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Cover: The very large and strong-flying robberfly *Blepharotes coriarius* Wiedemann is widespread across eastern Australia. *Blepharotes* contains six described and a similar number of undescribed species, restricted to Australia and New Guinea. They are easily recognised by their flat, usually yellow or orange abdomens, that bear dense, lateral tufts of hairs. From an original drawing by Geoff Thompson.

A NOTE ON THE LARVAL FOOD PLANTS OF *GRAPHIUM WEISKEI* (RIBBE) (LEPIDOPTERA: PAPILIONIDAE) IN PAPUA NEW GUINEA

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Abstract

Two species of plants, *Dryododaphne crassa* Schodde (Monimiaceae) and *Cryptocarya* sp. (Lauraceae), are recorded as potential larval food plants for *Graphium weiskei* (Ribbe), based on ovipositing females in the Kegsugl area, Simbu Province, Papua New Guinea, in upper montane moss forest during June 1999.

Introduction

Graphium weiskei (Ribbe, 1900) (Figs 1-2) is distributed throughout mainland New Guinea, occurring as far west as the Arfak Mountains in Irian Jaya (Indonesia), to Goodenough I. in the D'Entrecasteaux Islands of Papua New Guinea (Parsons 1998). It most commonly occurs in mid to upper montane primary forest at altitudes between 1,200 and 2,000 m, although it has been recorded at altitudes well below and above this range. The species is well known for its unique and extraordinary colours of pink, mauve and turquoise. For this reason, high quality specimens are in strong demand for the overseas butterfly trade and currently sell at 1.5 Kina per specimen (Insect Farming and Trading Agency [IFTA]).

Surprisingly little is known of the larval food plants and the early stages have not been described formally. Indeed, all specimens exported by IFTA are obtained as wild-caught adults (through a network of local collectors) and not through captive breeding and harvesting of the immature stages. Haugum and Samson (1980) noted that a female had been observed to oviposit on a 'species of *Sassafras* (Lauraceae)' at Wau and that oviposition also was observed on a small, unidentified tree at Erume. Parsons (1998) considered that the 'small, unidentified tree' represented a species of *Cinnamomum* (Lauraceae) but did not provide evidence for this conclusion. The genus '*Sassafras*' does not exist; however, the name '*sassafras*' is used frequently as the common name for *Doryphora sassafras* Endl., a species which belongs in the Monimiaceae, not Lauraceae. Hence, there is considerable doubt over the identity of the larval food plants in Papua New Guinea.

The following observations, although based on oviposition records only, are documented here because of the general paucity of reliable information. The species listed are considered to represent likely food plants and, hopefully, will stimulate further searching and rearing of the immature stages (and eventual documentation of the life history), leading to the sustainable farming of this exquisite butterfly.

Observations

During June 1999, while stationed for eight days collecting in the Kegsugl area of Simbu Province, Papua New Guinea, two separate observations were made of ovipositing females of *G. weiskei weiskei* in upper montane moss forest.

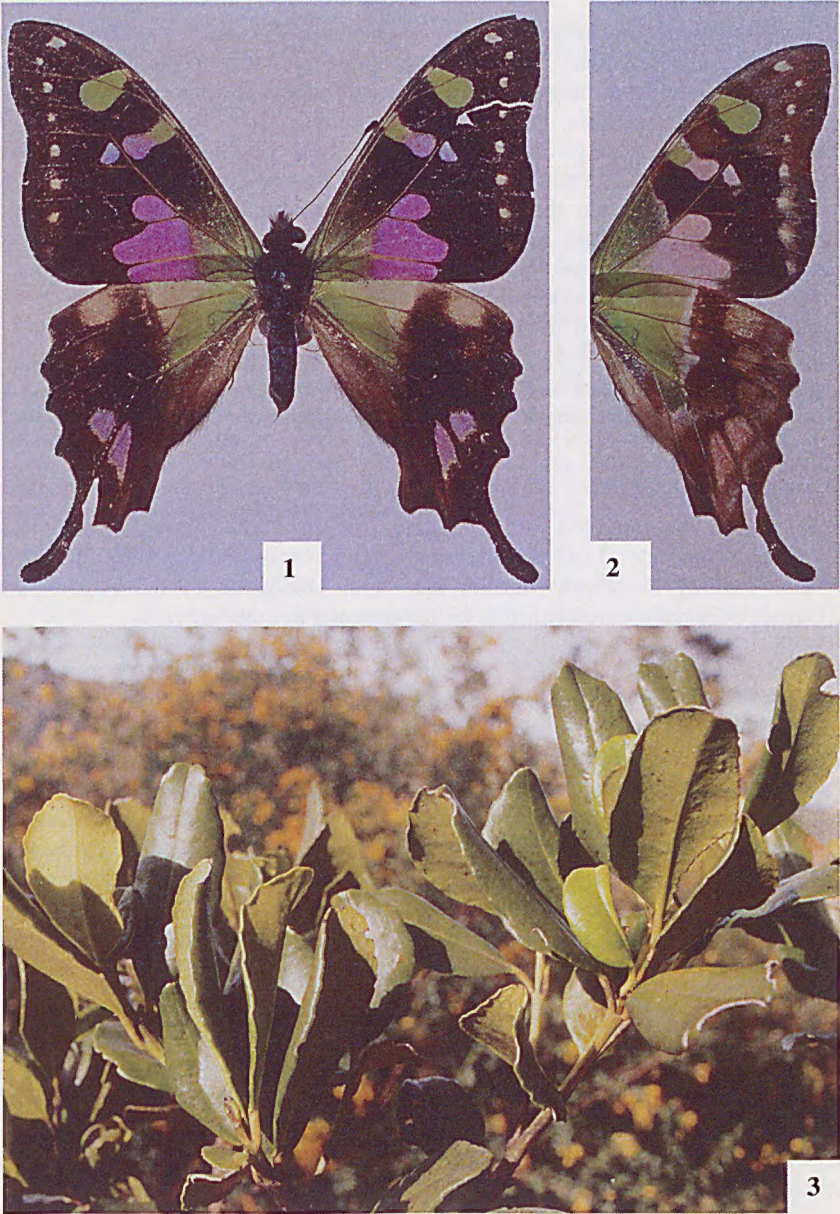
The first observation was made at 1350 h on 4 June, near the Lake Pindi Yaundo Lodge, about 3 km north of Kegsugl, at an altitude of approximately 2,800 m. A female was observed at about eye level (using binoculars, 10x25 magnification) to spend several minutes circling around and settling in the canopy of a large (ca 30 m in height) *Dryododaphne crassa* Schodde (Monimiaceae) (Fig. 3), growing on a steep slope above a watercourse. The female was seen to eventually settle on the underside of a branch about 2-3 m from the top of the tree. Once settled she then curled and extended her abdomen in a characteristic ovipositing manner and laid an egg on the bark, before flying off to 'inspect' other areas of the tree. Further observations of oviposition and the egg were not possible due to the density of the vegetation and the height of the tree. However, it is probable that other eggs were being laid, given the intensity with which the female was searching the tree and frequently settling.

The second observation occurred at 1225 h on 7 June, in a gully about 3-4 km south-east of Kegsugl, at an altitude of approximately 2,700 m. A female was observed at close range to spend several minutes intensely searching, whilst in flight, the foliage of a shrub (ca 2 m in height) of *Cryptocarya* sp. (Lauraceae), growing on the edge of a watercourse. During this period, the female frequently settled and laid several eggs on the underside of older leaves in the lower half of the plant. All eggs were deposited singly and were typical of the genus *Graphium* Scopoli, being spherical, smooth and yellowish-green in colour. The female (Figs 1-2) was eventually netted and retained as a voucher specimen.

Voucher specimens of the two plants mentioned above are deposited in the Herbarium of the Papua New Guinea Forest Research Institute, Lae.

Discussion

Graphium weiskei belongs to a distinct taxonomic clade (the *weiskei* group), within the *sarpedon* group of subgenus *Graphium*. The *weiskei* group includes five other closely related species (Okano 1984, Hancock 1985, Parsons 1998, Müller and Tennent 1999). The life histories and larval food plants are unknown for four of these species: *G. batjanensis* Okano from Batjan [= Bacan], northern Maluku (Indonesia), *G. stresemanni* (Rothschild) from Ceram [= Seram], southern Maluku (Indonesia), *G. kosii* Müller & Tennent from New Ireland (Papua New Guinea) and *G. gelon* (Boisduval) from New Caledonia and the Loyalty Is.



Figs 1-3. (1-2) *Graphium weiskei*, adult female, upper and undersides; (3) *Dryododaphne crassa* (Monimiaceae), putative larval food plant of *G. weiskei* at Kegsugl (2,800 m), Simbu Province, Papua New Guinea.

The fifth species in the group is *G. macleayanum* (Leach), whose larvae, in Australia, are recorded feeding on a large number of plants belonging primarily to the Monimiaceae and Lauraceae, with a few species of Rutaceae and Winteraceae also being used (Common and Waterhouse 1981). *Doryphora sassafras* is commonly used in New South Wales and at least three species of *Cryptocarya* are recorded as host plants. It is therefore interesting to note that the putative food plants recorded for *G. weiskei* in eastern mainland Papua New Guinea also belong to the Monimiaceae and Lauraceae, two primitive and closely related families of plants. Since closely related species of butterflies frequently share similar larval food plants at the higher (and sometimes lower) taxonomic levels as a result of coevolution (Ehrlich and Raven 1965), it is considered very likely that *G. weiskei* larvae would feed on plants within the Monimiaceae and Lauraceae and that *Dryododaphne crassa* and *Cryptocarya* sp. almost certainly represent larval food plants.

Acknowledgments

We are greatly indebted to Joe Wiakabu of the Papua New Guinea Forest Research Institute (Lae) for identifying the plants. William Wanuma and Peter Parr of Denglagu Mission and John Dobunaba of the Papua New Guinea Forest Research Institute kindly assisted in other ways.

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EMERGENCE PATTERNS AND DENSITIES OF CICADAS (HEMIPTERA: CICADIDAE) NEAR CALOUNDRA, SOUTH-EAST QUEENSLAND

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Abstract

A census of cicada exuviae, collected regularly over 5 months, is reported from a 5.0 ha site of coastal parkland with fringing mangroves, at Golden Beach, 3-4 km south of Caloundra, S.E. Queensland. Two emergence patterns occurred, both extending over about 4 months. One type characterized the higher density species *Psaltoda plaga* (Walker), *P. claripennis* Ashton, *P. harrisii* (Leach) and *Arunta perulata* (Guérin-Méneville), in which "explosive" emergence reached a peak in early-mid December, then slowly decreased over 75-80 days. Male/female ratios were initially high, but progressively decreased to become female dominated. The second pattern, shown by the low density species *Cicadetta hackeri* (Distant) and *Abricta curvicosta* (Germar), showed "diffuse" emergence with no systematic change of sex ratios. Exuvial densities for the six species were, respectively, 3,928, 3,582, 424, 292, 93 and 50 per ha, with a total density of 8,369 per ha (49 per tree), consistent with overseas data. Emergence of the six cicada species was synchronous, but their songs are species specific.

