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Calling locations and courtship calls of the frogs *Austrochaperina robusta* Fry, 1912 and *Pseudophryne covacevichae* Ingram & Corben, 1994 in northern Australia

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Abstract. Breeding season vocalizations in anuran amphibians offer crucial insights into reproductive behaviour and habitat selection. In this study we investigated calling sites and courtship calls of *Austrochaperina robusta* and *Pseudophryne covacevichae*, two terrestrial frog species native to northern Australia. Surveys revealed that 87% of calling *A. robusta* males were in direct contact with logs, roots, or trees. We recorded and described for the first time the courtship call of *A. robusta*, which was characterized by two short, high-pitched chirps and features unique acoustic properties. Of 140 *P. covacevichae* males, 10% were in proximity to egg clutches. The *P. covacevichae* courtship call is distinct from the advertisement call and consists of short, high-pitched chirps.

Keywords. Anura, breeding behaviour, habitat selection, vocalisation, advertisement call

Introduction

During the breeding season, most adult male anurans use advertisement calls to attract females. Where they choose to call is of interest, particularly for terrestrial or semi-terrestrial species, because the site often gives an indication of where nesting (clutch laying and care) may occur (Felton et al., 2006; Hoffmann and Mitchell, 2022), and this is important information for conservation and habitat protection. Characterizing different types of calls (e.g., advertisement vs. courtship) is also important because this differentiation can provide insights into how breeding behaviour unfolds.

Advertisement calls (males attracting females) are the best-known vocalizations, but anurans can produce other types of calls. These include 'release calls', uttered by frogs trying to avoid or leave amplexus (e.g., males mistaken for females or non-receptive females; Aronson, 1944; Blair, 1968); 'aggressive calls', uttered to establish territory and warn off potential competitors or to scare predators (e.g., Martins et al., 1998; de Kokubum et al., 2009); 'courtship calls', uttered by a male that is courting a female in close proximity (e.g., Felton et al., 2006; de Kokubum et al., 2009); and 'reciprocal calls', calls females use to communicate with males (often in response to the courtship call) before amplexus (de Kokubum et al., 2009; Faggioni et al., 2017). Courtship calls are likely used by many anuran species but are generally poorly known because they are typically quieter and are only used for a short period, right around the time of actual breeding (Wells, 2007). They are also typically more complex and variable than advertisement calls, with a wider range of frequency and amplitude modulation (Gerhardt and Huber, 2002). Here we describe calling sites and courtship calls of two terrestrial Australian frogs, the Robust Whistling Frog, *Austrochaperina robusta* Fry, 1912 (Fig. 1A), and the Magnificent Broodfrog, *Pseudophryne covacevichae* Ingram & Corben, 1994 (Fig. 1B).

Materials and Methods

***Austrochaperina robusta*.** This species is restricted to mid-elevation and upland rainforest of the Wet Tropics region of northeastern Queensland and lives among leaf litter and under logs and rocks (Hoskin and Hero, 2008). *Austrochaperina robusta* is a terrestrial breeding frog, with direct development (i.e., embryos develop to metamorphosis within the jelly capsules). The clutch (9–15 eggs) is laid in leaf litter or under a log or rock and is attended by an adult frog (Hoskin, 2004; Anstis et al., 2011).

Surveys for *A. robusta* took place in the Paluma Range (19.0107°S, 146.2055°E), during the wet season (between December and February) of 2022–2023.

