

# HOME RANGE OF THE SOUTHERN BLOSSOM BAT, *SYCONYCTERIS AUSTRALIS*, IN PAPUA NEW GUINEA

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Southern blossom bats, *Syconycteris australis* (Pteropodidae), were followed by radiotelemetry in lowland rainforest in Kau Wildlife Area, Madang Province, Papua New Guinea. Eleven individuals were monitored  $\leq 31$  days. Based on 706 radiotelemetry positions, home ranges of 11 bats were 2.7–13.6 ha. There were no significant differences in home-range sizes between sex or age classes, but there was individual overlap of the home ranges of these bats. Long axes of home ranges were 263–725 m. During each night, bats visited most parts of their home ranges; however, activity was concentrated in core-use areas representing 19–33% of the home range and containing  $\geq 1$  food patches. During the day, *S. australis* roosted in the foliage of trees. Bats showed fidelity to a day-roost area (0.4–10.8% of home range) but not to a single roost tree. Day-roost areas monitored within a given year showed virtually no overlap.

**Key words:** core-use area, day roost, home range, Papua New Guinea, southern blossom bat, *Syconycteris*

Estimation of home range is a vintage topic in mammalogy, but few attempts have been made to determine home ranges of the Chiroptera. Rough descriptions of spatial use and foraging movements most commonly are based on mist-netting and mark-recapture (Handley et al. 1991; LaVal 1970; LaVal and Fitch 1977); however, these techniques usually provide too little information to reliably describe home range. Home range has been estimated for bats only in a few cases in which radiotelemetry has been employed (Clark et al. 1993; Fleming 1997; Jong 1994; Robinson and Stebbings 1997; Wilkinson and Bradbury 1988). Published home ranges in these species vary from 35 ha in the common vampire bat, *Desmodus rotundus*, to 300,000 km<sup>2</sup> in the migratory nectarivore, *Leptonycteris curasoae*.

We present estimates of home range, core-use area, and day-roost area for the southern blossom bat, *Syconycteris australis*. These studies are part of a larger project that includes foraging and feeding behavior and energetics of Old World plant-visiting bats (Bonaccorso and McNab 1997). We chose *S. australis* for its abundance and wide distribution in Papua New Guinea and because its small body size suggested a small home-range size. This species has a large geographic distribution from Indonesia through Papua New Guinea and along the eastern coast of Australia from Cape York into northern New South Wales (Bonaccorso and McNab 1997). In Papua New Guinea, it occurs in forested and disturbed habitats from sea level to 3,000 m elevation, and usually it is the most abundant bat species in all habitats (Flannery 1995). In New Guinea the diet of *S. australis* proba-

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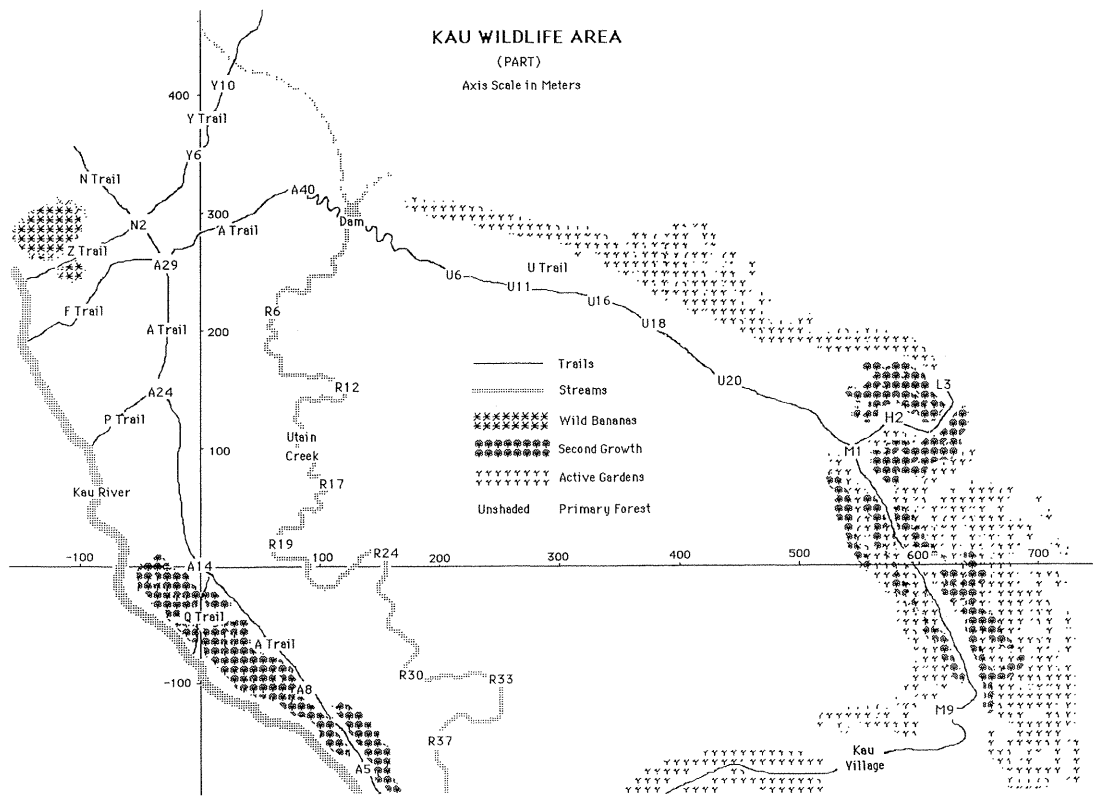


