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Roosting and breeding behaviour of Tawny Frogmouths *Podargus strigoides* in central-coastal Queensland

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Abstract. The roosting and breeding behaviour of a pair of Tawny Frogmouths *Podargus strigoides* was observed on the central Queensland coast over a period of 4 years (2018–2021). The study was conducted in a subtropical climate near Rockhampton, and provides data from a different geographical and climatic area compared with previous studies that were conducted in temperate southern Australia (New England Tablelands, Moree, and Sydney, New South Wales, and the Australian Capital Territory). Breeding data matched other studies: breeding in November–December, incubation of 28–30 days, fledging at 27–31 days, care of fledglings from 1–3 months, nests located in a horizontal fork of a tree on the edge of a clearing. Breeding success was high at 80% (8 of 10 nestlings survived). Roost sites were generally in tree species with a fibrous dark bark that provided camouflage, and were mostly within the leafy canopy (average height 9.11 m above ground), which provided protection from high daytime temperatures in both winter and summer. Only early in the morning on very cool days in winter did Frogmouths seek lower perches where sun exposure was greatest. These findings are consistent with other studies identifying thermoregulation and camouflage as important determinants of roost selection, although the need for greater sun exposure in winter was much lower in this study, reflecting the generally warm winter days. Fidelity to roost trees was high (90% of roosts were in four trees) and Frogmouths nested in a different tree each year. Both roosts and nests were confined to a home range of 1.6 ha. The frequency of feeding increased with nestling age, and was higher during the early part of the night. Overall, these findings advance understanding of the breeding biology of the Tawny Frogmouth in subtropical Australia.

Introduction

The Tawny Frogmouth *Podargus strigoides* is a member of the genus *Podargus*, of which there are three species in Australia. It is a native to Australia and has a distribution throughout the continent, including Tasmania (Higgins 1999; Holyoak 2020). It can be found in a wide range of habitats from lowland forest to alpine woodland, as well as suburban parks and gardens. It is a nocturnal species that roosts from dawn to dusk in a tree with a bark colour that provides camouflage (Körtner & Geiser 1999a). It hunts mainly insects at night but will also take small mammals, frogs and birds (Higgins 1999). In northern parts of its range, it breeds from October to December and has a clutch of two or three eggs.

To date, detailed information on roosting habits, breeding, and nesting of the species comes mainly from southern temperate Australia. This paper provides daily observational data over 4 years on roosting, breeding, and nesting habits of a pair of Tawny Frogmouths from a coastal site in central Queensland in subtropical Australia. The birds were of the grey morph subspecies *strigoides*.

Methods

Study site

The study took place between January 2018 and December 2021 at Coowonga, ~23 km north-east of Rockhampton, Queensland (23°16′S, 150°42′E), just north of the Tropic of Capricorn and ~10 km from the coast. The study site was in a fragmented patch of open woodland dominated by eucalypts and encompassed an area of ~2 ha (Figure 1).

Observations of birds

Over the study period, a pair of Tawny Frogmouths was monitored on most days to record in which tree(s) the birds roosted. If the birds were not found at a known roost site, a search was conducted over a wider area to find the new roost site. Observation of roost sites was either by binoculars (Swarovski SLC 10 x 42) or spotting scope (Swarovski ATX 85 mm), depending on the location of the roost. Care was taken to be as unobtrusive as possible so as not to affect normal behaviour. Data were collected on the location and height of a roost above ground, roost tree species, orientation of roost and whether the birds were roosting together. Records were not kept for November and December during breeding, when one bird was sitting on the nest and the other roosted in a nearby tree. Heights of the roosts were determined using an inclinometer and the triangulation method. The spatial location of nests was determined using a GPS and this information was then plotted on Google EarthTM (Google Inc.) to determine the distance between roosts and total area of the roosting and nesting locations over the study period.

At the end of each day, the Frogmouths were watched to record the time of departure from the roost. The sex of the bird that left the roost first and the direction of flight were also recorded. The sex of the birds was based on the characters given by Kaplan (2018): the male has a wider bill than the female as well as a squatter posture when roosting, and the female has a light-brown malar line along the cheek below the eye. Observations began at the time of sunset forecast by the Bureau of Meteorology and continued until both birds had flown from the roost. A Digitech digital light meter was used to record the amount of light (lux) at the time of leaving the roost. Using data from the Bureau of Meteorology, other variables recorded

Figure 1. Image of the study area, Coowonga, central-coastal Queensland, with the most favoured roost tree of the Tawny Frogmouths in the centre. Photo: Allan Briggs

were overnight temperature and the difference between time of leaving the roost and sunset.

