Australian Journal of Entomology (2003) **42**, 367–372

Flight movement of *Scapanes australis australis* (Boisduval) (Coleoptera: Scarabaeidae: Dynastinae) in Papua New Guinea: a radiotelemetry study

Laurence Beaudoin-Ollivier,[1,2]* Frank Bonaccorso,[3] Michael Aloysius[1] and Mathew Kasiki[1]

[1]*PNG Cocoa & Coconut Research Institute, PO Box 642, Madang, Papua New Guinea.*
[2]*Centre International de Recherche Agronomique pour le Développement, CIRAD-CP, TA 80/02 Avenue Agropolis, 34398 Montpellier cedex 5, France.*
[3]*Papua New Guinea National Museum and Art Gallery, PO Box 5560, Boroko, NCD, Papua New Guinea.*

Abstract We used radiotelemetry and/or chemical light-tags to track the flight of 15 individuals of *Scapanes australis* in Madang Province, Papua New Guinea. This species causes severe economic impacts on coconut palms in young plantations. Flights to feeding, mating, resting, and possibly oviposition sites covered distances of 52 to 835 m in males, and from 245 m to >1000 m in females. Upon release, females flew in a tight upward spiral above canopy level (>20 m), then usually flew along a single bearing out of radio reception within 1 min of initiating flight. Dispersing females probably follow scent trails to pheromone-releasing males that occupy feeding galleries excavated most frequently in coconut palms, or search for oviposition sites. Most tagged females were not found again, because they dispersed beyond the tracking capabilities of our radio-receivers, but one female was followed for 245 m to a feeding gallery excavated by an adult male. Males typically flew within 5 m of the ground, took erratic flight paths with numerous turns, and frequently circled coconuts and other host plants. We followed males from the release point until they ceased flight for a night. Males passed daylight hours either in a feeding gallery within a host plant or under soil litter.

Key words *Scapanes australis*, Coleoptera, flight distance, Papua New Guinea, radiotelemetry.

INTRODUCTION

Scapanes australis australis (Boisduval) is a large (40–58 mm long), nocturnal dynastine beetle of Papua New Guinea that causes severe damage to young trees in coconut plantations. The adult bores a gallery directly into the upper trunk, often destroying the growing bud and curtailing development of the palm. Less frequently, this beetle similarly damages the betelnut palm (*Areca catechu*) or banana plants (*Musa* spp.). Flight activity of *S. australis* peaks between 1830 and 2130 h each night, even during its reproductive period (Macfarlane 1982; Morin 1998; Beaudoin-Ollivier unpubl. data 2000). Bedford (1974, 1975, 1976), Morin (1998) and Prior *et al*. (2000) reported on microhabitat selection of adults and offered differing interpretations of flight performance, with the beetle being noted as a strong flier (Bedford 1976), a clumsy flier (Morin 1998) and a good nocturnal flier (Prior *et al*. 2000). Kakul *et al*. (1999) estimated that *S. australis* flies from ground level up to 10 m, based on captures in traps baited with pheromone scents. In damaged palms, males outnumber females (Bedford 1975; Morin 1998; Beaudoin-Ollivier unpubl. data 1999). Bedford (1975) suggested that males and females behave differently: males spend time more feeding and occupying host plants (for mating, resting, and feeding) than do females, which presumably devote much time searching for breeding males and oviposition sites.

Radiotelemetry has been a valuable tool in the study of animal movement for more than four decades. Recently, miniature transmitters (<10 g mass), suitable for attachment to insects and other animals, have become commercially available. Among the first uses of radio-telemetry to track insect movements have been studies on movement and dispersal of the scarab beetle *Osmoderma erimita* Scopoli, which does not fly very often and remains within 80 m of the point of capture (Thomas Ranius pers. comm. 1998). In another pioneering radio-telemetry study, the ground beetle, *Carabus coriaceus* L., a flightless species, had a maximum linear dispersal range of 388 m (Riecken & Raths 1996).

We report here the first radiotelemetry study of coleopteran flight movements. We attached miniature transmitters onto the prothorax of *S. australis* to measure distances of individual flights and cumulative movements over multiple nights for 15 *S. australis* adults of both sexes. We describe flight patterns, behaviour associated with selection of host plants, and the height of flights made by *S. australis*. We also present information on beetles followed to mating galleries, use of feeding plants, and diurnal resting sites. We failed to find the oviposition sites of females in the study area.