Introduction

Cicadas are a characteristic, conspicuous and often noisy component of the south-east Queensland (SEQ) summer insect fauna. Along coastal SEQ, cicada numbers are usually high and extend into adjacent mangrove zones. Common species include *Psaltoda plaga* (Walker), *Psaltoda claripennis* Ashton, *Psaltoda harrisii* (Leach), *Arunta perulata* (Guérin-Méneville), *Arunta interclusa* (Walker), *Pauropsalta rubea* (Goding & Froggatt), *Pauropsalta aktites* Ewart, *Cicadetta hackeri* (Distant), *Cicadetta oldfieldi* (Distant), *Cicadetta stradbrokeensis* (Distant), *Abricta curvicosta* (Germar) and *Birrima varians* (Germar). Surprisingly, only rather qualitative and anecdotal published data exist as to relative abundance and emergence patterns of Australian cicada species (e.g. summaries in Moulds 1990), although Coombs (1996) has reported on a four year survey of seasonal cicada occurrences for the New England Tablelands.

Cicada numbers are difficult to estimate quantitatively. The adults are cryptic, wary, mobile and often occur high in tree foliage, while the nymphal stage is passed underground within 'root-crown' systems. Previously published estimates of densities, from USA, Italy, South Africa and New Zealand, are based on counts of emergence holes, counts of nymphal skins (exuviae) and emergence traps (Dybas and Davis 1962, White *et al.* 1979, Karban 1984, Dean and Milton 1991, Milton and Dean 1992, White and Sedcole 1993, Williams *et al.* 1993, Anderson 1994), together with sound level measurements (Patterson *et al.* 1997).

The aims of the present survey were: (i) Estimate population densities of six cicada species within a selected coastal section of SEQ, by means of exuvial counts, during a complete emergence season; (ii) Document emergence

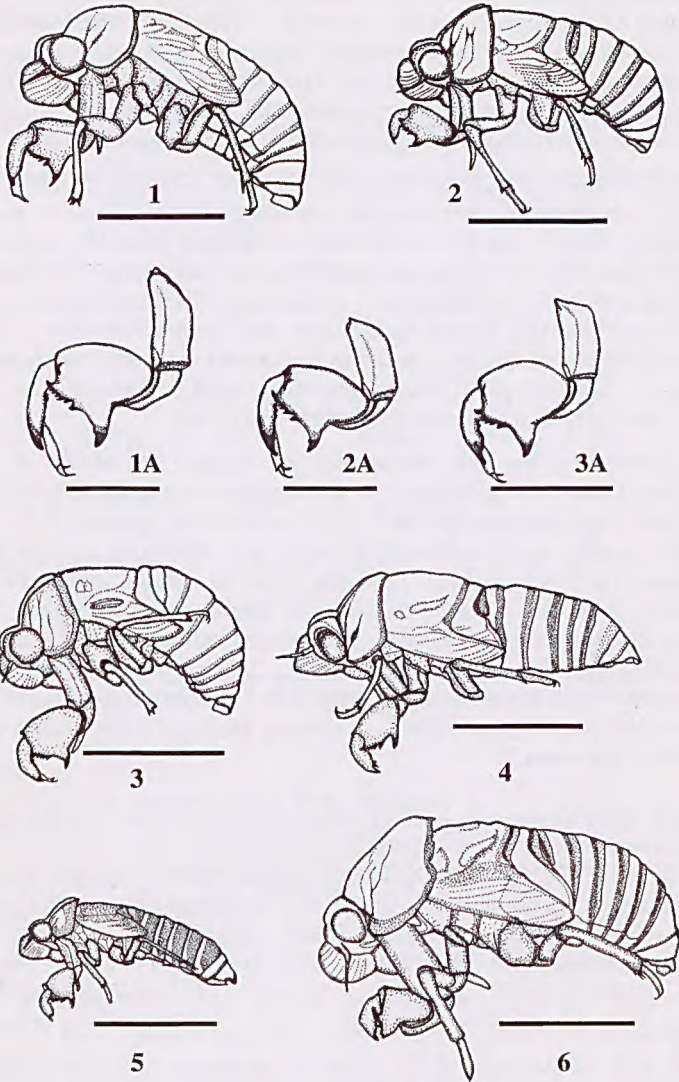
patterns and synchrony, including sex ratios; (iii) Estimate longevity of adult populations; (iv) Compare differences of song characteristics, considered critical to mate selection, between the temporally and spatially overlapping species.

Study area and methods

The census area comprised a narrow strip of coastal parkland, adjacent to high water mark, at Golden Beach, between 3.2 to 4.2 km south of Caloundra, SEQ. The area extended south from the 'Military Jetty' (26°50.06'S, 153°07.12'E) adjacent to the Bribie Channel, to Bells Creek, then to the western end of a local park (Jensen Park) adjacent to Bells Creek (26°50.41'S, 153°06.62'E). The site area can be referenced on Queensland Topographic Map Series R834, sheet 9544-III-NW, Caloundra (special), 1:25,000. The traverse length was 1.38 km, area 5.0 ha (excluding mangroves). The site consists of Holocene beach sands overlying estuarine muds and silts.

Dominant trees on the site are Coast She-Oak (*Casuarina equisetifolia*), Swamp Oak (*Casuarina glauca*), Blue Gum (*Eucalyptus tereticornis*), Common Paperbark (*Melaleuca quinquenervia*), Cotton Tree (*Hibiscus tilaceous*) and exotic Norfolk Pine (*Araucaria heterophylla*). Less common trees include Tuckeroo (*Cupaniopsis anacardioides*), Grey Ironbark (*Eucalyptus drepanophylla*), Swamp Oak (*Banksia integrifolia*), Hickory Wattle (*Acacia aulacocarpa*), Cabbage Tree Palm (*Livistonia australis*), Screw Pine (*Pandanus tectorius*), Red Ash (*Alphitonia excelsa*) and Bribie Island Pine (*Callitris columellaris*). Mangroves are dominated by *Avicennia marina* with small numbers of *Bruguiera gymnorhiza*.

Previous observations indicated that the site has an abundant cicada fauna between December-February. Exuviae (Figs 1-6) of the following six species were found in sufficient numbers for census purposes, listed in decreasing order of abundance based on qualitative estimates of intensities of singing: *P. plaga* (dominant), *P. claripennis*, *A. perulata*, *P. harrisii*, *C. hackeri* and *A. curvicosta*. Systematic searches were normally undertaken daily (less often each second day), from 10 October 1997 to 27 March 1998. The last day that newly emerged nymphs were located was 11 March. Results are presented (Figs 7-12) as successive two-day averages. Where a day was missed, the exuviae collected on the following day were averaged over the appropriate two-day period. The only major sampling gap occurred between 29 January and 16 February; exuvial numbers collected on 17 February were linearly extrapolated through the sampling gap, assuming a male/female ratio of unity (close to observed ratios either side of gap). Exactly the same area and trees were searched each day and all exuviae found were collected, categorised and counted. Exuviae were conspicuous, normally occurring on tree trunks to heights of about 3.5 m (rarely higher), with small numbers occurring on long grass.



Figs 1-6. Exuviae of the six species of cicada surveyed from southern Golden Beach, Caloundra. (1) *P. plaga*; (2) *P. claripennis*; (3) *P. harrisii*; (4) *A. curvicosta*; (5) *C. hackeri*; (6) *A. perulata*. 1-4 and 6 are males; 5 female. Scale lines = 1 cm. 1A, 2A, 3A, are fore leg femora of the exuviae of, respectively, *P. plaga*, *P. claripennis* and *P. harrisii*. Scale bars = 5 mm.

Eclosion occurred mostly at night but, at the height of the season, 'stragglers' emerged during morning, even to midday. Changing cicada densities were therefore equated with the number of exuviae progressively collected during the entire emergence period. 41,842 exuviae were recovered in total. Of the 852 trees occurring within the census site, 90% were 'productive', with exuviae found on them at some stage during the emergence season.

Specific identification of exuviae was based on a sample subset from which adults were observed emerging. The separation of exuviae of *A. perulata*, *A. curvicosta* and *C. hackeri*, from each other and from the three *Psaltoda* species, was achieved using size, markings and abdominal morphology (Figs 1-6). The overall morphologies of the three *Psaltoda* species, however, extensively overlap, including the fore leg femora. In view of the large numbers involved, identification was based on total body length, as listed in Table 1. The following size ranges were used: *P. plaga* ≥ 22.5 mm; *P. claripennis* >19.9 , <22.5 mm; *P. harrisii* ≤ 19.9 mm.

Notwithstanding the size discontinuities within the subset of reference samples, it was evident during counting that size continuities do exist between the three *Psaltoda* species, with females showing an overall bias towards slightly smaller sizes within each range. It is therefore possible that some 'leakage' of female exuviae into the adjacent smaller range division has occurred. A further potential difficulty is the curvature developed in exuviae during drying; when excessively pronounced, allowance for curvature was made. The reference specimens, however, also exhibited varying degrees of curvature (Figs 1-6), ensuring that the effect is minimised. All exuviae were sexed according to shape of the developing genitalia at the ventral tips of the nymphal abdomens.

Table 1. Body length statistics of identified *Psaltoda* exuviae. (Measurements are in mm).

	Males			Females			Total			
	Mean	σ	n	Mean	σ	n	Mean	σ	Range	n
<i>P. plaga</i>	23.92	1.26	12	24.13	1.43	4	23.97	1.26	22.71- 25.23	16
<i>P. claripennis</i>	21.37	0.94	10	20.66	1.19	11	21.00	1.11	19.89- 22.11	21
<i>P. harrisii</i> *	18.75	1.28	10	18.42	1.00	5	18.64	1.17	17.47- 19.81	15

* Supplemented with material collected from outside study area.

Results and discussion

The results of the census are summarised in Table 2.

individually and some also in small groups (<6 birds), searching for emerging nymphs and especially adults. Moreover, except for the Tawny Frogmouth, bird predation of emerging nymphs will be minimal at night when nymphal emergence is at its peak. Sporadic diurnal predation of emerging nymphs by the Bearded Dragon (*Amphibolurus barbatus*) was noted. Nymphs that failed to eclose were very rarely observed and evidently did not represent a significant mortality factor (cf. White *et al.* 1979).

Although no quantitative estimates of nymphal losses to predation could be made, qualitative observations suggest them to be <10%. Total exuvial numbers collected in this census will, however, provide minimum estimates of the emerging nymphal population and should provide an estimate of changing adult population patterns, over successive two-day intervals, during the summer season.

Exuvial distribution and adult dispersion

Exuviae were not evenly distributed through the census site, although no obvious differences of vegetation or soils were observed.

Psaltoda and *Abricta* nymphs emerged on all tree species except the exotic Norfolk Pines and only very rarely on the Common Paperbark. *A. perulata* extensively utilised casuarinas and sporadically the Norfolk Pines. *C. hackeri* emerged exclusively on the Common Paperbark. No eclosions were observed within tidally inundated mangroves, an observation that applies widely along coastal SEQ and includes nymphs of the mangrove cicada (*A. interclusa*). Only where local sand accumulations (above tidal inundation levels) had occurred within mangroves were occasional nymphal emergences found. The sites of emergence are significant as *P. plaga*, after emerging, aggregated within and adjacent to mangroves, as well as other vegetation adjacent to high water mark. *P. harrisii* formed smaller, localised aggregations high within clumps of casuarinas above the tidal zone, while *P. claripennis* dispersed more widely including into surrounding suburban gardens. *A. perulata* remained in trees close to the tidal zone, *C. hackeri* remained in the paperbarks, while *A. curvicosta* dispersed widely in low abundances in most tree types. The above observations are consistent with the habitat preferences of *P. plaga*, *P. harrisii*, *A. perulata*, and *A. curvicosta* which were determined quantitatively by MacNally and Doolan (1986) within a New South Wales coastal zone.

