STUDIES IN INTRASPECIFIC VARIATION.

III—Body-size and Biometrical Ratios in Various Types of Individuals of the Desert Locust, *Schistocerca gregaria* (Forskal). [Orthoptera, Acrididae.] [1]

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Contents.

Introduction.

While attempting to elucidate (Roonwal, 1936-1947*a*) the various types of intraspecific variations in the Desert Locust, *Schistocerca gregaria* (Forskål), the problem of variation in size and in biometrical ratios in the different types of individuals was taken up, and the results are presented here. Aspects of biometrical differences between *gregaria* and *solitaria* phases have been studied by a number of workers (*vide* Rao, 1937-1942; Murat, 1939; Vayssière and Lepesme, 1939; and Kennedy, 1939), but differences between other major types of intraspecific variations, discovered in recent years, remain unelucidated. These variations are : (i) Eye-stripe and related variations (Roonwal, 1936-1947). Two main types of *solitaria* individuals occur with regard to eye-stripes, *viz.*, 6- and 7-striped. Very rarely, 5- and 8-striped individuals are also encountered. *Gregaria* individuals are always 6-striped. (ii) Two *solitaria* colour-types occur irrespective of the eye-stripe variation. Blue-grey adults and green hoppers occur commonly, while the other and rarer colour type consists of fawn adults and hoppers (Roonwal, 1945*a*, 1946*a*).

Several problems, hitherto unsolved, present themselves with regard to body-size and biometrical ratios. For example: What are the degree and the probable causes of the differences, if any, in body-size between *gregaria* and *solitaria* individuals ? Among *solitaria* individuals themselves, is there any difference in size between 6- and 7-striped forms ? Does sexual dimorphism exist in the biometrical ratios; if so, what is the nature of these differences ? In the present account I have attempted to answer these and related questions in respect of three major types of individuals, *viz.*, *gregaria* (6-striped), *solitaria* 6-striped and *solitaria* 7-striped.

[1] For previous parts see *Rec. Indian Mus.*, XLIV, pp. 369-374 (1946) and *Indian J. Ent.*, VII, pp. 77-84 (1946).

The *gregaria* individuals measured were taken mostly from swarms of 1889-1891 and 1930-1931 all over India, with a sprinkling of Iranian specimens. All individuals in which the eye-stripes were clear had 6 stripes. The remainder were assumed to have the same number of stripes, since it has been demonstrated in recent years that *gregaria* individuals are invariably 6-striped (Rao, 1937, 1942; Rao and Gupta, 1939; Roonwal, 1941, 1945). The *solitaria* individuals measured were obtained in Mekran (Baluchistan, W. India) during late 1935-1936, and thus during the middle of the last "*solitaria*" or non-swarming period which extended from 1932 to 1939, a fresh swarming period having begun in 1940. The year 1936 was in every respect a typical *solitaria* year. Individuals of the blue-grey colour-type (*vide supra*) alone were utilised, though it may be mentioned that no obvious biometrical differences were noticeable between that and the fawn type.

The following data for the fawn type of *solitaria* individuals (southern Baluchistan, November 1935 to August 1936) were obtained and are given here for facility of comparison, even though the samples are small :

Males.

6-striped (8 individuals).—E, 51·0-57·0, mean 53·3 mm.; F, 24·0-28·0, mean 25·9 mm.; E/F, 1·96-2·23, mean 2·06.

7-striped (5 individuals).—E, 49·0-56·5, mean 52·8 mm.; F, 24·0-28·0, mean 25·8 mm.; E/F, 1·97-2·11, mean 2·04.

Females.

6-striped (5 individuals).—E, 59·5-64·2, mean 62·1 mm.; F, 29·3-31·7, mean 30·5 mm.; E/F, 1·96-2·13, mean 2·09.

7-striped (5 individuals).—E, 61·0-66·0, mean 63·8 mm.; F, 29·5-31·5, mean 30·7 mm.; E/F, 2·01-2·12, mean 2·07.

From continuous field observations over a considerable period (1935-1938), including the period under study (late 1935-1936), I could satisfy myself that the "solitaria" population studied was genuinely *solitaria*. Throughout that period, the population, though undergoing small fluctuations, was very low, seldom rising above 1000 per square miles. The breeding history was not precisely known. It may be stated that under *solitaria* conditions, with a very low population scattered over a vast area, with the breeding places scattered in tiny patches over an equally extensive area, and, finally, with long-distance *solitaria* migrations from one country or belt to another (*e.g.*, from Arabia and Iran into India, and *vice versa*), it is practically impossible to trace the exact breeding history of small samples of population. Therefore, the population density index, taken in conjunction with the actual morphological characteristics of the individuals themselves, and with the characteristics of the population in that and neighbouring areas during the months immediately preceding and following the period under study, provide the only satisfactory means of judging the nature of field populations.

