Appendix K Bat Call Analyses

Microbat Call Identification Report

Prepared for ("Client"):	AustralAsian Resource Consultants
Survey location/project name:	Lenton Mine
Survey dates:	14-22 March 2017
Client project reference:	
Job no.:	AARC-1702
Report date:	28 April 2017

Methods

Data received and post-processing

The survey was conducted at five sites over six consecutive nights, using two Anabat Express detectors (Titley Scientific, Brisbane). The raw zero-crossing analysis (ZCA) data and detector LOG files were downloaded by the client and sent to *Balance! Environmental* for analysis.

AnalookW (Corben 2015) was used to extract individual Anabat call sequence files from the ZCA data. This process yielded more than 43,500 sequence files for the analysis.

Call identification

All Anabat sequence files were viewed in *AnalookW* and a representative selection of all call types recorded at each site were selected for detailed analysis. Species identification achieved manually by comparing the call spectrograms with those of reference calls from central and northern Queensland and with reference to published call descriptions (e.g. Reinhold *et al.* 2001; Pennay *et al*. 2004). Calls with fewer than four clearly-defined, non-fragmented pulses were excluded from the analysis.

Species' identification was also guided by considering probability of occurrence based on general distribution information (Churchill 2008; van Dyck *et al.* 2013) and/or *Atlas of Living Australia* on-line database records (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).

Results & Discussion

Data quality

More than 80% of the sequence files contained only background noise (false triggers) or very low quality (weak/fragmented) bat calls that were of little use for species identification. Call identification was therefore based on a sub-set of 1179 files chosen from the 6000 or so sequence files that contained potentially identifiable bat calls.

Species identified

At least sixteen and probably seventeen species were recorded during the Lenton Mine survey of March 2017 (see Table 1). The large number of available calls meant that most species were reliably identifiable; however, some call types could not be resolved to species level at some sites, due to similarities between the calls of several species that are likely to occur in the study area. These calls were allocated to species groups and each member of the group listed as “possible” unless other calls were unequivocally identified to those species.

The species groups used in this analysis included:

- *Nyctophilus geoffroyi* / *N. gouldi* (impossible to distinguish in call data);
- *Chalinolobus gouldii* / *Scotorepens balstoni*;
- *Chalinolobus morio* / *Vespadelus troughtoni*;
- *Chalinolobus nigrogriseus* / *Scotorepens greyii*; and
- *Chalinolobus picatus* / *Vespadelus baverstocki* / *Miniopterus orianae oceanensis.*

Table 1 Microbat species recorded during the Lenton Mine survey, 14-22 March 2017.

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

Site:	FS02	FS03	FS05	FS06	FS07
Total sequence files:	3466	3262	2992	12049	21770
Total calls identified:	240	212	224	269	234
Chalinolobus gouldii	♦	♦	♦	♦	♦
Chalinolobus morio		□	♦	♦	□
Chalinolobus nigrogriseus	♦	♦	♦	□	♦
Chalinolobus picatus	♦	♦	♦	♦	♦
Nyctophilus geoffroyi / N. gouldi	♦		♦	♦	♦
Scotorepens balstoni	♦	□	♦	□	□
Scotorepens greyii	♦	♦	♦	♦	♦
Vespadelus baverstocki	□	□	♦	♦	♦
Vespadelus troughtoni	♦	♦	□	□	□
Miniopterus australis	♦		♦	♦	♦
Miniopterus orianae oceanensis	□	□	□	□	♦
Chaerephon jobensis	♦	♦	♦	♦	♦
Mormopterus lumsdenae	♦	♦	♦	♦	♦
Mormopterus ridei	♦	♦	♦	♦	♦
Saccolaimus flaviventris	♦	♦	♦	♦	♦
Taphozous troughtoni	♦	♦	♦	♦	♦

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.

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.

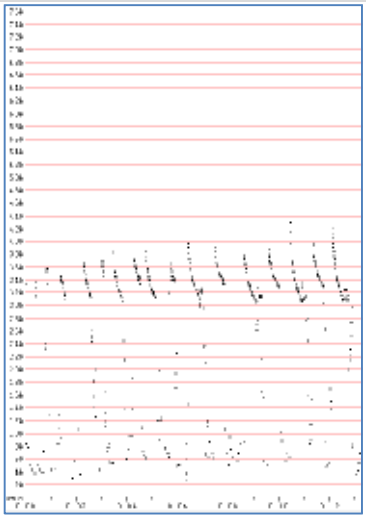
van Dyck, S., Gynther, I. and Baker, A. (ed.) (2013). *Field Companion to the Mammals of Australia*. New Holland; Sydney.

Glossary

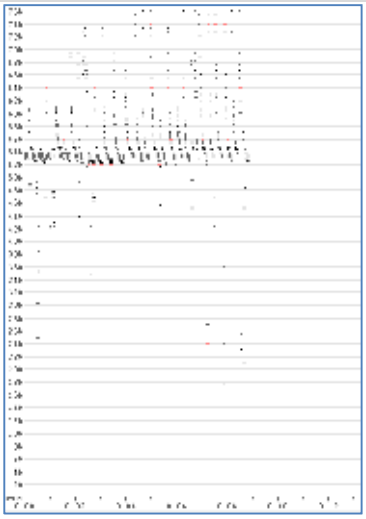
Technical terms used in this report are described in the following table.

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.

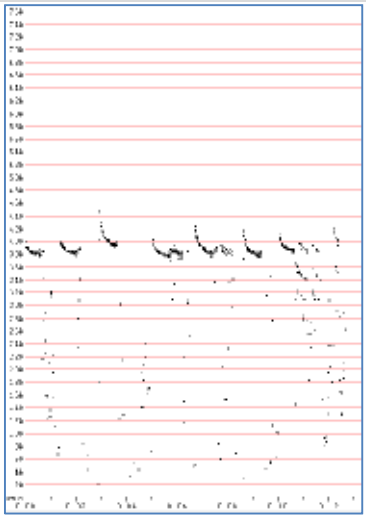
Appendix 1 Representative call sequences from the Lenton Mine survey, March 2017.
(AnalookW 'F7 compressed' display: x=time(s); y=frequency(kHz); time between pulses removed)