Emergence patterns

Two types of emergence patterns are illustrated by the data (Figs 7-12):

(i) The *Psaltoda* species, representing higher abundance, medium to larger-sized cicadas, had almost 'explosive' emergence patterns. The number of emerging nymphs rapidly increased to a peak over 10-15 days (late November to early December), followed by a relatively slow but uneven decline lasting about 75-80 days, terminating in early March. The total

eclosion period thus lasted about 4 months, with synchronous emergence occurring between the three species, even at peak emergence. The emergence patterns did not define smooth curves, with smaller secondary peaks evident in later December and January. During peak emergence, large numbers (<100-300) eclosed from localised trees or tree clumps, continuing for 3-4 nights, after which very small numbers emerged (<3) for a further 3-5 nights. Major emergence centres, in the meantime, had shifted to new sites (i.e. smaller scale emergence patterns were not strictly synchronous). Following the major emergence phase, the pattern was of small emergence numbers spread widely throughout the census area, with localised sporadic bursts of increased eclosion from both previously productive and unproductive trees.

Male/female sex ratios exhibited initial male dominance, the ratios then decreasing smoothly towards female dominated eclosion immediately following peak emergence. Ratios then tended to approach unity.

The total sex ratios for *P. plaga* and *P. claripennis* were close to unity. The sex ratio was, however, female biased for the less abundant *P. harrisii* (Table 2). The reason for this is unclear, but may be one case where significant early selective predation of male dominant nymphs did occur.

Arunta perulata exhibited a similar, but more symmetrical emergence pattern than the *Psaltoda* species, with later peak emergence and lower densities. The sex ratio changes were similar but less pronounced.

(ii) The second pattern, that of 'diffuse' emergence, was exemplified by *C. hackeri*. No clear emergence peak occurred and no systematic change in sex ratio was observed. This is an example of a widely distributed, highly cryptic cicada which exists in relatively low densities, especially along coastal SEQ in wallum and swamp environments where paperbarks are common. *A. curvicosta* also falls into this category and, although exhibiting a poorly defined peak emergence in December, displayed no systematic sex ratio changes. It is again a low density species in the census area.

Sex ratio changes during adult emergence, initially male dominated, were reported in some Odonata (Corbet 1999), moths (Young 1997) and the American periodical cicada (Williams *et al.* 1993). In the present case, although males did not all emerge before females, a systematic ratio change was apparent during the emergence season for the more abundant species.

The periods during which active singing were noted are shown in Figs 7-10 and 12. For *P. harrisii* and *P. claripennis*, the first songs were heard only 10-15 days after the dates of initial eclosion, whereas the cessation of singing approximately corresponded to the dates of final nymphal emergence. For *P. plaga*, initial singing correlated with initial eclosions but singing continued sporadically for 26 days after eclosion had ceased, suggesting that a small number of individuals had survived for over three weeks.

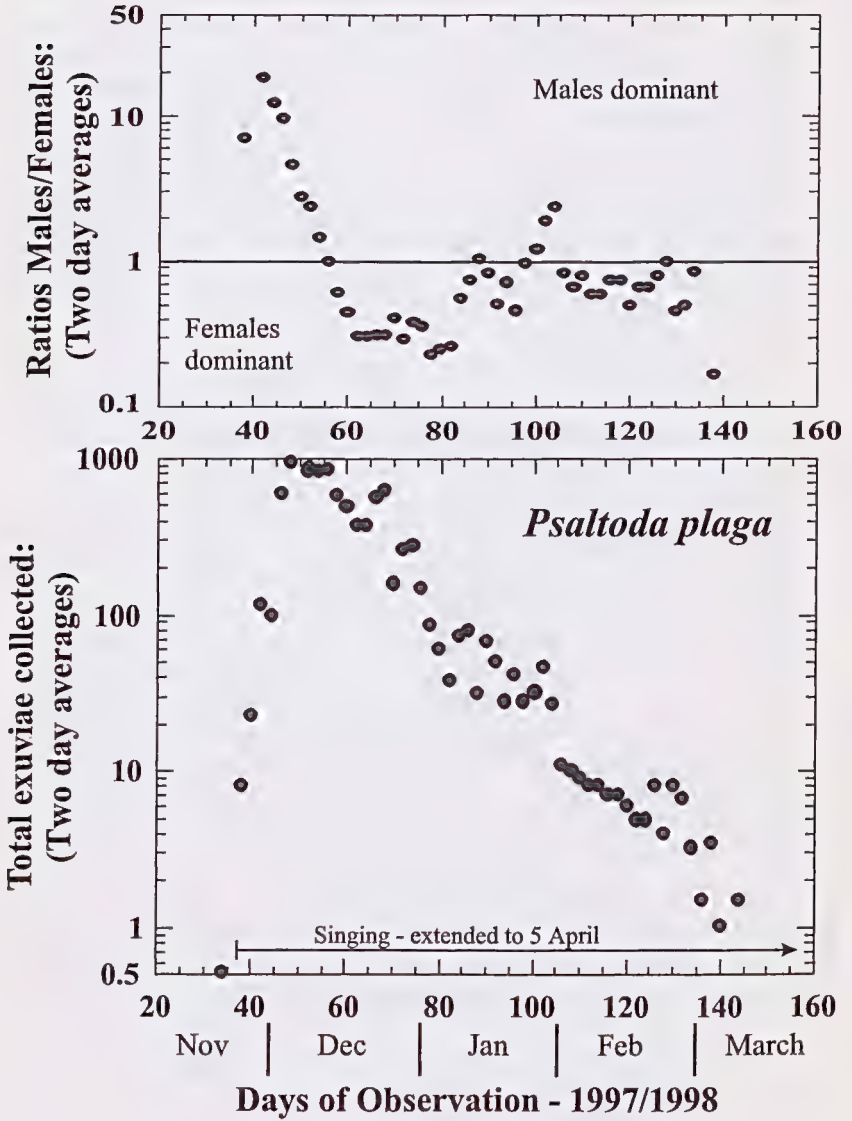


Fig. 7. Emergence pattern and accompanying sex ratio changes, in *P. plaga* at southern Golden Beach, Caloundra during 1997/1998. Period during which singing was heard is shown by bar.

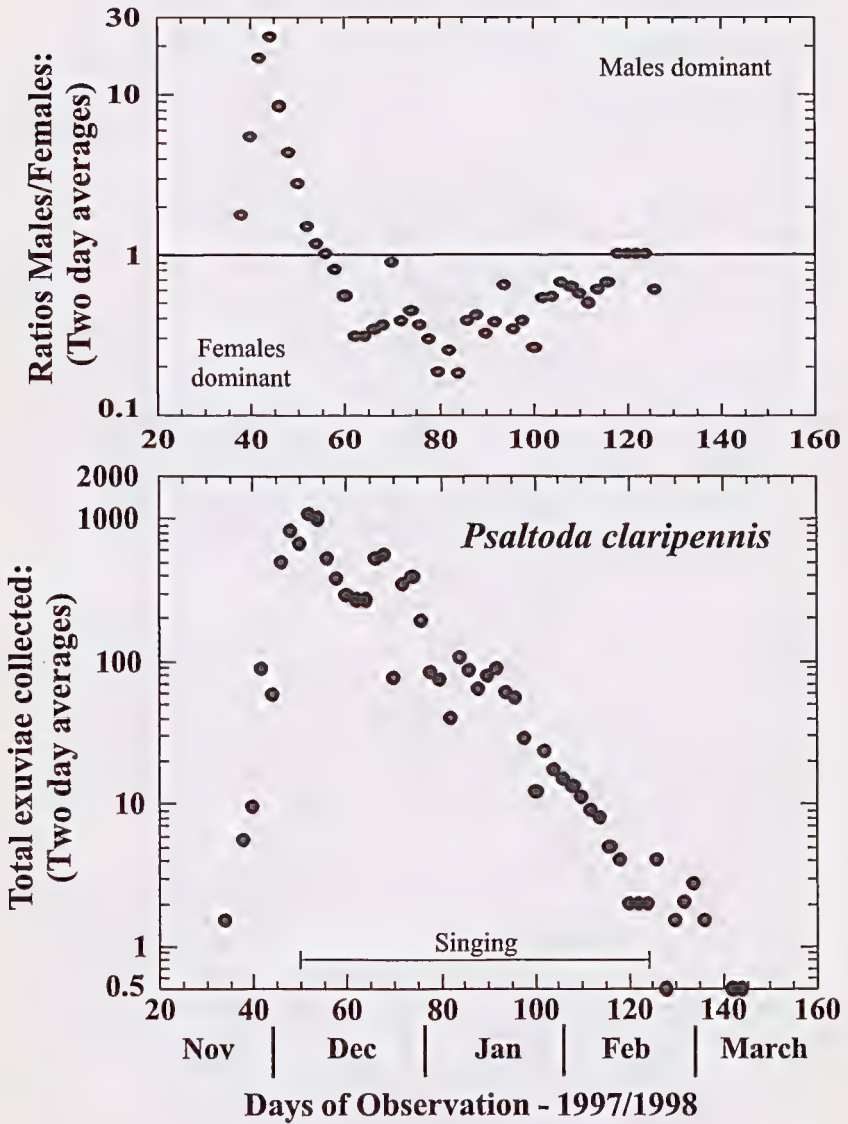


Fig. 8. Emergence pattern and accompanying sex ratio changes in *P. claripennis* at southern Golden Beach, Caloundra during 1997/1998. Period of singing is shown by bar.

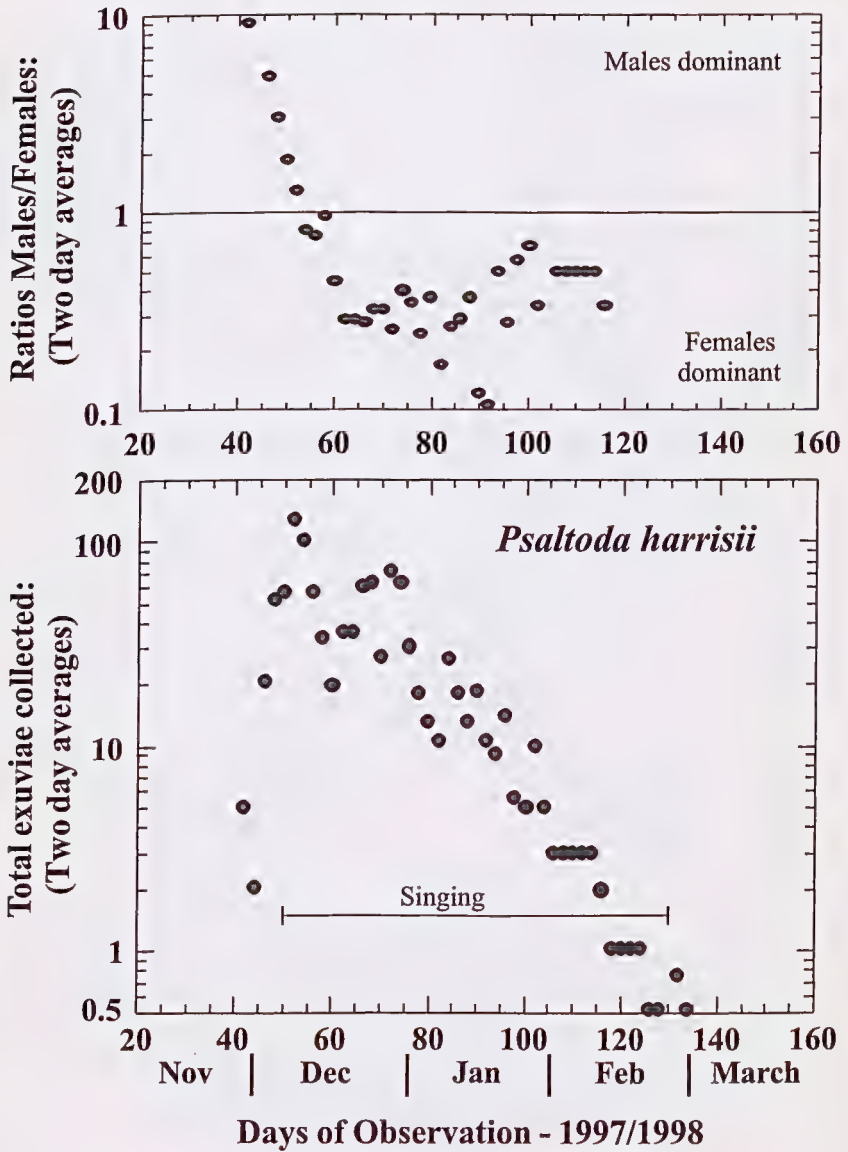


Fig. 9. Emergence pattern and accompanying sex ratio changes in *P. harrisii* at southern Golden Beach, Caloundra during 1997/1998. Period of singing is shown by bar.