Measurements were taken with a vernier calliper having dial graduations reading up to 0·1 mm. The mode of measurement was that recommended by the Fourth International Locust Conference (Cairo,

1936)[2]. The body-parts measured were (Tables 1-4): Length of elytron (E); length of hind-femur (F); maximum width of head in the genal region (C); length of pronotum at the keel (P); height of pronotum (H); and width of pronotum at the constriction (M). The biometrical ratios studied were: E/F, P/C, H/C and M/C. The sexes were analysed separately. The approximate number of specimens measured for various purposes was as follows:—Phase *gregaria*: 35-77. Phase *solitaria*: 6-striped, 152; 7-striped, 109-110.

SIZE OF BODY-PARTS.

The mean length of the elytron in males is 53·03 mm. in *gregaria*, 52·2 mm. in 6-striped *solitaria* and 52·4 mm. in 7-striped *solitaria* individuals; in females the mean length is 58·01, 61·6 and 62·9 mm. respectively (Tables 1 and 5).

The mean length of the hind-femur in males is 24·4 mm. in *gregaria*, 25·4 mm. in 6-striped *solitaria* and 26·1 mm. in 7-striped *solitaria* individuals; in females the mean length is 26·4, 29·4 and 30·9 mm. respectively (Tables 2 and 5).

For the head and the pronotum, measurements of *gregaria* individuals only were made (Tables 4*a-g* and 5). The mean figures (in mm.) are: C, ♂ 7·6, ♀ 7·9; P, ♂ 9·9, ♀ 10·5; H, ♂ 8·4, ♀ 8·9; and M, ♂ 5·9, ♀ 6·4.

It will be seen that regarding elytron and hind-femur lengths, the following differences are observable, the sexes being separately analysed (Tables 5 and 6): (i) Among *solitaria*, the 7-striped individuals are slightly larger than the 6-striped. (ii) The *gregaria* (all 6-striped) are considerably smaller than 6-striped *solitaria* and even more so than 7-striped *solitaria* individuals; the male elytron of *gregaria* is, however, exceptional in being longer. Regarding the degree of relative size-differences (Table 6), if the mean length of 6-striped *solitaria* is taken as 100 and the variation in other types calculated as percentages of it, the following points are noticeable:—Elytron length: *Gregaria* ♂♂ are 1·6% longer, and ♀♀ 5·8% shorter; 7-striped *solitaria* ♂♂ are 0·4% and ♀♀ 2·1% longer. Hind-femur length: *Gregaria* ♂♂ are 3·9% and ♀♀ 10·2% shorter; 7-striped *solitaria* ♂♂ are 2·8% and ♀♀ 5·1% longer.

In the Red Locust, *Nomadacris septemfasciata* (Serv.), the value of E in *gregaria* females is much smaller, and in *gregaria* males larger, than in *solitaria* (Lea and Webb, 1939); this condition is similar to that in *Schistocerca*. On the other hand, in the Moroccan Locust, *Dociostaurus maroccanus* (Thunb.) (Jannone, 1938, 1939), and in the Brown Locust, *Locustana pardalina* (Walk.) (Faure, 1932; Smit, 1939; Plessis, 1939), both E and F are longer in phase *gregaria* than in phase *solitaria*, irrespective of sex; this feature is especially pronounced in *Dociostaurus* where *gregaria* individuals are almost one and a half times as large as *solitaria* ones.

The question whether the number of moults undergone is the cause of size-differences in *S. gregaria* may now be considered, but before doing so, the condition known to occur in other Acrididae may be briefly stated. In the Acrididae the males are, as a rule, smaller than females

[2] The Fifth International Locust Conference (Brussels, 1938) recommended some minor alterations. These, however, do not affect the conclusions presented here.

TABLE

Variation in length (mm.) of elytron

Phase, sex and no. of eye-stripes.	Range and mean.		Number of							
	Min.-Max.	Mean.	46·0-46·9	47·0-47·9	48·0-48·9	49·0-49·9	50·0-50·9	51·0-51·9	52·0-52·9	53·0-53·9
greg. ♂ (6-striped)	50·0-57·0	53·03	..	..	..	..	3	2	3	1
sol. ♂ (6-striped)	46·5-57·0	52·2	1	3	2	6	11	11	20	13
sol. ♂ (7-striped)	48·7-56·0	52·4	..	..	2	1	3	2	4	6
greg. ♀ (6-striped)	50·5-66·1	58·01	..	..	..	..	2	0	1	2
sol. ♀ (6-striped)	55·0-67·0	61·6	..	..	..	..	..	..	..	..
sol. ♀ (7-striped)	56·2-67·5	62·9	..	..	..	..	..	..	..	..