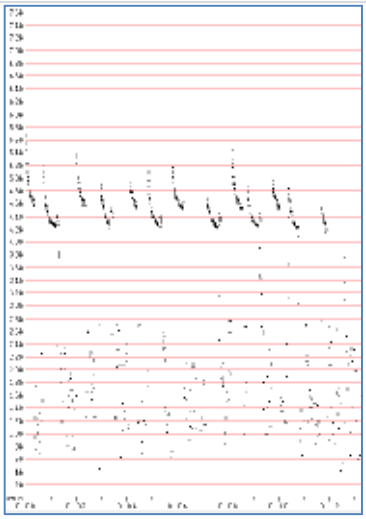
Chalinolobus gouldii



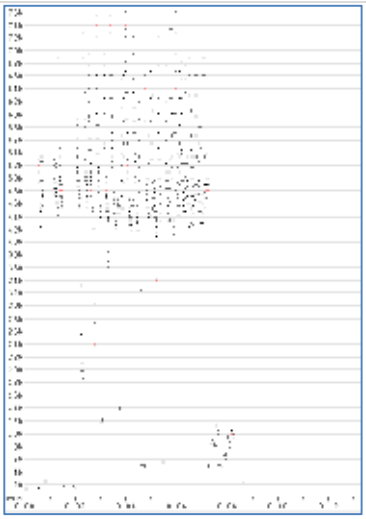
Chalinolobus morio



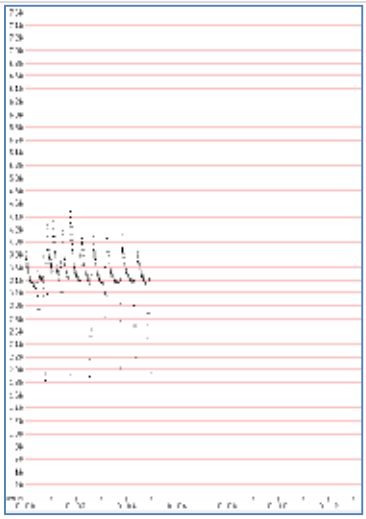
Chalinolobus nigrogriseus



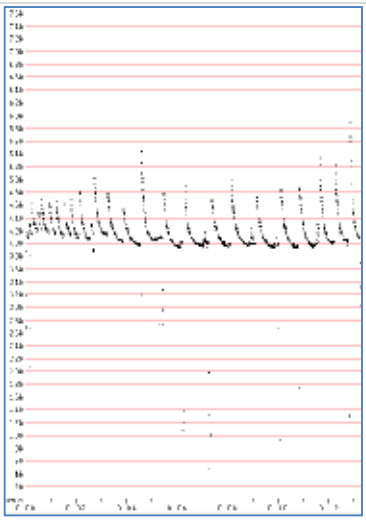
Chalinolobus picatus



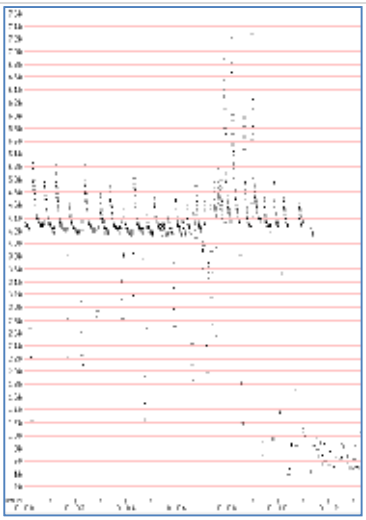
Nyctophilus species



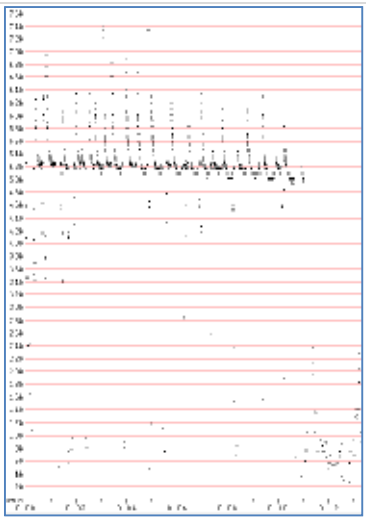
Scotorepens balstoni



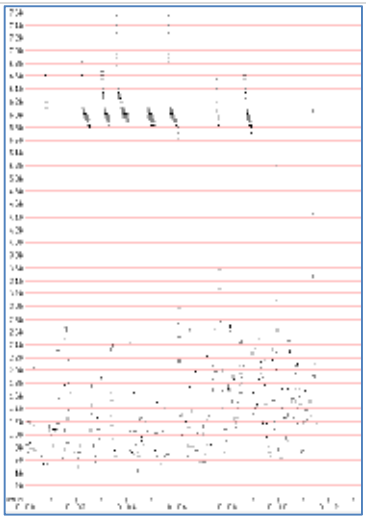
Scotorepens greyii



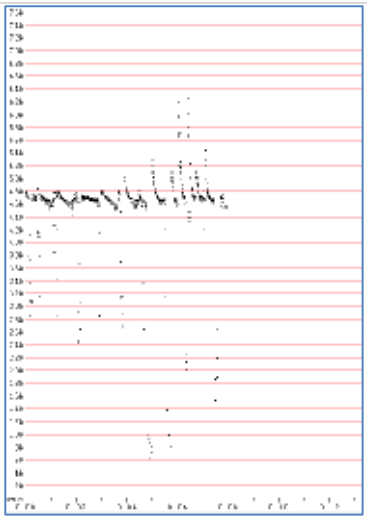
Vespadelus baverstocki



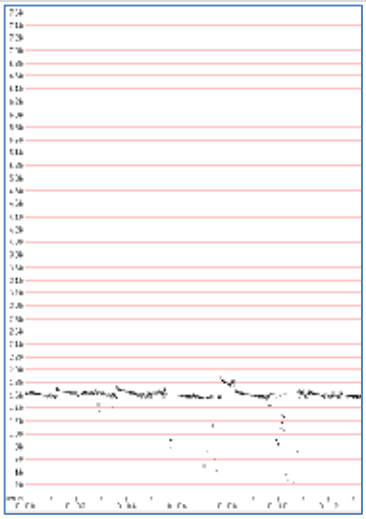
Vespadelus troughtoni



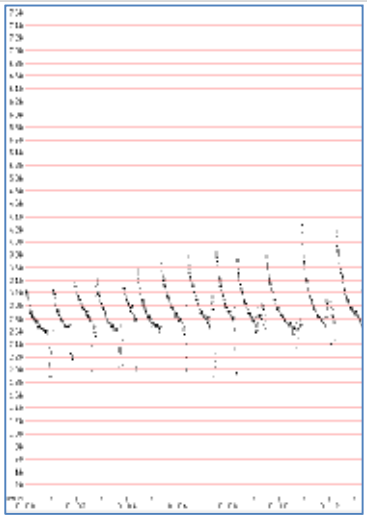
Miniopterus australis



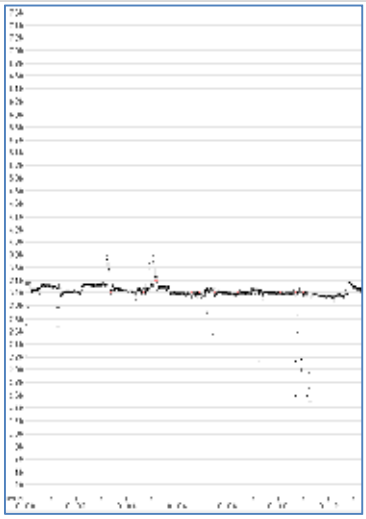
Miniopterus orianae oceanensis



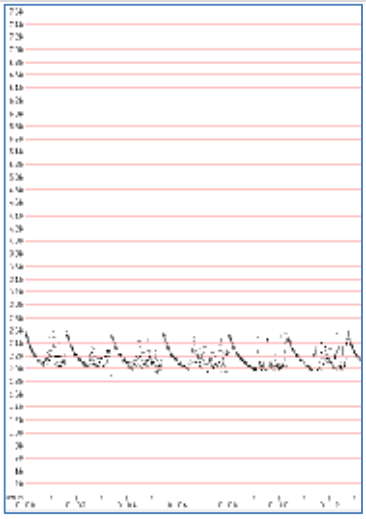
Chaerephon jobensis



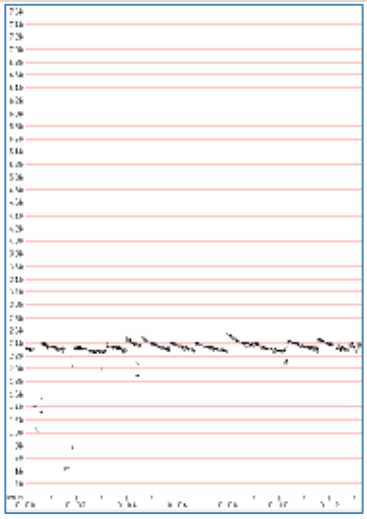
Mormopterus lumsdenae



Mormopterus ridei



Saccolaimus flaviventris



Taphozous troughtoni

Microbat Call Identification Report

Prepared for ("Client"):	AARC Environmental Solutions
Survey location/project name:	Lenton Mine
Survey dates:	22-27 February 2018
Client project reference:	
Job no.:	AARC-1802
Report date:	17 April 2018

Methods

Data received and post-processing

The survey was conducted at four sites over six consecutive nights, using two Anabat Express detectors (Titley Scientific, Brisbane) and a Song Meter SMZC detector (Wildlife Acoustics, Maynard MA, USA). *Balance! Environmental* received nine raw ZCA data files and accompanying detector LOG files from the two Express units, plus 862 ZC call-sequence files from the SMZC.

AnalookW (Corben 2017) was used to extract individual ZC call-sequence files from the Anabat Express ZCA data files. This process yielded more than 13,200 sequence files for the analysis. Most of those files were from Sites LAq01 & LAq02, with a high proportion apparently containing mainly background noise. Consequently, a generic noise filter was applied to data from those two sites, to extract only those files containing potentially-identifiable bat calls. This process removed about half of the sequence files, leaving an identification data set of some 8000 files from the four sites.

Call identification

All sequence files in the filtered data set were viewed in *AnalookW* and a representative selection of all call types recorded at each site were selected for detailed analysis. Species identification was achieved manually by comparing the call spectrograms with those of reference calls from central and northern Queensland and with reference to published call descriptions (e.g. Reinhold *et al.* 2001; Pennay *et al*. 2004). Calls with fewer than four clearly-defined, non-fragmented pulses were excluded from the analysis.

Species' identification was also guided by considering probability of occurrence based on general distribution information (Churchill 2008; van Dyck *et al.* 2013) and/or *Atlas of Living Australia* on-line database records (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 Jackson & Groves (2015), whose treatment of Australian mammal taxonomy elevates the sub-genus names proposed by Reardon *et al.* (2008, 2014) for the *Mormopterus* free-tailed bats to genus level. New names used in this report include:

- *Ozimops lumsdenae* (Northern Free-tailed Bat) – formerly *M. beccarii* (Beccari's Freetail Bat);
- *O. ridei* (Ride's Free-tailed Bat) – formerly *M.* 'species 2' (Eastern Freetail Bat); and
- *Setirostris eleryi* (Bristle-faced Free-tailed Bat) – formerly *M. eleryi* and *M.* 'species 6'.

Results & Discussion

At least 17 and up to 22 species were recorded during the Lenton Mine survey of February 2018 (see Table 1). The large number of available calls meant that most species were reliably identifiable; however, some call types could not be resolved to species level at some sites, due to similarities between the calls of several species that are likely to occur in the study area. These calls were allocated to species groups and each member of the group listed as "possible" unless other calls were unequivocally identified to those species.

The species groups used in this analysis included:

- *Chalinolobus morio / Vespadelus troughtoni*;
- *Chalinolobus nigrogriseus / Scotorepens* spp.;
- *Nyctophilus geoffroyi / N. gouldi* (impossible to distinguish in call data);
- *Scotorepens greyii / S. sanborni*;
- *Scotorepens orion / Scoteanax rueppellii*;
- *Vespadelus baverstocki / Miniopterus orianae oceanensis*;
- *Setirostris eleryi / Scotorepens greyii*; and
- *Taphozous troughtoni / Ozimops lumsdenae*.

Table 1 Microbat species recorded during the Lenton Mine survey, 22-27 February 2018.

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

Site:	LAq01	LAq02	LAq03	LAq04
Total sequence files:	4345	8520	862	371
Number of calls identified:	347	416	141	123
Chalinolobus gouldii	♦	♦	♦	♦
Chalinolobus morio	□	□	□	□
Chalinolobus nigrogriseus	♦	□		□
Chalinolobus picatus	♦	♦	♦	♦
Nyctophilus geoffroyi / N. gouldi	♦	♦		♦
Scotorepens balstoni	♦	♦	♦	
Scotorepens greyii / S. sanborni	♦	♦	♦	♦
Scotorepens orion / Scoteanax rueppellii	□	□	□	
Vespadelus baverstocki	♦	♦	♦	♦
Vespadelus troughtoni	♦	♦	□	♦
Miniopterus australis	♦	♦	♦	♦
Miniopterus orianae oceanensis	□	□		
Austronomus australis			♦	
Chaerephon jobensis	♦	♦	♦	♦
Ozimops lumsdenae	♦	♦	♦	♦
Ozimops ridei	♦	♦	♦	♦
Setirostris eleryi	□	□		
Saccolaimus flaviventris	♦	♦	♦	♦
Taphozous troughtoni	♦	♦	♦	□

References

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

Corben, C. (2017). *AnalookW for bat call analysis using ZCA. Version 4.2n*, 16 March 2017.