*Author to whom correspondence should be addressed (email: laurence.ollivier@cirad.fr).

MATERIALS AND METHODS

Our study area was 2 km south of the North Coast Highway and 90 km from Madang (4°41′S, 145°43′E), near Malas Village, Madang Province, Papua New Guinea. The landscape is characterised by secondary forest and smallholder gardens on a coastal plain with little slope and is dissected by small rivers and streams.

We used LB-2 transmitters manufactured by Holohil Systems (Carp, Ontario, Canada). These transmitters had a mass of 0.47–0.49 g, a frequency range in the 151 MHz band, and a battery life of approximately 10 days. Once a transmitter was activated by a solder connection to the battery, the best reception frequency was checked on a TRX-2000 S tracking receiver (Wildlife Materials, Carbondale, Illinois, USA). Transmitters were activated for 4 h, then checked for frequency drift and attached to the prothorax of a beetle with a drop of SuperGlue–3 (Henkel France s.a., Boulogme Billancourt, France) reinforced with medical tape (Fig. 1). The transmitter did not impede flight. The transmitter and adhesive were approximately 0.6 g, or 5–7% of the mass of a male *S. australis* and 6–7% of a female. A three-element, 140 mm long, Yagi antenna (Wildlife Materials, Carbondale, Il, USA) plugged into the receiver unit provided a maximum tracking range of 500 m at ground level.

We also marked some beetles for short-duration flight-tracking with chemical light-tags. These individuals had a 3 × 23 mm plastic cylinder of 0.18 g mass containing an enzyme substrate producing light (Star Light, Osaka Kagaku, Japan) attached just before release. These cylinders produced light for <3 h, and permitted observers to have continuous visual observation of flight paths until the light-tag faded. Two large males carried both radio transmitters and light tags of 0.8 g total mass, so that their flight paths could be followed for several hours and their diurnal resting positions located over several additional days.

Eight female and three male *S. australis* selected for their ability to fly after 10 min release in the laboratory were fitted with radio transmitters. In December 1998, we used radio transmitters on five beetles and in June 2000 on an additional six beetles. Two additional males and two additional females were equipped only with light tags. All radio- and light-tagged beetles were collected in plastic bucket-traps baited with pheromone and sugarcane (as synergist) or from damaged coconut crowns within a 0.83 ha area. No data were available on age, maturity, or sexual receptivity, but the body mass of each beetle was recorded on the day of release. All tagged individuals were fed on sugarcane for a maximum of 1 week in a laboratory to ensure that they were hydrated and well fed. All tagged beetles were released at a common point within the 0.83 ha collection area.

Fig. 1. Adult male *Scapanes australis australis* with transmitter device placed on the prothorax.

Using a hand held compass (Suunto, Helsinki, Finland) and a tape measure, we created a map of the 12 ha study area (Fig. 2) from 23 reference points along approximately 900 m of interconnecting roads, footpaths and creeks. Tracking stations were established at reference points usually within 20–100 m of activity centres or resting sites for each beetle. Receivers were moved as necessary to improve reception or to record multiple bearings on a stationary beetle. Bearings were read to the nearest degree. Time, signal strength, and gain setting (from gradations added by us to the gain dial of the receiver) were recorded with each bearing. Some positions were determined by triangulation from two or more reference points when a beetle was stationary. During flight, positions were calculated from single bearings along which distance was estimated from signal strength and gain (Law & Lean 1999; Winkelmann *et al*. 2000). The relationship of signal strength to distance was experimentally calibrated in the study area at standardised gain settings. With practice, single-bearing position-determination was equivalent to triangulation in accuracy (±15 m for most instances that were cross-checked) when limited to target animals within 150 m of the observer.

Beetles usually fly during the first hours of the night (Macfarlane 1982; Morin 1998), so we tracked beetles between 18.30 and 22.15 hours. For individuals with light tags, we were able to rapidly plot locations as they flew from the release point. We located the radio-tagged beetles during diurnal inactivity once every 24 h. Initially, we took the bearing of the signal, and walked in this direction until we located the beetle. We were able to determine the precise resting place of a beetle either in soil litter or on host plants using the attenuation feature of the TRX receiver and often could visually locate the beetle, usually by first seeing a small piece of coloured tape flagging the tip of the transmitter antennae (Fig. 1). The positions of beetles were marked with numbered flags and the distances and angles between successive movements were measured the following day and used to plot movements and resting positions of each beetle during its first night carrying the transmitter (Fig. 2). Subsequent movements were recorded once per day during daylight hours. Once a released beetle selected a feeding plant or mating gallery, it rarely moved on subsequent nights during the life of the radio-battery.