FIG. 1.—Map of the Kau Wildlife Area with reference points used in radiotracking and mist netting and to locate food resources and habitats. Scales for axes are in meters and are identical to those in Fig. 2 to permit cross-referencing.

bly includes fruit and nectar (Bonaccorso 1998). In Australia, there is evidence of geographic variation in the diet; in southern parts of their range, these bats are primarily nectarivorous, whereas in northeast Queensland they are facultative frugivores and to a lesser extent folivores (Law and Spencer 1995).

#### MATERIALS AND METHODS

Our study was undertaken 22 June–25 July 1994, 29 May–21 July 1995, 26 February–8 March 1996, and 4 June–6 July 1996 at the Kau Wildlife Area, Baitabag Village, Madang Province, Papua New Guinea. Kau was an 800-ha reserve of lowland rainforest at 20–66 m elevation that included primary old-growth (300 ha), successional, and riparian forests. The Biges and Kau Rivers and several small tributaries with permanent streams dissected the study

hills and valleys. There were numerous traditional vegetable and fruit gardens used in shifting agriculture adjacent to the wildlife area (Fig. 1). Mean annual precipitation for 1994–1996 at the nearby Christensen Research Institute was 3,460 mm (2,950–3,950 mm); the driest months were July and August (<100 mm/month).

With a compass and transect line, we mapped 150 reference points for radiotelemetry along trails (1.84 km) and Utain Creek (0.97 km) within the Kau Wildlife Area (Fig. 1). Reference points were marked with plastic flagging and metal tags and encompassed 39 ha.

Southern blossom bats were captured in mist nets; body mass (g), sex, age, and length of forearm were recorded, and each bat was fitted with a colored plastic band (A. C. Hughes, Ltd, Hampton Hill, Middlesex, United Kingdom) that passed through 2 slits cut in the patagium on either side of the distal forearm (Bonaccorso et al. 1976). This method of banding allowed

sition-sensitive radio transmitters (MD-2CP, Hohil Systems, Carp, Ontario, Canada). Transmitters were attached by a collar sheathed by surgical tubing and were stabilized at the back of the neck by Skinbond surgical cement (Smith and Nephew United, Largo, Florida). Complete transmitter units weighed about 1.75 g (<10% of the body mass of *S. australis*). We saw no evidence that radio weight altered the behavior of bats in flight cages, nor did we detect any change in the behavior of bats radiotracked  $\leq 31$  days in the field. Radiotagged animals were released near the site of capture, usually on the night of capture. Captive bats readily drank a 15% honey-water solution, and each bat was fed to satiation before release. Radiotelemetry data were not recorded on the night of release.

Animals were monitored with a 3-element Yagi antenna and a TRX 2000S tracking receiver (Wildlife Materials, Carbondale, Illinois). Tracking stations were located on map reference points. Most bearings were taken from a few primary stations, but receivers were moved as necessary to improve reception or to record additional bearings on a stationary bat. Bearings were taken with a handheld compass (Suunto, Helsinki, Finland) and were read to the nearest degree. Time, signal strength, and gain setting (from gradations added to the gain dial of the receiver) also were recorded for each bearing. Most nighttime positions were based on triangulations taken when a bat was stationary long enough to allow bearings to be recorded from  $\geq 2$  map locations. Some positions of bats were calculated from single bearings, and distance was estimated from signal strength. Relationship of signal strength to distance was calibrated experimentally in the field at standardized gain settings, and some estimates were adjusted to account for topography and obstructions known to influence signal reception. During partial or whole-night position sampling, we rarely lost radio contact with focal animals. When we were unable to maintain contact with a disappearing bat, contact was always reestablished in <20 min.