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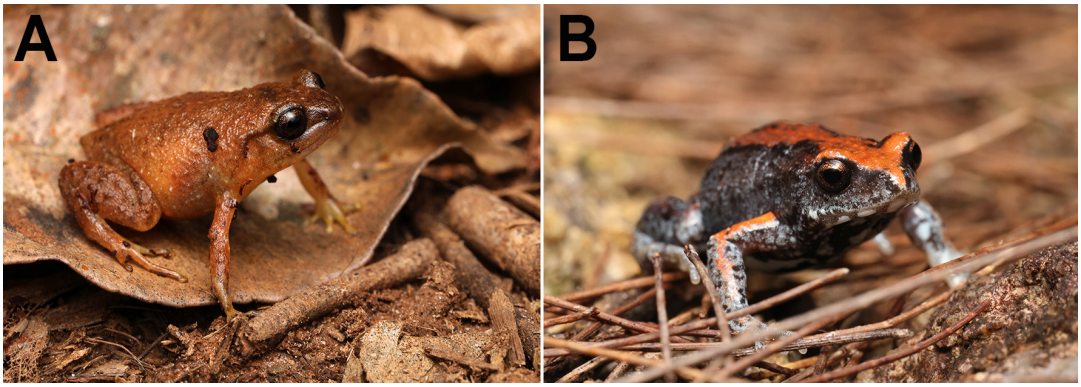

Figure 1. Adult male *Austrochaperina robusta* (A) and adult male *Pseudophryne covacevichae* (B) in northern Australia. Photos by Edward Evans (A) and Patrick Webster (B).

There was a total survey effort of 16 nights, with fieldwork conducted from 19:00–23:00 h. Two observers listened to calls and located individuals by approaching the calling male from different angles using a red light. When located, the location of the frog was documented (e.g., at ground level, under a leaf), a photo of the calling location was taken, and the distance to the closest log, rock, root, or tree was measured. Select calls were recorded using the Dictaphone application on an iPhone 11.

***Pseudophryne covacevichae*.** This species occupies ephemeral drainage lines and seepages in upland dry sclerophyll or wet sclerophyll forest of the Wet Tropics region (McDonald et al., 2002; Zozaya and Hoskin, 2015). They are a semi-terrestrial breeder, and males build shallow nests (depressions) on land, at the edge of a drainage line or seep. Tadpoles have a period of terrestrial development in the eggs, with the male typically in attendance (McDonald et al., 2002; Anstis 2013), and hatch into an adjacent water body when the nest is inundated by rising water. They complete their metamorphosis during an aquatic life phase (McDonald et al., 2002).

Surveys for *P. covacevichae* occurred at several locations in the Ravenshoe region (17.6070°S, 145.4823°E) and to the south in the Paluma Range (18.9980°S, 146.1134°E). Surveys occurred over 32 nights spread across February 2022 and November 2022–March 2023. Each survey began 30 min after sunset and ended by 23:00 h. Frogs were located by one or two observers, who approached a calling male and narrowed in on its location before carefully moving vegetation to locate the frog. Select calls were recorded on an iPhone 7 using the iPhone video application.

Calls of both species were analysed using Audacity sound analysis software v3.3.3 and Raven Lite v2.0 software. To calculate the mean call features we measured dominant frequency, peak frequency of single vocalization, call duration, length of a single vocalization, pulse rate, and the number of pulses/call. We also measured the interval between calls and the interval between any distinct components within individual calls. Data are displayed as mean ± standard deviation, where appropriate.

Results

***Austrochaperina robusta*.** Fifty-two calling males were located. Of these, 42 (81%) were concealed in leaf litter, four were inside a log, four were calling from loose soil (i.e., underground but near the surface), and two were on top of leaf litter. In terms of proximity to surface structures, 29 (56%) were calling while positioned directly against a log, branch, surface root, or tree base, nine were calling from the top of a log, root, or branch, and seven were positioned within a log or surface root. Therefore, 45 (87%) were in direct contact with a log, root, fallen branch, surface root, or tree base. The remaining seven individuals were calling from a distance > 10 cm from a log, root, branch, or tree base (average distance = 13 cm). All but one male were calling from sites without traces of surface water (although the surface was saturated by heavy rain), while one individual was calling from a small pool of water inside a log.

During the 16 nights in the field, a probable courtship call was only heard twice, and could only be recorded for one individual (Fig. 2A, B), while many males were heard emitting advertisement calls (Fig. 2C, D).

