13. Appendix D Proposed development area bat call report

Microbat Call Identification Report

Prepared for ("Client"):	Marine and Environmental Planning
Survey location/project name:	Mio College, Ayr
Survey dates:	9 June 2016
Client project reference:	
Job no.:	MEP-1601
Report date:	25 June 2016

Methods

Data overview

Two Anabat SD2 detectors (Titley Scientific, Brisbane) and one Song Meter SM2BAT detector (Wildlife Acoustics, USA) were deployed for a single survey night on 9th June 2016.

Anabat data were received in standard zero-crossing analysis (ZC) sequence file format; whereas the SM2BAT data were received as full-spectrum (WAV) files (one file for each 30 minutes of recording). These WAV files were converted to individual call sequence files, in both ZC and WAV formats, using Wildlife Acoustics' *Kaleidoscope* program. The total data set thus available for analysis contained 2280 unique call sequence files from the three detectors.

Call identification

All ZC sequence files were viewed using *AnalookW* (Corben 2015) and a subset chosen for further analysis, which contained representative samples of all call types recorded by each detector. Calls with fewer than four clearly-defined, non-fragmented pulses were excluded from selection. This subset included all calls that potentially represented any threatened species known or likely to occur in the lower Burdekin region.

Species identification was achieved manually by comparing the ZC sonograms and call parameters of the selected calls with those of reference calls from eastern Queensland and published call descriptions (Reinhold *et al.* 2001; Milne 2002, Pennay *et al*. 2004). Full-spectrum versions (i.e. those recorded on the Song Meter) of calls in the 18-28 kHz frequency range were also analysed in the *Kaleidoscope Viewer* to evaluate the presence and pattern of call harmonics, which can be diagnostic for the Critically Endangered (EPBC Act) Bare-rumped Sheath-tailed Bat (*Saccolaimus saccolaimus*).

Species' identification was also guided by considering probability of occurrence based on general distribution information (Churchill 2008; van Dyck *et al.* 2013) and/or database records obtained from Wildlife Online (http://www.ehp.qld.gov.au/wildlife/wildlife-online/index.html) and the Atlas of Living Australia (http://www.ala.org.au).

Reporting standard

The format and content of this report follows Australasian Bat Society standards for the interpretation and reporting of bat call data (Reardon 2003), available on-line at http://www.ausbats.org.au/.

Species nomenclature follows Reardon *et al* (2015).

Technical terms used in the report are described in the Glossary.

Results & Discussion

Species overview

Twelve call types, representing up to 14 species were positively identified, with one further call type equivocally attributed to the threatened *S. saccolaimus* (see Table 1). Two of the reliably identified call types were only attributable to genus level due to similarities in call characteristics of the following groups:

- *Nyctophilus* species
  - Three species potentially occur in the study area (*N. bifax, N. geoffroyi, N. gouldi*)
  - Steep, almost-linear linear (FM) call pulses are distinctive from those of other bat calls but cannot be reliably identified to species
  - Calls from this survey had characteristic frequency (Fc) around 50 kHz, suggesting probably *N. bifax* or *N. geoffroyi* more likely than *N. gouldii* (generally has lower Fc)
- *Scotorepens greyii* and *S. sanborni*
  - Steep, curvilinear (FM-qCF) pulses with Fc of 37-41 kHz
  - Distinguished from *Chalinolobus nigrogriseus* in same Fc range by shorter pulse duration and hooked pulse body (*cf.* longer and flatter body in *C. nigrogriseus*)
  - Both *Scotorepens* spp. are likely to occur in the study area

Threatened species – *Saccolaimus saccolaimus*

Calls potentially belonging to this species were analysed according to a scheme proposed by Dr K. Armstrong (pers. com.), as shown in Appendix 1.

Potential *S. saccolaimus* calls recorded by the Song Meter were analysed in both ZC and WAV formats. Due to the absence of harmonic structuring typical of *S. saccolaimus* calls, characteristic frequencies typically >24.5 kHz and pulse shapes being generally steep curvilinear, it was determined that all relevant calls in the Song Meter data set were attributable to *Mormopterus lumsdenae*.

Several calls recorded by both Anabat detectors were considered very likely to be from *Saccolaimus saccolaimus*. These calls had almost-flat pulses at Fc=22-24 kHz, with some evidence of frequency alternation typical of the species; however, with the absence of corroborating full-spectrum recordings, confirmation of identity required a statistical comparison of the call parameters with those of reference calls from several similar-calling species.

Call parameters were extracted using *AnalookW* and subject to a Discriminant Function Analysis (DFA) alongside parameters extracted from North-Queensland reference calls of *S. saccolaimus*, *S. flaviventris, C. jobensis* and *M. lumsdenae*. The resulting DFA plot (Figure 1) clearly demonstrates that the “unknown” calls from Mio College are most likely from *S. saccolaimus* as they cluster within or close to the confidence region of *S. saccolaimus* reference calls.

Table 1. Bats recorded during the Mio College survey, 9 June 2016.

♦ = at least one call was attributed unequivocally to the species for the date/site
□ = calls similar to those of the species were recorded, but could not be reliably identified
- = species not recorded

Detector:	Anabat 1	Anabat 2	Song Meter
Total ZC sequence files:	773	1005	502
No. of calls identified:	180	363	358
Chalinolobus gouldii	♦	♦	♦
Chalinolobus nigrogriseus	♦	♦	♦
Nyctophilus sp.	♦	♦	♦
Scotorepens balstoni	-	-	♦
Scotorepens greyii / S. sanborni	♦	♦	♦
Vespadelus troughtoni	♦	♦	♦
Miniopterus australis	♦	♦	♦
Miniopterus orianae oceanensis	♦	♦	♦
Chaerephon jobensis	♦	♦	♦
Mormopterus lumsdenae	♦	♦	♦
Mormopterus ridei	♦	♦	♦
Saccolaimus flaviventris	♦	♦	♦
Saccolaimus saccolaimus	□	□	-

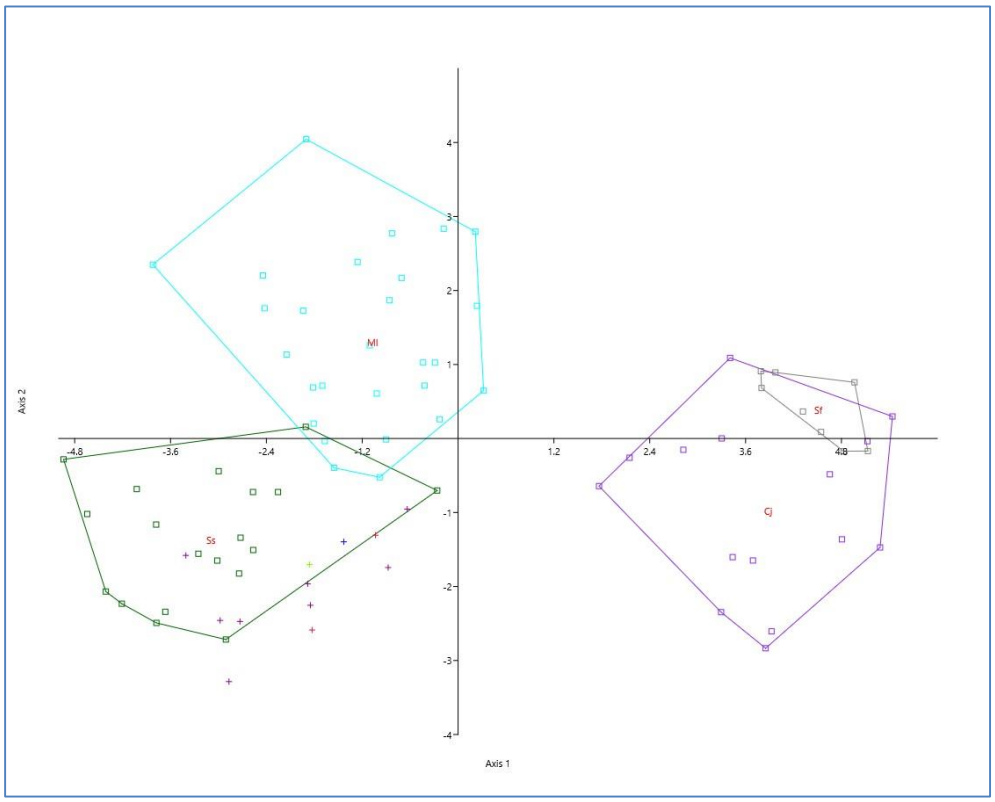


Figure 1. Discriminant Function Plot of call parameters from suspect *S. saccolaimus* calls ('+' symbols) and reference calls from *S. saccolaimus* (green), *M. lumsdenae* (light blue), *C. jobensis* (purple) and *S. flaviventris* (grey).

