Morphometrics of field populations of *Austracris guttulosa* (Walker) (Orthoptera: Acrididae) in Australia

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ABSTRACT   Field collections of the cyrtacanthacrid locust *Austracris guttulosa* were made over 5 years in Queensland. Morphometric measurements of elytron length (E), femur length (F) and head capsule width (C) and their ratios E/F and F/C indicated that the species did not exhibit phase polymorphism.

Introduction

An outbreak of the spur-throated locust, *Austracris guttulosa* (Walker) (lately *Nomadacris guttulosa* (Walker) (Key and Rentz 1994)), from 1970 to 1975 in eastern Australia (Elder *et al.* 1979; Casimir and Edge 1979; Elder 1995), provided an opportunity to test for any effect of density and behaviour on the morphometrics of the species.

Typically locusts exhibit phase polymorphism, with morphologically distinct forms or phases, "solitary" and "gregarious", which are the terminal expressions of a continuous polymorphic series (Uvarov 1966). Phase polymorphism can be a useful indicator of the swarming potential of locust concentrations as only the extreme gregarious phase of some locusts form migrating swarms (e.g. *Nomadacris septemfasciata* (Serville); Uvarov 1977).

Laboratory studies of the morphometrics of *A. guttulosa* reared from egg in individual glass jars indicated that the species was sexually dimorphic, females being larger than males (Elder 1989). Comparison of the morphometrics of these individually reared locusts and those from swarms from the east Kimberley region of Western Australia and from Richmond in Queensland (Bullen 1968) found no morphometric differences between these specimens, i.e. no evidence of phase polymorphism.

Methods

The collection locations and method of collection for the 8,615 locusts examined were described by Elder (1995). The specimens were collected from widespread locations in Queensland, between 14 October 1971 to 25 November 1976. Specimens were sexed (Dirsh 1953) and measurements of elytron length (E), femur length (F) (accuracy ± 0.1 mm) and head capsule width (C) (accuracy ± 0.06 mm) were taken and the ratios E/F and F/C calculated after the method of Uvarov (1966).

To test for differences between the sexes, a one way ANOVA (Dixon 1965) was used on early data; N = 1,600 adults taken in 162 collections made over the initial period 10 October 1971 to 13 September 1973. T-tests were later used to test for differences between this subset and a subset with solitary vs swarming collections.

Analyses of variance (ANOVA) using a general least square method (Harvey 1960) were used to allow for disproportionate subclass numbers. Results are presented as means for each main effect or as least square constants to give a best estimate of the deviation (positive or negative) from the overall mean of any particular effect. Skewness and kurtosis were calculated (McIntyre *et al.* 1971; Snedecor and Cochran 1976).

Results

Sexual dimorphism. T-tests showed that the means for each variable (n = 1,600) were usually significantly different (P < 0.001) to the means obtained in an analysis of solitary and swarming individuals (Table 1). The actual differences were so small that they were probably due to the climate effects discussed later. Male elytron lengths, femur lengths and head capsule widths were significantly smaller than those for females. Male elytron length/femur length ratios were significantly larger than those for females, but the difference between the means for the two sexes was 0.031 or 1.7% of the overall mean of 1.81. This is of doubtful biological significance, but more a function of the large numbers in the analysis. The femur length/head capsule width ratios were not significantly different between sexes.

Normality of distributions. For *A. guttulosa* to be considered phase polymorphic the frequency distributions of morphometric parameters and ratios of each sex should be non-normal and strongly bimodal. The morphometric data for all adults (solitary and swarming) collected up to 4 April 1975 (504 collections) were tested for overall normality, skewness and kurtosis and chi-square (χ^2) tests applied to each of 10 frequency distributions. The results indicated that the curves were non-normal in all cases. Female elytron lengths, male and female femur lengths and male and female E/F and F/C ratios exhibited leptokurtosis (pointed distribution) (P < 0.05). Female elytron lengths, male and female femur

lengths and head capsule widths and female E/F ratios were skewed to the left (negative) and female F/C ratios were skewed to the right (positive) (P < 0.05).

Comparison of solitary and swarming populations. Morphometric data from 12 swarming (i.e. gregarious) and 12 solitary adult populations were selected at random from the 597 field collections to test for polymorphism.

Analysis indicated that the behaviour (gregarious or solitary) by sex and sex by habitat interactions were not significant and they were omitted in the final analysis.

There was a significant behaviour by habitat interaction for elytron length, head capsule width and femur length/head capsule width ratio (Table

1). The different habitat types were differentiated on the basis of "Land system surveys of the Australian arid zone"—Division of National Mapping, Department of Minerals and Energy, in which the arid zone boundary line was based on the moisture index of Fitzpatrick and Nix (1970) (W. F. Mawson pers. comm.). Head capsule width showed a 2% decrease in size from arid to non-arid for solitary locusts and a 5% decrease for swarming locusts which was also reflected in the femur length/head capsule width ratio. The behaviour by habitat interaction for elytron length arose because solitary locusts were 2% larger in arid areas than non-arid, whereas swarming locusts from arid areas were 1% smaller.