A map of the study area (Fig. 1) was created, and positions for each bat were plotted. A grid was superimposed on the map, a zero intercept was chosen, and X,Y coordinates were determined for each position. For each bat, map coordinates were entered into a database that we accessed and analyzed using Antelope home-

range software (available at <http://www.biology.ucsd.edu/research/vehrencamp/programs.html>—J. Bradbury and S. Vehrencamp, in litt.). Following Wilkinson and Bradbury (1988), we used Anderson Fourier analysis (nonparametric) to calculate minimum area probabilities (MAP) for each bat. By convention, home range was defined as  $MAP = 0.95$  and core-use area as  $MAP = 0.5$ . We also included day-roost area for each bat. Because sample sizes for day roosts were smaller, we chose the nonprobabilistic minimum-convex-polygon method for analysis (Odum and Kuenzler 1955; Wilkinson and Bradbury 1988). Results are reported as  $\bar{X} \pm SD$ . Means for sex and age classes were compared for statistical significance ( $P < 0.05$ ) using *F*-tests.

## RESULTS

We include statistics for 11 *S. australis* for which position sample sizes were  $\geq 20$  (Table 1). Home ranges were 2.7–13.6 ha. The largest home range, occupied by adult female 110A, was more than twice that of the next largest home range. That bat also had the greatest long axis, 725 m. Male 110 had the smallest home range (2.7 ha) and core-use area (0.5 ha) but was radiotracked for portions of only 6 nights over 8 days. Mean home range of females was insignificantly larger than that of males (Table 2). With males and females pooled, there was no difference in mean home ranges between adults and subadults.

Marked southern blossom bats maintained stable home ranges for the durations of their tracking periods ( $\leq 31$  days). Home ranges overlapped between numerous individuals (Fig. 2), especially along Utain Creek, a main flyway through the center of our study area. Of 4 bats tracked during the same time period in 1996, home ranges of 2 females overlapped with each other and with those of 2 males, but the home ranges of the 2 males did not overlap.

The core-use areas of the 11 radiotagged *S. australis* ranged from 0.5 to 3.9 ha (Table 1) and represented 19–33% of the home ranges. Core-use areas contained  $\geq 1$  food resource patches known to be utilized by southern blossom bats.

TABLE 1.—Minimum area probabilities (MAP) and day-roost area of southern blossom bats in Papua New Guinea, 1994–1996.

Bat number	Sex	Age	Home range and core-use area			Day roost		
			<i>n</i>	95% MAP (ha)	Axis (m)	50% MAP (ha)	<i>n</i>	Area (ha)
110	M	Adult	105	2.7	263	0.5	5	0.01
169	M	Adult	77	6.5	575	1.3	15	0.32
159	F	Adult	145	6.9	520	1.9	16	0.69
209	F	Adult	54	5.1	499	1.7	12	0.54
190	F	Adult	91	4.3	400	1.3	6	0.39
150	M	Adult	24	3.7	378	1.1	15	0.25
129	M	Subadult	60	5.5	680	1.3	8	0.43
110A	F	Adult	24	13.6	725	3.9	8	0.16
089	F	Subadult	22	4.0	496	1.3	8	0.43
189	M	Subadult	38	3.1	287	0.8	8	0.31
170	M	Subadult	66	4.8	497	1.1	11	0.45

The day-roost areas (Table 1) of *S. australis* ranged from 0.01 to 0.69 ha. Distributions of day-roost positions for the 4 bats tracked simultaneously in 1996 showed only marginal overlap. All day-roost sites for each bat were located within its home range. With 1 exception, southern blossom bats selected roosting trees in riparian or old-growth forest. Although we could not find roosting bats visually, even with the aid of 8 by 10 binoculars, we were able to locate roost trees with confidence using radiotelemetry. Most were understory trees, <0.5 m diameter at breast height and <15 m high, but a few were canopy trees. All trees serving as day roosts had moderately large to large leaves (20–30 cm) that provided a shady, well-hidden retreat for these cryptic bats. When held in 5 by 2 by 2 m flight cages with a few rooted plants, these bats were sometimes difficult to find be-

cause they sheltered under drooping or folded leaves (these were not “tents” constructed by the bats—sensu Kunz et al. 1994). Adult male 110 had the smallest day-roost area and the smallest home range. This bat roosted most often just outside primary forest in a large tree (about 0.6 m DBH) surrounded by young successional shrubs close to a very rich fruiting stand of *Piper aduncum*.