TABLE

Variation in length (mm.) of hind-femu

Phase, sex and no. of eye-stripes.	Range and mean.		Number of							
	Min.-Max.	Mean.	20·5-20·9	21·0-21·4	21·5-21·9	22·0-22·4	22·5-22·9	23·0-23·4	23·5-23·9	24·0-24·4	24·5-24·9
greg. ♂ (6-striped)	22·6-26·0	24·4	..	..	..	..	4	1	2	6	6
sol. ♂ (6-striped)	22·0-28·0	25·4	..	..	..	1	1	3	3	6	12
sol. ♂ (7-striped)	24·0-28·0	26·1	..	..	..	..	..	..	..	1	1
greg. ♀ (6-striped)	20·8-29·5	26·4	1	0	0	0	1	0	2	2	1
sol. ♀ (6-striped)	25·0-31·5	29·4	..	..	..	..	..	..	..	..	..
sol. ♀ (7-striped)	27·0-33·0	30·9	..	..	..	..	..	..	..	..	..

1.

(*E*) *in* Schistocerca gregaria.

Individuals in each category (1 mm.).

54·0-54·9	55·0-55·9	56·0-56·9	57·0-57·9	58·0-58·9	59·0-59·9	60·0-60·9	61·0-61·9	62·0-62·9	63·0-63·9	64·0-64·9	65·0-65·9	66·0-66·9	67·0-67·9	Total.
2	1	1	1	..	..	..	..	..	..	..	..	..	..	14
9	10	1	2	..	..	..	..	..	..	..	..	..	..	89
4	1	2	..	..	..	..	..	..	..	..	..	..	..	25
1	2	2	1	3	2	5	1	1	0	2	0	1	..	26
..	1	2	2	2	6	6	14	11	11	3	2	2	1	63
..	..	2	2	1	3	2	17	9	13	17	7	8	3	84

2.

(*F*) *in* Schistocerca gregaria.

individuals in each category (0·5 mm.).

25·0-25·4	25·5-25·9	26·0-26·4	26·5-26·9	27·0-27·4	27·5-27·9	28·0-28·4	28·5-28·9	29·0-29·4	29·5-29·9	30·0-30·4	30·5-30·9	31·0-31·4	31·5-31·9	32·0-32·4	32·5-32·9	33·0-33·4	Total.
2	3	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	28
12	13	24	10	3	0	1	..	..	..	..	..	..	..	..	..	..	89
4	4	3	6	2	3	1	..	..	..	..	..	..	..	..	..	..	25
4	3	4	0	3	1	4	5	2	1	..	..	..	..	..	..	..	34
1	1	1	1	2	2	3	8	7	10	9	9	6	3	..	..	..	63
..	..	..	..	2	0	1	3	2	6	4	11	20	20	8	7	1	5

TABLE

Variation in the ratio E/F (elytron length/hind-femur

Phase, sex and no. of eye-stripes	Range and mean.		Number of						
	Min.-Max.	Mean.	1·84-1·86	1·87-1·89	1·90-1·92	1·93-1·95	1·96-1·98	1·99-2·01	2·02-2·04
gregaria: (6-striped) 1. ♂♂	2·04-2·30	2·18	..	..	..	..	..	..	1
gregaria: (6-striped) 2. ♀♀	2·08-2·43	2·24	..	..	..	..	..	..	..
gregaria: (6-striped) 3. Both	2·04-2·43	2·22	..	..	..	..	..	..	1
solitaria: (6-striped) 1. ♂♂	1·88-2·23	2·05	..	1	2	0	7	12	17
solitaria: (6-striped) 2. ♀♀	1·96-2·25	2·09	..	..	..	..	3	3	9
solitaria: (6-striped) 3. Both	1·88-2·25	2·07	..	1	2	0	10	15	26
solitaria: 7-striped) 1. ♂♂	1·85-2·13	2·004	1	0	2	1	2	9	5
solitaria: 7-striped) 2. ♀♀	1·93-2·17	2·03	..	..	..	10	6	20	17
solitaria: 7-striped) 3. Both	1·85-2·17	2·02	1	0	2	11	8	29	22

TABLE

Variation in the width of head (C), length of pronotum (P), H/C and M/C in Schistocerca gregaria,