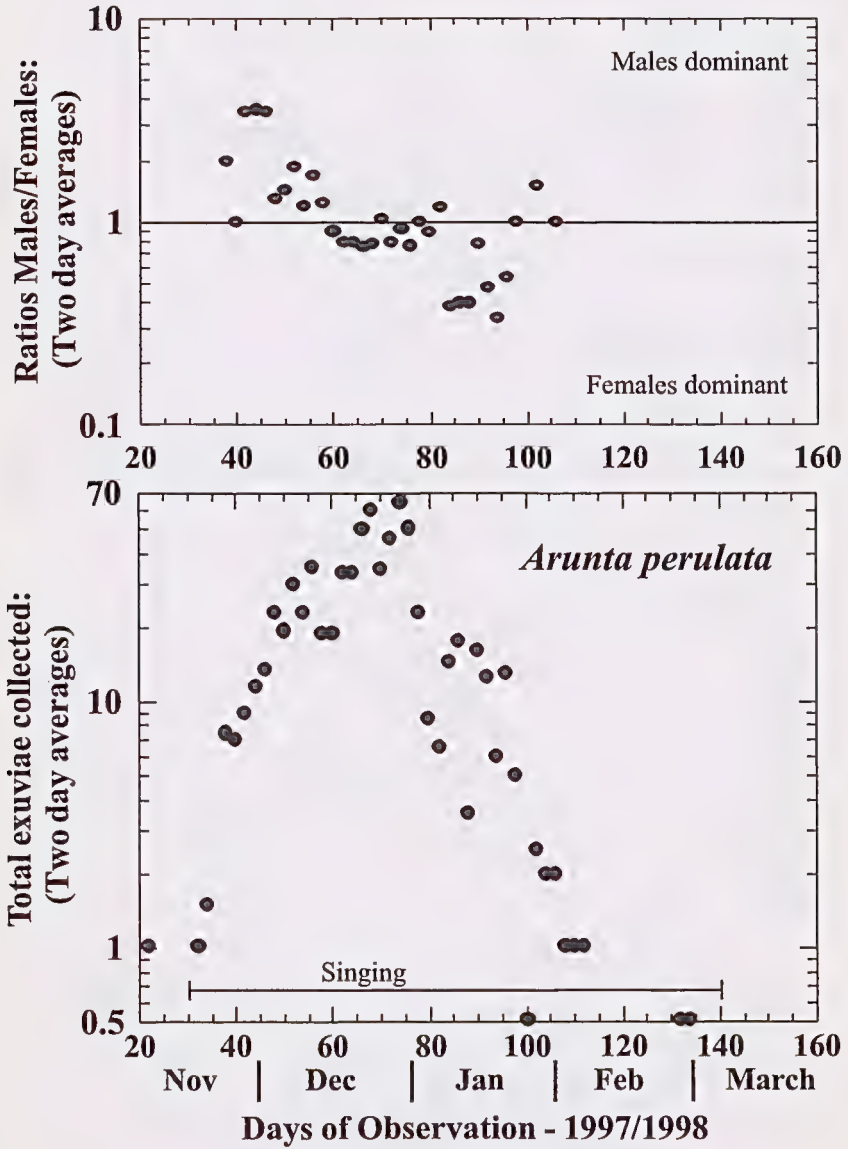


Fig. 10. Emergence pattern and accompanying sex ratio changes in *A. perulata* at southern Golden Beach, Caloundra during 1997/1998. Period of singing is shown by bar.

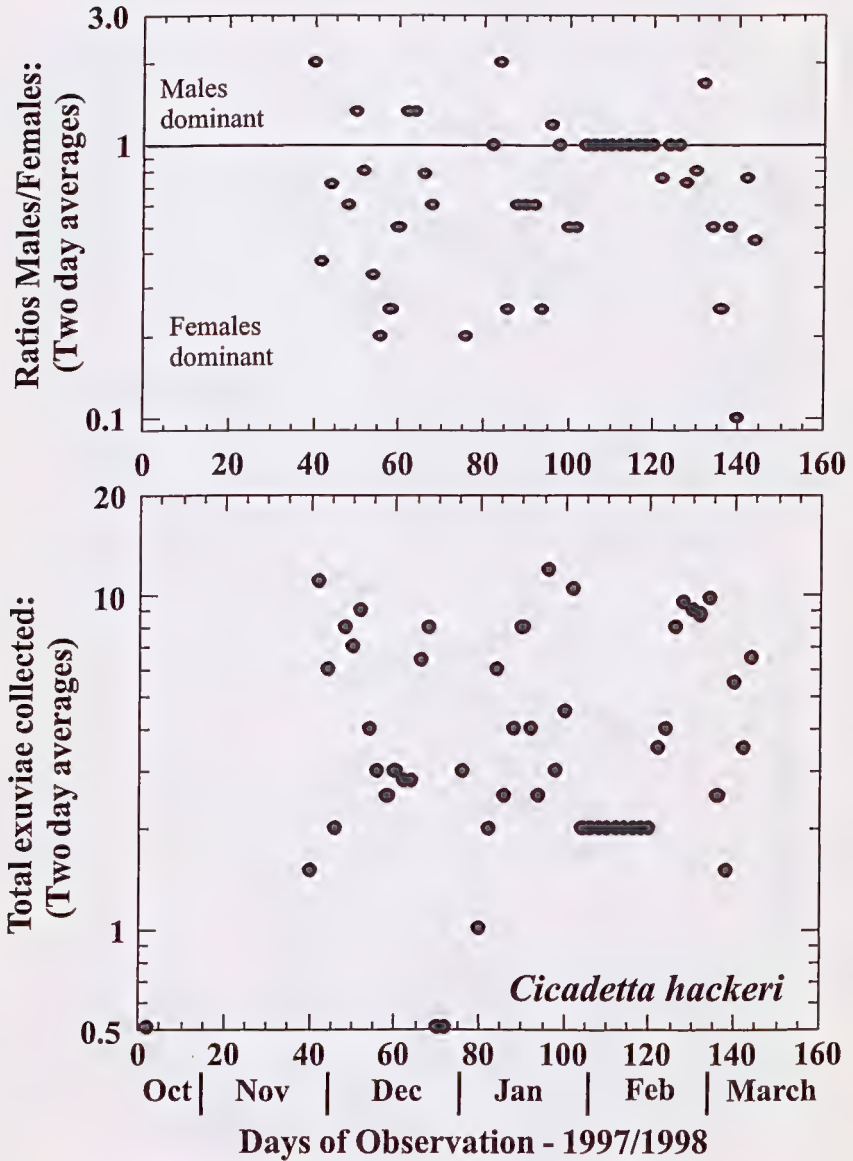


Fig. 11. Emergence pattern and accompanying sex ratio changes in *C. hackeri* at southern Golden Beach, Caloundra during 1997/1998. Singing was heard from early September to early May in and around the census site (see text).

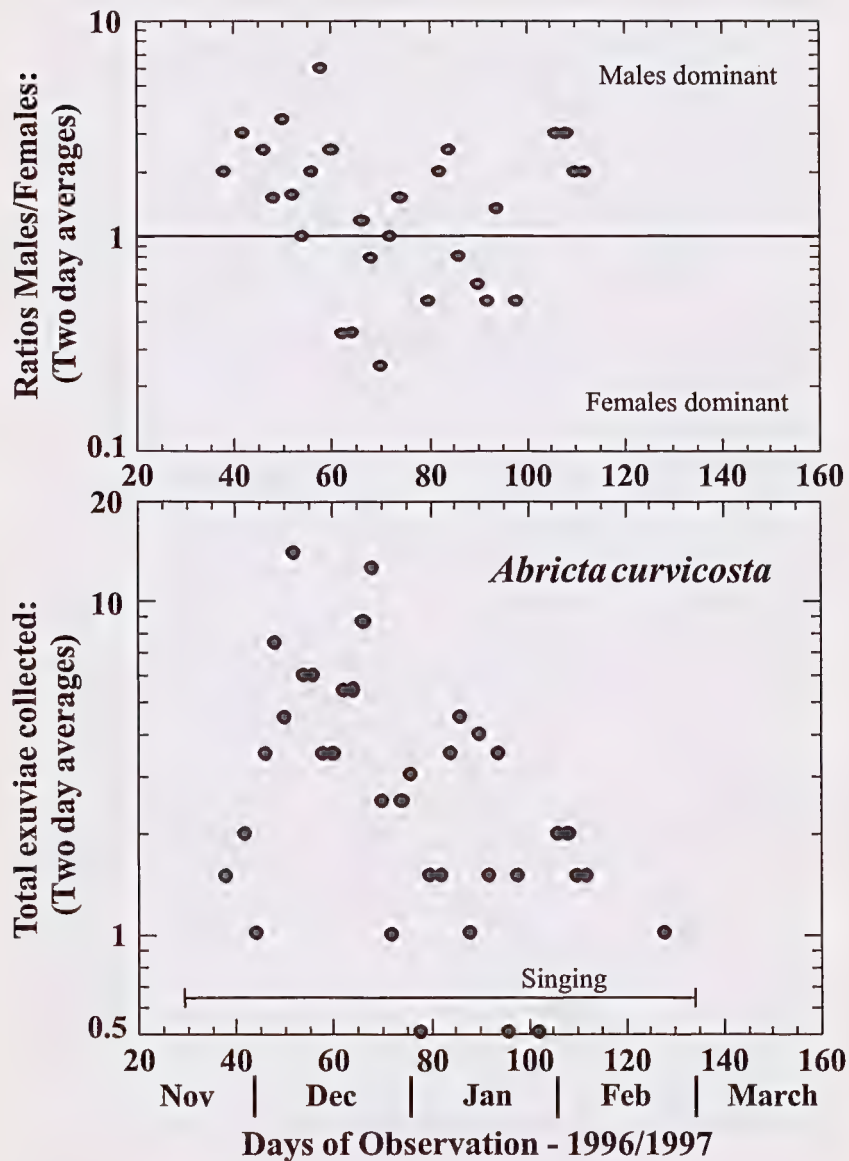


Fig. 12. Emergence pattern and accompanying sex ratio changes in *A. curvicosta* at southern Golden Beach, Caloundra during 1997/1998. Period of singing is shown by bar.