Sex significantly (P < 0.001) affected all three

Table 1. Effect of sex and the interaction between solitary or swarming behaviour, arid or non-arid habitat and adult morphometrics of *A. guttulosa*. Results expressed as least square means.

	Effect of sex		Males	Females
Elytron (E) (mm)	***		45.907	56.101
Femur length (F) (mm)	***		25.194	31.334
Head capsule width (C) (mm)	***		5.558	6.891
E/F	***		1.823	1.792
F/C	ns		4.544	

	Effect of behaviour by habitat interaction		Solitary	Swarming
Elytron length (mm)	**	Arid	51.813	50.503
		Non-arid	50.725	50.971
Head capsule width (mm)	*	Arid	6.336	6.326
		Non-arid	6.214	6.020
Femur length/head capsule width ratio	***	Arid	4.506	4.427
		Non-arid	4.549	4.695

* P < 0.05; ** P < 0.01; *** P < 0.001; ns Not significant.

Table 2. Effect of year, sex and habitat (arid or non-arid) on adult morphometrics of *A. guttulosa*. Results expressed as overall mean and least square constants†.

Source of variance	No.	Femur length F (mm)	Head capsule width C (mm)	F/C	Elytron length E (mm)	E/F
Overall mean	1,251	27.92	6.22	4.488	50.35	1.805
Year (Y)	**	**	**	**	**	**
1972	208	−0.05	−0.11	0.075	−0.36	−0.010
1973	352	−0.04	0.04	−0.036	−0.05	−0.000
1974	365	0.70	0.19	−0.021	1.58	0.012
1975	326	−0.61	−0.12	−0.108	−1.17	−0.002
Sex (S)	**	**	*	**	**	ns
Male	666	−3.00	−0.64	−0.013	−5.08	0.010
Female	585	3.00	0.64	0.013	5.08	−0.010
Habitat (H)	**	**	ns	**	**	ns
Arid	583	−0.29	ns	−0.045	−0.35	0.006
Non-arid	668	0.29	ns	0.045	0.35	−0.006
Y by S	ns	**	ns	*	*	ns
Y by H	**	*	**	**	ns	ns
S by H	**	*	ns	**	ns	ns

* P < 0.05; ** P < 0.01; ns not significant; † Least square constants estimate the direction (±) and distance from the overall mean for any particular effect.

Table 3. Femur length/head capsule width (F/C) and elytron length/femur length (E/F) ratios for *A. guttulosa* from various sources.

Rearing conditions	F/C		E/F		Reference
	Males	Females	Males	Females	
Laboratory	4.57	4.72	1.73	1.73	(Elder 1989)
Field	4.58	4.59	1.80	1.78	(Table 1)
Field	4.25	4.30	1.76	1.67	(Bullen 1968)

measurements and the elytron length/femur length ratio, males being smaller than females (Table 1). The differences due to sex (22% for elytron length and 24% for femur length and head capsule width) were much greater than for habitat or behaviour. **Year and habitat differences.** There was little apparent overall variation from the mean in any of the three parameters measured, or the calculated F/C and E/F ratios over the 5 years of the study (e.g. less than 1.6 mm for elytron length (Table 2)). Small size differences did occur between specimens collected from one year to the next and from arid as compared with non-arid habitats. These differences were further examined using material taken during November where collections were made over 4 consecutive years at 22 arid and non-arid locations (Elder 1995). The main effects (year, sex and habitat) and their interactions are all fixed. Consequently the only contending estimation of error is the residual term (pooled year by sex by habitat interaction and within cell variation). However, testing of main effects and first order interactions using this error term, resulted in most effects and interactions being significant (Table 2). This suggests a positive intra-cell correlation, amongst individual locusts of the same sex collected at the same location and year (i.e. environment), which results in an underestimation of true error variation.

The differences between the sexes and the years were considered large enough to be of biological importance.

Discussion

In polymorphic locusts there is a difference of 10 to 20% between the mean ratios for solitary and gregarious locusts (Uvarov 1966). The morphometric data provided here give no indication of phase polymorphism in *A. guttulosa*. The ratios obtained with *A. guttulosa* (Table 3) were similar to those expected of the extreme solitary phase of species such as *Schistocerca* Forskål, *N. septemfasciata* and *Locusta migratoria migratorioides* (Reichie and Fairmaire) (Uvarov 1966; Farrow and Colless 1980).

Uvarov (1966, 1977) noted that all species which exhibit phase polymorphism form concentrated hopper (nymphal) bands. While swarming adult *A. guttulosa* were observed in this study, concentrated hopper bands were never seen.

In the field, locusts increased in size from 1972 to a maximum in 1974 after which they reduced sharply to their smallest size in 1975 (Table 2). Their size was determined during the previous wet season when they were in the hopper stage. The species has an annual life cycle with hoppers present only in the wet season (Elder 1995). The wet season in 1973-4 was above average (Elder 1995). This lengthy period when fresh green grass was available for growth and development of the hoppers accounts for their larger size observed in 1974.

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