References

Churchill, S. (2008). *Australian Bats*. Jacana Books, Allen & Unwin; Sydney.

Corben, C. (2015). *AnalookW for bat call analysis using ZCA.* Version 4.1z, 20 September 2015.

Milne, D.J. (2002). *Key to the Bat Calls of the Top End of the Northern Territory*. Technical Report No. 71, Parks and Wildlife Commission of the Northern Territory, Darwin.

Pennay, M., Law, B. and Reinhold, L. (2004). *Bat Calls of New South Wales*. Department of Environment and Conservation, Hurstville.

Reardon, T. (2003). Standards in bat detector based surveys. *Australasian Bat Society Newsletter* **20**, 41-43.

Reardon, T.B., Armstrong, K.N. and Jackson, S.M. (2015). *A current taxonomic list of Australian Chiroptera. Version 2015-05-10.* URL: http://ausbats.org.au/

Reinhold, L., Law, B., Ford, G. and Pennay, M. (2001). *Key to the bat calls of south-east Queensland and north-east New South Wales*. Department of Natural Resources and Mines, Brisbane.

van Dyck, S., Gynther, I. and Baker, A. (eds.) (2013). *Field Companion to the Mammals of Australia*. New Holland; Sydney.

Glossary

Technical terms used in this report are described in the following table.

Approach phase	The part of a bat *call* emitted as the bat starts to home in on a detected prey item; a transitional series of *pulses* between the *search phase* and *feeding buzz*, that become progressively steeper and shorter in duration.
Call	Refers to a single bat call, made up of a series of individual sound *pulses* in one or more *phases* (*search, approach, feeding buzz*).
CF (=Constant Frequency)	A type of *pulse* in which the dominant component consists of a more-or-less 'pure tone' of sound at a Constant Frequency; with *shape* appearing flat on the sonogram. Often also contains a brief *FM* component at the beginning and/or end of the CF component (*viz.* FM-CF-FM).
Characteristic frequency (Fc)	The frequency of the flattest part of a *pulse*; usually the lowest frequency reached in the *qCF* component of a pulse. This is often the primary diagnostic feature for species identification.
Duration	The time period from the beginning of a *pulse* to the end of the pulse.
Feeding buzz	The terminal part of a *call*, following the *approach phase*, emitted as the bat catches a prey item; a distinctive, rapid series of very steep, very short-duration pulses.
FM (=Frequency Modulated)	A type of *pulse* in which there is substantial change in frequency from beginning to end; *shape* ranges from almost vertical and linear through varying degrees of curvature.
FC range	Refers to the range of frequencies occupied by the *characteristic frequency* section of *pulses* within a call or set of calls.
Frequency sweep or "band-width"	The range of frequencies through which a *pulse* sweeps from beginning to end; Maximum frequency (Fmax) – minimum frequency (Fmin).
Knee	The transitional part of a *pulse* between the initial (usually steeper) frequency sweep and the *characteristic frequency* section (usually flatter); time to knee (Tk) and frequency of knee (Fk) can be diagnostic for some species.
Pulse	An individual pulse of sound within a bat *call*; the *shape*, *duration* and *characteristic frequency* of a pulse are the key diagnostic features used to differentiate species.
Pulse body	The part of the *pulse* between the *knee* and *tail* and containing the *characteristic frequency* section.
Pulse shape	The general appearance of a *pulse* on the sonogram, described using relative terms related to features such as slope and degree of curvature. See also *CF, qCF* and *FM*.
qCF (=quasi Constant Frequency)	A type of *pulse* in which there is very little change in frequency from beginning to end; *shape* appears to be almost flat. Some pulses also contain an *FM* component at the beginning and/or end of the qCF component (*viz.* FM-qCF).
Search phase	The part of a bat *call* generally required for reliable species diagnosis. A consistent series of *pulses* emitted by a bat that is searching for prey or and/or navigating through its habitat. Search phase pulses generally have longer duration, flatter slope and more consistent shape than *approach phase* and *feeding buzz* pulses.
Sequence	Literally, a sequence of *pulses* that may be from one or more bats; but generally refers to a *call* or part (e.g. *phase*) of a call.
Tail	The final component of a *pulse*, following the *characteristic frequency* section; may consist of a short or long sweep of frequencies either upward or downward from the Fc; or may be absent.

Appendix 1 *Saccolaimus* species identification scheme proposed by Dr K. Armstrong

The likelihood of the presence of *Saccolaimus saccolaimus* based on a particular dataset might be assessed in the context of seven criteria that can be helpful in separating the calls of the three Australian species of *Saccolaimus* (**Table A1**). Selected calls could meet several criteria, however only meeting criterion 6 and/or criterion 7 would provide an unambiguous identification of the species.

REFERENCES

Armstrong, K.N., Hoye, G., Broken-Brow, J. and Ford, G. (2014). Overcoming impediments to effective survey of *Saccolaimus* species on Cape York, Queensland. Oral presentation at the 16th Australasian Bat Society Conference 22–25 April 2014, Townsville, Queensland. *The Australasian Bat Society Newsletter* 42: 34–35.

Coles, R., Britton, A., Boonman, A. and Clague, C. (2012). Discovery of a highly unusual alternating call frequency pattern used by the echolocating emballonurid bat *Saccolaimus saccolaimus* during foraging. Oral presentation at the 15th Australasian Bat Society Conference, Melbourne, Australia, 11–13 April 2012. *The Australasian Bat Society Newsletter* 38: 35–36.

Coles, R., Lane D. and Kovachev, I. (2014). Echolocation ecology and distribution of the bare-rumped sheathtail bat *Saccolaimus saccolaimus*: the Bornean-Australian connection. Oral presentation at the 16th Australasian Bat Society Conference 22–25 April 2014, Townsville, Queensland. *The Australasian Bat Society Newsletter* 42: 33.

Corben C. (2010). Acoustic identification of *Saccolaimus*. Oral presentation at the 14th Australasian Bat Society conference, Darwin, Northern Territory, 12–14 July 2010. *The Australasian Bat Society Newsletter* 35: 26.

Corben C. (2011). Bat calls of Borneo. Available at URL:

http://users.lmi.net/corben/BatsOfBorneo.htm#Bat%20Calls%20of%20Borneo

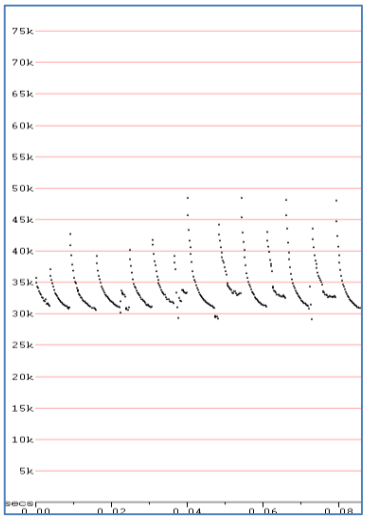
Meutstege, R., Coles, R. and Spencer, H. (2014). Observations on the foraging and roosting behaviour of the bare-rumped sheathtail bat *Saccolaimus saccolaimus* in the Cape Tribulation region of Queensland, Australia. Oral presentation at the 16th Australasian Bat Society Conference 22–25 April 2014, Townsville, Queensland. *The Australasian Bat Society Newsletter* 42: 34.