Cicadetta hackeri was heard singing from early September to early May (including areas peripheral to the study site), although exuviae were found only between 19 October and 11 March in the study site (Fig. 11). It therefore seems likely that the emergence season of this cicada lasted 7-8 months.

Exuvial densities

Psaltoda plaga and *P. claripennis* were the two dominant species, followed by *P. harrisii*, *A. perulata*, *C. hackeri* and *A. curvicosta* (Table 2), consistent with previous qualitative song observations. The total density of collected exuviae represented 8,370 individuals per ha. This may be compared with density estimates from comparable overseas studies (Table 3).

Table 3. Comparative overseas cicada population data.

	Environment	Range (ha ⁻¹)	Mean (ha ⁻¹)	Reference
American periodical cicadas (adults)				
<i>Magicalcanda septendecim</i>	Hardwood forest	11,000-63,000	-	Karban 1984
<i>M. cassini</i> (dominant)	Suburban	-	1,670,000	White <i>et al.</i> 1979
<i>M. tredecassini</i> (dominant)	Hardwood forest	-	66,456	Williams <i>et al.</i> 1993
<i>M. cassini</i>	Flood plain forest	1,160,000-8,350,000	3,720,000 (1956)*	Dybas and Davis 1962
<i>M. septendecim</i>	Upland forest	20,000-1,100,000	328,000	Dybas and Davis 1962
South Africa, southern Karoo				
<i>Quintillia cf. conspersa</i> (dominant)	Arid shrubland	800-24,800	6,080-8,760	Dean and Milton 1992; Milton and Dean 1992
New Zealand				
Six species	Subalpine grassland	<1,000-20,000	-	White and Sedcole 1993 (see also Lane 1993)
Italy, Tuscany, Mediterranean coastal				
<i>Cicada orni</i>	Pinewoods	4,882-36,582	19,722	Patterson <i>et al.</i> 1997
	Olive groves	2,172-4,482	3,236	Patterson <i>et al.</i> 1997

* By 1973 this number had dropped to 756,000, following Dutch Elm Disease (White *et al.* 1979).

The most spectacular cicada concentrations occur within the three species of American Periodical Cicadas, which can reach “super-abundance” levels in excess of a million per ha. Such numbers are not reported in Australia. The numbers reported from New Zealand sub-alpine grassland (six species), South African Karoo (dominated by 1 species), and coastal Italy (1 species) all encompass the total abundance estimates found in this study. The most relevant of the overseas estimates is the Mediterranean coastal area of Tuscany, containing pinewood and olive grove habitats. Pinewood contained the highest cicada populations (mean 19,722 per ha), compared to a mean of 3,236 per ha for olive groves. Although the pinewood habitat had higher overall populations per ha than reported here, estimates of exuviae per tree were 15.3, compared to 5.9 for olive groves (Patterson *et al.* 1997). The present study found a mean of 49 exuviae per tree (total data), or 23 and 21 per tree for *P. plaga* and *P. claripennis* respectively, higher than the Tuscany estimates. Overall, the exuviae (= cicada) densities found in this SEQ survey appear unexceptional.

Synchronous emergence and interspecific song recognition

Young (1980), in a study of peak emergence periods and habitats of cicadas in Costa Rica, concluded that his data supported the hypothesis that selection favoured emergence adaptations such as allochrony or habitat non-overlap amongst species. In the SEQ environment surveyed, synchrony of cicada emergences was clearly demonstrated, although the six cicada species occupied localised but still overlapping habitat niches. Such overlaps require that their mate recognition signals, specifically their songs, are clearly distinct from the spatially associated species.

The temporal structures (oscillograms/waveform plots) of the songs from each species were reported by Young and Josephson (1983 [*P. plaga* is listed as *P. argentata*]) and Ewart (1995). These show the distinctive structures of each song as seen by their pulse and phrase structures and pulse repetition rates. The differences are reinforced by their dominant frequencies. For *P. plaga*, *P. claripennis*, *P. harrisii*, *A. perulata*, *C. hackeri* and *A. curvicosta*, the dominant frequencies are, respectively, 3.6-4.7, 5.9-6.8, 4.3, 6.7-6.8, 10.6-11.1 and 9.5-9.6 kHz (Ewart, unpublished data). Further distinctions are seen in detailed structures of the frequency bands, i.e. whether broad or narrow, measured as bandwidths. These are derived from song spectra, in which the relative sound energy emitted between the lower (25%) and upper (75%) quartiles is determined. Respective values for the six cicadas species are 2.7, 2.1, 1.9, 1.4, 1.9 and 2.3 kHz. The songs of each species have their own uniquely defined acoustic characteristics.

Acknowledgments

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WHAT IS *NACADUBA MALLICOLLO MARKIRA* TITE?
A NEW SPECIES OF *NACADUBA* MOORE FROM THE SOLOMON
ISLANDS (LEPIDOPTERA: LYCAENIDAE)

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Abstract

Following recent collection of material in the Solomon Islands, the male holotype and female 'allotype' of *Nacaduba mallicollo markira* Tite from San Cristobal, Solomon Islands, are reassessed and found to belong to different species. *Nacaduba samsoni* sp. nov. is described from Nendo (Santa Cruz group), San Cristobal and Rennell Islands.

Introduction

In a synonymic list of the genus *Nacaduba* Moore, Tite (1963) paid particular attention to the south Pacific, describing several new taxa from the region, including *Nacaduba mallicollo markira* Tite from the large island of San Cristobal, at the eastern extremity of the Solomon archipelago. The taxon was described from a short series, including the male holotype (Figs 1-2) and female 'allotype' (Figs 3-4) collected by A. S. Meek at 'Markira harbour', on the south coast of San Cristobal, in 1908.

The group of polyommata lycaenid species which includes *N. mallicollo* Druce (*N. mallicollo*, *N. kurava* Moore, *N. berenice* Herrich-Schäffer) is in need of revision in the Solomon and New Hebrides archipelagos. Some species are notoriously difficult to separate using wing markings and identification is complicated by the fact that several species display marked individual variation. For example, either sex of *N. mallicollo* may be confused with corresponding sexes of *N. kurava* from some localities (but see discussion below regarding the Santa Cruz Islands) and the male genitalia of these species are similar. The genitalia of male *N. berenice*, with which *N. mallicollo* might also otherwise be confused, are diagnostic. Tite (1963) examined the genitalia of the *N. m. markira* holotype (Fig. 9), which correspond closely to those of nominotypical *N. m. mallicollo* from Vanuatu. The upperside of the female allotype of *N. m. markira* is similar in appearance to the female holotype of *N. m. mallicollo*, but the underside markings are quite dissimilar. Although Tite (1963) did not say so, the unusual appearance of the female of this pair may have initially attracted attention. The remaining specimens of the short type series (one male from Vella Lavella and two females from San Cristobal and Santa Ana) appear to conform to *N. mallicollo*.

As part of a study of Solomon Islands butterflies (Tennent 1998), the types of *N. m. markira* were examined in 1996. It was concluded that the two specimens may not be conspecific and that the unusually marked female may

be aberrant, although a lack of material made it difficult to pursue this suspicion. A series of nine females, together with a single male, collected on the island of Nendo in the Santa Cruz group in May 2000, suggested that the male holotype of *N. m. markira* was not conspecific with the allotype female and that the female was not aberrant but represented an undescribed species. A further female was collected on Rennell I. in August 2000.

Many *Nacaduba* species have similar underside patterns, characterised by a series of fine transverse lines. There is also usually a large subternal spot surrounded by orange and/or iridescent green or blue-green scales on the hindwing underside. Differences between some species are minor but despite marked sexual dimorphism on the upperside, underside markings are generally of similar appearance in the sexes of the same species. Figures 1-4 illustrate type specimens of *N. m. markira*, in which significant underside differences between the sexes (Figs 2, 4) may be observed. In particular, the subternal spot of the male is almost completely circled by pale orange and bordered iridescent green distally (a common *Nacaduba* feature), whilst the ternal spot of the female is boldly marked iridescent blue distally with no trace of orange.

***Nacaduba samsoni* sp. nov.**

(Figs 3-8, 10)

Nacaduba mallicollo markira; Tite, 1963: 82, pl. 1 (allotype ♀); misidentification.

Types. *Holotype* ♂, SOLOMON ISLANDS: Santa Cruz group, Nendo Island, Lata to Noipe, 60-140 m, 17.v.2000, W.J. Tennent (gen. prep. BMNH(V) 5974) (in The Natural History Museum, London [BMNH]). *Paratypes*: 3 ♀♀, same data as holotype; 1 ♀, same locality, 3.v.2000; 3 ♀♀, same locality, 5.v.2000; 3 ♀♀, same locality, 9.v.2000; 1 ♀, Rennell I., Tinggoa and road 10 km east, 8.viii.2000, W.J. Tennent; 1 ♀ ('allotype' of *Nacaduba mallicollo markira*), San Cristobal, Makira harbour [south coast], 1-8.v.1908, Meek (all BMNH).

Description. Male (Figs. 5-6) forewing length 16 mm; wing fringes dark brown, clearly tipped white (uniform muddy brown in *N. m. markira*); upperside bright mauve-blue (tinged pinkish in *N. m. markira*); underside pale grey-brown, basal markings indistinct; median and postmarginal markings white, spaces filled pale brown; submarginal area mainly white, with prominent series of crescent-shaped brown spots; subternal black spot large, edged iridescent blue-green distally with no trace of orange (all other *Nacaduba* species of the region, including *N. mallicollo*, have at least a trace of orange markings associated with the subternal spot). Genitalia (Fig. 10) similar to *N. mallicollo*; valva with hooked apex, directed inwards, approximately half the length of distal edge of valva (a slightly variable feature in some associated *Nacaduba* species; in the male holotype of *N. m. markira* [Fig. 9a] the hooked apex is significantly longer); distal edge with 7 (possibly 8) serrated 'teeth', larger than those of *N. mallicollo*; aedeagus shorter, more squat.



Figs 1-8. *Nacaduba* species. (1-2) *N. mallicollo markira*, holotype male (San Cristobal): (1) upperside, (2) underside; (3-4) *N. samsoni*, paratype female (San Cristobal) [*N. m. markira* 'allotype']: (3) upperside, (4) underside; (5-6) *N. samsoni*, holotype male (Nendo): (5) upperside, (6) underside; (7-8) *N. samsoni*, paratype female (Nendo): (7) upperside, (8) underside.

Female (Figs 3-4, 7-8) upperside superficially similar to *N. mallicollo*; upperside forewing with broad borders; median area pale blue, almost white, broken by veins, heavily suffused shining blue basally (less white overall, blue more dull in associated species); hindwing white, heavily suffused grey-blue; submarginal and marginal markings prominent; underside highly distinctive; fundamentally white; basal and median markings obscured; submarginal and marginal markings prominent, similar to male; subternal spot similar to that of male. A female from Rennell is more heavily suffused blue on the upperside and has more prominent underside markings.

