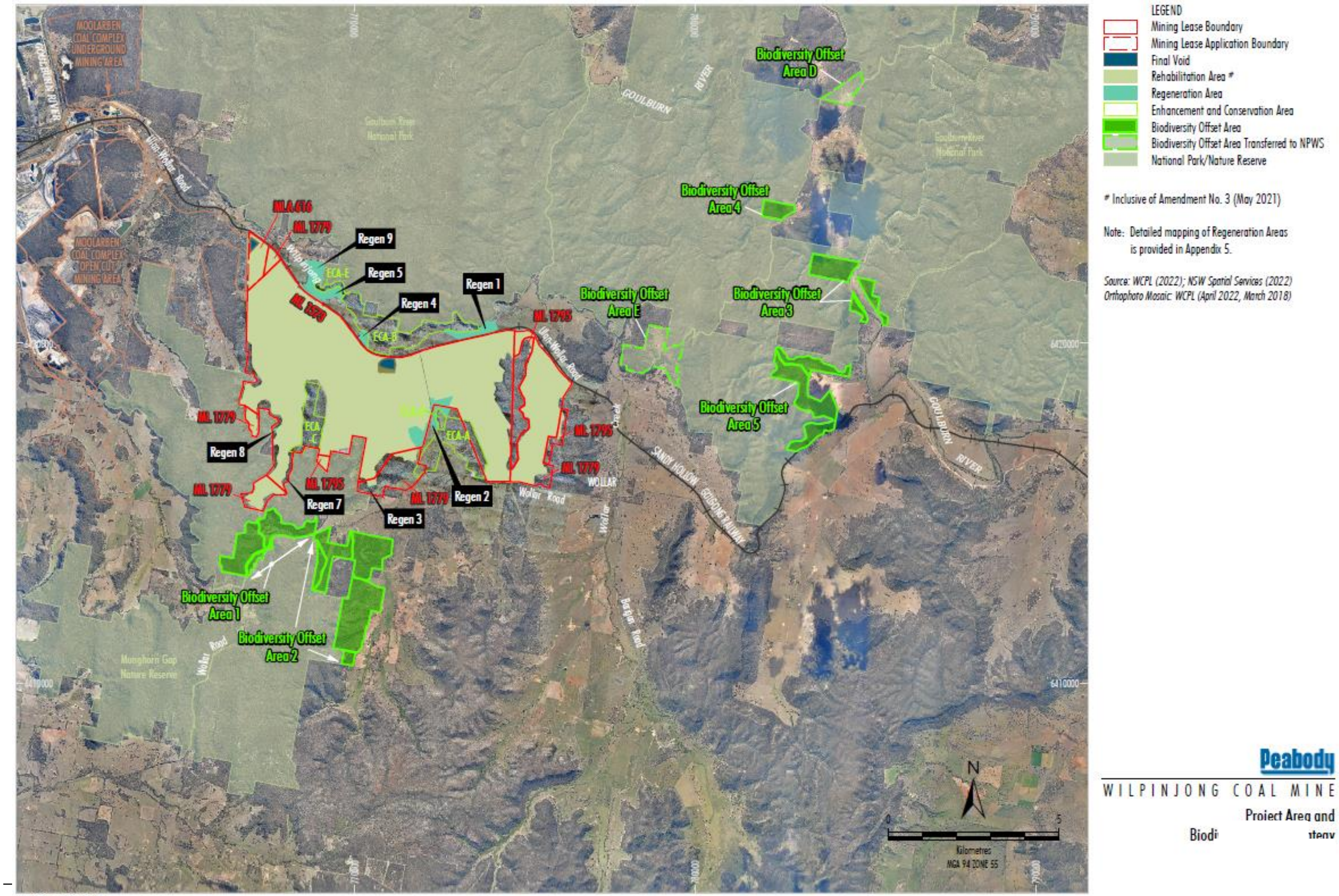
APPENDIX 5

BIODIVERSITY

Biodiversity Offset Strategy

All land within Biodiversity Offset Areas D and E were transferred to the National Parks Estate on the 13 January 2016.

All land within Biodiversity Offset Areas 1-5 (BOAs) were transferred to the National Parks Estate on the 02 August 2023



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Peabody

Biodiversity Reports

Wilpinjong Coal Mine
2023 Annual Biodiversity Monitoring Report

Wilpinjong Coal Pty Ltd

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Contents

List of Figures

List of Tables

Executive Summary

Eco Logical Australia (ELA) was engaged by Wilpinjong Coal Pty Ltd (WCPL) to undertake biodiversity monitoring at the Wilpinjong Coal Mine (WCM) in accordance with the WCM Biodiversity Management Plan (BMP) (WCPL 2021). Monitoring has historically been undertaken at established sites across the WCM Management Domains detailed within the BMP, including Biodiversity Offset Areas, Enhancement and Conservation Areas, Regeneration and Rehabilitation Areas, and reference sites.

The 2023 monitoring program was adapted to reflect a change in biodiversity monitoring objectives, primarily, a shift to monitoring Rehabilitation Areas, including two previously established monitoring plots, plots within 2021 seeded rehabilitation areas, and the establishment of plots within 2023 seeded rehabilitation areas.

Reference sites were established in 2019 and 2020 in areas that conform to WCPL's targeted rehabilitation BioMetric Vegetation Types (BVTs), in accordance with Condition 36 of the WCM Development Consent SSD 6764.

Floristic monitoring was undertaken in accordance with the biometric plot method prescribed in the BMP at both rehabilitation and reference sites. Attribute data for each site was collected and analysed to produce and overall site value score (SVS), which was then compared to both the local reference site monitoring data, and benchmark data for the target BVT. No significant conclusions can be drawn from the data at this early stage of the rehabilitation monitoring program.

Landscape Function Analysis (LFA) monitoring was also undertaken within the Rehabilitation Areas and Reference Sites. A decrease in the LFA scores from 2022 to 2023 monitoring was observed, likely due to the drier climactic conditions leading up to 2023 monitoring. Although these results are largely consistent with reference sites, the Trigger Action Response Plan (TARP) has been enacted and a review of LFA data is required.

Fauna monitoring was undertaken at both rehabilitation and reference sites, which identified a range of both native and introduced species utilising the areas. Native fauna included birds, microbat species, mammals, reptiles and amphibians. Of these, 10 species listed as threatened under the NSW *Biodiversity Conservation Act* (BC Act) 2016 and/or the Commonwealth *Environmental Protection and Biodiversity Act* (EPBC Act) 1999 were recorded. Five feral pest animal species and three priority weed species (Local Land Services 2023) were recorded within the rehabilitation areas.

1. Introduction

Wilpinjong Coal Pty Ltd (WCPL), a wholly owned subsidiary of Peabody Energy Australia Pty Ltd (Peabody), operates the Wilpinjong Coal Mine (WCM) located in the western coalfields of NSW approximately 48 km north-east of Mudgee, within the Mid-Western Regional Council (MWRC) Local Government Area (LGA).

The WCM originally operated under Project Approval (PA) 05-0021, granted under Part 3A of the NSW Environmental Planning and Assessment Act 1979 on 1 February 2006. A series of modifications to PA 05-0021 were approved until it was superseded by Development Consent SSD-6764, granted on 24 April 2017 for the Wilpinjong Extension Project (WEP).

A Biodiversity Offset Strategy was developed and augmented by WCPL to offset impacts on threatened species, populations or communities listed under the NSW *Biodiversity Conservation Act 2016* (BC Act) and /or the Commonwealth *Environment Protection Biodiversity Conservation Act 1999* (EPBC Act) in accordance with SSD-6764. The strategy comprised more than 4,500 ha of Management Domains (shown below in Figure 1):

- Biodiversity Offset Areas (BOAs)
- Enhancement and Conservation Areas (ECAs)
- Regeneration Areas
- Rehabilitation Areas

Following relinquishment of the BOAs to the NSW National Parks and Wildlife Service to be managed as part of National Parks, the 2023 biodiversity monitoring program was adapted to focus on rehabilitation areas. It is noted that bird monitoring was completed in the BOAs up to winter 2023, which has been documented in a standalone report.

1.1. Objectives

Eco Logical Australia (ELA) was engaged by WCPL to undertake biodiversity monitoring consistent with the requirements of Development Consent SSD-6764 and the methods outlined in the Wilpinjong Coal Biodiversity Management Plan (BMP) (WCPL 2021):

- BioMetric vegetation monitoring (Gibbons et al 2009)
- Landscape stability monitoring using Landscape Function Analysis (LFA) (Tongway and Hindley 2004)
- Terrestrial fauna monitoring.

In accordance with Condition 36 of the Development Consent SSD-6764, WCPL must demonstrate that rehabilitation areas have reached performance and completion criteria to generate ecosystems credits to offset impacts from the WEP, for the following prescribed Biometric Vegetation Types (BVTs):

- HU547 – Fuzzy Box Woodland
- HU981 – Rough Barked Apple Woodland / HU732 – Yellow box Grassy Woodland
- HU824 – White Box-Black Cypress Pine Shrubby Woodland.

Further, in accordance with Condition 36 and 37 of the Development Consent SSD-6764, WCPL must demonstrate rehabilitation areas have reached performance and completion criteria to generate species credit requirements for the critically endangered *Anthochaera phrygia* (Regent Honeyeater). This includes habitat within the associated BVTs:

- HU697 – Mugga Ironbark-Black Cypress Pine Open Forest
- HU732 – Yellow Box Grassy Woodland
- HU825 – Narrow-leaved Ironbark-Black Cypress Pine Grass Woodland.

Local reference sites have been established since the revised Performance and Completion Criteria for the Rehabilitation areas were developed in 2021. These revised performance and completion criteria acknowledge local Reference Site benchmarks as preferential to broader benchmark data. Comparisons with these sites allows for local environmental variations. The 2023 monitoring data from the Rehabilitation Areas is assessed against these local Reference Site benchmarks and the rehabilitation performance and completion criteria as detailed in Table 12 of the BMP (WCPL 2021).

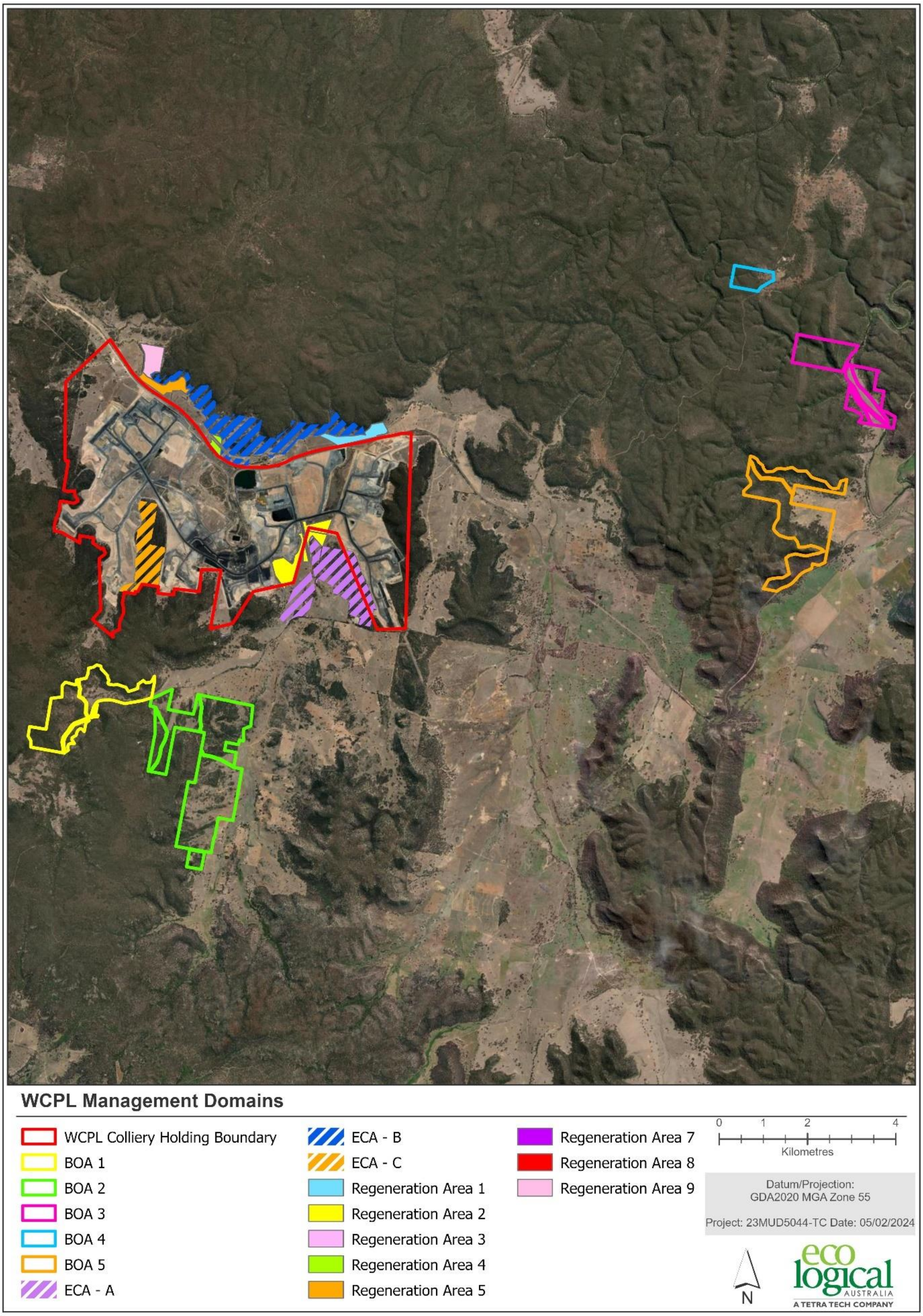

Figure 1: WCPL BOS Management Domains

2. Methodology

The 2023 biodiversity monitoring program was undertaken in the rehabilitation areas and a subset of the reference sites (per the three yearly rotation) in accordance with the methods and survey techniques prescribed in the BMP (WCPL 2021).

Weather conditions throughout the 2023 monitoring period are presented in Appendix A. Vegetation condition, class and coordinates for all monitoring sites are detailed in Appendix B.

2.1. Vegetation Monitoring

Autumn vegetation monitoring was undertaken between 12 and 14 April 2023 by ELA Ecologists Tahnee Coull and Lachlan Metzler. Spring vegetation monitoring was undertaken between 23 October and 7 November by ELA Ecologists Cheryl O'Dwyer, Kacey Tada, Tahnee Coull and Jack O'Sullivan. The locations of established and reference vegetation monitoring sites are illustrated in Figure 2 and Figure 3.

Seven Rehabilitation Area sites that were established in 2023 were monitored for the first time in February 2024. These sites were direct seeded in 2020 and 2021 to conform to BVT732, BVT824 and BVT697. Whilst these sites are not required to be monitored until years 3 – 4 (as per Table 11 in the BMP [WCPL 2021]), the establishment of BioMetric monitoring plots tracks early progress of these areas against the performance criteria to determine success of seeded areas and aid in management decisions if necessary. Monitoring was undertaken between 5 and 6 February by ELA ecologists Tahnee Coull and Lachlan Metzler, with locations of monitoring sites shown in Figure 4.

Vegetation monitoring was consistent with the BioMetric method of plot assessment prescribed in the BMP (WCPL 2021). Permanent BioMetric plots, comprising a 20m x 20m (0.04ha) plot nested within a 20m x 50m plot, were surveyed at each monitoring site. Within each plot, the following data was collected:

- Native species richness (NSR), cover and abundance within the 20m x 20m plot
- Native overstorey cover (NOC) and native mid-storey cover (NMS) – at regular 5m intervals along 50m transect (10 points)
- Native ground stratum (grass, shrub, other) and exotic cover (EC) – at regular 1m intervals along 50m transect (50 points)
- Habitat features (number of trees with hollows (NTH), length of logs (FL)) and proportion of overstorey species regeneration – within 20m x 50m plot.

All vascular plant species were recorded and identified to species where possible.

2.2. Landscape Function Analysis

Landscape Function Analysis (LFA) monitoring was undertaken during spring at five established sites within the Rehabilitation Areas and five reference sites (Figure 3: Spring 2023 vegetation monitoring sites Figure 3) in accordance with the methods prescribed in Tongway and Hindley (2004) and the BMP (WCPL 2021).

At each LFA site, a 50m transect line was established downslope between transect start and end markers. The majority of LFA transects directly correspond to the 50m BioMetric transect of the respective monitoring site. However, at several sites, the LFA transect does not align with the BioMetric transect, particularly where the BioMetric transect is set across slope. Along each LFA transect, LFA attributes were assessed to monitor the Landscape Organisation Index (LOI) and Soil Surface Assessment (SSA).

2.2.1. Landscape Organisation Index (LOI)

The LOI characterises and maps the spatial patterns of resource loss or accumulation at a site. The LOI provides a proportion of the transect occupied by patches (landscape elements that are relatively permanent and provide stable, resource accumulating structures, such as trees, shrubs, grassy tussocks, ground cover, and logs). A higher LOI implies a more stable transect that is less prone to erosion, with a maximum LOI value of 1.00 indicating a transect that is completely covered by patches. The SSA is more in depth, providing an index (0-100) of Stability, Soil Infiltration and Nutrient Cycling for the whole of the landscape (transect). Table 13 in the BMP (WCPL, 2021) outlines the SSA attributes that contribute to each of these three indices and are summarised in Table 1 below.

According to the LFA method, patches are long-term features that obstruct or divert water flow and/or collect/filter out material from runoff, and where there is evidence of resource accumulation. Inter-patches are zones where resources such as water, soil material and litter may be mobilised and freely transported either down slope when water is the active agent or down-wind when aeolian processes are active.

The following data was recorded for each patch/inter-patch along each LFA transect:

- Distance (m) from the start of the transect
- Patch width (cm)
- Patch/inter-patch identification.

The following patch types were defined and monitored across all LFA monitoring sites and monitoring periods:

- Bare soil
- Litter (including annual plants)
- Rock (>5 cm diameter)
- Logs (>10cm diameter)
- Ground cover (perennial)
- Shrub/tree
- Cryptogram
- Any combination of the above (e.g. ground cover – litter patch).

2.2.2. Soil Surface Assessment (SSA)

Each patch/inter-patch type identified in the landscape organisation data log was subject to an SSA. A subset of up to five occurrences of each patch/inter-patch type were monitored, and data relating to 11 Soil Surface Condition Indicators (SSCIs) were collected along the 50 m transect (Table 1).

Table 1: Soil Surface Condition Indicators used to determine the overall Soil Surface Analysis (see Table 13 BMP: WCPL, 2021)

SSCI	Description
Rain splash protection	Percentage cover of perennial vegetation to a height of 0.5 m. plus rocks > 2 cm and woody material > 1 cm in diameter or other long-lived, immoveable objects.
Perennial vegetation cover	Percentage perennial vegetation cover.
Litter	Percentage cover of annual grasses and ephemeral herbage (both standing and detached) as well as detached leaves, stems, twigs, fruit, dung, etc.
Cryptogam cover	Percentage cover of algae, fungi, lichens, mosses, liverworts and fruiting bodies of mycorrhizas.
Crust brokenness	Categorises soil crusts from 0-4 where 0 refers to 'no crust present' and 4 refers to an 'intact and smooth' soil crust.
Soil erosion type and severity	Categorises the aerial extent and severity of various erosion types from 'Insignificant' to 'Severe'.
Deposited materials	Categorises the extent and depth of deposited alluvial material
Soil surface roughness	Categorises the depth of surface depressions from 'smooth' to 'deep' depressions.
Surface nature (resistance to disturbance)	Categorises the soils capacity to resist disturbance based on the soils 'hardness' or 'brittleness'.
Slake Test	Categorises the soils stability when exposed to water
Texture	Categorises the soils water infiltration capacity from 'very slow' to 'high'

Baseline Data for the Slake Test and Texture SSCIs was used for the LFA analysis and was not assessed in the field in 2023. All other parameters were assigned a score in the field. Data was entered into the LFA calculation spreadsheets and used to calculate Soil Stability, Soil Infiltration and Nutrient Cycling indices.

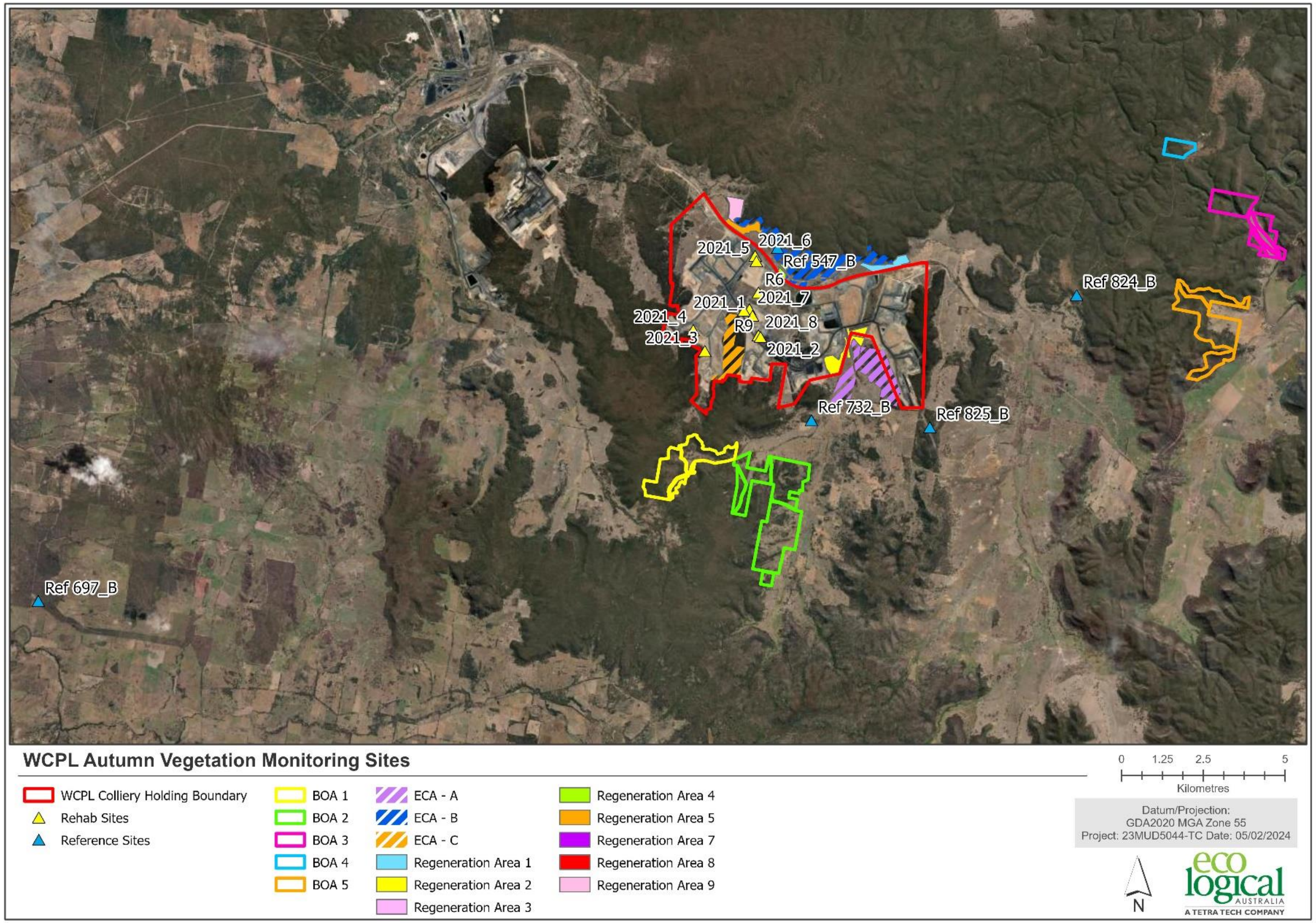

Figure 2: Autumn 2023 vegetation monitoring sites

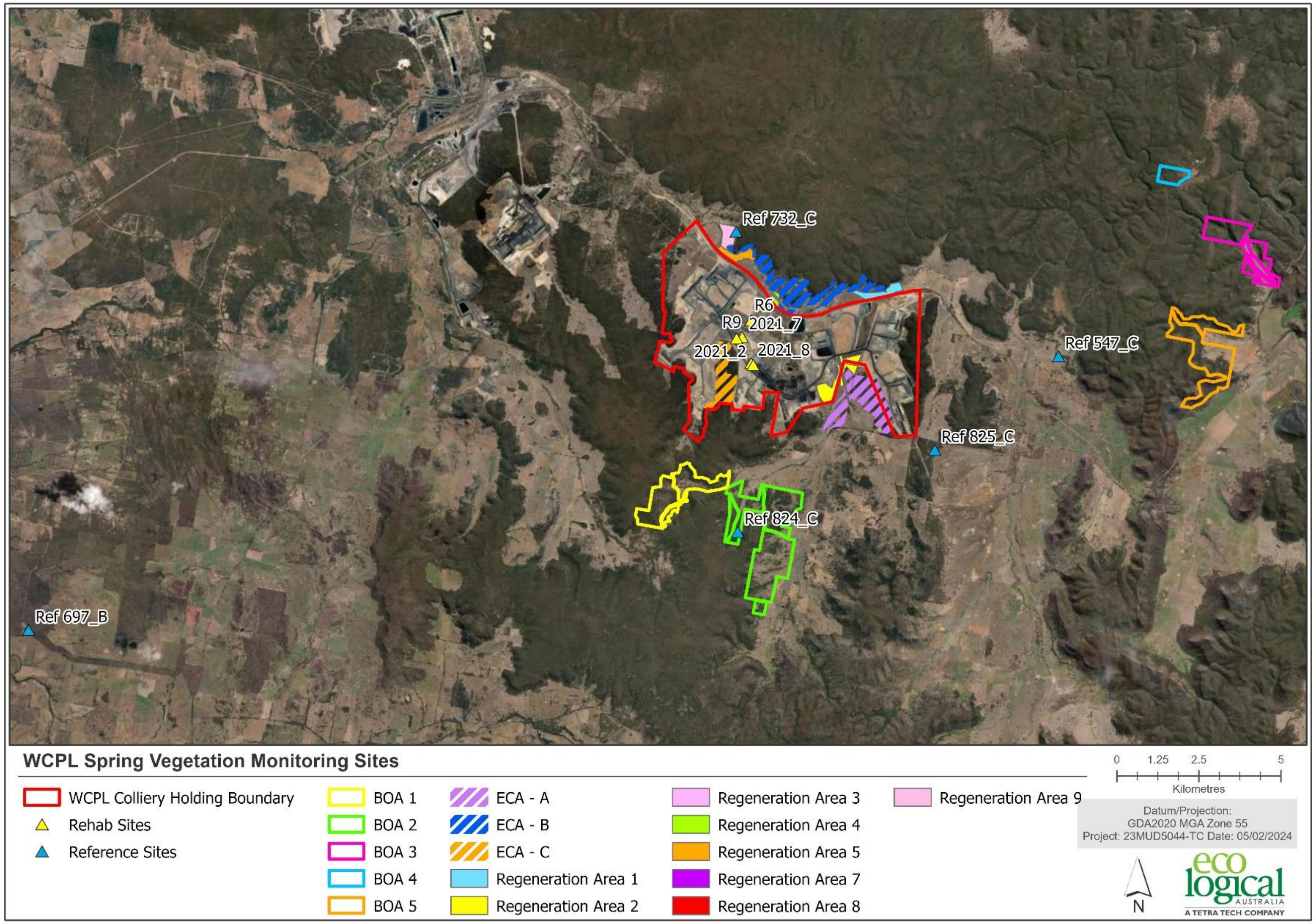

Figure 3: Spring 2023 vegetation monitoring sites

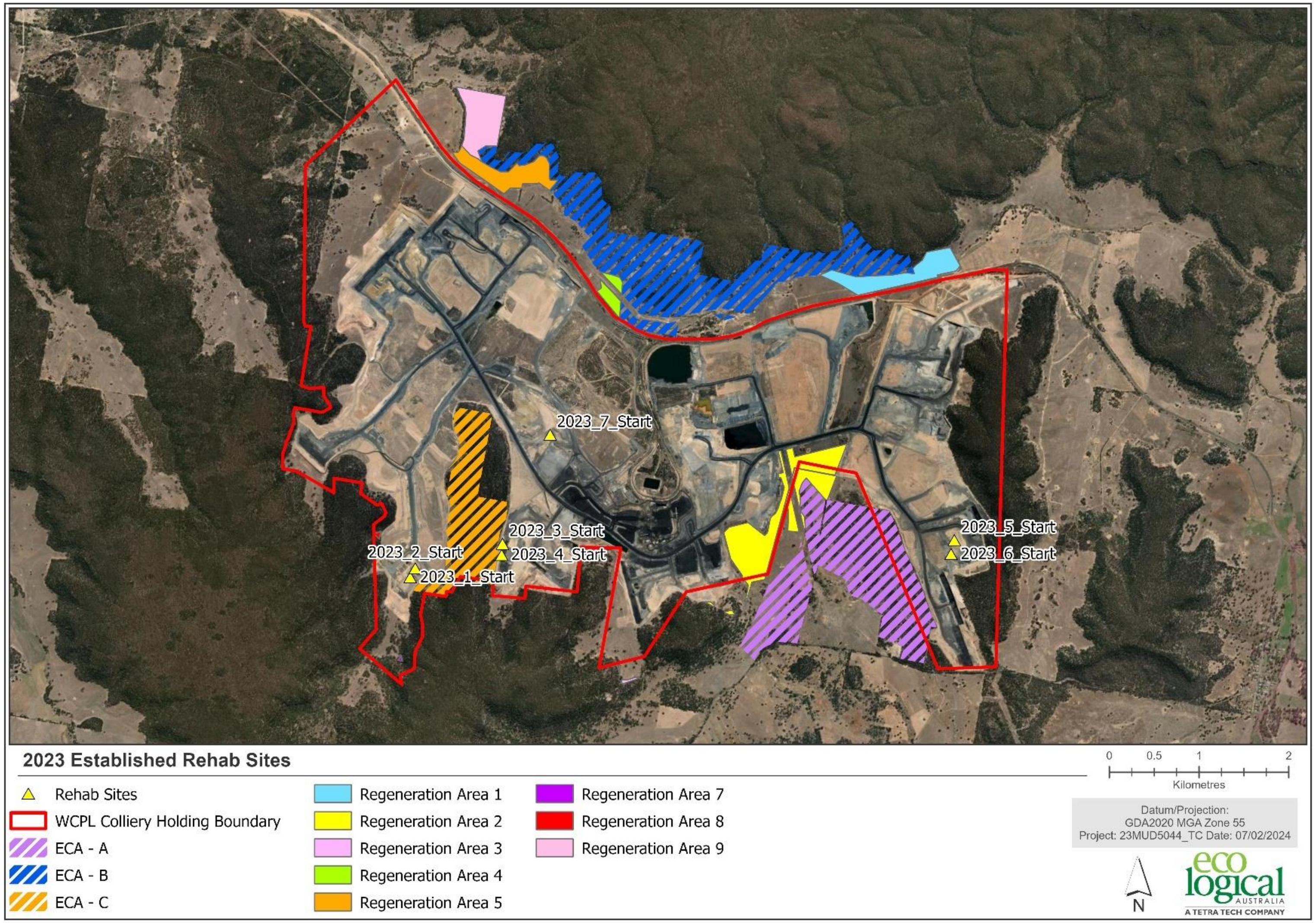

Figure 4: 2023 Established rehab monitoring sites

2.3. Fauna Monitoring

Terrestrial fauna monitoring undertaken in 2023 included:

- Bird surveys across three seasons (Summer, Winter, and Spring)
- Herpetological searches during spring
- Camera trapping in spring
- Microbat monitoring in spring.