Data were collected on commencement of building and location of the nest, number of eggs, and the durations of incubation and of the nestling stage. Roosting behaviour during nesting was recorded by noting which bird sat on the nest during the day, the location of the other bird's roost and the time of flying off the nest/roost. A motion-sensing camera (Swift Enduro) was used during the night to determine the frequency of feeding once the chicks had hatched. Photographs were taken when an adult returned to the nest. By parsing through these photographs, it was possible to determine the frequency of feeding through the night. Data were collected over a 20-day period in October and November 2020 and 2021.

Location of roost trees

Kaplan (2018) noted that two major factors influenced the selection of a roost: camouflage and thermoregulation. To assess these factors, records were kept of the tree species, and location and orientation of the roost in a tree, and the overnight temperature.

Results

Roost tree species

In total, 15 roost trees were identified during the study, of which eight were Queensland Peppermint *Eucalyptus exserta*, which has a fibrous grey bark, grows to 20 m high and has a dense crown of leaves. A further four roost trees were Yellow Stringybark *E. acmenoides*, which has a deeply furrowed and fibrous reddish-grey bark and can grow to 25 m. Two roosts were in Narrow-leaved Ironbark *E. crebra*, which has a hard rough black bark and grows to 35 m in height. One roost was on the dead and fallen branch of a Lemon-scented Gum *Corymbia citriodora* that was lodged under the canopy of a Cabbage Tree Palm *Livistona australis*. The heights of roosts above ground varied from 2.00 to 14.35 m, the average height being 9.11 m.

Location of roosts

The roost was usually high in the crown of the tree, just below the canopy, on branches that were either horizontal or sloping gently. However, during winter (when temperatures dropped below 10°C), and after breeding, much lower roost locations were selected.

Frequency of roost use and roost orientation

A total of 712 roosting events was recorded during the study. These events involved 17 separate roosts. The number of times that each roost was used over the 4-year study period is shown in Table 1.

The Tawny Frogmouths in this study used the same roost position for up to 13 consecutive days and used the same roost tree for up to 38 consecutive days. In some trees, there was more than one roost position, with the majority of roost days being in the tree in which Roosts 1, 2 and 3 were located (Table 1).

Table 1. Frequency of roost site usage by a pair of Tawny Frogmouths based on daily observations, Coowonga, Queensland. Roosts 1, 2 and 3 were in the same tree.

Roost no.	*No. of days of used*
1	240
2	144
3	14
4	1
5	1
6	15
7	4
8	60
9	6
10	23
11	130
12	6
13	48
14	2
15	8
16	9
17	1

The roost branches curved to the north-east or north-west, with the birds most often roosting facing west. On occasions when they roosted facing east, they reversed their position before flying at dusk.

In the main roost tree (Roosts 1, 2 and 3 in Table 1), there were three roost positions, two at 10.2 m just under the canopy and one at 3.4 m near the base of the tree. The lower roost (Roost 3) was used on only 14 occasions when the overnight temperature dropped below 10°C (Table 1).

The birds roosted in the same tree and sat side by side during 59% of observations of roost sites (Table 2). The frequency of roosting side by side was lowest during summer and spring but higher in autumn and winter.

Table 2. Roosting by a pair of Tawny Frogmouths at the study site, Coowonga, central-coastal Queensland, 2018–2021: number of days each month when the birds were observed roosting together. Records were not kept during November and December each breeding season because one bird was on the nest and the other was perched in a nearby tree.

Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*Jun.*	*Jul.*	*Aug.*	*Sep.*	*Oct.*
15	29	64	60	55	66	53	65	30	0

Behaviour and time and ambient light levels at roost departure

The male and female both commenced preening and stretching their wings 15–20 minutes before flying away from a roost. They orientated themselves on the roost branch to face the direction in which they eventually flew.