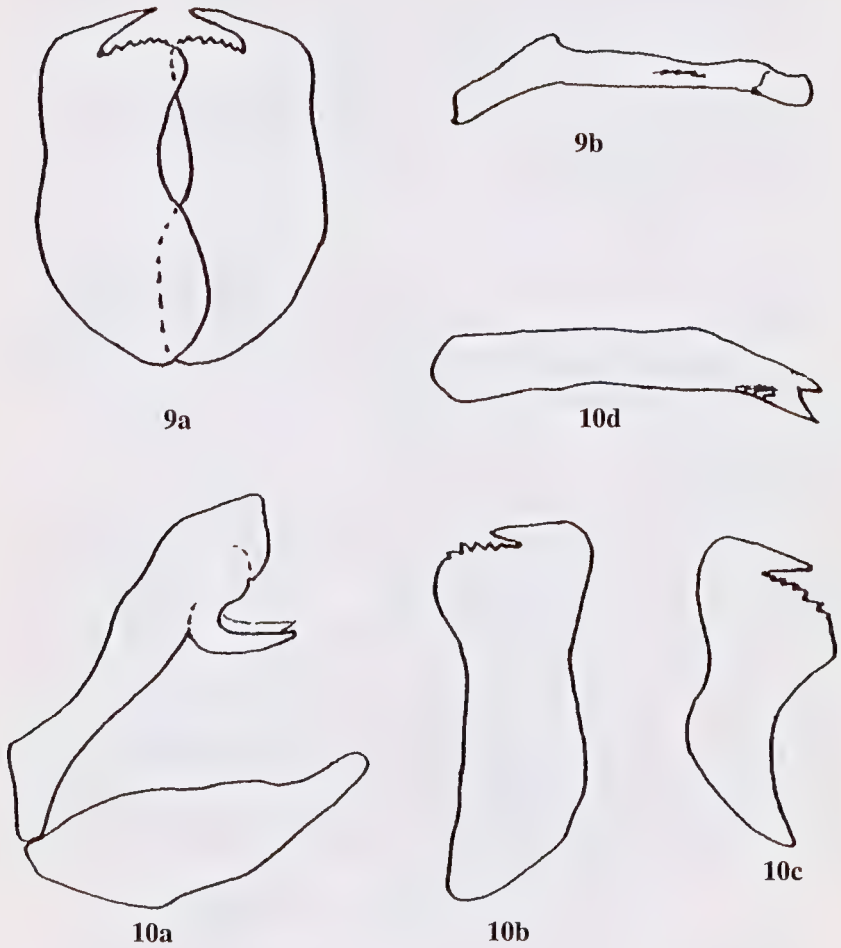
Etymology. The new species is named for Chris Samson, in recognition of his butterfly studies in the Solomon and New Hebrides archipelagos, including the Santa Cruz group (Samson 1979, 1980).

Distribution. Solomon Islands: San Cristobal, Rennell and Nendo (Santa Cruz).

Discussion

The author remained in the Santa Cruz group for several months in 2000 and collected extensively on Nendo whilst waiting for transport to the more remote islands of the group. The habits of *N. samsoni* were dissimilar to other *Nacaduba* and associated species present. Females were uncommon and had a deceptively slow flight. All were taken in flight or whilst feeding at the small white flowers of *Mikania micrantha* (Asteraceae). Males were apparently quite common, but extremely wary and could be seen in places where *Mikania* vines covered trees at considerable height, flying around vines 20-30 metres above the ground. Even at a distance, their pale undersides were distinctive and it was suspected, looking through binoculars, that this was the male associated with the very pale females already collected. On the few occasions when males were observed at lower levels they remained only fleetingly before returning to higher vegetation. Only one male was eventually collected.

Nacaduba samsoni is unlikely to be confused with any similar species on the island of Nendo. *N. kurava cruzens* Tennent occurs on the island; this is a distinctive subspecies with constant markings by comparison with subspecies elsewhere (Tennent 2000). *N. berenice* has not been reported from the Santa Cruz group. On Rennell, *N. kurava* has not been reported, whilst *N. berenice* has been recorded only from a single pair similar to *N. b. korene* Druce, collected in 1953 (Howarth 1962). The female of this pair is quite different in phenotype to the female *N. samsoni* recorded here from Rennell. *N. samsoni* may also occur on islands of Vanuatu, the type locality of *N. mallicollo*. Female *N. mallicollo* are invariably more blue on the upperside than *N. samsoni*, have at least some orange associated with the underside hindwing ternal spot and are rarely as white overall on the under surface, although some individuals may be difficult to separate.



Figs 9-10. *Nacaduba* species, male genitalia. (9) *N. mallicollo markira* (BMNH slide No. 24602; G.E.T 382), a, valvae (posterior view); b, aedeagus (lateral view); (10) *N. samsoni* (BMNH(V) No. 5974); a, genitalia (aedeagus removed) (lateral view); b, left valva (posterior view); c, right valva (posterior view, slightly angled); d, aedeagus (lateral view).

The island of San Cristobal and its satellites (Ugi, Santa Ana, Santa Catalina) have a higher proportion of endemic species and subspecies of butterfly taxa than any other island of the archipelago. The male of *N. m. markira* is very similar to nominotypical *N. m. mallicollo* from Vanuatu. Collection of further material in due course will no doubt establish whether the name *markira* is synonymous with *N. m. mallicollo*. As already intimated, a detailed revision is required to fully resolve the identity and distribution of this closely associated group of lycaenid butterflies.

Acknowledgments

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THREE NEW *HYPOCHRYSOPS* C. & R. FELDER TAXA FROM THE SOLOMON ISLANDS, INCLUDING A NEW SPECIES FROM THE SANTA CRUZ GROUP (LEPIDOPTERA: LYCAENIDAE)

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Abstract

Three new taxa of *Hypochrysops* C. & R. Felder are described from the Solomon Islands: *H. architas marie* subsp. nov. from the New Georgia group, *H. julie* sp. nov. from the eastern Santa Cruz group and *H. scintillans jamesi* subsp. nov. from New Georgia.

Introduction

Hypochrysops C. & R. Felder, 1860, occurs from Malaysia and Thailand to the Solomon Islands and contains approximately 60 species. Only one species is confirmed as occurring west of Wallace's Line (Sands 1986) and the genus occurs principally from the Moluccas to the Solomons. Sands (1986) divided *Hypochrysops* into 20 species-groups, incorporating three of the four Solomons species (*H. architas* Druce, 1891, *H. scintillans* (Butler, 1882) and *H. taeniatus* Jordan, 1908) in the *anacletus* species-group and the remaining species, *H. alyattes* Druce, 1891, in the *hippuris* species-group. The most easterly member of the genus previously known is *H. taeniatus*, confined to the island of San Cristobal. Of the remaining Solomons species, *H. architas* occurs in three subspecies from Bougainville to Guadalcanal and Malaita, *H. scintillans* occurs on Guadalcanal and Florida (see discussion), and *H. alyattes* has been reported from the New Georgia group (Gizo), Santa Isabel, Guadalcanal, Florida and Malaita. During recent fieldwork in the Solomon Islands, undescribed subspecies of *H. architas* and *H. scintillans* were collected on New Georgia and an undescribed species was discovered on the Santa Cruz island of Nendo.

Hypochrysops architas marie subsp. nov.

(Figs 1-4, 13)

Types. Holotype ♂, SOLOMON ISLANDS: New Georgia group, New Georgia, west, c. 3 km north of Munda, 100 m, 2.xi.1997, W.J. Tennent (gen. prep. BMNH (V) 4881 (JT349)) (in The Natural History Museum, London [BMNH]). *Paratypes*: 1 ♀, Gizo, xi.1903, Meek; 1 ♂, Rendova, ii.1904, Meek; 1 ♀, same data as holotype, 4.xi.1997; 1 ♀, Rendova, north coast, Mendali Point, 0-160 m, 27.iv.2001, W.J. Tennent (all BMNH); 1 ♀, Gizo, 0-140 m, xii.1980, N.L.H. Krauss (Bernice P. Bishop Museum, Honolulu).

Description. Similar in appearance to other subspecies of *H. architas*. Male (Figs 1-2) forewing length 16.5 mm; upperside clear dark blue, similar to *H. narcissus eucletas* C. & R. Felder, 1865, from Indonesia (purple or purple-blue in *H. a. architas* and *H. a. cratevas* Druce, 1891); upperside forewing

blue area slightly reduced; underside bands red (orange-red in other *H. architas* subspecies). Genitalia (Fig. 13) similar to *H. a. architas*. Female (Figs 3-4) similar to other *H. architas* subspecies on both surfaces.

Etymology. Most of our knowledge of Solomon Islands butterflies stems from the work of Albert Stewart Meek and Charles Morris Woodford. This taxon is named after Marie, Albert Meek's daughter, whom the author was privileged to meet in Brisbane in 1997, aged 92.

***Hypochrysops julie* sp. nov.**

(Figs 5-8, 11)

Types. *Holotype* ♂, SOLOMON ISLANDS: Santa Cruz group, Nendo Island, ca 4 km (by road) south of Lata, 160 m, secondary growth on edge of village garden, 11.x.1997, W.J. Tennent (in BMNH). *Paratypes:* 1 ♂, 1 ♀, same data as holotype; 5 ♂♂, 1 ♀, same data, 10.x.1997 (♂♂ including gen. preps. BMNH (V) 4879 & 4880); 3 ♂♂, 1 ♀, same data, 13.x.1997; 1 ♂, same data, 14.x.1997; 1 ♀, Nendo, south-west central, Forestry camp, 140-160 m, 28.iv.2000, W.J. Tennent; 6 ♂♂, 16 ♀♀, Nendo, Lata to Noipe, 60-140 m, 5.v.2000, W.J. Tennent; 17 ♂♂, 6 ♀♀, same data, 9.v.2000; 5 ♂♂, 2 ♀♀, same data, 12.v.2000; 4 ♂♂, same data, 17.v.2000; 1 ♂, 3 ♀♀, Santa Cruz group, Vanikoro, main island, eastern coastal strip, 2.iv.2000, W.J. Tennent; 1 ♀, Vanikoro, north-east of Lale village, SL-100 m, 4.iv.2000, W.J. Tennent; 1 ♀, Vanikoro, Lale village gardens, 20-140 m, 5.iv.2000, W.J. Tennent; 1 ♀, same data, 6.iv.2000 (all BMNH).

Description. Intermediate in appearance between *H. architas* and *H. taeniatus*. Male (Figs 5-6) forewing length 14 mm; upperside similar to *H. taeniatus*, ground colour dull purple-blue; upperside forewing apex thinly lined black; underside similar to *H. architas*, underside forewing markings less distinct; underside hindwing median, submedian and postbasal bands darker orange than in *H. taeniatus* (red in *H. architas*), broadly bordered iridescent emerald green (pale green in *H. architas*); thin, broken black postmedian line, independent from marginal markings. Genitalia (Fig. 11) typical of *anacletus* group; posterior of sociuncus deeply indented dorsally; valva similar to *H. taeniatus*, less deeply indented anteriorly. Female (Figs 7-8) upperside dark brown; upperside forewing with indistinct pale discal patch, tinged violet-blue distad; basal blue suffusion characteristic of *H. architas* and *H. taeniatus* lacking; upperside hindwing unmarked; underside markings similar to male, metallic green markings less extensive.

Etymology. This attractive new species is named after the author's wife Julie, who continues to support his long periods in the field.