Jackson, S. and Groves, C. (2015). *Taxonomy of Australian Mammals*. CSIRO Publishing, Melbourne.

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., Adams, M., McKenzie, N. and Jenkins, P. (2008). A new species of Australian freetail bat *Mormopterus eleryi* sp. nov. (Chiroptera: Molossidae) and a taxonomic reappraisal of *M. norfolkensis* (Gray). *Zootaxa* 1875: 1-31.

Reardon, T. B., McKenzie, N. L., Cooper, S. J. B., Appleton, B., Carthew, S. and Adams, M. (2014). A molecular and morphological investigation of species boundaries and phylogenetic relationships in Australian free-tailed bats *Mormopterus* (Chiroptera: Molossidae). *Aust. J. Zool*. **62**, 109–136.

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. (ed.) (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*).
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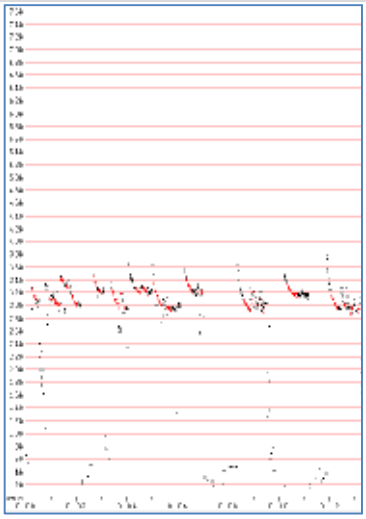
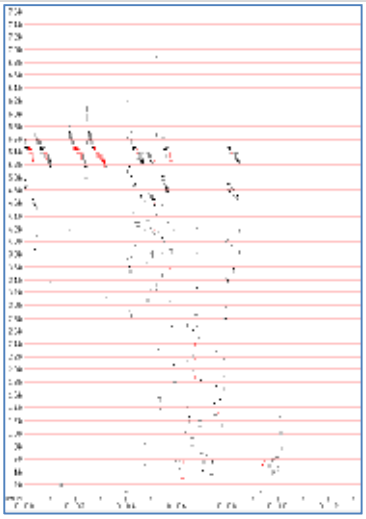
Characteristic frequency (Fc)	The frequency of the flattest part of a *pulse*; usually the lowest frequency reached in the *qCF* component of a pulse. This is often the primary diagnostic feature for species identification.
Duration	The time period from the beginning of a *pulse* to the end of the pulse.
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.

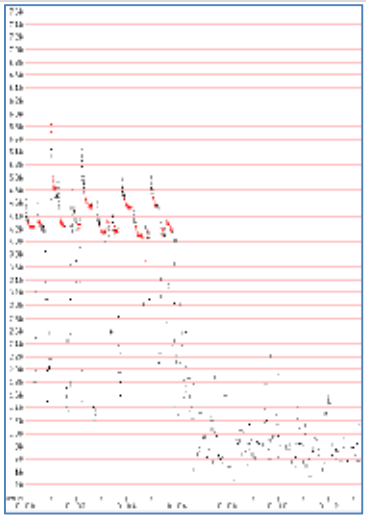
Appendix 1 Representative call sequences from the Lenton Mine survey, February 2018.
(AnalookW 'F7 compressed' display: x=time(s); y=frequency(kHz); time between pulses removed)



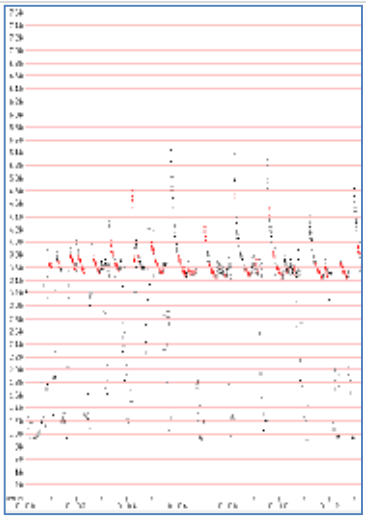
Chalinolobus gouldii



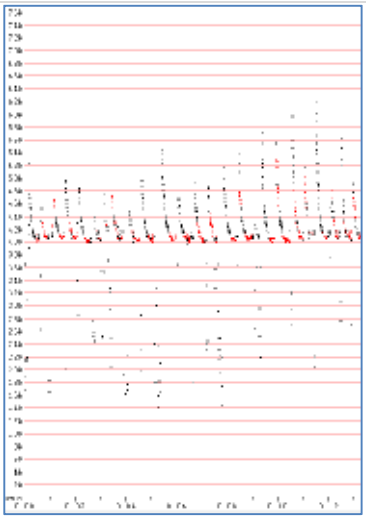
Chalinolobus morio



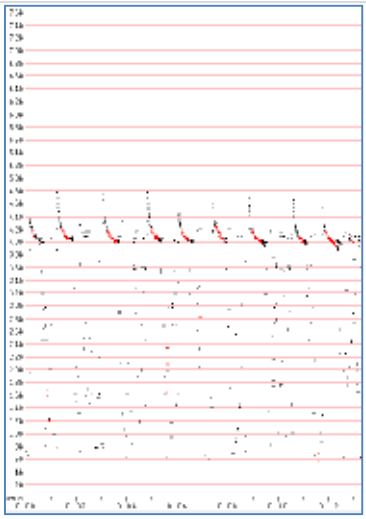
Chalinolobus picatus



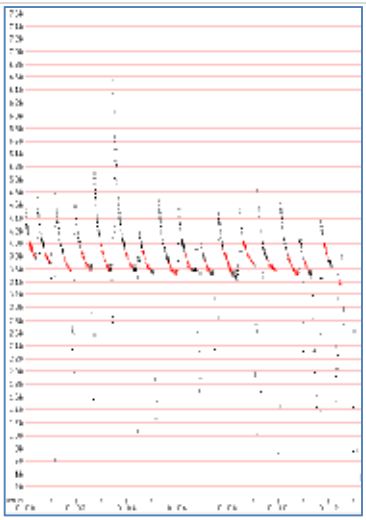
Scotorepens balstoni



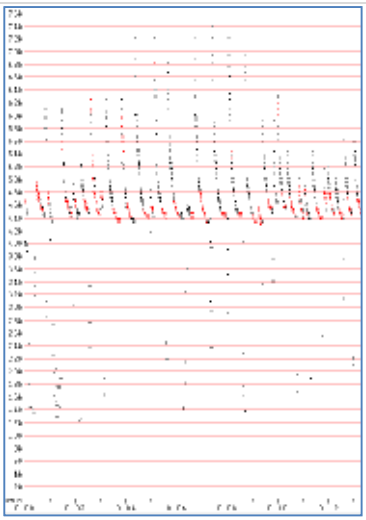
Scotorepens greyii / S. sanborni



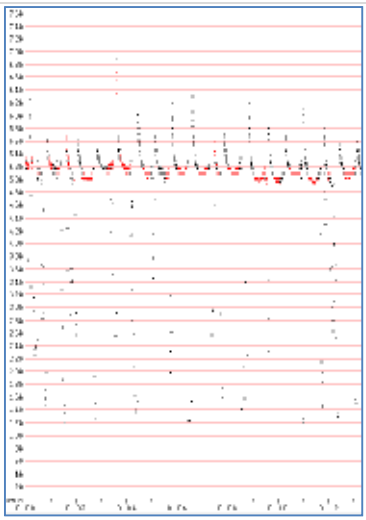
Scotorepens sp. / Ch. nigrogriseus



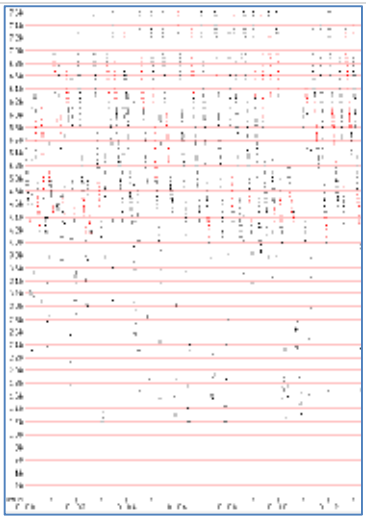
Scoteanax rueppellii / S. orion



Vespadelus baverstocki



Vespadelus troughtoni



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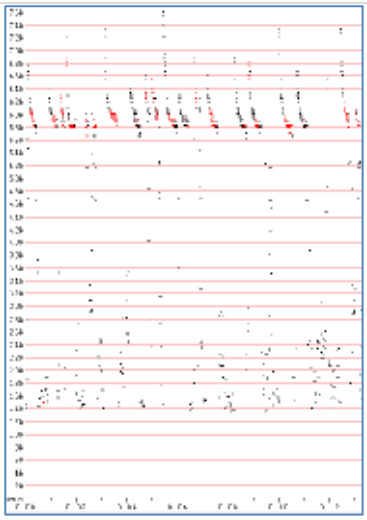
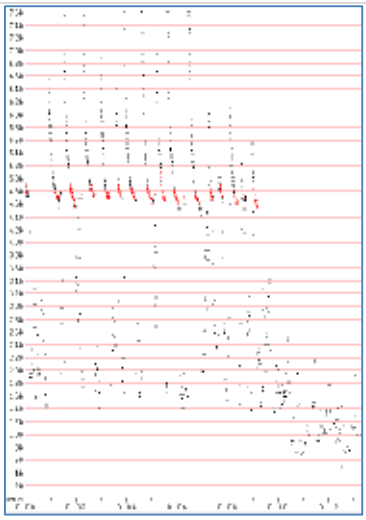
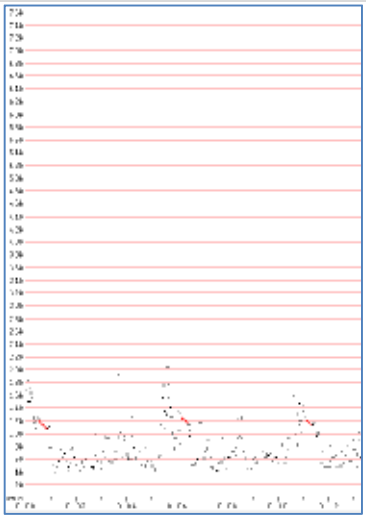