The average time of leaving the roost varied seasonally with day length: 1854 h (Eastern Standard Time) in January and 1750 h in June (Figure 2). However, birds tended to take longer to leave the roost after sunset in winter than in summer (Figure 3). The difference in time between sunset and flying from the roost varied from an average of 17 minutes in January to 31 minutes in June and 15 minutes in December (Figure 3).

The amount of light (lux) at the time of flying from the roost varied through the year from an average of 6.40 in January to 0.31 in June through to 2.30 in October (Figure 4). No measurements were taken in November and December so as not to disturb breeding.

The male was the first to fly on 83% of occasions and, typically, the female waited several minutes before flying off. At times, when an immature bird was roosting with the adults, one adult flew off, followed first by the immature and then the other adult. Direction of first flight after roosting was mainly to the west or north-west across a gully (95% of flights).

Selection of nest tree and chronology of nesting

Nest trees were always in the same general location as roost trees but the nest was never built in a roost tree. One nest was built in a Yellow Stringybark, one in a Queensland Peppermint and two nests in separate Narrow-leaved Ironbarks. A different tree was used during each breeding season and each of the trees was positioned on the edge of a clearing. Each nest was located in a fork of a horizontal branch and always on the lowest branch of the nest tree. The heights of the nests above ground were 7.30, 9.28 (two nests), and 10.08 m.

The date on which nesting was first observed across the 4 years of observation was as follows: 2 October 2018, 6 October 2019, 1 October 2020, and 17 September 2021. In each of 2018 and 2019, there were two eggs, and in 2020 and 2021, there were three eggs. Incubation time was 28–30 days and fledging took place after another 27–31 days. Eight of 10 nestlings survived, a breeding success rate of 80%. In 2021, the nest was predated and two of the three nestlings were killed but the identity of the predator was unknown.

Parental behaviour during nesting

During incubation, the male sat on the nest through the day and the female took over at dusk. However, the female did not take over immediately and there was a gap of up to 90 minutes after the male had flown before the female took over incubation. The adults took turns at incubating during the night so that each bird could hunt and feed. During the day, the female roosted in a nearby tree and sometimes in the same tree but on a different branch.

The same pattern was observed when there were nestlings, the male sitting on the nest during the day while the female roosted in a nearby tree, or occasionally beside the nest. Both male and female flew off shortly after sunset and began hunting, returning to the nest through the night to feed the nestlings.

Feeding frequency

The first feeding event generally took place just after 1900 h, with an average time of 1918 h. Feeding frequency of 5-day-old nestlings was 12 times/night, and reached 42 times/night at 16 days old (Figure 5). Only the number of feeding events could be recorded whereas the identity of the nestling that received the food could not be determined. The average feeding frequency over a 20-day period was one food delivery every 12.5 minutes, with the longest period between feeding events being 80 minutes and the shortest 1 minute. Feeding was more frequent during the early part of the night up to *c*. 2130 h. The last feed typically took place around 0400 h, with the latest at 0440 h, and the average at 0408 h.

Post-fledging behaviour

In the first 3–4 weeks after fledging, the family of Frogmouths roosted on branches as low as 2 m above the ground and was not observed in any of the previously used roost trees The adults and any remaining juveniles were not seen using a high roost in a previously used roost tree until 2 months after fledging. The dispersal of the young happened progressively, with the last juvenile not leaving until >2 months after fledging. However, in the

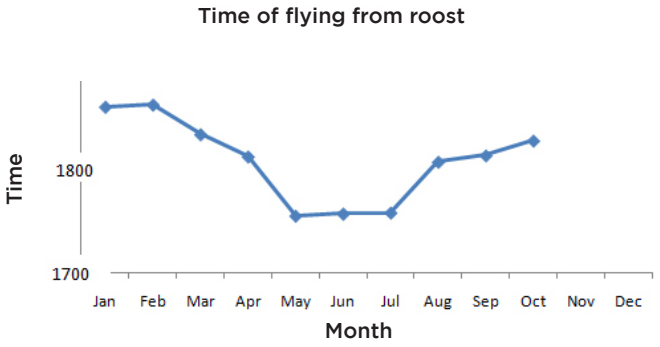

Figure 2. Average time of day (Eastern Standard Time) of Tawny Frogmouths departing from the day roost over 4 years at the study site, central-coastal Queensland, 2018–2021.

