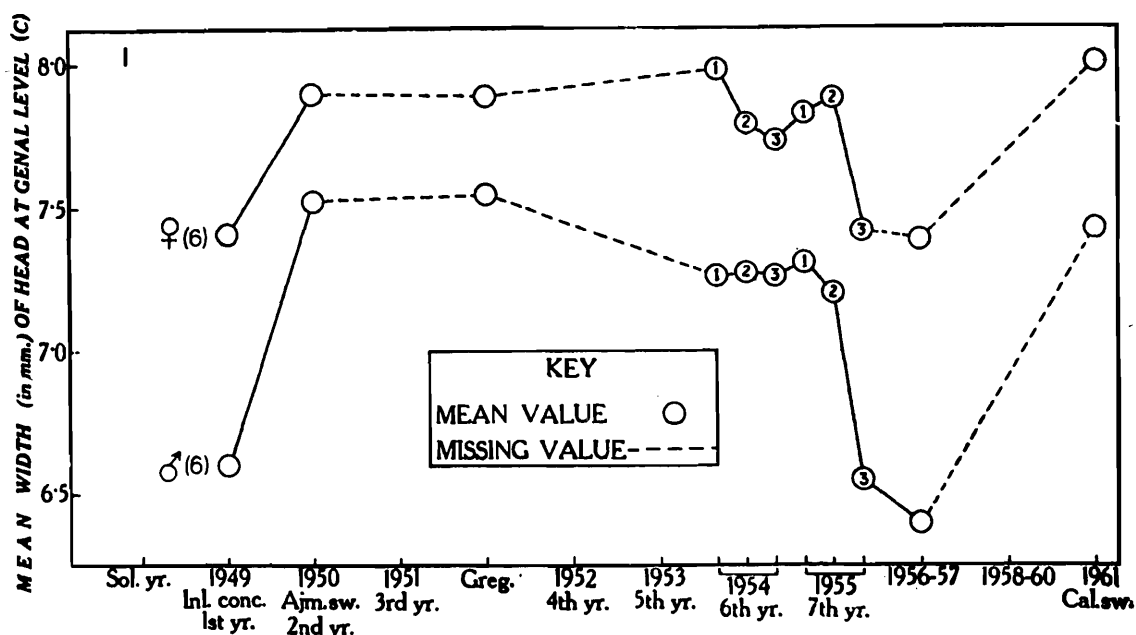
Thus, the width of head at the ocular level is correlated with the degree of gregarization and solitariness of the population. It tends to increase from a lower *solitaria* level to a higher *gregaria* level, particularly in males. This phase-transformation apparently takes place in one generation, *i.e.*, very quickly.

## 3. Width of head at genal level (C)

(Text-fig. 1)

(a) *Mean values.*—The mean values (mm.) of C in the available populations for swarming and non-swarming periods (1949–61) are as follows:—

Populations (and eye-stripes)	Mean width (mm.) $\pm$ S.E.	
	Males	Females
6-greg.	7.55 $\pm$ 0.04	7.89 $\pm$ 0.07
1949-Kakko Conc. (6)	7.60 $\pm$ 0.033	7.41 $\pm$ 0.041
1950-Ajm.Sw. (6)	7.53 $\pm$ 0.082	7.90 $\pm$ 0.248
1954-Gr. I (6)	7.26 $\pm$ 0.10	7.98 $\pm$ 0.07
1954-Gr. II (6)	7.27 $\pm$ 0.01	7.79 $\pm$ 0.02
1954-Gr. III (6)	7.26 $\pm$ 0.02	7.73 $\pm$ 0.03
1954-Gr. I (7)	6.97 $\pm$ 0.32	7.65 $\pm$ 0.09
1954-Gr. II (7)	—	7.70 $\pm$ 0.22
1954-Gr. III (7)	6.50 $\pm$ 0.14	7.67 $\pm$ 0.16
1955-Gr. I (6)	7.31 $\pm$ 0.07	7.83 $\pm$ 0.07
1955-Gr. II (6)	7.20 $\pm$ 0.02	7.88 $\pm$ 0.02
1955-Gr. III (6)	6.55 $\pm$ 0.04	7.42 $\pm$ 0.16
1955-Gr. I (7)	6.63 $\pm$ 0.14	—
1955-Gr. II (7)	6.30	7.63 $\pm$ 0.15
Ph. { 1955-Gr. III (7)	6.67 $\pm$ 0.05	7.70 $\pm$ 0.05
sol. { 1956-57 (6)	6.40 $\pm$ 0.043	7.39 $\pm$ 0.088
sol. { 1956-57 (7)	6.75 $\pm$ 0.064	7.74 $\pm$ 0.090
1961-Cal.Sw. (6)	7.43 $\pm$ 0.040	—



Text.-fig 1.—*Schistocerca gregaria*. Graph showing the trend of variability in the width of head at genal level (C) in various populations, viz., swarming populations (1949–55 and '61), non-swarming populations (1956–57), and “typical” phases *solitaria* and *gregaria*. The missing values are shown in broken lines. Numerals in the circles indicate the population—Groups (1–3) of a particular year.

For other explanations see text,



(b) *Discussion.*—Data for the population of seven years (1949, '50, '54, '55, '56, '57 and '61) are available. Of these populations of 1950, 1954 (Grs. I–III), 1955 (Grs. I and II) and 1961 represent the *gregaria* facies and those of 1949, 1955 (Gr. III) and 1956-57 the *solitaria* facies.

This character, C, is the most sensitive phase-differentiating character. The mean value is significantly lower in *solitaria* population than in *gregaria*. Further, the 6- eye-striped individuals are significantly smaller than 7-striped ones in both sexes, and females are significantly larger than males.

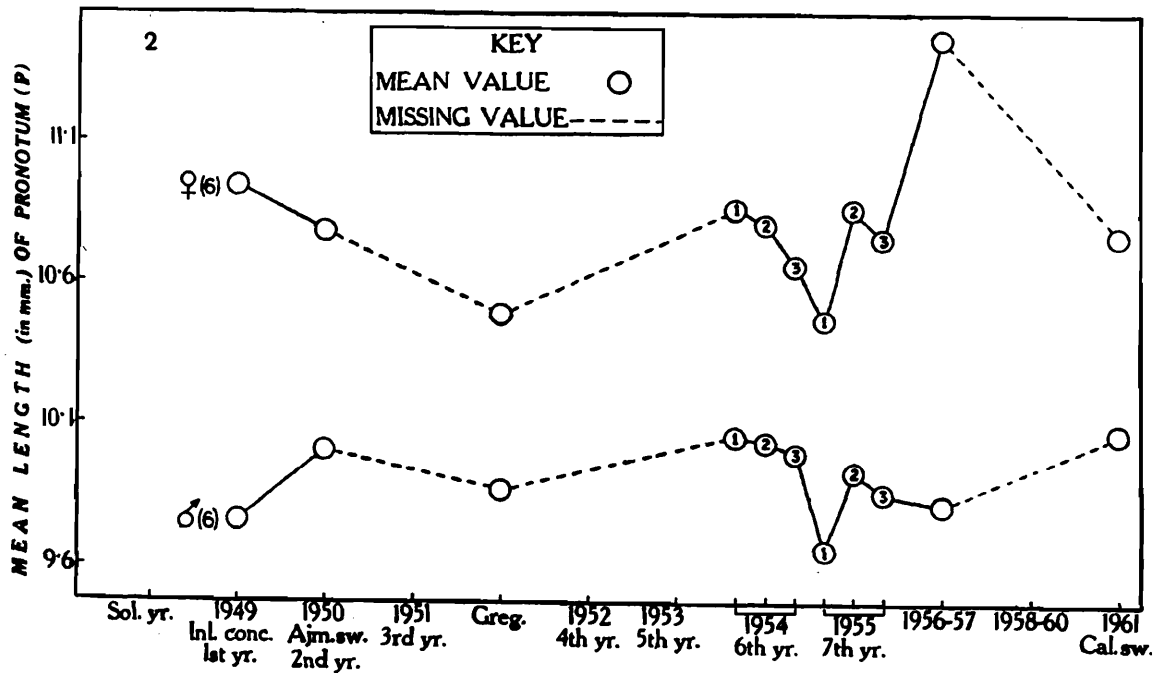
Thus, the width of the head at genal level is narrower in typical *solitaria* than in *gregaria* populations. In the latter it is wider and the value acquires a certain stability. The character is distinctly correlated with phase, and phase-transformation takes place in one generation, *i.e.*, very quickly.