#### DISCUSSION

The few published studies of home range in bats indicate that there is large size variation linked to distribution of food in space and time. Mean home range of *S. australis* at Kau Wildlife Area was 5.5 ha (Table 2); this is smaller than for any other species of bat yet studied. Common vampire bats, *Desmodus rotundus*, tracked in Costa Rica over 8 days (Wilkinson 1985) had a mean

TABLE 2.—Minimum area probabilities (MAP), day-roost area, and long axis of home range of southern blossom bats in Papua New Guinea, 1994–1996.

Group	<i>n</i>	95% MAP (ha)		50% MAP (ha)		Day-roost (ha)		Axis (m)	
		$\bar{X}$	<i>SD</i>	$\bar{X}$	<i>SD</i>	$\bar{X}$	<i>SD</i>	$\bar{X}$	<i>SD</i>
All	11	5.5	3.0	1.5	0.9	0.4	0.2	484	145
Adult males	3	4.3	2.0	2.9	0.4	0.2	0.2	405	158
Adult females	4	7.5	4.2	2.2	1.2	0.5	0.2	536	136
All adults	7	6.1	3.6	1.7	1.1	0.3	0.2	480	150
All subadults	4	4.4	1.0	1.1	0.2	0.4	0.1	490	161

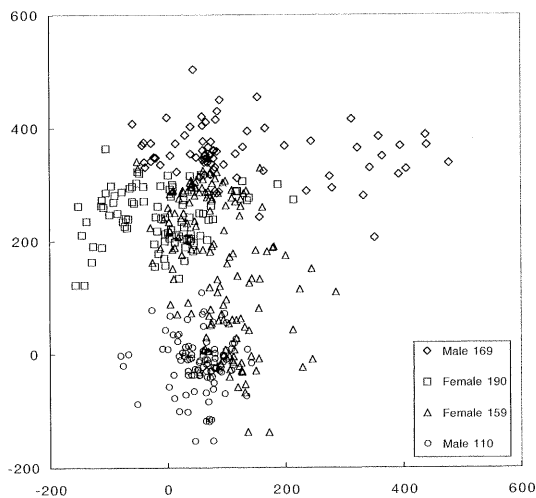


FIG. 2.—Radiotelemetry positions of 4 *S. australis* tracked during overlapping time periods in June–July 1996. Scales for axes are in meters; total area of the plot is 64 ha.

home range of 35 ha. At this site, vampires fed on cattle that were rotated among pastures. Clark et al. (1993) radiotracked lactating *Plecotus townsendii* in Oklahoma and found that foraging areas of individuals determined by the minimum-convex-polygon method were 37–727 ha. Variations in size and location of foraging areas and distance from the maternity colony were affected by variability in insect densities, changing energy demands, visits to the cave to nurse, and competition with newly volant young. Robinson and Stebbings (1997) determined that the home ranges of 32 *Eptesicus serotinus* in Great Britain were 1,600–475,800 ha. This colonial species switches foraging areas in response to fluctuations in insect availability and returns to the same day roost throughout the year. *E. nilssoni* in Sweden also switches foraging sites through the summer with movements  $\leq 30$  km from the day roost (Jong 1994). Within serial periods of about 10 days, these bats have mean home ranges of 11.6–23.1 ha. Fleming (1997) reported the annual home range of the nectarivore *Leptonycteris curasoae* to be about 300,000 km<sup>2</sup>. During their annual migration between Arizona and

Jalisco, Mexico, individuals of this species have 1-way movements of 1,500 km in response to the seasonal availability of flowering cacti and agaves (Ceballos et al. 1997). Because home range of *L. curasoae* was calculated as a minimum convex polygon, it included long migration corridors as well as foraging areas. *Carollia perspicillata*, a 20-g frugivore, undertakes small-scale migrations between habitats in dry tropical forest in Costa Rica and has an annual home range of 500 km<sup>2</sup> (Fleming 1997). Terrestrial mammals of size similar to *S. australis* generally occupy smaller home ranges. For example, *Microtus ochrogaster* and *Synaptomys cooperi* had home ranges of  $\leq 0.7$  ha (Danielson and Swihart 1987).