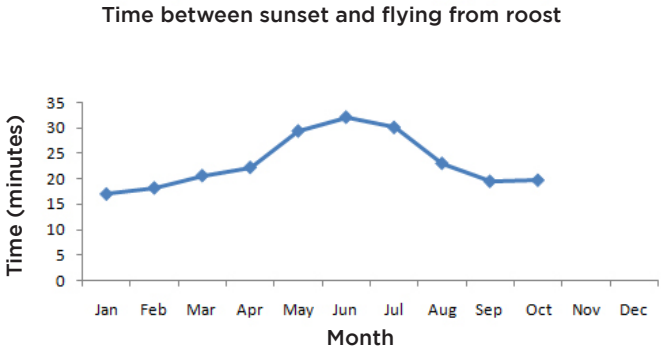

Figure 3. Average time in minutes between sunset and Tawny Frogmouths departing from the day roost over 4 years at the study site, central-coastal Queensland, 2018–2021.

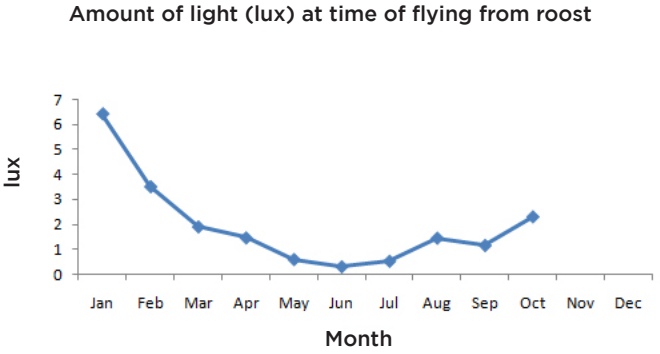

Figure 4. Average light level (lux) at the time that Tawny Frogmouths departed from the day roost over 4 years at the study site, central-coastal Queensland, 2018–2021.

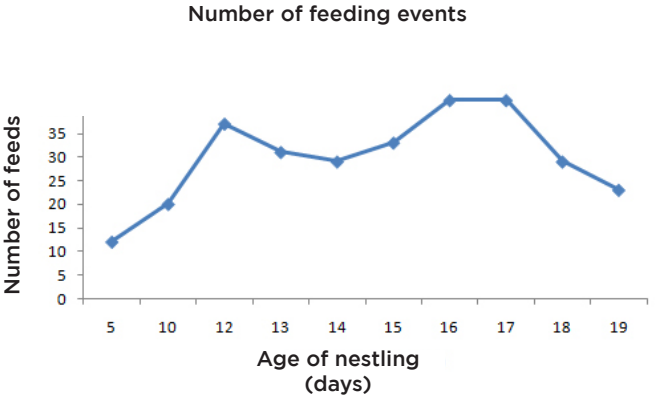

Figure 5. Feeding of nestlings by Tawny Frogmouths: number of feeding events/night over 20 days of the nestling period at the study site, central-coastal Queensland, 2018–2021.

2021 breeding season, when two nestlings were predated, the surviving nestling stayed with the adults for 94 days. After dispersal, the juveniles were not seen again in their natal territory.

Discussion

Selection of roost tree

Kaplan (2018, p. 50) noted that a Tawny Frogmouth chooses roost trees that "best match its own colouration and markings" for concealment. The most commonly used roost tree in the present study, Queensland Peppermint, has a bark colour very similar to the plumage of the species. Consequently, a Frogmouth was very difficult to differentiate from a short branch when its body was extended into the camouflage posture.

Location of roost

Kaplan (2018, p. 53) noted that the main consideration for choosing a roosting location in a tree was for thermoregulation, taking the form of both "protection from high temperatures in summer months and from cold temperatures in winter months". Kaplan's study took place in the temperate climate of the New England Tableland near Armidale, New South Wales, whereas my study took place in subtropical central Queensland near Rockhampton, where summer maximum temperatures can reach 40°C but winter minimum temperatures rarely go below 5°C. In my study, the Frogmouths remained protected from the sun in the canopy during summer. In winter, they were never seen to sunbathe in the upper canopy even on cold days, probably because typical winter days warm quickly, averaging 26°C by midday. However, there were instances on very cold winter mornings when the roost position might have been changed for purposes of thermoregulation. When temperatures dropped below 10°C, the birds used a lower roost position, receiving morning sun earlier than at the higher roost positions, and thus increasing body temperature after a relatively cold night. This behaviour occurred on only a few occasions during June, July and August. These results indicate that roosting behaviour is strongly influenced by climatic conditions, which in my study area vary from hot during summer to mild during winter, so there is little need for exposure to the sun for warmth. Protection from the sun under a leafy canopy appeared to be the most important requirement.

