The white-striped free-tailed bat (Tadarida australis) is a common species of insectivorous bat found in mainland Australia. Despite its abundance, very little is known about its roosting ecology. I used radiotelemetry collected during 3 seasons to examine roost fidelity and roosting associations of a summer roosting group. Bats were trapped at a large communal roost in subtropical urban Brisbane, Australia. A total of 132 radiotracking days and nights provided 509 bat-days of data, with each bat being tracked for 26.9 days ± 28.6 SD. Seventeen new roost trees were found, scattered throughout an area of >200 km². Roost cavities were located inside eucalypt trees >83 cm diameter at breast height. Tagged T. australis switched roosts every 10.6 ± 7.9 days on average and spent most of their time in day-roosts with smaller roosting groups despite being 1st caught at the communal roost. I quantified associations between pairs of tagged bats using a pairwise sharing index. The consistent negative values of the pairwise sharing index I calculated indicated that members associated with roost-mates less often than predicted by chance. However, bats typically associated at night at the communal roost, even when they did not occupy it during the day. For every day-visit recorded per bat at the communal roost, each bat visited the same roost twice at night on average. This suggests that nocturnal movements of individuals should be included in assessments of associations between individuals. I postulate that this species employs a fission–fusion pattern based on individual movements to and from 1 communal site. I also argue that the roost network of 1 communal roost and many satellite roosts may be regarded as a single interconnected unit.

Key words: fission–fusion, roost fidelity, roost network, roost-sharing behavior, roost-switching behavior, suburban Australia, Tadarida australis

In some mammal societies, stable social groups frequently divide into subgroups for varying periods of time before rejoining (e.g., Bräger 1999; Henzi et al. 1997; Packer et al. 1990; Robinson and Janson 1987). This phenomenon is known as fission–fusion (Kummer 1971). The mechanisms selecting for this behavior are not fully understood but have been discussed in the context of resource availability, maintenance of long-term relationships, and predation pressure (Henzi et al. 1997; Robinson and Janson 1987). The dynamics of separation and regrouping are usually described by examining group membership of individuals and determining the proportion of time these individuals spend together using association indices (e.g., Cross et al. 2005; Henzi et al. 1997; Kerth and König 1999; Willis and Brigham 2004).

Insectivorous bats are a suitable taxon in which to study fission–fusion dynamics because many species are known to shift roosts regularly (Kunz and Lumsden 2003). Bats roost in natural (e.g., caves, rock crevices, tree hollows, and tree foliage) or human-made structures (buildings, mines, and bat boxes). Roost changes may be influenced by season, reproductive stage, food availability, thermoregulation, predation pressure, parasite accumulation, site disturbance, or a combination of these (Kunz and Lumsden 2003; Lewis 1995). Some species shift roosts almost daily (roost lability, e.g., O’Donnell and Sedgeley 1999), whereas other species remain at the same site over several years (roost fidelity; e.g., McCracken and Bradbury 1981). In recent years the definition of the term “bat colony” (Bradbury 1977) has undergone revision. A colony is now regarded as a social unit of individuals based on the interactions of members (reviewed in Burland and Worthington Wilmer 2001). However, this social unit of roosting bats may still split into several subunits when bats select diurnal roost sites (Kerth and König 1999; Kerth et al. 2001; O’Donnell 2000). In some bat species, individuals appear to associate with certain roost-mates and roost in nonrandom aggregations spread over several roost sites, despite daily changes of roost sites, fluctuating group sizes, and overlap of foraging ranges...
The white-striped free-tailed bat, *Tadarida australis* Gray, 1838 (Molossidae), is an endemic insectivorous species of mainland Australia (Churchill 1998; Rhodes and Richards, in press). The species is a fast flyer and typically feeds at high altitudes (Churchill 1998). In urban areas of southeastern Queensland it roosts in the hollows of large eucalypt trees (Rhodes and Wardell-Johnson 2006). Ovulation, copulation, and fertilization occur late in the austral winter (Kitchener and Hudson 1982). Females give birth between mid-December and mid-January and aggregate in tree roosts with several hundred individuals (Rhodes and Richards, in press). Although the white-striped free-tailed bat is regarded as abundant, little is known about the roosting ecology of this species (Churchill 1998; Rhodes and Richards, in press).

