

## Bionomics of *Austracris guttulosa* (Walker) (Orthoptera: Acrididae) During the 1970-75 Outbreak in Queensland, Australia

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**ABSTRACT** Studies of *Austracris guttulosa* (Walker) showed that oviposition was dispersed and never aggregated and that the nymphs were solitary rather than gregarious. Swarms consisted of overwintering adults in a state of reproductive diapause. Swarms dispersed once sexual maturation commenced in spring. Local and long distance movements resulted in outbreak expansion from arid to coastal and subcoastal districts of Queensland. Parasites, parasitoids and predators are listed and their distribution and effect on locust populations discussed.

### Introduction

The spur-throated locust, *Austracris guttulosa* (Walker) (formerly *Nomadacris guttulosa* (Walker)) (Key and Rentz 1994), has long been recognised as an occasional serious pest of crops in northern Australia (Key 1938; Bullen 1968; Casimir and Edge 1979; Elder *et al.* 1979). Bullen (1968) summarised the Australian data on outbreaks during 1935-68 and concluded that five of the seven outbreak periods in those 33 years began in years of average or above average rainfall following drought periods. Outbreaks were Australia-wide, lasted between 1-5 years and populations persisted locally for 1-4 years.

Casimir (1962) suggested that, for *Chortiocetes terminifera* (Walker), drought periods reduce populations of both locust and natural enemies. On the return of favourable conditions, locust populations are free to increase without the restriction of natural enemies and a comparable scenario may operate for *A. guttulosa*. Differences in the quality and quantity of food available could also be a direct effect of drought preceding an outbreak.

An outbreak of *A. guttulosa* occurred in Queensland and New South Wales, Australia from 1970 to 1975 (Casimir and Edge 1979; Elder *et al.* 1979). Casimir and Edge (1979) and Casimir (1987) described local and long distance movements of *A. guttulosa* in New South Wales. This paper reports aspects of field biology and outbreak dynamics during that period. Records of long distance (300 km) movements in Queensland presented in this paper complement the observations of Casimir and Edge (1979) and Casimir (1987).

### Materials and methods

Field studies on *A. guttulosa* were undertaken from October 1971 to November 1976 (Elder 1995). Regular collections of locusts were made from a study area at Barmount (22°32'S, 149°06'E). Supplementary collections and reports of swarms and movements of locusts were made by officers of the Department of Primary

Industries and local residents. In addition, two major locust surveys were undertaken each year in November and March. Collections from various locations were designated as arid, subcoastal and coastal (Elder 1995).

**Collection methods.** Samples were taken on foot using a standard 457 mm diameter black net. At each site sampling continued for a maximum of 30 min or until 13 males and 13 females had been obtained. During the first 6 months of the study, specimens were killed by freezing. Subsequently, specimens were placed directly into a mixture of 80% ethanol, 3% glacial acetic acid and 17% water to fix body tissues for dissection and internal examination.

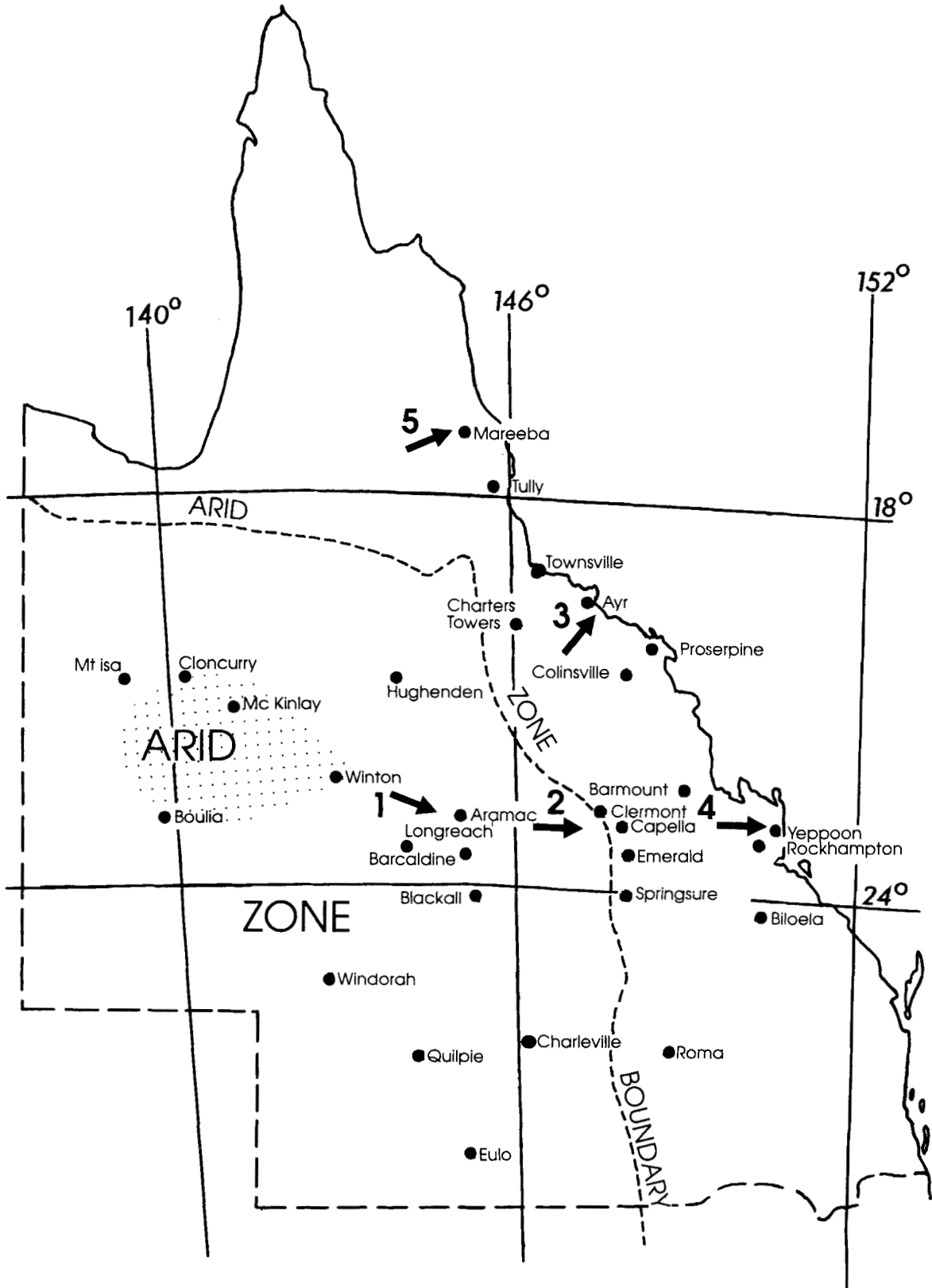
During 1973-74, the Queensland Government, and in 1974-75, the Commonwealth and Queensland Governments combined, provided compensation to land holders for the cost of insecticidal control of *A. guttulosa* and *Locusta migratoria* (L.). Records resulting from compensation claims were also used in studying the outbreak.