The presence of recently fledged Frogmouths also influenced roost height: families roosted much lower during the first 3–4 weeks after fledging, presumably reflecting poor flying ability of younger birds (Körtner & Geiser 1999b).

Fidelity to roost

High roost fidelity in Tawny Frogmouths has been reported in multiple publications (Schodde & Mason 1980; Ingram 1994; Higgins 1999), whereas Körtner & Geiser (1999a) found that a considerable number of different roost trees was used and speculated that other studies might have

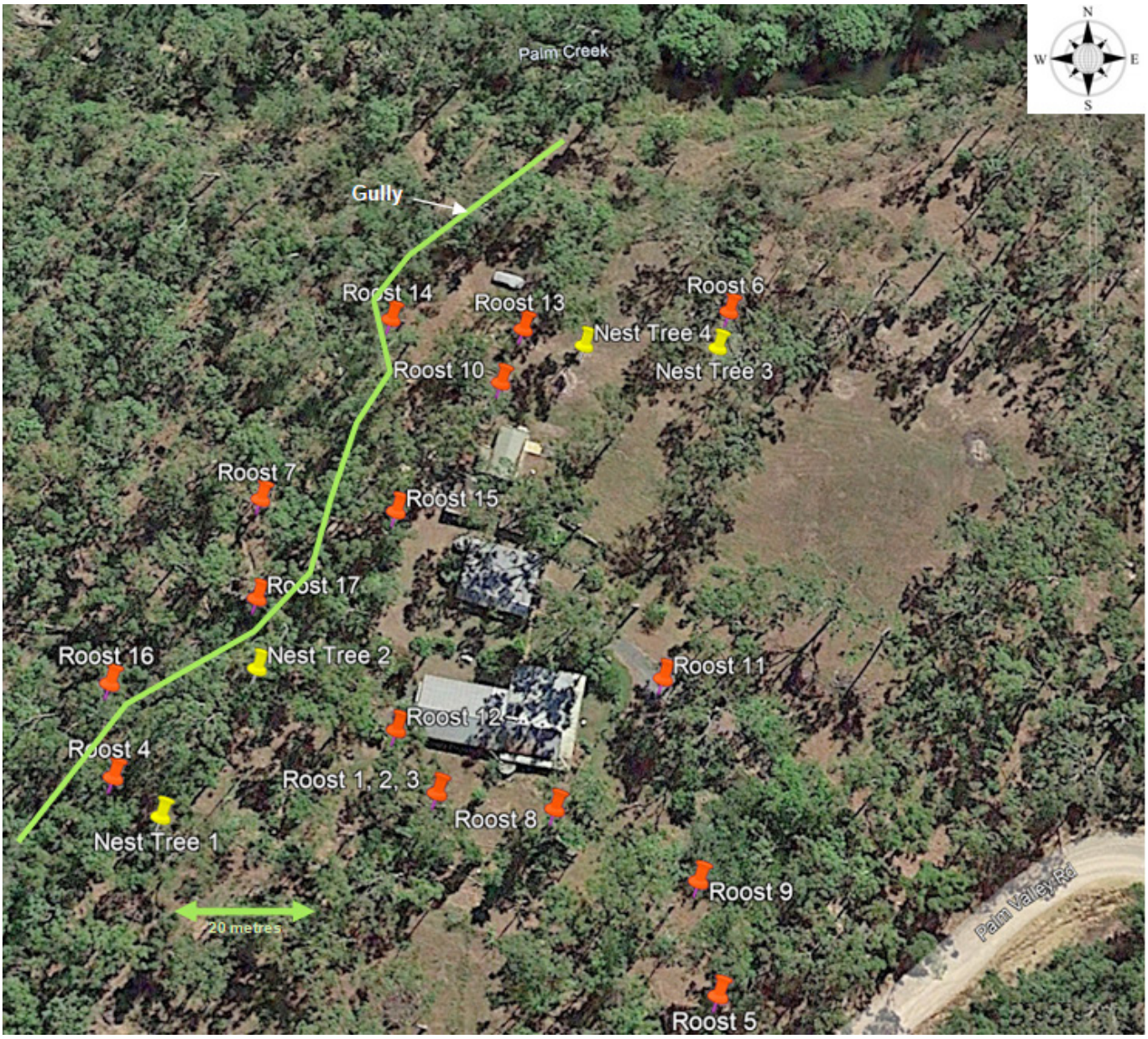

Figure 6. Roosting and nesting locations of Tawny Frogmouths at the study site, central-coastal Queensland, 2018–2021. Image source: Google Earth

been over a short term or restricted to urban situations where few roost trees were available. Körtner & Geiser (1999a) conducted their study of roosting in the Northern Tablelands of New South Wales, which is a well-forested area and concluded (p. 501) that: "Birds rarely used the same roost over extended time periods and most roosts were used for less than 3 days". In contrast, the present study, which was conducted in a woodland with relatively widely spaced trees, found that roost fidelity was high over a period of 4 years, with four trees (comprising six roosts) accounting for 90% of roosting events (Figure 6).

Kaplan (2018) noted that roost trees were selected to provide camouflage from predators as well as for thermoregulation. In my study, the loss of only two fledglings in 2021 and a breeding success rate of 80% based on the 2018–2021 data, indicate a low rate of predation. Possible predators of the young in 2021 include the Carpet Python *Morelia spilota*, which was the main terrestrial predator of the Tawny Frogmouth present in the study area during the study period. Aerial predators, such as Pied Currawongs *Strepera graculina*, goshawks *Accipiter* spp., and falcons *Falco* spp., were present but were never seen to approach a Frogmouth nest, suggesting that nests might have been well concealed from predation by aerial predators. Southern Boobooks *Ninox boobook* were present in the study area but are unlikely to predate Frogmouth nestlings as they are similar in size to the Tawny Frogmouth; adult Frogmouths could probably defend the nest successfully against Boobooks. It may be that the lower apparent risk of predation in this region, and less need to change roost position for thermoregulation in a subtropical climate, provide conditions whereby survival of Tawny Frogmouths is not as dependent on repeatedly changing roost position.