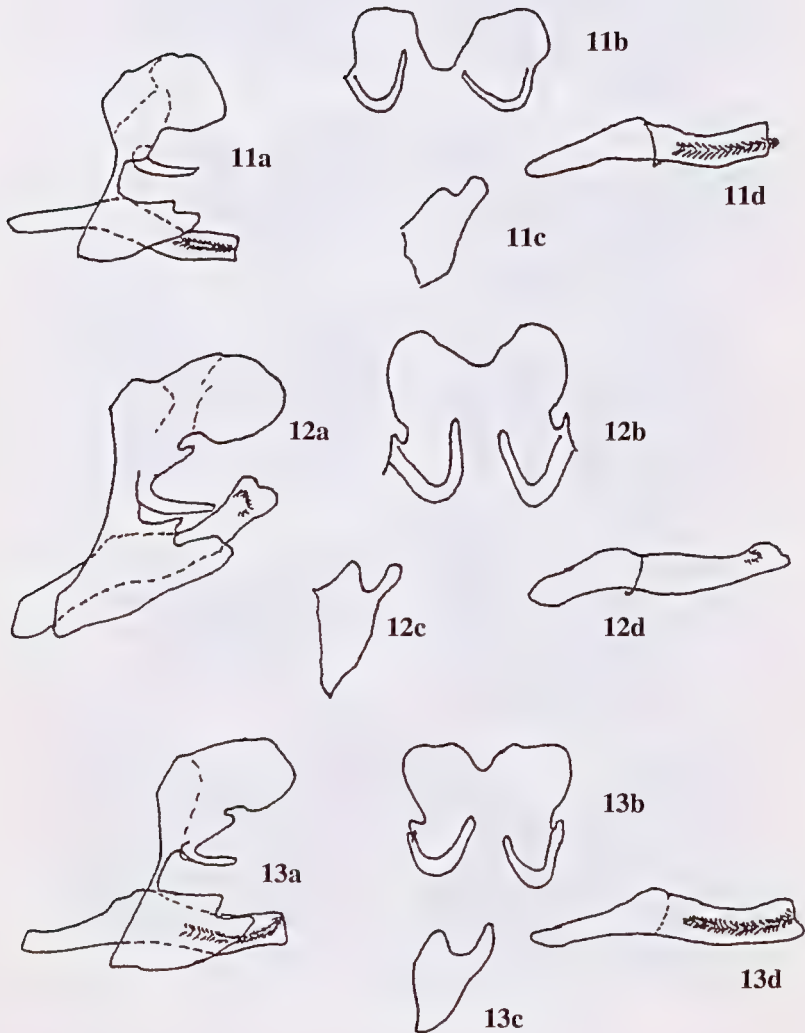
***Hypochrysops scintillans jamesi* subsp. nov.**

(Figs 9-10, 12)

Types. *Holotype* ♂, SOLOMON ISLANDS: New Georgia group, New Georgia, west, c. 3 km north of Munda, 100 m, 4.xi.1997, W.J. Tennent (in BMNH). *Paratype* ♂, same data as holotype (gen. prep. BMNH (V) 4882 (JT348)) (BMNH).



Figs 1-10. New *Hypochrysops* taxa. (1-4) *H. architas marie*: (1) male upperside (Rendova paratype); (2) male underside (holotype); (3) female upperside (Rendova paratype); (4) female underside (New Georgia paratype). (5-8) *H. julie*: (5) male upperside (Vanikoro paratype); (6) male underside (holotype); (7) female upperside (Nendo paratype); (8) female underside (Nendo paratype). (9-10) *H. scintillans jamesi*: (9) male upperside (paratype); (10) male underside (holotype). Scale = 1 cm.



Figs 11-13. *Hypochrysops* species, male genitalia: a, genitalia; b, sociuncus; c, valva (left); d, aedeagus. (11) *H. julie*; (12) *H. scintillans jamesi*; (13) *H. architas marie*.

Description. Male (Figs 9-10) similar to *H. s. constancea* D'Abrera, 1971; larger, forewing length 20 mm; upperside blue darker, less purple; upperside forewing with distal edge of blue discal patch prominently sagittate; upperside hindwing blue less extensive at apex than *H. s. constancea*; underside red and iridescent gold markings bold; underside ground colour olive-brown (yellow-brown in *H. s. constancea*); underside forewing basal area suffused orange (lacking in the only male of *H. s. constancea* seen). Genitalia (Fig. 12) similar to *H. s. scintillans*. Female unknown.

Etymology. Charles Morris Woodford, the first Resident Commissioner of the Solomon Islands, was the first person to collect butterflies systematically there (Tennent 1999). This taxon is named after Jim Woodford, Charles' great-nephew and traveller/adventurer in his own right, who was generous in his hospitality during the author's field visits to the Solomons between 1997 and 2000.

Discussion

The Solomon archipelago, which includes the large island of Bougainville (politically part of Papua New Guinea), is a significant area of endemism and New Georgia group populations of a number of butterfly species are distinct from populations found on adjacent island groups. Discovery of a *Hypochrysops* species in the Santa Cruz group, politically part of the Solomon Islands but faunistically also allied to the islands of Vanuatu to the south, represents a significant easterly extension of the range of this genus.

Aside from *H. s. jamesi*, described above, the only subspecies of *H. scintillans* known from the Solomon Islands is *H. s. constancea*. The female holotype of the latter taxon is from Guadalcanal and was illustrated by D'Abrera (1971), but appears not to have been labelled as such until Sands' (1986) revision. It now bears an additional label marked 'Holotype, *Hypochrysops scintillans constantacea* [sic], examined by D. Sands, 1984'. No paratypes were designated by D'Abrera but, judging from material available at that time in the BMNH, they comprised a second female with similar data to the holotype, a further female labelled 'Tugela (Woodford)' and a male labelled 'Gela, Woodford', all of which have now been labelled. 'Gela', or Nggela, is a name for the island now more usually known as Florida. The locality known as 'Tugela' is more problematic and it is not certain that an island or place of this name exists, or has ever existed. Although the name appears on several Solomons labels, usually (but not exclusively) associated with Woodford material and often (but not in this case) with Guadalcanal, it does not appear on any map, nor does it appear in the comprehensive Pacific gazetteers in use at the time of Woodford. The name is not mentioned in any of the numerous publications of Woodford, including a book (Woodford 1890) in which he gave an account of his life in the Solomons and the places he visited. The Solomon Islands Government Archivist in Honiara has no record of the name (Mr Ishmail Avui, pers.

comm.). Although less likely, it is possible that the name is a corruption of 'Tulagi', a small island in the Florida group and the pre-Second World War national capital of the Solomon Islands.

The distribution of *H. s. constancea* was given by D'Abrera (1971, 1978, 1990) as 'Guadalcanal, Tugela' and, regardless of whether 'Tugela' exists or existed on Guadalcanal, or whether it in fact refers to Tulagi, the known distribution of *H. s. constancea* may be taken as Guadalcanal and Florida.

Acknowledgments

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**THE CRAZY ANT *ANOPLOLEPIS GRACILIPES* (SMITH)
(HYMENOPTERA: FORMICIDAE) IN EAST ARNHAM LAND,
AUSTRALIA**

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Abstract

Anoplolepis gracilipes (Smith) was first recorded from the Australian mainland in East Arnhem Land, Northern Territory, in May 1990. In a survey during November 1999, it was found over five river drainage systems covering an area of approximately 2,500 km² but was mainly confined to thin strips of monsoon rainforest bordering perennial springs and streams. It was found only once in dry open *Eucalyptus* woodland. Highest populations were found in a disturbed habitat, although the ant was absent from Nhulunbuy town and aboriginal communities. The large area infested with *A. gracilipes* suggests that an eradication campaign would be extremely difficult.

Introduction

Crazy ant, *Anoplolepis gracilipes* (Smith) (= *longipes* (Jerdon)), is a tramp species thought to be native to Africa (Way and Khoo 1992). The ant has been spread by commerce throughout East Africa, Asia and the Pacific (Lewis *et al.* 1976). *A. gracilipes* is a pest of agricultural, domestic and natural environments (Lewis *et al.* 1976, Haines *et al.* 1994, Rao and Veeresh 1994) and, like many tramp species, forms unicolonial, polygynous colonies (Reimer 1994).

Crazy ant is frequently a pest of orchard crops because it nurtures sap-feeding insects. Copious amounts of honeydew produced by sap-sucking insects results in the growth of sooty mould on the leaves of fruit trees (Haines and Haines 1978a, Haines *et al.* 1994, Young 1996b). The ant often encourages pest species indirectly by harassing predators and parasites of the pests (Young 1996a). Additionally, *A. gracilipes* excavates around the roots of crops such as sugar cane and coffee, undermining the roots and causing the plants to collapse (Lewis *et al.* 1976, Haines and Haines 1978a, Rao and Veeresh 1994).

A. gracilipes is primarily a scavenger and will enter houses in search of food, which has led to the ant's reputation as a household pest (Lewis *et al.* 1976). It will also pester confined domestic animals, such as poultry (Haines and Haines 1978b, Haines *et al.* 1994).

The greatest impact of crazy ant is on the ecology of natural environments (Lewis *et al.* 1976, Haines and Haines 1978a, Haines *et al.* 1994). There are numerous reports of crazy ants displacing other invertebrate species (especially ants and spiders), forcing vertebrate species to vacate infested areas, attacking the young of nesting birds and altering the floral composition

(Lewis *et al.* 1976, Haines and Haines 1978a, Gillespie and Reimer 1993, Rao and Veeresh 1994, O'Dowd *et al.* 1999). A recent example is on Christmas Island, where *A. gracilipes* is having a detrimental effect on rainforest vegetation, populations of the red land crab *Gecarcoidea natalis* Pocock and nesting sea birds (O'Dowd *et al.* 1999).

A. gracilipes was first recorded from mainland Australia on the Gove Peninsula, East Arnhem Land, Northern Territory, following a survey by the Parks and Wildlife Commission of the Northern Territory during May 1990 (Reichel and Andersen 1996, Shattuck 1999). The collection locality was at Balkbalkbuy, 77 km south-west of Nhulunbuy airport, on the Katherine to Nhulunbuy road (N. Gambold, pers. comm.) (Fig. 1). Two of us (GAB and GRY) confirmed the presence of the ant at this site during October 1999. In view of the importance of *A. gracilipes* as an agricultural and environmental pest outside mainland Australia, it was decided to determine the distribution of the ant in East Arnhem Land and consequently the feasibility of an eradication campaign.

The vegetation of the Gove Peninsula mainly consists of tall, open woodland dominated by *Eucalyptus tetradonta* and *E. minata* (Lynch and Wilson 1998). The woodland is interspersed with small areas of monsoon rainforest associated with perennial springs and streams (Wilson *et al.* 1990, Russell-Smith 1991).

Materials and Methods

During three days of investigation, the Gove Peninsula was searched on foot, by vehicle and quad bike. Preference was given to accessible areas on or near roads and tracks, especially near the upper reaches of watersheds, permanent watercourses and around aboriginal communities. Each individual inspection site had the GPS coordinates recorded and was investigated for 0.5 man-hours or until crazy ants were detected. Ants were visually located by raking leaf litter with sticks, searching where sooty mould was present on plants or by placing a small quantity of tuna-based cat food in 20 cm lengths of hollow bamboo. Representative samples were taken from each site where crazy ants were present.

Since personal experience of this ant in overseas countries had demonstrated the requirement for moisture and suitable nesting conditions, investigations were concentrated in areas where water, either above or below ground, was accessible. During the survey, accessible water was generally restricted to watercourses. The *Eucalyptus* woodland, which covers the great majority of the watershed areas, was affected by the prolonged absence of rain and the annual wild fires prevalent in this region.