Heithaus and Fleming (1978) measured foraging movements of 105 individual short-tailed fruit bats (*Carollia perspicillata*) in dry tropical forest in Costa Rica. Although they did not calculate home range, maximum 1-way foraging distance from a central roost cave was 3,200 m in the wet season. In the dry season, many individuals moved to new roost sites and foraging areas and thus had a large annual home range. At the Kau study site, the greatest long axis of home range in *S. australis* was 725 m. In New South Wales, at the southern margin of its geographic range, *S. australis* is primarily a nectarivore, and individuals commuted  $\leq 4,000$  m to feed in coastal heathland (Law 1993). Despite similarities in size (17–20 g) and food habits (*Piper* and *Ficus* species) between *C. perspicillata* and *S. australis*, it is not surprising that a central refuging species such as *C. perspicillata* had a larger foraging range than a solitary foliage-roosting species such as *S. australis*. Also, rainforest and its successional stages may provide a higher density of food resources than dry tropical forest.

Core-use area represented about one-third or less of the home range of *S. australis* (Table 2). Core-use areas had little overlap between individuals monitored within a year. However more overlap may

occur because  $\leq 5$  individuals were monitored in the same year. More bats were known to use the study area. For example, in 1995, we captured 19 *S. australis* in nets set along a section of Utain Creek spanning a straight line distance of 400 m. Moreover, only 4 of the 48 *S. australis* captured in 1994–1996 were recaptured in the same year and only one from the previous year. All core-use areas had  $\geq 1$  food patch (fruits of *Piper aduncum* or *Ficus* or flowers of *Musa*). It is unclear whether food resources within the core-use areas are defended from other individuals, but frequent audible vocalizations emitted by this species at Kau suggest that this may occur. These vocalizations were the same as those heard during agonistic encounters between individuals that we observed in a flight cage.

Most foliage roosting species change roosts frequently. Lewis (1995) found that 25 species of bats of 45 surveyed often changed roosts. Law (1993) noted that most roosts of *S. australis* in New South Wales coastal forests were in the foliage of sub-canopy trees, and most were occupied for only 1 night. Although blossom bats do not show long-term fidelity to individual roost trees at Kau, they do maintain fidelity to relatively small roost areas. By frequently switching roost trees, *S. australis* may minimize the ability of predators to locate roosts.

Foraging movements of *S. australis* often were predictable. For example, in 1996, bat 110 made several trips every night from west of Utain Creek to the vicinity of gardens north of U18, stayed for 15–20 minutes, and returned, essentially following the same flight path each time. Bat 209 sequentially visited the same 4 food patches on each of 3 consecutive nights in March 1996. Although no single bat was monitored for  $>31$  days, we believe that most *S. australis* are resident throughout the year at Kau Wildlife Area. Mist-netting and qualitative checks of key resource plants indicate that bat populations and food sources generally are stable throughout the year at this

site (F. Bonaccorso, in litt.). Furthermore, our telemetry studies took place in both wet and dry seasons, with no noticeable seasonal difference in home range or behavior of the bats.

In captivity, *S. australis* consumes 15% honey water from top-well feeder tubes. When offered papaya, bats seemed to prefer it to honey water. Papaya is abundant in gardens and probably is taken by *S. australis* after the fruits are opened by larger frugivores. Fruits of *Piper aduncum* also are eaten by captives, and seeds of this species appear more frequently than any other species in the feces of wild-caught bats. We netted *S. australis* in *P. aduncum* patches, in stands of wild and domestic bananas, and in  $\leq 1$  m of a cluster of small dark reddish figs (*Ficus*).

Several pteropodid bat species potentially compete for food resources with *S. australis* in the Kau Wildlife Area. *Macroglossus minimus*, a nectarivore, frequents primary forest and gardens. It is often caught in patches of wild and domestic bananas. *Dobsonia minor* also is common in the forest, where it feeds on *Ficus* fruits, and in successional areas, where *Piper aduncum* is abundant. Other frugivore species include *Paranyctimene raptor*, *Nyctimene albiventer*, and the less common *N. aello*. All these species use the same flyways and were sometimes captured in the same nets as *S. australis*.

At Kau, *S. australis* has the smallest home range of any bat yet studied. We believe that this results from relatively stable and abundant food resources, generalized diet of this species, and high availability of roost sites. Both mesic tropical forest and garden habitats at Kau produce fruits and flowers continuously despite a nominal dry season. Based on fecal samples, *S. australis* was found to feed on fruits of several species of *Ficus* and fruits of *Piper aduncum*. Netting and direct observation suggest significant use of nectar and pollen of both wild and domestic banana flowers. Finally, as solitary foliage roosters, *S. australis* are

not limited by roost sites. All previous home-range studies pertain to bat species that are concentrated by the limited availability of caves or tree hollows and thus must disperse to forage. We predict that other solitary, foliage-roosting bats in rain-forest environments also will have small home ranges.

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