(*a*) Width of

C	Range and mean.		Number of				
	Min.-Max.	Mean.	6·6-6·7	6·8-6·9	7·0-7·1	7·2-7·3	7·4-7·5
♂♂	6·7-8·0	7·6	1	0	0	7	8
♀♀	6·9-8·8	7·9	0	1	3	2	1

(*b*) Length of

P	Range and mean.		Number of			
	Min.-Max.	Mean.	8·7-8·9	9·0-9·2	9·3-9·5	9·6-9·8
♂♂	8·9-10·7	9·9	1	2	5	5
♀♀	8·7-11·9	10·5	2	0	5	3

3.

length) in Schistocerca gregaria.

individuals in each category (0·03).

2·05-2·07	2·08-2·10	2·11-2·13	2·14-2·16	2·17-2·19	2·20-2·22	2·23-2·25	2·26-2·28	2·29-2·31	2·32-2·34	2·35-2·37	2·38-2·40	2·41-2·43	Total.
0	1	1	1	4	1	1	1	1	..	..	..	..	12
..	1	2	0	1	4	6	5	0	2	1	0	1	23
0	2	3	1	5	5	7	6	1	2	1	0	1	35
17	14	15	1	1	1	1	..	..	..	..	..	..	89
12	6	15	8	3	2	2	..	..	..	..	..	..	63
29	20	30	9	4	3	3	..	..	..	..	..	..	152
3	1	1	..	..	..	..	..	..	..	..	..	..	25
12	5	10	3	3	..	..	..	..	..	..	..	..	34
15	6	11	3	1	..	..	..	..	..	..	..	..	109

4 (*a*—*g*).

height of pronotum (*H*), *width of pronotum* (*M*), *and the ratios P/C, phase* gregaria. (*All measurements in mm.*).

head (C)

individuals in each category (0·2 mm.).

7·6-7·7	7·8-7·9	8·0-8·1	8·2-8·3	8·4-8·5	8·6-8·7	8·8-8·9	Total.
10	5	3	..	..	..	..	34
9	7	3	9	3	0	2	40

pronotum (P).

individuals in each category (0·3 mm.).

9·9-10·1	10·2-10·4	10·5-10·7	10·8-11·0	11·1-11·3	11·4-11·6	11·7-11·9	Total.
8	7	3	..	..	..	..	31
5	3	3	7	5	4	3	40

Table 4

Variation in the width of head (C), length of pronotum (P) H/C and M/C in Schistocerca gregaria,

(*c*) Height of

H	Range and mean.		Number			
	Min.-Max.	Mean.	7·5-7·6	7·7-7·8	7·9-8·0	8·1-8·2
♂♂	7·8-8·9	8·4	..	2	5	
♀♀	7·5-10·0	8·9	1	2	2	3

(*d*) Width of

M	Range and mean.		Number				
	Min.-Max.	Mean.	5·0-5·1	5·2-5·3	5·4-5·5	5·6-5·7	5·8-5·9
♂♂	5·3-6·5	5·9	..	1	3	6	11
♀♀	5·0-7·3	6·4	1	0	2	1	5

(*e*) Ratio

P/C	Range and mean.		Number			
	Min.-Max.	Mean.	1·17-1·19	1·20-1·22	1·23-1·25	1·26-1·28
♂♂	1·17-1·49	1·31	2	0	3	5
♀♀	1·21-1·42	1·32	..	1	2	9

(*f*) Ratio

H/C	Range and mean.		Number	
	Min.-Max.	Mean.	1·03-1·05	1·06-1·08
♂♂	1·04-1·19	1·11	4	5
♀♀	1·03-1·29	1·13	3	4

(*g*) Ratio

M/C	Range and mean.		Number	
	Min.-Max.	Mean.	0·71-0·72	0·73-0·74
♂♂	0·71-0·86	0·78	2	3
♀♀	0·71-0·88	0·81	1	1

(*continued*).

height of pronotum (*H*), *width of pronotum* (*M*), *and the ratios P/C, phase* gregaria. (*All measurements in mm.*).

pronotum (H).

of individuals in each category (0·2 mm.).									
8·3-8·4	8·5-8·6	8·7-8·8	8·9-9·0	9·1-9·2	9·3-9·4	9·5-9·6	9·7-9·8	9·9-10·0	Total.
5	12	3	4	..	..	..	..	..	34
1	4	6	7	2	4	6	3	2	43

pronotum (M).