It is noted that fauna monitoring on the now relinquished BOAs 1 - 5 was undertaken and the results have been provided to WCPL in a separate report. Nest box inspections were also completed and have been documented in a separate report provided to WCPL.

The methodology and survey effort for each target species are per the methods prescribed within the BMP (WCPL 2021) and are summarised in Table 2. Locations of fauna monitoring sites are shown below in Figure 5. WCPL has proposed to only commence fauna monitoring in rehabilitation areas after five years of establishment and thus only two long term established (2) rehabilitation sites were monitored.

2.3.1. Bird Monitoring

Bird monitoring was undertaken across three seasons; summer, winter, and spring, to provide a complete bird species list. Winter bird surveys are undertaken specifically to target those species that feed on the blossoms of winter-flowering eucalypts and lerps.

2.3.2. Ground Fauna Monitoring

Ground fauna monitoring is undertaken in spring only and consisted of infra-red camera observations and herpetological searches. Infra-red motion sensitive camera were installed across five (5) reference sites and two (2) rehabilitation sites during spring, concurrent with spring bird monitoring (**Error! Reference source not found.**). Ground trapping of fauna through the use of pitfall and funnel traps was not conducted in 2023, following successful implementation of non-invasive ground fauna monitoring techniques in 2022.

2.3.3. Microbat Monitoring

Microbat monitoring is undertaken in spring using ultrasonic acoustic recording devices. Acoustic microbat monitoring devices were deployed across five reference sites and two (2) rehabilitation sites during spring, concurrent with spring bird monitoring (**Error! Reference source not found.**). Each detector was set to survey ultrasonic microbat calls passively for at least two consecutive nights during the survey period. A total of 14 survey nights were completed during this survey.

Acoustic analysis was undertaken by ELA microbat ecologist Tara Dowling, with the analysis report provided in Appendix C.

Table 2: Fauna monitoring methods summary

Target Species	Methodology	Total Survey Effort
Birds	Bird survey consisting of 10 minutes recording all birds seen/heard within 50 m radius of central plot point, and further 10 minutes recording all birds seen/heard within balance of a 2-ha plot. Call playback for the Critically Endangered Regent Honeyeater was played during surveying. The location of flowering Eucalypt and Mistletoe species were recorded using Survey123 to identify foraging sources specific to the Regent Honeyeater	80 total minutes per site (20 minutes per survey, per person, per site), over one morning and one afternoon.
Ground fauna (amphibians, mammals, reptiles)	Infra-red cameras were installed on trees and attached to large woody debris to monitor for ground fauna. Rocks and logs including augmented habitat features were searched for reptiles.	Cameras were installed at five reference sites and two rehabilitation sites for two nights. Searches were conducted during spring bird surveys.
Bats	Automated ultrasonic acoustic recording to identify all bat species occurring.	Recording for 2 nights (6pm – 6am), at five reference sites and two rehabilitation sites.
Mammals	Opportunistic collection of scats and observations of tree scratching's, animal tracks and paw prints.	Opportunistic
All	Any sightings of fauna recorded whilst moving throughout the Project Area and located using a GPS.	Opportunistic

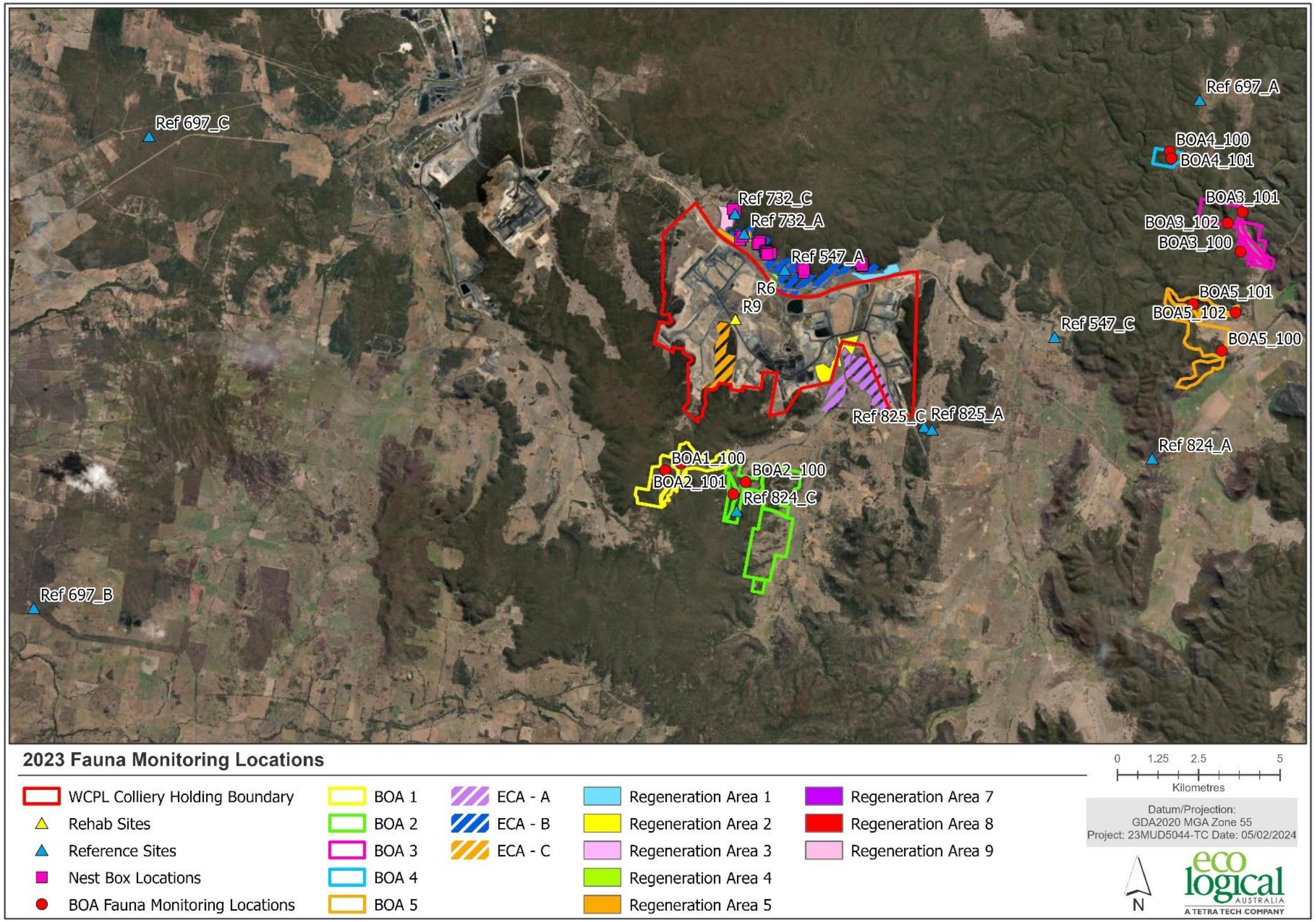

Figure 5: 2023 Fauna monitoring sites

3. Results and Discussion

The results of the 2023 biodiversity monitoring program are presented below.

3.1. Vegetation Monitoring

A total of 307 plant species were recorded across all vegetation and reference sites monitored during autumn and spring 2023, consisting of 203 native species, 89 exotic species and 15 species that were not able to be identified as either native or exotic due to lack of plant material. A complete list of flora species recorded during the 2023 monitoring period is included in Appendix E.

Bushfire in Cope State Forest impacted reference site Ref_697C and thus was swapped with reference site Ref_697B during spring monitoring.

3.1.1. Assessment against Rehabilitation BVT Benchmarks and WCPL Performance Criteria

Vegetation monitoring results for the Rehabilitation Areas were assessed against the WCPL Rehabilitation Performance Criteria and the Local Reference Site BVT Benchmarks (see Appendix D). A Site Value Score (SVS) was calculated for each site using the BioMetric Tool (NSW Department Environment Climate Change and Water, DECCW 2011) which combines the quality and quantity of native vegetation by measuring ten condition variables within a plot compared to the pre-European benchmarks for the BVT.

Table 3 and Table 4 present the individual site attribute and SVS for each 2023 rehabilitation monitoring site. Error! Reference source not found. presents comparison of sites against the Local Reference Site B VT Benchmarks and Error! Reference source not found. presents comparison of sites against the approved WCPL Performance Criteria and. SVS which do not meet the BVT Benchmark Targets or Performance Criteria are highlighted in red – monitoring results from these sites trigger the Interim Rehabilitation Performance Criteria (Years 1 – 10) Trigger Action Response Plan (TARP) detailed in Table 19 of the BMP (WCPL 2021). Amber is not applied to the SVS as anything below the Benchmark Target or Performance Criteria is considered LOW. A colour coding system has been applied to all site attribute results.

- GREEN indicates site attributes that have met the relevant Benchmark Targets or Performance Criteria (indicating that no additional management intervention is required)
- AMBER indicates site attributes that have not met the relevant Benchmark Targets or Performance Criteria, but are within 50 - <100% of the targets
- RED indicates site attributes that are <50% of the relevant Benchmark Targets or Performance Criteria.

Table 3: Assessment against Local Reference Site BVT Benchmarks* for Rehabilitation Sites within their respective BVT

BVT	Season	Site	Vegetation Condition	SVS	Site attributes (% cover)									
					NSR	NOC	NMC	NGCG	NGCS	NGCO	EC	NTH (Count)	OR	FL (M)
HU824	Autumn	R6	Low	26	26	11	0	1	1	0	23	0	1	1
	Spring	R6	Mod to good – poor	44	20	8.5	8.5	13	0	0	4	0	0.8	1
	Autumn	R9	Low	31	28	17.1	0	2	0	1	16	0	0	25
	Spring	R9	Mod to good – medium	55	17	21.5	5.2	3	0	1	2	0	1	34
	Autumn	2021_6	Low	18	16	0	0	20	0	2	16	0	0	0
	Autumn	2021_7	Low	24	27	0	0	7	0	9	16	0	0	0
	Spring	2021_7	Low	21	22	0	0	2	0	0	16	0	1	0
	Autumn	2021_8	Low	24	28	0	0	14	0	5	17	0	0	0
	Spring	2021_8	Low	27	27	0	0	2	0	0	13	0	1	0
HU697	Autumn	2021_1	Low	26	23	0	0	5	0	5	27	0	0	0
	Autumn	2021_2	Mod to good – poor	44	24	0	1	3	0	4	20	0	0	0
	Spring	2021_2	Low	25	25	0	0	2	0	0	9	0	0	0
HU732	Autumn	2021_3	Mod to good – high	65	36	0	0	8	0	10	2	0	0	130
	Autumn	2021_4	Mod to good – high	65	30	0	0	11	0	13	4	0	0	75
	Autumn	2021_5	Mod to good – medium	51	23	0	0	16	1	2	21	0	0	0

SVS = Site Value Score, NSR = Native Plant Species Richness, NOC = Native Overstorey Cover, NMC = Native Midstorey Cover, NGCG = Native Ground Stratum Cover (grasses), NGCS = Native Ground Stratum Cover (shrubs), NGCO = Native Ground Stratum Cover (other), EC = Exotic Plant Cover, NTH = Number of Trees with Hollows, OR = Overstorey Regeneration and FL = Length of Fallen Logs

*BVT Benchmarks are taken from Local Reference Sites and was approved by DPIE on June 2021, and is incorporated into the BMP (WCPL, 2021)

Table 4: Assessment against WCPL Rehabilitation Performance Criteria * for Rehabilitation Sites within their respective BVT

BVT	Season	Site	Vegetation Condition	SVS	Site attributes (% cover)									
					NSR	NOC	NMC	NGCG	NGCS	NGCO	EC	NTH (Count)	OR	FL (M)
HU824	Autumn	R6	Mod to good – medium	49	26	11	0	1	1	0	23	0	1	1
	Spring	R6	Mod to good – high	69	20	8.5	8.5	13	0	0	4	0	0.8	1
	Autumn	R9	Mod to good – medium	52	28	17.1	0	2	0	1	16	0	0	25
	Spring	R9	High – benchmark	89	17	21.5	5.2	3	0	1	2	0	1	34
	Autumn	2021_6	Low	29	16	0	0	20	0	2	16	0	0	0
	Autumn	2021_7	Low	29	27	0	0	7	0	9	16	0	0	0
	Spring	2021_7	Low	32	22	0	0	2	0	0	16	0	1	0
	Autumn	2021_8	Low	29	28	0	0	14	0	5	17	0	0	0
	Spring	2021_8	Low	32	27	0	0	2	0	0	13	0	1	0
HU697	Autumn	2021_1	Low	24	23	0	0	5	0	5	27	0	0	0
	Autumn	2021_2	Mod to good – poor	40	24	0	1	3	0	4	20	0	0	0
	Spring	2021_2	Low	24	25	0	0	2	0	0	9	0	0	0
HU732	Autumn	2021_3	Mod to good – high	65	36	0	0	8	0	10	2	0	0	130
	Autumn	2021_4	Mod to good – high	65	30	0	0	11	0	13	4	0	0	75
	Autumn	2021_5	Mod to good – medium	51	23	0	0	16	1	2	21	0	0	0

SVS = Site Value Score, NSR = Native Plant Species Richness, NOC = Native Overstorey Cover, NMC = Native Midstorey Cover, NGCG = Native Ground Stratum Cover (grasses), NGCS = Native Ground Stratum Cover (shrubs), NGCO = Native Ground Stratum Cover (other), EC = Exotic Plant Cover, NTH = Number of Trees with Hollows, OR = Overstorey Regeneration and FL = Length of Fallen Logs

*Rehabilitation Biometric Performance Criteria was approved by DPIE on June 2021, and is incorporated into the BMP (WCPL, 2021)

3.1.2. Reference Site BioMetric Assessment

BioMetric results for Reference Sites monitored during Autumn and Spring for 2023 are presented below (Table 5). SVS has been calculated against the Local Reference Site BVT Data in Table 12 of the BMP (WCPL 2021), to give an indication of local environmental variations throughout 2023. Of the five (5) References Sites designated for 2023 spring monitoring, Ref_697C was affected by bushfire in Cope State Forest prior to spring monitoring and Ref_697B was surveyed instead.

Table 5: 2023 Reference Site BioMetric Data

Season	Vegetation Community	Site	Site attributes (% cover)										
			SVS	NSR	NOC	NMC	NGCG	NGCS	NGCO	EC	NTH	OR	FL (m)
Autumn 2023	HU547	Ref_547B	65	51	16.5	14.2	11	4	9	0	0	1	15
Spring 2023	HU547	Ref_547C	83	22	31.5	0	12	0	3	2	1	1	28
Autumn 2023	HU697	Ref_697B	62	34	17.6	0	1	9	2	0	2	0.66	16
Spring 2023	HU697	Ref_697B	90	33	18.7	1	6	3	4	0	4	0.5	35
Autumn 2023	HU732	Ref_732B	74	43	31.5	0	25	0	13	3	8	0.66	8
Spring 2023	HU732	Ref_732C	73	21	14.5	2	18	3	2	1	1	1	20
Autumn 2023	HU824	Ref_824B	78	54	18.5	5.9	8	3	14	1	2	0.33	75
Spring 2023	HU824	Ref_824C	84	45	22.5	13.6	4	5	0	0	9	0.33	110
Autumn 2023	HU825	Ref_825B	78	56	24.5	3	1	3	4	0	1	0	51
Spring 2023	HU825	Ref_825C	49	41	12.4	19	13	1	0	0	0	1	13

NSR = Native Plant Species Richness, NOC = Native Overstorey Cover, NMC = Native Mid storey Cover, NGCG = Native Ground Stratum Cover (grasses), NGCS = Native Ground Stratum Cover (shrubs), NGCO = Native Ground Stratum Cover (other), EC = Exotic Plant Cover, NTH = Number of Trees with Hollows, OR =Table 3Table 3 Overstorey Regeneration and FL = Length of Fallen Logs

Assessment against Local Reference Site BVT Benchmarks

This is the third year comparing rehabilitation monitoring results against the approved Local Reference Site BVT benchmarks (Table 3), allowing for seasonal, yearly comparisons to be made for the established rehabilitation floristic sites R6 and R9 (Figure 6 and Figure 7)

The overall SVS for R6 and R9 were lower in autumn than spring (Table 3) largely due to a lack of midstory cover in autumn. This is consistent with local environmental variations at reference sites, shown in Table 5. Exotic cover had decreased in both seasons in comparison to 2022 monitoring, particularly in spring where exotic decreased by 60% at R6 and 38% at R9.

Figure 6: SVS calculated from Local Reference Site Benchmarks Autumn 2021-2023

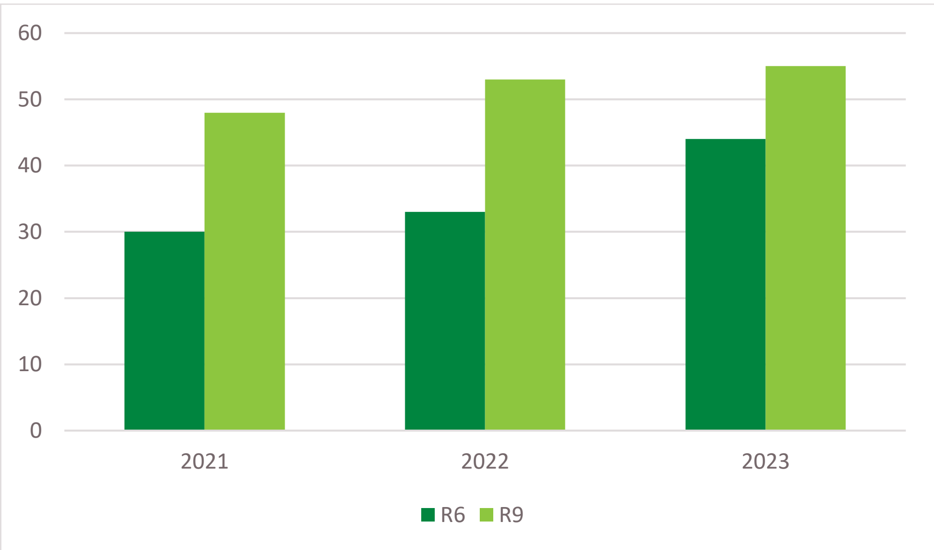

Figure 7: SVS calculated from Local Reference Site Benchmarks Spring 2021-2023

The 2021 seeded rehabilitation sites SVS has increased at all sites except for 2021_6, native species richness has increased at all sites and exotic cover has decreased at all sites.

The Mudgee area experienced high rainfall during 2022, with high temperatures and low rainfall in the lead up to and during spring 2023 (Appendix A). It is likely that these conditions simulated summer conditions, leading to early germination and hence earlier flowering in 2023. This lead to groundcover (both native and exotic) being low across the region and have had a significant effect on some rehabilitation sites.

3.1.3. Weeds

Weed species classified as priority weeds under the Central Tablelands Regional Strategic Weed Management Plan 2023-2027 (Central Tablelands LLS 2023) were identified at several monitoring sites across the Management Domains. These priority weeds and their site locations are presented below in Table 6**.**

Table 6: Priority weeds recorded in 2023

Scientific Name	Common Name	State Priority Weed	Regional Priority Weed	Sites recorded
Heliotropium amplexicaule	Blue Heliotrope		Y	2021_3
Hypericum perforatum	St John's Wort		Y	R6, R9, 2021_3, 2021_4, 2021_5, 2021_7, 2021_8, 2023_1, 2023_2, Ref_732B, Ref_824B
Opuntia stricta	Prickly Pear	Y	Y	Ref_824B

3.2. Landscape Function Analysis

Landscape Organisation Index (LOI) is an output from the LFA. The LOI is a function of the proportion of a transect occupied by patches. Patches are areas of resource loss or gain, as a result of movement downslope, and are defined by soil surface elements including perennial vegetation cover, litter or large woody debris, or rocks, which help retain soil and resources are a site. A LOI value close to 100% (1.0) implies a transect can retain resources, which is an important characteristic of a self-sustaining ecosystem. Bare soil does not contribute to LOI.

A self-sustaining ecosystem is deemed to have been achieved when SSA scores of 50 or more are recorded (the LFA Completion Criteria, expected to be achieved by Year 10 of the management cycle). Incremental improvement toward that target is expected with each year of monitoring. Failure to achieve an increase of 5% in the annual LFA scores represents a trigger for implementation of the Landscape Stability LFA TARP described in Table 21 of the BMP (WCPL 2021). Comparative annual results have been colour-coded to provide a visual indicator, with green reaching or exceeding the incremental increase of 5% or more, and red showing an increase of less than 5% (or in some cases, a reduction from the previous year). Red colour-coded cells indicate the TARP needs to be implemented. Results maintained at or above the Completion Criteria (50%) have been coded green regardless of comparative incremental increases or decreases from previous monitoring periods.

The LOI and SSA scores calculated from spring 2023 LFA monitoring are presented in Table 7 and Error! Reference source not found. below. The results are presented as a comparison to 2022 LFA monitoring data to provide an assessment against the LFA completion criteria.

3.2.1. Rehabilitation Areas

Five LFA monitoring sites located within Rehabilitation Areas were monitored in 2023. The LOI and SSA scores for these sites are presented in Table 7**.** Three of these sites (2021_2, 2021_7 and 2021_8) are in their first round of LFA monitoring and are considered baseline data.

Spring 2023 monitoring results show decreases in LOI from spring 2022 monitoring at the two established rehabilitation sites R6 and R9. The LOI is heavily influenced by climatic conditions and the associated generation of litter and plant cover, which was observed to be low in the hot and dry conditions leading up to the 2023 monitoring, resulting in patches of bare ground and resulting low LOI scores.

LFA scores are provided below in Table 7 with year on year comparisons provided in Figures 8 to 10.