The overall objective of my study was to investigate the roost-switching behavior of a known summer roosting group of *T. australis* at 1 communal roost. Specifically I addressed the following questions: How many bats use the communal roost and other roosts associated with the communal roost? Does trapping at the communal roost influence its use? To what extent does *T. australis* show roost fidelity? Do members of the roosting group switch roosts and exhibit fission–fusion sociality? Do individuals select roost-mates at random or do they share day-roosts with bats captured and radiotracked at the same time? Do tagged bats associate at night at any of the known roost sites?

**Materials and Methods**

**Study area.**—Field sites were located in the Brisbane River catchment, including metropolitan Brisbane and its outer suburbs, in subtropical, eastern Australia (27°30’S, 153°31’E; Fig. 1). The landscape is undulating and dominated by a mosaic of mostly urban developments with planted gardens, as well as parklands with scattered mature eucalypts, the most abundant being the forest red gum (*Eucalyptus tereticornis*). The metropolitan region includes bushland reserves, ranging from 1 to 20 km² in area. The fringes of metropolitan Brisbane are dominated by cleared pastures with scattered mature trees and larger bushland remnants (Catterall and Kingston 1993).

Capture and examination.—Bats were captured while exiting at dusk in 4 sets of mist nets (0.1–10 m high and 18 m wide) erected in a V-shape around the roost tree used by several hundred individuals (hereafter communal roost). This tree was located in a suburban park, 4 km south of Brisbane’s central business district. The mist nets were taken down 1 h after the 1st bats left the roost, even if bats still remained in the roost.

Pregnancy was detected by gently palpating the abdomen. Lactating females had swollen mammary glands from which milk could be expressed. Females without obvious nipples, with hair growing over their nipples, or both, were classified as nonreproductive. Reproductive males were identified by distended epididymides. Adults were distinguished from juveniles (young of the year) by fusion of the metacarpal–phalangeal joints (Racey 1974). Capture and handling methods were approved by the Animal Ethics Committee of Griffith University and followed guidelines for the care and use of animals approved by the American Society of Mammalogists (Animal Care and Use Committee 1998). Those individuals not involved in the radiotracking study were released at the roost site immediately after processing.

**Telemetry.**—I tracked *T. australis* during 3 different radiotracking periods: 22 radiotracking days during November 2001 (pregnancy), 88 days from February to May 2003 (lactation and postlactation), and 22 days in March and April 2002 (postlactation). In the 1st tracking period (November 2001), individuals carried 1.6-g transmitters (model BD-2G; Holohil Systems, Carp, Ontario, Canada; Table 1) attached between the scapulae (Hamilton and Barclay 1994) using Vetbond (3M, St. Paul, Minnesota).

In the 2nd period (March–April 2002), 6 transmitters were affixed using collars. Of these, 3 transmitters were 1.6-g models (MD-2C; Holohil Systems; Table 1) attached by a thin cotton thread that was inserted through a small, flexible plastic tube and knotted together at the back of the neck. The other 3 were 1.6-g model LT2 (Tiley Electronics, Ballina, New South Wales, Australia; Table 1) with customized surgical-rubber bands placed around the bat’s neck. The collar-transmitters and the aerials also were glued to the back of each individual in order to keep the transmitter and aerial fixed dorsally, avoiding unnecessary friction and reducing disturbance for each bat. All collars were designed to break open and fall off, because reliable recapture of individuals was impossible.