In December 1998, there was a half moon during the tracking period, whereas in June 2000, the moon was full or nearly full. Air temperatures were 24–29°C, and relative

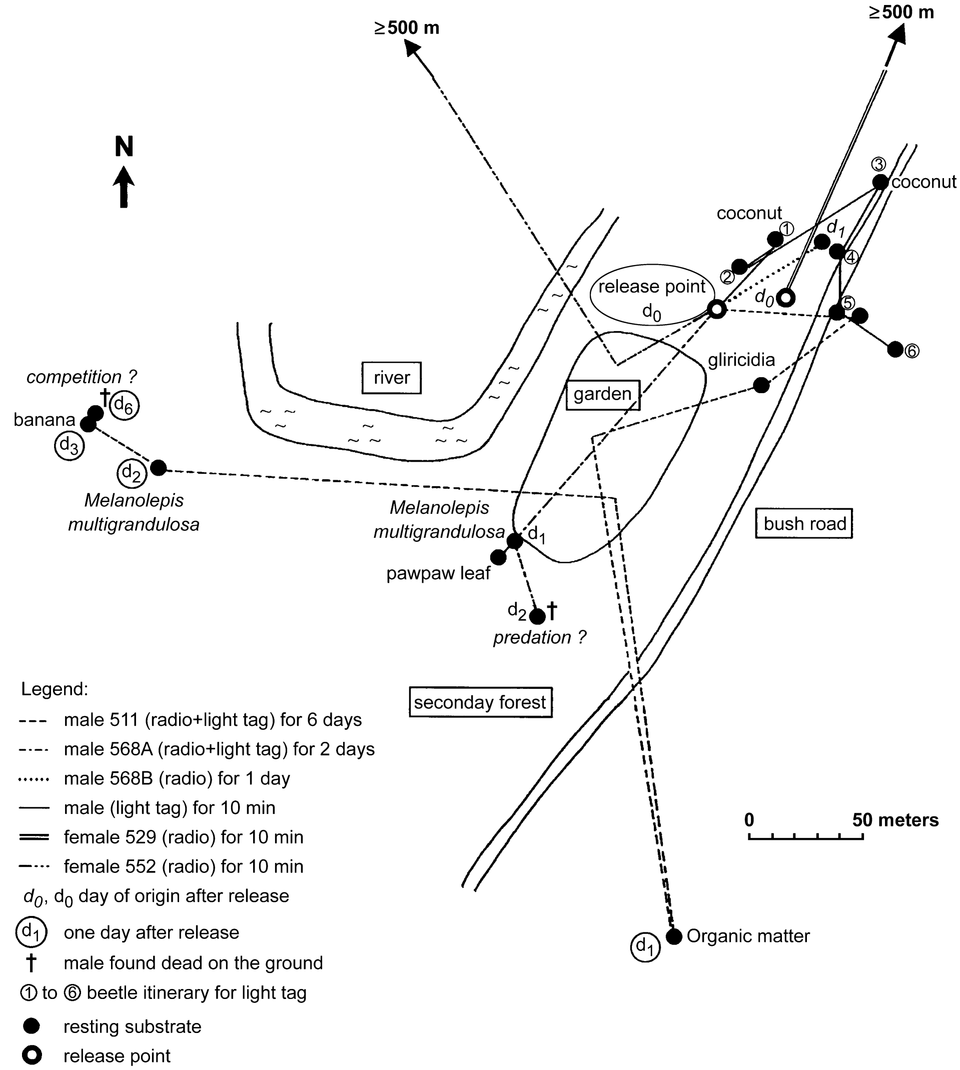

Fig. 2. Movement patterns of six individuals of *Scapanes australis australis* in a regrowth secondary forest and land planted as gardens by smallholders.

humidity was 86–94% in June 2000. They were not recorded in December 1998. Temperature and relative humidity were obtained from a portable electronic thermohygrometer (model ETHG913R, Oregon Scientific, Portland, Oregon, USA).