Table 7: LOI and SSA results for Rehabilitation Area transects

Site	Monitoring Season	Landscape Organisation Index (%)	Soil Surface Assessment		
			Stability	Infiltration	Nutrient cycling
R6	Spring 2023	0.56	45.9	27.2	19.6
	Spring 2022	0.85	48.9	25.6	18.5
		Annual incremental increase	-3	1.6	1.1
R9	Spring 2023	0.86	49	25.7	19.2
	Spring 2022	1	50.3	26.1	23.1
		Annual incremental increase	-1.3	-0.4	-3.9
2021_2	Spring 2023	0.71	44.6	24.6	16.4
2021_7	Spring 2023	0.98	45.2	33.7	29.3
2021_8	Spring 2023	0.8	46.4	26.1	21.9

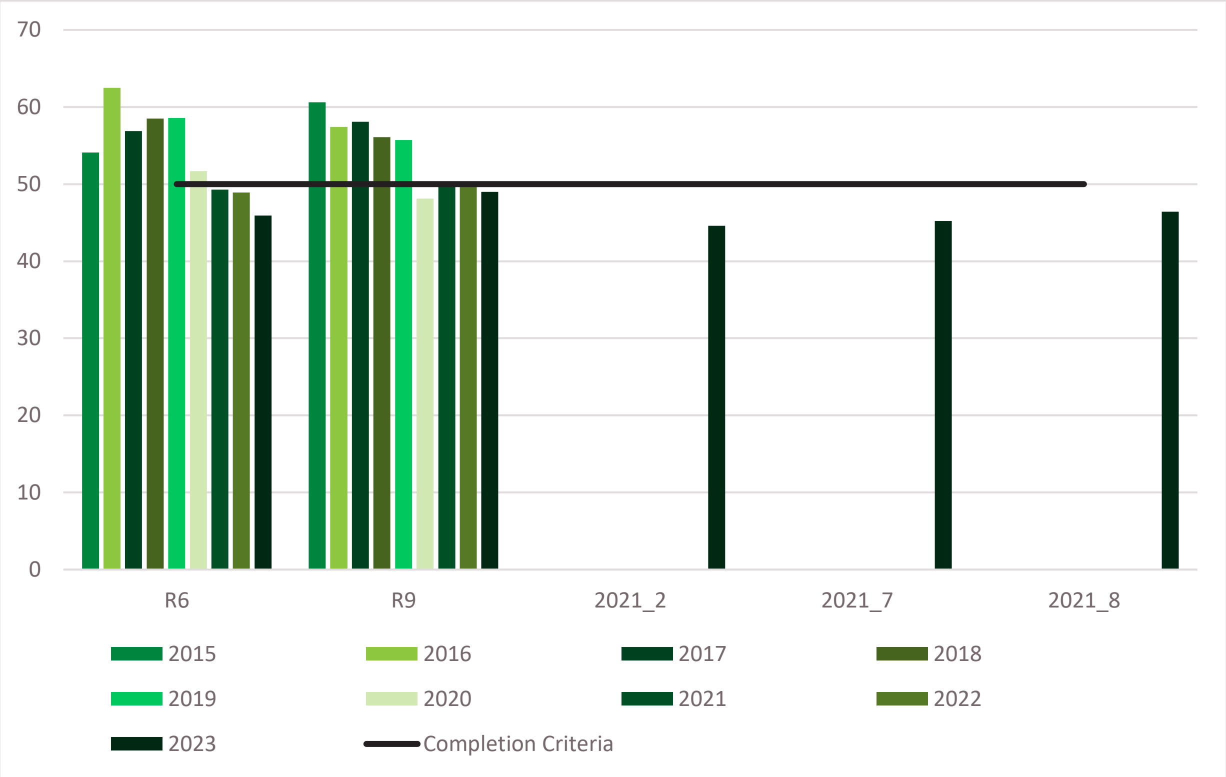

Figure 8: 2015-2023 Stability LFA scores for Rehabilitation sites

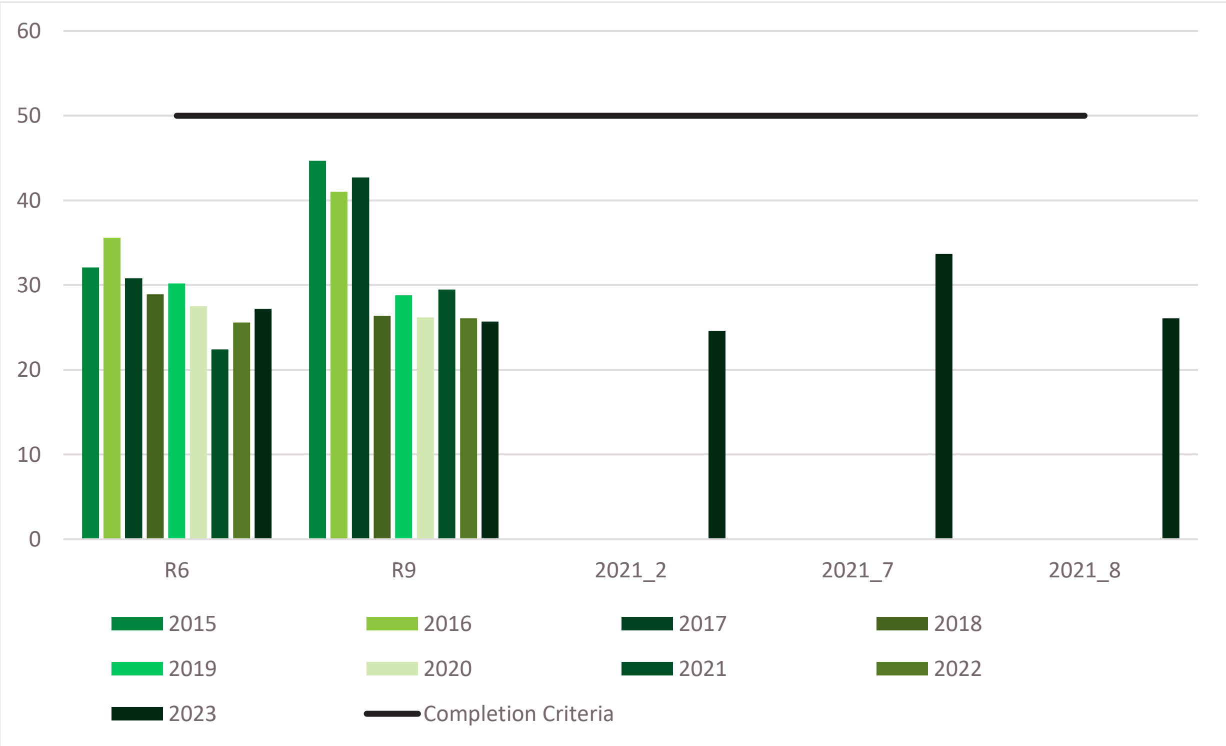

Figure 9: 2015-2023 Infiltration LFA scores for Rehabilitation sites

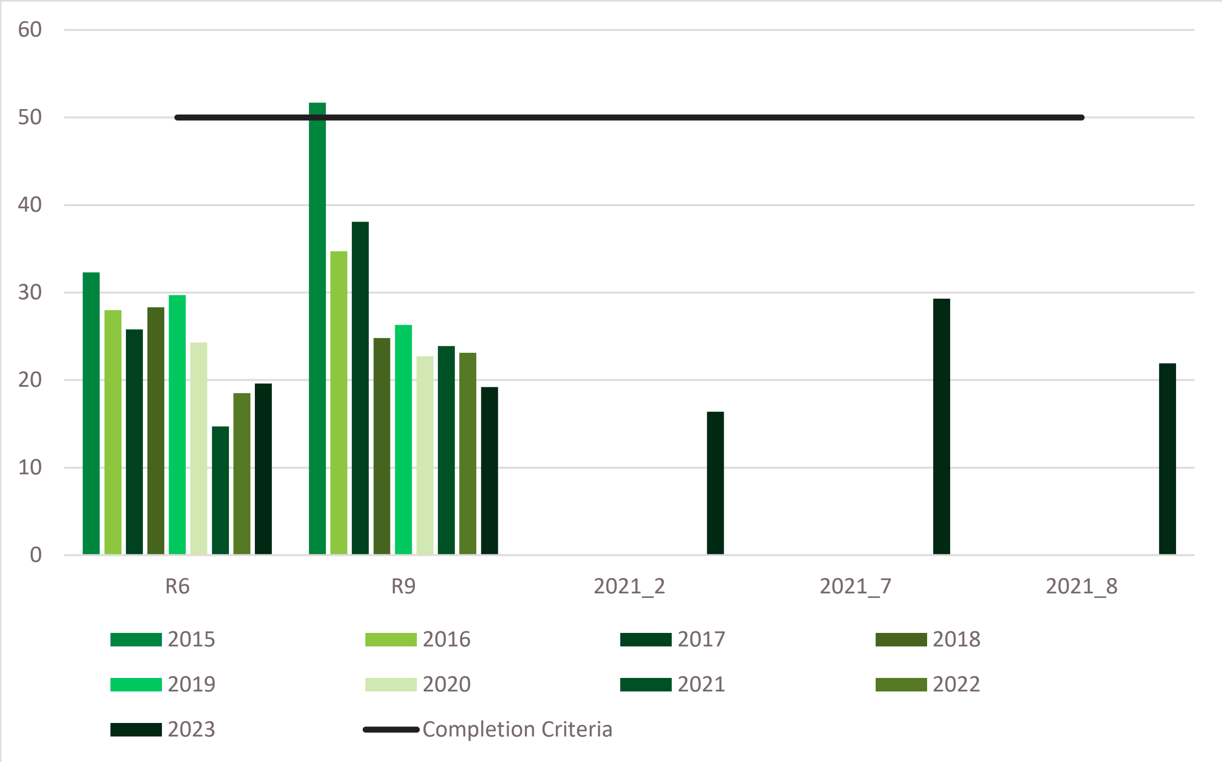

Figure 10: 2015-2023 Nutrient cycling scores for Rehabilitation sites

3.2.2. Reference Sites

LFA monitoring was undertaken at five reference sites in 2023. The LOI and SSA scores for these sites are presented in Table 8Error! Reference source not found..

Reference sites recorded high LOI scores (>0.8). All sites are occupied with patches of perennial ground cover and litter contributing to a self-sustaining, stable landform.

Table 8: LOI and SSA results for reference sites

Site	Monitoring Season	Landscape Organisation Index (%)	Soil Surface Assessment		
			Stability	Infiltration	Nutrient cycling
Ref_547C	Spring 2023	0.97	52.8	25.5	18.7
Ref_697B	Spring 2023	0.8	57.1	36.9	34.2
Ref_732C	Spring 2023	0.92	57.6	38.5	35.1
Ref_824C	Spring 2023	0.94	45.3	43.5	35.9
Ref_825C	Spring 2023	1	44.5	25.4	16

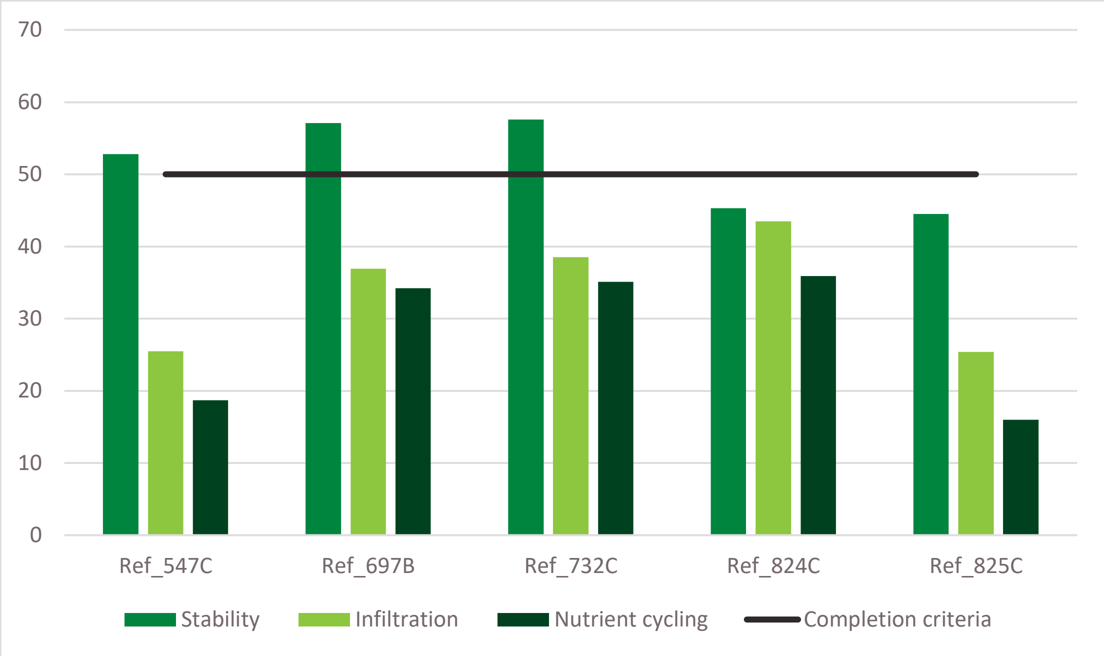

Figure 11: 2023 reference site LFA scores

3.2.3. Discussion of LFA Monitoring Sites

Most sites recorded relatively high LOI scores (>0.71). R6 recorded 0.56 which is a decrease from 2022 monitoring (0.85). This is attributed to an increase in bare soil at this site, due to unfavourable climatic conditions. Despite this, SSA scores have not changed significantly, with infiltration and nutrient cycling increasing.

Dominant patch types across sites were perennial groundcover, bare soil, and litter; consistent with previous years. The LFA data for the reference sites is presented in **Error! Reference source not found.** below. A year-on-year comparison of stability, infiltration and nutrient cycling scores are present below in Figure 8 to Figure 10. 2021 established sites are in their first round of monitoring and cannot yet be compared to previous data.

Three (3) reference sites met completion criteria for stability**Error! Reference source not found.**. These were the only attributes to reach LFA completion criteria during 2023 monitoring. No rehabilitation sites met completion criteria for stability (Figure 8), yet are largely consistent with target reference sites. A decrease was recorded at R6 this round; however, it is still above the Ref_824C site stability score. Figure 8 shows stability scores have been subject to fluctuation over the years. In 2020 when the region was experiencing drought scores dropped significantly and have generally remained consistent since.

No rehabilitation or reference sites met the completion criteria for infiltration (Figure 9) or nutrient cycling (Figure 10) in 2023. Scores for both have fluctuated since the commencement of monitoring. Despite this, R6 achieved the target 5% increase in both parameters in 2023.

Infiltration is affected by litter decomposition, surface roughness and surface nature. Nutrient cycling is affected by perennial vegetation cover, litter cover, extent of litter decomposition, cryptogram cover and soil surface roughness (Tongway and Hindley 2004). The rehabilitation sites were observed to have limited litter decomposition, low to moderate cover of perennial vegetation (i.e. grasses) and generally uniform soil micro topography.

Low scores may also be attributed to the compacted soils on which the rehabilitation sites are located. No sites have met the completion criteria for infiltration or nutrient cycling and exhibit an overall declining trend. However, this is largely consistent with the reference sites which recorded similar scores and are also yet to reach completion criteria.

3.2.4. Review of LFA results against Trigger Action Response Plan (TARP)

As per the BMP (WCPL 2021), a TARP is implemented if LFA scores are not incrementally improving towards the respective Completion Criteria by 5% each monitoring year. The TARP provides a plan to review and monitor these sites and increase remedial actions to address declining scores. As per the TARP, a review of these scores is required to be undertaken. Unfavourable climatic conditions leading to an increase of bare soil at rehabilitation sites has had a significant impact on LFA scores during spring 2023.

Stability scores historically have fluctuated around the benchmark value of 50, but no site has achieved benchmark for Infiltration or Nutrient Cycling. However, rehabilitation site trends are largely consistent with reference sites trends. The LFA review should consider whether or not using reference site LFA data as benchmarks is feasible and it is recommended that this review include a consideration of the management aims for which the LFA monitoring seeks to address and the efficacy of the LFA method to inform the achievement of these aims.

3.3. Rehabilitation sites established in 2023

Preliminary monitoring was undertaken at seven (7) sites direct seeded in 2020 and 2021. Seeding was designed to establish these sites as the target BVTs listed in Section 1 above. Vegetation monitoring consistent with the methods described in Section 2 were undertaken to determine early progress of these areas, although establishment of BioMetric monitoring plots is not required until years 3 – 4 within the Rehabilitation Areas (as per Table 11 within the BMP [WCPL 2021]).

3.3.1. Vegetation Monitoring

A total of 151 species were recorded across the 2023 rehabilitation sites. Species recorded included 96 native species and 46 exotic species, with a further nine (9) species unable to be identified as native or exotic. The full list of flora species is included in Appendix E.

Results were assessed against the Local Reference Sites BVT benchmarks and the WCPL Rehabilitation Performance Criteria as described in Section 3.1.1 and is provided in Table 9 and Table 10 below.

All 2023 rehabilitation sites met the Moderate to Good SVS under both the Local Reference Site BVT Benchmarks and the WCPL Performance Criteria. NSR, NGCG and EC were within benchmarks for all sites. No canopy cover was recorded at any site; however juvenile canopy species were recorded in good condition at all sites. A relatively high diversity of native species showed a good survival rate of plants and good baseline data which currently indicates potential to for SVS scores to improve over time without intervention.

Site 2023_4 was showing signs of gully erosion not only within the BioMetric plot but also within the surrounds (Figure 12 and Figure 13). Without intervention the erosion could increase and impact the site long-term.

Figure 12: Gully erosion at site 2023_4

Figure 13: Gully erosion near site 2023_4

Table 9: 2023 established rehabilitation sites, assessment against Local Reference Site BVT Benchmarks

BVT	Site	Vegetation Condition	SVS	Site attributes (% cover)									
				NSR	NOC	NMC	NGCG	NGCS	NGCO	EC	NTH (Count)	OR	FL (M)
HU732	2023_1	Mod to good - poor	40	43	0	12.5	25	5	0	0	0	0	0
	2023_2	Mod to good - poor	36	35	0	30.7	29	3	1	4	0	0	0
	2023_3	Mod to good - poor	40	34	0	37	17	20	1	0	0	0	0
	2023_4	Mod to good - medium	48	40	0	35.6	21	13	0	0	0	0	120
HU824	2023_5	Mod to good - poor	40	33	0	18.1	14	10	2	8	0	0	25
	2023_6	Mod to good - poor	40	45	0	18.3	4	7	1	8	0	0	70
HU697	2023_7	Mod to good - medium	51	41	0	4	9	1	0	19	0	0	0

Table 10: 2023 established rehabilitation sites, assessment against WCPL Rehabilitation Performance Criteria

BVT	Site	Vegetation Condition	SVS	Site attributes (% cover)									
				NSR	NOC	NMC	NGCG	NGCS	NGCO	EC	NTH (Count)	OR	FL (M)
HU732	2023_1	Mod to good - medium	56	43	0	12.5	25	5	0	0	0	0	0
	2023_2	Mod to good - poor	43	35	0	30.7	29	3	1	4	0	0	0
	2023_3	Mod to good - medium	46	34	0	37	17	20	1	0	0	0	0
	2023_4	Mod to good - medium	52	40	0	35.6	21	13	0	0	0	0	120
HU824	2023_5	Mod to good - good	65	33	0	18.1	14	10	2	8	0	0	25
	2023_6	Mod to good - good	59	45	0	18.3	4	7	1	8	0	0	70
HU697	2023_7	Mod to good - medium	51	41	0	4	9	1	0	19	0	0	0

3.4. Fauna Monitoring

Fauna monitoring was undertaken during summer, winter, and spring in 2023, with 112 species of fauna recorded comprising birds, microbats, mammals, reptiles and amphibians.

Ten threatened species were recorded, including:

- *Melithreptus gularis* (Black-chinned Honeyeater [eastern subspecies])
- *Climacteris picumnus victoriae* (Brown Treecreeper [eastern subspecies])
- *Stagonopleura guttata* (Diamond Firetail)
- *Artamus cyanopterus* (Dusky Woodswallow)
- *Petroica phoenicea* (Flame Robin)
- *Glossopsitta pusilla* (Little Lorikeet)
- *Grantiella picta* (Painted Honeyeater)
- *Chthonicola sagittatus* (Speckled Warbler)
- *Chalinonolus dwyeri* (Large-eared Pied Bat)
- *Miniopterus orianae oceanensis* (Large Bent-winged Bat)

A complete list of fauna species recorded during the 2023 monitoring program is provided in Appendix F.

3.4.1. Bird Monitoring

3.4.1.1. Rehabilitation Areas

There are two fauna sites within the Rehabilitation Areas, R6 and R9. R9 has developed a moderately dense shrub layer and developing canopy layer. The shrub and canopy layer at R6 is still developing. R9 recorded higher overall species richness counts in 2023 compared to 2022. R6 recorded the same overall species richness compared to 2022. *Chthonicola sagittata* (Speckled Warbler) were recorded during surveys at both Rehabilitation sites. This species is listed as Vulnerable under the NSW BC Act.

The number of bird species at each location are shown in Table 11 Overall species richness recorded within the rehabilitation areas from 2015-2023 are shown in Error! Reference source not found.. This graph indicates an overall increasing trend in bird species richness within rehabilitation areas since 2015, validating the improvement of vegetation throughout these areas.

Table 11: Species richness recorded during 2023 monitoring at rehabilitation areas

Season	Number of bird species recorded	
	R6	R9
Summer	21	16
Winter	17	14
Spring	20	13
Overall bird species richness	37	29

The survey methodology includes monitoring for flowering Eucalypt and Mistletoe species to provide an indication of habitat potential for the Regent Honeyeater. At site R6, *Eucalyptus blakelyi* (Blakely's Red Gum) was flowering during spring, and *Eucalyptus punctata* (Grey Gum) during summer.

Outlined in Table 12 are the nectivorous bird species (i.e. feed on nectar) that have been recorded on rehabilitation sites in 2023. These species are surrogate species to determine if the rehabilitation areas can support the critically endangered Regent Honeyeater (*Anthochaera phrygia*) as per section 6.3 of the BMP (2021). It should be noted that whilst Noisy Miner (*Manorina melanocephala*) are considered surrogate species in that they share similar habitat and dietary requires to the Regent Honeyeater, this species will outcompete Regent Honeyeater in the wild. '*Aggressive exclusion of birds from woodland and forest habitat by over-abundant Noisy Miner*' is listed as a key threatening process under the BC Act and EPBC Act.

Table 12: Nectivorous species recorded at Rehabilitation Sites R6 and R9

Rehabilitation site	Scientific name	Common Name
R6	*Caligavis chrysops*	Yellow-faced Honeyeater
	Lichenostomus penicillatus	White-plumed Honeyeater
	Acanthagenys rufogularis	Spiny-cheeked Honeyeater
	Lichmera indistincta	Brown Honeyeater
	Melithreptus brevirostris	Brown-headed Honeyeater
	Lichenostomus leucotis	White-eared Honeyeater
	Acanthorhynchus tenuirostris	Eastern Spinebill
	Philemon corniculatus	Noisy Friarbird
	Dicaeum hirundinaceum	Mistletoebird
	Manorina melanocephala	Noisy Miner
R9	*Philemon corniculatus*	Noisy Friarbird
	Lichenostomus penicillatus	White-plumed Honeyeater
	Caligavis chrysops	Yellow-faced Honeyeater
	Manorina melanocephala	Noisy Miner
	Acanthagenys rufogularis	Spiny-cheeked Honeyeater
	Anthochaera carunculata	Red Wattlebird

3.4.1.2. Reference Sites

Results of the bird surveys within the reference sites are shown in Table 13.

Table 13: Reference Sites bird species richness recorded during 2023 monitoring

Season	Number of species recorded										
	Ref 547_A	Ref 547_C	Ref 697_A	Ref 697_B	Ref 697_C	Ref 732_A	Ref 732_C	Ref 824_A	Ref 824_C	Ref 825_A	Ref 825_C
Summer	17	*	21	*	*	20	*	21	*	26	*
Winter	*	11	*	*	16	*	18	*	12	*	11
Spring	*	13	*	21	*	*	27	*	30	*	22
Overall bird richness	17	19	21	21	16	20	33	21	35	26	28

Outlined in Table 14 are the nectivorous bird species that have been recorded at the reference sites. These species are surrogate species for the critically endangered Regent Honeyeater, which indicates that the Reference Sites have the capacity to support this species as per Section 6.3 of the BMP (WCPL 2021).

Table 14: Nectivorous species recorded at the Reference Sites recorded during 2023 monitoring

Scientific name	Common name
Lichmera indistincta	Brown Honeyeater
Melithreptus brevirostris	Brown-headed Honeyeater
Acanthorhynchus tenuirostris	Eastern Spinebill
Ptilotula fusca	Fuscous Honeyeater
Dicaeum hirundinaceum	Mistletoebird
Philemon corniculatus	Noisy Friarbird
Manorina melanocephala	Noisy Miner
Grantiella picta	Painted Honeyeater
Anthochaera carunculata	Red Wattlebird
Myzomela sanguinolenta	Scarlet Honeyeater
Acanthagenys rufogularis	Spiny-cheeked Honeyeater
Plectorhyncha lanceolata	Striped Honeyeater
Lichenostomus leucotis	White-eared Honeyeater
Melithreptus lunatus	White-naped Honeyeater
Lichenostomus penicillatus	White-plumed Honeyeater
Lichenostomus melanops	Yellow-tufted honeyeater
Lichenostomus chrysops	Yellow-faced Honeyeater

3.4.2. Microbat Monitoring

Microbats were monitored during spring 2023 at R6, R9 and five reference sites. A summary of the results is provided in Table 15, with the full ultrasonic analysis report attached as Appendix C**.**

A total of 5,500 identifiable call sequences were recorded during the survey. There were 11 species of microbats recorded as definite species with the potential of up to 21 species. This includes up to seven species listed as vulnerable under the BC Act and EPBC Act. Based on the call profiles, two listed species were deemed to have been definitely present within the study areas, including:

- *Chalinolobus dwyeri* (Large-eared Pied Bat [BC Act and EPBC Act])
- *Miniopterus orianae oceanensis* (Large Bent-winged Bat [BC Act])

A further five species could potentially be present within the study areas. As outlined in Appendix C, potential calls are classified where the quality and structure of the call profiles are such that there is some or low probability of confusion with species that produce similar call profiles. These species include:

- *Falsistrellus tasmaniensis* (Eastern False Pipistrelle [BC Act])
- *Nyctophilus corbeni* (Corben's Long-eared Bat [BC Act and EPBC Act])
- *Saccolaimus flaviventris* (Yellow-bellied Sheathtail Bat [BC Act])
- *Scoteanax rueppellii* (Greater Broad-nosed Bat [BC Act])
- *Vespadelus troughtoni* (Eastern Cave Bat [BC Act])

Table 15: 2022 Microbat species and species combinations lists by site, as derived from ultrasonic call results for each WCPL site

Scientific Name	Common name	R6	R9	REF547C	REF697B	REF732C	REF824C	REF825C
Austronomus australis	White-striped Free-tailed Bat	-	-	✓	✓	✓	-	✓
Chalinolobus dwyeri^*	Large-eared Pied Bat	✓	✓	✓	✓	✓	✓	✓
Chalinolobus gouldii	Gould's Wattled Bat	✓	✓	✓	✓	✓	✓	✓
Chalinolobus morio	Chocolate Wattled Bat	-	P	✓	P	P	✓	P
*Falsistrellus tasmaniensis**	Eastern False Pipistrelle	-	P	-	-	P	-	-
*Miniopterus orianae oceanensis**	Large Bent-winged Bat	P	P	P	✓	✓	P	P
Nyctophilus corbeni^ / Nyctophilus geoffroyi / Nyctophilus gouldi*	Corben's Long-eared Bat / Lesser Long-eared Bat / Gould's Long-eared Bat	-	-	✓	✓	✓	✓	✓
Ozimops planiceps	Southern Free-tailed Bat	✓	✓	✓	✓	✓	✓	✓
Ozimops ridei	Ride's Free-tailed Bat	P	P	✓	✓	✓	✓	P
Rhinolophus megaphyllus	Eastern Horseshoe Bat	✓	-	✓	-	✓	✓	✓
*Saccolaimus flaviventris**	Yellow-bellied Sheathtail Bat	-	-	-	-	-	-	P
*Scoteanax rueppellii**	Greater Broad-nosed Bat	P	P	-	P	P	-	-
Scotorepens balstoni	Inland Broad-nosed Bat	✓	✓	P	P	✓	P	-
Scotorepens greyii	Little Broad-nosed Bat	-	-	-	P	P	-	-
Vespadelus darlingtoni	Large Forest Bat	-	P	P	P	P	P	P
Vespadelus pumilus	Eastern Forest Bat	-	P	P	-	P	P	-
Vespadelus regulus	Southern Forest Bat	P	P	P	P	P	P	P
*Vespadelus troughtoni**	Eastern Cave Bat	-	P	P	P	P	P	P
Vespadelus vulturnus	Little Forest Bat	P	P	P	✓	✓	P	P

✓ = species present, P = species potentially present. *Listed as vulnerable under the BC Act and ^listed as vulnerable under the EPBC Act.

3.4.3. Ground Fauna Monitoring

Three native animals were recorded within rehabilitation areas and are listed in Table 16 below. This is comparable with 2022 results.

Table 16: Native animal species recorded on rehabilitation areas during 2023 monitoring

Class	Common Name	Scientific Name	Site
Mammal	Eastern Grey Kangaroo	*Macropus giganteus*	R6, R9
Amphibian	Eastern Banjo Frog	*Limnodynastes dumerilii*	R9
Amphibian	Spotted Marsh Frog	*Limnodynastes tasmaniensis*	R9

Five pest species were recorded on the rehabilitation sites and are listed in Table 17 below. This is an increase from two (2) pest species during 2022 monitoring. All species in this table except Brown Hare are listed as priority pest species in the region (LLS 2018) and should be managed accordingly.

Table 17: Feral animal species recorded on rehabilitation areas during 2023 monitoring

Class	Common Name	Scientific Name	Site	Count
Mammal	European Red Fox	*Vulpes vulpes*	R6	1
Mammal	Feral Pig	*Sus scrofa*	R6	1
			2023_1	1
Mammal	Wild Rabbit	*Oryctolagus cuniculus*	R9	1
Mammal	Brown Hare	*Lepus europaeus*	R6	2
			R9	2
Mammal	Fallow Deer	*Dama dama*	R9	10

As per the BMP (WCPL 2021), *'Control of feral fauna populations is considered essential to the success of any revegetation/regeneration works as these species have the potential to damage establishing vegetation through grazing and/or tramping'.* Existing management plans targeting Feral Pig and Wild Rabbit need to continue to ensure populations of these species remain low. Fallow Deer were not recorded in the rehabilitation areas in 2022. This species can have significant impacts on shrubs and trees and were observed in a herd of 10 individuals within R9. Deer need to be controlled to safeguard revegetation efforts.

Reference sites

Six native animals were recorded at reference sites and are listed in Table 18 below. This is comparable with 2022 results.

Table 18: Native animal species recorded at reference sites during 2023 monitoring

Class	Common Name	Scientific Name	Site
Mammal	Eastern Grey Kangaroo	*Macropus giganteus*	Ref_697B, Ref_732C, Ref_825C
Mammal	Red-necked Wallaby	*Notamacropus rufogriseus*	Ref_697B, Ref_732C, Ref_825C

Class	Common Name	Scientific Name	Site
Mammal	Swamp Wallaby	*Wallabia bicolor*	Ref_825C
Reptile	Lace Monitor	*Varanus varius*	Ref_732C, Ref_547B (during nest box monitoring)
Reptile	Eastern Bearded Dragon	*Pogona barbata*	Ref_547B (during nest box monitoring)
Reptile	Common Garden Skink	*Lampropholis guichenoti*	Ref_732C

Two pest animals were recorded at the reference sites and are listed in Table 19 below. This is an increase from 2022 monitoring, where no pest species were recorded at reference sites.