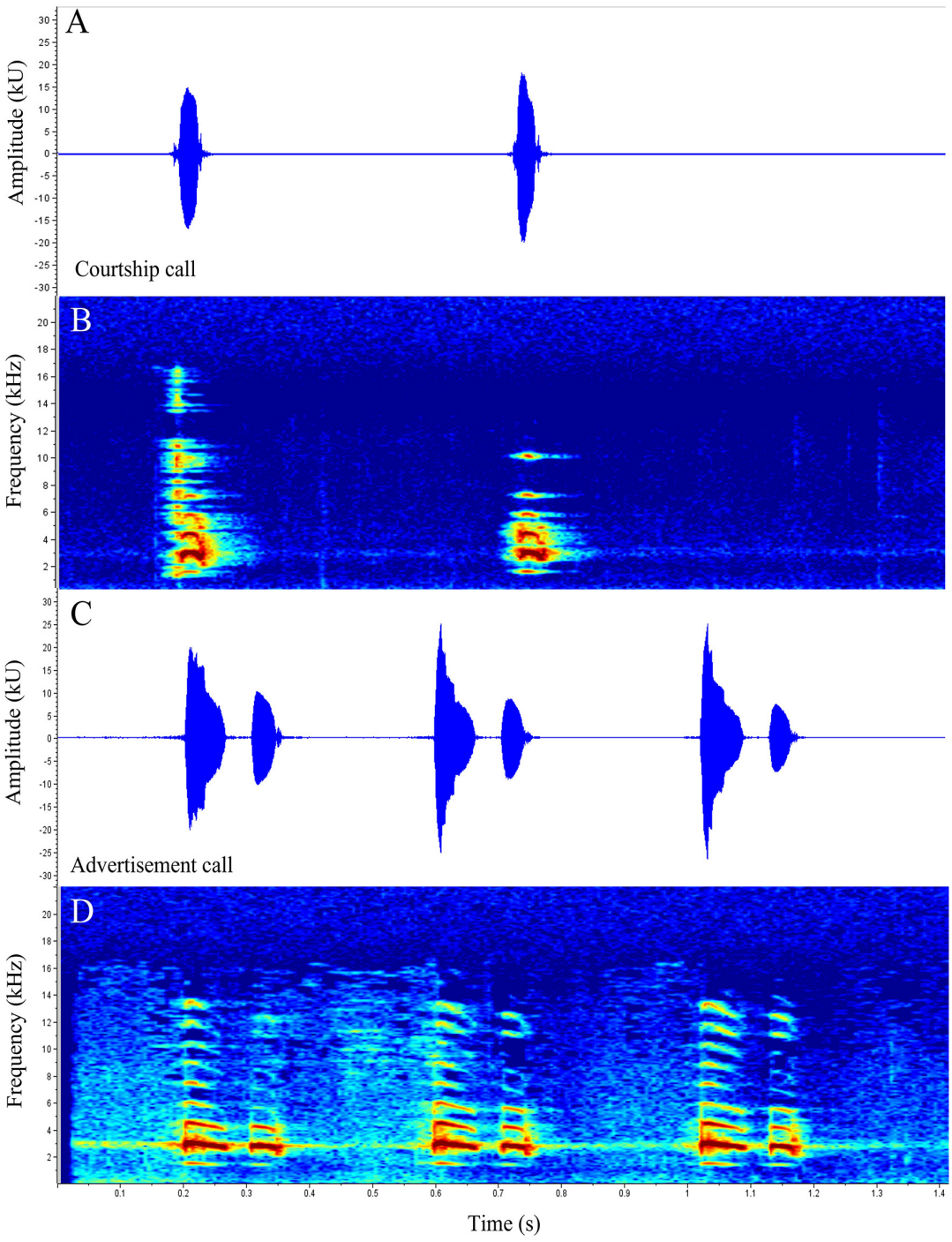

Figure 2. Vocalizations of *Austrochaperina robusta* in northern Australia. Shown are a single courtship call in waveform (A) and as an audio spectrogram (B), along with a single advertisement call in waveform (C) and as an audio spectrogram (D). The waveform displays amplitude against time, while the audio spectrogram displays call frequency and call energy/intensity (degree of colour) against time.