Le Souef (1937) commented that after breeding the whole Frogmouth family departed from the normal roost area, with the adults not returning for 3 months. A similar pattern of departure was observed in my study, with the family departing from the roost area when the chicks had fledged in late November/early December, but the adults returned much sooner (after only 1 month) than noted by Le

Souef and had one or more juveniles with them. Typically, in my study, the juveniles stayed with the adults for 1–2 months before leaving the family group. An exception occurred in 2021 when the one surviving nestling from the predation event stayed with the adults for 94 days after fledging, which is an extraordinarily long time; a possible explanation is that the trauma of the predation caused the juvenile to be reluctant to leave. This pattern was consistent with Kaplan (2018, p. 110), who commented that "The timetable for dispersal does not seem to follow specific patterns for all tawny frogmouth."

Amount of light (lux) when leaving roost

During summer, the Frogmouths left the roost when there was still good light, e.g. in January the lux level was 6.5. As the year progressed and the days shortened, the birds left the roost when it was almost completely dark, e.g. in June the lux level was down to 0.3 (see Figure 4). This light level corresponds to *c.* 1830 h in summer and 1730 h in winter (see Figure 2).

Fidelity to nesting and roost area

Le Souef (1937, p. 253) commented that for a period of 10 years a pair of Tawny Frogmouths had nested in the same tree and for roosting they would "occasionally seek a new tree, but they spend most of the year within a radius of about 100 yards of the nesting site". Higgins (1999) also cited instances of high fidelity to roost site, nest tree, and nest site, mainly in temperate south-eastern Australia.

In my study, the pair of Frogmouths nested in four different species of trees over a period of 4 years and used 15 different roost trees. However, roost fidelity was high: 90% of roosting events were in the four most commonly used trees. This indicates that there was no fidelity to nest trees but substantial fidelity to roost trees. However, roost trees and nest trees were all within an area of 1.6 ha (Figure 6), indicating high fidelity to an area or home range, as suggested by previous studies.