In the 3rd period (February–May 2003) 8 adult females were fitted with 1.9-g collar-transmitters (model MD-2C; Holohil Systems; Table 1) to allow for increased signal strength. A thicker cotton thread was used to keep the transmitter attached for up to 16 weeks. Transmitters of all 3 types represented 3.2–5.1% of mean body mass (Aldridge and Brigham 1988).

New roost sites were located by tracking bats from a car with an omnidirectional antenna mounted on the roof (model RA-5A; Telonics, Mesa, Arizona) connected to a Regal 2000 telemetry receiver (Tiley Electronics). Airspace restrictions...
**Table 1.**—Radiotelemetry data for 19 *Tadarida australis* gathered during November 2001, March–April 2002, and February–May 2003 in urban Brisbane, Australia.

<table>
<thead>
<tr>
<th>Bat no.</th>
<th>Sex</th>
<th>Reproductive status</th>
<th>Tracking days (n)</th>
<th>Transmitter type</th>
<th>Days in CR</th>
<th>Group size of CR (n)</th>
<th>Distance SR to CR (m)</th>
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</tbody>
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a F = female, M = male.
b NR = nonreproductive, Preg = pregnant, PL = postlactating.
c Number of radiotracking days where bat was accounted for.
d See text for explanations of transmitter types.
e CR = communal roost. Radiotracking days where bats were found roosting in the communal roost (e.g., bat 01 was found on capture night [C] and on day 20).
f Maximum number of bat exits at the communal roost counted during peak summer months (December–early March).
g Number of roosts other than the communal roost (satellite roosts [SRs]; — = no data; + = not all day-roosts were found.
h Distance from satellite roosts to the communal roosts (m).
i Maximum number of bat exits counted at each satellite roost.
j Number of times each bat has been recorded to visit the roost area (RA), to visit the communal roost (CR), or passing through the roost area for a short period of time (<2 min) during nighttime tracking.

and signal interference precluded use of aircraft for tracking. Once signals were detected, a 3-element, handheld unidirectional antenna (model AY/C Yagi antenna; Titley Electronics) in combination with a Regal receiver were used to locate the bat’s day-roost. Bats were tracked to day-roosts on a daily basis for as long as transmitters remained attached.

**Roost counts.**—Exit counts at the communal roost began 17 months before tracking, in order to document patterns of roost use before trapping commenced, and continued until the end of the study period (July 2000–June 2003). Tagged bats were tracked to new roost sites (hereafter satellite roosts) and roosting group sizes were assessed using exit counts. Roosts were observed from the ground, about 5 m away from the tree, where the roost entrance could be backlit against the sky but bats could not see the observer (emergence was otherwise delayed). Ultrasonic detectors (Anabat; Titley Electronics) were used to confirm species identification (Herr and Klomp 1997). Exit counts began 30 min before sunset and ceased 30 min after an individual had exited and bats could no longer be heard inside the roost. Counts were made once each week at each roost site during summer (November–March), and once each month during the rest of the year. At the communal roost, some bats approached the roost at dusk and entered before all bats had departed. Thus, I could only obtain a minimum estimate of group size. To avoid double counting individuals, I stopped counting once bats commenced entering the roost. Satellite roosts found in the summer period of 2001–2002 also were observed the following summer (2002–2003).

**Roost-switching behavior.**—Once roost trees were located via telemetry, I recorded location coordinates with a handheld global positioning system unit and measured biophysical tree and site characteristics (e.g., tree species, diameter, height, and roost entrance characteristics; see Rhodes and Wardell-Johnson [2006] for further details). To assess roost-switching patterns of individuals I mapped the movements of bats between their diurnal roost sites and measured the distances between consecutive roost sites per bat using global positioning system coordinates plotted on a digital aerial photograph with
a resolution of 0.6 m (Mapview—Queensland Department of Natural Resources and Water 2002). The percentage of roost use of each roost tree per bat was calculated by dividing the number of days spent by each bat in a particular roost location by the total number of tracking days multiplied by 100.