**Dissection.** Adults were first examined for ectoparasites, and then dissected by making an incision along the mid-lateral line on each side of the abdomen and across the dorsal surface of the abdomen between the tympanal organs. The head and thorax were then opened along the dorsal median line. Nymphs were dissected by making an incision along the median line of the dorsal surface from head to abdomen. The presence of parasitoids was recorded.

**Analyses.** As there was a low number of parasitised locusts, the number of locusts and number of these parasitised were totalled across 6-month periods (1 January to 30 June and 1 July to 31 December for each year) from the 576 collections made. Logistic regressions were used to test for differences in levels of parasitism across time (in 6-month periods), zones (arid, subcoastal and coastal) and host sex and their interactions for parasitoids and ectoparasites separately.

### Results

**Geographic distribution.** *A. guttulosa* was



**Fig. 1.** Queensland localities mentioned in text. The stippled area is where large swarms were reported from May to early November 1974. The arrows indicate the direction of movement from this area in late 1974: 1, 12-18 October; 2, 18 October; 3, 12-19 November; 4, 26-30 November; 5, late December. Arrows were inserted only where locust origin and arrival points could be inferred from reports or direct observation.

collected throughout Queensland in areas which included both very high average annual rainfall (Tully 2,000 mm) and low rainfall (Boulia 257 mm) (Fig. 1). Specimens were usually more plentiful among denser and taller vegetation, e.g. around waterholes or along stream banks, than in sparse or short vegetation. Except for 1971, which followed a number of years of drought, swarms (as distinct from loose swarms described below) were recorded mainly in areas of cracking clay soils in the arid zone (Fig. 2). The cracking clay soils support the more nutritious or productive native pasture communities including mitchell grass and blue grass (Weston 1990). Loose swarms, aggregations large and dense enough to be noticed by the general public, but lacking the cohesion of normal swarms, were reported from many coastal locations in 1974.

**Behaviour.** Oviposition was observed rarely but never occurred collectively in egg-beds. Females laying eggs were observed only during the day. This may have been due to the difficulty of finding them at night and because of their cryptic coloration. Females readily and quickly withdrew their abdomen from the soil and flew off if disturbed. In flight, such females were easily recognisable by their abdomens hanging down at right angles to the head and thorax.

During the study, 177 *A. guttulosa* swarms were recorded in the March to November period with the highest frequency between July and October. Adults remained sexually immature from March to late September-November (Elder 1995) and swarming was recorded only in this period preceding the onset of sexual maturity. By December and January, a large proportion of the population was sexually mature (Elder 1995) which was coincident with a breakdown of swarming behaviour. In February, newly fledged sexually immature adults were incapable of the sustained flight required for swarm development. They had soft cuticles and their fat body was undeveloped.

Migration by swarms during warmer weather was slow (approx. 4-8 km per h) and at estimated heights of up to 80 m, often with no individuals flying below 2-3 m. In cold weather, the swarms were inactive with individuals roosting in belts of trees, their combined weight occasionally being large enough to break branches. On warm days, individuals moved into adjacent grassland or crops to feed, returning to the trees in mid to late afternoon. In some areas, extensive feeding on the trees and shrubs occurred, often resulting in complete defoliation. In these situations, the only plant apparently rejected as a food source was the introduced *Nerium* sp. (oleander).

Dense infestations of adults and nymphs were common during the 1973-74 and 1974-75 periods and even though densities were similar to those of *L. migratoria* at that time, nymphs were never observed moving in dense bands.

**Mass displacements.** Mass displacement of populations between early 1974 and February 1975 provided information on the long distance movements of adults.

Between May and early November 1974, very large, dense swarms were reported overwintering west of Hughenden-Blackall (Fig. 1: stippled area). No large swarms were reported east of this district. In the infested area between Winton, Boulia and McKinlay, very dense almost contiguous aggregations were present. As these aggregations had been present in the area at least since the end of the breeding season, it is probable that they resulted from eggs laid there by the previous generation.

Movements of 200-400 km to the north and south-east of this district occurred during 12-18 October 1974 when high density populations including loose swarms were initially reported in the Longreach, Barcaldine, Blackall, Aramac (Fig. 1: arrow 1) and Mt. Isa districts (Fig. 1). On 18 October, there was a mass displacement of locusts over 300-400 km to the east resulting in infestation of the Emerald, Capella and Clermont districts (Fig. 1: arrow 2).