#### 4. *Length of pronotum (P)*

(Text-fig. 2)

(a) *Mean values.*—The mean length (mm.) of P in the available populations for swarming and non-swarming periods (1949–61) are as follows:—

<i>Populations (and eye-stripes)</i>	<i>Mean length (mm.) ± S.E.</i>		
	<i>Males</i>	<i>Females</i>	
<i>6-greg.</i>	7.55 ± 0.04	7.89 ± 0.07	
1949- <i>Kakko Conc.</i> (6)	9.76 ± 0.054	10.94 ± 0.088	
1950- <i>Ajm.Sw.</i> (6)	10.01 ± 0.108	10.78 ± 0.343	
1954-Gr.I(6)	10.06 ± 0.12	10.86 ± 0.10	
1954-Gr.II(6)	10.04 ± 0.03	10.81 ± 0.03	
1954-Gr.III(6)	10.00 ± 0.04	10.66 ± 0.04	
1954-Gr.I(7)	10.30 ± 0.78	11.22 ± 0.20	
1954-Fr.II(7)	—	11.60 ± 0.36	
1954-Gr.III(7)	9.90 ± 0.28	11.77 ± 0.34	
1955-Gr.I(6)	9.66 ± 0.11	10.47 ± 0.11	
1955-Gr.II(6)	9.94 ± 0.02	10.86 ± 0.03	
1955-Gr.III(6)	9.86 ± 0.06	10.76 ± 0.29	
1955-Gr.I(7)	9.67 ± 0.44	—	
1955-Gr.II(7)	10.00	11.50 ± 0.29	
<i>Ph.</i> {	1955-Gr.III(7)	10.20 ± 0.08	11.90 ± 0.10
	1956-57 (6)	9.82 ± 0.078	11.46 ± 0.176
<i>sol.</i> {	1956-57 (7)	10.24 ± 0.149	12.10 ± 0.129
1961- <i>Cal.Sw.</i> (6)	10.07 ± 0.090	10.79 ± 0.090	



Text-fig. 2.—*Schistocerca gregaria*. Graph showing the trend of variability in the length of pronotum (P) in various populations as in Text-fig. 1. For explanations see Text-fig. 1 and the text.

(b) *Discussion*.—Data for the populations of six years, along with those of “typical” *gregaria*, are available. Of these, those of the years 1950, 1954 (Grs. I–III), 1955 (Grs. I and II) and 1961 represent the *gregaria* facies, and those of 1949, 1955 (Gr. III) and 1956–57 the *solitaria* facies.

The mean value in the *solitaria* facies population is significantly higher than in the *gregaria* for females, the difference in males being less pronounced. Within each phase—and eye-stripe group, females are significantly larger than males; and 6-striped individuals are smaller than 7-striped ones in both sexes.

In females, the length of the pronotum value increases as the populations moves from the *gregaria* to the *solitaria* facies. This tendency is reversed in males and the values tend, though at a slower rate, to decrease as the populations approach the *solitaria* condition.

Phase-transformation takes place in one generation *i.e.*, quickly and the change is more pronounced in males than in females.

### 5. Height of pronotum (H)

(a) *Mean values*.—The mean value (mm.) of H in the available populations for the swarming and non-swarming periods (1949–61) are as follows:—

Populations (and eye-stripes)	Mean height (mm.) $\pm$ S.E.	
	Males	Females
1954-Gr. I(6)	8.16 $\pm$ 0.10	8.93 $\pm$ 0.07
1954-Gr. II(6)	7.99 $\pm$ 0.02	8.69 $\pm$ 0.03
1954-Gr. III(6)	7.90 $\pm$ 0.03	8.49 $\pm$ 0.03
1954-Gr. I(7)	8.50 $\pm$ 0.40	9.39 $\pm$ 0.10
1954-Gr. II(7)	—	9.30 $\pm$ 0.20

Populations (and eye-stripes)	Mean height (mm.) $\pm$ S.E.	
	Males	Females
1954-Gr.III(7)	7.83 $\pm$ 0.16	9.07 $\pm$ 0.12
1955-Gr.I(6)	8.03 $\pm$ 0.08	8.70 $\pm$ 0.11
1955-Gr.II(6)	8.14 $\pm$ 0.02	8.98 $\pm$ 0.03
1955-Gr.III(6)	8.20 $\pm$ 0.04	9.10 $\pm$ 0.27
1955-Gr.I(7)	8.13 $\pm$ 0.26	—
1955-Gr.II(7)	7.70	9.37 $\pm$ 0.21
Ph. { 1955-Gr.III(7)	8.40 $\pm$ 0.09	9.90 $\pm$ 0.07
sol. { 1956-57 (6)	7.86 $\pm$ 0.047	9.13 $\pm$ 0.142
sol. { 1956-57 (7)	8.25 $\pm$ 0.086	9.57 $\pm$ 0.116

(b) *Discussion.*—Data for the populations of only four years (1954–57) are available. Of these, the populations of 1954 (Grs. I–III) and 1955 (Grs. I and II) represent *gregaria* facies and of 1955 (Gr.III) and 1956-57 the *solitaria* facies. The mean value is significantly higher in males than in females in *gregaria* populations. The character P is moderately phase—sensitive.

Within the same phase- and eye-stripe—group, females are significantly larger than males and 6-striped individuals are significantly smaller than 7-striped ones in both sexes. Thus, the height of pronotum decreases with the increase of gregarization, particularly in females. For males, however, this tendency is reversed. Phase transformation takes place, in one generation, *i.e.*, quickly.

#### 6. Width of pronotum at the constriction (M)

(a) *Mean values.*—The mean values of M in the available populations for the swarming and non-swarming periods (1949–61) are as follows :—

Populations (and eye-stripes)	Mean width (mm.) $\pm$ S.E.	
	Males	Females
6-greg.	5.86 $\pm$ 0.04	6.36 $\pm$ 0.08
1954-Gr.I(6)	5.95 $\pm$ 0.08	6.71 $\pm$ 0.07
1954-Gr.II(6)	5.73 $\pm$ 0.01	6.38 $\pm$ 0.02
1954-Gr.III(6)	5.64 $\pm$ 0.02	6.23 $\pm$ 0.03
1954-Gr.I(7)	6.27 $\pm$ 0.33	6.85 $\pm$ 0.06
1954-Gr.II(7)	—	6.70 $\pm$ 0.27
1954-Gr.III(7)	5.59 $\pm$ 0.12	6.67 $\pm$ 0.15
1955-Gr.I(6)	5.80 $\pm$ 0.05	6.52 $\pm$ 0.07
1955-Gr.II(6)	5.91 $\pm$ 0.01	6.63 $\pm$ 0.02
1955-Gr.III(6)	5.84 $\pm$ 0.03	6.67 $\pm$ 0.15
1955-Gr.I(7)	5.80 $\pm$ 0.15	—
1955-Gr.II(7)	5.70	6.78 $\pm$ 0.12
Ph. { 1955-Gr.III(7)	5.98 $\pm$ 0.05	7.09 $\pm$ 0.04
sol. { 1956-57 (6)	5.54 $\pm$ 0.038	6.55 $\pm$ 0.069
sol. { 1956-57 (7)	5.89 $\pm$ 0.080	6.85 $\pm$ 0.066

(b) *Discussion.*—Data for the populations of only four years (1954-57) along with those of “typical” *gregaria* are available. Of these, the populations of the year 1954 (Grs. I–III) and 1955 (Grs. I and II) represent the *gregaria* facies and of 1955-Gr.III and 1956-57 the *solitaria* facies. In males, the pronotum is significantly wider in *gregaria* populations than in *solitaria* ones, but females are less sensitive. The character M shows moderate phase-sensitivity in differentiating populations. Within each phase- and eye-stripe group, females have wider pronotum than males.