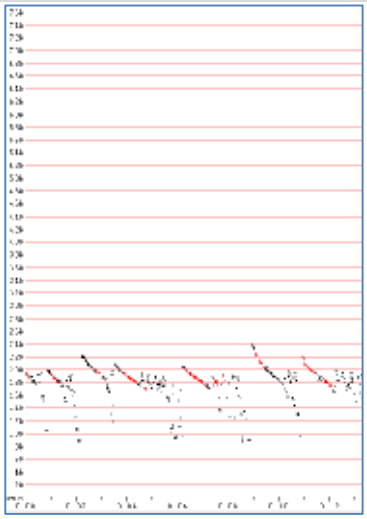
Miniopterus australis



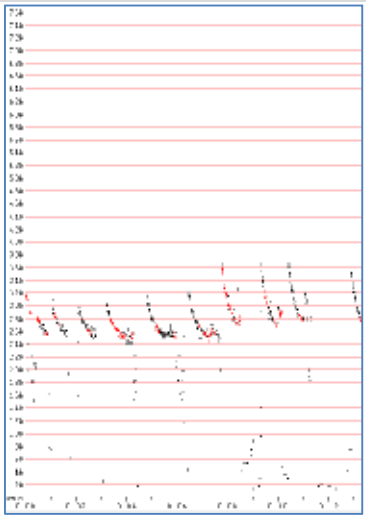
M. o. oceanensis / V. baverstocki



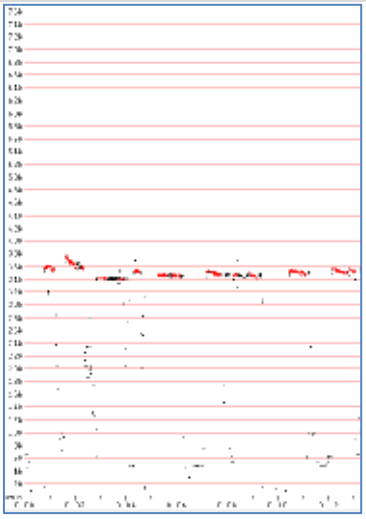
Austronomus australis



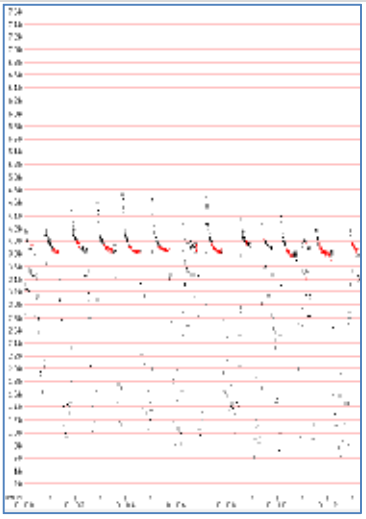
Chaerephon jobensis



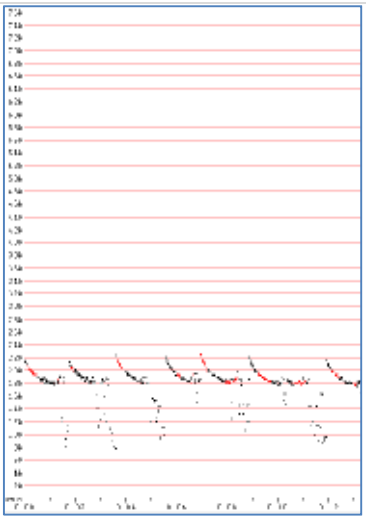
Ozimops lumsdenae



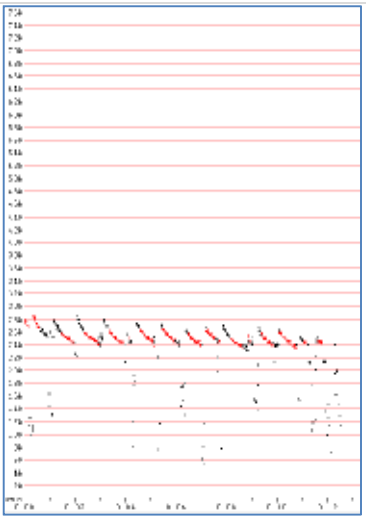
Ozimops ridei



Setirostris eleryi / Scotorepens greyii



Saccolaimus flaviventris



Taphozous troughtoni

Microbat Call Identification Report

Prepared for ("Client"):	AARC Environmental Solutions
Survey location/project name:	Lenton Road Diversion
Survey dates:	30 April – 4 May 2018
Client project reference:	
Job no.:	AARC-1808
Report date:	4 July 2018

Methods

Survey summary

The survey was conducted at five sites, using four Anabat detectors (Titley Scientific, Brisbane). Four sites were sampled using Anabat Express, while an Anabat Swift was deployed at the fifth site. Sites were sampled from sunset to sunrise over four (LRF01, LRF02) or three (LRF03, LRF04, LRF05) consecutive nights. The detector deployed at LRF03 was apparently started on the night of 30th April, but the log file for that night shows that no recording session commenced.

Site coordinates recorded by the detectors varied slightly from those provided in the "Notes" document submitted with the data (**Appendix 1**), with LRF01 being approximately 400m south of the "Notes" location and LRF04 being some 500m east of the "Notes" location (see **Figure 1**).

Data received and post-processing

Balance! Environmental received 14 raw ZCA data files and accompanying log files from the four Express units, plus 6132 full-spectrum (WAV format) files from the Swift.

Zero-crossing analysis bat-call sequence files (ZC files) were extracted from the Express ZCA data files using *AnalookW* (Version 4.2n; Corben 2017) and from the Swift WAV files using *Kaleidoscope Pro* (Version 4.5.5; Wildlife Acoustics, Maynard MA, USA). This process yielded 13,562 ZC files.

Bat-call analysis and identification

Call analyses were performed using the Cluster Analysis function of *Kaleidoscope Pro,* which allows all ZC files to be rapidly scanned and automatically clustered into groups of calls with similar pulse-characteristics. All clusters are then manually scanned in spectrogram view and allocated to species or unresolved groups.

Manual verification of call identities was based on comparison of call spectrograms and derived metrics with those of reference calls from central and 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 species' occurrence based on published distribution information (e.g. Churchill 2008; van Dyck *et al.* 2013) and on-line database records (e.g. 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 Jackson & Groves (2015), whose treatment of Australian mammal taxonomy elevates the sub-genus names proposed by Reardon *et al.* (2008, 2014) for the *Mormopterus* free-tailed bats to genus level. New names used in this report include:

- *Ozimops lumsdenae* (Northern Free-tailed Bat) – formerly *M. beccarii* (Beccari's Freetail Bat); and
- *O. ridei* (Ride's Free-tailed Bat) – formerly *M.* 'species 2' (Eastern Freetail Bat).

Figure 1. Bat-detector deployment sites for the Lenton Road Diversion survey, 31 April – 4 May 2018.

Note variance in locations of LRF01 and LRF04 (refer Appendix 1 for explanation)

Results & Discussion

The cluster analysis recognised 1936 bat calls and grouped them into 15 clusters. Verification of call identities in those clusters resulted in the positive allocation of 1375 calls to eight species (see upper portion of **Table 1**).

The identities of the remaining 561 calls were unresolved, due to similarities in call characteristics of several species that may occur in the study area. These calls were allocated to one of six species groups (see lower portion of **Table 1**), three of which contain only species that were also positively identified from more typical calls. The other three unresolved groups represent up to four additional species (i.e. probable total number of species recorded was 12).

Sample spectrograms of all identified call types are shown at **Appendix 2**.

Table 1 Microbat species recorded during the Lenton Road Diversion survey, 30/4-4/5/2018.

Number of calls allocated to each species/group per site.

Site:	LRF01	LRF02	LRF03	LRF04	LRF05	Species Total
Positively identified calls						
Chalinolobus gouldii	2	2		20	37	61
Chalinolobus picatus	81	13	5	1	26	126
Vespadelus troughtoni	989	4	24	1	33	1051
Miniopterus australis	4	8		5	2	19
Chaerephon jobensis	7		2	11	2	22
Ozimops lumsdenae	24	5	6		24	59
Ozimops ridei			1	2	5	8
Saccolaimus flaviventris	16	1	1	3	8	29
Unresolved calls						
C. gouldii/O. ridei	3	7	1	12	378	401
C. gouldii/Scotorepens balstoni				9		9
Chalinolobus nigrogriseus/Scotorepens greyii	11	17	3	19	28	78
C. picatus /Scotorepens sanborni	22	5	7		14	48
S. flaviventris/C. jobensis	7		3	2	3	15
S. flaviventris/O. lumsdenae	6		1		3	10
Site Total	1172	62	54	85	563	1936

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

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Reardon, T., Adams, M., McKenzie, N. and Jenkins, P. (2008). A new species of Australian freetail bat *Mormopterus eleryi* sp. nov. (Chiroptera: Molossidae) and a taxonomic reappraisal of *M. norfolkensis* (Gray). *Zootaxa* 1875: 1-31.

Reardon, T. B., McKenzie, N. L., Cooper, S. J. B., Appleton, B., Carthew, S. and Adams, M. (2014). A molecular and morphological investigation of species boundaries and phylogenetic relationships in Australian free-tailed bats *Mormopterus* (Chiroptera: Molossidae). *Aust. J. Zool*. **62**, 109–136.