During 12-19 November, mass displacements to the north-east took place and populations invaded Collinsville, Proserpine, Townsville and Charters Towers districts (Fig. 1: arrow 3). The source of these locusts was difficult to ascertain because the swarms (Fig. 1: stippled area) dispersed with the October movements (see above) and locusts were distributed over a very wide area. A survey of the Boulia and McKinlay districts on 19 November failed to locate any of the large swarms previously observed and I believe that this district was the primary source of the invasion of northeastern Queensland. By 24 November, no large swarms were located in any of the Longreach, Windorah, Quilpie, Charleville, Roma and Springsure districts and these swarms are believed to have contributed to an influx into southeastern Queensland with numerous adults appearing on the Darling Downs and as far east as Brisbane.

During 26-30 November, an increase in *A. guttulosa* numbers occurred along the coast from Proserpine to Yeppoon (Fig. 1: arrow 4). Further south, increases in locust numbers were reported from Biloela, Eulo, Blackall and Charleville on 12 December. In late December 1974, there was an increase in the density of adult populations in the Mareeba district (Fig. 1: arrow 5). On 7 January 1975, adult *A. guttulosa* were reported washed up on beaches near Ayr. At this time, fewer adults were reported along the coast between Ayr and Rockhampton.

Coincident with the displacements in northeastern Queensland, movements to the coast commenced in October 1974 in southeastern Queensland, east of Charleville.

Movements prior to late November were

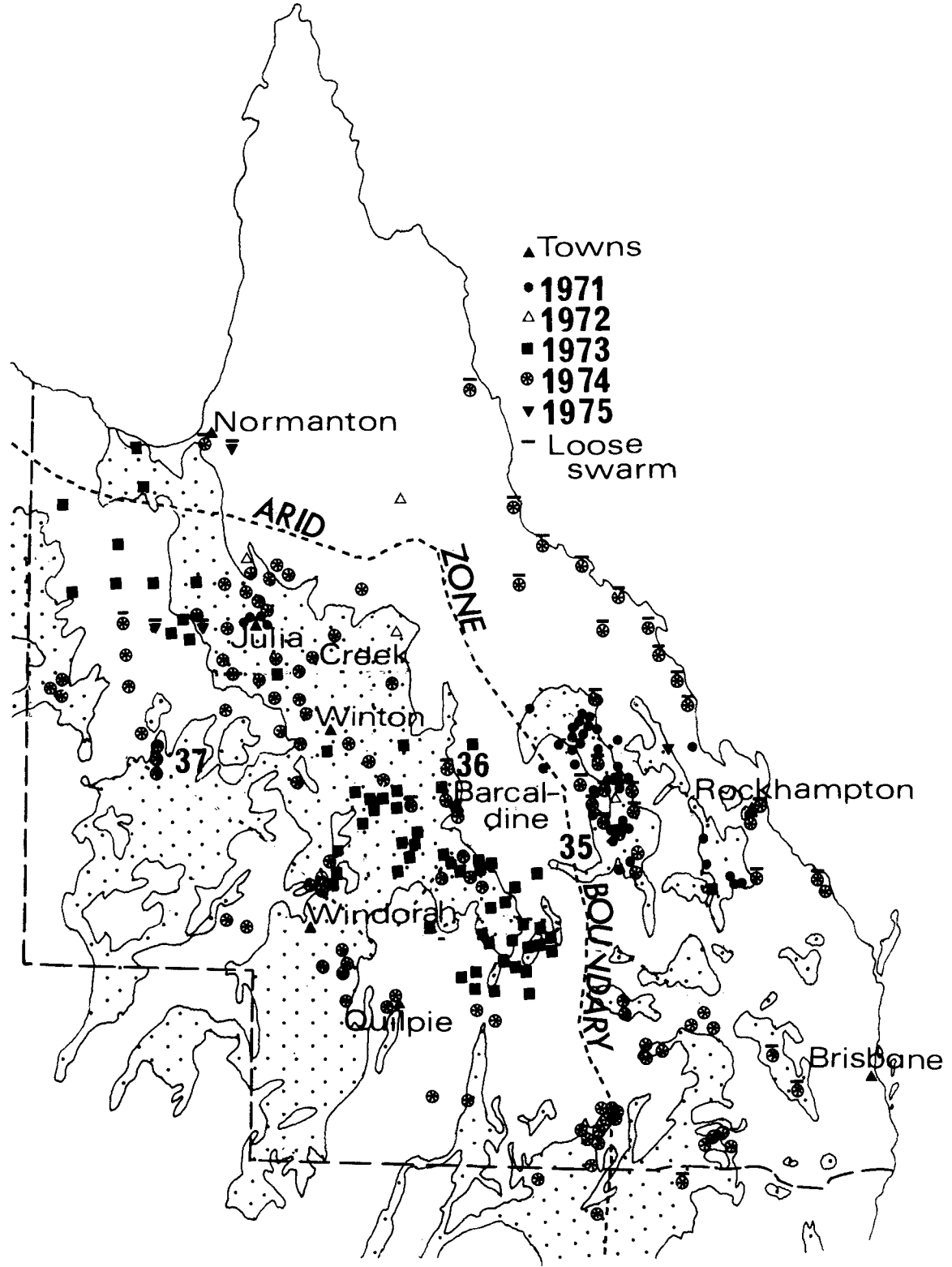


Fig. 2. Distribution of loose swarms and overwintering swarms of *A. guttulosa* during 1971-1975. Areas of cracking clay soils are stippled. Loose swarms (aggregations large enough to be noticed by the general public and reported) are indicated by a dash over the appropriate year symbol.

associated with the passage of cold fronts from west to east (Fig. 3 and Australian Bureau of Meteorology 3 pm synoptic weather charts for 13 and 17 October and 14 and 26 November 1974).

During a subsequent outbreak in 1995, there were no similar cold fronts extending into the tropics and, although large numbers of spur-throated locusts were present in western Queensland in 1995, movements similar to 1974 did not occur (Hunter pers. comm.). Cold fronts as compared to troughs are associated with more agitated weather conditions. As a result larger particles are lifted off the land surface into the atmosphere and presumably this would include locusts (Australian Bureau of Meteorology, Rockhampton pers. comm.).