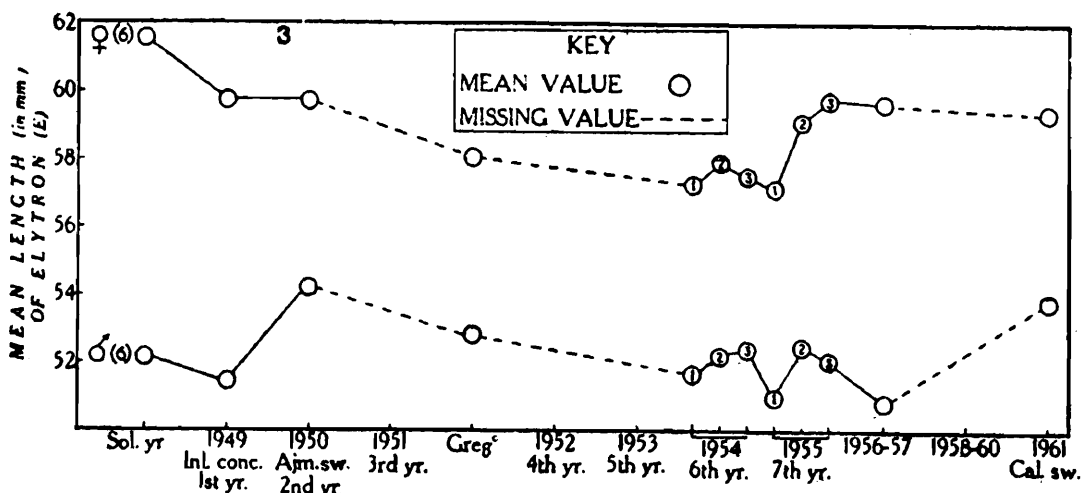
Thus, the width of pronotum increases with the increase of gregarization particularly in males; females are less sensitive. Phase-transformation takes place quickly, in one generation, and the change is reflected more in males than in females.

### 7. Length of elytron (*E*)

(Text-fig. 3)

(a) *Mean values.*—The mean values of *E* in the available populations for the swarming and non-swarming periods (1949–61) are as follows:—

Populations (and eye-stripes)	Mean length (mm.) $\pm$ S.E.		
	Males	Females	
6-sol.	52.15 $\pm$ 0.24	61.56 $\pm$ 0.31	
7-sol.	52.38 $\pm$ 0.42	62.90 $\pm$ 0.26	
6-greg.	52.85 $\pm$ 0.52	58.01 $\pm$ 0.81	
1949-Kakko Conc.(6)	51.46 $\pm$ 0.29	59.73 $\pm$ 0.42	
1949-Kakko Conc.(7)	—	61.38 $\pm$ 1.41	
1950-Ajm.Sw.(6)	54.16 $\pm$ 0.70	59.70 $\pm$ 1.68	
1954-Gr.I(6)	51.71 $\pm$ 0.97	57.24 $\pm$ 1.27	
1954-Gr.II(6)	52.25 $\pm$ 0.13	57.90 $\pm$ 0.18	
1954-Gr.III(6)	52.41 $\pm$ 0.21	57.51 $\pm$ 0.25	
1954-Gr.I(7)	51.83 $\pm$ 2.32	—	
1954-Gr.II(7)	—	61.90 $\pm$ 4.65	
1954-Gr.III(7)	51.77 $\pm$ 1.32	64.10 $\pm$ 0.80	
1955-Gr.I(6)	51.01 $\pm$ 0.49	57.09 $\pm$ 0.72	
1955-Gr.II(6)	52.48 $\pm$ 0.13	59.09 $\pm$ 0.14	
1955-Gr.III(6)	52.07 $\pm$ 0.31	59.74 $\pm$ 0.91	
1955-Gr.I(7)	50.23 $\pm$ 1.51	—	
1955-Gr.II(7)	50.20	60.22 $\pm$ 0.90	
Ph. {	1955-Gr.III(7)	52.58 $\pm$ 0.43	63.39 $\pm$ 0.48
	1956-57 (6)	52.07 $\pm$ 0.31	59.62 $\pm$ 0.823
sol. {	1956-57 (7)	53.25 $\pm$ 0.578	62.94 $\pm$ 0.584
1961-Cal.Sw.(6)	53.82 $\pm$ 0.45	59.36 $\pm$ 0.82	



Text-fig. 3.—*Schistocerca gregaria*. Graph showing the trend of variability in the length of elytron (E) in various populations as in Text-fig. 1.  
For explanations see Text-fig. 1 and the text.

(b) *Discussion*.—Data for the population of seven years, along with the “typical” values for phases *gregaria* and *solitaria*, are thus available. Of these, the populations for the periods 1950, 1954 (Grs. I–III), 1955 (Grs. I and II) and 1961 represent the *gregaria* facies and those for 1949, 1955 (Gr. III) and 1956–57 the *solitaria* or near-*solitaria* facies.

The length of elytron in the *gregaria* populations is significantly longer than in the *solitaria* ones in males and smaller in females. Within the same phase—and eye-stripe-group, females have significantly longer elytra than males; and 6-eye-striped individuals have smaller elytra than 7-striped ones.

The trend thus is that in males E increases as the population tends towards phase *gregaria*; and in females the reverse occurs. On the whole, the length of elytron is not a very phase-sensitive character.

### 8. Restricted width of elytron ( $W_1$ )

(a) *Mean values*.—The mean values of  $W_1$  in the available populations for the swarming and non-swarming periods (1949–61) are as follows:—

Populations (and eye-stripes)	Mean width (mm.) $\pm$ S.E.	
	Males	Females
1954-Gr. I(6)	7.05 $\pm$ 0.10	7.67 $\pm$ 0.08
1954-Gr. II(6)	7.13 $\pm$ 0.02	7.76 $\pm$ 0.02
1954-Gr. III(6)	7.02 $\pm$ 0.03	7.60 $\pm$ 0.03
1954-Gr. I(7)	6.57 $\pm$ 0.29	7.52 $\pm$ 0.07
1954-Gr. II(7)	—	7.90 $\pm$ 0.24
1954-Gr. III(7)	6.54 $\pm$ 0.21	8.03 $\pm$ 0.29
1954-Gr. III(7)	—	—
1955-Gr. I(6)	6.89 $\pm$ 0.07	7.66 $\pm$ 0.07
1955-Gr. II(6)	7.10 $\pm$ 0.02	7.82 $\pm$ 0.02
1955-Gr. III(6)	6.66 $\pm$ 0.05	7.36 $\pm$ 0.16
1955-Gr. I(7)	6.57 $\pm$ 0.43	—

Populations (and eye-stripes)	Mean width (mm.) $\pm$ S.E.		
	Males	Females	
1955-Gr.II(7)	6.20	7.67 $\pm$ 0.14	
Ph. {	1955-Gr.III(7)	6.71 $\pm$ 0.07	7.84 $\pm$ 0.06
	1956-57 (6)	6.47 $\pm$ 0.066	7.52 $\pm$ 0.100
	1956-57 (7)	6.76 $\pm$ 0.093	7.94 $\pm$ 0.065

(b) *Discussion.*—Data for the population of four years (1954–57) are available. Of these, the populations for 1954 (Grs. I–III) and 1955 (Grs. I and II) represent the *gregaria* facies, and for 1955 (Gr.III) and 1956-57 the *solitaria* facies.

The 'restricted' width of elytron is significantly greater in *gregaria* populations than in *solitaria* ones. Within the same phase—and eye-stripe group, females have significantly wider elytron than males; 6-striped individuals have significantly narrower elytra than 7-striped ones in both sexes.