Table 19: Feral animal species recorded at reference sites during 2023 monitoring

Class	Common Name	Scientific Name	Site	Count
Mammal	European Red Fox	*Vulpes vulpes*	Ref_697B	1
Mammal	Fallow Deer	*Dama dama*	Ref_732C	1

A complete fauna species list in provided in Appendix F.

4. Recommendations and Conclusions

4.1. BioMetric Monitoring

BioMetric monitoring was undertaken within the rehabilitation management domains and selected Reference sites prescribed by the BMP during 2023.

When assessed against the WCPL Rehabilitation Performance Criteria, R6 and R9 are at or above the Moderate to Good SVS, even when SVS had decreased when compared to 2022 monitoring. When assessed against the local reference site benchmarks, both sites were Low in autumn and Moderate to Good SVS in Spring. Encouragingly, exotic cover decreased significantly since 2022 monitoring.

It is recommended to undertake a review of the monitoring methods across the rehabilitation areas to align the program with the objectives of both WCPL's BMP and rehabilitation program. The monitoring methods in the current form only provides an assessment of tracking toward benchmark data to generate SVS; it does not provide any information on the rehabilitation areas progression toward the target BVT.

4.2. Landscape Function Analysis monitoring

The LOI data captured during 2023 observed overall lower LOI scores due to increases in bare soil and thus decreases perennial vegetation cover when compared to 2022 monitoring. All stability scores are close to, or just above completion criteria, indicating low erosion levels. However, none of the rehabilitation sites met the completion criteria for infiltration or nutrient cycling, (except R6 which had a 5% increase in scores from 2022). Nevertheless, these results are consistent with the five reference sites monitored during spring 2023.

Given that the sites have not met the 5% yearly increase towards completion criteria, these results have triggered the relevant TARP. It is recommended that the TARP review include consideration of the management aims for which LFA monitoring seeks to address, and the efficacy of the LFA method to inform achievement of these aims. The use of remote sensing (e.g. LiDAR and Digital Elevation Models [DEMS]) can be used to assess slope, gradient and erosion at high resolution across rehabilitated areas in addition with erosion and stability transects which can mirror the BioMetric transects utilised for floristic monitoring.

4.3. Rehabilitation sites established in 2023

Within the newly established rehabilitation sites, all sites recorded SVS considered Moderate to Good with NSR, NGCG and EC all within benchmark range. When compared to the WCPL Performance Criteria, all sites also met the NGCS criteria and most met the NGCO criteria.

All sites had relatively high native species richness and several surviving canopy species. Only three of the seven sites had FL and it is recommended that felled timber be placed at the remaining sites. In general, sites currently indicate that SVS and other BioMetric attributes could continue to increase long-term with little intervention.

It is recommended that these sites continue to be monitored as per the BMP, focusing on the progression of canopy species and weed/pest management. 2023_4 and the surrounding area had significant gully erosion. This area will require regrading or infilling, followed by re-seeding.

4.4. Fauna Monitoring

Bird species richness in the rehabilitation areas was comparable with 2022 results. R6 remained the same and R9 increased slightly. This is a positive indication that despite the drier year and subsequent drop in water sources and food availability, increases in bird diversity will continue to be recorded as the vegetation develops in rehabilitation areas. A range of surrogate nectivorous bird species were recorded at both rehabilitation sites, indicated that the sites may function as suitable habitat for the Regent Honeyeater in the long-term. In addition, flowering eucalypts were recorded in the rehabilitation areas during summer and spring.

Up to 21 microbat species were recorded during spring surveys, including seven (7) species listed as vulnerable on the BC Act and EPBC Act. Microbat monitoring has been conducted on the rehabilitation areas for a number of years and shows the presence of a variety of bat species using the area, presumably as foraging habitat only due to the immaturity of trees and lack of old growth hollows. Species richness has increased since 2022 and it is encouraging to record a diversity of microbats utilising the rehabilitation areas even if only for foraging.

Implementation of infra-red cameras and ground searches following on from the 2022 recommendation continued to yield similar results to trapping methods previously utilised during fauna monitoring. It is recommended that these methods continue to be utilised and should be reflected in future BMP reviews. In light of removing trapping from the fauna monitoring program, it is recommended that after conducting bird surveys 10 minutes of herpetological searches are undertaken to get a comprehensive measure of reptile presence across the WCM Management Domains.

The continued observations of pest species within the rehabilitation areas may affect the success of revegetation works, and management should be considered a priority to reduce presence.

4.5. Recommendations Summary

Monitoring	Summary
Vegetation Monitoring	
Rehabilitation sites	Conduct a review of the monitoring program to align it with the rehabilitation objectives of the BMP and rehabilitation management plans. Options could include: • A greater spread of sites across the rehabilitation areas • Additional methodology to assess species assemblages and allow for analysis against target BVT compositions.
Reference sites	Continue monitoring as per the BMP, including flowering eucalypt species.
LFA	LFA TARP has been triggered with 2023 monitoring results. A review of the current LFA program is recommended. Review should consider the following: • Management actions sought to be measured by LFA monitoring • The efficacy of the current LFA method to inform the achievement of these management actions • The use of remote sensing, such as LiDAR and DEMs
2023 established rehabilitation sites	Continue to monitor as per the BMP. Implement weed and pest management, as baseline data at these sites show early success of initial revegetation efforts.
Fauna Monitoring	
Bird monitoring	Sustained and increasing bird species richness at rehabilitation sites indicate that management actions are improving biodiversity and habitat. Monitoring should be continued as per the BMP.
Microbat monitoring	Microbat species richness increased significantly from 2022 monitoring. Although the areas are likely only used as foraging habitat, this indicates that management actions are improving biodiversity within the rehabilitation areas. It is recommended that microbat monitoring continue to be undertaken at the rehabilitation and reference sites.
Ground fauna monitoring	The use of infra-red cameras and herpetological searches yielded similar results to those species recorded during the 2022 monitoring and trapping. It is recommended that cameras and active searches continue to be utilised. The recording of Fallow Deer within the rehabilitation areas should be closely monitored. This species has the ability to significantly impact shrubs and trees in revegetated areas. It is recommended that early control measures be put in place for this species. Additionally, it is recommended to extend herpetological searches to 10 minutes after each bird survey is undertaken throughout the year to gain a comprehensive measure of reptile presence.

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Appendix A Weather Conditions

Table 20: 2023 Monthly mean and historical average weather conditions

Month	2023 Averages (WCPL)			Historical Averages		
	Mean min. temp (°C)	Mean max. temp (°C)	Total Rainfall (mm)	Mean min. temp (°C)	Mean max. temp (°C)	Total Rainfall (mm)
January	16.2	30.4	48.6	16.1	30.9	67.1
February	15.6	30.6	24.6	15.6	29.4	62.3
March	15.3	29.5	64.6	12.9	26.9	55.1
April	9.5	22.0	47.8	7.9	22.9	39.3
May	2.5	18.3	2.8	4.0	18.6	37.0
June	2.9	16.2	28.8	2.4	15.0	43.7
July	3.0	17.2	23.2	1.2	14.6	42.9
August	3.4	19.6	29.8	1.6	16.2	41.1
September	5.2	24.4	18	4.3	19.7	41.7
October	9.0	25.7	36.2	7.8	23.2	52.1
November	14.5	27.7	94	11.2	26.3	56.7
December	17.0	32.1	59.6	13.7	28.9	60.7

SOURCE: WCPL (2023 DATA); BUREAU OF METEOROLOGY, 2023 (HISTORICAL AVERAGES) TEMPERATURE DATA FROM GULGONG POST OFFICE WEATHER STATION NUMBER 62013. RAINFALL FROM WOLLAR (BARRIGAN ST) WEATHER STATION NUMBER 62032.

Table 21: Monthly Rainfall from 2013-2033 (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2013	73.6	54.2	61.4	12.2	17.4	77.9	20.8	6.6	33.0	8.8	78.6	27.6	472.1
2014	15.6	60.0	112.6	62.8	13.8	29.8	28.6	28.8	14.6	15.4	24.4	126.7	533.1
2015	127.6	11.6	9.4	108.4	42.8	42.8	38.0	53.8	7.8	61.0	59.0	118.4	680.6
2016	152.1	7.2	23.5	14.8	66.8	104.2	101.1	40.9	198.7	86.6	51.9	90.6	938.4
2017	27.8	34.2	146	23	32.4	10.4	5.8	25.2	3	28.4	92.6	102.6	531.4
2018	24.4	77	24.6	42.2	12.4	21.6	1.2	43.8	39.6	56.8	47.4	91.2	482.2
2019	54.8	7.4	108.8	0	17.6	10.6	2.6	10.2	23	5.6	22	3	265.6
2020	27.2	127	92	117	16	23.4	70	36.4	77.2	150.6	17.4	161.6	915.8
2021	52.6	126.6	159.8	1.8	9.4	84.4	66.8	25.4	44.2	40.8	249.2	81.4	942.4
2022	101.4	16	119.8	95	43.6	13	136.4	103.2	93.8	174.4	64	26.6	987.2
2023	48.6	24.6	64.6	47.8	2.8	28.8	23.2	29.8	18	36.2	94	59.6	478
Historical Mean – Wollar (Barrigan St)	67.1	62.3	55.1	39.3	37	43.7	42.9	41.1	41.7	52.1	57	60.9	593.1

Appendix B Biodiversity Monitoring Sites

Table 22: 2023 autumn monitoring sites

Domain	Site	Management Domain	Condition	Vegetation Class	Easting	Northing
Rehabilitation	R6	Rehabilitation	Rehabilitation	BVT824	769566	6419516
	R9	Rehabilitation	Rehabilitation	BVT824	769120	6418969
	2021_1	Rehabilitation	Rehabilitation	BVT697	769385	6418808
	2021_2	Rehabilitation	Rehabilitation	BVT697	769628	6418156
	2021_3	Rehabilitation	Rehabilitation	BVT732	767926	6417731
	2021_4	Rehabilitation	Rehabilitation	BVT732	767571	6418373
	2021_5	Rehabilitation	Rehabilitation	BVT732	769504	6420477
	2021_6	Rehabilitation	Rehabilitation	BVT824	769464	6420638
	2021_7	Rehabilitation	Rehabilitation	BVT824	769290	6419007
	2021_8	Rehabilitation	Rehabilitation	BVT824	769565	6418209
Reference Sites	Ref_547B	Reference site	Reference site	BVT547	778934	778934
	Ref_697B	Reference site	Reference site	BVT697	751096	751096
	Ref_732B	Reference site	Reference site	BVT732	769183	769183
	Ref_824B	Reference site	Reference site	BVT824	769159	769159
	Ref_825B	Reference site	Reference site	BVT825	775163	775163

Table 23: 2023 spring monitoring sites

Domain	Site	Management Domain	Condition	Vegetation Class	Easting	Northing
Rehabilitation	R6	Rehabilitation	Rehabilitation	BVT824	769566	6419516
	R9	Rehabilitation	Rehabilitation	BVT824	769120	6418969
	2021_1	Rehabilitation	Rehabilitation	BVT697	769385	6418808
	2021_2	Rehabilitation	Rehabilitation	BVT697	769628	6418156
	2021_3	Rehabilitation	Rehabilitation	BVT732	767926	6417731
	2021_4	Rehabilitation	Rehabilitation	BVT732	767571	6418373
	2021_5	Rehabilitation	Rehabilitation	BVT732	769504	6420477
	2021_6	Rehabilitation	Rehabilitation	BVT824	769464	6420638
	2021_7	Rehabilitation	Rehabilitation	BVT824	769290	6419007
	2021_8	Rehabilitation	Rehabilitation	BVT824	769565	6418209
Reference Sites	Ref_547C	Reference site	Reference site	BVT547	778934	778934
	Ref_697B	Reference site	Reference site	BVT697	751096	751096
	Ref_732C	Reference site	Reference site	BVT732	769183	769183
	Ref_824C	Reference site	Reference site	BVT824	769159	769159

Domain	Site	Management Domain	Condition	Vegetation Class	Easting	Northing
	Ref_825C	Reference site	Reference site	BVT825	775163	775163

Table 24: 2023 fauna monitoring sites

Area	Site ID	Coordinates		Management Zone	Vegetation Class	Survey		
		Easting	Northing			Fauna	Bats	Birds
BOA-1	BOA1_100	766963	6414300	Native vegetation (good resilience)	Western Slopes Dry Sclerophyll Forest		Y	Y
	BOA1_101	767441	6414516	Regeneration (moderate resilience)	Western Slopes Grassy Woodland			Y
BOA-2	BOA2_100	769440	6413937	Native vegetation (good resilience)	Western Slopes Dry Sclerophyll Forest			Y
	BOA2_101	769050	6413570	Native vegetation (good resilience)	Western Slopes Grassy Woodland			Y
BOA-3	BOA3_100	784649	6421025	Native vegetation (good resilience)	Western Slopes Grassy Woodland		Y	Y
	BOA3_101	784714	6422246	Native vegetation (good resilience)	Western Slopes Grassy Woodland			Y
	BOA3_102	784258	6421909	Native vegetation (good resilience)	Dry Rainforest			Y
BOA-4	BOA4_100	782475	6424100	Native vegetation (good resilience)	Western Slopes Grassy Woodland			
	BOA4_101	782527	6423888	Native vegetation (good resilience)	Western Slopes Dry Sclerophyll Forest			
BOA-5	BOA5_100	784073	6417976	Native vegetation (good resilience)	Western Slopes Dry Sclerophyll Forest			Y
	BOA5_101	783192	6419415	Native vegetation (good resilience)	Western Slopes Grassy Woodland		Y	Y
	BOA5_102	784493	6419150	Native vegetation (good resilience)	Western Slopes Dry Sclerophyll Forest			Y
Rehabilitation	R6	769562	6419517	Rehabilitation - Woodland	Western Slopes Dry Sclerophyll Forest	Y	Y	Y
	R9	769118	6418973	Rehabilitation - Woodland	Western Slopes Dry Sclerophyll Forest	Y	Y	Y
Reference sites	Ref 824_A	6414688	781932	N/A	HU824	Y	Y	Y
	Ref 732_C	6422269	769182	N/A	HU732			Y
	Ref 824_C	6413073	769159	N/A	HU824			Y
	Ref 547_C	6418422	778934	N/A	HU547			Y

Area	Site ID	Coordinates		Management Zone	Vegetation Class	Survey		
		Easting	Northing			Fauna	Bats	Birds
	Ref 697_C	6424600	751095	N/A	HU697			Y
	Ref 825_A	6415657	774926	N/A	HU825	Y	Y	Y
	Ref 825_C	6415573	775162	N/A	HU825			Y

Appendix C Microbat Ultrasonic Analysis Report

Appendix D BioMetric Performance and Completion Criteria (Rehabilitation Monitoring)

Table 12 Biometric Performance & Completion Criteria

Attribute (WCPL2021)	BVT	Native Plant Species Richness MIN-MAX (No. species)		Native Over Storey Cover MIN-MAX (%)[7]		Native Mid – Storey Cover MIN-MAX (%)		Native Ground Cover Grass MIN-MAX (%)		Native Ground Cover Shrubs MIN-MAX (%)		Native Ground Cover Other MIN-MAX (%)		Number of Trees with Hollows	Total Length Fallen Logs (m)	
Local Reference Site BVT Data (WCPL, 2021)	HU547	15-45		15-26		0-6		4-58		0-2		2-34		0	38.22	
	HU732	17-62		9-28		0-0.2		2-50		0-2		2-38		0	25	
	HU697	22-50		17-23		1-13		4-12		0-14		0-20		0	38	
	HU824	27-61		12.7-30.5		0.7-13.7		0-18		0-8		2-38		3	83.39	
	HU825	27-52		16.5-27		0.4-7		0-52		0-12		0-34		1	58	
Completion Criteria		**1**		**1**		**1**		**1**		**1**		**1**		**0**	**0.5**	
Allowable Future Attribute Score Increases Relative to Benchmark (After OEH, 2014b, 2015)		**>50%**		**>25<200%**		**>25<200%**		**>25<200%**		**>25<200%**		**>25<200%**		**N/A**	**>25%**	
WCPL Criteria	BVT	Comp.	Perf.	Comp.	Perf.	Comp.	Perf.	Comp.	Perf.	Comp.	Perf.	Comp.	Perf.		Comp.	Perf.
	HU547	7.5-22.5	3.75-11.25	3.75-52	1.88-52	1.25-100	1-100	1-100	0.5-100	0.5-20	0-10	0.5-68	0.25-68	NIL	9.56	4.78
	HU732	8.5-31	4.25-11.25	2.25-56	1.88-56	0.5-20	0-20	0.5-100	0.25-100	0.5-20	0-10	0.5-76	0.25-76		6.25	3.13
	HU697	11-25	5.50-12.5	4.25-46	2.13-46	2.5-100	1-100	1-24	0.5-24	1.25-20	1-10	0-40	0-40		9.5	4.75
	HU824	13.5-30.5	6.75-15.25	3.18-61	1.59-61	2.5-100	1-100	0-36	0-36	1.25-20	1-10	0.5-76	0.25-76		16.5	8
	HU825	13.5-26	6.75-13	4.13-54	2.06-54	2.75-100	1-100	0-104	0-104	1.25-60	1-30	0-68	0-68		14.5	7.25

Attribute (OEH, 2017)	Exotic Plant Cover (% of total cover)		Regeneration[7] (% of over-storey species that are naturally regenerating)		Overall Site Value Score (OEH, 2015) (average of plots in vegetation zone)	
Completion Criteria	**1**		**0.5**		**16.93**	
Allowable Future Attribute Score Increases Relative to Benchmark (After OEH, 2014b, 2015)	**<45%**		**25%**			
WCPL Criteria	Comp.	Perf.	Comp.	Perf.	Comp.	Perf.
All relevant BVTs	<45%	<90%	To be determined based on number of OS species	No regeneration	17	7

[7] Relevant Regent Honeyeater habitat criteria, in concurrence with the presence/absence monitoring for mistletoe and surrogate nectivore bird species
Comp. = Completion Criteria
Perf. = Performance Criteria at 10 years after landform establishment

Appendix E Flora Species List

Family	Scientific Name	Native/Exotic
Amaranthaceae	*Alternanthera denticulata*	Native
Amaranthaceae	*Alternanthera nana*	Native
Amaranthaceae	*Alternanthera pungens*	Exotic
Amaranthaceae	*Dysphania pumilio*	Native
Amaranthaceae	*Enchylaena tomentosa*	Native
Anthericaceae	*Laxmannia gracilis*	Native
Apiaceae	*Cyclospermum leptophyllum*	Exotic
Apiaceae	*Daucus glochidiatus*	Native
Apocynaceae	*Gomphocarpus fruticosus*	Exotic
Apocynaceae	*Gomphocarpus sp.*	Exotic
Araliaceae	*Hydrocotyle laxiflora*	Native
Asparagaceae	*Arthropodium minus*	Native
Asphodelaceae	*Dianella caerulea*	Native
Asphodelaceae	*Dianella longifolia*	Native
Asphodelaceae	*Dianella revoluta*	Native
Asteraceae	*Aster sp.*	Exotic
Asteraceae	*Aster subulatus*	Exotic
Asteraceae	*Bidens subalternans*	Exotic
Asteraceae	*Calotis cuneifolia*	Native
Asteraceae	*Calotis lappulacea*	Native
Asteraceae	*Carthamus lanatus*	Exotic
Asteraceae	*Cassinia cunninghamii*	Native
Asteraceae	*Cassinia quinquefaria*	Native
Asteraceae	*Cassinia sifton*	Native
Asteraceae	*Cenchrus clandestinus*	Exotic
Asteraceae	*Centaurea calcitrapa*	Exotic
Asteraceae	*Chondrilla juncea*	Exotic
Asteraceae	*Chrysocephalum apiculatum*	Native
Asteraceae	*Cineraria lyratiformis*	Exotic
Asteraceae	*Cirsium vulgare*	Exotic
Asteraceae	*Conyza bonariensis*	Exotic
Asteraceae	*Cotula australis*	Native
Asteraceae	*Cymbonotus lawsonianus*	Native
Asteraceae	*Dittrichia graveolens*	Exotic

Family	Scientific Name	Native/Exotic
Asteraceae	*Euchiton involucratus*	Native
Asteraceae	*Euchiton sp.*	Native
Asteraceae	*Euchiton sphaericus*	Native
Asteraceae	*Gamochaeta calviceps*	Exotic
Asteraceae	*Gamochaeta purpurea*	Exotic
Asteraceae	*Gamochaeta sp.*	Exotic
Asteraceae	*Hypochaeris radicata*	Exotic
Asteraceae	*Lactuca saligna*	Exotic
Asteraceae	*Lactuca serriola*	Exotic
Asteraceae	*Lactuca sp.*	Exotic
Asteraceae	*Lagenophora stipitata*	Native
Asteraceae	*Ozothamnus diosmifolius*	Native
Asteraceae	*Ozothamnus sp.*	Native
Asteraceae	*Pseudognaphalium luteo-album*	Native
Asteraceae	*Schkuhria pinnata*	Exotic
Asteraceae	*Senecio quadridentatus*	Native
Asteraceae	*Senecio sp.*	Native/exotic
Asteraceae	*Sigesbeckia orientalis*	Native
Asteraceae	*Solenogyne dominii*	Native
Asteraceae	*Solenogyne sp.*	Native
Asteraceae	*Sonchus asper*	Exotic
Asteraceae	*Sonchus oleraceus*	Exotic
Asteraceae	*Taraxacum officinale*	Exotic
Asteraceae	*Tolpis barbarta*	Exotic
Asteraceae	*Vittadinia cuneata*	Native
Asteraceae	*Vittadinia muelleri*	Native
Asteraceae	*Xanthium spinosum*	Exotic
Asteraceae	*Conyza parva*	Exotic
Boraginaceae	*Cynoglossum australe*	Native
Boraginaceae	*Echium plantagineum*	Exotic
Boraginaceae	*Heliotropium amplexicaule*	Exotic
Brassiaceae	*Brassica sp.*	Exotic
Brassicaceae	*Lepidium africanum*	Exotic
Brassicaceae	*Lepidium bonariense*	Exotic
Brassicaceae	*Rapistrum rugosum*	Exotic
Brassicaceae	*Sisymbrium officinale*	Exotic

Family	Scientific Name	Native/Exotic
Cactaceae	*Opuntia stricta*	Exotic
Campanulanceae	*Wahlenbergia communis*	Native
Campanulanceae	*Wahlenbergia gracilis*	Native
Campanulanceae	*Wahlenbergia sp.*	Native
Carophyllaceae	*Paronychia brasiliana*	Exotic
Carophyllaceae	*Petrorhagia nanteuilii*	Exotic
Carophyllaceae	*Petrorhagia dubia*	Exotic
Caryophyllaceae	*Cerastium glomeratum*	Exotic
Caryophyllaceae	*Cerastium vulgare*	Exotic
Casuarinaceae	*Allocasuarina gymnanthera*	Native
Casuarinaceae	*Allocasuarina luehmannii*	Native
Casuarinaceae	*Allocasuarina sp.*	Native
Casuarinaceae	*Allocasuarina verticillata*	Native
Chenopodiaceae	*Atriplex sp.*	Native
Chenopodiaceae	*Chenopodiaceae sp.*	Native/Exotic
Chenopodiaceae	*Chenopodium album*	Exotic
Chenopodiaceae	*Atriplex sp.*	Native
Chenopodiaceae	*Einadia hastata*	Native
Chenopodiaceae	*Einadia nutans*	Native
Chenopodiaceae	*Einadia polygonoides*	Native
Chenopodiaceae	*Einadia trigonos*	Native
Chenopodiaceae	*Salsola australis*	Native
Chenopodiaceae	*Sclerolaena sp.*	Native
Chenopodiaceae	*Atriplex semibaccata*	Native
Concolculaceae	*Convolvulus erubescens*	Native
Convolvulaceae	*Dichondra inglewood*	Native
Convolvulaceae	*Dichondra repens*	Native
Cupressaceae	*Callitris endlicheri*	Native
Cyperaceae	*Carex appressa*	Native
Cyperaceae	*Carex inversa*	Native
Cyperaceae	*Cyperus eragrostis*	Exotic
Cyperaceae	*Cyperus gracilis*	Native
Cyperaceae	*Cyperus sp.*	Native/exotic
Cyperaceae	*Fimbristylis dichotoma*	Native
Cyperaceae	*Gahnia aspera*	Native
Cyperaceae	*Isolepis inundata*	Native

Family	Scientific Name	Native/Exotic
Cyperaceae	*Isolepis sp.*	Native
Cyperaceae	*Lepidosperma laterale*	Native
Cyperaceae	*Schoenus apogon*	Native
Cyperaceae	*Schoenus ericetorum*	Native
Cyperaceae	*Schoenus sp.*	Native
Dilleniaceae	*Hibbertia circumdans*	Native
Dilleniaceae	*Hibbertia obtusifolia*	Native
Ericaceae (Epacridoideae)	*Acrotriche rigida*	Native
Ericaceae (Epacridoideae)	*Astroloma humifusum*	Native
Ericaceae (Epacridoideae)	*Brachyloma daphnoides*	Native
Ericaceae (Epacridoideae)	*Epacris sp.*	Native
Ericaceae (Epacridoideae)	*Leucopogon virgatus*	Native
Ericaceae (Epacridoideae)	*Lissanthe strigosa*	Native
Ericaceae (Epacridoideae)	*Melichrus erubescens*	Native
Ericaceae (Epacridoideae)	*Styphelia triflora*	Native
Euphorbiaceae	*Euphorbia drummondii*	Native
Fabaceae (Caesalpinioideae)	*Senna sp.*	Native
Fabaceae (Faboideae)	*Daviesia genistifolia*	Native
Fabaceae (Faboideae)	*Fabaceae sp.*	Native
Fabaceae (Faboideae)	*Glycine clandestina*	Native
Fabaceae (Faboideae)	*Glycine tabacina*	Native
Fabaceae (Faboideae)	*Grona varians*	Native
Fabaceae (Faboideae)	*Hardenbergia violacea*	Native
Fabaceae (Faboideae)	*Indigofera adesmiifolia*	Native
Fabaceae (Faboideae)	*Indigofera australis*	Native
Fabaceae (Faboideae)	*Indigofera sp.*	Native/exotic
Fabaceae (Faboideae)	*Ornithopus compressus*	Exotic
Fabaceae (Faboideae)	*Oxytes brachypoda*	Native
Fabaceae (Faboideae)	*Pultenaea foliolosa*	Native
Fabaceae (Faboideae)	*Pultenaea microphylla*	Native
Fabaceae (Faboideae)	*Pultenaea sp.*	Native
Fabaceae (Faboideae)	*Swainsona galegifolia*	Native
Fabaceae (Faboideae)	*Trifolium angustifolium*	Exotic
Fabaceae (Faboideae)	*Trifolium arvense*	Exotic
Fabaceae (Faboideae)	*Trifolium campestre*	Exotic
Fabaceae (Faboideae)	*Trifolium glomeratum*	Exotic

Family	Scientific Name	Native/Exotic
Fabaceae (Faboideae)	*Trifolium repens*	Exotic
Fabaceae (Faboideae)	*Trifolium sp.*	Exotic
Fabaceae (Faboideae)	*Trifolium subterraneum*	Exotic
Fabaceae (Faboideae)	*Trifolium angustifolium*	Exotic
Fabaceae (Mimosaceae)	*Acacia dawsonii*	Native
Fabaceae (Mimosaceae)	*Acacia dealbata*	Native
Fabaceae (Mimosaceae)	*Acacia buxifolia*	Native
Fabaceae (Mimosaceae)	*Acacia decora*	Native
Fabaceae (Mimosaceae)	*Acacia doratoxylon*	Native
Fabaceae (Mimosaceae)	*Acacia floribunda*	Native
Fabaceae (Mimosaceae)	*Acacia gladiiformis*	Native
Fabaceae (Mimosaceae)	*Acacia implexa*	Native
Fabaceae (Mimosaceae)	*Acacia ixiophylla*	Native
Fabaceae (Mimosaceae)	*Acacia leucolobia*	Native
Fabaceae (Mimosaceae)	*Acacia linearifolia*	Native
Fabaceae (Mimosaceae)	*Acacia longifolia*	Native
Fabaceae (Mimosaceae)	*Acacia penninervis*	Native
Fabaceae (Mimosaceae)	*Acacia polybotrya*	Native
Fabaceae (Mimosaceae)	*Acacia sp.*	Native
Fabaceae (Mimosaceae)	*Acacia spectabilis*	Native
Fabaceae (Mimosaceae)	*Acacia ulicifolia*	Native
Fabaceae (Mimosaceae)	*Acacia verniciflua*	Native
Fabaceae (Mimosaceae)	*Acacia caesiella*	Native
Fabaceae (Mimosaceae)	*Acacia pravissima*	Native
Gentianaceae	*Centaurium sp.*	Exotic
Gentianaceae	*Centaurium tenuiflorum*	Exotic
Geraniaceae	*Erodium crinitum*	Native
Geraniaceae	*Geranium molle*	Exotic
Geraniaceae	*Geranium solanderi*	Native
Goodeniaceae	*Goodenia hederacea*	Native
Haloragaceae	*Gonocarpus elatus*	Native
Haloragaceae	*Gonocarpus sp.*	Native
Haloragaceae	*Gonocarpus tetragynus*	Native
Haloragaceae	*Haloragis heterophylla*	Native
Hypericaceae	*Hypericum gramineum*	Exotic
Hypericaceae	*Hypericum perforatum*	Exotic