of individuals in each category (0·2 mm.).							
6·0-6·1	6·2-6·3	6·4-6·5	6·6-6·7	6·8-6·9	7·0-7·1	7·2-7·3	Total.
8	3	2	..	..	..	..	34
3	7	7	8	3	4	1	42

P/C.

of individuals in each category (0·03).							
1·29-1·31	1·32-1·34	1·35-1·37	1·38-1·40	1·41-1·43	1·44-1·46	1·47-1·49	Total.
8	9	0	3	0	0	1	31
6	7	4	5	3	..	..	37

H/C.

of individuals in each category (0·03).							
1·09-1·11	1·12-1·14	1·15 1·17	1·18-1·20	1·21-1·23	1·24-1·26	1·27-1·29	Total.
9	9	3	4	..	..	..	34
10	11	7	2	2	0	1	40

M/C.

of individuals in each category (0·02).							
0·75-0·76	0·77-0·78	0·79-0·80	0·81-0·82	0·83-0·84	0·85-0·86	0·87-0·88	Total.
5	13	5	3	1	2	..	34
2	9	7	9	6	3	2	40

even in those species in which both the sexes undergo the same number of moults. The size-difference in such cases may possibly be due to the males having a faster rate of development than the females. The number of moults is only one of the causes of size-differences within the species. When an extra-moult is peculiar to the females only, the adults of that sex are usually considerably larger than the males, as in the Rice Grasshopper, *Hieroglyphus banian* (Coleman and Kuhni Kannan, 1911). In *Colemania sphenarioides*, where Coleman (1911) showed that about one-half the number of individuals in each sex undergo an extra-moult, the size of the adults is very variable, the body-length being 23-40 mm. in males and 25-40 mm. in females; the females are, on the average, larger.

Mathur (1938) stated for *S. gregaria* that difference in the number of moults is the cause of the slight size-superiority of *solitaria* over *gregaria* individuals. No comparative measurements were, however, given, nor evidently were eye-stripe variations and their developmental causes taken into account. When this is done, as shown below, Mathur's statement does not receive support. For the present discussion the length of the hind-femur alone will be considered, as this character is generally regarded as a good indicator of body-size in the Acrididae. The main conclusions thus arrived at, however, apply equally well to the elytron, except in *gregaria* males.

Comparing first the 6-striped *solitaria* with *gregaria* (6-striped), it is seen that the latter are smaller by 3·9-10·2%. Both these types are known to undergo the *same* number of moults, *viz.*, five (*vide* Roonwal, 1937, 1946*c*; and others,) so that the size-difference that exists in this case cannot be attributed to an extra-moult but must be caused by some other factor probably connected with phases. Within the *solitaria* phase, the 7-striped individuals are larger than 6-striped ones by 2·8-5·1%. How far is this size-superiority due to an extra-moult which is known to occur in some 7-striped individuals? In the absence of measurements of 7-striped individuals with and without an extra-moult, I shall take into consideration some indirect evidence for comparison.

It is generally recognized that the growth quotient or Przibram's quotient, Q, *i.e.*, $\frac{\text{length in one instar}}{\text{length in previous instar}}$, for growth in length of the various body-parts of insects is governed by the progression factor $\sqrt[3]{2}$ or 1·26. Bodenheimer (1927) has shown that *Schistocerca gregaria* conforms to this rule, the increase with each moult being either 1·26 or a multiple of this figure, *viz.*, $1{\cdot}26^2$ (or 1·6), $1{\cdot}26^3$ (or 2), and so on. Later, Spett (1934) showed that while in some Acrididae, *e.g.*, *Acridium bipunctatum* Linn. and *A. subulatum* Linn., Q closely approximates 1·26, in others, *e.g.*, *Chorthippus parallelus* Zett., *C. albomarginatus* (De Geer), *Dociostaurus maroccanus* Thunb., *Locusta migratoria* Linn.[3] and *Oedipoda coerulescens* (Linn.), it is considerably higher, being about 1·31-1·44. It will thus be seen that a moult in these Acrididae results

[3] Spett dealt with the typical subspecies, *L. m. migratoria* Linn., since he was dealing with Russian material. For the African subspecies, *L. migratoria migratorioides* (R. and F.), Duarte (1939) stated that Q approximates the Przibram value of 1·26; he makes no reference to Spett's work.

in a linear increase of not appreciably less than about 1·26-1·44 times or 26-44%. In the *solitaria* phase of *S. gregaria* the maximum superiority, in regard to hind-femur length, of 7-striped over 6-striped individuals is not more than about 5·1%, which is much less than would be expected as a result of an extra-moult in *all* 7-striped individuals. Taking the normal increase due to a moult as at least 26%, it would appear that not more than about 5·1/26% or about one-fifth of the total number of 7-striped individuals undergo an extra-moult[4].