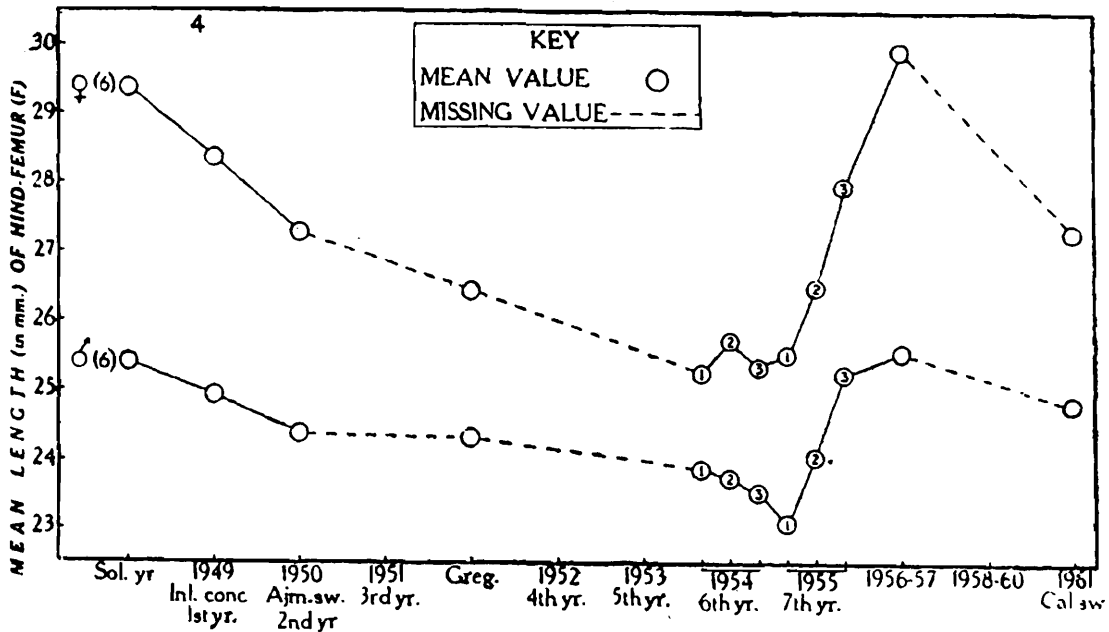
The character  $W_1$  is among the very sensitive characters for differentiating the phases. Phase transformation takes place quickly, in one generation. In both sexes the 'restricted' width of elytron tends to increase from a lower *solitaria* level to a higher *gregaria* level, particularly in 6- eye-striped individuals.

### 9. Length of hind-femur (F)

(Text-fig. 4)

(a) *Mean values.*—The mean values of F in the available populations for the swarming and non-swarming periods (1949–61) are as follows:—

Populations (and eye-stripes)	Mean length (mm.) $\pm$ S.E.		
	Males	Females	
6-sol.	25.40 $\pm$ 0.12	29.37 $\pm$ 0.18	
7-sol.	26.13 $\pm$ 0.21	30.92 $\pm$ 0.13	
6-greg.	24.32 $\pm$ 0.20	26.44 $\pm$ 0.37	
1949-Kakko Conc.(6)	24.92 $\pm$ 0.16	28.35 $\pm$ 0.25	
1949-Kakko Conc.(7)	—	29.94 $\pm$ 0.92	
1950-Ajm.Sw.(6)	24.37 $\pm$ 0.29	27.28 $\pm$ 0.61	
1954-Gr.I(6)	23.88 $\pm$ 0.33	25.25 $\pm$ 0.39	
1954-Gr.II(6)	23.76 $\pm$ 0.07	25.71 $\pm$ 0.10	
1954-Gr.III(6)	23.54 $\pm$ 0.11	25.36 $\pm$ 0.14	
1954-Gr.I(7)	—	29.50 $\pm$ 1.00	
1954-Gr.II(7)	—	29.90 $\pm$ 1.45	
1954-Gr.III(7)	25.73 $\pm$ 0.71	—	
1955-Gr.I(6)	23.11 $\pm$ 0.26	25.52 $\pm$ 0.34	
1955-Gr.II(6)	24.06 $\pm$ 0.07	26.50 $\pm$ 0.07	
1955-Gr.III(6)	25.24 $\pm$ 0.16	27.97 $\pm$ 0.90	
1955-Gr.I(7)	25.30 $\pm$ 0.64	—	
1955-Gr.II(7)	25.10	28.63 $\pm$ 0.55	
Ph. {	1955-Gr.III(7)	26.12 $\pm$ 0.23	31.21 $\pm$ 0.22
	1956-57 (6)	25.56 $\pm$ 0.152	29.92 $\pm$ 0.389
sol. {	1956-57 (7)	27.09 $\pm$ 0.253	31.73 $\pm$ 0.288
1961-Cal.Sw.(6)	24.82 $\pm$ 0.23	27.32 $\pm$ 0.33	



Text-fig. 4.—*Schistocerca gregaria*. Graph showing the trend of variability in the length of hind-femur (F) in various populations as in Text-fig. 1.

For explanations see Text-fig. 1 and the text.

(b) *Discussion*.—Data for the populations of seven years (1949, '50, '54, '57 and '61), along with "typical" values for phases *gregaria* and *solitaria*, are available. Of these years, the populations of 1950, 1954 (Grs. I–III), 1955 (Grs. I and II) and 1961 represent the *gregaria* facies, and those of 1949, 1955 (Gr. III) and 1956–57 the *solitaria* facies.

In both sexes, the hind-femur is significantly longer in *solitaria* than in *gregaria* populations. Within the same phase- and eye-stripe-group, females have significantly longer hind-femora than males; and 6-striped individuals have smaller hind-femora than 7-striped ones. This is one of the more sensitive character for differentiating the phase. In both sexes, the length of hind-femur is negatively correlated with the intensity of gregarization, the length increasing as the population approach to the *solitaria* facies.

#### IV—MORPHOMETRIC RATIOS

##### 1. *General*

The following seven morphometrical ratios, for which adequate data are available in literature, are discussed below; for others the data are either meagre or absent :—

- |                     |        |
|---------------------|--------|
| 1. P/C              | 5. E/F |
| 2. M/C              | 6. E/C |
| 3. H/C              | 7. F/C |
| 4. E/W <sub>1</sub> |        |

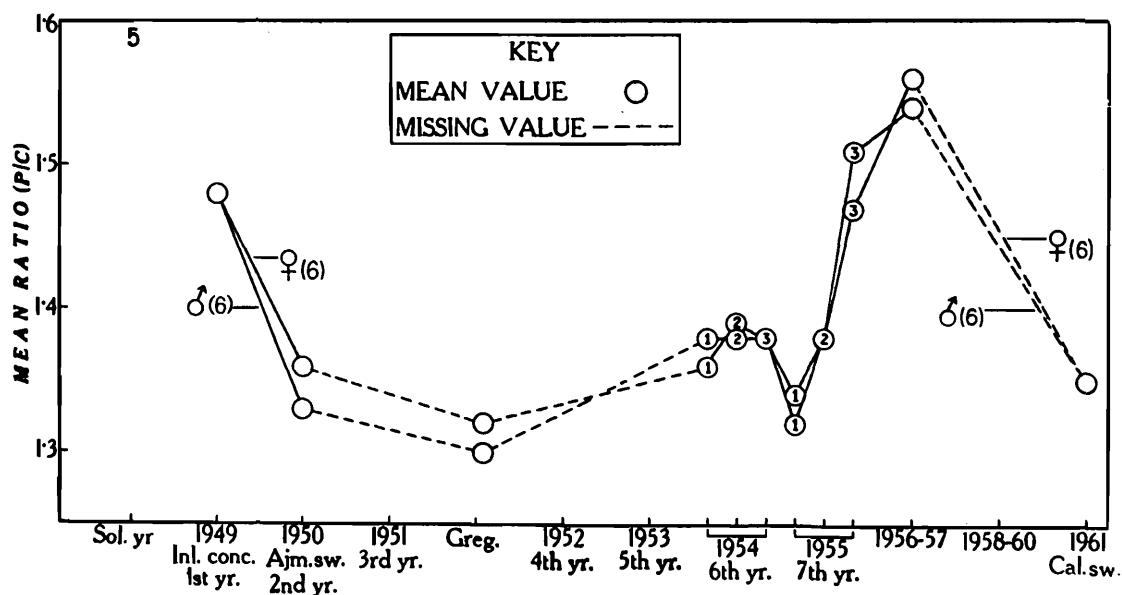
The ratios are discussed with respect to their phase-significance in relation to sex and eye-stripes, along with their trend in various populations.

