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# Supplementary Material

## What can echolocation recordings reveal about the foraging ecology of *Saccolaimus saccolaimus* (Emballonuridae) in north-western Australia?

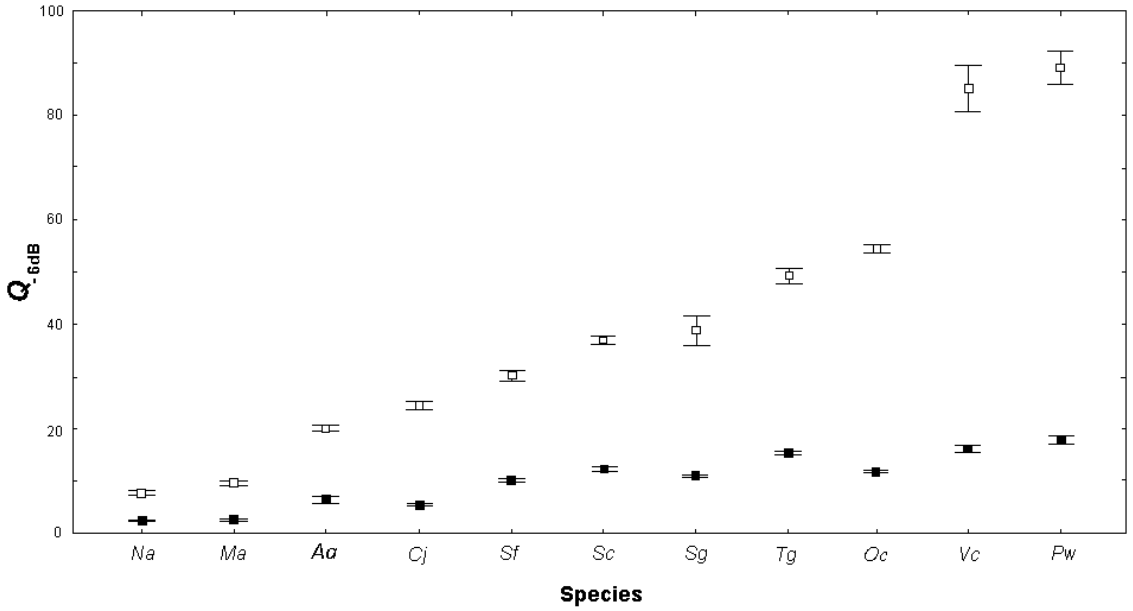
N. L. McKenzie[A,C] and R. D. Bullen[B]

[A]Woodvale Research Centre, DBCA, Wildlife Place, Woodvale, WA 6026, Australia.

[B]43 Murray Drive, Hillarys, WA 6025, Australia.

[C]Corresponding author. Email: norman.mckenzie1@gmail.com

**Appendix 1.** The relationship between $Q_{SM2}$ to $Q_{Anabat}$ was derived empirically for each species. The 11 species illustrated are ordered according to average $Q_{SM2}$ (the fineness-of-tuning of their search-mode pulses 6 dB below peak), with 95% confidence intervals shown. Solid boxes are values measured from Anabat2 recordings (see Methods); hollow boxes are values measured from Wildlife Acoustics SM2BAT recordings at a sampling rate of 384 kHz. Species codes are provided in Appendix 2. Sample-sizes, and sample-averages are tabulated below.




| | ***Na*** | ***Ma*** | ***Aa*** | ***Cj*** | ***Sf*** | ***Sc*** | ***Sg*** | ***Tg*** | ***Oc*** | ***Vc*** | ***Pw*** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **SM2** | | | | | | | | | | | |
| av$F_{peak}$ (kHz) | 51.8 | 45.3 | 11.9 | 17.7 | 18.6 | 19.7 | 37.9 | 24.7 | 30.8 | 61.4 | 48.6 |
| av$Q_{SM2}$ | 7.7 | 9.3 | 19.7 | 24.6 | 30.3 | 37.1 | 39.1 | 49.7 | 55.0 | 85.3 | 89.5 |
| s.d. | 2.0 | 2.0 | 3.1 | 4.5 | 5.0 | 3.2 | 13.1 | 7.0 | 9.2 | 22.1 | 14.3 |
| #pulses | 73 | 64 | 108 | 147 | 81 | 64 | 65 | 90 | 124 | 99 | 80 |
| #sequences | 15 | 11 | 17 | 19 | 20 | 14 | 16 | 23 | 14 | 20 | 15 |
| #localities | 9 | 6 | 7 | 11 | 14 | 10 | 8 | 12 | 6 | 8 | 8 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Anabat** | | | | | | | | | | | |
| av$F_{peakC}$ (kHz) | 50.7 | 43.4 | 12.0 | 18.4 | 18.1 | 19.6 | 38.2 | 24.7 | 32.0 | 61.0 | 49.0 |
| av$Q_{Anabat}$ | 2.3 | 2.5 | 6.7 | 5.4 | 10.3 | 12.5 | 10.9 | 15.3 | 11.8 | 16.1 | 18.1 |
| s.d. | 0.7 | 0.6 | 2.3 | 1.7 | 2.6 | 1.7 | 2.7 | 2.8 | 3.3 | 3.5 | 3.8 |
| #pulses | 136 | 44 | 38 | 190 | 161 | 66 | 281 | 225 | 275 | 95 | 94 |
| #sequences | 11 | 16 | 17 | 27 | 20 | 12 | 59 | 41 | 43 | 30 | 6 |
| #localities | 6 | 6 | 13 | 18 | 16 | 10 | 40 | 39 | 5 | 28 | 5 |
| **$Q_{SM2}/Q_{Anabat}$** | **3.4** | **3.7** | **2.9** | **4.6** | **2.9** | **3.0** | **3.6** | **3.2** | **4.7** | **5.3** | **4.9** |