If this conclusion is correct, it is to be expected that as regards size the 7-striped *solitaria* individuals will fall into two groups: (i) Those which have undergone an extra-moult and are at least about 1·26 times or 26% larger than 6-striped *solitaria*; these constitute a certain proportion of the population. (ii) Those which have not undergone an extra-moult and are about the same size as 6-striped *solitaria*; these constitute the remainder. (*Vide* also Roonwal, 1947, for additional proof of the existence of these two types of 7-striped individuals.)

TABLE 5.

Summary of means of biometrical data (Tables 1-4) on S. gregaria.

Phase, sex and number of eye-stripes.	E	F	E/F	C	P	H	M	P/C	H/C	M/C
greg. ♂♂ : (6-striped)	53·03	24·4	2·18	7·6	9·9	8·4	5·9	1·31	1·11	0·86
sol. ♂♂ : (6-striped)	52·2	25·4	2·05	..	..	..	..	..	..	..
sol. ♂♂ : (7-striped)	52·4	26·1	2·004	..	..	..	..	..	..	..
greg. ♀♀ : (6-striped)	58·01	26·4	2·24	7·9	10·5	8·9	6·4	1·32	1·13	0·88
sol. ♀♀ : (6-striped)	61·6	29·4	2·09	..	..	..	..	..	..	..
sol. ♀♀ : (7-striped)	62·9	30·9	2·03	..	..	..	..	..	..	..

TABLE 6.

Percentage of mean size-differences in E and F in S. gregaria, *taking 6-striped* solitaria *as 100.*

Phase, sex and number of eye-stripes.	E	F
greg. ♂♂ : (6-striped)	+1·6%	—3·9%
sol. ♂♂ : (6-striped)	100	100
sol. ♂♂ : (7-striped) . . .	+0·4%	+2·8%
greg. ♀♀ : (6-striped)	—5·8%	—10·2%
sol. ♀♀ : (6-striped)	100	100
sol. ♀♀ : (7-striped)	+2·1%	+5·1%

[4] This, of course, assumes that the size-superiority under discussion is due entirely to an extra-moult.

Sexual Dimorphism.

As in other Acrididae, the females in *S. gregaria* are larger than males of that type and phase; this is evident from the mean dimensions given in Tables 1-5. The degree of sexual dimorphism was calculated as a percentage by which the mean length in females is greater than the mean length in males (Table 7). This figure may be termed the *sexual dimorphism percentage.* Thus, for the elytron-length (E) of a population, the percentage will be obtained by the expression $\frac{E♀}{E♂} \times 100$.

Table 7.

Mean sexual dimorphism percentages in S. gregaria.

Type of individuals.	Sexual dimorphism percentage.					
	E	F	C	P	H	M
gregaria (6-striped)	9·4	8·2	3·9	6·1	5·95	8·5
solitaria (6-striped)	18·01	15·7	..	..	..	..
solitaria (7-striped) .	20.04	18·4	..	..	..	..

It will be noticed (Table 7) that in regard to both elytron and hind-femur lengths the sexual dimorphism percentage in *solitaria* individuals is nearly double that in *gregaria.* Among *solitaria* individuals themselves, sexual dimorphism is more marked (by about 2% regarding E and 2·7% regarding F) in 7-striped than in 6-striped individuals.

Murat (1939) had already observed in W. Africa that sexual dimorphism in elytron-length is more marked in *solitaria* than in *gregaria* individuals; he was, however, unaware of eye-stripe variations. As an index for the elytron Murat had employed the " sexual dimorphism ratio ", *viz.*, E♀/E♂, his figures being 1·09 for *gregaria* and about 1·18-1·26 for *solitaria* individuals. If my measurements for E and F are analysed in that way, the following ratios are obtained (Table 8) :—