## 2. Ratio P/C

(Text-fig. 5)

(a) *Mean values.*—The mean values of the ratio P/C in the available populations for the swarming and non-swarming periods (1949–61) are as follows:—

Populations (and eye-stripes)	Mean ratio $\pm$ S.E.	
	Males	Females
<i>6-greg.</i>	1.305 $\pm$ 0.011	1.324 $\pm$ 0.009
1949- <i>Kakko Conc.</i> (6)	1.483 $\pm$ 0.007	1.477 $\pm$ 0.008
1950- <i>Ajm.Sw.</i> (6)	1.330 $\pm$ 0.011	1.363 $\pm$ 0.018
1954-Gr.I (6)	1.38 $\pm$ 0.02	1.36 $\pm$ 0.01
1954-Gr.II (6)	1.38 $\pm$ 0.002	1.39 $\pm$ 0.002
1954-Gr.III (6)	1.38 $\pm$ 0.004	1.38 $\pm$ 0.003
1954-Gr.I (7)	1.47 $\pm$ 0.05	1.47 $\pm$ 0.02
1954-Gr.II (7)	—	1.48 $\pm$ 0.08
1954-Gr.III (7)	1.52 $\pm$ 0.02	1.54 $\pm$ 0.03
1955-Gr.I (6)	1.32 $\pm$ 0.012	1.34 $\pm$ 0.011
1955-Gr.II (6)	1.38 $\pm$ 0.003	1.38 $\pm$ 0.002
1955-Gr.III (6)	1.51 $\pm$ 0.007	1.47 $\pm$ 0.025
1955-Gr.I (7)	1.46 $\pm$ 0.033	—
1955-Gr.II (7)	1.59	1.50 $\pm$ 0.027
Ph. { 1955-Gr.III (7)	1.52 $\pm$ 0.011	1.54 $\pm$ 0.009
sol. { 1956-57 (6)	1.54 $\pm$ 0.010	1.56 $\pm$ 0.019
sol. { 1956-57 (7)	1.52 $\pm$ 0.020	1.57 $\pm$ 0.014
1961- <i>Cal.Sw.</i> (6)	1.35 $\pm$ 0.007	1.35 $\pm$ 0.008



Text-fig. 5.—*Schistocerca gregaria*. Graph showing the trend of variability in the ratio P/C in various populations as in Text-fig. 1.

For explanations see Text-fig. 1 and the text.

(b) *Discussion.*—Data for the population of seven years are available. Of these, the populations of 1950, 1954 (Grs. I–III) 1955 (Grs. I and II)



and 1961 represent *gregaria* facies and those for 1949, 1955 (Gr. III) and 1956-57 the *solitaria* facies.

The mean value of P/C in *solitaria* populations is significantly higher than in *gregaria* ones in both sexes. Except in 7-striped forms, no significant sexual difference is seen. The ratio P/C is highly phase-sensitive. It bears an inverse relationship with the intensity of gregarization, the values rising as the population tends towards the *solitaria* phase.

### 3. Ratio M/C

(a) *Mean values.*—The mean values of M/C, in the available populations for swarming or non-swarming periods (1949–61), are as follows:—

<i>Populations (and eye-stripes)</i>	<i>Mean ratio ± S.E.</i>	
	<i>Males</i>	<i>Females</i>
<i>6-greg.</i>	0.779 ± 0.008	0.805 ± 0.005
1954-Gr.I(6)	0.82 ± 0.01	0.84 ± 0.01
1954-Gr.II(6)	0.79 ± 0.001	0.82 ± 0.001
1954-Gr.III(6)	0.78 ± 0.002	0.80 ± 0.002
1954-Gr.I(7)	0.90 ± 0.01	0.90 ± 0.01
1954-Gr.II(7)	—	0.85 ± 0.01
1954-Gr.III(7)	0.86 ± 0.01	0.87 ± 0.02
1955-Gr.I(6)	0.79 ± 0.005	0.83 ± 0.008
1955-Gr.II(6)	0.82 ± 0.002	0.84 ± 0.001
1955-Gr.III(6)	0.89 ± 0.003	0.90 ± 0.012
1955-Gr.I(7)	0.87 ± 0.032	—
1955-Gr.II(7)	0.91	0.88 ± 0.012
<i>Ph.</i> { 1955-Gr.III(7)	0.90 ± 0.006	0.92 ± 0.004
{ 1956-57 (6)	0.87 ± 0.005	0.89 ± 0.009
<i>sol.</i> { 1956-57 (7)	0.87 ± 0.013	0.89 ± 0.007

(b) *Discussion.*—Data for the populations of four years (1954–57), along with the “typical” value for phase *gregaria*, are available. Of these, the populations for 1954 (Grs. I–III) and 1955 (Grs. I and II) represent the *gregaria* facies and those for 1955 (Gr.III) and 1956-57 the *solitaria* facies.

The ratio M/C is significantly higher in *solitaria* phase in both sexes, but no sexual and eye-stripe differences are noticed. It is very sensitive ratio for differentiating the phases. In both sexes, ratio M/C is negatively correlated with the degree of gregarization, the value decreasing with the increase of gregarization.

## 4. Ratio H/C

(a) *Mean values.*—The mean values of H/C in the available populations for the swarming and non-swarming periods (1949–61) are as follows:—

Populations (and eye-stripes)	Mean ratio $\pm$ S.E.	
	Males	Females
<i>6-greg.</i>	1.112 $\pm$ 0.008	1.126 $\pm$ 0.007
1954-Gr.I(6)	1.13 $\pm$ 0.01	1.12 $\pm$ 0.01
1954-Gr.II(6)	1.10 $\pm$ 0.002	1.12 $\pm$ 0.002
1954-Gr.III(6)	1.09 $\pm$ 0.003	1.10 $\pm$ 0.002
1954-Gr.I(7)	1.22 $\pm$ 0.004	1.23 $\pm$ 0.009
1954-Gr.II(7)	—	1.19 $\pm$ 0.03
1954-Gr.III(7)	1.20 $\pm$ 0.01	1.18 $\pm$ 0.02
1955-Gr.I(6)	1.10 $\pm$ 0.008	1.12 $\pm$ 0.009
1955-Gr.II(6)	1.13 $\pm$ 0.002	1.14 $\pm$ 0.002
1955-Gr.III(6)	1.25 $\pm$ 0.006	1.24 $\pm$ 0.016
1955-Gr.I(7)	1.23 $\pm$ 0.014	—
1955-Gr.II(7)	1.22	1.23 $\pm$ 0.016
Ph. { 1955-Gr.III(7)	1.25 $\pm$ 0.008	1.29 $\pm$ 0.002
sol. { 1956-57 (6)	1.23 $\pm$ 0.006	1.24 $\pm$ 0.009
sol. { 1956-57 (7)	1.22 $\pm$ 0.010	1.24 $\pm$ 0.009

(b) *Discussion.*—Data for the populations of four years (1954–57), along with the “typical” value for phase *gregaria*, are available. Of these, the populations for 1954 (Grs. I–III) and 1955 (Grs. I and II) represent the *gregaria* phase and those for 1955 (Gr.III) and 1956–57 the *solitaria* phase. The ratio is significantly higher in the *solitaria* phase than in the *gregaria*; no sexual and eye-stripes differences are seen. The ratio is a sensitive phase-discriminant character. It increases with the decrease in intensity in gregarization.