**Roost-sharing behavior.**—I used a pairwise sharing index (Willis and Brigham 2004, 2005) to assess whether tagged *T. australis* selected roost-mates at random or whether bats were more likely to share roosts with individuals captured and radiotracked at the same time. This index compares the observed rate of co-occupancy by pairs of bats with an expected value. The expected value is calculated based on the individual roost-switching behavior of each bat in the pair, combined with the number of simultaneous days that both bats were tracked (Willis and Brigham 2004, 2005). Positive values indicate that bats share roosts more often than expected by chance, whereas negative values indicate the bats share roosts less often than expected by chance (Willis and Brigham 2004). I only included bat pairs for which I knew the day-roost used by both individuals on at least 5 simultaneous days (Willis and Brigham 2004).

**Nocturnal use of the communal roost and surrounding area.**—One radiotelemetry station was located at the communal roost on all nights of tracking. The high elevation of this site made it well suited to following the movements of tagged bats, and also permitted simultaneous observation of the communal roost and surrounding area. Tracking was conducted each night, usually for 3–6 h after sunset, although I also tracked from the communal roost between midnight and sunrise on 2 occasions. I recorded time, location, and length of stay by each tagged bat at the communal roost.

**Nocturnal use of other roosts.**—In addition to observations at the communal roost, satellite roosts were observed once each week from sunset for up to 3 h. On 1 occasion the satellite roost used by bat 06 was observed from sunset to sunrise. Exit and entrance times and behavior were recorded for tagged and untagged bats. In addition, I checked for signals from tagged bats every 15 min to determine if tagged bats visited the satellite roost or its surrounding area.

**Statistical analysis.**—Tracking data were pooled as a consequence of the small sample size of different sexes and different reproductive stages. Data are presented in the text as means ± SD. *N* refers to the population number (e.g., number of animals), whereas *n* describes the sample size (e.g., number of observations or bat-days). Mann–Whitney *U*-tests were used to compare samples because many data sets were not normally distributed (Wilk–Shapiro statistics [W]). Correlation between variables was tested using Spearman’s *R* (Zar 1999). Significance was assessed using an alpha value of 0.05.

**RESULTS**

**Captures.**—I captured 100 bats at the communal roost on 3 trapping nights. In November 2001, 2 nonreproductive males and 17 pregnant females were captured. In March 2002, the majority of individuals captured were volant, almost fully grown juveniles (12 males and 3 females), indicating that the reproductive season had ended (Churchill 1998). The remaining 8 bats were adult, postlactating females. In February 2003, trapping was conducted during the expected lactation period when I predicted that the offspring were old enough to be left behind in the roost. All 58 bats captured were females and none showed any signs of reproduction (neither pregnant nor lactating), possibly as a consequence of a severe local drought in 2002–2003 in eastern Australia (Australian Government, Bureau of Meteorology 2006).

**Telemetry.**—I tracked 19 individuals on 132 nights giving a total of 509 bat-days (Table 1). Each bat was tracked for an average 26.9 ± 28.6 days (*N* = 19). Three pregnant females and 2 nonreproductive males were tagged in November 2001. Two females groomed off their transmitters the next day and transmitter signals from another 2 bats (1 female and 1 male) were not heard again after release. I followed the remaining male for 22 days (Table 1). In March and April 2002, 6 postlactating females were tracked for 2–22 days. In the last period (February–May 2003), I tracked 8 nonreproductive females for 10–88 days (Table 1).

**Roost trees and locations.**—The communal tree, a tallowwood (*Eucalyptus microcorys*), was 24 m tall, with a diameter of 100 cm (measured 1.3 m above the ground) and the roost entrance was located on the main trunk, 6 m above the ground. In addition to the communal tree, tagged bats used 17 other roost trees (Fig. 1). The average diameter of satellite roost trees was 82.8 ± 29.6 cm with heights of 11–43 m (25.0 ± 9.2 m; *n* = 17). The average height of the entrance to satellite roosts was 15.8 ± 6.3 m. Roost entrances were in branches or trunks, often leading to a larger trunk cavity with internal diameters of >30 cm (Rhodes and Wardell-Johnson 2006).