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. (ed.) (2013). *Field Companion to the Mammals of Australia*. New Holland; Sydney.

Glossary

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

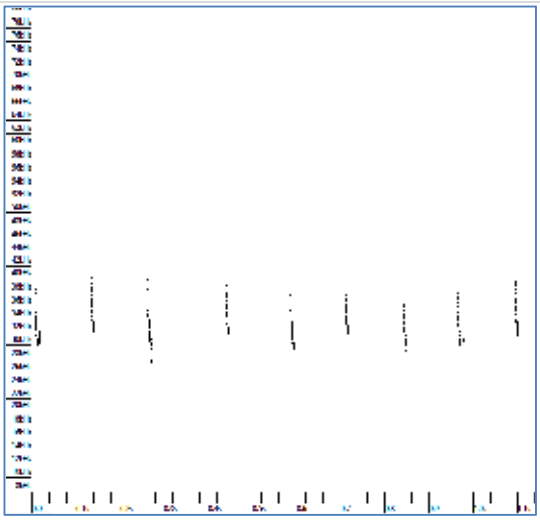
Approach phase	The part of a bat *call* emitted as the bat starts to home in on a detected prey item; a transitional series of *pulses* between the *search phase* and *feeding buzz*, that become progressively steeper and shorter in duration.
Call	Refers to a single bat call, made up of a series of individual 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 Bat-detector deployment notes provided by AARC.

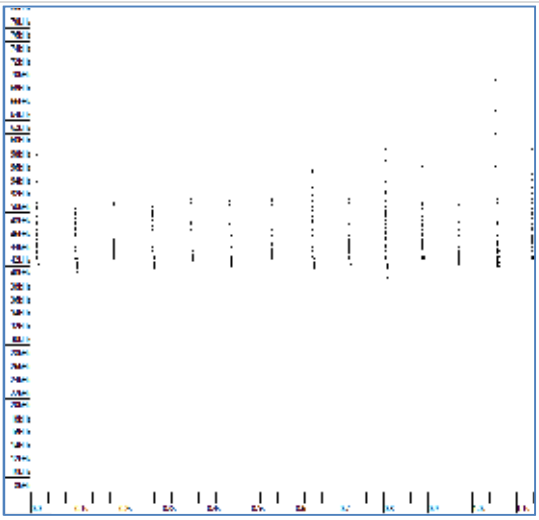
Red comments added by Greg Ford (Balance! Environmental)

Anabat Sites	
LRF01	-21.57075 148.11784 **-21.57421 148.11709 from detector log file** **Anabat # 2:** 30th April to 3rd May – 4 nights **GF AE1 SN304071** **NB:** position recorded by detector is approximately 380 metres south of original position shown in this table; i.e. in small watercourse near where track diverts around small ridge, rather than on foot-slope of main ridge further north *E.crebrea* dominant woodland with no shrub layer. Aristida spp. Dominate the ground layer. Located between sites LRF02 (to the West) and LRF04 (E).
LRF02	-21.5702148.10505 **Anabat # 1:** 30th April to 3rd May – 4 nights **AARC AE SN434344** *E.crebrea* dominant woodland with no shrub layer. Aristida spp. Dominate the ground layer. Located between LRF01 (E) and LRF03 (NW)
LRF03	-21.55558 148.09875 **Anabat # 1:** 30th April to 3rd May – 4 nights **AARC AE SN434354** 11.10.3 – Acacia catenulata or A. shirleyi open forest on coarse-grained sedimentary rocks. Crests and scarps. Located NW of LRF02. Most Western site.
LRF04	-21.57396 148.12372 **-21.57531 148.12864 from detector log files** **Anabat # 2:** 1st to 3rd May – 3 nights **GF AS2 SN474552** **NB:** position recorded by detector is approximately 500 metres east of original position shown in this table; i.e. east of Red Hill Rd, rather than on west side near junction of track 11.3.2 –Eucalyptus populnea woodland to open woodland. E. melanophloia may be present and locally dominant. Site is located E of LRF01. To the West there is open pasture.
LRF05	-21.5695 148.1452 **Anabat # 2:** 1st to 3rd May – 3 nights **GF AE2 SN434252** 11.3.25 - Eucalyptus camaldulensis or E. tereticornis open forest to woodland. Other tree species such as Casuarina cunninghamiana, E. coolabah, Melaleuca bracteata, Melaleuca viminalis, Livistona spp. (in north), Melaleuca spp. and Angophora floribunda are commonly present and may be locally dominant. Site is located ENE from LRF04. Most Eastern Site.

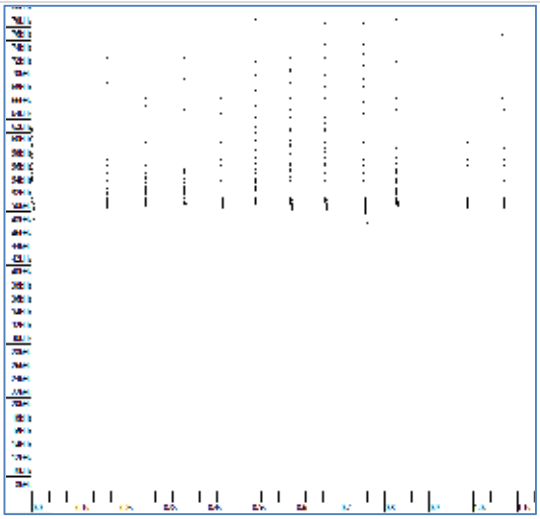
Appendix 2 Representative call sequences from the Lenton Road Diversion survey, 30/4-4/52018.
Kaleidoscope zero-crossing analysis sonograms; true-time; *x*-axis = 0.02 sec per tick-mark