**Appendix 2**. Species foraging strategy, foraging microhabitat, climatic range, phylogeny, muscle mass class and flight speed.

Population (Western Australian bioregion) from which study animals were recorded: K (Kimberley bioregions), P (Pilbara), C (Coolgardie), M (Murchison), SW (temperate forest regions). Usual foraging strategy categories: $A_H$ = air superiority involving highly agile turns, $A_O$ = air superiority in open situations, I = interceptor, $S_{2D}$ = two dimensional surface gleaning, $S_{3D}$ = 3D-surface gleaning (includes 'P', trawling for tiny fish and aquatic invertebrates). Usual foraging microhabitat categories: OC = over canopy, AC = above canopy, BS/O = beside stand in open, BS/A beside stand, against clutter, IS = inside stand. Geographical range abbreviations: Tr = tropical, Te = temperate, a =arid, m = mesic. Family name abbreviations: E = Emballonuridae, M = Molossidae, Mi = Miniopteridae, V = Vespertilionidae (includes N = Nyctophilinae). Flight muscle mass classes: LE = low energy, GE = general energy and HE = high energy (Bullen and McKenzie 2004). $V_{ae}$ = maximum aerobic level-flight speed (Bullen *et al.* 2016), av$F_{peak}$ = peak frequency of pulses comprising search mode echolocation sequences; av$f_W$ = average wing-beat frequency; 'av #seq/locn' = average (s.d., N) number of sequences analysed per location. The average $f_W$ and $V_{mode}$ values for molossids excludes flight with un-cambered wings (Bullen *et al.* 2014), and for Nyctophilinae exclude 'departure' calls (McKenzie and Bullen 2012).