All satellite roosts were in eucalypts, both living (*n* = 12) and dead (*n* = 5). Specific identity of live eucalypt roosts was *Corrymbia citriodora* subsp. *variegata* (*n* = 2), *Eucalyptus propinqua* (*n* = 1), *E. microcorys* (*n* = 1), *E. moluccana* (*n* = 1), *E. racemosa* (*n* = 5), and *E. tereticornis* (*n* = 2).

**Roost counts.**—*Tadarida australis* did not use the communal roost during the Austral winter months of June and July. Bats returned between late August and early September for the mating season (Kitchener and Hudson 1982; Fig. 2a). The communal roost group size peaked during summer (December–March). In the summer of 2002–2003, however, bat numbers remained relatively low until rain relieved the drought in early February. Bat numbers decreased beginning in late March (Fig. 2a). Trapping and tracking did not appear to influence the bats’ use of the roost because the pattern of roost occupation at the communal roost remained the same between July 2000 and June 2003 (Fig. 2a).

The pattern of roost occupancy at satellite roosts was similar to that at the communal roost, although the numbers were much smaller (Figs. 2b and 2c; Table 1). Except for a single satellite roost used by bat 02 in November 2001, none of the satellite roosts were reused in the 2nd summer of the study (tagged or untagged; Figs. 2b and 2c).

**Day-roost-switching.**—1 categorized satellite roosts into primary and secondary satellite roosts, where the primary satellite roost for any individual was the 1st-discovered new roost. The communal roost was located centrally with respect to the
FIG. 2.—Counts of white-striped free-tailed bats (Tadarida australis) a) exiting the communal roost and b, c) at satellite roosts. If multiple roost counts were made in a month, the highest number is shown. a) Counts at the communal roost (July 2000–June 2003). Numbers 1–3 indicate timing of the 3 capture events at the roost. b) Counts at satellite roosts used by bats 01–03 and 06–08. Bats 01–03 were caught in November 2001 and their satellite roosts were observed from November 2001 until July 2003. Bats 06–08 were caught in March 2002 and satellite roosts were observed from March 2002 until July 2003. c) Counts for bats 12–19. Bats were caught in February 2003. Bats 13–15 used 2 satellite roosts during the period of observations. Satellite roosts of these bats were observed from February to June 2003.

satellite roosts (Fig. 3). The satellite trees were located up to 13.5 km from the communal roost (6.8 ± 2.8 km; Table 1; Fig. 3). Three bats used secondary satellite roosts (Table 1; Fig. 3). Secondary roost trees were located 500 ± 532 m away from the primary satellite roosts (Fig. 3).

Most individuals returned to the communal roost at regular intervals, although not all returned on the day after capture (Table 1). Of the 19 bats tracked, I obtained roost-switching data for 14 bats (Table 1; Fig. 3). These 14 bats spent most tracking days in primary satellite roosts (64.6% ± 34.4%), followed by unknown roosts (23.1% ± 34.2%), the communal roost (9.7% ± 29.4%), and secondary satellite roosts (2.6% ± 5.7%; Figs. 4a and 4b). Tagged bats switched roosts every 10.6 ± 7.9 days and spent most days roosting away from the communal roost (Mann–Whitney U-test; n = 14, 14; U = 0.00, P < 0.001; Figs. 4a and 4b). Tagged individuals only roosted together in the communal roost.

Four tagged bats did not reuse the communal roost (Table 1; Figs. 4a and 4b). The remaining 10 returned to the communal roost 2.1 ± 2.3 times for up to 5 consecutive days at a time and made a total of 32 visits to the communal roost. The interval between reuse of the communal roost varied from 1 to 20 days (7.0 ± 4.5 days; Table 1). There was no significant correlation between the number of days a bat was tracked and the number of revisits to the communal roost (n = 14; r = 0.35, P = 0.21).