5. Ratio E/W<sub>1</sub>

(a) *Mean values.*—The mean values of the ratio E/W<sub>1</sub> in the available populations for the swarming and non-swarming periods (1949–61) are as follows:—

Populations (and eye-stripes)	Mean ratio $\pm$ S.E.	
	Males	Females
1954-Gr.I(6)	7.49 $\pm$ 0.08	7.58 $\pm$ 0.06
1954-Gr.II(6)	7.32 $\pm$ 0.01	7.49 $\pm$ 0.01
1954-Gr.III(6)	7.47 $\pm$ 0.02	7.55 $\pm$ 0.02
1954-Gr.I(7)	7.90 $\pm$ 0.10	—
1954-Gr.II(7)	—	—
1954-Gr.III(7)	7.82 $\pm$ 0.14	7.78 $\pm$ 0.23
1955-Gr.I(6)	7.41 $\pm$ 0.068	7.45 $\pm$ 0.081
1955-Gr.II(6)	7.42 $\pm$ 0.016	7.57 $\pm$ 0.015

Populations (and eye-stripes)	Mean ratio $\pm$ S.E.		
	Males	Females	
1955-Gr.III(6)	7.88 $\pm$ 0.038	8.10 $\pm$ 0.123	
1955-Gr.I(7)	7.69 $\pm$ 0.285	—	
1955-Gr.II(7)	8.10	7.92 $\pm$ 0.132	
Ph. { sol. {	1955-Gr.III(7)	7.84 $\pm$ 0.068	8.12 $\pm$ 0.045
	1956-57 (6)	7.87 $\pm$ 0.063	7.96 $\pm$ 0.067
	1956-57 (7)	7.89 $\pm$ 0.076	7.93 $\pm$ 0.048

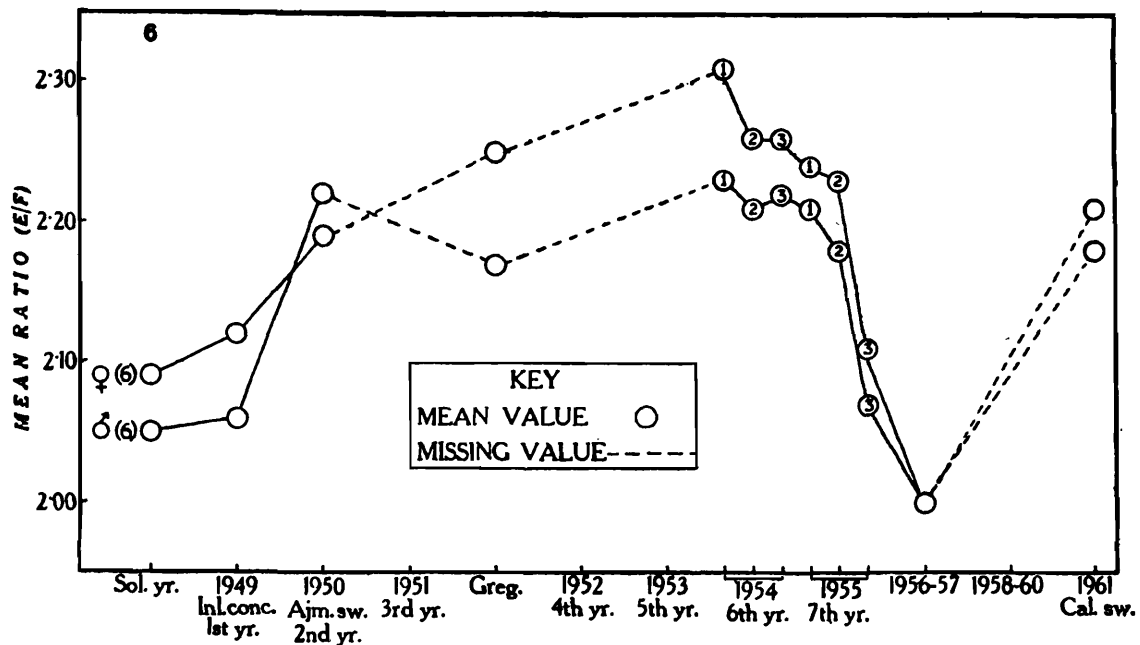
(b) *Discussion.*—Data for the populations of four years (1954–57) are available. Of these, the populations for 1954 (Grs. I–III) and 1955- (Grs. I and II) are of the *gregaria* phase and those for 1955 (Gr. III) and 1956-57 of the *solitaria* phase. The ratio is significantly lower in *gregaria* than in *solitaria* phase. No sexual and eye-stripes differences, are seen. Since the values of the ratio in the two phases are far apart, it may be considered as a useful ratio for discriminating the phases. The ratio bears an inverse relationship with the intensity of gregarization, the values increasing as the populations move towards the *solitaria* phase.

## 6. Ratio E/F

(Text-fig. 6)

(a) *Mean values.*—The mean values of the ratio E/F in the available populations for the swarming and non-swarming periods (1949–61) are as follows :—

Populations (and eye-stripes)	Mean ratio $\pm$ S.E.		
	Males	Females	
6-sol.	2.05 $\pm$ 0.012	2.09 $\pm$ 0.008	
7-sol.	2.00 $\pm$ 0.006	2.03 $\pm$ 0.007	
6-greg.	2.17 $\pm$ 0.024	2.25 $\pm$ 0.017	
1949-Kakko Conc.(6)	2.06 $\pm$ 0.010	2.12 $\pm$ 0.011	
1949-Kakko Conc.(7)	—	2.07 $\pm$ 0.022	
1950-Ajm.Sw.(6)	2.22 $\pm$ 0.023	2.19 $\pm$ 0.035	
1954-Gr.I(6)	2.23 $\pm$ 0.03	2.31 $\pm$ 0.03	
1954-Gr.II(6)	2.21 $\pm$ 0.004	2.26 $\pm$ 0.004	
1954-Gr.III(6)	2.22 $\pm$ 0.007	2.26 $\pm$ 0.02	
1954-Gr.I(7)	—	—	
1954-Gr.II(7)	—	—	
1954-Gr.III(7)	2.00 $\pm$ 0.03	—	
1955-Gr.I(6)	2.21 $\pm$ 0.018	2.24 $\pm$ 0.016	
1955-Gr.II(6)	2.18 $\pm$ 0.004	2.23 $\pm$ 0.004	
1955-Gr.III(6)	2.07 $\pm$ 0.010	2.11 $\pm$ 0.031	
1955-Gr.I(7)	1.99 $\pm$ 0.013	—	
1955-Gr.II(7)	2.00	2.10 $\pm$ 0.021	
Ph. { sol. {	1955-Gr.III(7)	2.01 $\pm$ 0.009	2.04 $\pm$ 0.008
	1956-57 (6)	2.00 $\pm$ 0.005	2.00 $\pm$ 0.013
	1956-57 (7)	1.97 $\pm$ 0.012	1.99 $\pm$ 0.008
1961-Cal.Sw.(6)	2.18 $\pm$ 0.010	2.21 $\pm$ 0.070	



Text-fig. 6.—*Schistocerca gregaria*. Graph showing the trend of variability in the ratio E/F in various populations as in Text-fig. 1.

For explanations see Text-fig. 1 and the text.

(b) *Discussion*.—Data for the populations of seven years, along with “typical” values for phases *gregaria* and *solitaria* are available. Of these, the populations for 1950, 1954 (Grs. I–III), 1955 (Grs. I and II) and 1961 are of the *gregaria* phase and those for 1949, 1955 (Gr.III) and 1956-57 of the *solitaria* phase.

Unlike other ratios, E/F is significantly larger in *gregaria* populations than in *solitaria* ones. No sexual difference is seen. But eye-stripe differences are noticeable and 7-striped males have significantly larger ratios than 6-striped ones. The ratio is highly phase-sensitive. It increases with the increase in the intensity of gregarization.

### 7. Ratio E/C

(a) *Mean values*.—The mean values of E/C in the available populations for the swarming and non-swarming periods for four years (1954–57) are as follows :—

Populations (and eye-stripes)	Mean ratio $\pm$ S.E.	
	Males	Females
1954-Gr.I(6)	7.31 $\pm$ 0.08	7.30 $\pm$ 0.09
1954-Gr.II(6)	7.20 $\pm$ 0.01	7.45 $\pm$ 0.01
1954-Gr.III(6)	7.21 $\pm$ 0.02	7.43 $\pm$ 0.02
1954-Gr.I(7)	7.44 $\pm$ 0.13	—
1954-Gr.II(7)	—	—
1954-Gr.III(7)	7.86 $\pm$ 0.09	8.22 $\pm$ 0.32
1955-Gr.I(6)	6.98 $\pm$ 0.05	7.29 $\pm$ 0.06
1955-Gr.II(6)	7.30 $\pm$ 0.01	7.50 $\pm$ 0.01
1955-Gr.III(6)	7.98 $\pm$ 0.04	8.03 $\pm$ 0.14
1955-Gr.I(7)	7.57 $\pm$ 0.07	—

Populations (and eye-stripes)	Mean ratio $\pm$ S.E.		
	Males	Females	
1955-Gr.II(7)	7.97	7.96 $\pm$ 0.11	
Ph. {	1955-Gr.III(7)	7.92 $\pm$ 0.05	8.23 $\pm$ 0.03
	1956-57 (6)	7.95 $\pm$ 0.041	8.07 $\pm$ 0.050
	sol. { 1956-57 (7)	7.89 $\pm$ 0.067	8.14 $\pm$ 0.058