Family	Scientific Name	Native/Exotic
Iridaceae	*Sisyrinchium rosulatum*	Exotic
Juncaceae	*Juncus sp.*	Native/exotic
Juncaceae	*Juncus subsecundus*	Native
Juncaceae	*Juncus usitatus*	Native
Lamiaceae	*Ajuga australis*	Native
Lamiaceae	*Hemigenia cuneifolia*	Native
Lamiaceae	*Marrubium vulgare*	Exotic
Lamiaceae	*Mentha diemenica*	Native
Lamiaceae	*Salvia sp.*	Native/exotic
Lamiaceae	*Salvia verbenaca*	Exotic
Lauraceae	*Cassytha pubescens*	Native
Lomandraceae	*Lomandra filiformis*	Native
Lomandraceae	*Lomandra glauca*	Native
Lomandraceae	*Lomandra multiflora*	Native
Loranthaceae	*Amyema miquelii*	Native
Loranthaceae	*Amyema pendula*	Native
Lythraceae	*Lythrum hyssopifolia*	Native
Malvaceae	*Brachychiton populneus*	Native
Malvaceae	*Modiola caroliniana*	Exotic
Malvaceae	*Sida corrugata*	Native
Malvaceae	*Sida cunninghamii*	Native
Malvaceae	*Sida rhombifolia*	Exotic
Malvaceae	*Sida sp.*	Native/exotic
Myrtaceae	*Angophora floribunda*	Native
Myrtaceae	*Calytrix tetragona*	Native
Myrtaceae	*Eucalyptus albens*	Native
Myrtaceae	*Eucalyptus blakelyi*	Native
Myrtaceae	*Eucalyptus bridgesiana*	Native
Myrtaceae	*Eucalyptus conica*	Native
Myrtaceae	*Eucalyptus crebra*	Native
Myrtaceae	*Eucalyptus dealbata*	Native
Myrtaceae	*Eucalyptus fibrosa*	Native
Myrtaceae	*Eucalyptus melliodora*	Native
Myrtaceae	*Eucalyptus punctata*	Native
Myrtaceae	*Eucalyptus sideroxylon*	Native
Myrtaceae	*Eucalyptus sp.*	Native

Family	Scientific Name	Native/Exotic
Myrtaceae	*Kunzea parvifolia*	Native
Myrtaceae	*Melaleuca thymifolia*	Native
Myrtaceae	*Sannantha cunninghamii*	Native
Oxalidaceae	*Oxalis perennans*	Native
Phyllanthaceae	*Phyllanthus hirtellus*	Native
Phyllanthaceae	*Phyllanthus sp.*	Native/exotic
Phyllanthaceae	*Phyllanthus virgatus*	Native
Phyllanthaceae	*Poranthera microphylla*	Native
Phytolaccaceae	*Phytolacca octandra*	Exotic
Pittosporaceae	*Bursaria spinosa*	Native
Plantaginaceae	*Plantago debilis*	Native
Plantaginaceae	*Plantago lanceolata*	Exotic
Plantaginaceae	*Plantago varia*	Native
Plantaginaceae	*Veronica plebeia*	Native
Poaceae	*Anthosachne scabra*	Native
Poaceae	*Austrostipa pubescens*	Native
Poaceae	*Echinochloa esculenta*	Exotic
Poaceae	*Capillipedium sp.*	Native
Poaceae	*Aira cupaniana*	Exotic
Poaceae	*Aristida ramosa*	Native
Poaceae	*Aristida sp.*	Native
Poaceae	*Aristida vagans*	Native
Poaceae	*Aristida warburgii*	Native
Poaceae	*Arundinella nepalensis*	Native
Poaceae	*Austrostipa densiflora*	Native
Poaceae	*Austrostipa scabra*	Native
Poaceae	*Austrostipa verticillata*	Native
Poaceae	*Bothriochloa macra*	Native
Poaceae	*Briza minor*	Exotic
Poaceae	*Bromus catharticus*	Exotic
Poaceae	*Bromus hordeaceus*	Exotic
Poaceae	*Bromus molliformis*	Exotic
Poaceae	*Chloris truncata*	Native
Poaceae	*Chloris ventricosa*	Native
Poaceae	*Cymbopogon refractus*	Native
Poaceae	*Cynodon dactylon*	Native

Family	Scientific Name	Native/Exotic
Poaceae	*Dichanthium sericeum*	Native
Poaceae	*Dichelachne micrantha*	Native
Poaceae	*Digitaria ammophila*	Native
Poaceae	*Digitaria breviglumis*	Native
Poaceae	*Digitaria eriantha*	Exotic
Poaceae	*Digitaria parviflora*	Native
Poaceae	*Digitaria sp.*	Native/exotic
Poaceae	*Echinochloa crus-galli*	Exotic
Poaceae	*Echinopogon caespitosus*	Native
Poaceae	*Ehrharta erecta*	Exotic
Poaceae	*Eleusine tristachya*	Exotic
Poaceae	*Enneapogon gracilis*	Native
Poaceae	*Entolasia stricta*	Native
Poaceae	*Eragrostis brownii*	Native
Poaceae	*Eragrostis cilianensis*	Exotic
Poaceae	*Eragrostis curvula*	Exotic
Poaceae	*Eragrostis leptostachya*	Native
Poaceae	*Eragrostis sp.*	Native/exotic
Poaceae	*Eriochloa crebra*	Native
Poaceae	*Eriochloa procera*	Native
Poaceae	*Eriochloa sp.*	Native
Poaceae	*Erodium sp.*	Native/exotic
Poaceae	*Hordeum sp.*	Exotic
Poaceae	*Lachnagrostis filiformis*	Native
Poaceae	*Lachnagrostis sp.*	Native
Poaceae	*Lolium perenne*	Exotic
Poaceae	*Lolium rigidum*	Exotic
Poaceae	*Lolium sp.*	Exotic
Poaceae	*Microlaena stipoides*	Native
Poaceae	*Panicum effusum*	Native
Poaceae	*Paspalidium jubiflorum*	Native
Poaceae	*Paspalidium sp.*	Native
Poaceae	*Paspalum dilatatum*	Exotic
Poaceae	*Phalaris aquatica*	Exotic
Poaceae	*Poa sp.*	Native/exotic
Poaceae	*Poaceae sp.*	Native/exotic

Family	Scientific Name	Native/Exotic
Poaceae	*Rytidosperma caespitosum*	Native
Poaceae	*Rytidosperma erianthum*	Native
Poaceae	*Rytidosperma monticola*	Native
Poaceae	*Rytidosperma pallidum*	Native
Poaceae	*Rytidosperma racemosum*	Native
Poaceae	*Rytidosperma sp.*	Native
Poaceae	*Setaria parviflora*	Exotic
Poaceae	*Setaria pumila*	Exotic
Poaceae	*Sporobolus creber*	Native
Poaceae	*Sporobolus elongatus*	Native
Poaceae	*Themeda triandra*	Native
Poaceae	*Urochloa panicoides*	Exotic
Poaceae	*Vulpia myuros*	Exotic
Poaceae	*Vulpia sp.*	Exotic
Polygonaceae	*Persicaria prostrata*	Native
Polygonaceae	*Polygonum aviculare*	Exotic
Polygonaceae	*Rumex acetosella*	Exotic
Polygonaceae	*Rumex brownii*	Native
Portulacaceae	*Portulaca oleracea*	Native
Primulaceae	*Lysimachia arvensis*	Exotic
Primulaceae	*Sonchus sp.*	Native/exotic
Proteaceae	*Hakea dactyloides*	Native
Proteaceae	*Persoonia linearis*	Native
Proteaceae	*Persoonia sp.*	Native
Proteaceae	*Hakea sp.*	Native
Pteridaceae	*Cheilanthes sieberi*	Native
Ranunculaceae	*Clematis aristata*	Native
Rosaceae	*Rosa rubiginosa*	Exotic
Rubiaceae	*Asperula conferta*	Native
Rubiaceae	*Galium australe*	Native
Rubiaceae	*Galium sp.*	Native/exotic
Rubiaceae	*Opercularia diphylla*	Native
Rubiaceae	*Pomax umbellata*	Native
Rubiaceae	*Richardia stellaris*	Exotic
Rutaceae	*Correa reflexa var. reflexa*	Native
Santalaceae	*Exocarpos sp.*	Native

Family	Scientific Name	Native/Exotic
Santalaceae	*Exocarpos strictus*	Native
Sapindaceae	*Dodonaea viscosa*	Native
Sapindaceae	*Dodonaea triangularis*	Native
Scrophulariaceae	*Eremophila debilis*	Native
Scrophulariaceae	*Verbascum thapsus*	Exotic
Solanaceae	*Solanum campanulatum*	Native
Solanaceae	*Solanum cinereum*	Native
Solanaceae	*Solanum nigrum*	Exotic
Solanaceae	*Solanum prinophyllum*	Native
Solanaceae	*Solanum sp.*	Native/exotic
Thymelaeaceae	*Pimelea linifolia*	Native
Thymelaeaceae	*Pimelea sp.*	Native
Verbenaceae	*Verbena bonariensis*	Exotic
Verbenaceae	*Verbena sp.*	Native/exotic

Appendix F Fauna Species List

Scientific Name	Common Name	BC Act	EPBC Act
Aves			
Australian King-Parrot	*Alisterus scapularis*		
Australian Magpie	*Gymnorhina tibicen*		
Australian Raven	*Corvus coronoides*		
Australian Wood Duck	*Chenonetta jubata*		
Black-chinned Honeyeater (eastern subspecies)	*Melithreptus gularis gularis*	V	
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*		
Brown Gerygone	*Gerygone mouki*		
Brown Goshawk	*Accipiter fasciatus*		
Brown Honeyeater	*Lichmera indistincta*		
Brown Thornbill	*Acanthiza pusilla*		
Brown Treecreeper (eastern subspecies)	*Climacteris picumnus victoriae*	V	
Brown-headed Honeyeater	*Melithreptus brevirostris*		
Buff-rumped Thornbill	*Acanthiza reguloides*		
Cicadabird	*Edolisoma tenuirostris*		
Common Bronzewing	*Phaps chalcoptera*		
Crimson Rosella	*Platycercus elegans*		
Double-barred Finch	*Stizoptera bichenovii*		
Eastern Rosella	*Platycercus eximius*		
Eastern Spinebill	*Acanthorhynchus tenuirostris*		
Eastern Whipbird	*Psophodes olivaceus*		
Eastern Yellow Robin	*Eopsaltria australis*		
Fan-tailed Cuckoo	*Cacomantis flabelliformis*		
Flame Robin	*Petroica phoenicea*	V	
Fuscous Honeyeater	*Ptilotula fusca*		
Galah	*Eolophus roseicapillus*		
Grey Butcherbird	*Cracticus torquatus*		
Grey Shrike-thrush	*Colluricincla harmonica*		
Jacky Winter	*Microeca fascinans*		
Laughing Kookaburra	*Dacelo novaeguineae*		
Lewin's Honeyeater	*Meliphaga lewinii*		
Little Lorikeet	*Glossopsitta pusilla*	V	

Scientific Name	Common Name	BC Act	EPBC Act
Little Raven	*Corvus mellori*		
Magpie-lark	*Grallina cyanoleuca*		
Mistletoebird	*Dicaeum hirundinaceum*		
Musk Lorikeet	*Glossopsitta concinna*		
Noisy Friarbird	*Philemon corniculatus*		
Noisy Miner	*Manorina melanocephala*		
Olive-backed Oriole	*Oriolus sagittatus*		
Pacific Black Duck	*Anas superciliosa*		
Painted Honeyeater	*Grantiella picta*	V	
Pallid Cuckoo	*Heteroscenes pallidus*		
Pied Butcherbird	*Cracticus nigrogularis*		
Pied Currawong	*Strepera graculina*		
Red Wattlebird	*Anthochaera carunculata*		
Red-browed Finch	*Neochmia temporalis*		
Red-capped robin	*Petroica goodenovii*		
Restless Flycatcher	*Myiagra inquieta*		
Rockwarbler	*Origma solitaria*		
Rufous Whistler	*Pachycephala rufiventris*		
Sacred Kingfisher	*Todiramphus sanctus*		
Satin Bowerbird	*Ptilonorhynchus violaceus*		
Scarlet Honeyeater	*Myzomela sanguinolenta*		
Silvereye	*Zosterops lateralis*		
Speckled warbler	*Chthonicola sagittata*	V	
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*		
Spotted Pardalote	*Pardalotus punctatus*		
Striated Pardalote	*Pardalotus striatus*		
Striated Thornbill	*Acanthiza lineata*		
Striped Honeyeater	*Plectorhyncha lanceolata*		
Sulphur-crested Cockatoo	*Cacatua galerita*		
Superb Fairy-wren	*Malurus cyaneus*		
Superb Lyrebird	*Menura novaehollandiae*		
Tree Martin	*Petrochelidon nigricans*		
Wedge-tailed Eagle	*Aquila audax*		
Weebill	*Smicrornis brevirostris*		
Welcome Swallow	*Hirundo neoxena*		
White-browed Babbler	*Pomatostomus superciliosus*		

Scientific Name	Common Name	BC Act	EPBC Act
White-browed Scrubwren	*Sericornis frontalis*		
White-eared Honeyeater	*Nesoptilotis leucotis*		
White-naped Honeyeater	*Melithreptus lunatus*		
White-plumed Honeyeater	*Ptilotula penicillata*		
White-throated Gerygone	*Gerygone olivacea*		
White-throated Treecreeper	*Cormobates leucophaea*		
White-winged Chough	*Corcorax melanorhamphos*		
Willie Wagtail	*Rhipidura leucophrys*		
Wonga Pigeon	*Leucosarcia melanoleuca*		
Yellow Thornbill	*Acanthiza nana*		
Yellow-faced Honeyeater	*Caligavis chrysops*		
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*		
Yellow-tufted Honeyeater	*Lichenostomus melanops*		
Mammals			
Brown Hare	*Lepus europaeus*		
Chocolate Wattled Bat	*Chalinolobus morio*		
Corben's Long-eared Bat	*Nyctophilus corbeni*	V	V
Eastern Cave Bat	*Vespadelus troughtoni*	V	
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*	V	
Eastern Forest Bat	*Eptesicus pumilus*		
Eastern Grey Kangaroo	*Macropus giganteus*		
Eastern Horseshoe Bat	*Rhinolophus megaphyllus*		
European Red Fox	*Vulpes vulpes*		
Fallow Deer	*Dama dama*		
Feral Pig	*Sus scrofa*		
Gould's Wattled Bat	*Chalinolobus gouldii*		
Greater Broad-nosed Bat	*Scoteanax rueppellii*	V	
Inland Broad-nosed Bat	*Scotorepens balstoni*		
Large Bent-winged Bat	*Miniopterus orianae oceanensis*	V	
Large Forest Bat	*Vespadelus darlingtoni*		
Large-eared Pied Bat	*Chalinolobus dwyeri*	V	V
Lesser Long-eared Bat	*Nyctophilus geoffroyi*		
Little Broad-nosed Bat	*Scotorepens greyii*		
Little Forest Bat	*Vespadelus vulturnus*		
Gould's Long-eared Bat	*Nyctophilus gouldi*		
Red-necked Wallaby	*Notamacropus rufogriseus*		

Scientific Name	Common Name	BC Act	EPBC Act
Ride's Free-tailed Bat	*Ozimops ridei*		
Southern Forest Bat	*Vespadelus regulus*		
Southern Free-tailed Bat	*Ozimops planiceps*		
Swamp Wallaby	*Wallabia bicolor*		
White-striped Free-tailed Bat	*Austronomus australis*		
Wild Rabbit	*Oryctolagus cuniculus*		
Yellow-bellied Sheathtail Bat	*Saccolaimus flaviventris*	V	
Reptiles			
Common Garden Skink	*Lampropholis guichenoti*		
Eastern Bearded Dragon	*Pogona barbata*		
Lace Monitor	*Varanus varius*		
Amphibians			
Eastern Banjo Frog	*Limnodynastes dumerilii*		
Spotted Marsh Frog	*Limnodynastes tasmaniensis*		

Ultrasonic bat call analysis report

Wilpinjong Annual Monitoring

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Contents

List of Tables

1. Background

The purpose of this project was to analyse ultrasonic bat call data collected as part of the Spring 2023 microbat monitoring across the Wilpinjong Coal Mine Management Domains (the study area) and forms part of an ongoing annual biodiversity monitoring program. The survey was undertaken to:

- Determine microbat species presence/potential presence
- Collate number of microbat calls recorded (microbat species activity)

This report contains a brief description of the ultrasonic field survey, details the methods used to analyse the microbat call data and provides the results of this analysis for the project.

2. Methods

2.1. Ultrasonic data collected at the study area

Seven sites were surveyed passively using Song Meter Mini Bat's and Anabat Swifts and recorded in WAV file format. Detectors were deployed for two nights each between the 23 October to the 26 October, equating to a total of 14 detector nights (Table 1). The detectors were placed in five reference sites and two mine rehab sites. The survey effort, detector types and a description of detector locations are summarised in Table 1. Settings for each of the detectors are in Table 2.

Table 1. Location of survey sites and information on data recorded at all sites.

Site ID	GPS location	Date start	Date end	No. detector nights	No. files	Habitat description
Ref547_C	-32.197310, 149.785380	24/10/2023	26/10/2023	2	2,471	Woodland
Ref697_C	-32.210700, 149.772440	24/10/2023	26/10/2023	2	1,515	Forest
Ref732_C	-32.199610, 149.785550	24/10/2023	26/10/2023	2	3,570	Woodland
Ref824_C	-32.187610, 149.777120	24/10/2023	26/10/2023	2	451	Woodland
Ref825_C	-32.188470, 149.785170	24/10/2023	26/10/2023	2	527	Woodland
R6	-32.328752, 149.863712	23/10/2023	25/10/2023	2	48	Rehab
R9	-32.333813, 149.860038	23/10/2023	25/10/2023	2	173	Rehab
TOTAL	-	-	-	14	8,755	-

Table 2. Settings for the seven detectors deployed.

Site ID	Make and model	Sensitivity	Gain	Min. trigger freq.	Min. event time	Trigger window	Max. file length
Ref547_C	Song Meter Mini Bat	-	12	16	15	3	15
Ref697_C	Song Meter Mini Bat	-	12	16	15	3	15
Ref732_C	Song Meter Mini Bat	-	12	16	15	3	15
Ref824_C	Song Meter Mini Bat	-	12	16	15	3	15
Ref825_C	Song Meter Mini Bat	-	12	16	15	3	15
R6	Anabat Swift	5	-	11	2	-	15
R9	Anabat Swift	8	-	10	2	-	15

2.2. Call analysis

Calls were analysed in Anabat Insight version 2.0.8-0-g4157d1f (Titley Scientific, 2023). Files were first run through the 'All Bats' filter to separate bat calls from noise files. Files that passed the 'All Bats' filter were processed through a region-specific decision tree which added a species label to files which passed specific parameters and removed files containing less than 3 pulses. To check that the decision tree was functioning correctly a sample of the trash file is viewed to ensure no bat calls were present. Species were manually verified using the 'Bat calls of New South Wales' regional echolocation guide (Pennay et al., 2004) and the accompanying reference library of calls downloaded from the NSW Department of Environment and Planning website. Bat calls were analysed by Tara Dowling (Environmental Scientist, Eco Logical Australia) with a subsample of calls reviewed by Rodney Armistead (Senior Ecologist, RA Environmental Consultants).

2.2.1. General rules for bat call identification

Bat calls analysis uses species-specific call parameters including call shape, characteristic frequency, initial slope and time between pulses (Reinhold et al., 2001). To ensure reliable and accurate results, the following protocols (adapted from Lloyd et al., 2006) were followed:

- Call sequences not attributed to insectivorous bat calls (e.g. insect buzzes, wind, rain and anthropogenic noise) were dismissed from analysis,
- Recorded calls containing less than three pulses were not analysed and these sequences were labelled as unidentifiable, being too short to confidently determine the identity of the species producing the call (Law et al., 1999),
- Search phase calls were used in the analysis, rather than feeding buzzes or social calls (McKenzie et al., 2002). Feeding buzzes were only identified if there were sufficient search phase pulses before or after. Social calls are not typical of species and provide poor descriptive power and cannot be used for identification purposes.

- For calls able to be used for species identification, two categories of confidence were used (Mills et al., 1996):
    - Present: the quality and structure of the call profile is such that the bat species may not be confused with other species,
    - Potentially present: the quality and structure of the call profile is such that the bat species may be confused with other species that produce similar call profiles.
- Call sequences of inferior quality and therefore not able to be identified to any bat species are labelled as unidentifiable but are included in quantification of overall bat activity.

2.2.2. Limitations of call analysis

Many insectivorous bat species produce calls that overlap in call profile parameters and depending on the call quality and type recorded (search phase, feeding buzz, social calls), cannot always be separated. Additionally, weather and climatic conditions affect the detectability of calls and the quality of those calls recorded. Calls were only positively identified to species when the defining characteristics were present and there was no chance of confusion between species with overlapping and / or similar calls. Calls that could not positively be identified to species level due to intermediate characteristics between multiple species were therefore given a species complex.

Chalinobus gouldii, *Ozimops planiceps*, *Ozimops ridei* and *Scotorepens balstoni* can be difficult to separate. *C. gouldii* was separated if characteristic frequency was approximately 28 to 34 kHz with alternating hockey shaped pulses present (Pennay et al. 2004). Non-alternating relatively flat calls were assigned to either *O. planiceps* (Fc ≈24-27 kHz) or *O. ridei* (≈30kHz). *S. balstoni* calls were identified if a slope of greater than 200 OPS, hooked or hockey bat shaped pulses that were non-alternating, and a average Fc that fell between 29 and 34 kHz (Pennay et al. 2004). Otherwise, calls were assigned to multi-species groups.

Scoteanax rueppellii calls can overlap with *Falsistrellus tasmaniensis, S. balstoni. F. tasmaniensis* calls lack upsweeping tails and can be difficult to distinguish from *Scotorepens greyii* and *S. rueppellii*. *S. balstoni* can be separated if the frequency of the knee is above 37 kHz and pre-characteristic section drops by more than 3 kHz in *S. rueppellii (*Pennay et al. 2004). Where calls overlap in Fc and could not be separated a multi-species complex was utilised.

Both *Nyctophilus corbeni*, *Nyctophilus geoffroyi* and *Nyctophilus gouldii* occur within the study area but their call parameters are so similar that they cannot be separated to species (Pennay et al. 2004) and as such are grouped.

Miniopterus orianae oceanensis calls may overlap with *Vespadelus darlingtoni*, *Vespadelus regulus* and *Vespadelus vulturnus*. *M. orianae oceanensis* can be distinguished if the calls have a down-sweeping tail, long characteristic section and / or uneven consecutive pulses (Pennay et al. 2004). *Vespadelus regulus* and *V. vulturnus* was identified if Fc ≈47-48.5 kHz and upsweeping curved pulses present. The calls of *Vespadelus darlingtoni* can at times, be more difficult to separate from *M. orianae oceanensis.*

Vespadelus troughtoni calls overlap with *Chalinobus morio*, *V. vulturnus,* and *Vespadelus pumilus*. *Vespadelus troughtoni* calls can be separated from *C. morio* by having an up-sweeping tail, however *V.*

troughtoni and *V. vulturnus* calls cannot be separated if both species distributions overlap (Pennay et al. 2004). If the end frequency is lower than 51 kHz, can be identified to *V. troughtoni* or *V. vulturnus*. If the end frequency is higher than 54.5 kHz, can be identified to *V. pumilus* (Reinholdt et al. 2001).

2.3. Bat activity

Bat activity is represented by the number of calls or passes recorded for each species or species complex. The number of calls was calculated for all species and species complexes that were determined as present and/or potentially present. The level of bat activity is not an indication on the number of individual bats located within a particular location as a single bat can fly past a detector multiple times.

2.4. Reporting

This report adheres to the standards outlined by the Australasian Bat Society Inc. for insectivorous bat surveys using bat detectors (Australasian Bat Society, 2006). Species taxonomic lists and nomenclature adheres to Armstrong et al., 2020.

3. Results

A total of 8,755 files were collected and analysed from seven detectors between 23 October and 26 October. The 'All Bats' filter removed 332 files and 'pulse count not greater than 3' removed a further 159 files from the analysis. A sub-set of these files was checked and primarily contained insect noise.

3.1. Species occurrence

Bat species occurrence at all sites is shown in Table 3. Call recordings were mixed quality with the Song Meter Mini's containing lower quality recordings. Species that were unable to be separated from a species complex or had calls with limited distinguishing features were marked as potentially present. Representative calls for the species from this dataset are included in the Appendix.

Table 3. Occurrence of bat species at seven sites in the study area.

Scientific Name	R6	R9	REF547C	REF697C	REF732C	REF824C	REF825C
Austronomus australis	-	-	✓	✓	✓	-	✓
Chalinolobus dwyeri	✓	✓	✓	✓	✓	✓	✓
Chalinolobus gouldii	✓	✓	✓	✓	✓	✓	✓
Chalinolobus morio	-	P	✓	P	P	✓	P
Falsistrellus tasmaniensis	-	P	-	-	P	-	-
Miniopterus orianae oceanensis	P	P	P	✓	✓	P	P

Scientific Name	R6	R9	REF547C	REF697C	REF732C	REF824C	REF825C
Nyctophilus corbeni / Nyctophilus geoffroyi / Nyctophilus gouldi	-	-	✓	✓	✓	✓	✓
Ozimops planiceps	✓	✓	✓	✓	✓	✓	✓
Ozimops ridei	P	P	✓	✓	✓	✓	P
Rhinolophus megaphyllus	✓	-	✓	-	✓	✓	✓
Saccolaimus flaviventris	-	-	-	-	-	-	P
Scoteanax rueppellii	P	P	-	P	P	-	-
Scotorepens balstoni	✓	✓	P	P	✓	P	-
Scotorepens greyii	-	-	-	P	P	-	-
Vespadelus darlingtoni	-	P	P	P	P	P	P
Vespadelus pumilus	-	P	P	-	P	P	-
Vespadelus regulus	P	P	P	P	P	P	P
Vespadelus troughtoni	-	P	P	P	P	P	P
Vespadelus vulturnus	P	P	P	✓	✓	P	P
✓ = species present, P = species potentially present.							

3.2. Bat activity

A total of 5,550 identifiable call sequences were recorded across all seven detectors. Table 4 outlines the number of calls for each species or species complex at each of the survey sites. The 556 unidentifiable files were manually identified after the filters had been applied and contained a mixture of anthropogenic noise, insects, unidentifiable sounds, feeding buzzes and low-quality calls that could not be attributed to a species or species complex.

Table 4. Activity (number of calls) for species at each site.