Bat 12 left the communal roost area immediately after release, returned the next night for about 5 min, but was not detected again for 22 consecutive days, indicating that it used alternative roosts and foraging areas. This individual returned to a satellite roost for 11 tracking days but was never located again. The satellite roosts of the 3 bats fitted with LT2 collar-transmitters were never found, although day roosting, night visits, or both, to the communal roost were recorded (Table 1).

Roost-sharing behavior.—I calculated the pairwise sharing index for 30 different pairwise combinations (3 in 2002 and 27 in 2003) involving 11 individuals. The values of the pairwise sharing index for all pairs were negative (−0.55 ± 0.19; n = 30, N = 11), indicating that roost switching did not mean that individuals used the same roosts. There was no difference in values of the pairwise sharing index between tracking periods in 2002 and 2003 (Mann–Whitney U-test, n = 3, 27; U = 25.0,
indicating that this lack of association persisted between seasons.

Nocturnal use of the communal roost and surrounding area.—During tracking periods, I found that bats visited the communal roost, visited the roost area, or passed through the communal roost simultaneously (n = 4 occasions on 4 different nights) or circled together over the communal roost area (n = 20 occasions on 12 different nights).

I also observed tagged and untagged bats flying in groups of up to 20 around the communal roost tree. The group size changed continuously as different individuals joined and left the swarm. This behavior was observed throughout the night, from the end of December to the middle or end of February (2000–2002) and until mid-March in 2003. Throughout the night, loud audible vocalizations could be heard from inside the communal roost and from individuals flying over the tree. This behavior started as soon as the 1st bats visited the roost (10–20 min after 1st emergence) and ended just before dawn. Heavy rain and thunderstorms did not alter this behavior.

Nocturnal use of satellite roosts.—In contrast to observations at the communal roost, bats inside satellite roosts rarely vocalized before emergence. No bats returned to these roosts during the 3 h after sunset and I did not observe any swarming behavior. Swarming also did not take place during all-night observations at the satellite roost used by bat 06. No tagged bat, other than bat 06, visited this roost location.

**DISCUSSION**

Roost fidelity and roost-sharing behavior.—Hollow-dependent bats exhibit a spectrum of roost-switching behavior, from daily changes (roost lability) to high levels of fidelity. Kunz and Lumsden (2003) categorized 3 such groups: species that shift almost daily, bats that shift every 3–10 days, and those that are faithful to 1 site for a long period of time. The roost-switching behavior of *T. australis* was characterized by infrequent roost changes and loyalty by each bat to a small number of roost sites. This behavior places them into the medium spectrum of roost fidelity (Kunz and Lumsden 2003).

The majority of satellite roosts were not reused in subsequent tracking seasons. In contrast, the communal roost was used each year, but it is not known whether the same individuals revisited year after year. Similarly, the noctule bat (*Nyctalus noctula*) does not reuse roost trees between years and 60% of known roost sites remain vacant (Kronwitter 1988). In contrast, North American big brown bats (*Eptesicus fuscus*) reuse roosts from previous years (Willis and Brigham 2004) but long-tailed bats (*Chalinolobus tuberculatus*) in New Zealand rarely reuse roosts (O’Donnell and Sedgeley 1999).

The capture of only nonreproductive females in early February 2003 was unexpected because the exit counts at the communal roost were within the range of the previous years when the communal roost also was used as a maternity roost. Roost counts at this roost over a 3-year period demonstrated that the number of bats remained high during summer and that netting did not influence roost use. On the other hand, examination of my data indicates that tagged bats spent 90% of their days roosting in groups in satellite trees away from the communal roost, although individuals returned at irregular intervals. Because only a small percentage of bats I caught at the communal roost tree were tagged, movements by the majority of individuals remain unknown. The untagged bats were likely part of the small groups observed at satellite roosts.
members of the same roosting group appear to have dispersed over a number of roosts on any given day, similar to other forest-dwelling bats (O’Donnell and Sedgeley 1999; Willis and Brigham 2004). I therefore postulate that a network of separate roosts used by members of 1 communal roosting group should be considered as a single interconnected unit. This network of tree roosts may function in a similar manner as a single larger roost, such as a cave, as proposed by Willis and Brigham (2004).