While the advertisement call of *A. robusta* consists of a series of chirps arranged in couplets (Hoskin, 2004), the presumed courtship call consists of two short, single, high-pitched chirps. Courtship calls were uttered 6 s apart (call interval: 5.97 ± 1.10 s) and the interval between the two short chirps within each call was 0.58 ± 0.06 s. Each courtship call had the following characteristics (n = 12): dominant frequency 2.79 ± 0.02 kHz, duration 0.058 ± 0.001 s, pulse rate 2.38 ± 0.44 pulses/s. By following the courtship call we found the calling male with two recently metamorphosed froglets and another adult frog (presumably female) in a small burrow 4 cm underground in aerated light soil with small roots. We marked the location and went back 24 h later but found only one frog and no nest in the burrow.

Pseudophryne covacevichae. A total of 140 calling male *P. covacevichae* were located, all beneath leaf litter, deep inside the base of grass tussocks or under small woody debris. These males were all calling from within a drainage channel or from a seepage area, directly on the banks of the drainage channel, or along raised grassy tussocks in the seep. Of 140 males, 14 (10%) were located within 10 cm of a clutch of eggs, with three of these males sitting in direct contact with the eggs. It is likely that more of the males had clutches, but we did not search more than 10 cm from each male to limit damage or disturbance to the breeding microhabitat.

During a survey in the Paluma Range in March 2023, a probable courtship call of *P. covacevichae* was heard and recorded (Fig. 3A, B). The typical advertisement call of *P. covacevichae* consists of a series of 'cricks', sometimes with two syllables 'crick-k' repeated every 6–10 s (Fig. 3C, D; Vanderduys, 2012). The courtship call, however, consists of a short, single, high-pitched chirp, repeated every 6–7 s (call interval: 6.7 ± 0.40). Each courtship call had the following characteristics (n = 3): dominant frequency 2.85 ± 0.08 kHz; duration 0.078 ± 0.001 s; pulse rate 2.68 ± 0.04 pulses/s. The male produced this call sporadically and hence it took some time to locate. While attempting to locate the calling male, a female was found in the same patch of leaf litter as the male (about 10 cm from the male). The frog was deemed to be female based on paler coloration (Rush, 2023). When observed under low light for several minutes, the frog was found to be orientated and moving slowly towards the calling male. Further searching then located and disturbed the calling male. He was underneath leaf litter (with overhanging grass), sitting on top of over 30 eggs in various stages of development. Two other males were producing a standard advertisement call within 1 m of the male producing the courtship call. This was the only instance of a probable courtship call heard during the 32 survey nights.

Discussion

Some terrestrial or semi-terrestrial breeding frog species produce advertisement calls directly from the vicinity of the nest (e.g., Martin et al., 2011; this study) but others vocalize a distance away from the nest site (e.g., Felton et al., 2006; de Kokubum et al., 2009). This is probably because calling right from the nest site can attract predators or competitors, potentially reducing reproductive success (Wells, 2007). Therefore, some frog species call away from the nest site and then use soft courtship calls to lead a receptive female there. An example is *Cophixalus australis* Hoskin, 2012, a microhylid frog from the Wet Tropics region of northeastern Australia. Males call on average a distance of 112 cm away from their nest site by using a loud advertisement call to attract females, and then lead females with a soft courtship call to the nesting site (Felton et al., 2006). Even if males call directly from the nest site, or in close proximity, they can still produce a courtship call to encourage an approaching female.

More than 80% of the *A. robusta* males in this study were found hidden within leaf litter, likely as a strategy to minimize the risk of predation (Muñoz and Halfwerk, 2022). Additionally, a minimum of 78% of these frogs were in direct proximity to logs, surface roots, trees, or fallen branches. These objects potentially serve as amplification tools for males to enhance their calls and attract a greater number of females (e.g., Lardner and Bin Lakim, 2002; Muñoz and Halfwerk, 2022). Additionally, they may call near these surface objects if the clutch is then laid under or against them.