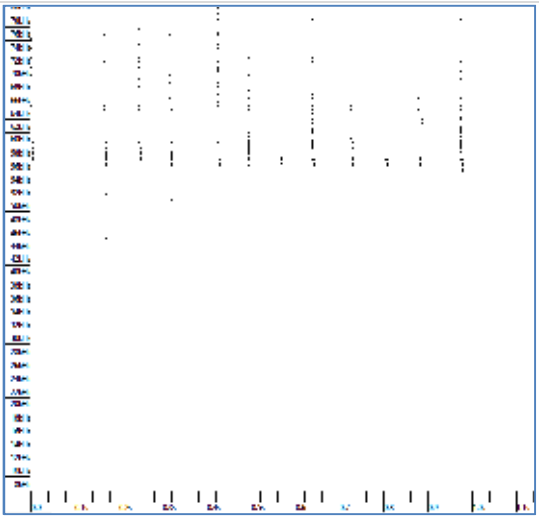
Chalinolobus gouldii



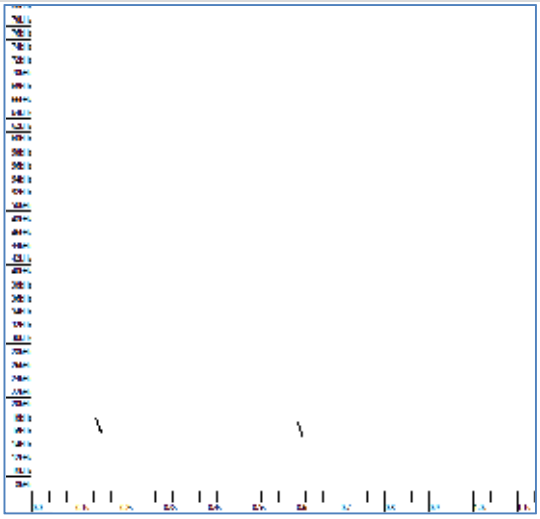
Chalinolobus picatus



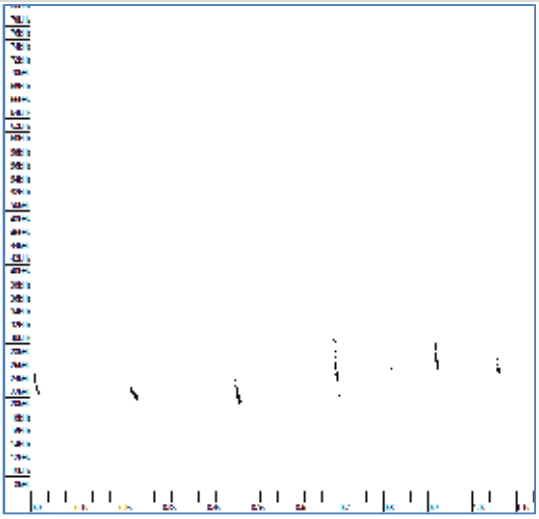
Vespadelus troughtoni



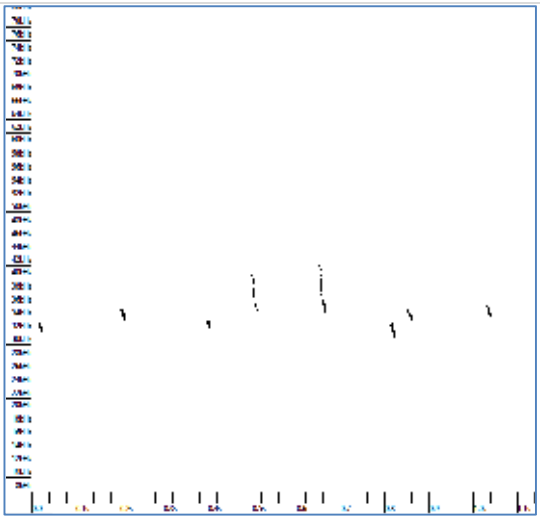
Miniopterus australis



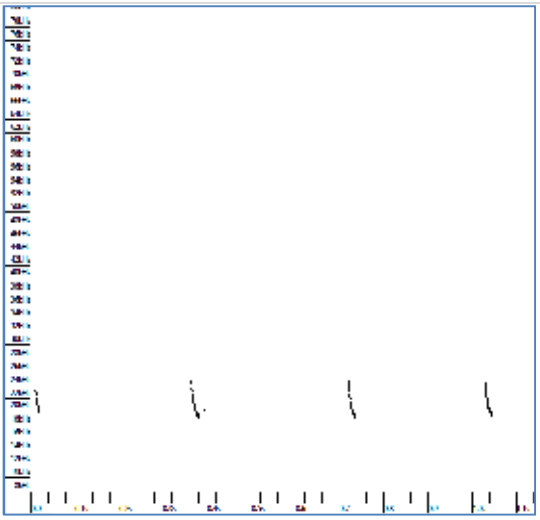
Chaerephon jobensis



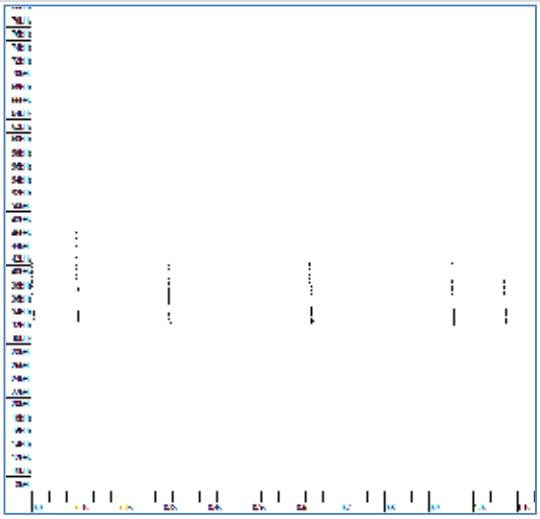
Ozimops lumsdenae



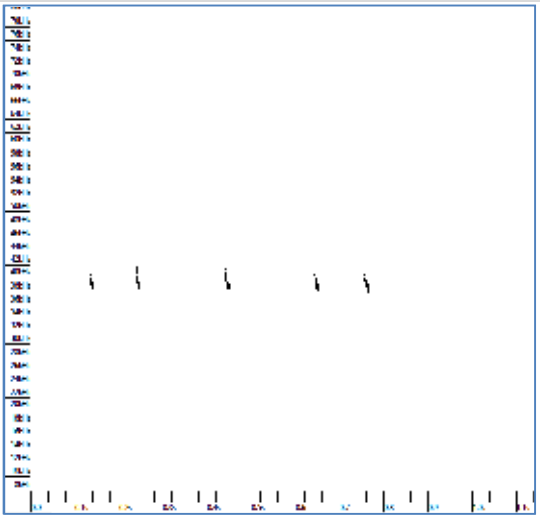
Ozimops ridei



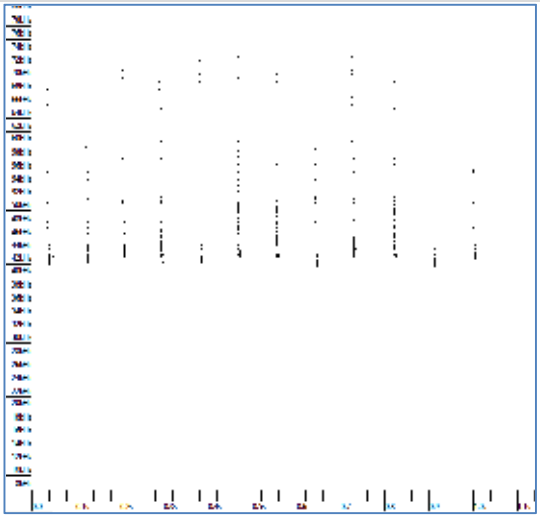
Saccolaimus flaviventris



C. gouldii/Scotorepens balstoni



Chalinolobus nigrogriseus/Scotorepens greyii



C. picatus /Scotorepens sanborni

Microbat Call Identification Report

Prepared for ("Client"):	AARC Environmental Solutions
Survey location/project name:	Lenton Gap
Survey dates:	2-7 April 2019
Client project reference:	
Job no.:	AARC-1905
Report date:	19 May 2019

Methods

Data received and post-processing

Balance! Environmental received eight raw ZCA data files and accompanying log files, recorded using two Anabat Express detectors (Titley Scientific; Brisbane).

All ZCA files were processed with *Anabat Insight* (Titley Scientific) to extract bat-call sequence files (ZC files) and remove non-bat noise from the dataset (using the default "Allbats" filter).

Bat-call analysis and identification

Call analyses were performed in *Anabat Insight*, with all ZC files passed through a Decision Tree analysis to group detected calls based on a combination of pulse characteristics, such as characteristic frequency (Fc), time between calls (TBC) and pulse curvature.

The preliminary call identities applied by the Decision Tree process were then confirmed or adjusted manually by comparing call spectrograms and derived metrics with those of reference calls from central and northern Queensland and/or with published call descriptions (e.g. Reinhold et al. 2001). Consideration was also given to the probability of species' occurrence based on published distribution information (e.g. Churchill 2008; van Dyck et al. 2013) and on-line database records (e.g. 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 Jackson and Groves (2015).

Results & Discussion

The file conversion and noise removal process yielded a total analysis data set of 941 ZC files: 706 from site LGF01; and 235 from site LGF02.

At least 12 and up to 14 species were recorded (**Table 1**), with 11 call types reliably identified to individual species.

More than 76% (531) of the recognised bat calls were reliably identified to species level, with four species (*Chalinolobus gouldii, Chaerephon jobensis, Ozimops lumsdenae* and *O. ridei*) contributing over 55% of the total calls recorded. The other 162 calls (23% of total) were not reliably identifiable, having mixed or intermediate call-characteristics that could have represented two or more species. These were allocated to one of several "unresolved species groups". **Appendix 1** provides a breakdown of the numbers of calls attributable to identified species and unresolved groups at each site.

The unresolved call groups included three call-types that potentially represented three additional species: *Miniopterus orianae oceanensis; Scotorepens sanborni;* and *Vespadelus baverstocki*. Where such calls were encountered at a site, the relevant species are shown as "possible" in **Table 1.**

Sample spectrograms of all identified call types are shown at **Appendix 2**.

Table 1 Microbat species recorded during the Lenton Gap survey, 2-7 April 2019.

♦ = 'definite' - at least one call was attributed unequivocally to the species at the site
□ = 'possible' - calls like those of the species were recorded, but were not reliably identified

Site name:	LGF01	LGF02
Chalinolobus gouldii	♦	♦
Chalinolobus nigrogriseus	♦	♦
Chalinolobus picatus	♦	□
Scotorepens balstoni	♦	♦
Scotorepens greyii	♦	♦
Scotorepens sanborni	□	□
Vespadelus baverstocki	□	□
Vespadelus troughtoni	♦	♦
Miniopterus australis	♦	♦
Miniopterus orianae	□	□
Chaerephon jobensis	♦	♦
Ozimops lumsdenae	♦	♦
Ozimops ridei	♦	♦
Saccolaimus flaviventris	♦	♦

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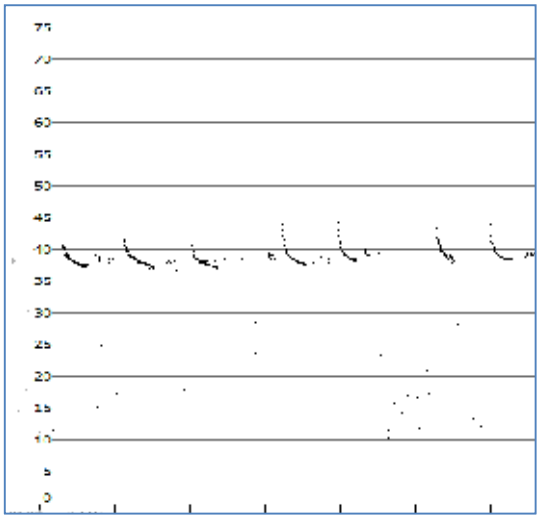
Appendix 1 Bat calls recorded during the Lenton Gap survey, 2-7 April 2019.

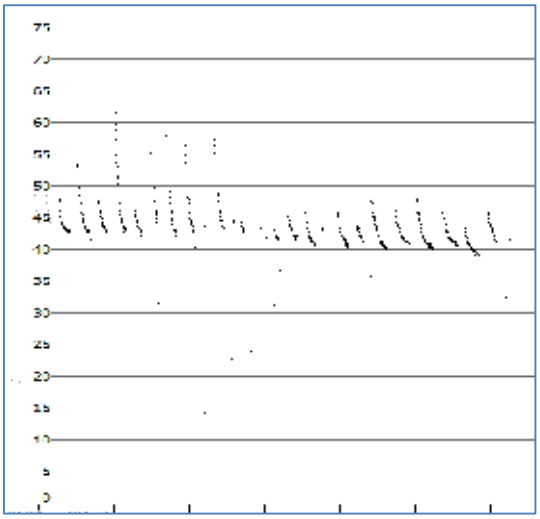
Number of calls allocated per species or unresolved species group per site

Site name:	LGF01	LGF02	Species total
Positively identified calls			
Chalinolobus gouldii	41	60	101
Chalinolobus nigrogriseus	26	1	27
Chalinolobus picatus	38		38
Scotorepens balstoni	3	1	4
Scotorepens greyii	11	2	13
Vespadelus troughtoni	1	2	3
Miniopterus australis	11	6	17
Chaerephon jobensis	44	28	72
Ozimops lumsdenae	53	45	98
Ozimops ridei	86	26	112
Saccolaimus flaviventris	27	19	46
Unresolved calls			
C. gouldii / O. ridei	35	10	45
C. picatus / M. orianae	2	3	5
S. greyii / C. nigrogriseus	5	2	7
S. greyii / C. picatus	39	4	43
S. greyii / S. sanborni	11	1	12
S. sanborni / V. baverstocki	25	5	30
S. balstoni / O. ridei	2	2	4
S. flaviventris / C. jobensis	13	1	14
C. jobensis / O. lumsdenae	1	1	2
Site total	474	219	693