Research into fission–fusion sociality among other cavity-roosting bats has demonstrated strong associations between individuals with bats tending to associate with certain preferred roost-mates (Heise and Schmidt 1988; Kerth and König 1999; O’Donnell and Sedgeley 1999; Vonhof et al. 2004; Willis and Brigham 2004). My application of the same methodology as Willis and Brigham (2004, 2005) enabled me to compare roost-sharing behavior of T. australis with that of E. fuscus, a species that exhibits a fission–fusion roosting pattern. The majority of pairwise combinations of E. fuscus had positive values for the sharing index, indicating that these individuals associated with roost-mates more often than predicted by chance (Willis and Brigham 2004). In contrast, tagged T. australis shared roosts less often than predicted by chance. Despite my small sample size, the consistently negative index values with small variance suggest that tagged bats may have actively avoided each other. This behavior remained the same during 3 radiotracking periods regardless of their reproductive stage.

The reason for the behavior remains unclear, but there are several possible explanations. One reason could be that lactating females exhibit different roost-switching dynamics to those I observed. None of the tagged bats had dependent offspring in the communal roost. I hypothesize that lactating females shift roosts less often as a consequence of the large energetic costs involved in moving nonvolant young between roosts (reviewed in Kunz and Lumsden 2003). Another possible hypothesis is predator avoidance. Pregnant, nonreproductive, and postlactating bats might perceive a high risk of predation associated with the large aggregation at the communal roost and choose to stay away. The loud audible vocalizations recorded at the communal roost (M. Rhodes, in litt.) may alert predators, such as tawny frogmouths (Podargus strigoides), to a large congregation of bats (Fenton et al. 1994). I regularly observed a female frogmouth move from a nearby roost to a perch opposite the roost entrance of the bats when bats began producing echolocation calls. The bird chased bats after they emerged. I hypothesize, that for a fast-flying bat such as T. australis, the most vulnerable time may be during emergence (Black et al. 1979; Czechura 1983). On the other hand, bats also may be vulnerable to diurnal terrestrial predators entering the roost through the large hollows connected to the roost cavity (Mansergh and Huxley 1985). Carpet pythons (Morelia spilota variegata) and lace monitors (Varanus varius) are common potential predators in urban Brisbane (Queensland Museum 1995).

It remains unclear why roost-switching was only observed between satellite roosts and the communal roost, but not between satellite roosts. Apart from the central location of the communal roost and the large number of bats using it, no measured physical characteristics or tree attribute differentiated the communal roost from other day-roost sites (Rhodes and Wardell-Johnson 2006). Thus, tree and site attributes may not have influenced the roost-switching behavior of individuals. Further work is required to investigate the roost-switching behavior of T. australis at other locations, including satellite roosts and other communal roosts found in the same study area. 2004). In contrast, tagged T. australis shared roosts less often as a consequence of the large energetic costs involved in moving nonvolant young between roosts (reviewed in Kunz and Lumsden 2003). Another possible hypothesis is predator avoidance. Pregnant, nonreproductive, and postlactating bats might perceive a high risk of predation associated with the large aggregation at the communal roost and choose to stay away. The loud audible vocalizations recorded at the communal roost (M. Rhodes, in litt.) may alert predators, such as tawny frogmouths (Podargus strigoides), to a large congregation of bats (Fenton et al. 1994). I regularly observed a female frogmouth move from a nearby roost to a perch opposite the roost entrance of the bats when bats began producing echolocation calls. The bird chased bats after they emerged. I hypothesize, that for a fast-flying bat such as T. australis, the most vulnerable time may be during emergence (Black et al. 1979; Czechura 1983). On the other hand, bats also may be vulnerable to diurnal terrestrial predators entering the roost through the large hollows connected to the roost cavity (Mansergh and Huxley 1985). Carpet pythons (Morelia spilota variegata) and lace monitors (Varanus varius) are common potential predators in urban Brisbane (Queensland Museum 1995).