Milne, D.J., Jackling, F.C., Sidhu, M., and Appleton, B.R. (2009). Shedding new light on old species identifications: morphological and genetic evidence suggest a need for conservation status review of the critically endangered bat, *Saccolaimus saccolaimus*. *Wildlife Research* 36: 496–508.

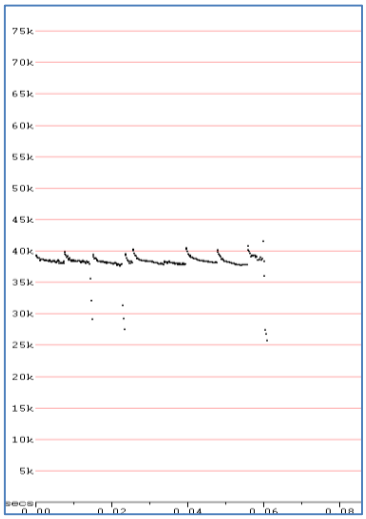
TABLE A1. Criteria used to attribute call types to the bare-rumped sheath-tailed bat *Saccolaimus saccolaimus*. A tick or a cross indicates whether an observation consistent with that particular criterion was observed in the recordings from the present survey.

	Indicative of a species of *Saccolaimus*
✔	1. Characteristic frequency of the second (loudest, based on microphone sensitivity) harmonic between c. 20 and 25 kHz (Milne et al. 2009; Armstrong et al. 2014; K.N. Armstrong unpublished data; evident in AnaBat or full spectrum format data). This criterion is indicative of, but not exclusively characteristic of *Saccolaimus*.
✔	2. In multi-harmonic representations available from full spectrum recordings, the characteristic frequency of the fundamental at around 10–12 kHz, and of the third harmonic around 30–35 kHz (Armstrong et al. 2014; K.N. Armstrong unpublished data; evident sometimes in AnaBat or more usually full spectrum format data; see examples of harmonic fragments in the AnaBat-recorded calls presented by Milne et al. 2009). This criterion is exclusively characteristic of *Saccolaimus*.
✔	3. A pulse shape that is either curvilinear or serpentine (a typical curvilinear chirp with a terminal droop) (Milne et al. 2009; Armstrong et al. 2014; K.N. Armstrong unpublished data; evident in AnaBat or full spectrum format data). This criterion is indicative of, but not exclusively characteristic of *Saccolaimus*.
✔	4. Measurements from pulses that fall within the confidence region of *S. saccolaimus* in an ordination plot constructed from the Discriminant Function Analysis of a range of low frequency emitting bats from northern Australia (Armstrong et al. 2014). This criterion is indicative of, but not exclusively characteristic of *Saccolaimus*. Note that there is often variation from other low frequency emitting species that can fall close to the cluster centroid of *S. saccolaimus*, so points falling within the confidence region of this species are not absolutely diagnostic.
✗	5. Feeding buzz shape differing from that of *S. flaviventris* as described by Corben (2010, 2011), which can be diagnostic in the absence of the Papuan sheath-tailed bat *S. mixtus* (K.N. Armstrong unpublished data; evident in AnaBat or full spectrum format data).
	Diagnostic of the species *Saccolaimus saccolaimus* (given criteria 1–5) in sympatry with *S. mixtus*.
✔	6. Alternation of high and low characteristic frequency in successive pulses within the band 20–25 kHz (Milne et al. 2009; evident in AnaBat or full spectrum format data).
✗	7. Repeated triplet or doublet pulse sequences as described by Coles et al. (2012, 2014) and Meutstege et al. (2014) (evident in full spectrum format data only).

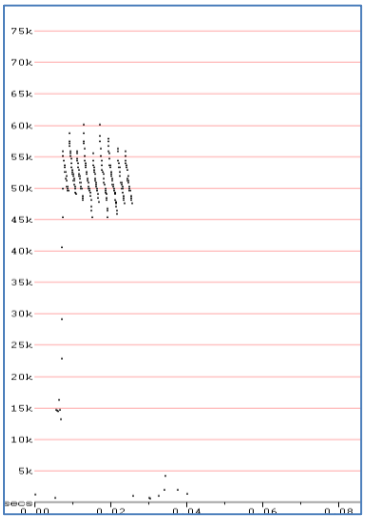
Appendix 2 Representative ZC sonograms from the Mio College survey, 9 June 2016.
(Scale: 10msec per tick; time between pulses removed)



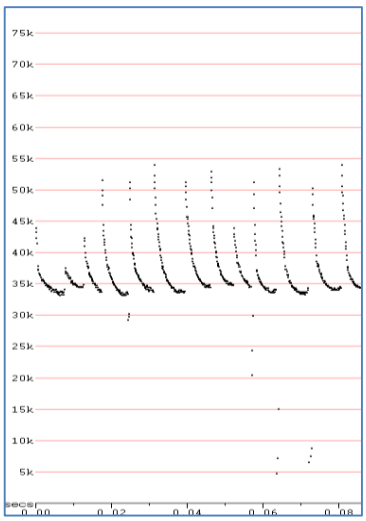
Chalinolobus gouldii



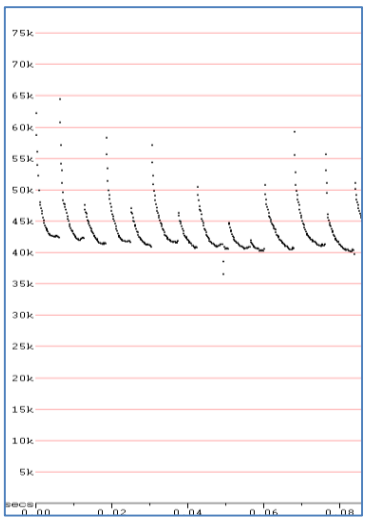
Chalinolobus nigrogriseus



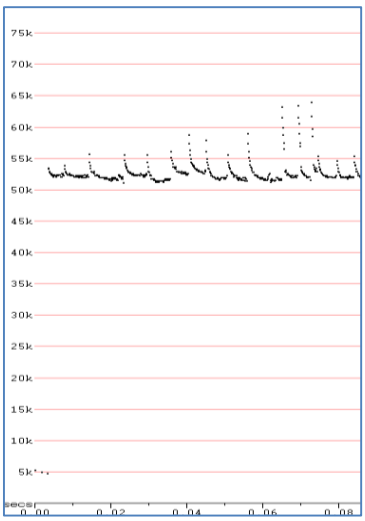
Nyctophilus sp.