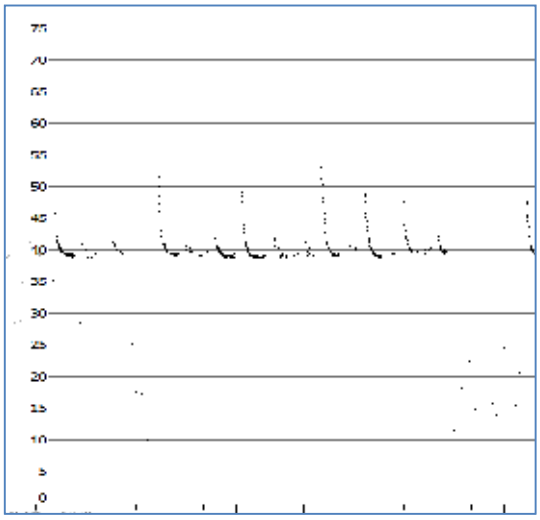
Appendix 2 Representative call sequences from the Lenton Gap survey, 2-7 April 2019.
x-axis = 10 ms per tick-mark; time between pulses removed



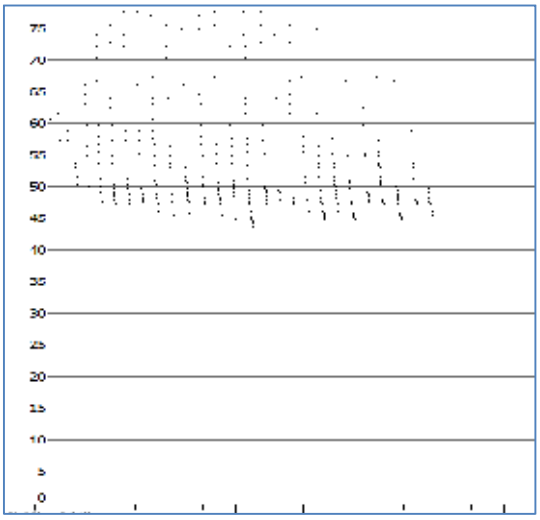
Chalinolobus nigrogriseus



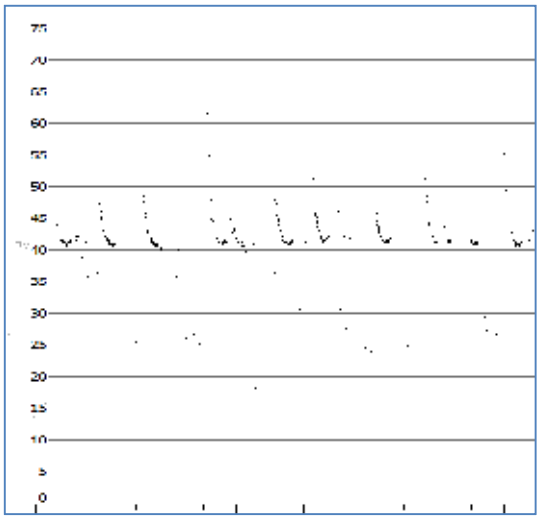
Chalinolobus picatus



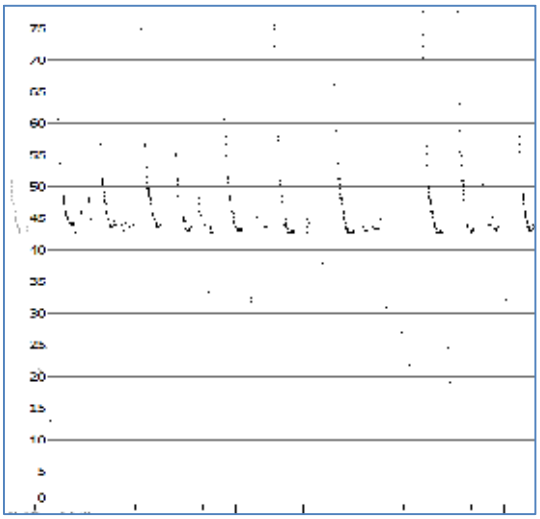
Scotorepens greyii



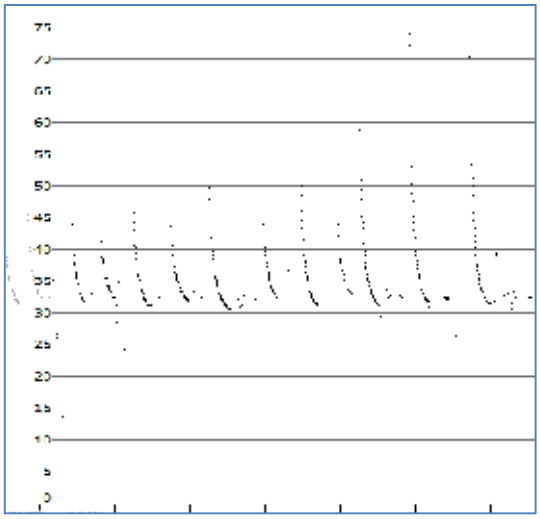
C. picatus / Miniopterus orianae oceanensis