*Effect of mass displacements on outbreak expansion:* The *A. guttulosa* outbreak in 1973-74 was confined to southeastern Queensland whereas the outbreak in 1974-75 occurred in all crop growing regions of the state (Elder *et al.* 1979). In 1974-75, for which detailed records are available (Elder *et al.* 1979), most spray applications were made between 1 January and 31 March 1975 on nymphs and newly fledged adults. These populations were the progeny of adults which migrated into the cropping areas in the last quarter of 1974.

**Parasites and predators.** One ectoparasite, five parasitoids and five predators were recorded (Table 1). The host-specific mite ectoparasite *Podapolipoides barmounti* Husband (Podapo-

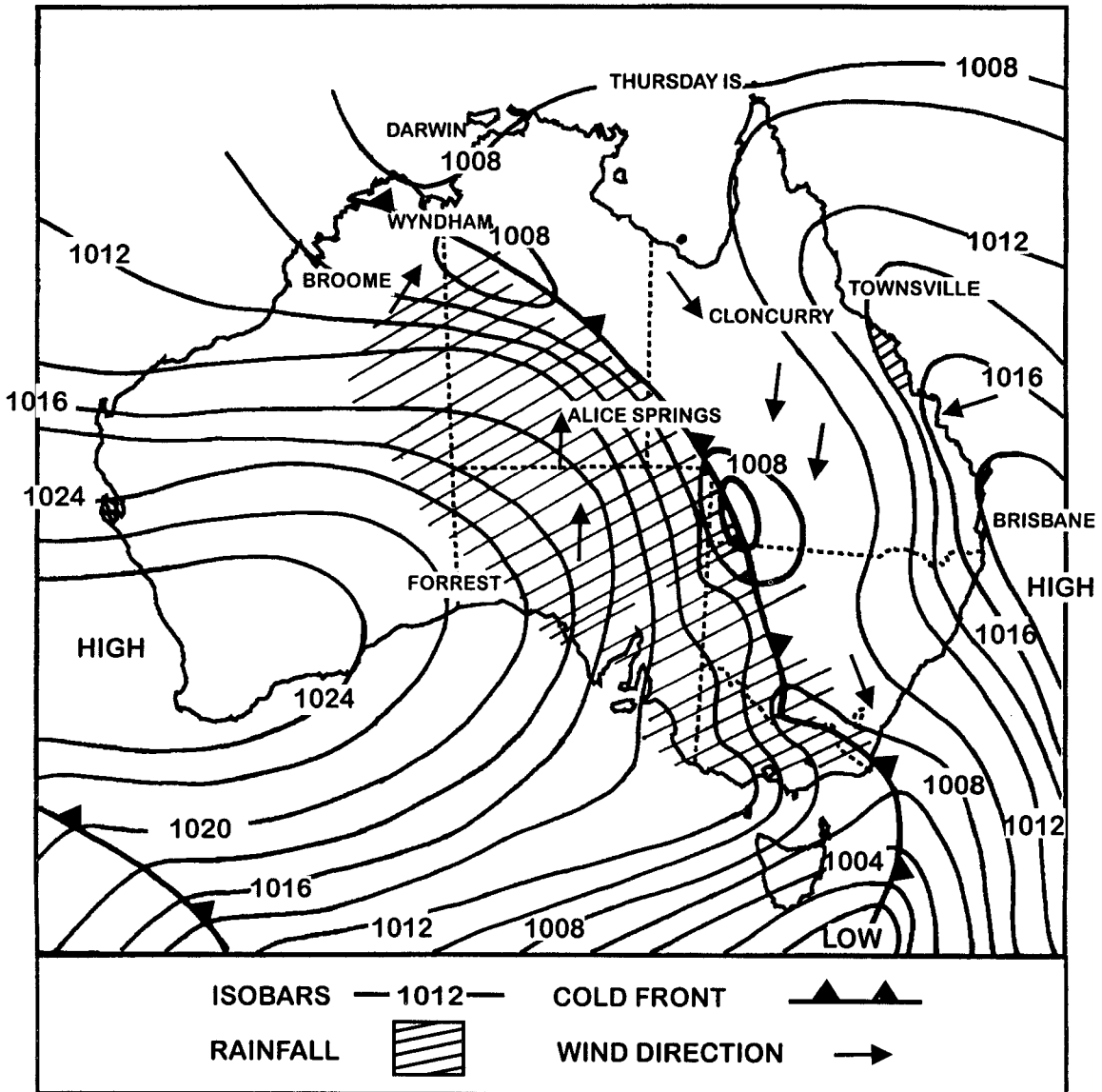


Fig. 3. Synoptic weather chart for 3 pm 16 October 1974 illustrates a cold front associated with the large scale movement of *A. guttulosa* adults. The extension into the tropics is unusual for cold fronts as this extension usually occurs as a weak trough.

lipidae) (Husband 1990) occurred throughout the year on locusts in arid, sub-coastal and coastal areas. It was found mostly on wing bases and intersegmental membranes.

Parasitoids were present in all months. Only *Blaesoxipha* spp. larvae and *Blaesoxipha rufipes* Macquart (= *pachytyli* Skuse (Pape 1994)) (Diptera: Sarcophagidae) adults were identified from the arid zone (Fig. 4). Multiple parasitism was observed with one late instar female nymph containing three larvae of which two were *Blaesoxipha* spp. and one was a tachinid.

Eighteen locusts out of 576 collections had tachinid eggs (length 0.639 mm  $\pm$  0.032 mm (mean  $\pm$  SD),  $n = 10$ ; width, mean 0.373 mm  $\pm$  0.014 mm,  $n = 10$ ), possibly of *Phorocerosoma postulans* (Walker). Eggs were attached to body parts in the following numbers: head (7), thorax (5), eye (3), wing (1), femur (1) and antenna (1). Tachinid larvae subsequent emerged from three adult *A. guttulosa* on which an egg had been found, but they did not survive past the puparium stage. This contrasted with *Blaesoxipha* spp. which were readily bred out to adults. *Blaesoxipha* spp. are viviparous as Cantrell (1978, 1980) obtained larvae from the abdomen of both *B. rufipes* and *B. valangae* Aldrich (= *similis* Cantrell (Papae 1994)).