| Code | Species | Population | Usual Foraging Strategy | Usual Foraging Microhabitat | Range | Family | Flight muscle mass class | $V_{ae}$ | av$F_{peak}$ (sd, n) | av$f_W$ (sd, n) | av#seq/locn (sd, N) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cj* | *Chaerephon jobensis* (Miller) | K | I [2] | OC-AC [2] | Tr, a, m | M | LE | 7.4 | 18.0 (1.9, 44) | 8.4 (0.4, 44) | 2.5 (1.4, 18) |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cj* | *Chaerephon jobensis* (Miller) | P | I [1] | OC-AC [1] | Tr, a, m | M | LE | 8.4 | 17.7 (1.2, 34) | 8.3 (1.2, 34) | 1.6 (0.9, 16) |
| *Cg* | *Chalinolobus gouldii* (Grey) | K | $A_H$ [2] | BS/O [2] | Tr, m | V | HE | 6.9 | 31.5 (1.3, 109) | 9.3 (0.8, 109) | 2.3 (1.4, 7) |
| *Cg* | *Chalinolobus gouldii* (Grey) | P | $A_H$ [1] | BS/O [1] | Tr, a | V | HE | 6.5 | 32.1 (1.3, 128) | 9.4 (1.3, 128) | 2.4 (1.6, 22) |
| *Cm* | *Chalinolobus morio* (Grey) | P | $A_H$ [1 3] | BS/A [1 3] | Te, Tr, a, m | V | HE | 5.7 | 51 (0.5, 35) | 10.6 (1.6, 35) | 6 (--, 1) |
| *Cn* | *Chalinolobus nigrogriseus* (Gould) | K | $A_H$ [2] | BS/O [2] | Tf, m | V | HE | 5.6 | 39.5 (1.8, 74) | 10.7 (0.5, 74) | 2.4 (1.4, 5) |
| *Fm* | *Falsistrellus mackenziei* Kitchener | SW | A [4] | BS/O [4] | Te, m | V | GE | 7.6 | 35.1 (1.5, 43) | 8.1 (0.4, 43) | 1.3 (0.5, 7) |
| *Ms* | *Miniopterus schreibersii orianae* Thomas | K | $A_H$ [2] | BS/A-BS/O [2] | Tr, m | Mi | HE | 5.8 | 49.4 (1.2, 163) | 9.5 (1, 163) | 5.4 (6.7, 5) |
| *Ma* | *Myotis macropus* (Gould) | K | P (A-$S_{3D}$ [2]) | BS/O [2] | Tr, m | V | GE | 6.3 | 41.5 (2.6, 123) | 9.5 (1.3, 123) | 3.2 (4.4, 5) |
| *Na* | *Nyctophilus arnhemensis* Johnson | K | $S_{3D}$ [2] | BS/A-IS [2] | Tr, m | N | GE | 5.3 | 50.3 (3.7, 89) | 10.4 (1.3, 89) | 2.2 (1.8, 5) |
| *Nd* | *Nyctophilus daedalus* Thomas | K&P | $S_{3D}$ [1 2] | BS/A-IS [1 2] | Tr, a, m | N | GE | 5.7 | 54.7 (3.4, 23) | 9.8 (1.1, 23) | 2.4 (0.6, 4) |
| *Ng* | *Nyctophilus geoffroyi pallescens* (Thomas) | K | $S_{3D}$ [2] | BS/A-IS [2] | Tr, a, m (mangal) | N | GE | 5 | 47.9 (1.3, 65) | 10.4 (1.3, 65) | 2.4 (1.6, 3) |
| *Ng* | *Nyctophilus geoffroyi pallescens* (Thomas) | P | $S_{3D}$ [1] | BS/A-IS [1] | Tr, a, m (mangal) | N | GE | 5.3 | 47.3 (3.1, 114) | 10.8 (1, 114) | 2.3 (2.1, 14) |
| *Nw* | *Nyctophilus walkeri* Thomas | K | $S_{3D}$-A [2] | BS/A [2] | Tr, m | N | HE | 5.3 | 60.8 (3.6, 85) | 11.2 (0.8, 85) | 1.6 (1.4, 5) |
| *Oc* | *Ozimops cobourgianus* (Johnson) (= *Mormopterus loriae cobourgiana*) | K&P | $A_O$ [1] | OC-BS/A [1] | Tr, a, m (mangal) | M | LE | 6.7 | 32.1 (1.8, 386) | 10.1 (0.7, 177) | 6.3 (7.3, 10) |
| *Ol* | *Ozimops lumsdenae* Reardon *et al*. (= *Mormopterus beccarii*) | K | I [2] | OC-BS/O [2] | Tr, m | M | LE | 7.6 | 27.6 (1.3, 84) | 9.4 (0.9, 84) | 6 (--, 1) |
| *Ol* | *Ozimops lumsdenae* Reardon *et al*. (= *Mormopterus beccarii*) | P | I [1] | OC-BS/O [1] | Tr, a | M | LE | 7.6 | 27.3 (1.9, 33) | 9.6 (0.9, 33) | 1.6 (0.7, 15) |
| *Pw* | *Pipistrellus westralis* Koopman | K | $A_H$ [2] | BS/A [2] | Tr, m | V | GE | 5.8 | 49.1 (1.6, 89) | 11.2 (1.1, 89) | 4.0 (5&3, 2) |
| *Sf* | *Saccolaimus flaviventris* (Peters) | P | $A_O$ [1 2] | OC [1 2] | Tr, a, m | E | GE | 8 | 17.1 (1.4, 72) | 7.9 (0.8, 72) | 1.9 (1, 21) |
| *Sg* | *Scotorepens greyii* (Grey) | K | $A_H$ [2] | BS/O [2] | Tr, a, m | V | HE | 6.1 | 39.7 (1.4, 166) | 10.6 (0.5, 166) | 1.9 (1.9, 8) |
| *Sg* | *Scotorepens greyii* (Grey) | P | $A_H$ [1] | BS/O [1] | Tr, a, m | V | HE | 6.4 | 37.5 (1.5, 111) | 10.6 (0.9, 111) | 2 (1.6, 23) |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Ss* | *Scotorepens sanborni* (Troughton) | K | $A_H$ [2] | BS/A-BS/O [2] | Tr, m | V | HE | 6.1 | 41.1 (2.0, 99) | 10.8 (0.5, 99) | 5.4 (2.6, 3) |
| *Ta* | *Austronomus australis* (Gray) (= *Tadarida australis*) | COOL | I [1 3] | OC [1 3] | Tr, Te, a, m | M | GE | 8.7 | 12.5 (1.4, 39) | 7.7 (0.7, 39) | 1.6 (1.1, 13) |
| *Tg* | *Taphozous georgianus* Thomas | K | $A_O$ [1 2] | OC [1 2] | Tr, m | E | GE | 7.1 | 24.7 (0.6, 98) | 8.2 (0.3, 98) | 1.8 (1.2, 8) |
| *Tg* | *Taphozous georgianus* Thomas | P | $A_O$ [1 2] | OC [1 2] | Tr, a | E | GE | 7.5 | 24.6 (1.0, 69) | 8.5 (1.1, 69) | 2 (1.5, 18) |
| *Th* | *Taphozous hilli* Kitchener | MUR | $A_O$ [1] | OC [1] | Tr, Te, a | E | GE | 7.1 | 25.7 (0.8, 140) | 8.2 (1, 140) | 9 (6.6, 4) |
| *Vc* | *Vespadelus caurinus* (Thomas) | K | $A_H$ [2] | BS/A [2] | Tr, m | V | HE | 4.2 | 61 (1.6, 40) | 11.8 (0.6, 40) | 1.5 (0.8, 8) |
| *Vd* | *Vespadelus douglasorum* (Kitchener) | K | $A_H$ [2] | BS/A [2] | Tr, m | V | GE | 5.8 | 51.1 (1.4, 53) | 10.4 (0.6, 53) | 1.8 (1.5, 4) |
| *Vf* | *Vespadelus finlaysoni* Kitchener *et al.* | P | $A_H$ [1] | BS/A [1] | Tr, Te, a | V | HE | 4.6 | 56.3 (1.6, 74) | 11.4 (1.5, 74) | 2.4 (2.8, 19) |
| *Sf* K | *Saccolaimus flaviventris* (Peters) | K | | | Tr, a, m | E | | | 18.3 (1.6, 46) | 7.2 (0.4, 46) | 2.0 (2.2, 23) |
| *Sc* K&NT | *Saccolaimus saccolaimus* Temminck | K&NT | | | Tr, m | E | | | 20.3 (0.8, 51) | 7.3 (0.3, 51) | 2.0 (1.8, 25) |