Forty-nine sites were sampled from a range of habitats on the Gove Peninsula. Eleven of these were away from creek lines in *Eucalyptus* woodland.

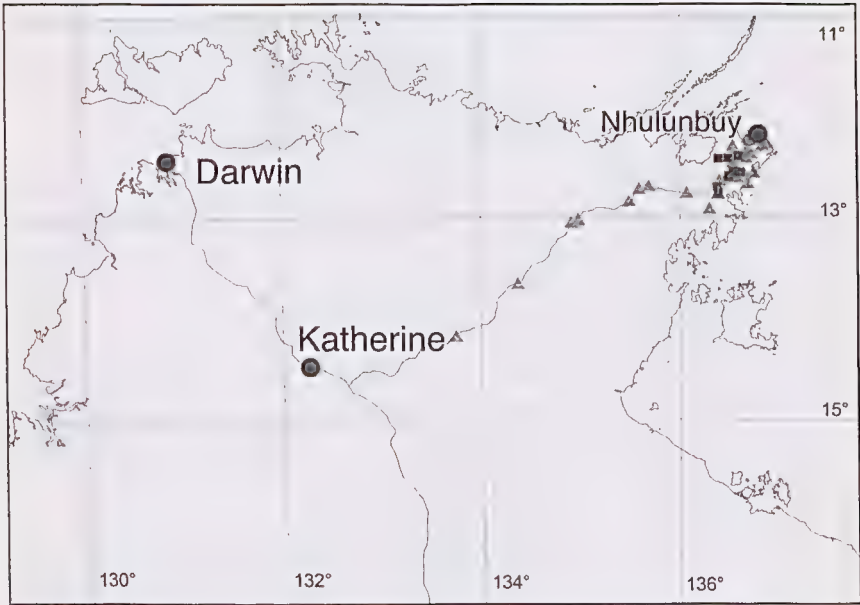


Fig. 1. Top End of the Northern Territory showing the Nhulunbuy to Katherine road and areas searched for *A. gracilipes* (■ = presence; ▲ = absence).

Results

Crazy ant was found in five drainage systems on the Gove Peninsula covering an area of approximately 2,500 km² (Fig. 2). The ant was absent from the port and town of Nhulunbuy as well as the nearby Yirkala community. It was abundant around the first detection point at Balkbalkbuy, which is a permanent watercourse bordered by a thin strip of monsoon rainforest up to 5 m wide. Balkbalkbuy is used as a camping area and for parking earthmoving equipment. The resulting refuse and disturbance had encouraged the ant by providing shelter and nesting sites. Downstream from Balkbalkbuy, the ant was present and abundant for at least 700 m along the creek and for a further 200 m along a larger adjoining tributary. It was by far the dominant ant species in parts of the monsoon rainforest along the creek and appeared to have displaced native species of ant, including the green ant *Oecophylla smaragdina* (Fabricius). While crazy ants were found along the creek line, the ant had not invaded a dense patch of monsoon rainforest surrounding a spring, which feeds the creek at Balkbalkbuy.

At Balkbalkbuy, *A. gracilipes* formed large, interconnected soil colonies. Nests containing brood were also found under discarded car tyres and rubber mats. Tuna proved highly attractive to the ant with workers swarming around the bait within ten minutes of placement in the bamboo tubes. Additionally, the ant rapidly colonised the tubes; workers, alate and dealate queens, alate males and brood were present in tubes left out overnight.

The ant was less abundant in the other four drainage systems, being patchily distributed in shaded areas along creek banks and in the upper reaches of drainage systems. In one instance nests were found in a clay and shale creek bank above the normal wet season water level.

There appeared to be an association between the ant and monsoon rainforest growing along the creeks. This vegetation provided shade and leaf litter, creating a favourable habitat for the ant. The ant was not found in dry open woodland away from creek lines, except in one instance where a colony was found nesting in disturbed rock and soil beside the Katherine to Nhulunbuy road, possibly indicating that the ant had been transported there by earthmoving equipment or other vehicles.

Workers were observed climbing the trunks of trees and foraging over foliage but it was not apparent whether this indicated arboreal nests or ants searching for either sap-sucking homopterans or nectar. On one occasion *A. gracilipes* was observed tending *Saissetia* sp. (Hemiptera: Coccidae) on *Buchanania obovata* (Anacardiaceae), the leaves of which were covered in sooty mould. However, in other localities where the ant was found sooty mould was not detected on the vegetation.

Discussion

Anoplolepis gracilipes was found in shaded, moist areas of monsoon rainforest with a year-round layer of leaf litter and was generally absent from open *Eucalyptus* woodland. Haines and Haines (1978b) in the Seychelles and Young (1996b) in Papua New Guinea showed that, while the ant would forage over 24 hours in tropical climates, maximum foraging activity occurred at temperatures ranging from 26-30°C and relative humidities from 65-90%. Rao and Veeresh (1991) observed maximum foraging activity at temperatures between 24 and 28°C. Temperatures in open woodland are often >34°C, free moisture is unavailable for 4-5 months of the year and the leaf litter is burnt during annual dry season fires. These conditions make the woodland an unfavourable habitat for the ant during the dry season. Conversely, the more permanent leaf litter and mulch layer of the monsoon rainforest (Bowman and Wilson 1988) provides *A. gracilipes* with a cooler and more stable habitat. The failure of crazy ant to colonise dense monsoon rainforest near Balkbalkbuy is unexplained.

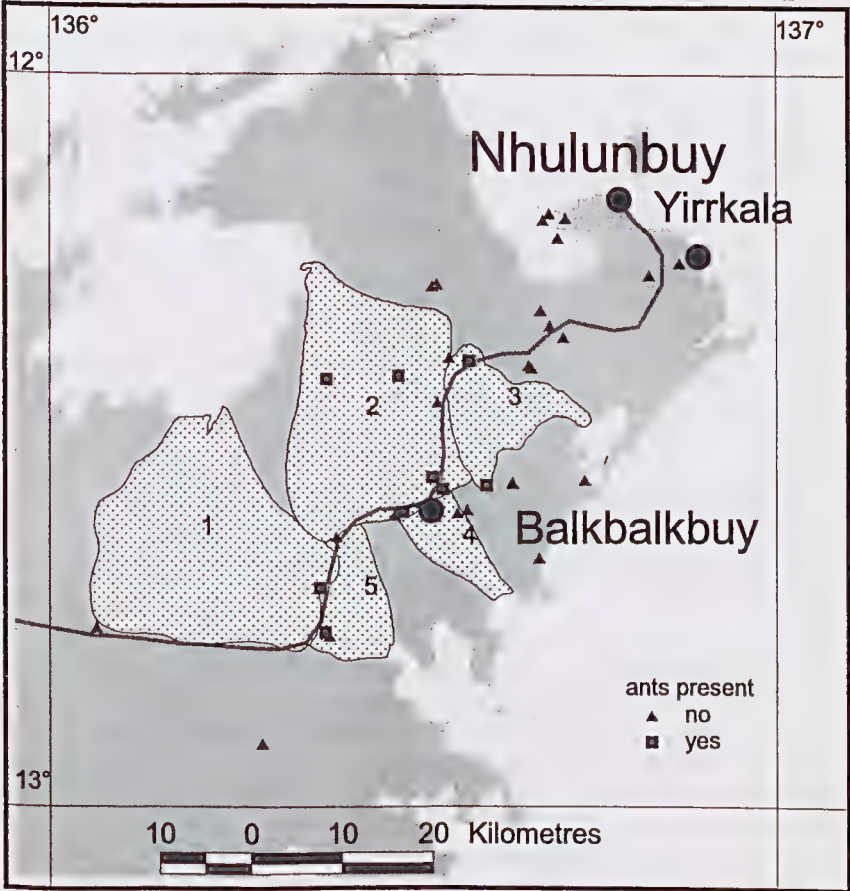


Fig. 2. Gove Peninsula, East Arnhem Land, showing the Nhulunbuy - Katherine road, five drainage systems and survey sites, indicating the presence or absence of *A. gracilipes*. Drainage systems: 1 = Goromuru River; 2 = Cato River; 3 = Wonga Creek; 4 = Balkbalkbuy Creek; 5 = Ngabinya Creek.

While both alate queens and males are known to fly, there is no evidence of mating flights and it appears that colonies reproduce by budding (Haines and Haines 1978b, Haines *et al.* 1994). During the wet northwest monsoon, conditions are probably favourable for sexuals and workers carrying brood to walk across open *Eucalyptus* woodland, enabling them to colonise new areas of monsoon rainforest. The dry season would isolate these new colonies from the original one. As demonstrated by the rapidity of colonising bamboo tubes, the ant can be spread readily by human activities. These factors could explain the patchy distribution of *A. gracilipes* on the Gove Peninsula.

Population density of *A. gracilipes* was greatest at Balkbalkbuy where the ant was able to construct large nests under refuse. The rapid colonisation of bamboo tubes suggests that the populations of *A. gracilipes* are limited by nesting sites in areas where the environment is favourable to the ant. In the Seychelles, Haines and Haines (1978b) concluded that population size was probably limited by the availability of food and nesting sites.

From work in the Seychelles and Christmas Island, it may be assumed that, on the Gove Peninsula, *A. gracilipes* obtains its protein by feeding on invertebrates inhabiting leaf litter in monsoon rainforests (Haines *et al.* 1994, O'Dowd *et al.* 1999). It is not immediately apparent where the ant sources carbohydrate, although it is likely to be either nectar or other plant exudates (Haines *et al.* 1994, Young, 1996a). Contrary to observations of ants tending homopterans on Christmas Island (O'Dowd *et al.* 1999), the ant was observed to tend honey-dew producing homopterans on only one occasion during this survey.

If *A. gracilipes* were to spread to tropical horticultural production areas the ant could damage sugar cane and tree crops as a result of excavating around root systems, encouraging sap-feeding insects and reducing the effectiveness of parasites and predators of pest species.

Monsoon rainforest occurs throughout north and north-western Australia as isolated patches (typically 1-10 ha), usually associated with permanent water, surrounded by vast areas of savanna woodland (Russell-Smith 1991). These rainforests have a very significant ant fauna (Reichel and Andersen 1996), which is an important component of biodiversity in the Northern Territory (Hoffmann *et al.* 1999). The exotic ant *Pheidole megacephala* (F.) has significantly reduced the richness and abundance of native ants and other invertebrates in a rainforest patch at Howard Springs near Darwin (Hoffmann *et al.* 1999). In view of observations made on the Gove Peninsula, *A. gracilipes* can be regarded as an equally serious threat to the invertebrate fauna of monsoon rainforests in northern Australia.

The detection of the ant in 1990 on an isolated creek bank more than 80 km from the nearest town and the subsequent discoveries of populations spread over 2,500 km², suggest that the ant has been established in the area for at least several decades. Furthermore, its presence along creeks far removed from human habitation suggests that the initial introduction could go back to mining exploration in the last 30 or 40 years, construction and military activities during the Second World War or even to the annual visits of Maccassan traders more than a century ago. There are undoubtedly populations of *A. gracilipes* on the Gove Peninsula that remain undetected and in view of the large and inaccessible area known to be infested, an eradication campaign would be very difficult.

Further dispersal of *A. gracilipes* by earth moving equipment and other vehicles from its current range is a continuing possibility and processes should be put in place to contain the ant in the Gove Peninsula.

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