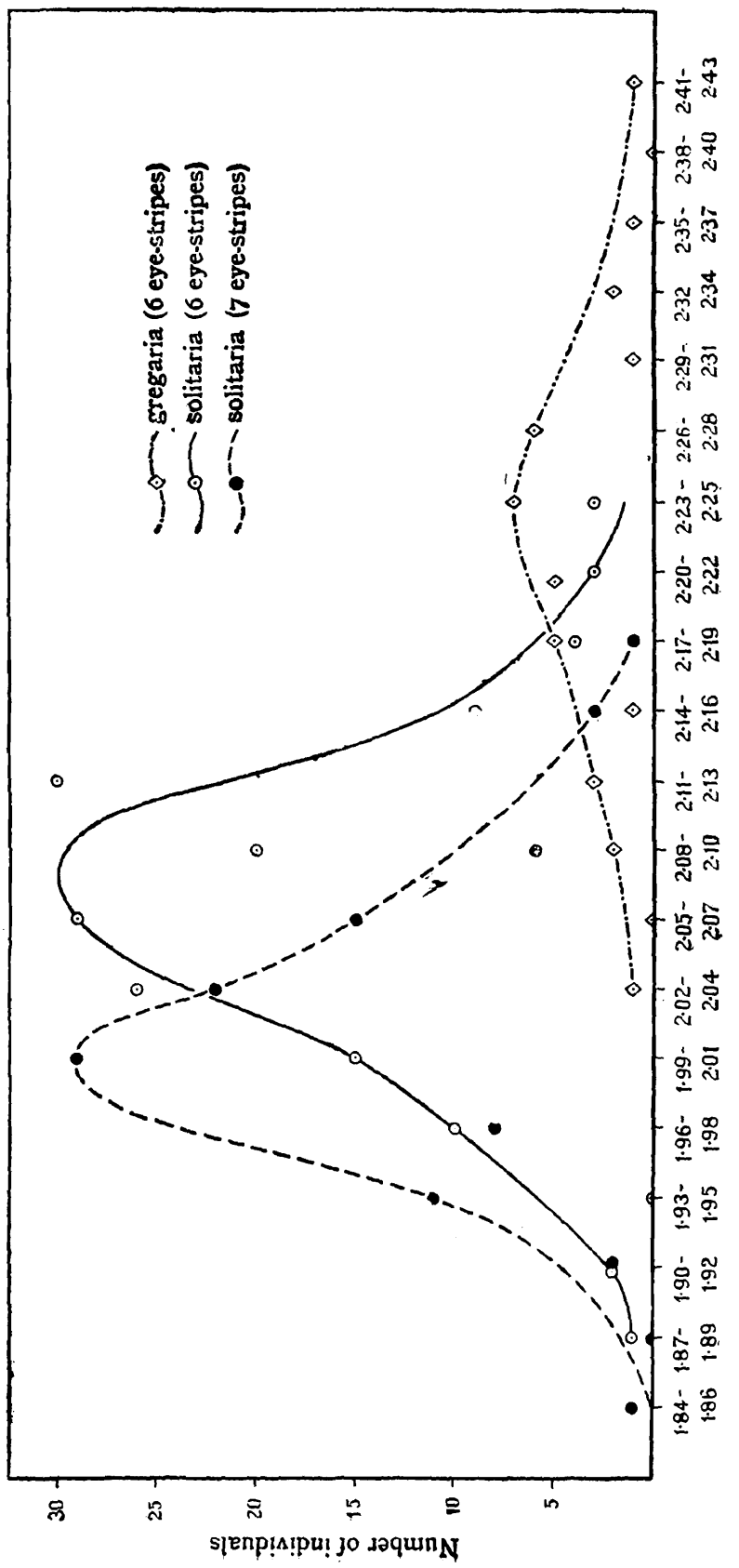
Table 8.

Mean sexual dimorphism ratios in S. gregaria.

Ratio	*gregaria* (6-striped)	*solitaria* (6-striped)	*solitaria* (7-striped)
E♀/E♂	1·09	1·18	1·2
F♀/F♂	1·08	1·16	1·18

A similar variation in the sexual dimorphism ratio was noticed in *Nomadacris septemfasciata* by Lea and Webb (1939) and in *Locustana pardalina* by Faure (1932) and Plessis (1939). That ratio was found to be a more valuable index of phase than the commonly employed E/F ratio.

The use of sexual dimorphism, expressed either as ratio or as percentage—preferably the latter because of the larger figures obtained and the consequent ease of comparison—is recommended here for the assessment of phase in populations of *S. gregaria* in the field.



TEXT-FIG. 1.—Graph of E/F ratios of various types of individuals of *Schistocerca gregaria*, namely, phase *gregaria* 6-striped, *solitaria* 6-striped and *solitaria* 7-striped. (From data in Table 3.)

Biometrical Ratios.

E/F ratio.

The analysis of the E/F ratios (Text-fig. 1) shows (Tables 3, 5 and 9-11) that, irrespective of sexual variation within each group, the 6-striped *solitaria* individuals have a higher mean ratio (E/F 2·07) than 7-striped *solitaria* (E/F 2·02). The *gregaria* individuals of course have, as is well-known, a much higher mean ratio (E/F 2·22, from the measurements given here) than the *solitaria*.