Parasitism by dipteran parasitoids at three non-arid locations (Barmount, Emerald and Emerald irrigation area, 5 km from Emerald) from mid September to early May indicated that for 1973-74 parasitism rates were substantial, although parasites were present throughout the period (Fig. 5). In 1974-75, rates were mostly very low from October to early March after which they built up to levels similar to those in the 1973-74 season. The period from mid October to early January 1974-75 was marked by an influx into non-arid areas (including the three areas above) of very large

numbers of locust adults from the arid areas of Queensland (Fig. 1) which were largely parasitoid free resulting in a depression of parasitism level in the invasion areas (Fig. 5). Collections in early to mid November 1974 at 16 locations in arid areas west of Emerald produced one parasitised locust out of 270 individuals. A similar result was obtained in early November 1973 when one parasitoid was found in 158 locusts collected from eight western locations. By the end of May 1975, parasitism was as high as 35% (Fig. 5) and there had been a large decrease in the size of populations. For the Ayr district, parasitism rates of 10% were recorded on 24 January and up to 50% by 17 February by which time a general decline in populations was becoming evident. The mortality of host populations as a result of parasitism could exceed the parasitism levels recorded by 2-3 fold given the high level of turnover of parasites during the January to February sampling interval (Kaldor and Baker 1996). Throughout 1975-76, populations of *A. guttulosa* were low with no reports of swarms in Queensland.

Although parasitism levels were higher overall in coastal followed by subcoastal and then arid zones, there was a highly significant ( $P < 0.001$ ) time by zone interaction for both internal parasitoids and ectoparasites (Fig. 6) due to differences in parasitism levels for the zones not being consistent across time (e.g. in Fig. 6 the three zones are significantly ( $P < 0.05$ ) different from each other for the second half of 1973, while for the second half of 1975 they are not different). There was a significant ( $P < 0.05$ ) sex by time interaction for ectoparasites because in the last half of 1972 and 1974 females had higher parasitism levels than males. The reason for this could not be explained.

The egg parasitoid *Scelio bipartitus* Kieffer was

**Table 1.** Parasites, parasitoids and predators of *A. guttulosa* recorded between October 1971 and November 1996 in Queensland.

Agent	No. of collections out of 597 parasitised	Notes
<b>Ectoparasite</b>		
<i>Podapolipoides barmounti</i> Husband (Podapolipidae)	135	Maximum 50% parasitised at any 1 site
<b>Parasitoids</b>		
<i>Gordius</i> sp. (Gordiidae)	1	From coastal swampy habitat; Nematomorpha (gordioid worms)
<i>Blaesoxipha</i> spp. (Sarcophagidae)	40	Mixed <i>B. rufipes</i> and <i>B. valangae</i> and possibly <i>B. hardyi</i> Lopes
<i>B. rufipes</i> Macquart	13	
<i>B. valangae</i> Aldrich	6	
<i>Phorocerosoma postulans</i> (Walker) (Tachinidae)	30	
Mixed dipterous larvae	46	Not identified
<i>Scelio bipartitus</i> Kieffer (Scelionidae)	1	One egg pod parasitised out of the few egg pods found
<b>Predators</b>		
<i>Macroderma gigas</i> Dobson (Megadermidae)		Ghost bat; <i>A. guttulosa</i> may make up a large percentage of diet between September and December (J. Toop pers. comm.)
<i>Cracticus nigrogularis</i> (Gould) (Cracticidae)		Butcher bird; Aves
<i>Gymnorhina tibicen</i> (Latham) (Cracticidae)		Australian magpie; Aves
<i>Threskiornis spinicollis</i> (Jameson) (Platalidae)		Straw-necked ibis; Aves
<i>Milus migrans</i> (Boddaret) (Accipitridae)		Black kite; Aves

recorded from Emerald from one of the less than 30 egg pods found. This is a new host record for *S. bipartitus*, a widely distributed species in eastern Australia (Baker *et al.* 1996). It is unlikely to have a significant effect on populations because of the solitary laying habits of *A. guttulosa*.

One mammal and four bird predators were recorded (Table 1), none of which are likely to significantly affect populations during outbreaks due to their inherent inability to increase their population size at a rate commensurate with their prey.

**Discussion**

While fitting the definition of a locust (a grasshopper that swarms), *A. guttulosa* lacks a number of characteristics normally associated with locust populations (Table 2). These differences need to be considered in designing control programs.

This study and the studies of Elder (1989, 1995) indicate that slow moving swarms which occur from March to November should be controlled if they occur in or near cropping areas (within 10-30 km) depending on topography, time of year,