RESULTS

The movements of four males are shown in Figure 2 and summarised in Table 1. Light-tagged males confined flight to within 5 m of the ground, flew in zig-zag paths initially, and then in tight circles around host plants once these were encountered. Each male briefly landed on multiple potential host plants before settling for 1 or more days. One male was observed over a flight course of 210 m (Fig. 2, Table 1). Coconut palms were highly favoured, as indicated by circular flights around them and landings. One male equipped with a light tag was observed exploring several plants (Fig. 2). Some males sampled several host plants on the release night, but spent the following day buried in soil litter before choosing a host plant on a subsequent night. In addition to coconut palms, plants used for resting or feeding are *Gliricidia sepium, Melanolepis multigrandulosa*, *Carica papaya, Areca catechu* and *Musa peekelii.* Most males first landed on a host plant within 50 m of the release point, but then flew and landed repeatedly while sampling potential hosts over increasing distances. Over longer distances, we were successful in following males (but not females) on foot with the receiver units. Males had maximum displacement of 835 m from the release point.

Females made brief spiralling flights to rise above canopy level (20–30 m), then usually flew along a steady bearing until they were beyond the range of our receivers. They disappeared from telemetry contact within several minutes of initial flight. Although we could determine the bearing along which most females disappeared, usually we could not find the females again. However, one female was found 16 h after release inside a feeding gallery within a coconut tree also occupied by a male. This female had moved 245 m from the release point. We attempted to find other females after they disappeared by walking along the bearing during the night of

Table 1 Flight distances and resting substrates of radio-tagged and light-tagged adult *Scapanes australis australis*

Sex	ID	Body mass (g)	Tag	Flight distance (m)	Cumulative distance (m)	Resting substrate	Time on substrate	Day after release	Release date
Male	511	6.87	radio†	109	109	*Gliricidia*	3 min	0	13 June 2000
				300	409	soil litter	1 day	1	
				193	602	*Melanolepis*	1 day	2	
				199	801	*Musa*	1 day	3	
				(34)	(835)	dead, on ground	–	6	
Male	568 A	8.73	radio†	142	142	*Carica*	–	0	15 June 2000
				6	148	*Melanolepis*	1 day	1	
				(32)	(180)	dead, on ground	–	2	
Male	568 B	–	radio	52	52	coconut gallery	1 day	1	19 June 2000
Male	003	–	light	36	36	coconut crown	–	0	13 June 2000
				19	55	coconut crown	–	0	
				69	124	coconut crown	–	0	
				35	159	coconut crown	–	0	
				25	184	coconut crown	–	0	
				26	210	coconut crown	–	0	
Male	004	–	light	>100	–	lost	–	0	13 June 2000
Female	329 a	7.35	radio	245	245	male feeding gallery, coconut	>6 h	1	7 December 1998
Female	350	7.58	radio	>500	–	n.r.	–	1	7 December 1998
Female	329 b	6.43	radio	>500	–	n.r.	–	1	9 December 1998
Female	371	7.73	radio	>500	–	n.r.	–	1	9 December 1998
Female	391	7.63	radio	>500	–	n.r.	–	1	9 December 1998
Female	529	6.78	radio	>1000	–	n.r.	–	1	12 June 2000
Female	511	7.13	radio	0	–	n.r.	–	1	13 June 2000
Female	552	8.95	radio	>1000	–	n.r.	–	1	13 June 2000
Female	001	–	light	>100	–	n.r.	–	0	12 June 2000
Female	002	6.93	light	>100	–	n.r.	–	0	June 2000

n.r., not recorded; †radio plus light tag. Numbers in parentheses indicate displacement of beetle carcass by a predator.

release and the following day, and by driving in the direction of the last recorded bearing the following day. These females moved >500 m within several minutes of release and we are confident they moved well beyond 1 km within a single night, because we could not locate radio signals the following day even when moving several kilometers in a north–south direction along a road (searching in an east–west direction was limited to 400 m because of the lack of a road).

All of the flights during our study occurred at temperatures <28°C and relative humidity (RH) >85%. The start of flights appeared to be synchronised to sunset (18.15 hours), and then lasted for 1–4 h. First flight was recorded at 18.30 hours and last flight at 22.15 hours.

The total area covered by the experimental beetles (excluding females that flew out of telemetry range) was 12 ha. We were able to track male beetles for a maximum of 6 days before transmitter batteries failed or we left the study site.