[1] McKenzie and Bullen (2009); [2] McKenzie and Bullen (2012); [3] Bullen and McKenzie (2001); [4] Van Dyck and Strahan (2008).

## References


<jrn>Bullen, R. D., and McKenzie, N. L. (2001). Bat airframe design – flight performance, stability and control in relation to foraging ecology. *Australian Journal of Zoology* **49**, 235–261. doi:10.1071/ZO00037</jrn>

<jrn>Bullen, R. D., and McKenzie, N. L. (2004). Bat flight-muscle mass: implications for foraging strategy. *Australian Journal of Zoology* **52**, 605–622. doi:10.1071/ZO04036</jrn>

<jrn>Bullen, R. D., McKenzie, N. L., and Cruz-Neto, A. P. (2014). Aerodynamic power and mechanical efficiency of bat airframes using a quasi-steady model. *CEAS Aeronautical Journal* **5**, 253–264. doi:10.1007/s13272-014-0104-5</jrn>

<jrn>Bullen, R. D., McKenzie, N. L., and Cruz-Neto, A. P. (2016). Characteristic flight speeds in bats. *CEAS Aeronautical Journal* **7**, 621–643. doi:10.1007/s13272-016-0212-5</jrn>

<jrn>McKenzie, N. L., and Bullen, R. D. (2009). The echolocation calls, habitat relationships, foraging niches and communities of Pilbara microbats. *Records of the Western Australian Museum* **78**(Supplement), 123–155. doi:10.18195/issn.0313-122x.78(1).2009.123-155</jrn>

<jrn>McKenzie, N. L., and Bullen, R. D. (2012). An acoustic survey of zoophagic bats on islands in the Kimberley, Western Australia, including data on the echolocation ecology, organisation and habitat relationships of regional communities. *Records of the Western Australian Museum* **81**(Supplement), 67–108. doi:10.18195/issn.0313-122x.81.2012.067-108</jrn>

<bok>Van Dyck, S., and Strahan, R. (2008). ‘Mammals of Australia.’ (New Holland Publishers: Australia.)</bok>