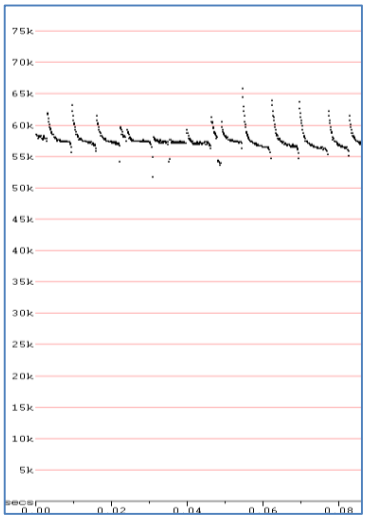
Scotorepens balstoni



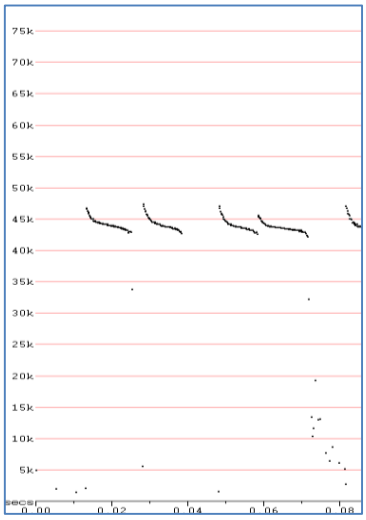
Scotorepens greyii or *S. sanborni*



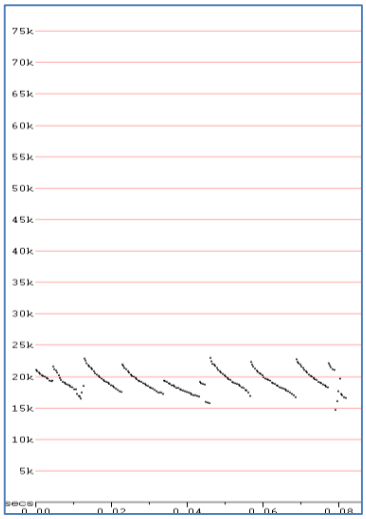
Vespadelus troughtoni



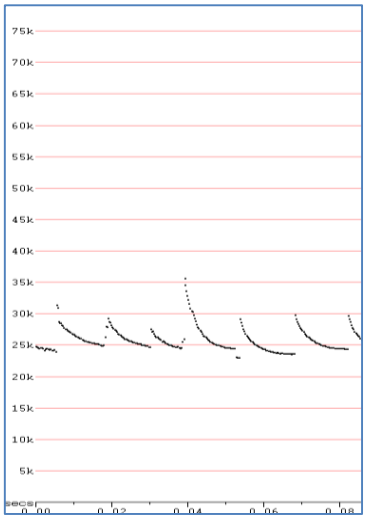
Miniopterus australis



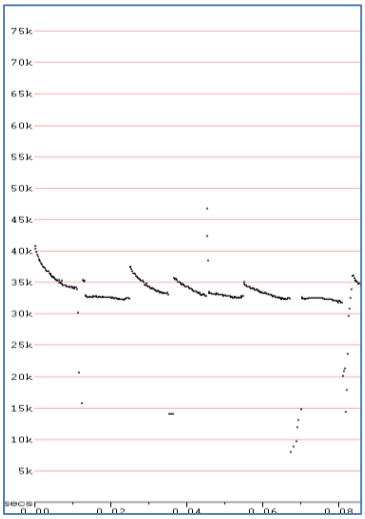
Miniopterus orianae oceanensis



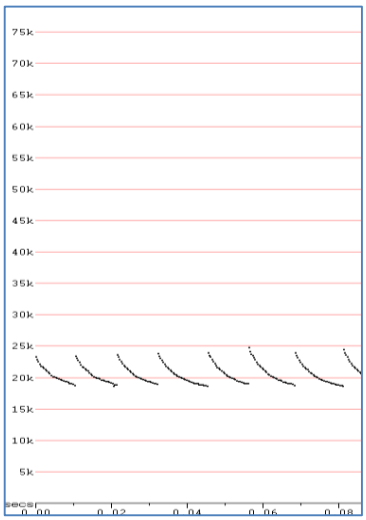
Chaerephon jobensis



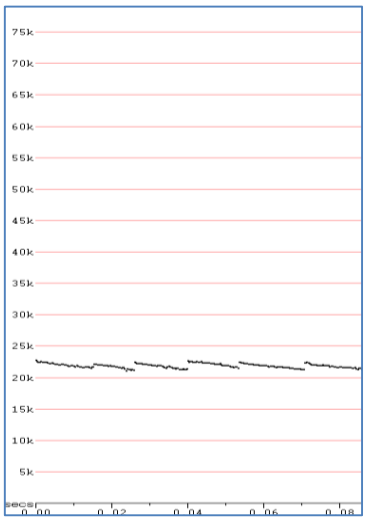
Mormopterus beccarii



Mormopterus ridei



Saccolaimus flaviventris



Probably *S. saccolaimus*

14. Appendix E – Proposed conservation area bat call report

Microbat Call Interpretation Report

Prepared for ("Client"):	Wild Environmental Consultants
Survey location/project name:	1450 Barratta Road, CLARE
Survey dates:	24 November 2016
Client project reference:	
Job no.:	WIL-1601
Report date:	13 December 2016

Methods

Survey summary

Bat calls were recorded over a single night using two Song Meter SM2BAT detectors (Wildlife Acoustics, USA) and two Anabat detectors (Titley Scientific, Brisbane). Data files were downloaded from the detectors by the client and sent to Balance! Environmental for post-processing and call analysis. The data set thus received included over 15,000 zero-crossing (ZC) format sequence files from the two Anabats and 390 full-spectrum format (WAV) files form the Song Meters.

Post-processing

The Song Meter (SM) WAV files were converted to ZC file format using Wildlife Acoustics' *Kaleidoscope* (Version 4.0.3) with the "Advanced signal processing" feature disabled. This process yielded 374 ZC files for the two SM detectors.

Many of the ZC files contained only background noise or poor quality calls that were of no use for species identification, so a generic noise filter was applied in *AnalookW* (Corben 2015) to select only those files containing potentially-identifiable bat calls.

Call analysis and identification

Zero-crossing analysis

All ZC sequence files that passed the noise filter were analysed using *AnalookW*. A subset of files representing all call types recorded by each detector was selected for call identification. The call sub-set included all calls that potentially belonged to a threatened species.

Species identification was achieved manually by comparing the ZC spectrograms of the selected calls with those of reference calls from northern Queensland and/or with published call descriptions (e.g. Reinhold et al. 2001; Milne 2002; Pennay et al. 2004). Consideration was also given to the probability of occurrence based on known species distributions (e.g. Churchill 2008; van Dyck & Strahan 2008).

Full-spectrum analysis

Full-spectrum copies of potential threatened species calls were viewed using the *Kaleidoscope Viewer* to confirm identities assigned to the ZC files. In particular, calls in the 18-28 kHz frequency range were assessed to determine the presence and pattern of harmonics, which can be used to differentiate between *Saccolaimus* species, *Mormopterus lumsdenae* and *Chaerephon jobensis*.

The call classification scheme for *Saccolaimus* spp. devised by Dr K. Armstrong (pers. comm.; see Appendix 1) was used to determine the likelihood of the threatened *S. saccolaimus* being present in the study area.

Activity patterns indicative of bats roosting on-site

Where threatened species were detected (positive and/or tentative call identification), the recording times were analysed to assess the possibility that those bats may be using day-time roosts in close proximity to the recording location. Calls recorded within the first 15-30 minutes after dusk are assumed to be bats emerging from roosts close to the detector. This analysis does not provide a definitive conclusion of on-site roost use; rather it provides an indication that threatened species' roosts may be present and warrant further investigation if clearing activities are proposed.

Reporting standard

The format and content of this report follows Australasian Bat Society standards for the interpretation and reporting of bat call data (Reardon 2003), available on-line at http://www.ausbats.org.au/.

Species nomenclature follows Reardon *et al.* (2015).

Results & Discussion

Species recorded

At least thirteen species were recorded during the Clare survey (Table 1). Eleven call types were reliably identified to individual species and another two distinctive call types potentially represented an additional 2-5 species. Some calls could not be resolved to species level due to similarities in call features between a number of species that potentially occur in the study area.