DISCUSSION

Scapanes australis is a serious pest of coconuts and damage from this beetle is particularly severe in East New Britain and Madang Provinces. Our study of the movement of *S. australis* provides a basis for understanding their microhabitat and dispersal behaviour and will allow researchers in Papua New Guinea to more thoroughly interpret trapping data and develop strategies to optimise methods to control this pest in plantations. Although previous mark-and-recapture experiments (Macfarlane 1982) on *S. australis* measured average distances traveled, that technique provided no information on detailed behaviour during flight. Our study, using a combination of radio- and light-tagging, allowed us to make observations of host-plant and habitat selection, the precise location of feeding and mating sites, and also demonstrated previously unknown sexual differences in the flight patterns and distance of movements of *S. australis*.

Free-roaming insects often behave differently than tethered insects in their flight behaviour (see Kutsch 1999). For example, tethering influences flight performance in locusts (Zarnack & Wortmann 1989) and also wing-beat frequency is higher in free flight than in a tethered condition (Baker *et al.* 1981; Kutsch & Stevenson 1981). We suggest that radio- and light-tags of <8% of body mass modify flight behaviour far less than tethering. They probably have negligible effects, because the insect has freedom to move where it chooses, and the behaviours we observed appear similar to natural behaviours. Thus, radio-telemetry using light-weight transmitters attached so as not to impede flight mechanics opens numerous possibilities for the study of free-roaming insects in their natural habitats.

Females apparently move long distances from mating sites in coconut plantations to egg-laying sites possibly in forest habitats (Macfarlane 1982). Six of the seven females that we fitted with radios moved >500 m (the maximum detection range of the transmitter) within 3 min of release. Possibly females are dispersing greater distances to insure outbreeding with unrelated males because the cost of flight is less for females given their smaller body mass and wing-loading. Although newly emerged beetles might show different movement patterns (Sanders 1984), our experiments demonstrate that *S. australis* females can disperse over distances of >1000 m within a night. Thus populations may colonise isolated blocks of habitat and this has implications for pest-management strategies.

Whilst dispersing females fly above the forest canopy and move large distances, males remain below the canopy, flying with many turns and circling patterns. However, over several days males search for host plants in areas of up to 12 ha during repeated short flights. Four males settled on host plants within 500 m of the release point. Some of these males remained in a single feeding gallery for a few days, whereas others moved amongst several host plants in the same period. Similar movements in search of host plants occur in the bark beetle, *Ips typographus* L. (Forsse & Solbreck 1985).

Although our results are limited to a small number of individuals, the understanding of movement in *S. australis* is critical for understanding the impact of beetle colonisation in young coconut plantations. Males probably search out species-specific chemical signatures emitted from host plants that offer food and a hiding place from predators. Once several potential hosts are sampled and a suitable host plant is selected, a male excavates a feeding gallery and then releases a mating and aggregative pheromone that attracts both males and females. Copulation occurs in the feeding gallery and resident males may compete with intruding males for the feeding gallery and for access mating with females coming to the gallery. High priorities for future investigation using telemetry might include the following: how do males and females orientate towards male pheromones source according aggregation pheromone identification (Rochat *et al.* 2000)? Do differences exist in the movements of starved and satiated beetles; are there correlations between flight behaviour and nutrient reserves (Nemec *et al.* 1993)? Do movements and behaviour patterns differ in the two subspecies, *S. a. australis* and *S. a. grossepunctatus*?

With the recent development of miniature transmitters, radiotelemetry is a useful technique making it feasible to follow flying insects >5 g in body mass. Especially in tropical environments, there are many candidate species among the Coleoptera, Lepidoptera and Orthoptera. Our study is the first use of radiotelemetry to track the movements of flying Coleoptera, although ground-dwelling or sedentary beetles previously have been studied with this technique (Riecken & Raths 1996). Radio-telemetry allows behaviour to be observed directly or indirectly. For example, the precise timing, location and distance of movements, flight dynamics, and dispersal patterns may be observed, also microhabitat preferences over daily and seasonal cycles can be determined. Furthermore, it is possible to identify simultaneously a large number of animals within an ecosystem and to follow their individual movements.

ACKNOWLEDGEMENTS

Funding for this study was provided by the Cocoa and Coconut Research Institute, Papua New Guinea, and the Stabex Funds of the European Union. We are grateful to the landowners at Malas, especially to Anton, for permitting our radio telemetry observations on his property. We thank Mastic for providing security for our camp and equipment during our fieldwork. Kalangpain Samai and Kelu, assistants in the entomology section at the Cocoa and Coconut Research Institute, cared for beetles in the laboratory. We thank J. Winkelmann for assistance with transport of the radio transmitters to Papua New Guinea and for critically reading our manuscript. This paper is Number 14 in the Contributions in Natural History of the Papua New Guinea National Museum and Art Gallery.