Scientific Name	R6	R9	REF547C	REF697C	REF732C	REF824C	REF825C
A. australis	-	-	4	20	4	-	7
C. dwyeri	4	12	62	3	117	7	5

Scientific Name	R6	R9	REF547C	REF697C	REF732C	REF824C	REF825C
C. gouldii	7	44	125	243	35	31	61
C. gouldii / O. planiceps and O. Ridei	-	-	1	-	-	-	1
C. gouldii / O. Ridei	2	7	155	56	51	21	20
C. gouldii / S. balstoni	3	2	1	1	4	1	-
C. morio	-	2	100	4	212	18	4
C. morio / M. orianae oceanensis / V. vulturnus	-	-	7	3	-	1	-
C. morio / V. troughtoni	-	-	-	-	5	-	-
C. morio / V. troughtoni and V. pumilus	-	-	-	-	2	1	
C. morio / V. troughtoni and V. vulturnus	-	5	644	116	59	75	118
C. morio / V. vulturnus	-	-	105	42	99	2	-
F. tasmaniensis / S. rueppellii / S. balstoni / S. greyii	-	2	-	-	1	-	-
M. orianae oceanensis	-	-	1	11	4	-	-
M. orianae oceanensis / V. darlingtoni / V. regulus and *V. vulturnus*	4	15	38	22	11	3	53
M. orianae oceanensis / V. regulus and *V. vulturnus*	1	11	310	408	233	13	10
M. orianae oceanensis / V. vulturnus	-	-	-	119	107	4	3
N. corbeni / N. geoffroyi and *N. gouldi*	-	-	9	13	21	26	25
O. planiceps	7	16	77	160	45	1	78
O. planiceps / O. ridei	2	3	-	7	1	2	3

Scientific Name	R6	R9	REF547C	REF697C	REF732C	REF824C	REF825C
O. ridei	-	1	26	7	7	4	1
R. megaphyllus	1	-	66	-	17	37	9
S. flaviventris	-	-	-	-	-	-	1
S. rueppellii / S. balstoni	1	1	-	1	1	-	-
S. balstoni	1	8	-	2	3	-	-
S. rueppellii / S. balstoni	-	-	-	1	2	-	-
Scotorepens greyii	-	-	-	-	-	-	-
V. regulus / V. vulturnus	3	42	243	168	166	-	54
V. troughtoni / V. pumilus	-	1	1	-	5	-	-
V. troughtoni / V. vulturnus	-	-	-	19	9	1	2
V. vulturnus	-	-	-	64	87	-	-
TOTAL CALLS	36	172	1975	1490	1308	248	455
Unidentifiable	-	-	334	108	26	44	44
COMBINED TOTAL	36	172	2309	1598	1334	292	499

4. Discussion and conclusion

There were at least eleven and up to twenty one species recorded during this survey (Table 3; Table 4). This includes up to seven threatened species listed under the NSW Biodiversity Conservation Act 2016 (BC Act) and two species listed under the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act). The two threatened species confirmed to be present included:

- *C. dwyeri* (Vulnerable, BC Act and EPBC Act)
- *M. orianae oceanensis* (Vulnerable, BC Act)

The five threatened species evaluated to be potentially present included:

- *F. tasmaniensis* (Vulnerable, BC Act)
- *N. corbeni* (Vulnerable, BC Act and EPBC Act)
- *S. flaviventris* (Vulnerable, BC Act)
- *S. rueppellii* (Vulnerable, BC Act)
- *V. troughtoni* (Vulnerable, BC Act)

Many calls were unable to be reliably separated and were identified as a species complex. The *C. morio / V. troughtoni / V. vulturnus* species complex had the highest number of call sequences (1017) with the majority of these calls (644) being recorded at REF547C. It should be noted that the low quality of the recordings at REF547 made these species difficult to separate and contributed to the large number of calls being placed into this species complex.

C. gouldii had the highest number of calls (546) that were attributed to a potential or reliable single species call. Followed by *O. planiceps* (384), *C. morio* (340), *C. dwyeri* (210), *V. vulturnus* (151), *R. megaphyllus* (130), *O. ridei* (46), *A. australis* (35), *M. orianae oceanensis* (16), *S. balstoni* (14), and *S. flaviventris* (1). *A. australis* is likely to be underrepresented in the data due to the call settings for the majority of the detectors not being set to encompass this species characteristic frequency of 10-16 kHz. The majority of *A. australis* recorded were located in combination with another bat calling at a higher frequency in the same file.

5. References

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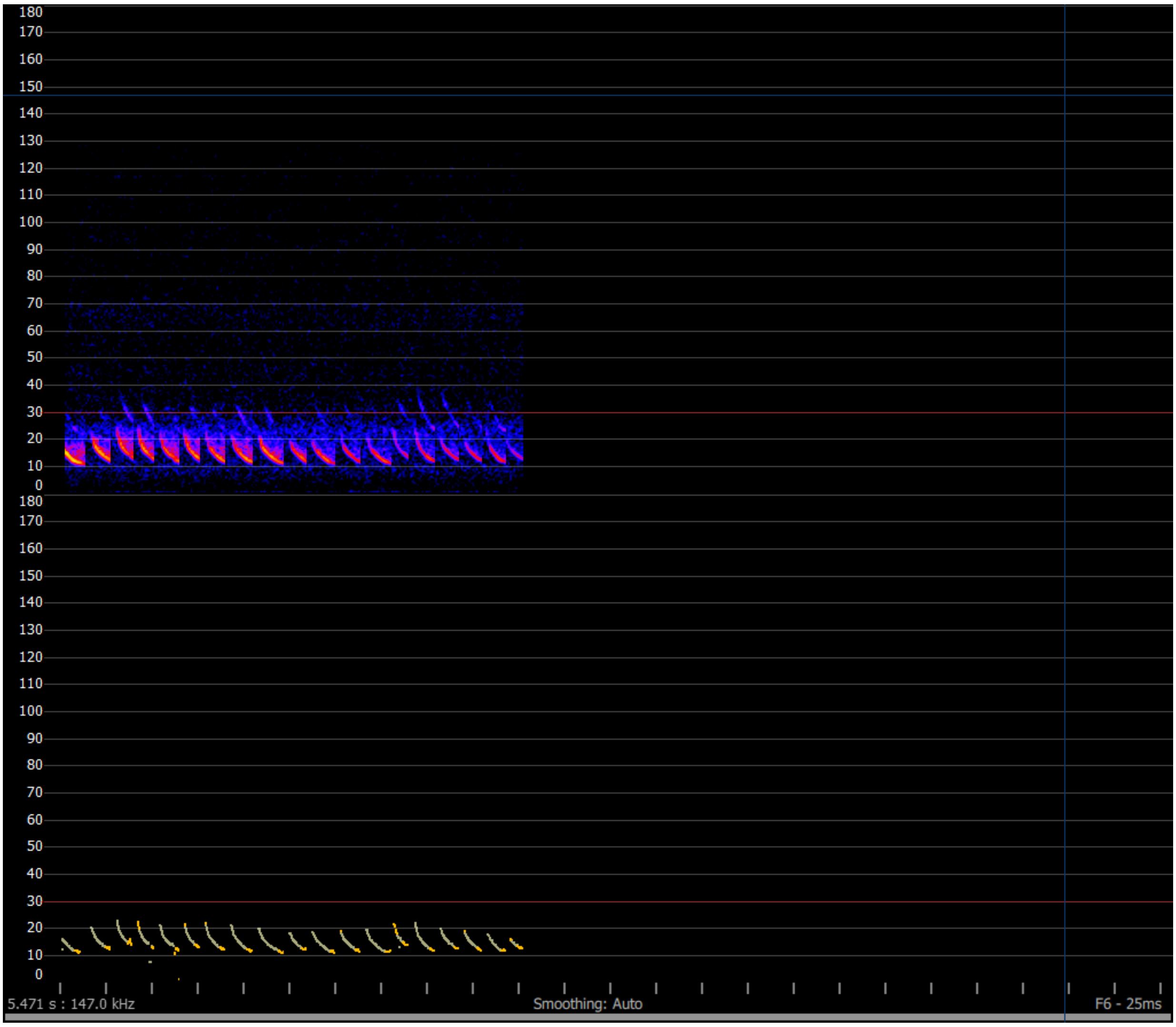
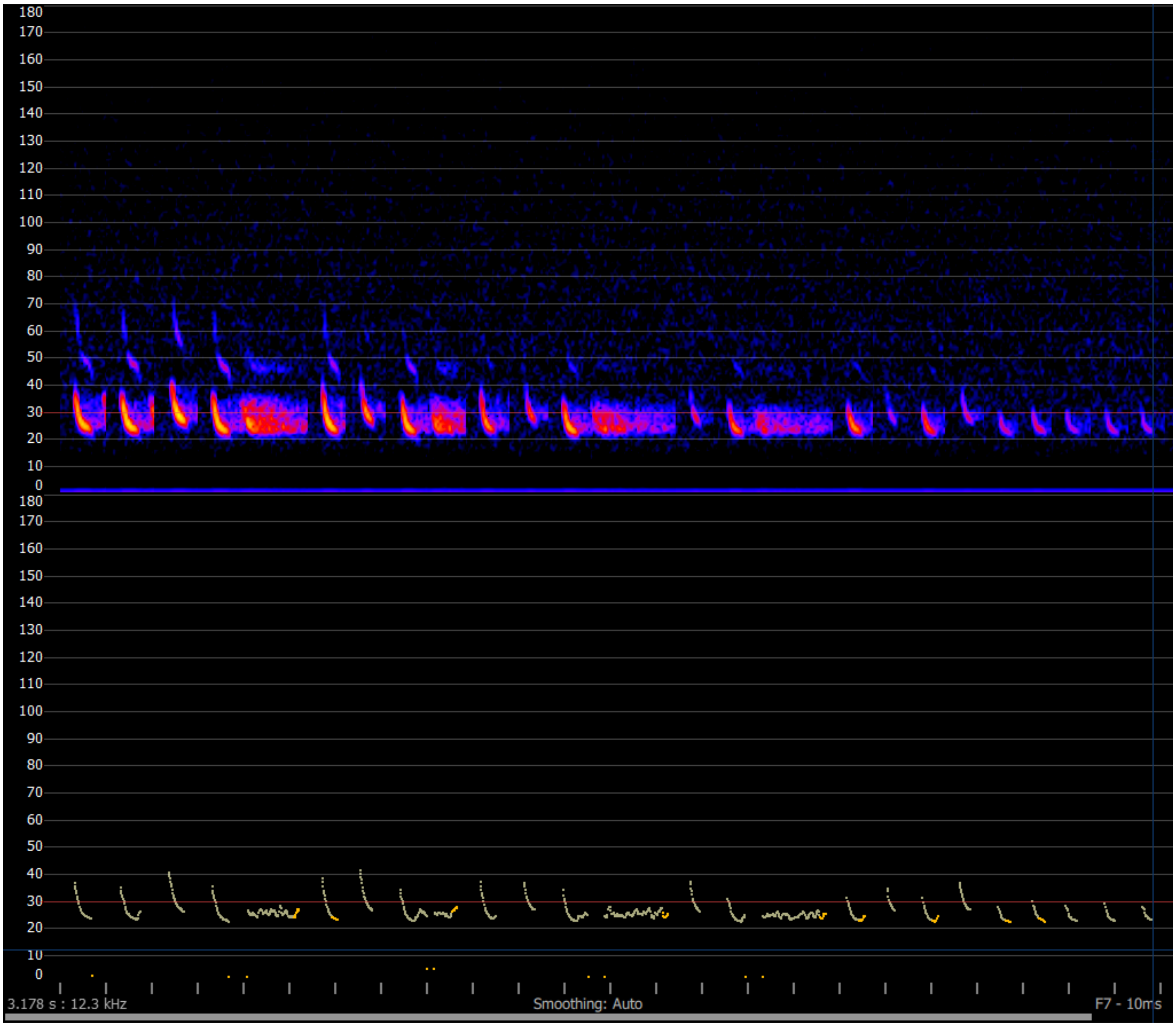
Reinhold, L., Law, B., Ford, G., & Pennay, M. (2001). *Key to the bat calls of south-east Queensland and north-east New South Wales*.

Titley Scientific. (2023). *Anabat Insight* (2.0.7-0-g3e26022).

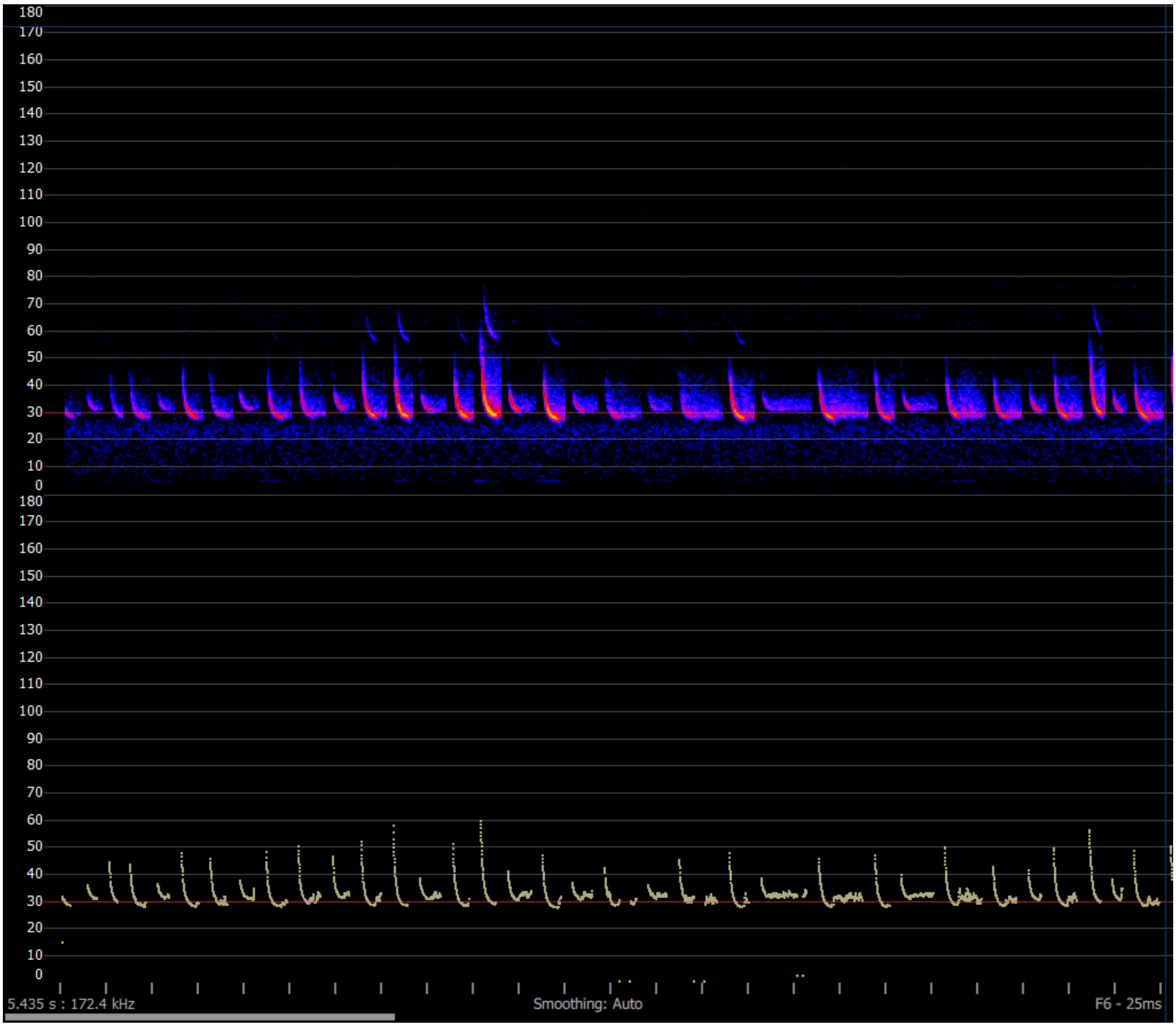
6. Appendix: Example calls from this dataset



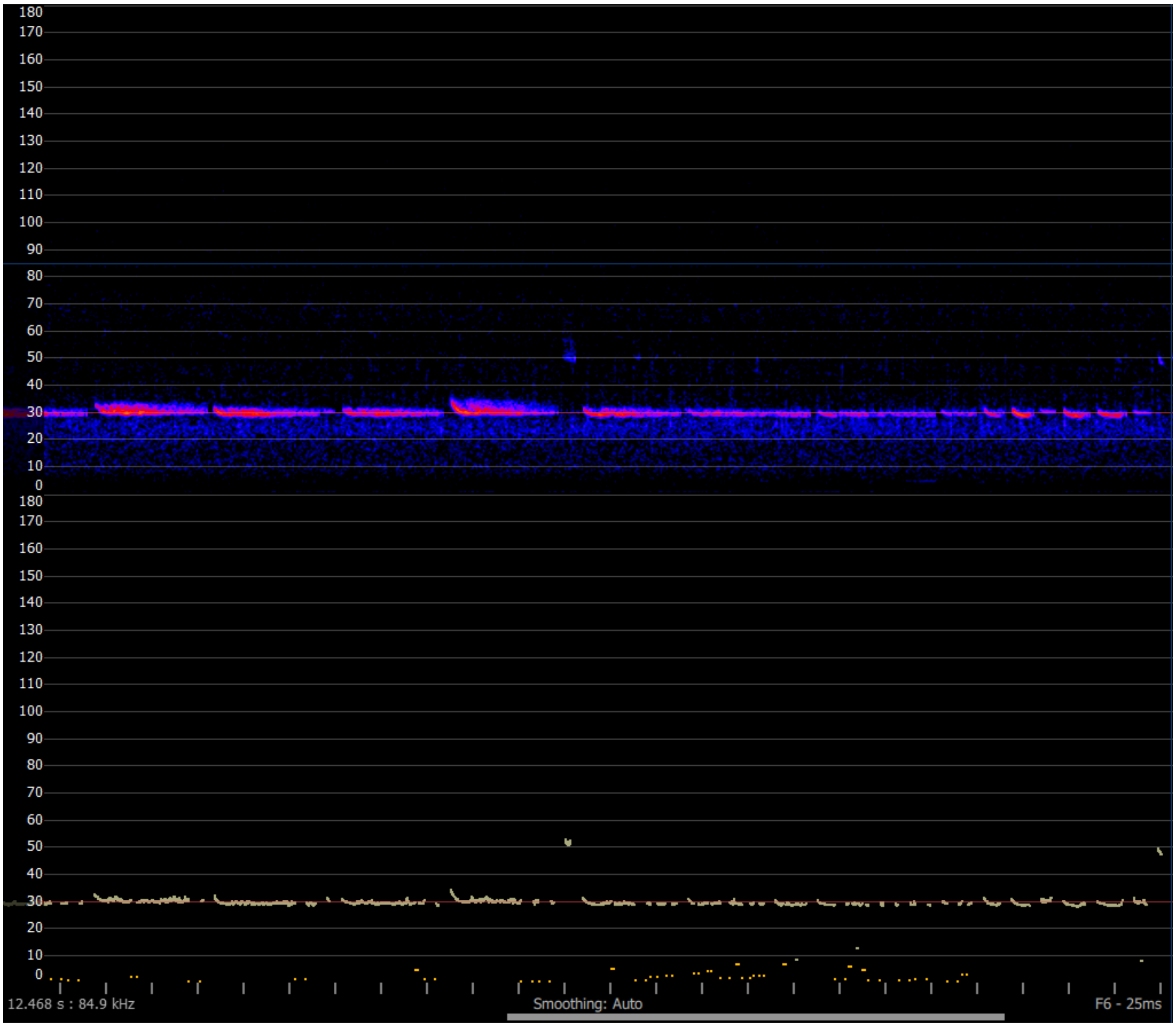
Appendix 1. Example call of *A. australis* recorded at REF825C. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F6 zoom level, time on the x-axis with ticks 25 ms apart and frequency on the y-axis.



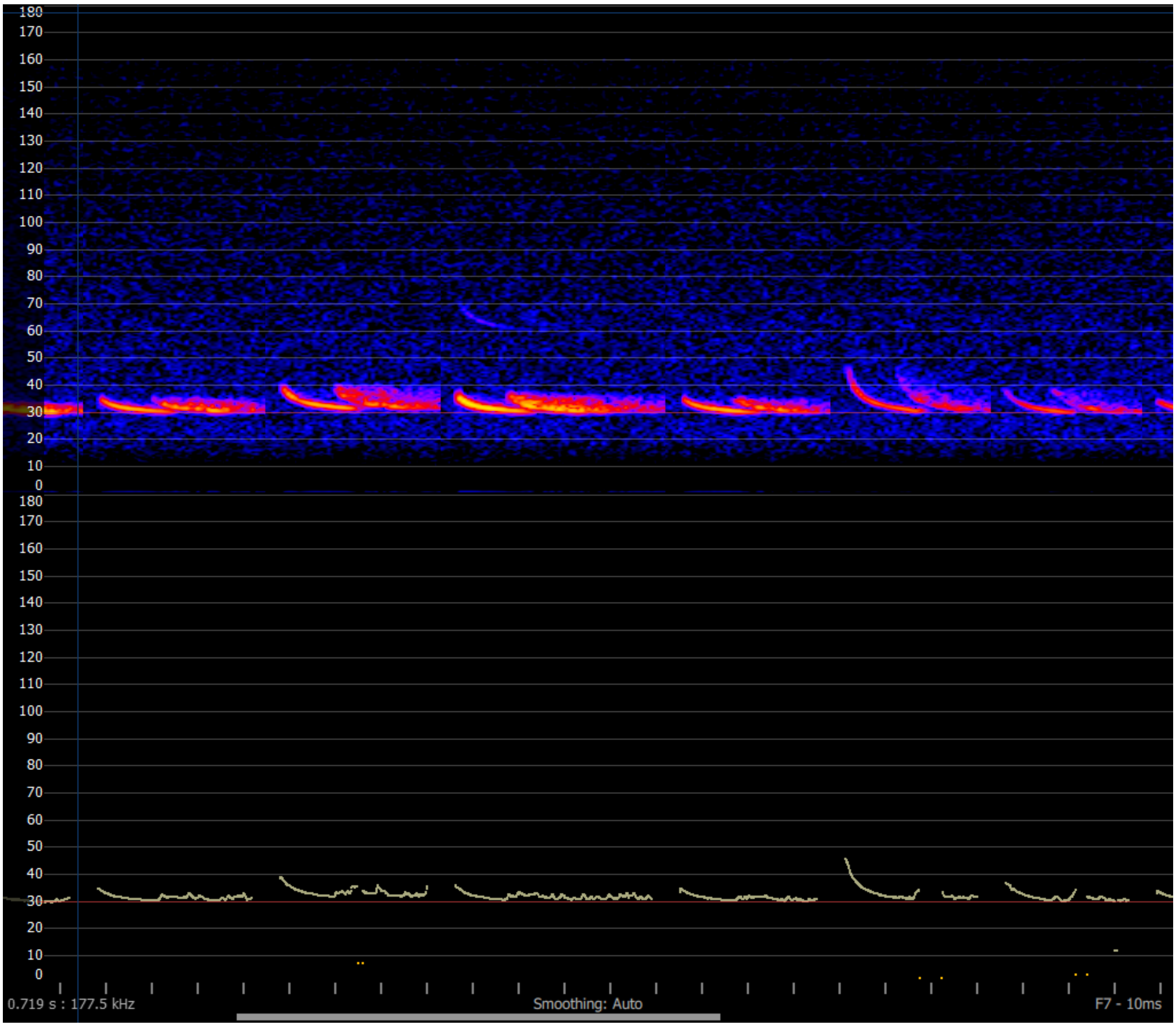
Appendix 2. Example call of *C. dwyeri* recorded at R6. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F7 zoom level, time on the x-axis with ticks 10 ms apart and frequency on the y-axis.



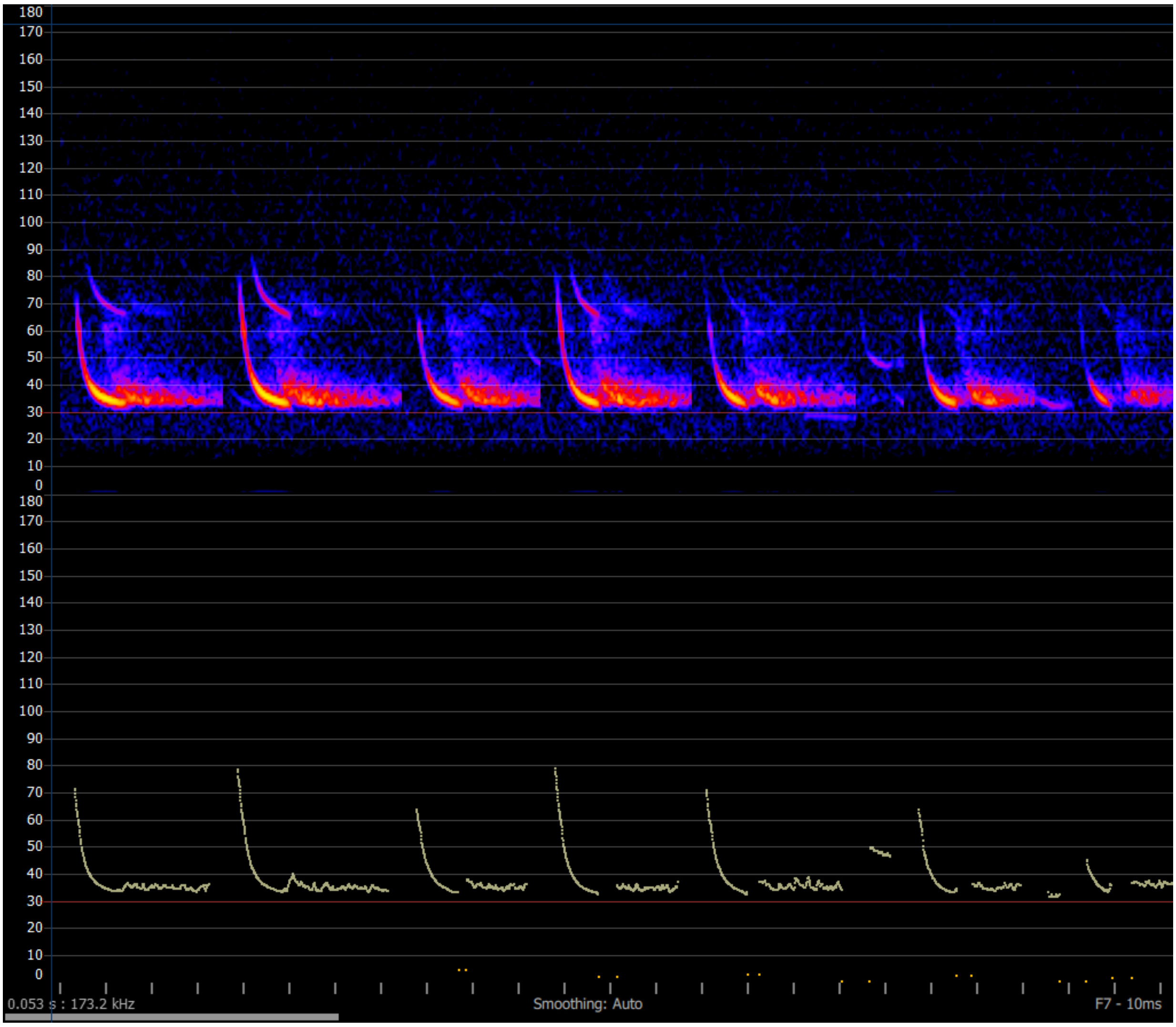
Appendix 3. Example call of *C. gouldii* recorded at REF825C. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F6 zoom level, time on the x-axis with ticks 25 ms apart and frequency on the y-axis.