The unresolved calls were allocated to the following species groups:

- *Chalinolobus gouldii* / *Mormopterus ridei*
    - Both species reliably identified on basis of steep, curvilinear pulses (*C. gouldii*) versus flat or slightly curvilinear pulses (*M. ridei*), but several brief and/or noisy calls had intermediate features and could not be positively identified
- *Chalinolobus nigrogriseus* / *Scotorepens greyii* / *S. sanborni*
    - Steep curvilinear calls with characteristic frequency (Fc) in the range 37-40 kHz but usually difficult to reliably differentiate
    - All three species likely to be present in the study area
- *Myotis macropus* / *Nyctophilus species*
    - Steep, linear pulses with broad frequency sweep down to about 40 kHz
    - Only four brief calls recorded and not possible to differentiate
    - Up to three *Nyctophilus* species – *N. bifax*, *N. geoffroyi* and *N. gouldi* – are potentially present in the study area
    - *M. macropus* is more likely to be recorded over water and *Nyctophilus* spp. in woodland sites
- *Miniopterus orianae oceanensis* / *Vespadelus* sp. / *Pipistrellus* sp.
    - Steep curvilinear calls with Fc=43-46 kHz
    - Some calls had broad, flattish pulse-bodies characteristic of *M. o. oceanensis*, but many had narrow, hooked bodies more typical of *Vespadelus* and *Pipistrellus* species
    - The study area lies outside the confirmed distributions of *Vespadelus* and *Pipistrellus* species that call in this frequency range; however, it is possible that either *P. adamsi* or *V. baverstocki* occur in the area
- *Vespadelus troughtoni* / *Chalinolobus morio*
    - Steep curvilinear pulses with Fc=48-53 kHz, usually differentiated on hooked pulse body with upswept tail (*V. troughtoni*) versus flattish body with downward-sweeping tail (*C. morio*)
    - Both species positively identified, but a few weak/noisy calls not differentiated

Table 1 summarise the species recorded at each site; and sample spectrograms of each recorded call type are shown at Appendix 2. Technical terms used in the above call descriptions are explained in the Glossary.

Table 1 Microbat species recorded during the Clare survey, 24 November 2016.

Species shown in ***bold type*** are threatened species listed under *EPBC Act* (Cwlth) and/or *NC Act* (Qld)

Detector	AB1	AB2	SM1	SM2
No. of identifiable ZC sequence files	141	367	274	86
No. of calls identified	87	308	155	11
Species positivey identified				
Chalinolobus gouldii	✔	✔	✔	
Chalinolobus morio		✔		
Scotorepens balstoni	✔	✔		
Vespadelus troughtoni		✔	✔	
Miniopterus australis	✔	✔	✔	
Miniopterus orianae oceanensis	✔	✔	✔	✔
Chaerephon jobensis	✔	✔	✔	
Mormopterus lumsdenae	✔		✔	✔
Mormopterus ridei	✔	✔	✔	✔
Saccolaimus flaviventris			✔	
Saccolaimus saccolaimus	✔	✔	✔	
Calls not positively identified				
C. gouldii or *M. ridei*	✔		✔	
Chalinolobus nigrogriseus or *Scotorepens* sp.	✔	✔	✔	✔
Myotis macropus or *Nyctophilus* sp.	✔		✔	
M. o. oceanensis or *Vespadelus* sp. or *Pipistrellus* sp.		✔	✔	✔
V. troughtoni or *C. morio*			✔	

Threatened species – *Saccolaimus saccolaimus*

The Bare-rumped Sheath-tailed Bat (*S. saccolaimus*) is listed as **Endangered** under the *Nature Conservation Act 1992* and **Vulnerable** under the *Environment Protection and Biodiversity Conservation Act 1999*. The species' EPBC status was revised from Critically Endangered to Vulnerable on 7th December 2016 (DEE 2016).

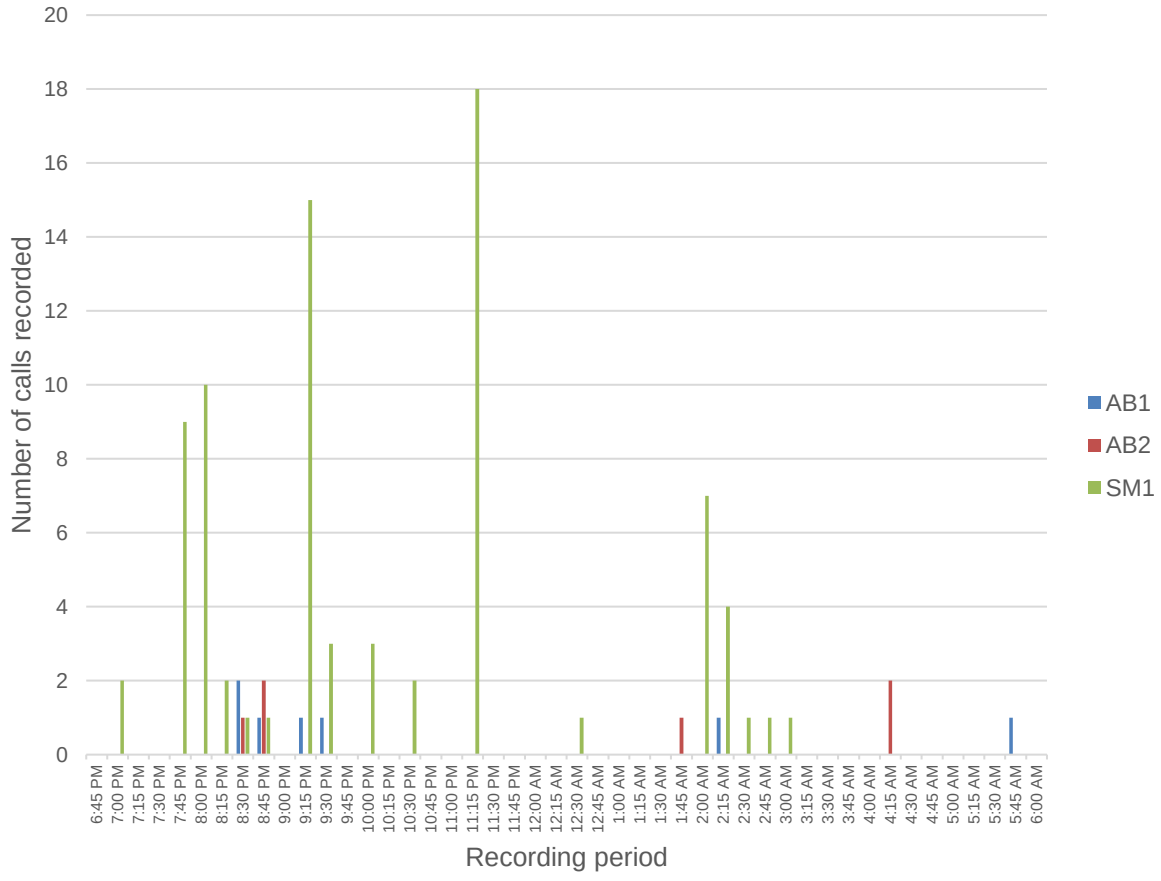
This species' presence was confirmed using a classification scheme proposed by Dr K. Armstrong (pers. comm.), using both ZC and WAV format call data. Six of the seven classification criteria used in that scheme were tested during this analysis (see Appendix 1). Statistical analysis (Criterion 4) was not undertaken because the other criteria were sufficient to obtain a positive identification for *S. saccolaimus* in the majority of calls in the relevant frequency range.