REFERENCES

Baker PS, Gewecke M & Cooter RI. 1981. The natural flight of the migratory locust, *Locusta migratoria* L. III. Wing-beat frequency, flight speed and attitude. *Journal of Comparative Physiology* **141**, 233–237.

Bedford GO. 1974. Descriptions of the larvae of some rhinoceros beetles (Col. Scarabaeidae, Dynastinae) associated with coconut palms in New Guinea. *Bulletin of Entomological Research* **63**, 445–472.

Bedford GO. 1975. Immigration of *Oryctes rhinoceros* (L.) and *Scapanes australis grossepunctatus* Sternb. (Coleoptera, Scarabaeidae, Dynastinae) into plantings of young coconut palms in New Britain. *Bulletin of Entomological Research* **65**, 109–116.

Bedford GO. 1976. Observations on the biology and ecology of *Oryctes rhinoceros* and *Scapanes australis* (Coleoptera: Scarabaeidae: Dynastinae): Pest of coconut palms in Melanesia. *Journal of the Australian Entomological Society* **15**, 241–251.

Forsse E & Solbreck C. 1985. Migration in the bark beetle *Ips typographus* duration timing and height of flight. *Zeitschrift für Angewandte Entomologie* **100**, 47–57.

Kakul TK, Laup S, Stathers T, Beaudoin-Ollivier L, Morin JP & Rochat D. 1999. Trapping and disruption of the mating activity of *Scapanes australis* using live males as bait in Papua New Guinea. *Coconut Research and Development* **15**, 131–149.

Kutsch W. 1999. Telemetry in insects: the 'intact animal approach'. *Theory in Biosciences* **118**, 29–53.

Kutsch W & Stevenson P. 1981. Time-correlated flights of juvenile and mature locusts: a comparison between free and tethered animals. *Journal of Insect Physiology* **27**, 455–459.

Law BS & Lean M. 1999. Common blossom bats (*Syconycteris australis*) as pollinators in fragmented Australian tropical rainforest. *Biological Conservation* **91**, 201–212.

Macfarlane R. 1982. *Entomologist's Report. Ministry of Home Affairs and National Development 1981–82.* Solomon Islands Government, Honiara, Solomon Islands.

Morin JP. 1998. *Study Mission to Detect a Pheromone in* Scapanes australis *in Papua New Guinea. 9 November to 16 December 1997.* Doc CP 939. CIRAD, Montpellier, France.

Nemec V, Zumr V & Stary P. 1993. Studies on the nutritional state and the response to aggregation pheromones in the bark beetle, *Ips typographus* (L.) (Col. Scolytidae). *Journal of Applied Entomology* **116**, 358–363.

Prior RNB, Morin JP & Rochat D *et al*. 2000. New aspects of the biology of the Melanesian rhinoceros beetle *Scapanes australis* (Col. Dynastidae) and evidence for field attraction to males. *Journal of Applied Entomology* **124**, 41–50.

Riecken U & Raths U. 1996. Use of radiotelemetry for studying dispersal and habitat use of *Carabus coriaceus* L. *Annales Zoologici Fennici* **33**, 109–116.

Rochat D, Ramirez-Lucas P, Malosse C, Aldana R, Kakul T & Morin JP. 2000. Role of solid-phase microextraction in the identification of highly volatile pheromones of two rhinoceros beetles *Scapanes australis* and *Strategus aloeus* (Coleoptera, Scarabaeidae, Dynastinae). *Journal of Chromatography A* **885**, 433–444.

Sanders W. 1984. The behavior of the scolytid, *Ips typographus*, during the flight period. *Anzeiger für Schaedlingskdunde Pflanzenschutz Umweltschutz* **57**, 131–134.

Winkelmann JR, Bonaccorso FJ & Strickler TL. 2000. Home range of the southern blossom bat, *Syconycteris australis,* Papua New Guinea. *Journal of Mammalogy* **81**, 198–204.

Zarnack W & Wortmann M. 1989. On the so-called constant-lift reaction of migratory locusts. *Journal of Experimental Biology* **147**, 111–124.

Accepted for publication 16 May 2003.