Our findings for *A. robusta* support those of Hauselberger and Alford (2005), who found that calling males do not appear to be calling directly at a nest site. This is based on the fact that no clutches were found with the 52 males we located, and none were found with the 53 calling *A. robusta* that were located by Hauselberger (2002). This suggests that *A. robusta* either call from sites away from their nest sites or do not call after they obtain a clutch (Hauselberger and Alford, 2005). While there have been no records of *A. robusta* with multiple clutches, related *Cophixalus* species have been found with multiple clutches (e.g., Hoskin, 2004; Anstis et al., 2011), so it is possible that *A. robusta*

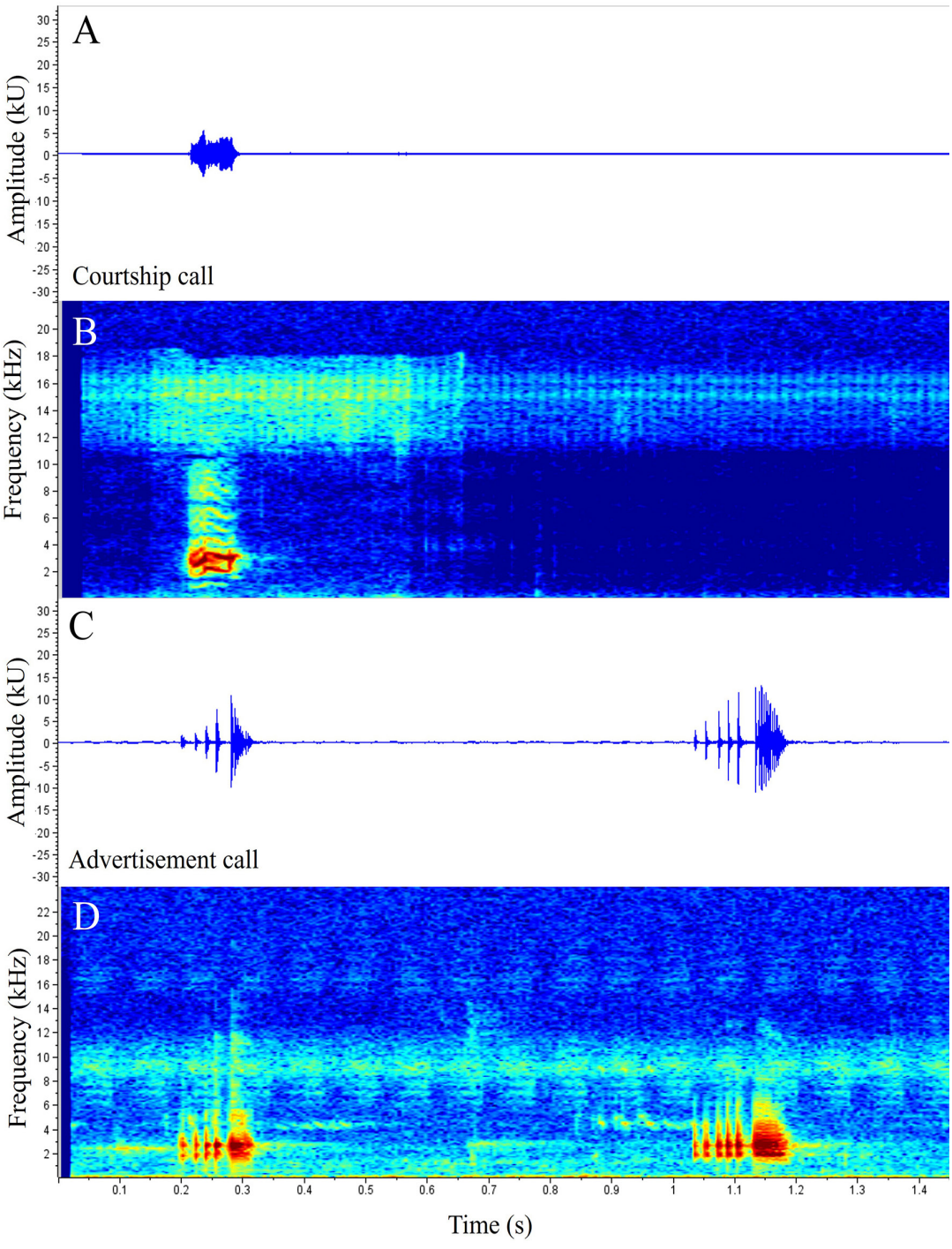

Figure 3. Vocalizations of *Pseudophryne covacevichae* in northern Australia. Shown are a single courtship call in waveform (A) and an audio spectrogram (B), along with a single advertisement call in waveform (C) and as an audio spectrogram (D). The waveform displays amplitude against time, while the audio spectrogram displays call frequency and call energy/intensity (degree of colour) against time.

shows similar behaviour. It is also likely that *A. robusta* does not call directly from the nesting sites but uses a courtship call to lead a female to the nest.

We have documented what we believe to be a courtship call in *A. robusta*, even though a clutch of eggs was not subsequently found. The male was calling from what appeared to be a nest chamber and a probable female was in attendance (along with two froglets, possibly indicating a previous clutch). Due to how well-hidden the probable nest site was (4 cm underground), it took over 20 min to locate the calling male, while carefully removing the soil and illuminating with white headtorch lights. Disturbance by the observers probably caused the mating event of the male *A. robusta* producing the courtship call to be unsuccessful. When eventually located, the probable female was approximately 1 cm from the male, who was still producing the courtship call. It is also possible that the female simply chose not to mate with the male. This has been documented for *C. australis*, where courtship calls and leading to a nest site do not always result in mating (Felton et al., 2006).