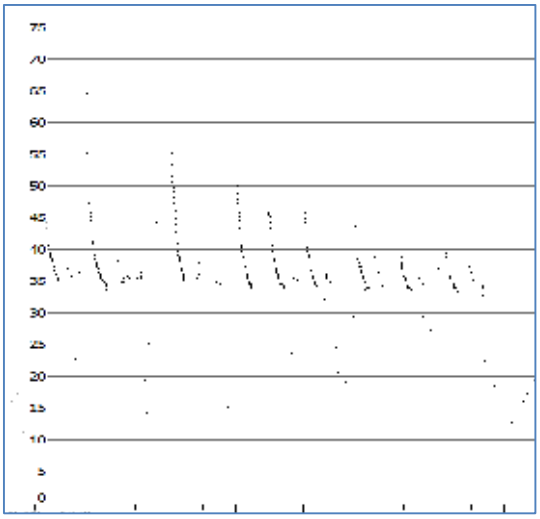
S. greyii / S. sanborni



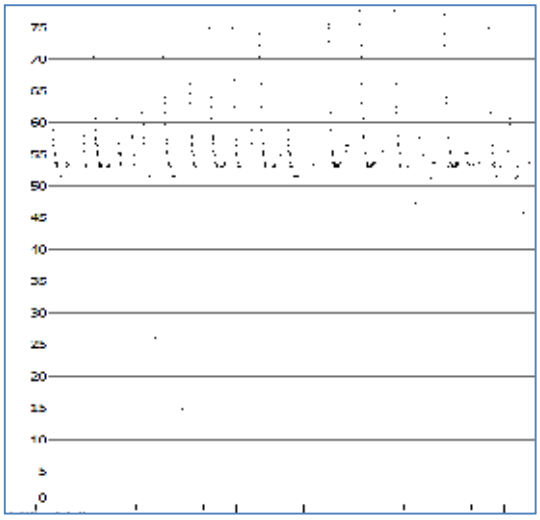
S. sanborni / V. baverstocki



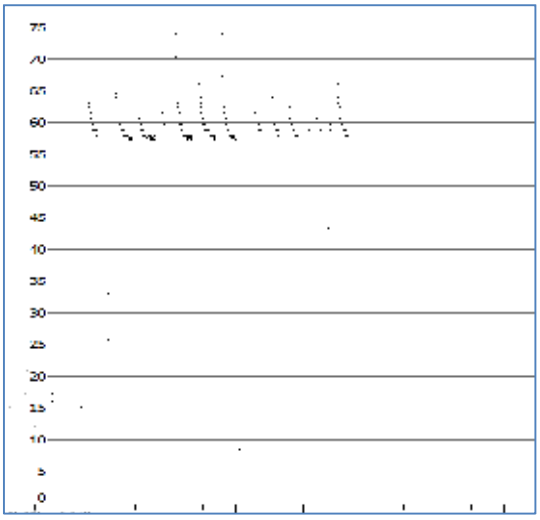
Chalinolobus gouldii



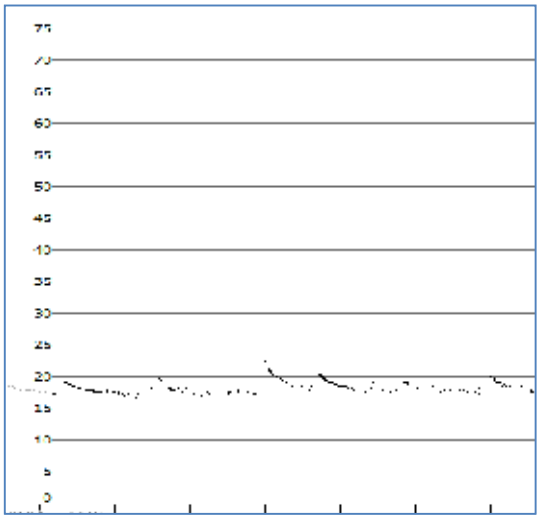
Scotorepens balstoni



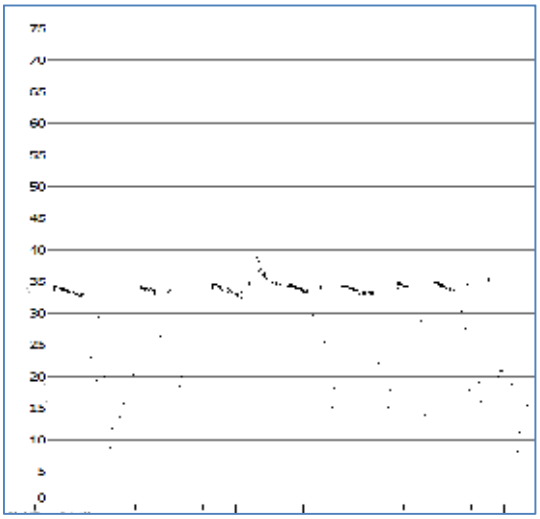
Vespadelus troughtoni



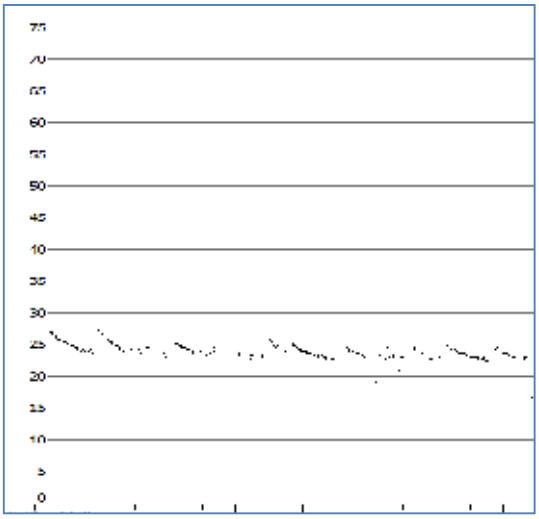
Miniopterus australis



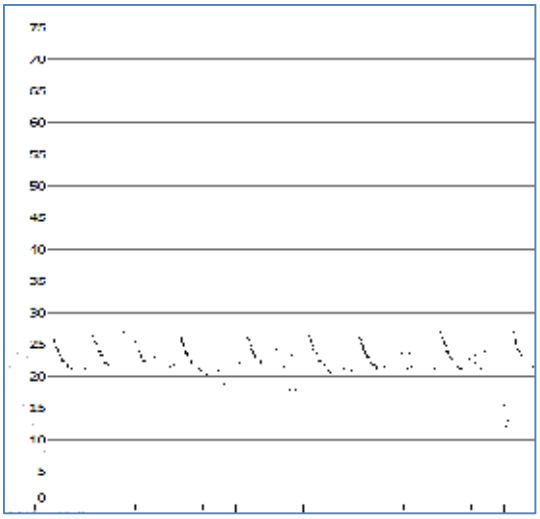
Chaerephon jobensis



Ozimops ridei



Ozimops lumsdenae



Saccolaimus flaviventris

Appendix L GDE Site Assessment

L

Transect Number	NE1		Associated REs		11.3.4 11.3.25	
Vegetation Health						
Scientific Name	**Common Name**	**Total Stems >20cm DBH**	**Number with Dieback**	**Proportion of Trees with Dieback**	**Canopy Colour**	**Stratum Dominance**
GDV07						
Corymbia tessellaris	Moreton Bay ash	9	1	11%	Bright green	Dominant
Acacia salicina	Sally wattle	1	0	0%	Dull green	Occasional
GDV08						
Eucalyptus tereticornis	Blue gum	3		0%	Bright green	Co-dominant
Corymbia clarksoniana	Clarkson's bloodwood	2		0%	Bright green	Associated
Corymbia tessellaris	Moreton Bay ash	5	1	20%	Bright green	Co-dominant
Potential GDE species only total		**20**	**2**	**10%**		

Canopy Cover				
Site	**Tree Layer**		**Shrub Layer**	
	(m)	**(%)**	**(m)**	**(%)**
GDV07	28	56		
GDV08	13	26	3	6
Average	**20.5**	**41**	**3**	**6**

L

Transect Number	NE2		Associated RE	11.3.25		
Vegetation Health						
Scientific Name	**Common Name**	**Total Stems >20cm DBH**	**Number with Dieback**	**Proportion of Trees with Dieback**	**Canopy Colour**	**Stratum Dominance**
GDV03						
Eucalyptus tereticornis	Blue gum	2		0%	Bright green	Associated
Terminalia oblongata	Yellowwood	3		0%	Bright green	Dominant
Acacia harpophylla	Brigalow	2		0%	Dull green	Associated
Eucalyptus populnea	Poplar box	1		0%	Bright green	Associated
Corymbia tessellaris	Moreton Bay ash	1		0%	Orange	Associated
GDV04						
Corymbia tessellaris	Moreton Bay ash	5	1	20%	Bright green	Dominant
Acacia salicina	Sally wattle	1		0%	Dull green	Associated
GDV05						
Corymbia tessellaris	Moreton Bay ash	2	2	100%	Orange	Dominant
Eucalyptus tereticornis	Blue gum	5		0%	Bright green	
Bauhinia sp.		1		0%	Bright green	
Potential GDE species only total		**16**	**3**	**19%**		

Canopy Cover				
Site	**Tree Layer**		**Shrub Layer**	
	(m)	**(%)**	**(m)**	**(%)**
GDV05	19	38	1	2
Average	**19**	**38**	**1**	**2**

L

Transect Number	NE3		Associated RE	11.3.25		
Vegetation Health						
Scientific Name	**Common Name**	**Total Stems >20cm DBH**	**Number with Dieback**	**Proportion of Trees with Dieback**	**Canopy Colour**	**Stratum Dominance**
GDV01						
Corymbia tessellaris	Moreton Bay ash	4	1	25%	Orange	Dominant
Bauhinia hookeri	White bauhinia	1		0%	Bright green	Dominant
Acacia salicina	Sally wattle	1		0%	Bright green	Associated
Indet.		1		0%	Bright green	Associated
Eucalyptus tereticornis	Blue gum	1		0%	Bright green	Associated
Potential GDE species only total		**5**	**1**	**20%**		

Canopy Cover				
Site	**Tree Layer**		**Shrub Layer**	
	(m)	**(%)**	**(m)**	**(%)**
GDV01	38	76	3	6
Average	**38**	**76**	**3**	**6**

L

Transect Number	NE4		Associated RE	11.3.25		
Vegetation Health						
Scientific Name	**Common Name**	**Total Stems >20cm DBH**	**Number with Dieback**	**Proportion of Trees with Dieback**	**Canopy Colour**	**Stratum Dominance**
GDV10						
Eucalyptus populnea	Popular box	2	0	0%	Bright green	Dominant
Acacia salicina	Sally wattle	1	0	0%	Bright green	Associated
Acacia harpophylla	Brigalow	2	0	0%	Dull green	Associated
Potential GDE species only total		2	0	0%		

Canopy Cover				
Site	**Tree Layer**		**Shrub Layer**	
	(m)	**(%)**	**(m)**	**(%)**
GDV10		0	6	12
Average	**18**	**36**	**6**	**12**

L

Transect Number	IR2			Associated REs		11.3.25 11.3.4	
Vegetation Health							
Scientific Name	**Common Name**	**Total Stems >20cm DBH**	**Number with Dieback**	**Proportion of Trees with Dieback**	**Canopy Colour**	**Stratum Dominance**	**Notes**
GDV15							
Eucalyptus populnea	Popular box	9		0%	Bright green	Dominant	Partial branch die back
GDV16							
Corymbia tessellaris	Moreton Bay ash	17	1	6%	Bright green	Dominant	Selective Logging
Corymbia clarksoniana	Clarkson's bloodwood	2		0%	Bright green	Occasional	
Acacia Salicina	Sally wattle	1		0%	Bright green	Occasional	
GDV17							
Corymbia tessellaris	Moreton Bay ash	4		0%	Dull green	Dominant	Selective logging
Corymbia clarksoniana	Clarkson's bloodwood	1		0%	Bright green	Present	
Bauhinia hookeri	White bauhinia	2		0%	Bright green	Associated	Marginal necrosis
Potential GDE species only total		33	1	3%			

Canopy Cover				
Site	**Tree Layer**		**Shrub Layer**	
	(m)	**(%)**	**(m)**	**(%)**
GDV11	13	26		
GDV12	25	50		
GDV13				
Average	**19**	**38**		

L

Transect Number	IR3			Associated REs		11.3.25 11.3.2 11.3.4	
Vegetation Health							
Scientific Name	**Common Name**	**Total Stems >20cm DBH**	**Number with Dieback**	**Proportion of Trees with Dieback**	**Canopy Colour**	**Stratum Dominance**	**Notes**
GDV19							
Eucalyptus populnea	Popular box	3	1	33%	Bright green	Dominant	
Alectryon oleifolius		1		0%	Dull green	Present	
GDV20							
Corymbia tessellaris	Moreton Bay ash	4	1	25%	Bright green	Dominant	
Acacia salicina	Sally wattle	3		0%	Bright green	Dominant T2	
Bauhinia hookeri	White bauhinia	1		0%	Bright green	Dominant T3	
GDV21							
Bauhinia hookeri	White bauhinia	4		0%	Bright green	Dominant T2	
Corymbia tessellaris	Moreton Bay ash	2		0%	Bright green	Dominant T1	Orange new leaves (minor)
Potential GDE species only total		9	2	22%			

Canopy Cover				
Site	**Tree Layer**		**Shrub Layer**	
	(m)	**(%)**	**(m)**	**(%)**
GDV19	22	44		
GDV20	39	78	6	12
GDV21	32	64	15	30
Average	**31**	**41.4**	**10.5**	**21**

L

Transect Number	IR4			Associated RE	11.3.4 11.3.25	
Vegetation Health						
Scientific Name	**Common Name**	**Total Stems >20cm DBH**	**Number with Dieback**	**Proportion of Trees with Dieback**	**Canopy Colour**	**Stratum Dominance**
GDV22						
Corymbia tessellaris	Moreton Bay ash	2			Bright green	Dominant T2
Corymbia dallachiana	Ghost gum	1			Bright green	Associated T2
Eucalyptus populnea	Popular box	2	1	50%	Bright green	Dominant T1
Potential GDE species only total		**5**	**1**	**20%**		

Canopy Cover				
Site	**Tree Layer**		**Shrub Layer**	
	(m)	**(%)**	**(m)**	**(%)**
GDV22	13	26	31	62
Average	**13**	**26**	**31**	**62**

L