Assessment of possible roost emergence

A review of the recording times for all *S. saccolaimus* calls shows that the majority were recorded between 7:45 PM and 11:15 PM (see Figure 1). Time of last light on the 24th November was approximately 7:00 PM (http://sunrisesunset.willyweather.com.au/qld/northern/townsville.html), so the small peak in *S. saccolaimus* recorded by the SM1 detector in the 30 minutes from 7:45 – 8:15 PM could indicate an emergence of bats from one or more roosts in the vicinity of that detector.

Most of the calls attributed to *S. saccolaimus* for detector SM1 were also consistent with reference calls of the species recorded as they emerged from a roost tree in the Cairns Botanical Gardens (G. Ford, unpublished data). The characteristic sinuous pulse shapes of relatively short duration (compared with search-phase calls) appear to be typical of *S. saccolaimus* when emerging from or returning to roost sites. See Appendix 2 for sample spectrograms illustrating these characteristics.

Figure 1. Saccolaimus saccolaimus activity at three detector sites; Clare, North Qld; 24/11/2016



References

Churchill, S. (2008). *Australian Bats*. Jacana Boos, Allen & Unwin; Sydney.

Corben, C. (2015). *AnalookW for bat call analysis using ZCA.* Version 4.1t. Downloaded from www.titley.com.au.

DEE (2016). Nine species (8 mammals, 1 bird) that are listed as threatened species under the EPBC Act have been transferred to different categories. Australian Government Department of the Environment and Energy, Media Centre (online) viewed 12/12/2016 at URL http://www.environment.gov.au/news/2016/12/07/nine-species-8-mammals-1-bird-are-listed-threatened-species-under-epbc-act-have-been

Milne, D.J. (2002). *Key to the bat calls of the Top End of the Northern Territory*. Technical Report No. 71; Parks and Wildlife Commission of the Northern Territory, Darwin.

Pennay, M., Law, B. and Reinhold, L. (2004). *Bat Calls of New South Wales*. Department of Environment and Conservation, Hurstville.

Reardon, T. (2003). Standards in bat detector based surveys. *Australasian Bat Society Newsletter* **20**, 41-43.

Reardon, T.B., Armstrong, K.N. and Jackson, S.M. (2015). A current taxonomic list of Australian Chiroptera. Australasian Bat Society. Version 2015-05-15. URL: http://ausbats.org.au/taxonomic-list/4589345107

Reinhold, L., Law, B., Ford, G. and Pennay, M. (2001). *Key to the bat calls of south-east Queensland and north-east New South Wales*. Department of Natural Resources and Mines, Brisbane.

van Dyck, S. and Strahan, R. (ed.) (2008). *The Mammals of Australia* (Third Edition). New Holland; Sydney.

Glossary

Technical terms used in this report are described in the following table.

Approach phase	The part of a bat *call* emitted as the bat starts to home in on a detected prey item; a transitional series of *pulses* between the *search phase* and *feeding buzz*, that become progressively steeper and shorter in duration.
Call	Refers to a single bat call, made up of a series of individual sound *pulses* in one or more *phases* (*search, approach, feeding buzz*).
CF (=Constant Frequency)	A type of *pulse* in which the dominant component consists of a more-or-less 'pure tone' of sound at a Constant Frequency; with *shape* appearing flat on the sonogram. Often also contains a brief *FM* component at the beginning and/or end of the CF component (*viz.* FM-CF-FM).
Characteristic frequency (Fc)	The frequency of the flattest part of a *pulse*; usually the lowest frequency reached in the *qCF* component of a pulse. This is often the primary diagnostic feature for species identification.
Duration	The time period from the beginning of a *pulse* to the end of the pulse.
Feeding buzz	The terminal part of a *call*, following the *approach phase*, emitted as the bat catches a prey item; a distinctive, rapid series of very steep, very short-duration pulses.
FM (=Frequency Modulated)	A type of *pulse* in which there is substantial change in frequency from beginning to end; *shape* ranges from almost vertical and linear through varying degrees of curvature.
FC range	Refers to the range of frequencies occupied by the *characteristic frequency* section of *pulses* within a call or set of calls.
Frequency sweep or "band-width"	The range of frequencies through which a *pulse* sweeps from beginning to end; Maximum frequency (Fmax) – minimum frequency (Fmin).
Knee	The transitional part of a *pulse* between the initial (usually steeper) frequency sweep and the *characteristic frequency* section (usually flatter); time to knee (Tk) and frequency of knee (Fk) can be diagnostic for some species.
Pulse	An individual pulse of sound within a bat *call*; the *shape*, *duration* and *characteristic frequency* of a pulse are the key diagnostic features used to differentiate species.
Pulse body	The part of the *pulse* between the *knee* and *tail* and containing the *characteristic frequency* section.
Pulse shape	The general appearance of a *pulse* on the sonogram, described using relative terms related to features such as slope and degree of curvature. See also *CF, qCF* and *FM*.
qCF (=quasi Constant Frequency)	A type of *pulse* in which there is very little change in frequency from beginning to end; *shape* appears to be almost flat. Some pulses also contain an *FM* component at the beginning and/or end of the qCF component (*viz.* FM-qCF).
Search phase	The part of a bat *call* generally required for reliable species diagnosis. A consistent series of *pulses* emitted by a bat that is searching for prey or and/or navigating through its habitat. Search phase pulses generally have longer duration, flatter slope and more consistent shape than *approach phase* and *feeding buzz* pulses.
Sequence	Literally, a sequence of *pulses* that may be from one or more bats; but generally refers to a *call* or part (e.g. *phase*) of a call.
Tail	The final component of a *pulse*, following the *characteristic frequency* section; may consist of a short or long sweep of frequencies either upward or downward from the Fc; or may be absent.

Appendix 1 .

Notes on a proposed identification scheme for *Saccolaimus* spp.

Prepared by Dr Kyle Armstrong

The likelihood of the presence of *Saccolaimus saccolaimus* based on a particular dataset might be assessed in the context of seven criteria that can be helpful in separating the calls of the three Australian species of *Saccolaimus* (**Table A1**). Selected calls could meet several criteria, however only meeting criterion 6 and/or criterion 7 would provide an unambiguous identification of the species.

REFERENCES

Armstrong, K.N., Hoye, G., Broken-Brow, J. and Ford, G. (2014). Overcoming impediments to effective survey of *Saccolaimus* species on Cape York, Queensland. Oral presentation at the 16th Australasian Bat Society Conference 22–25 April 2014, Townsville, Queensland. *The Australasian Bat Society Newsletter* 42: 34–35.

Coles, R., Britton, A., Boonman, A. and Clague, C. (2012). Discovery of a highly unusual alternating call frequency pattern used by the echolocating emballonurid bat *Saccolaimus saccolaimus* during foraging. Oral presentation at the 15th Australasian Bat Society Conference, Melbourne, Australia, 11–13 April 2012. *The Australasian Bat Society Newsletter* 38: 35–36.

Coles, R., Lane D. and Kovachev, I. (2014). Echolocation ecology and distribution of the bare-rumped sheathtail bat *Saccolaimus saccolaimus*: the Bornean-Australian connection. Oral presentation at the 16th Australasian Bat Society Conference 22–25 April 2014, Townsville, Queensland. *The Australasian Bat Society Newsletter* 42: 33.

Corben C. (2010). Acoustic identification of *Saccolaimus*. Oral presentation at the 14th Australasian Bat Society conference, Darwin, Northern Territory, 12–14 July 2010. *The Australasian Bat Society Newsletter* 35: 26.

Corben C. (2011). Bat calls of Borneo. Available at URL:

http://users.lmi.net/corben/BatsOfBorneo.htm#Bat%20Calls%20of%20Borneo

Meutstege, R., Coles, R. and Spencer, H. (2014). Observations on the foraging and roosting behaviour of the bare-rumped sheathtail bat *Saccolaimus saccolaimus* in the Cape Tribulation region of Queensland, Australia. Oral presentation at the 16th Australasian Bat Society Conference 22–25 April 2014, Townsville, Queensland. *The Australasian Bat Society Newsletter* 42: 34.