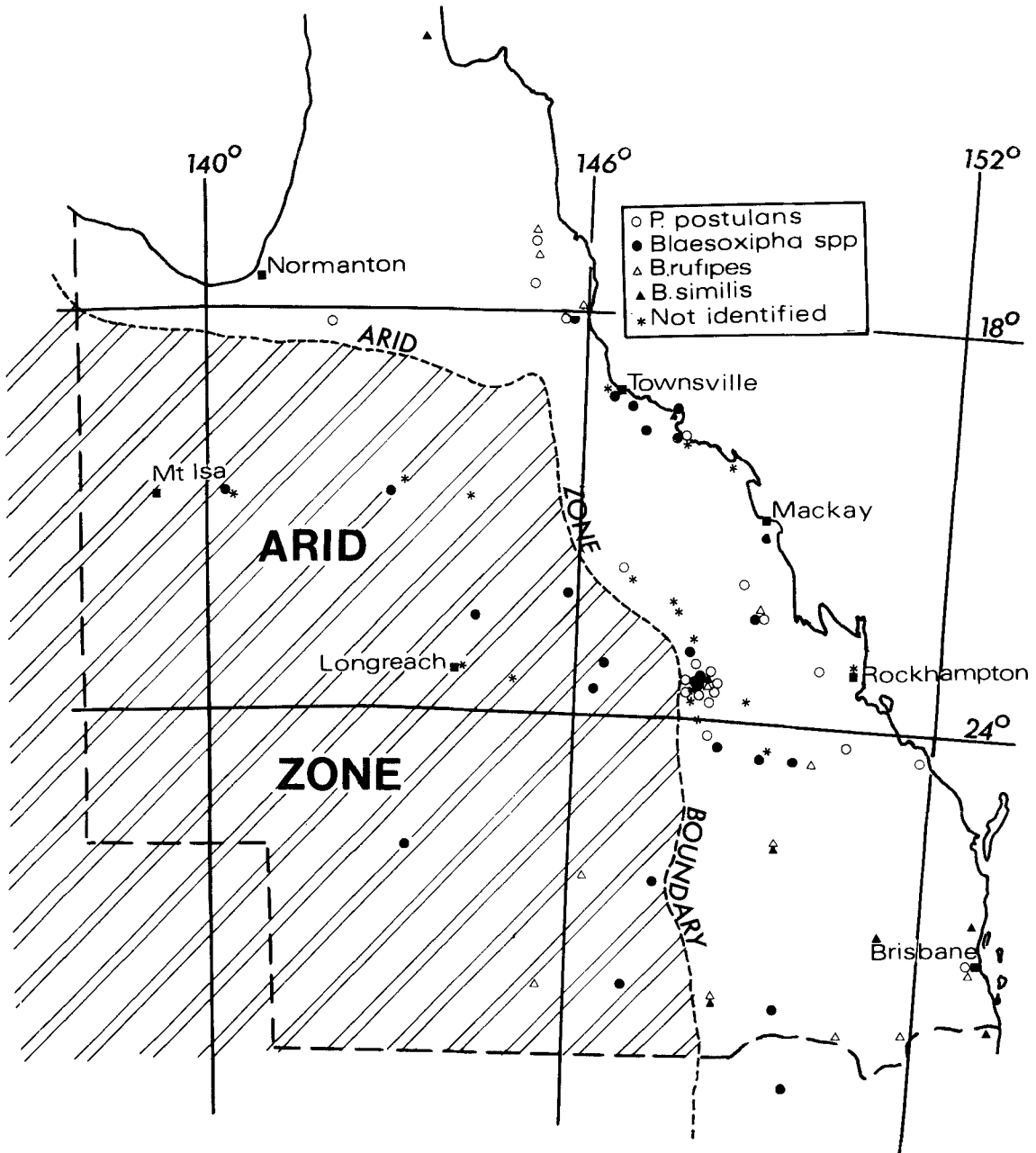


Fig. 4. Geographic distribution of identified dipterous internal parasites of *A. guttulosa*.

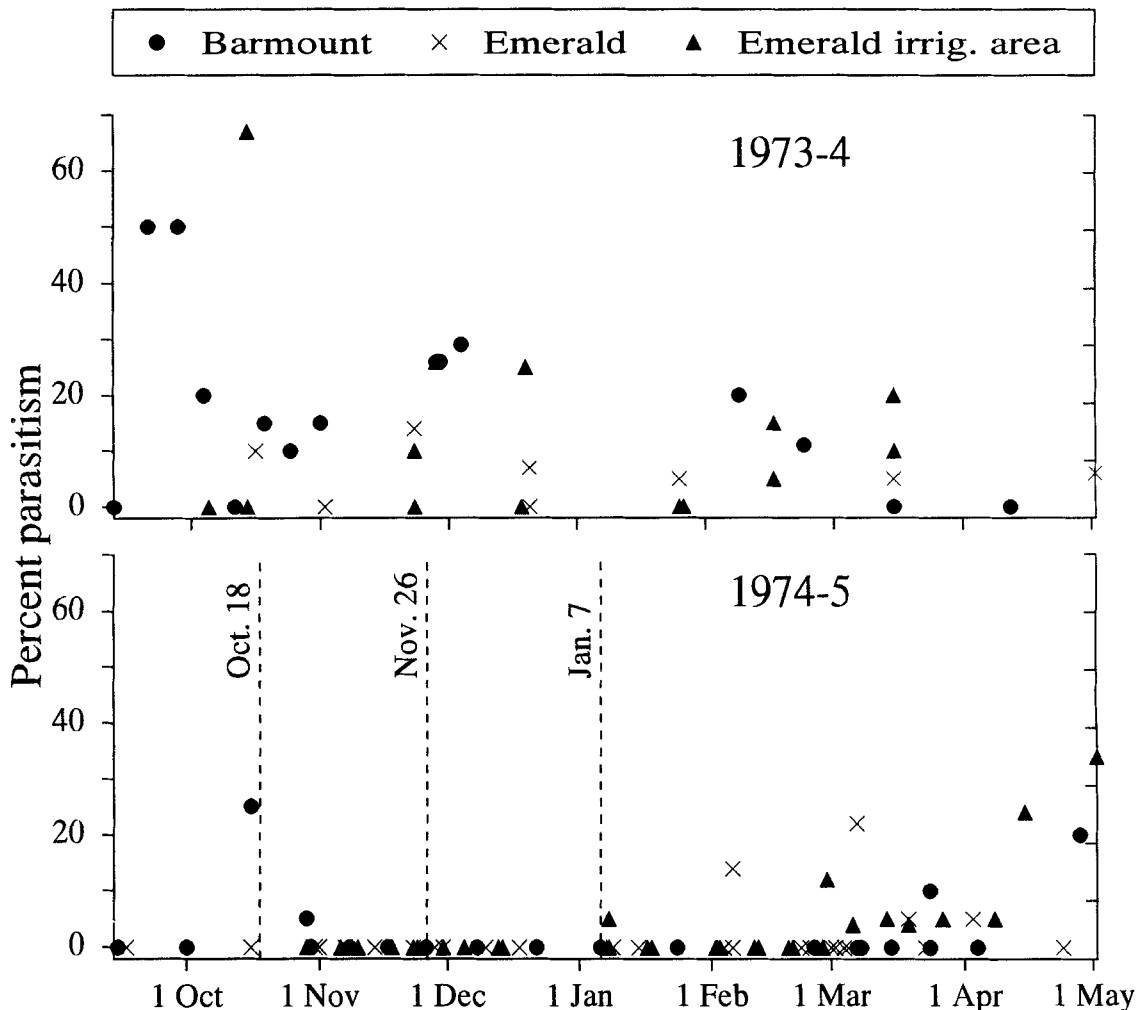
direction of movement, and organisational and political considerations. Control should be undertaken before the swarms disperse with the onset of sexual maturation from October to December. Destruction of swarms distant from crop areas is unwarranted, as there is a low probability that they will eventually reach crops. If they do, it is usually by means of long distance flights by solitary individuals. *A. guttulosa* is univoltine and these solitary individuals do not