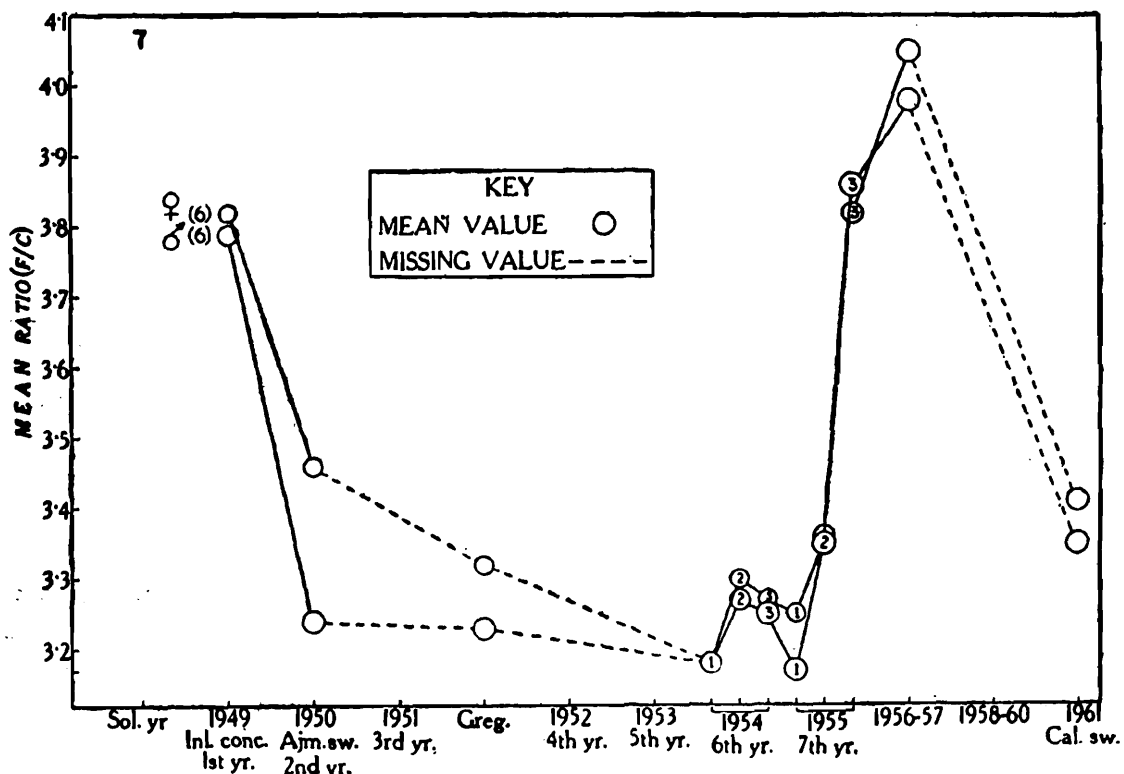
(b) *Discussion.*—The populations for 1954 (Grs. I–III) and 1955 (Grs. I and II) represent the *gregaria* phase and those for 1955 (Gr.III) and 1956-57 the *solitaria* phase. The ratio is significantly smaller in *gregaria* populations than in *solitaria* ones. Only in the 7- eye-striped category, females are significantly larger than males, there being no other differences in the various eye-stripes categories. Like other ratios involving C (width of head at the genal level), E/C is a highly phase sensitive ratio. It bears an inverse relationship with the intensity of gregarization, the value falling as the populations tend towards *gregaria* phase.

### 8. Ratio F/C

(Text-fig. 7)

(a) *Mean values.*—The mean values of F/C in the available populations for the swarming and non-swarming periods (1949–61) are as follows:—

Populations (and eye-stripes)	Mean ratio $\pm$ S.E.		
	Males	Females	
6-greg.	3.233 $\pm$ 0.032	3.320 $\pm$ 0.032	
1949-Kakko Conc.(6)	3.790 $\pm$ 0.024	3.824 $\pm$ 0.027	
1950-Ajm.Sw.(6)	3.237 $\pm$ 0.036	3.458 $\pm$ 0.079	
1954-Gr.I(6)	3.18 $\pm$ 0.02	3.18 $\pm$ 0.04	
1954-Gr.II(6)	3.27 $\pm$ 0.01	3.30 $\pm$ 0.01	
1954-Gr.III(6)	3.25 $\pm$ 0.01	3.27 $\pm$ 0.01	
1954-Gr.I(7)	—	3.86 $\pm$ 0.007	
1954-Gr.II(7)	—	3.70 $\pm$ 0.007	
1954-Gr.III(7)	3.92 $\pm$ 0.04	—	
1955-Gr.I(6)	3.17 $\pm$ 0.04	3.25 $\pm$ 0.04	
1955-Gr.II(6)	3.35 $\pm$ 0.01	3.36 $\pm$ 0.01	
1955-Gr.III(6)	3.86 $\pm$ 0.03	3.82 $\pm$ 0.09	
1955-Gr.I(7)	3.81 $\pm$ 0.02	—	
1955-Gr.II(7)	3.98	3.79 $\pm$ 0.08	
Ph. {	1955-Gr.III(7)	3.93 $\pm$ 0.02	4.04 $\pm$ 0.02
	1956-57 (6)	3.98 $\pm$ 0.021	4.05 $\pm$ 0.024
	sol. { 1956-57 (7)	4.02 $\pm$ 0.038	4.11 $\pm$ 0.038
1961-Cal.Sw.(6)	3.35 $\pm$ 0.010	3.41 $\pm$ 0.020	



Text-fig. 7.—*Schistocerca gregaria*. Graph showing the trend of variability in the ratio F/C in various populations as in Text-fig. 1.

For explanations see Text-fig. 1 and the text.

(b) *Discussion*.—Data for the population of seven years along with the “typical” values for phase *gregaria*, are available. Of these, the populations for 1950, 1954 (Grs. I–III), 1955 (Grs. I and III) and 1961 represent the *gregaria* phase and those for 1949, 1955 (Gr. III) and 1956–57 the *solitaria* phase.

The ratio in *solitaria* phase populations is significantly higher than in *gregaria* phase in both sexes. Only in the 6-eye-striped category, females are significantly larger than males, their being no other difference in the eye-stripes categories. The ratio F/C is found to be one of the most sensitive characters for discriminating the phases. It varies inversely with the intensity of gregarization, and falls as the populations tend towards the *gregaria* phase.

## V—DISCUSSION

### 1. General

The study of population dynamics in the Desert Locust is approached here with the aid of such “population-indicators” as the morphometric characters (size of body-parts and their ratios).

### 2. Eye-stripes and sex-ratios

The eye-stripe (5-, 8-striped) composition and sex-ratio being associated with phase transformation, their study in relation to these chains of populations (1949–61) is most desirable. The population of the initial year (1949-*Kakko concentration*) of the Ninth Cycle in India, is characterized by the high proportion (94%) of 6-striped individuals,

and the male:female ratio is 54:46. A 5-striped form is recorded for the first time in this population. Its appearance in a population heading towards *gregaria* will serve as a clue for associating it with either of the phases.

In the *Ajmer swarm* (1950), the sample-size is not sufficiently large ( $n' = 15$ ) to enable us to place too much reliance on the observed sex-ratio ( $\sigma^71 : \text{♀}29\%$ ). The presence of 7-striped individuals, although in exceedingly small proportions, in this swarming population is an important phenomenon and its occurrence may be attributed to the initial stage of the cycle.

The proportion of 6-striped individuals in the swarming 1954-population is 99% and the sex-ratio  $\sigma^53 : \text{♀}47$ .

In the 1955-population also, the 6-striped individuals predominate (93%). The sex-ratio is  $\sigma^51 : \text{♀}49$ , thus closely approaching the 50:50 ratio. A few 8- eye-striped form appear in the last quarter of this year, thus indicating the advent of the *solitaria* period (Roonwal, 1954). A few 5- eye-striped individuals were also observed during the mid-year period.