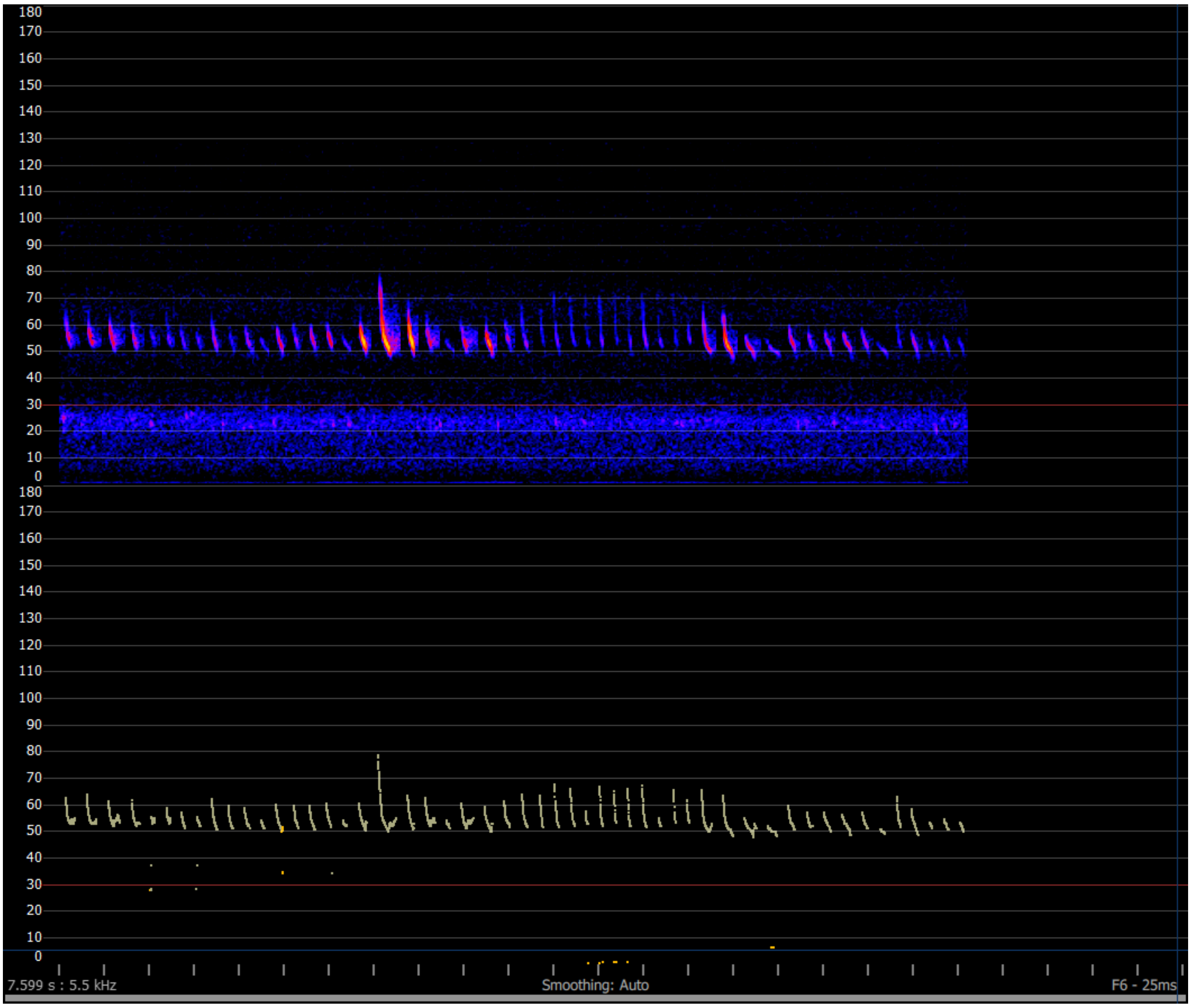
Appendix 4. Example *C. gouldii* / *O. planiceps* and *O. ridei* species complex call recorded at REF825C. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F6 zoom level, time on the x-axis with ticks 25 ms apart and frequency on the y-axis.



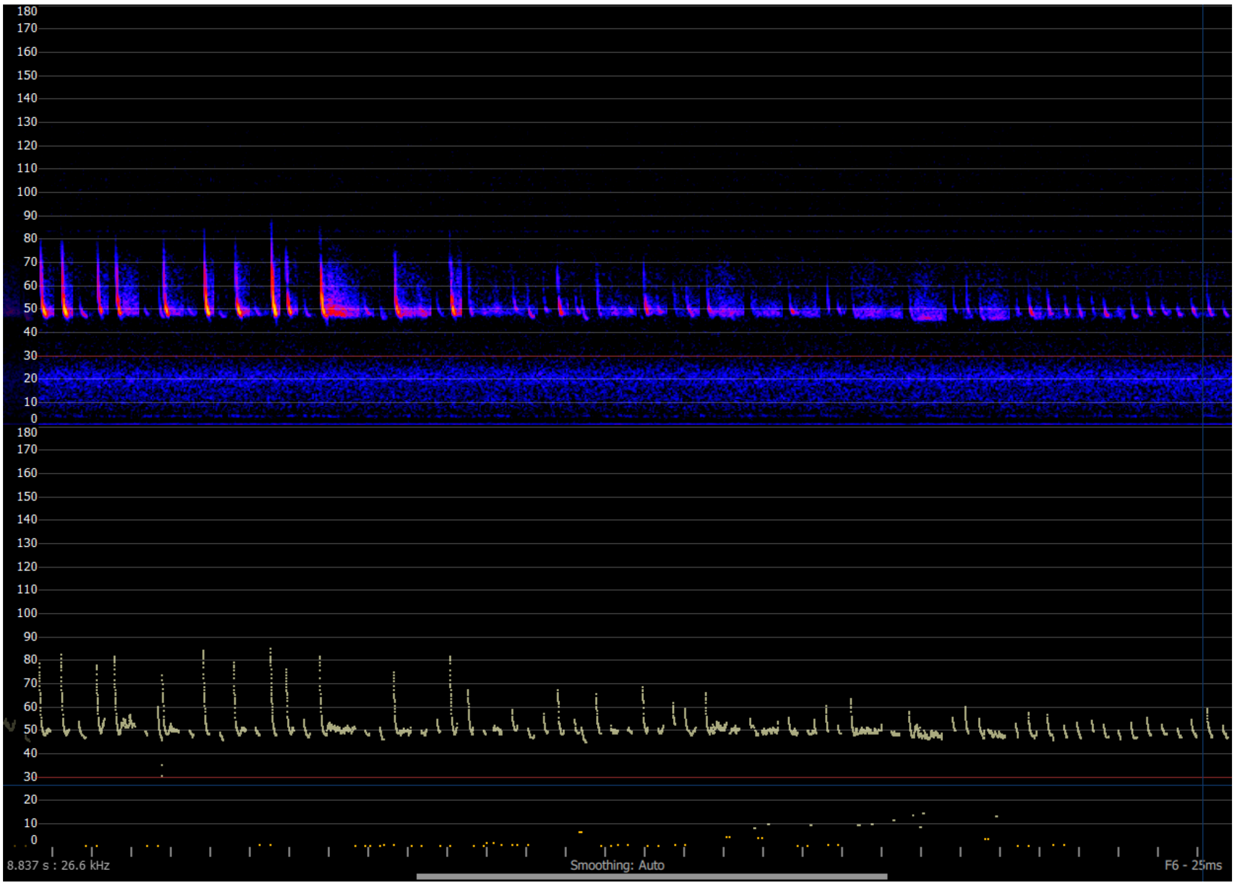
Appendix 5. Example *C. gouldii* and *O. ridei* and species complex call recorded at R9. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F7 zoom level, time on the x-axis with ticks 10 ms apart and frequency on the y-axis.



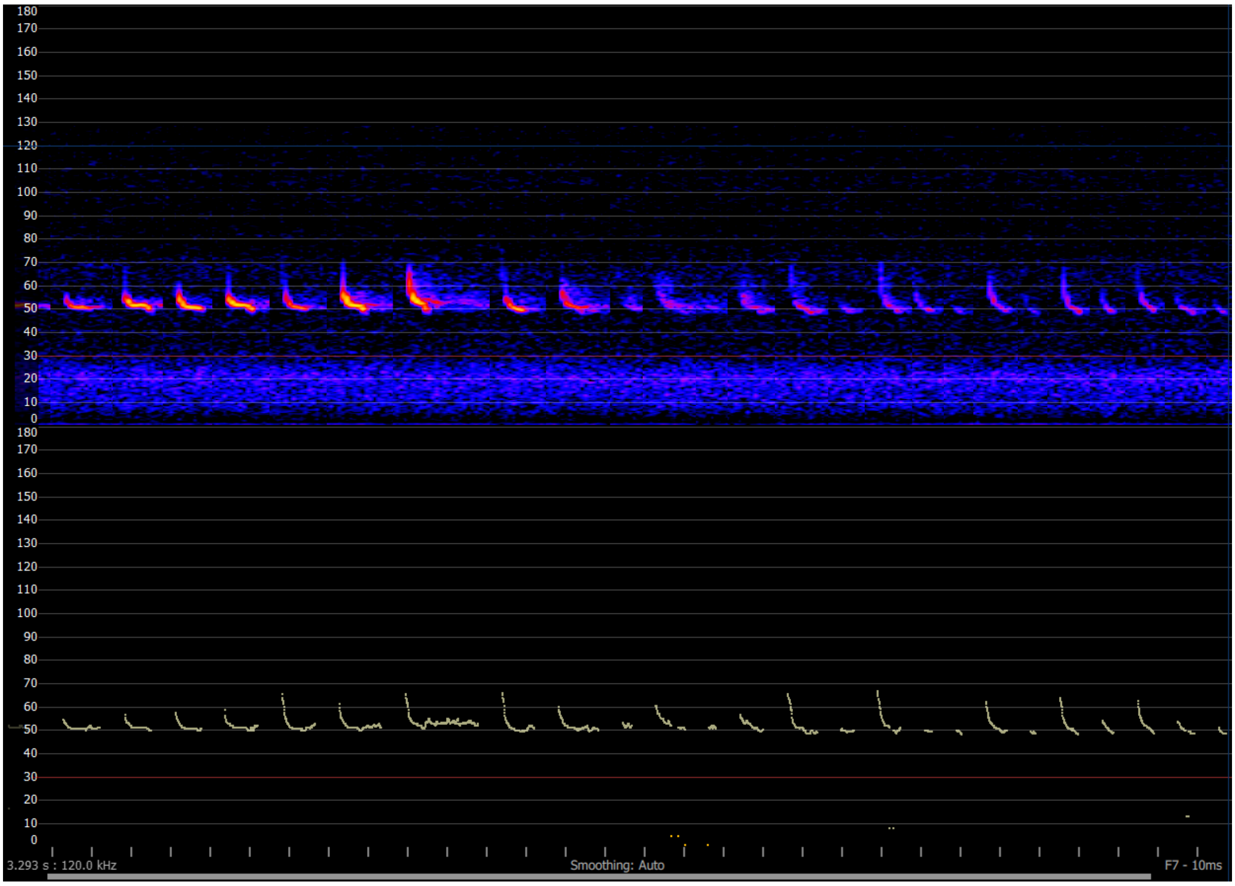
Appendix 6. Example of *C. gouldii* and *S. balstoni* and species complex call recorded at R6. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F7 zoom level, time on the x-axis with ticks 10 ms apart and frequency on the y-axis.



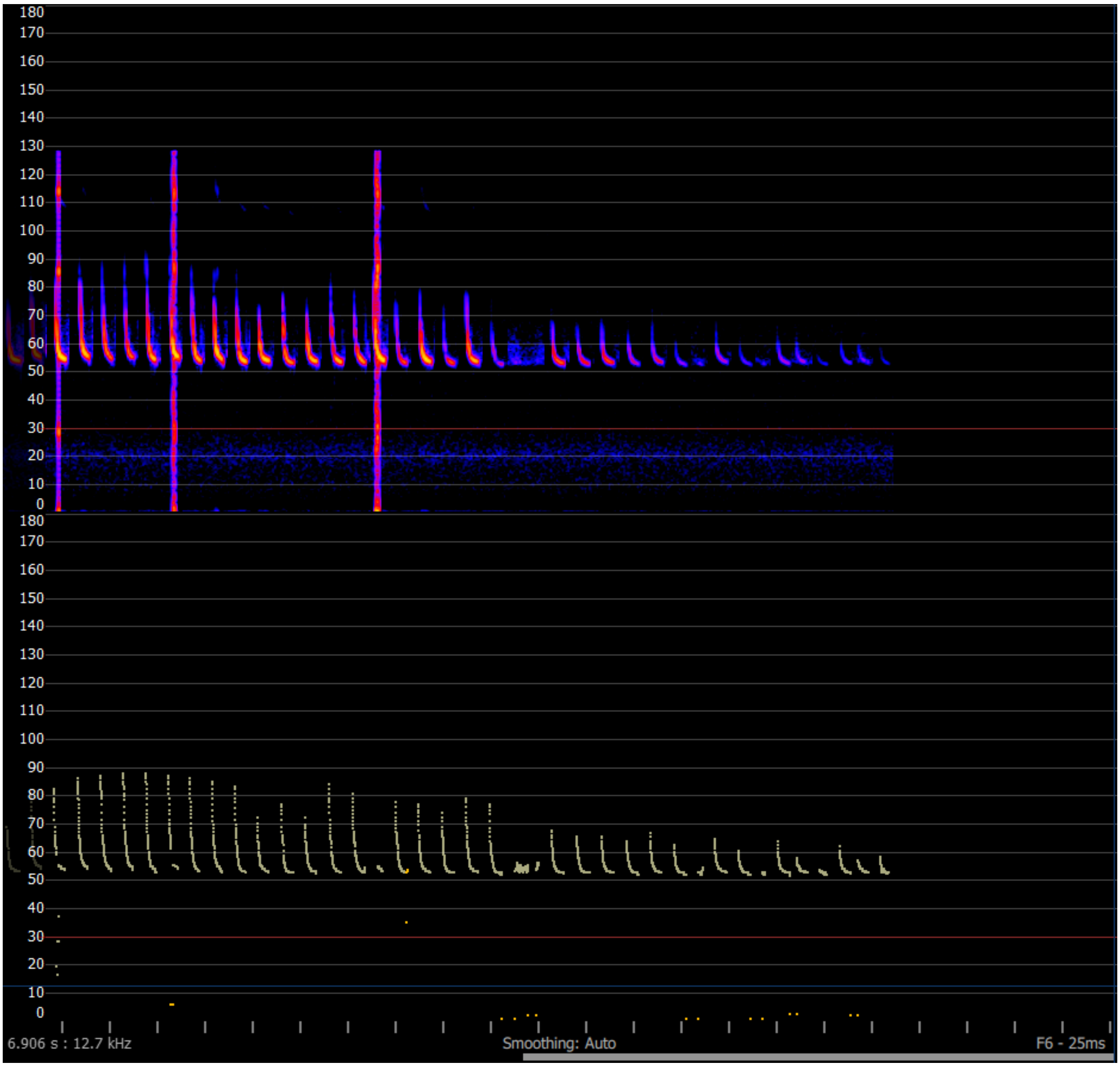
Appendix 7. Example call of *C. morio* recorded at REF824C. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F6 zoom level, time on the x-axis with ticks 25 ms apart and frequency on the y-axis.



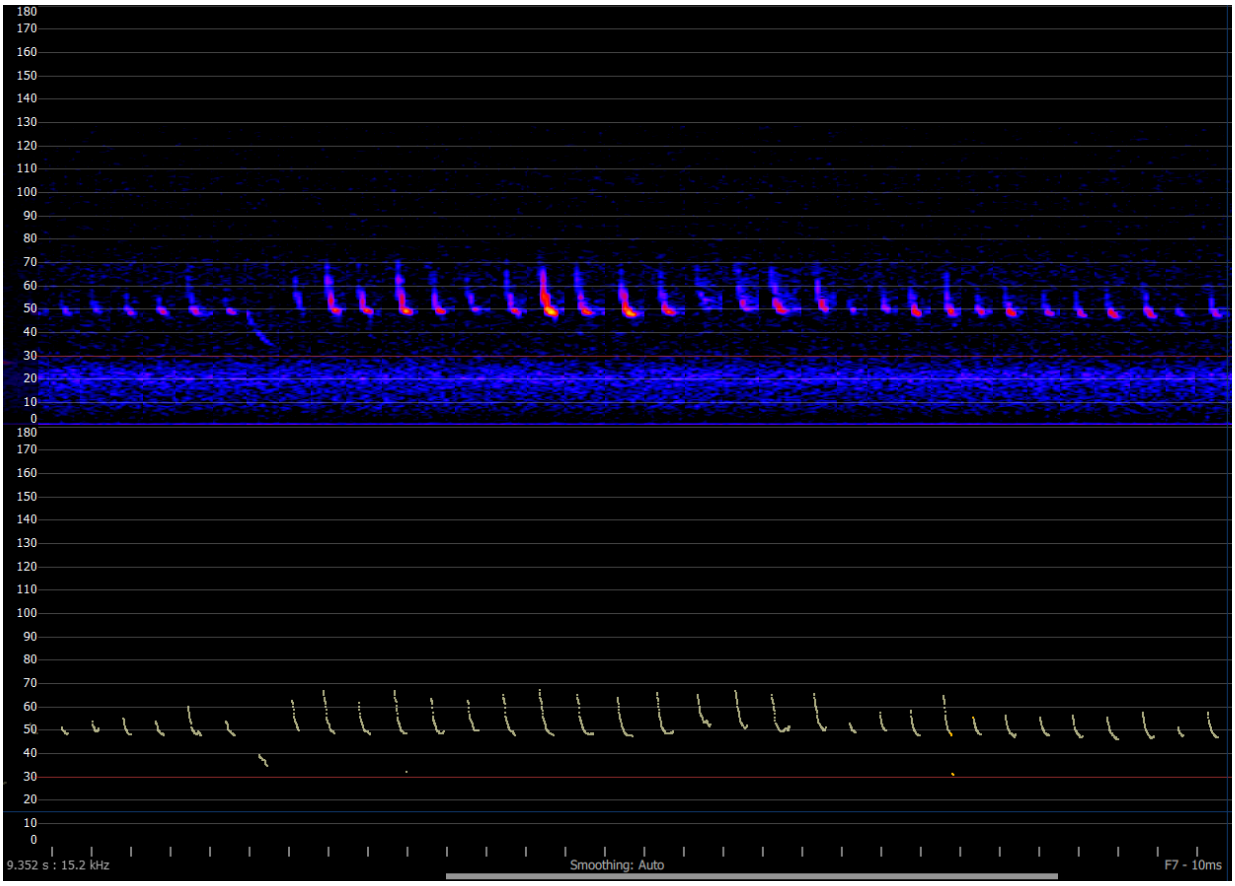
Appendix 8. Example call of *C. morio / M. orianae oceanensis/ V. vulturnus* recorded at REF697C. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F6 zoom level, time on the x-axis with ticks 25 ms apart and frequency on the y-axis.



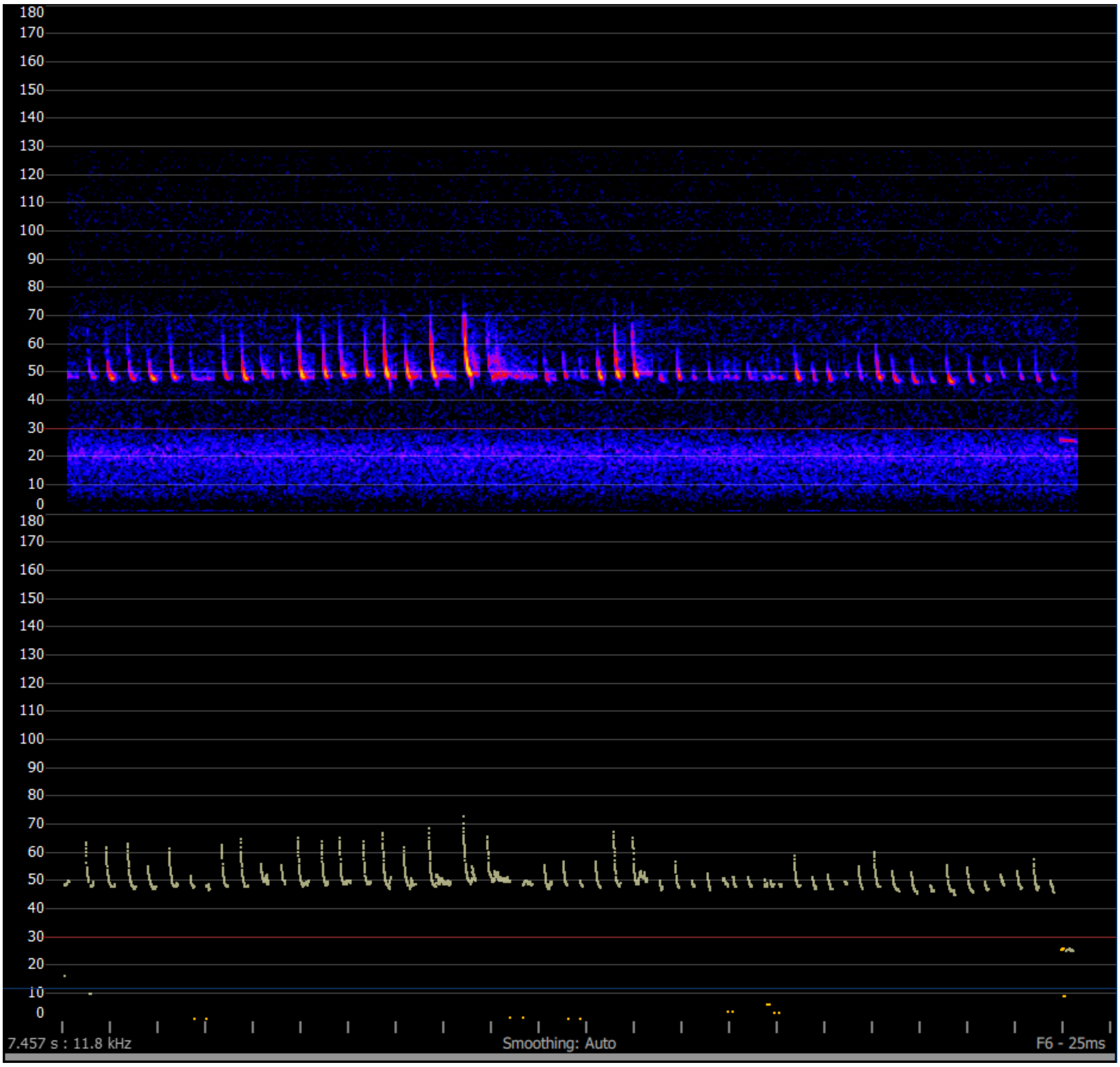
Appendix 9. Example of *C. morio* and *V. troughtoni* and species complex call recorded at R6. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F7 zoom level, time on the x-axis with ticks 10 ms apart and frequency on the y-axis.



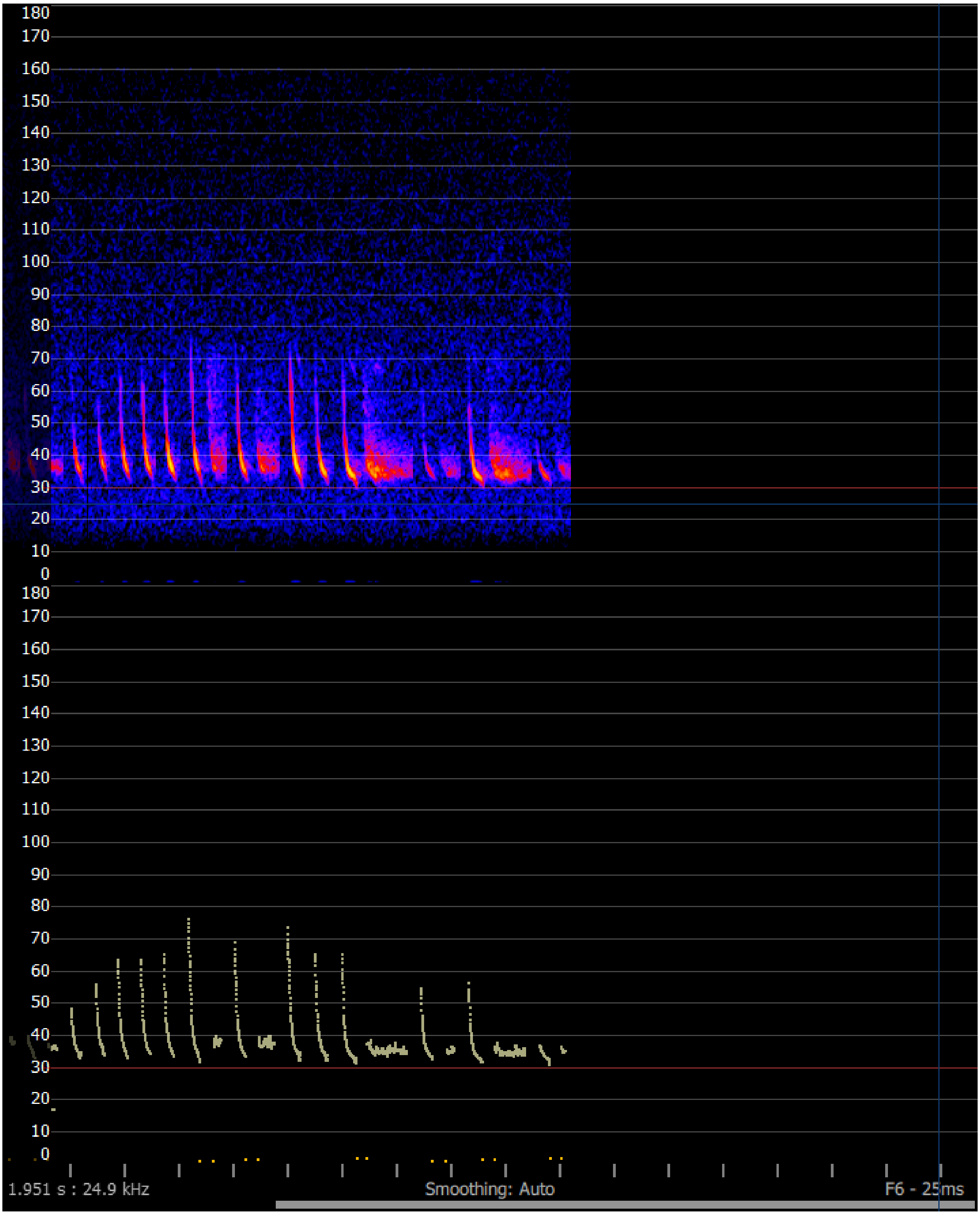
Appendix 10. Example of *C. morio* / *V. pumilus* and *V. troughtoni* and species complex call recorded at REF732C. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F6 zoom level, time on the x-axis with ticks 25 ms apart and frequency on the y-axis.



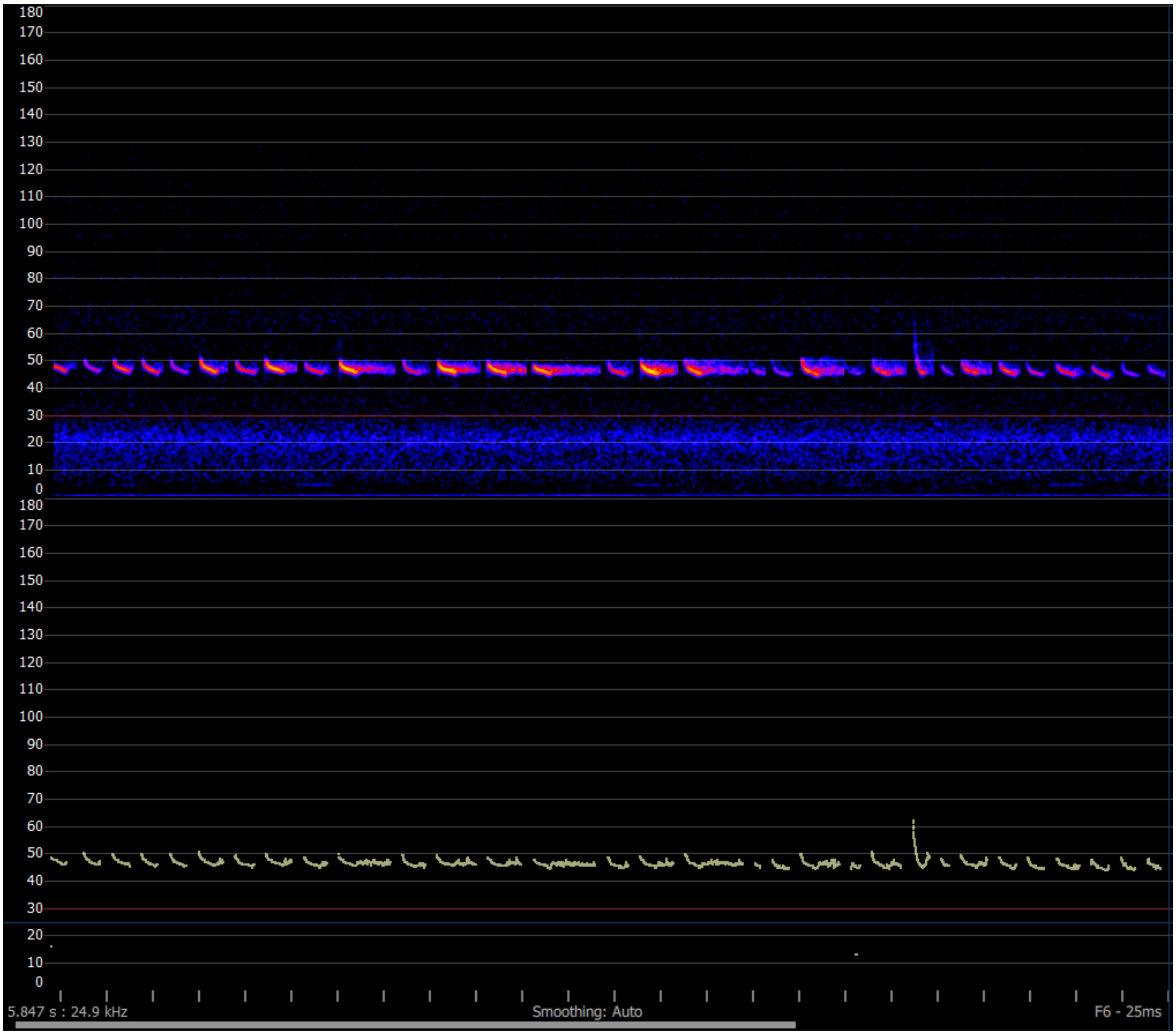
Appendix 11. Example of *C. morio / V. troughtoni* and *V. vulturnus* species complex call recorded at REF732C. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F6 zoom level, time on the x-axis with ticks 25 ms apart and frequency on the y-axis.