Table 9.

E/F ratios (both sexes together) in S. gregaria. (*From Table 3.*)

Phase and number of eye-stripes	E/F	
	Range	Mean
gregaria (6-striped)	2·04-2·43	2·22
solitaria (6-striped) . .	1·88-2·25	2·07
solitaria (7-striped) .	1·85-2·17	2·02

The figures given in Tables 3 and 5 may be analysed in another way, *viz.*, by comparing the percentage of individuals belonging to each phase-group among 6- and 7-striped *solitaria* forms, assuming the limits of each group as follows:

solitaria: E/F 2·05 and below (to about 1·85).

transiens [5]: E/F 2·06-2·15.

gregaria: E/F 2·16 and above (to about 2·43).

It will be seen (Table 10) that in both the 6- and 7-striped *solitaria* group under study there is a sprinkling of high ratio or "*gregaria*" individuals. The proportion of the latter is, however, much higher (8·6%) in the 6-striped than in the 7-striped (0·9%) group.

Table 10.

Distribution of solitaria *populations of* S. gregaria *by E/F phase-groups.*

Nature of population	% of population in each E/F phase-group		
	solitaria	*transiens*	*gregaria*
solitaria (6-striped) .	39·5	51·9	8·6
solitaria (7-striped) .	67	32·1	0·9

[5] The reality of the intermediate phase-group, *transiens*, is, in my experience, highly doubtful, although some authors repeatedly use this term to designate intermediate and, supposedly, at least partially distinguishable individuals. Its retention, however, as a purely arbitrary intermediate group may sometimes be desirable for convenience of the statistical analysis of quantitative data.

The E/F ratios also display sexual dimorphism (Tables 3 and 11). Within each phase- and eye-stripe group, the mean E/F ratio is higher in females than in males by 1·3-2·8%. The difference is lowest (1·3%) in the group with the lowest E/F ratio (7-striped *solitaria*) and highest (2·8%) in the group with the highest ratio (*gregaria*). In other words, the degree of sexual dimorphism increases with the progress towards higher ratios; this is the opposite of what occurs with regard to the size of the body-parts, *e.g.*, length of elytron and hind-femur.

TABLE 11.

Sexual dimorphism in E/F ratios in S. gregaria.

Phase and number of eye-stripes	Mean E/F		%mean superiority of ♀ over ♂
	♂	♀	
gregaria (6-striped) . . .	2·18	2·24	2·8%
solitaria (6-striped) . . .	2·05	2·09	1·95%
solitaria (7-striped) . . .	2·004	2·03	1·3%

In *Nomadacris septemfasciata* (Lea, 1938) and *Locustana pardalina* (Plessis, 1939; Smit, 1939) also the E/F ratio within each phase is higher in females than in males.

Other ratios.

With regard to other ratios, I have figures only for *gregaria* individuals (Tables 4*e-g* and 5). Here again, females tend to have higher ratios than males, the means being as follows:—P/C: ♂♂ 1·31, ♀♀ 1·32; H/C: ♂♂ 1·11, ♀♀ 1·13; M/C: ♂♂ 0·78, ♀♀ 0·81.

SUMMARY.

1. The size and biometrical ratios of the body-parts were studied in the three major types of individuals of the Desert Locust, *viz.*, phase *gregaria* 6-eye-striped, and phase *solitaria* 6- and 7-striped.

2. Regarding the length of the elytron (E) and that of the hind-femur (F), *gregaria* individuals are the smallest (except in male E), 6-striped *solitaria* larger, and 7-striped *solitaria* the largest.

3. The cause of the size-differences between the 6-striped *gregaria* and 6-striped *solitaria* forms is not the difference in the number of moults (both have 5 moults), but some other factor probably connected with phase. The difference between 6- and 7-striped *solitaria* is attributable in part only to the difference in the number of moults—a small proportion of the 7-striped individuals undergo 6 moults; the remaining 7-striped and all the 6-striped individuals undergo only 5 moults.

4. Within each group, the females are larger than males in respect of all the body-parts, the sexual dimorphism being greatest in 7-striped *solitaria* and least in *gregaria*. The use of the "sexual dimorphism percentage", *i.e.*, the percentage by which females are larger than males in a population-group, provides a convenient method for the determination of phase in the field.

5. The mean E/F ratio is lowest in 7-striped *solitaria* (2·02), higher in 6-striped *solitaria* (2·07), and highest in *gregaria* (2·22). It also exhibits sexual dimorphism, being higher in females than in males; the dimorphism is greatest in *gregaria*, and least in 7-striped *solitaria*.

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