In contrast, some male *P. covacevichae* males (albeit only 10%) were located in close proximity (within 10 cm) of an egg clutch. These males were generally uttering an advertisement call, except for the single male uttering a probable courtship call. This call was deemed to be a courtship call based on the obviously different characteristics of the call and the fact that a female was in close proximity, was orientating towards, and moving in the direction of the male. As other nearby male *P. covacevichae* were not producing this type of call, this suggests that the male was aware of the female's proximity and was attempting to guide her to the nest. Due to our single, short observation, and given the limited total number of observations of males calling in proximity to clutches, we cannot conclude that males of this species generally call from the nest site and use a courtship call to attract a female that approaches the nest, or that they call a distance away from the nest and use a courtship call to lead the female to the nest. It is hypothesized that the presence of an adult male *Pseudophryne* is not essential for larval development or hatching success (Woodruff, 1977). Instead, it has been proposed that remaining at a nest with eggs maximizes the male's prospect for further reproductive activity because females are more receptive to mating with a male that already has eggs (Woodruff, 1977). If this is the case across species, it is possible that the individual producing the courtship call in our observation was sitting directly over the eggs in preparation for the female to enter the nest site.

Potential courtship calls have been reported in three other species of *Pseudophryne* (Pengilley, 1971), and is most clearly defined for the Southern Corroboree Frog, *Pseudophryne corroboree* Moore, 1953. In all instances where a courtship call was documented for *P. corroboree*, a gravid female was found in or near the burrow of the male producing the call (Pengilley, 1971). This aligns with our observation of the male making the probable courtship call, as a female *P. covacevichae* was located nearby. In general, the courtship calls of the three *Pseudophryne* studied by Pengilley (1971) can be described as having shorter call duration, less obvious structural components within the call, and faster pulse rate than their respective advertisement calls. The courtship call we report here for *P. covacevichae*, shows these same general differences to their advertisement call.

Austrochaperina robusta is only the second species of Australian microhylid (24 species), for which a courtship call is known, while the courtship call of *P. covacevichae* is only the fourth for the genus (14 species). Understanding the breeding biology of these and other groups of frogs is increasingly important as we aim to mitigate impacts on breeding sites of wild populations, and potentially look to maintain captive breeding colonies.

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