reform swarms; any subsequent swarms in the invasion areas are the result of successful breeding over the summer-autumn period and swarm formation by individuals of the next generation during autumn-winter. This is quite unlike other locusts such as *L. migratoria* and *C. terminifera* which are multivoltine and can breed and form swarms in the same season (Baker and Casimir 1985). Baker and Casimir (1985) suggested a similar strategy for control of *A. guttulosa* swarms

**Table 2.** Comparison of characteristics commonly associated with locusts to those of *A. guttulosa*.

Characteristics commonly associated with locusts (Uvarov 1966)	Characteristics of <i>A. guttulosa</i>
Phase polymorphic	Phase polymorphism not observed
E/F* and F/C** ratios vary with phase	E/F and F/C ratios constant (Elder 1996)
Colour of adults and nymphs varies with phase	Colour of adults and nymphs independent of behaviour (Elder 1989)
Sexually mature adults may swarm	Sexually mature adults disperse
Nymphs may form dense bands	Nymphs never in dense bands
Oviposition by swarms in egg-beds	Individual oviposition sites widely separated

\*E/F, elytron length/femur length ratio; \*\*F/C, femur length/head capsule width ratio.



**Fig. 5.** Internal parasitism (%) of *A. guttulosa* for three locations for 1973-74 (above) and 1974-75 (below). The dotted vertical lines indicate times when large scale locust movements into the area were recorded.



(without distinguishing between cropping and non cropping areas).

Outside the March to November period, any *A. guttulosa* control should be regarded as crop protection as practised for any other mobile, solitary, agricultural pest. During outbreak control campaigns, Baker and Casimir (1985) suggested that control of nymphs is impracticable. However, control of nymphs of *A. guttulosa* may be necessary, when seedling crops are invaded from surrounding grassland or grassed contour banks (Elder *et al.* 1979). Similarly, solitary adults can cause problems during this period. Under these circumstances, farmers are best placed to undertake control.

Records of swarming populations suggest that *A. guttulosa* outbreaks in coastal and subcoastal

zones during the summers of 1973-74 and 1974-75 (Elder *et al.* 1979) originated from high density populations, first recorded the previous winter as swarms in the central western areas of Queensland within the arid zone (Fig. 2). In 1994-95, at least, these locusts migrated as individuals, in association with the passage of a series of cold fronts, to coastal and subcoastal districts (the non-arid zone) during October-January and oviposited there. Their progeny were responsible for the majority of resultant crop losses. These coastal/subcoastal populations did not survive at densities sufficiently high to form overwintering swarms. Some of the reasons for failure to survive in the non-arid zone were internal parasitism (Fig. 6), suicidal migration of adults out to sea, and predation. The effect of ectoparasites is unknown.