In the 1956-57 population the eye-stripe composition 6:7 striped as 60:40 is at variance with that of the previous years as is seen from the decline of the proportion of 6-striped individuals. The proportion of males (60%), on the other hand, goes up.

The swarming population of 1961 (*Calcutta swarm*) is free from 5-, 7- and 8- eye-striped individuals and only 6-striped ones occurring. The sex-ratio is  $\sigma^55 : \text{♀}45$ . This slight deviation from the 50:50 ratio in swarms may be ascribed to sampling fluctuations.

### 3. *Morphometric characters and ratios*

The dynamics of morphometric variation in the desert locust populations for a complete swarming non-swarmling cycle is compared here for the first time. This will help in the understanding of the variation-intensity of a locust plague and finding out characters which are variation—stable (*vide*, Roonwal, 1954). Each of the populations has been compared with other known populations and with the "typical" values for the phases in order to assess the extent of disparity. For the initial year (*Kakko concentration*, 1949) of the ninth (1949–55), swarming cycle, the variation was studied by utilizing five characters (C, P, E, W and F) and four ratios (P/C, E/W<sub>1</sub>, E/F and F/C). A high degree of sexual difference is recorded with regard to all characters and the ratio E/F. There is generally no difference between 6- and 7- eye-striped individuals. Compared with "typical" values for the phases, this population is seen to be of non-swarmling or *solitaria* facies, even though the population is rather high (over 18,000 per square mile). Though occupying an intermediate position, it tends towards the *solitaria* phase. The greater dispersion of values in this initial concentration as compared to the extreme phases is an indicator of its heterogeneity.

In the *Ajmer Swarm* (1950), belonging to the second year of 1949–55 swarming cycle, the same set of characters and ratios as in the previous year as mentioned above, was used. Comparison with “typical” *gregaria* and the initial *Kakko Concentration* (1949) shows some resemblance of the swarm with the previous years population. The difference between the two populations is due to the increase of gregarization in the second year, and males are more variable than females. (As stated earlier, the populations of the years 1951–53 were not considered; they belong to heavy swarms and may therefore, be presumed to be of *gregaria* nature).

Populations of the years 1954 and 1955 are of considerable interest as belonging to the last facet of the 1949–55 Swarming Cycle. For finding any seasonal influence on the morphometry and for convenience of study, the population of each of these years was divided into three natural Groups (I–III) each comprising of four consecutive months. Eight characters (O, C, P, H, M, E,  $W_1$  and F) and seven ratios (P/C, M/C, H/C, E/ $W_1$ , E/F, E/C and F/C) were used. Several important results were derived. Thus, plasticity here is more pronounced in females than in males, and there is a high degree of sexual dimorphism in Groups II and III for 1954-population. The eye-stripe composition (6- and 7-striped) differ to a great extent, particularly in Group III (September–December population). The group-difference is well exhibited by the character M and the ratio M/C, F/C and H/C.

A decided difference is found between Groups II (May–August) and III (September–December). Irrespective of the Groups, the 1954-population as a whole differs from the “typical” *solitaria* phase populations in respect of the characters E, F and the ratio E/F. Generally speaking, the values in the penultimate year’s population have greater leanings towards the typical *gregaria* phase and the *Ajmer Swarm* (1950) than towards the *solitaria* phase and the *Kakko Concentration* (1949). The length of the hind-femur (F) has proved to be a sensitive character in this respect.

Two new characters (A and B)\* and one ratio (K/L) were also utilized in the 1955-population which belongs to the last year of the 1949–55 Cycle.

The values of morphometric characters in the 1955-population suddenly change in the last four months to resemble that of the *solitaria* phase. The first two Groups (I and II), however, are similar to the Groups of the 1954-population which are of the *gregaria* type. The sex difference is also very high, females having higher values than males in almost all cases (the ratio K/L being an exception). Notwithstanding the difference between the Groups I and II, their morphological similarity is not greatly disturbed. Compared to the “typical” values for the phases, the 1955-Groups I–II are found to closely approach the typical *gregaria* and Group III the typical *solitaria* values. This finding is further confirmed when the groups are compared with the *Ajmer Swarm* (1950) and the *Kakko Concentration* (1949). The characters

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\* A, length of eye; B, maximum width of eye; K, greatest; and L, narrowest, width of metasternal interspace.



C,  $W_1$ , F and the ratios involving C are highly sensitive under different degrees of population densities.

For the 1956-57 population, the same set of characters and ratios as in 1954 was studied. This is a population from two non-swarmling years, just following the 1949-55 Swarming Cycle in India. Samples being taken from scattered population of low densities, the distribution over the whole year is not uniform so that "Groupings", as in the years 1954 and 1955, were not done. A point of interest is that high sexual and eye-stripes (6- and 7-striped) differences are recorded with regard to all the morphometric characters, where as such differences are lacking in respect of most of the ratios. Another characteristic of this population is the lack of consistency in its affinity to the "typical" phases. For some characters and ratios it is closer to *gregaria* phase and for the others to the *solitaria* phase. This may be due to the instability of the population which is not yet completely freed from the influence of gregarization. In spite of this, the population has a greater affinity to phase *solitaria*, as is obvious from the general consideration of the several morphometric characters.

In 1961, a typical swarm sample from Calcutta was studied in respect of four characters (C, P, E and F) and three ratios P/C, E/F and F/C). Like *Ajmer Swarm* of 1950, this also represents the population of the second year of a Swarming Cycle (the Tenth) in India, though the samples were collected in the early period of the third year. The comparative study of their characteristics has a special significance. A point of difference between the two years 1950 and 1961, lies in the smaller dispersion of values of the 1961-swarm than in the 1950 one, and in the "typical" *gregaria* phase values. Except for F/C in males, the two swarms do not differ appreciably. The correlation between F and C varies in degrees in the two swarms. In other pairs of characters, *viz.*, (E, F), (E, C), (E, P), (F, P) and (C, P), the association, though generally higher in the 1961 swarm, is not significantly different. Generally speaking a few points of dissimilarity that are noted indicate the greater homogeneity and fuller gregarization of the *Calcutta Swarm* as compared to *Ajmer Swarm*.

The morphometric superiority of females over males has been judged by the Sexual Dimorphism Percentage (S.D.P.) (Roonwal, 1949). This measure was used to substantiate the inter-sex comparison of mean sizes. Though not very efficient as a phase discriminant, the S.D.P. values help to some extent in identifying populations of *gregaria* facies from those of *solitaria* ones. It has been noticed that gregarization in a population is correlated with S.D.P.—inversely for morphometric characters (size of the body-parts) and directly for their ratios.

From these population studies an assessment can be made of the efficacy of the different morphometric characters and ratios for introducing a considerable "distance" between two populations or phases. It has been observed that the performance of many characters do not remain the same in different types of population-comparison. Among the very few characters which retain their sensitivity uniformly, the width of head at the genal level (C) is the most outstanding. The

other important characters to be utilized along with C are M, E,  $W_1$  and F. The ratios which involve the use of C are all sensitive. The ratio E/F is, however, a sophisticated ratio for phase-discrimination, and is less uniformly sensitive than the others.

#### VI—SUMMARY

1. Morphometric data obtained from the present thesis and published elsewhere in the literature is used for studying the population dynamics of the Desert Locust during the period 1949 to 1961 (representing the Ninth and earlier part of the Tenth Locust Cycle in India).

2. Ten morphometric characters (size of body-parts) and eight ratios along with eye-stripe composition and sex-ratios are considered.

3. The important role of eye-stripe and sex-ratios as "indicators" in the study of phase biology and population dynamics of the Desert Locust is discussed.

4. The morphometric character 'C' (width of head at genal level) emerged as the most phase sensitive character. The other sensitive characters are M (width of pronotum at the constriction), E (length of elytron),  $W_1$  (restricted width of elytron) and F (length of hind-femur).

5. Among the ratios, which involve the use of C (width of head at genal level) were found to be most sensitive.

6. The sensitive role of certain body-size and ratios, along with behaviour of the sexes in varying population densities, and the intra-specific divergence in different population groups are discussed.

7. The trend and performances of sensitive characters and ratio indicates the existence of more or less set pattern in the phase-biology of the Desert Locust.

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