Kaplan (2018) commented that Tawny Frogmouths change their roost positions frequently and that it is rare for them to use the same roost for more than three consecutive days. Differing from this pattern, my study found that the Frogmouths used the same roost position for up to 13 days and the same roost tree for up to 38 days.

Selection of nest tree

Nest height in this study averaged 9.2 m above ground, which is comparable with that found by Rae & Rae (2014) for a large sample of 145 Tawny Frogmouth nest sites. All nests in the present study were in trees on the edge of clearings and on a suitable horizontal branch with a fork. Nests were also located on the lowest branch of a tree, which is consistent with Rae & Rae (2014), who noted that location of nests appeared to be related to providing concealment from predators and detection of any approaching predators.

Laying dates and behaviour during incubation

The dates of laying are within the range provided by Higgins (1999), who reported Tawny Frogmouth breeding mainly from August to December, with peak laying in September and October. Consistent with Kaplan (2018), in my study the male incubated during the day and the female roosted in a nearby tree. At night, the pair shared incubation duties so each could also hunt. Kaplan (2018) commented that at the changeover the eggs were not exposed to the weather for more than a few minutes. In my study, however, there were periods of up to 90 minutes after the male flew from the nest before the female arrived to incubate. The warmer subtropical climate may account for this as evening temperatures rarely dropped below 20°C in the study area.

Frequency of feeding

Unlike data loggers used in previous studies (Körtner & Geiser 1999b), the use of a motion-sensing camera allowed more detailed information on parental care of nestlings to be obtained. Consistent with young birds developing and requiring more food as they grow, the rate of feeding increased with Tawny Frogmouth nestling age. The frequency of feeding was higher during the early part of the night, with sometimes as little as 1 minute between the arrival of the male and female. The frequency of feeding decreased as the night progressed, with intervals of up to 80 minutes between consecutive feeding events recorded.

Conclusion

This study of Tawny Frogmouth roosting and nesting behaviour has produced results that are consistent with many of the conclusions drawn by previous studies while also identifying some differences that can be attributed mainly to climatic conditions. The study also adds new information about the frequency of feeding of nestlings and the use of a different nest tree each breeding season. Further work is needed to determine the significance of these observations. Although the sample size of 15 roost trees and four nests studied over 4 years has limitations, the congruence of this study with the findings of other authors indicates valid methodology and also points to interesting areas for further study.

Acknowledgements

I would like to thank my wife Paula who, with her sharp hearing, could pinpoint roosting locations from the birds' contact *oom* call. This ability saved me considerable time in locating roost trees.

References

Higgins, P.J. (Ed.) (1999). *Handbook of Australian, New Zealand & Antarctic Birds, Volume 4: Parrots to Dollarbird*. Oxford University Press, Melbourne.

Holyoak, D.T. (2020). Tawny Frogmouth (*Podargus strigoides*), version 1.0. In: del Hoyo, J., Elliott, A., Sargatal, J., Christie, D.A. & de Juana, E. (Eds). *Birds of the World*. Cornell Lab of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bow.tawfro1.01

Ingram, G.J. (1994). Tawny Frogmouths. In: Strahan, R. (Ed.). *Cuckoos, Nightbirds and Kingfishers of Australia*, pp. 88–90. Angus & Robertson, Sydney.

Kaplan, G. (2018). *Tawny Frogmouth*. CSIRO Publishing, Melbourne.

Körtner, G. & Geiser, F. (1999a). Roosting behaviour of the Tawny Frogmouth (*Podargus strigoides*). *Journal of Zoology, London* **248**, 501–507.

Körtner, G. & Geiser, F. (1999b). Nesting behaviour and juvenile development of the Tawny Frogmouth *Podargus strigoides. Emu* **99**, 212–217.

Le Souef, A.S. (1937). Note on the Tawny Frogmouth (*Podargus strigoides*). *Emu* **36**, 253.

Rae, S. & Rae, D. (2014). Orientation of Tawny Frogmouth (*Podargus strigoides*) nests and their position on branches optimises thermoregulation and cryptic concealment. *Australian Journal of Zoology* **61**, 469–474.

Schodde, R. & Mason, I.J. (1980). *Nocturnal Birds of Australia*. Lansdowne Editions, Melbourne.

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