Nocturnal fission–fusion dynamics.—Since Kummer (1971) applied the concept of fission–fusion to primates, this pattern of social behavior has been recorded for a variety of mammalian taxa, including cetaceans, microchiropteran bats, primates, and ungulates (e.g., Brüger 1999; Chivers and Corkeron 2002; Cross et al. 2005; Henzi et al. 1997; Kerth and König 1999; Packer et al. 1990; Robinson and Janson 1987; Vonhof et al. 2004; Willis and Brigham 2004). However, fission–fusion societies vary in the amount of association among individuals between and within species. Cross et al. (2005) argued that traditional association and fission–fusion indices are more likely to represent a fission and fusion history of groups rather than individual preferences because individual choices may be limited by environmental constraints (e.g., predation). In microchiropteran bats, descriptions of fission–fusion societies are typically based on diurnal roost-sharing behavior of dyads (Kerth and König 1999; O’Donnell and Sedgeley 1999; Vonhof et al. 2004; Willis and Brigham 2004) presumably because documenting the associations between individuals during the night is difficult. I found that fission–fusion sociality can occur despite negative day-roost–sharing associations. The individual T. australis I studied met at night at a central location even if they did not always associate during the day. Hence, a colony of T. australis may be better described by social interactions, as proposed by Burland and Worthington Wilmer (2001).

My data are consistent with a fission–fusion social structure. However, in contrast to other such societies among bats, the fission and fusion events I observed reflect movements by individuals to and from 1 communal roost as well as nocturnal activity in, at, or near the same roost. In other systems, fission–fusion appears to result from switching by individual bats between a large population of diurnal roosts. This suggests that previous studies might have underestimated the strength of association by individuals within colonies. I argue that nocturnal movements of individual bats should be included in assessments of association. Furthermore, it may be possible that the social organization of fission–fusion societies in bats is not always dependent on attractions between certain individuals but between individuals and the roosting group as a whole (cf., Kerth and König 1999) or as a result of passive aggregation (Wilkinson 1985).

Given that the communal roost also was used as a maternity roost, the individuals of the aggregation I studied may be related to one another, as has been found in other bat species (Kerth and König 1999). Searches for additional roosts in metropolitan Brisbane revealed another 13 roosts: 3 communal roosts with roosting groups of more than 120 individuals and 10 roosts with fewer than 30 bats (Rhodes and Wardell-Johnson 2006). However, I did not record tagged bats visiting...
these additional roosts despite some of them being closer to the satellite roosts than the communal roost. It is possible that these additional roosts were part of different roost networks of *T. australis* with members of other networks rarely interconnecting, similar to *C. tuberculatus* in New Zealand (O’Donnell 2000).

An adequate explanation of the observed pattern of splitting up during the day and meeting at night at a central roost is limited by other comparable studies of *T. australis*. However, I hypothesize that a large interconnected network of individual roost trees may enable the colonial roosting group to use alternative roost sites should the primary roost be damaged or destroyed (Lewis 1995). Visits to the communal roost may ensure that members of the same roosting group locate each other and share information on other potential roost sites (Kerth et al. 2006). On the other hand, regular visits at a central roost may serve as a mechanism for information exchange on foraging sites (Wilkinson and Boughman 1998). Information about feeding sites may be important for hollow-dependent bats, such as *T. australis*, where multiple roosts are distributed over a large area.

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**LITERATURE CITED**


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