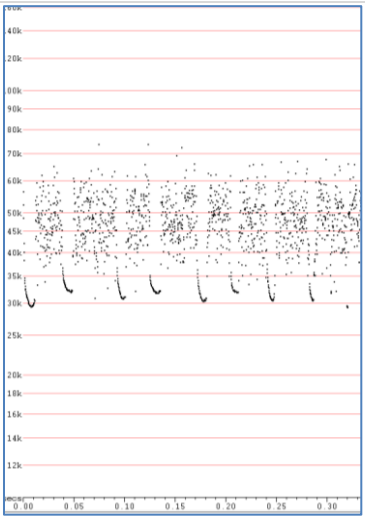
Milne, D.J., Jackling, F.C., Sidhu, M., and Appleton, B.R. (2009). Shedding new light on old species identifications: morphological and genetic evidence suggest a need for conservation status review of the critically endangered bat, *Saccolaimus saccolaimus*. *Wildlife Research* 36: 496–508.

Table A1 Criteria used to attribute call types to the bare-rumped sheath-tailed bat *Saccolaimus saccolaimus* (after K. Armstrong, pers. comm.).

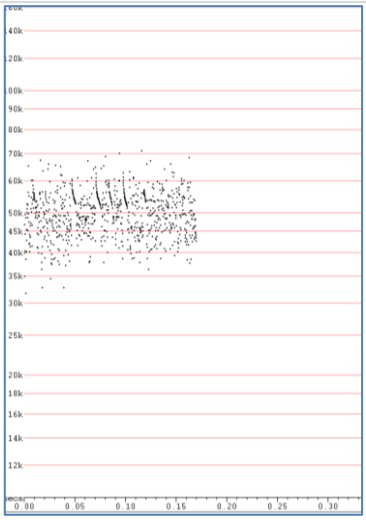
- ✔ in the first column indicates whether an observation consistent with the relevant criterion was observed in the recordings.
- ✗ indicates the criterion was not met in any of the data from this survey.
- ***?*** indicates some calls showed evidence of the feature but it was insufficient for definitive species identification

	Indicative of a species of *Saccolaimus*
✔	1. Characteristic frequency of the second (loudest, based on microphone sensitivity) harmonic between c. 20 and 25 kHz (Milne et al. 2009; Armstrong et al. 2014; K.N. Armstrong unpublished data; evident in AnaBat or full spectrum format data). This criterion is indicative of, but not exclusively characteristic of *Saccolaimus*.
✔	2. In multi-harmonic representations available from full spectrum recordings, the characteristic frequency of the fundamental at around 10–12 kHz, and of the third harmonic around 30–35 kHz (Armstrong et al. 2014; K.N. Armstrong unpublished data; evident sometimes in AnaBat or more usually full spectrum format data; see examples of harmonic fragments in the AnaBat-recorded calls presented by Milne et al. 2009). This criterion is exclusively characteristic of *Saccolaimus*.
✔	3. A pulse shape that is either curvilinear or serpentine (a typical curvilinear chirp with a terminal droop) (Milne et al. 2009; Armstrong et al. 2014; K.N. Armstrong unpublished data; evident in AnaBat or full spectrum format data). This criterion is indicative of, but not exclusively characteristic of *Saccolaimus*.
✗	4. Measurements from pulses that fall within the confidence region of *S. saccolaimus* in an ordination plot constructed from the Discriminant Function Analysis of a range of low frequency emitting bats from northern Australia (Armstrong et al. 2014). This criterion is indicative of, but not exclusively characteristic of *Saccolaimus*. Note that there is often variation from other low frequency emitting species that can fall close to the cluster centroid of *S. saccolaimus*, so points falling within the confidence region of this species are not absolutely diagnostic.
✔	5. Feeding buzz shape differing from that of *S. flaviventris* as described by Corben (2010, 2011), which can be diagnostic in the absence of the Papuan sheath-tailed bat *S. mixtus* (K.N. Armstrong unpublished data; evident in AnaBat or full spectrum format data).
	Diagnostic of the species *Saccolaimus saccolaimus* (given criteria 1–5) in sympatry with *S. mixtus*.
?	6. Alternation of high and low characteristic frequency in successive pulses within the band 20–25 kHz (Milne et al. 2009; evident in AnaBat or full spectrum format data).
?	7. Repeated triplet or doublet pulse sequences as described by Coles et al. (2012, 2014) and Meutstege et al. (2014) (evident in full spectrum format data only).

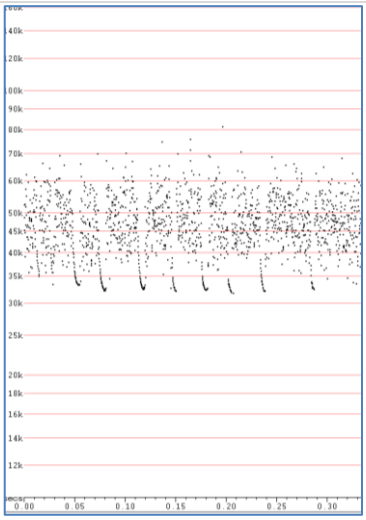
Appendix 2 Representative call sequences from the Clare survey, 24th November 2016.