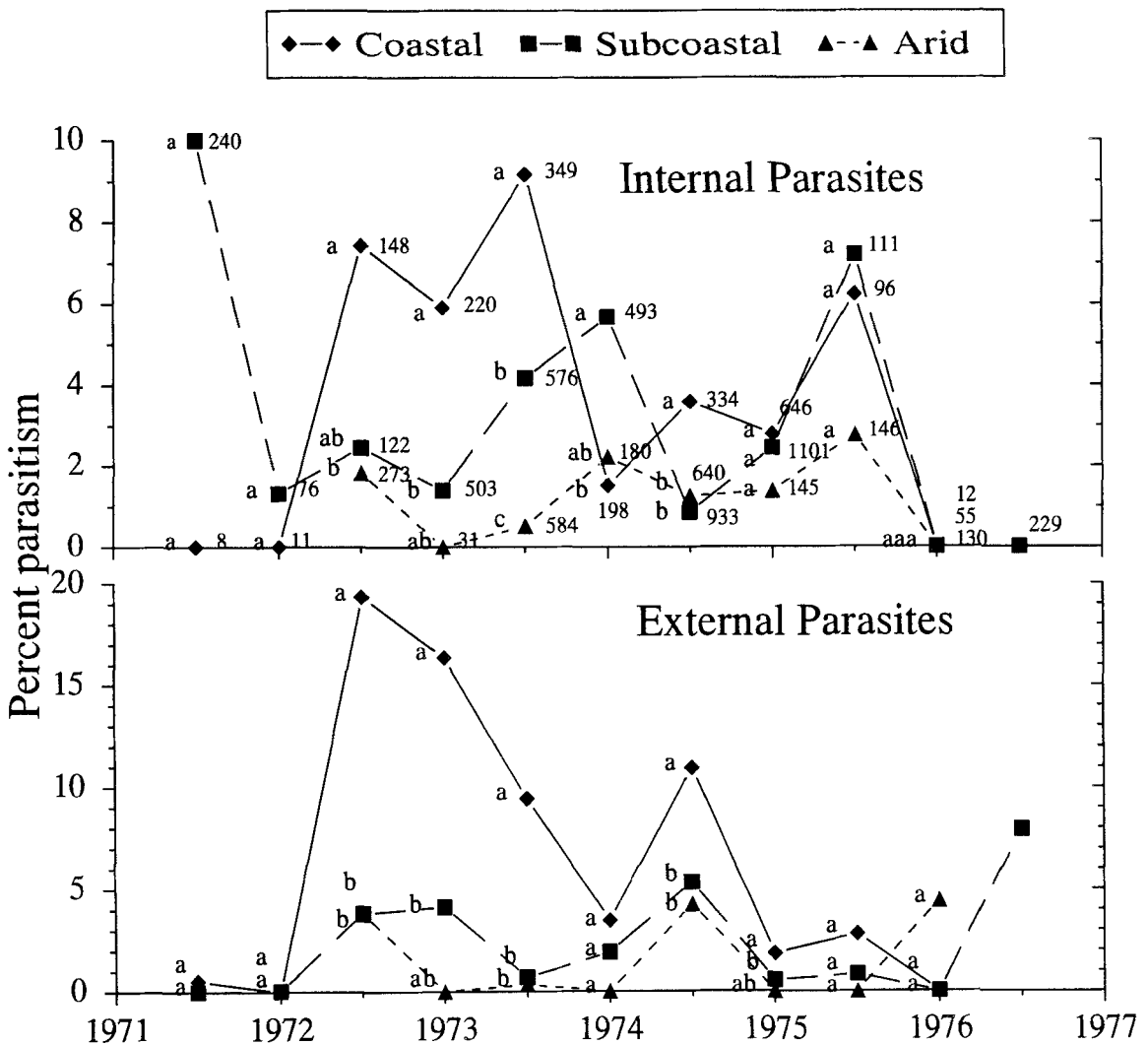


Fig. 6. Internal parasitism (%) and external parasitism (%) of *A. guttulosa* in three zones over time. Note that parasitism levels tend to be higher in the coastal zone followed by the subcoastal and then the arid zone. The points indicate the estimated (by logistic regression analysis) per cent parasitism based on the number of individuals (indicated in internal parasites) for that zone over the relevant 6-month period. Points with the same letter within each 6-month period were not significantly different ( $P < 0.05$ ). The tick marks along the x axis are for each 6-month period with the first data points for 1 July to 31 December 1972.

Farrow (1979) noted the importance of cold fronts and associated disturbed weather in the movement and survival of *C. terminifera*. Downwind displacement in disturbed weather results in the concentration of locusts in an area where rain is likely to have fallen. This is extremely important behaviour for survival in an arid region. The daytime movements of *A. guttulosa* swarms, as distinct from night flights of dispersed locusts recorded by Casimir and Edge (1979), were from north to south and were associated with a deep low pressure system south of Australia and a persistent northerly airflow over eastern Australia. These daytime movements were not associated with a cold front. Casimir (1987) recorded similar north to south movements of swarms. Movement of swarms was generally slow and the distances involved less than 20 km/d. Casimir showed that large scale dispersal flights occurred mainly at night following the onset of sexual maturation in late October continuing into November and December 1974. One of these movements of dispersed individuals was large, with locusts appearing up 350 km to the east of Casimir's (1987) study location and this was also associated with a cold front (Australian Bureau of Meteorology synoptic chart 3 pm 13 November 1974). This movement occurred at the same time as the west to east movements, some 1,000 km to the north, reported here.

The tachinid parasite *P. postulans* was collected only from *A. guttulosa* in non-arid zones, while *Blaesoxipha* spp. parasitised *A. guttulosa* in both arid and non-arid zones (Fig. 4). A reduction in internal parasitism rates in non-arid zones was coincident with an influx of adults from the arid zone in the period October 1974 to January 1975, implying the immigrant individuals were relatively free of parasitoids. By the first 6 months of 1975, locusts collected from the three zones had similar internal parasitism levels (Fig. 6).

With the exception of 1968, the years 1965 to late 1970 were drought years (Robinson 1976). Swarms of *A. guttulosa* which occurred in the dry winter of 1971 originated in a non-arid zone (area centred on Clermont) where, on the above observations, high parasitism levels should have reduced locust numbers to below swarming levels. The development of swarms in the non-arid zone probably occurred because of a temporary shift towards the coast of the arid zone boundary leading to a decline in the size of parasitoid populations. I observed a similar development of swarms in the Clermont district following a number of years of drought in 1995.

The parasitoids recorded in this study are generalists, *B. rufipes* has a wide distribution in Afrotropical, Palaearctic, Oriental and Australasian/Oceanian regions and a wide host range in grasshoppers and locusts including all the economically important acridid species in

Australia (Allsopp 1978; B. K. Cantrell pers. comm.; Baker 1995). It was much more frequently encountered than *B. valangae*. *B. hardyi* Lopes has also been recorded from *A. guttulosa* in the Kimberleys (Western Australia) and Barkly Tablelands (Northern Territory) (Cantrell 1978, 1980; Pape 1994). *P. postulans* occurs in Queensland, the Northern Territory, Papua New Guinea, the Solomon Islands and is widespread in the Oriental and Afrotropical regions (B. K. Cantrell pers. comm.).

Importantly, *B. rufipes* has a very rapid larval development time (3.75 d at 35°C and 7.9 d at 20°C; Baker 1995). This rapid turnover of parasitic stages and unsynchronised development allow this parasitoid to rapidly reduce host populations when environmental factors are suitable (Kaldor and Baker 1996). This is especially true of *A. guttulosa*, given an annual life-cycle in which only sexually immature adults are present from April to October providing 6 months prior to sexual maturation in which a parasitoid induced decline may impact on the population dynamics of the host.

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