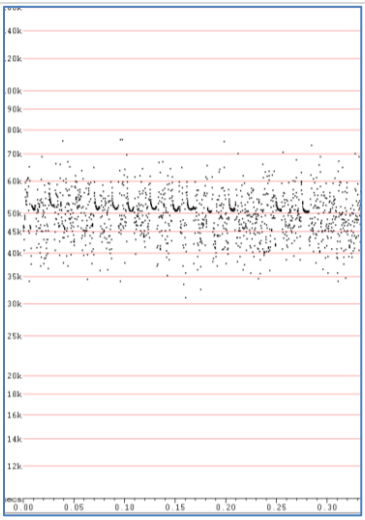
Chalinolobus gouldii



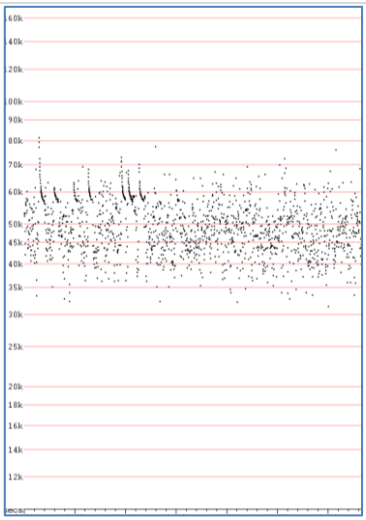
Chalinolobus morio



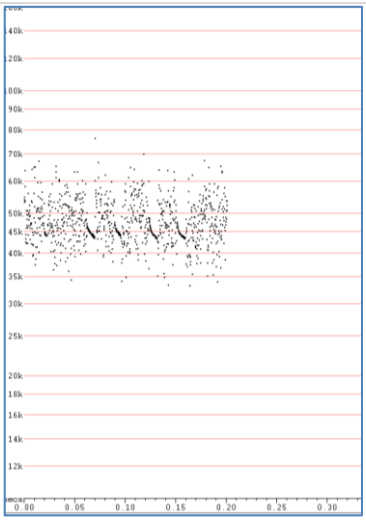
Scotorepens balstoni



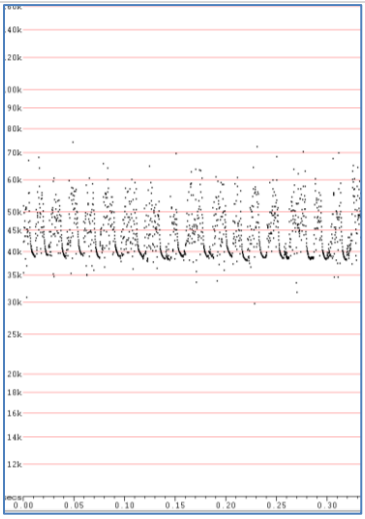
Vespadelus troughtoni



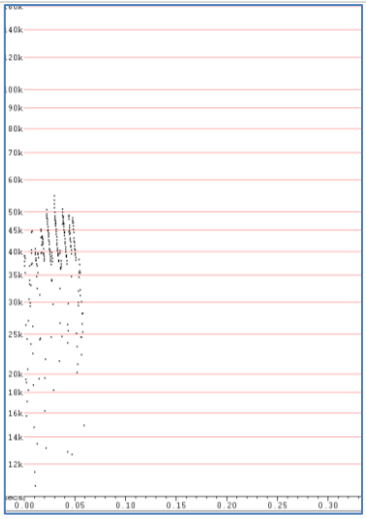
Miniopterus australis



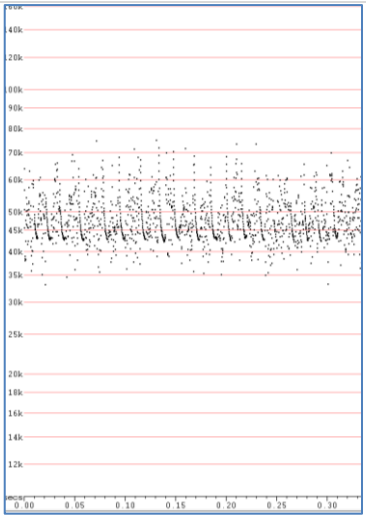
Miniopterus orianae oceanensis



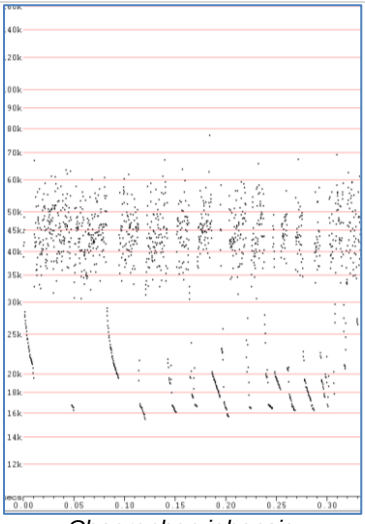
C. nigrogriseus / *Scotorepens* sp.



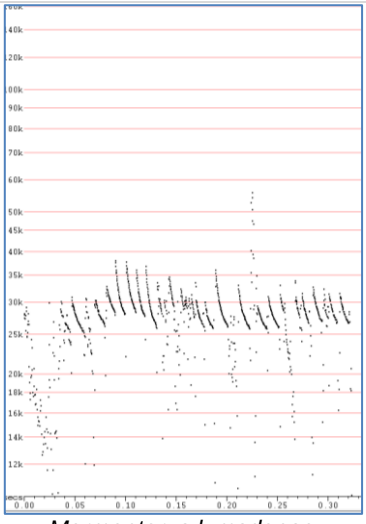
Myotis macropus / *Nyctophilus* sp.



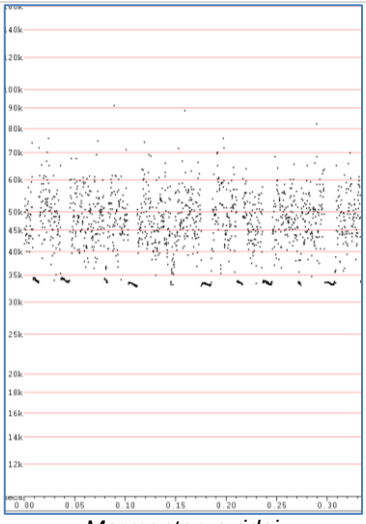
Possibly *Vespadelus* / *Pipistrellus*



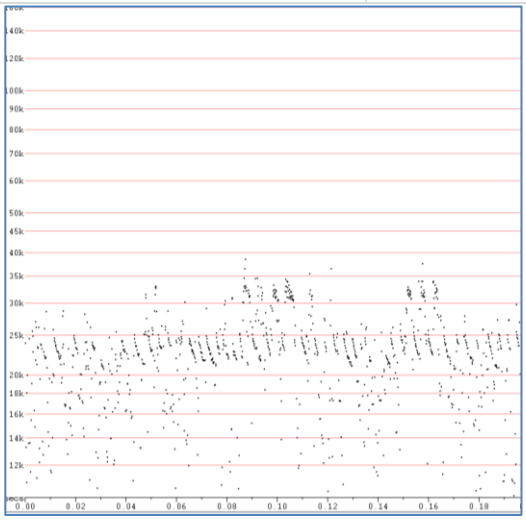
Chaerephon jobensis

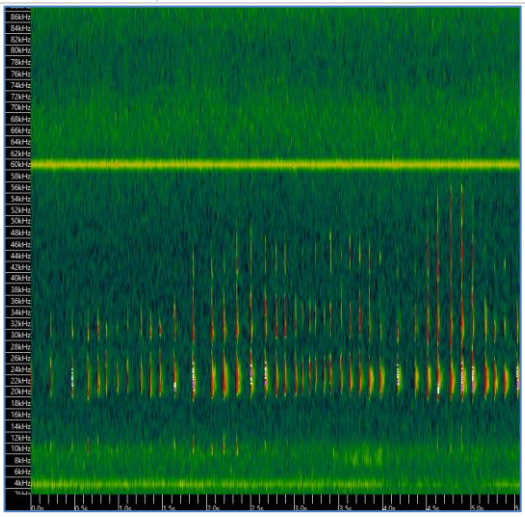


Mormopterus lumsdenae

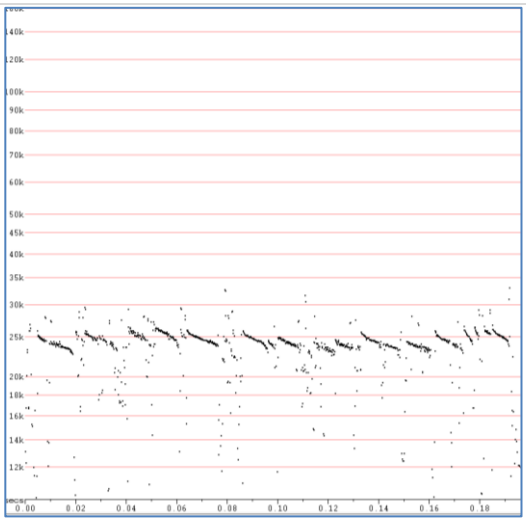


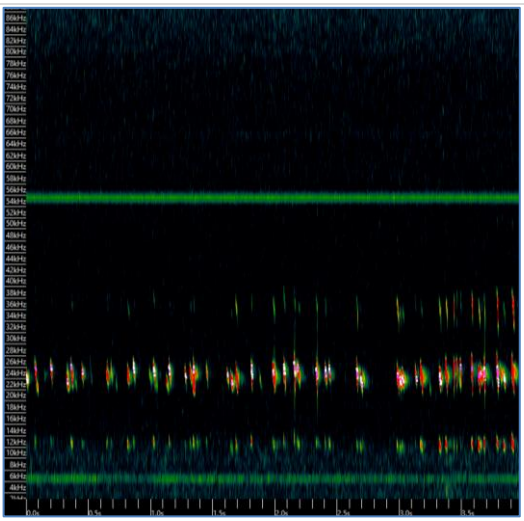
Mormopterus ridei





Saccolaimus flaviventris (ZC and WAV versions of same call)





Saccolaimus saccolaimus (ZC and WAV versions of same call)