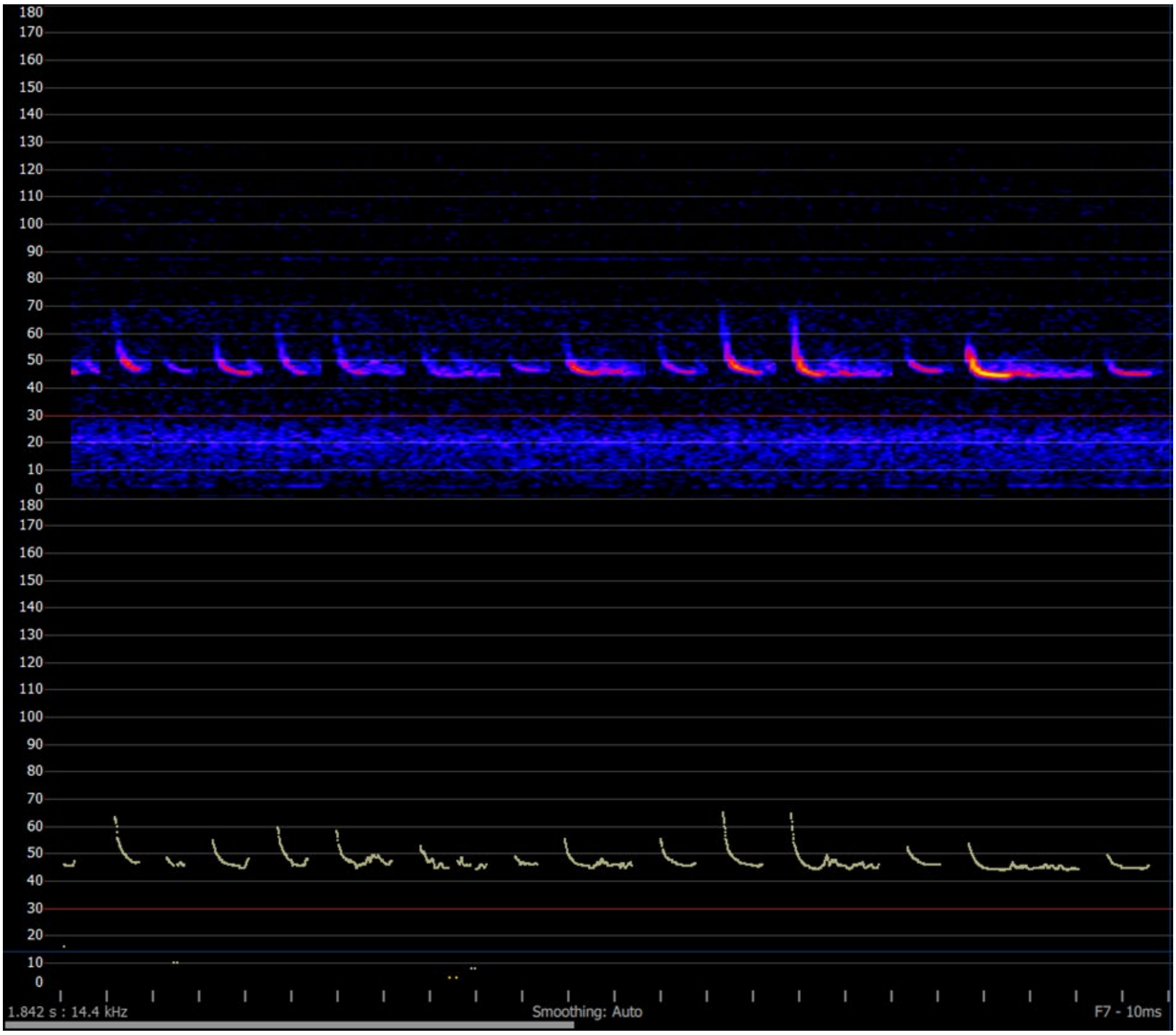
Appendix 12. Example of *C. morio* and *V. vulturnus* species complex call recorded at REF732C. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F6 zoom level, time on the x-axis with ticks 25 ms apart and frequency on the y-axis.



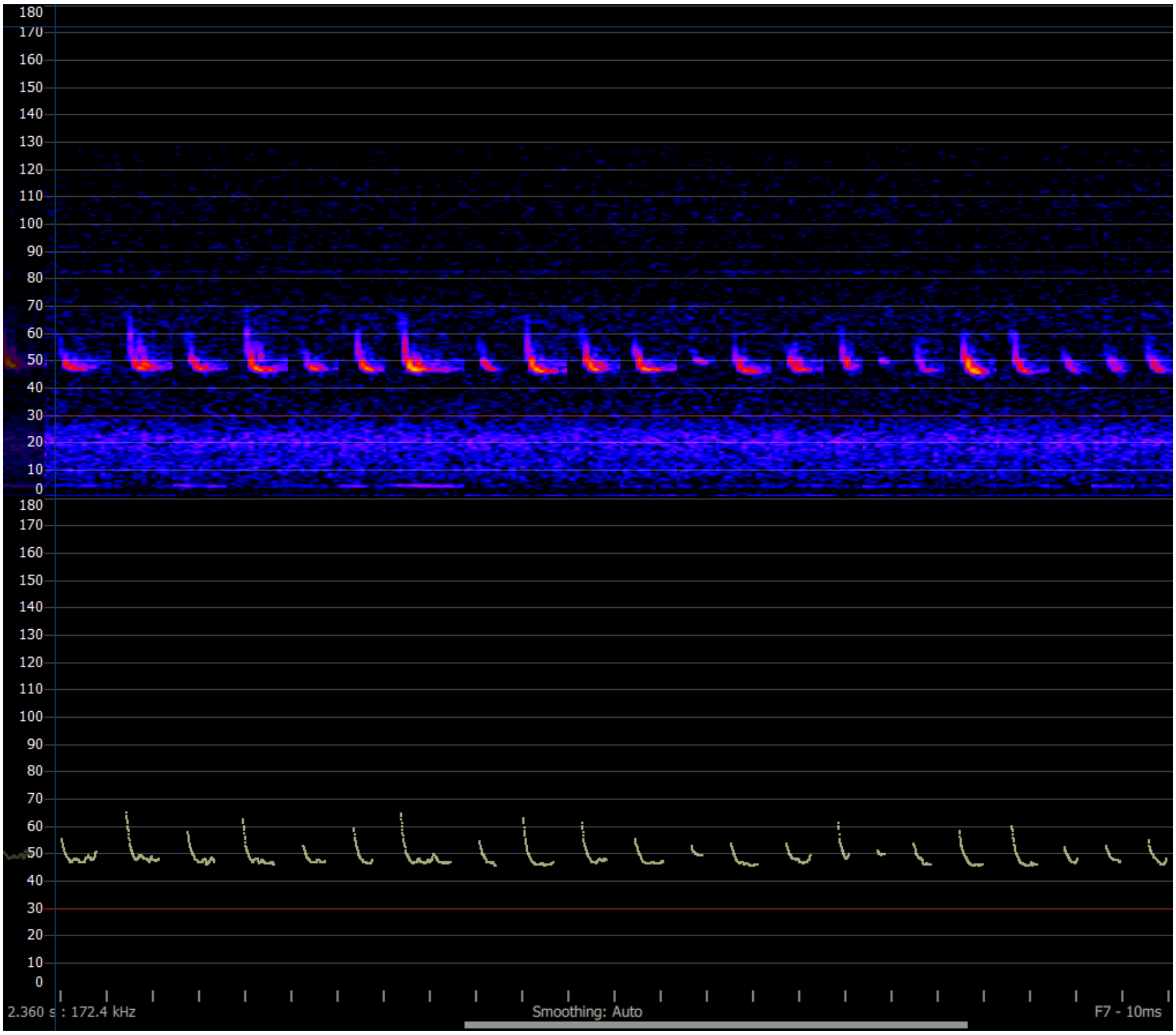
Appendix 13. Example of *F. tasmaniensis* / *S. rueppellii*/*S. balstoni* and *S. greyii* species complex call recorded at R9 Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F6 zoom level, time on the x-axis with ticks 25 ms apart and frequency on the y-axis.



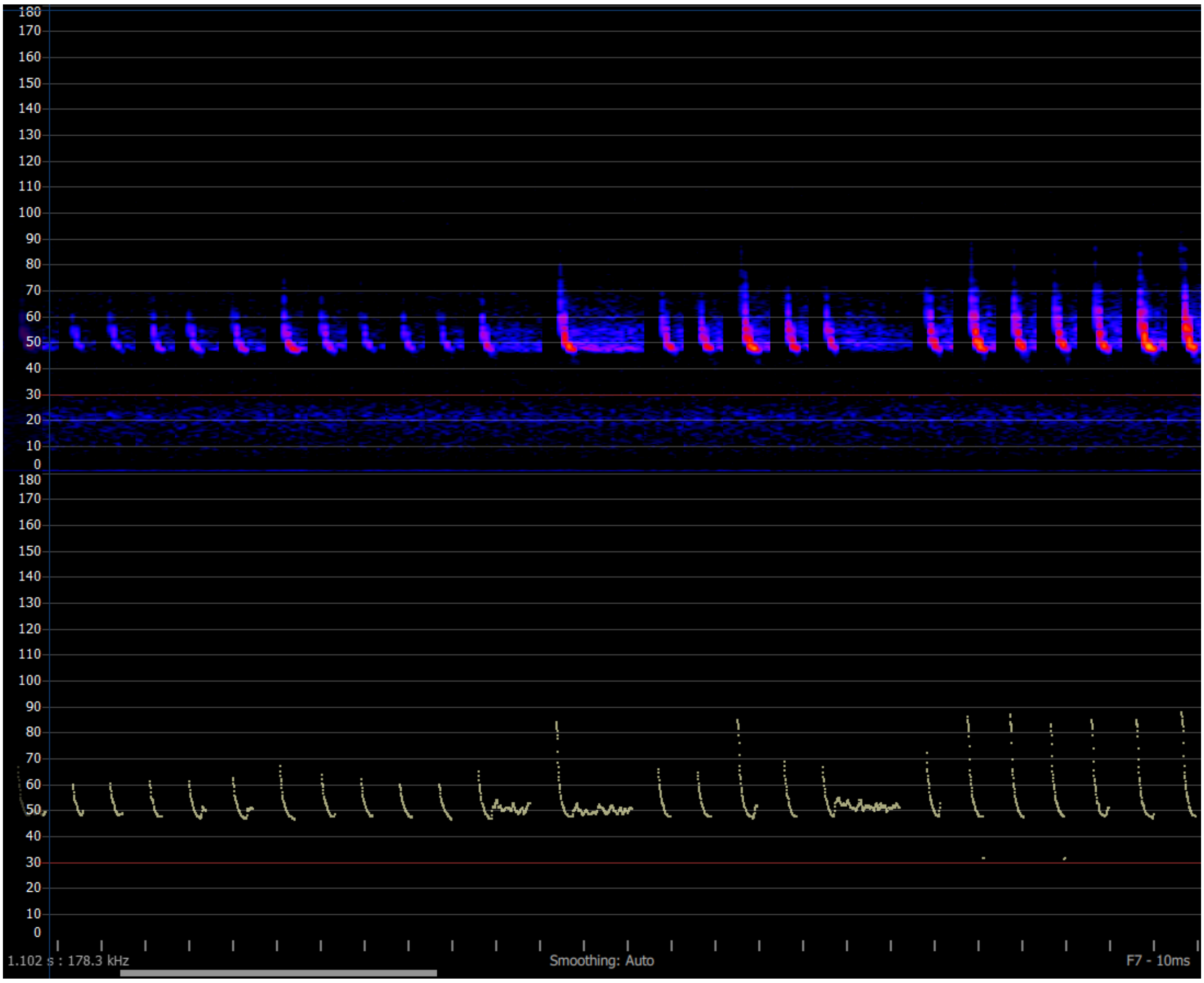
Appendix 14. Example call of *M. orianae oceanensis* at REF697B Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F6 zoom level, time on the x-axis with ticks 25 ms apart and frequency on the y-axis.



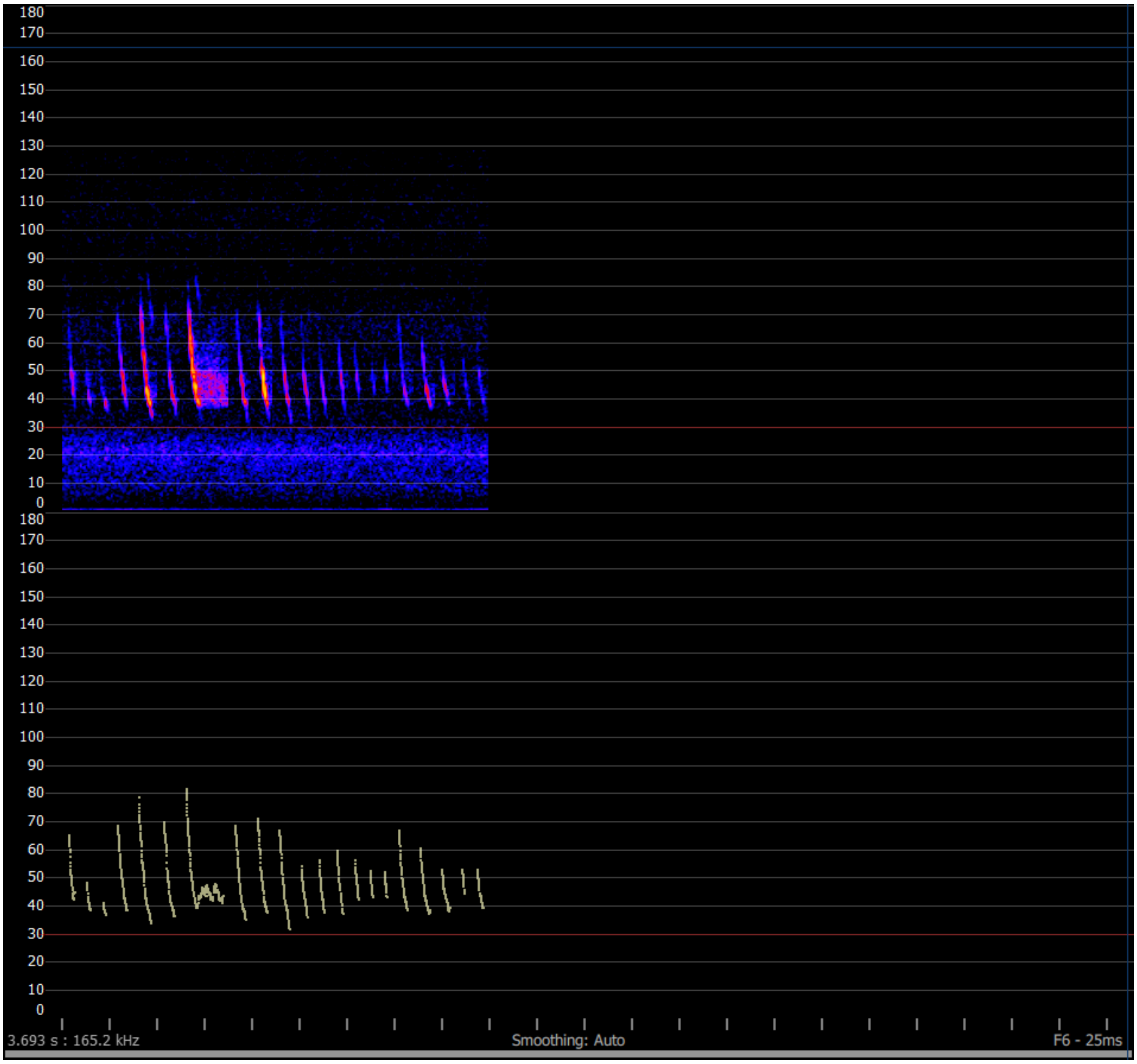
Appendix 15. Example of *M. orianae oceanensis/ V. darlingtoni / V. regulus and V. vulturnus* species complex call recorded at REF697C. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F7 zoom level, time on the x-axis with ticks 10 ms apart and frequency on the y-axis.



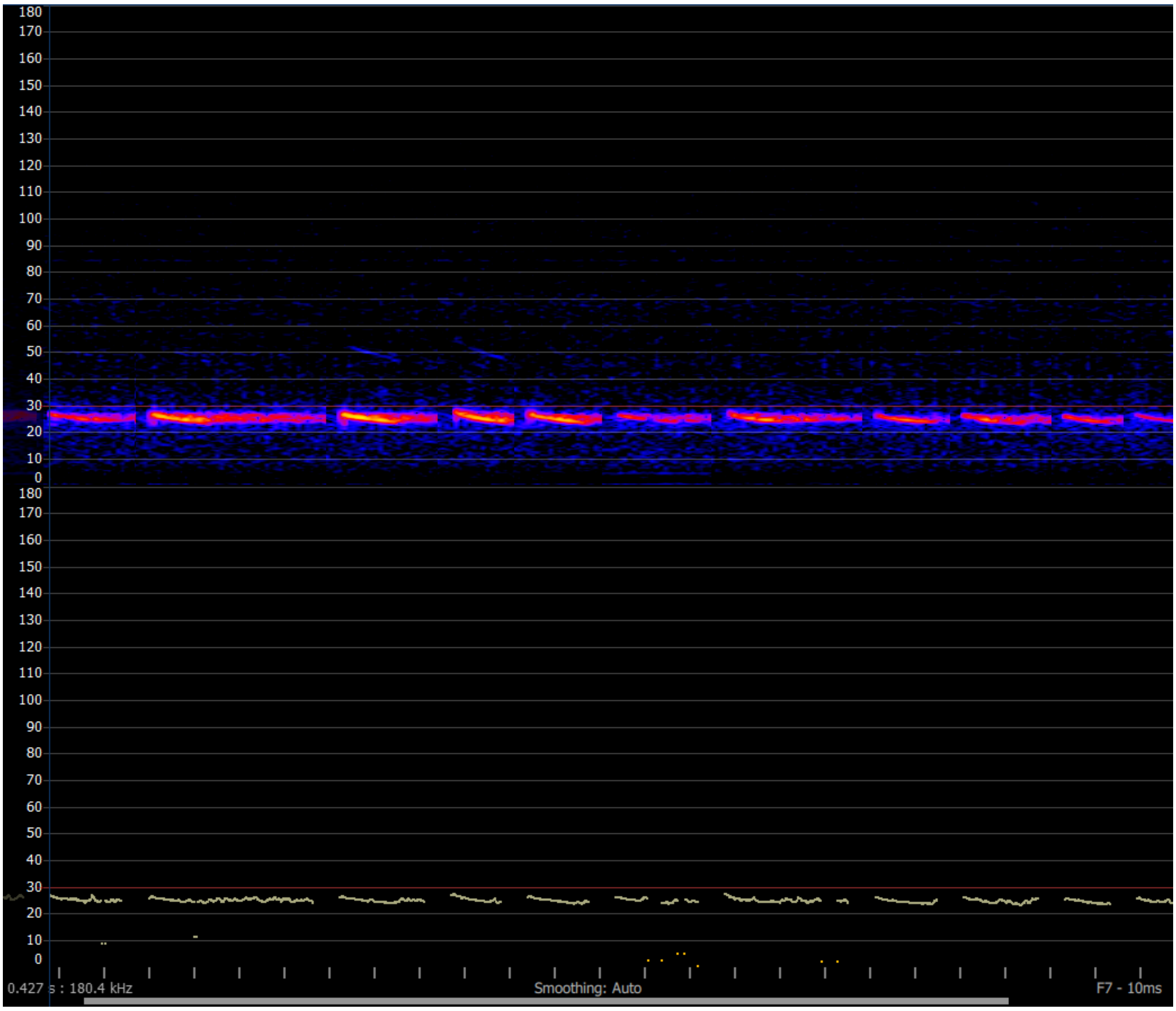
Appendix 16. Example of *M. orianae oceanensis / V. regulus* and *V. vulturnus* species complex call recorded at REF697C. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F7 zoom level, time on the x-axis with ticks 10 ms apart and frequency on the y-axis.



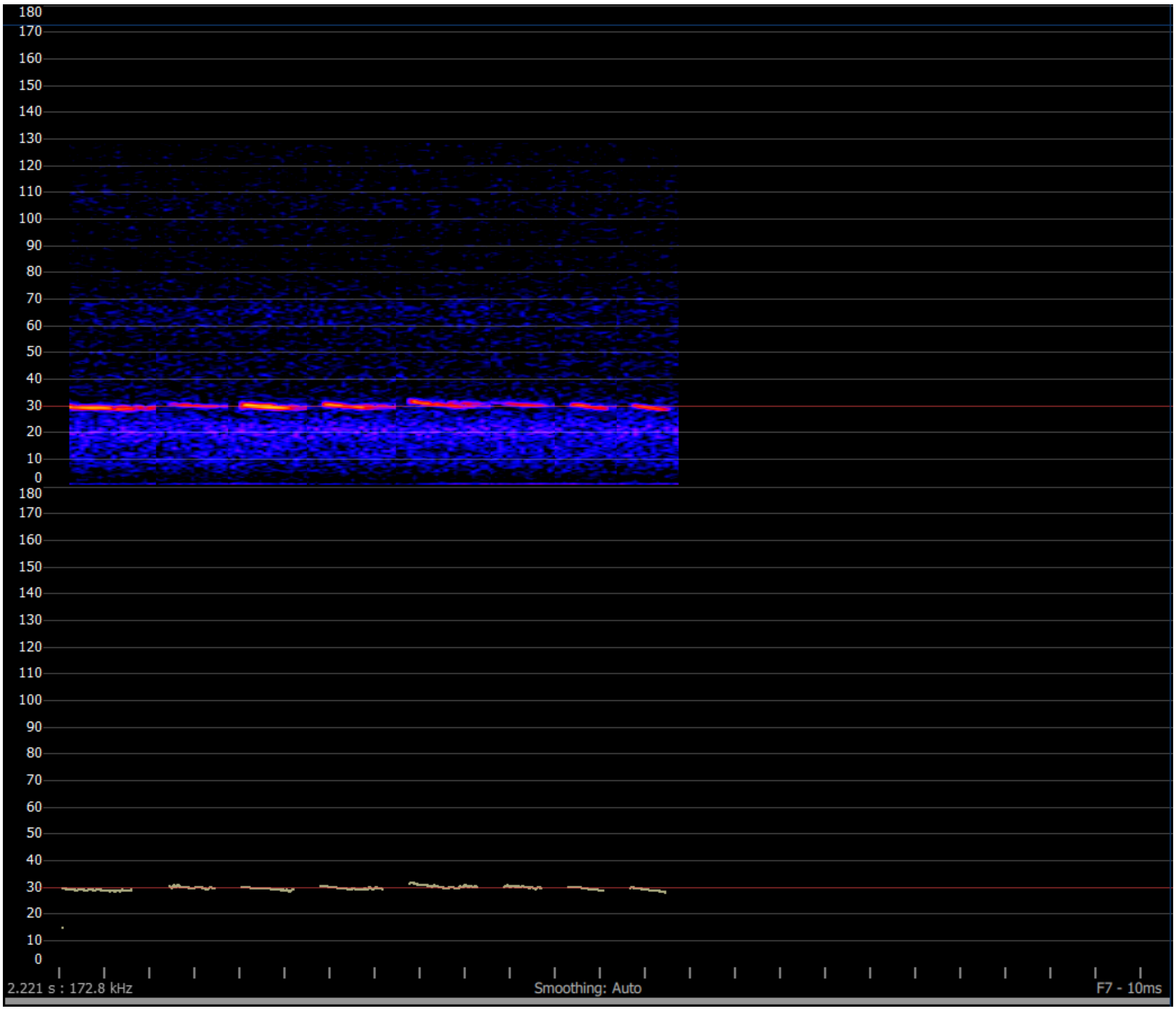
Appendix 17. Example of *M. orianae oceanensis* and *V. vulturnus* species complex call recorded at REF697C. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F7 zoom level, time on the x-axis with ticks 10 ms apart and frequency on the y-axis.



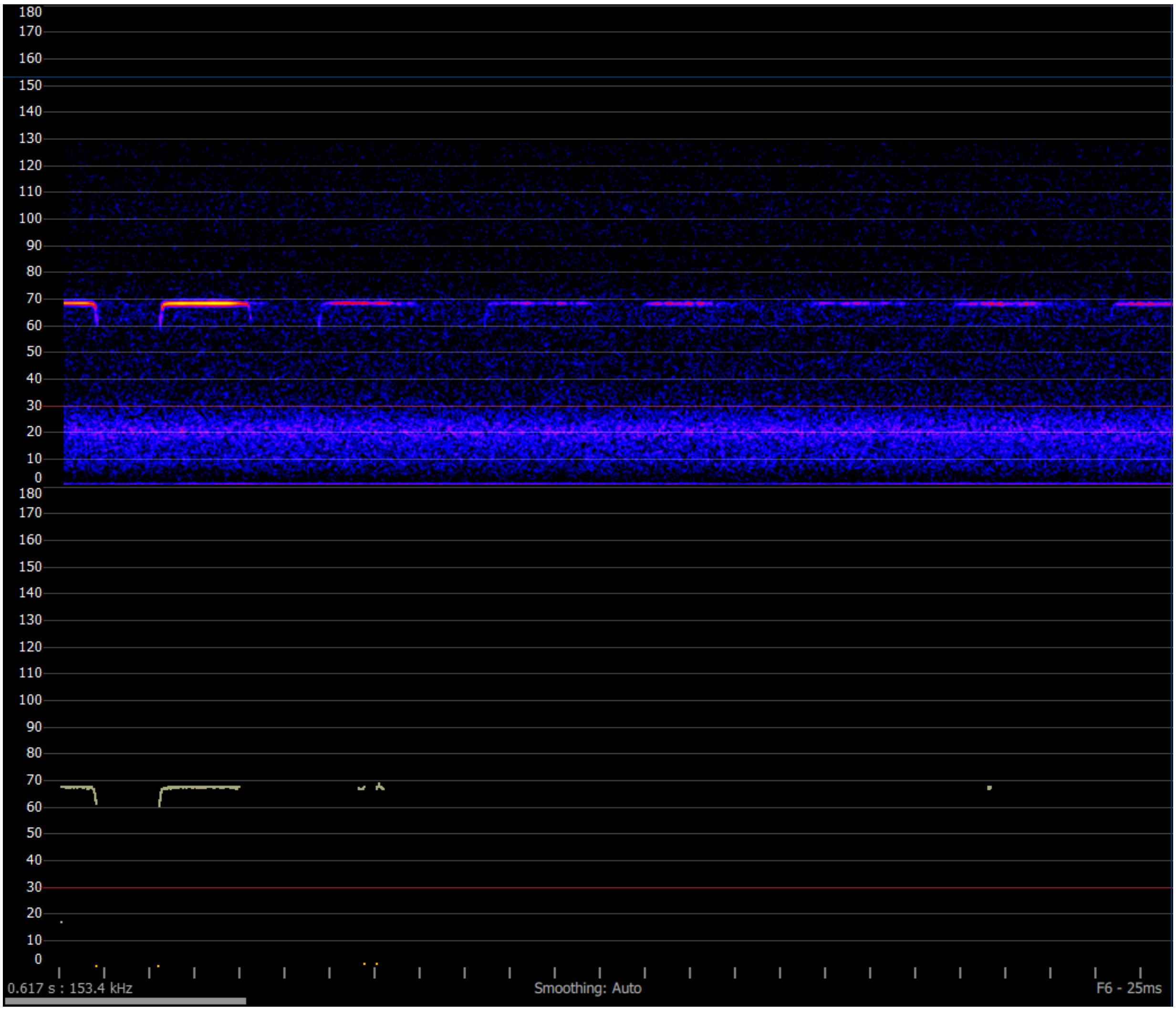
Appendix 18. Example call of *Nyctophilus* Spp. at REF732C Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F6 zoom level, time on the x-axis with ticks 25 ms apart and frequency on the y-axis.



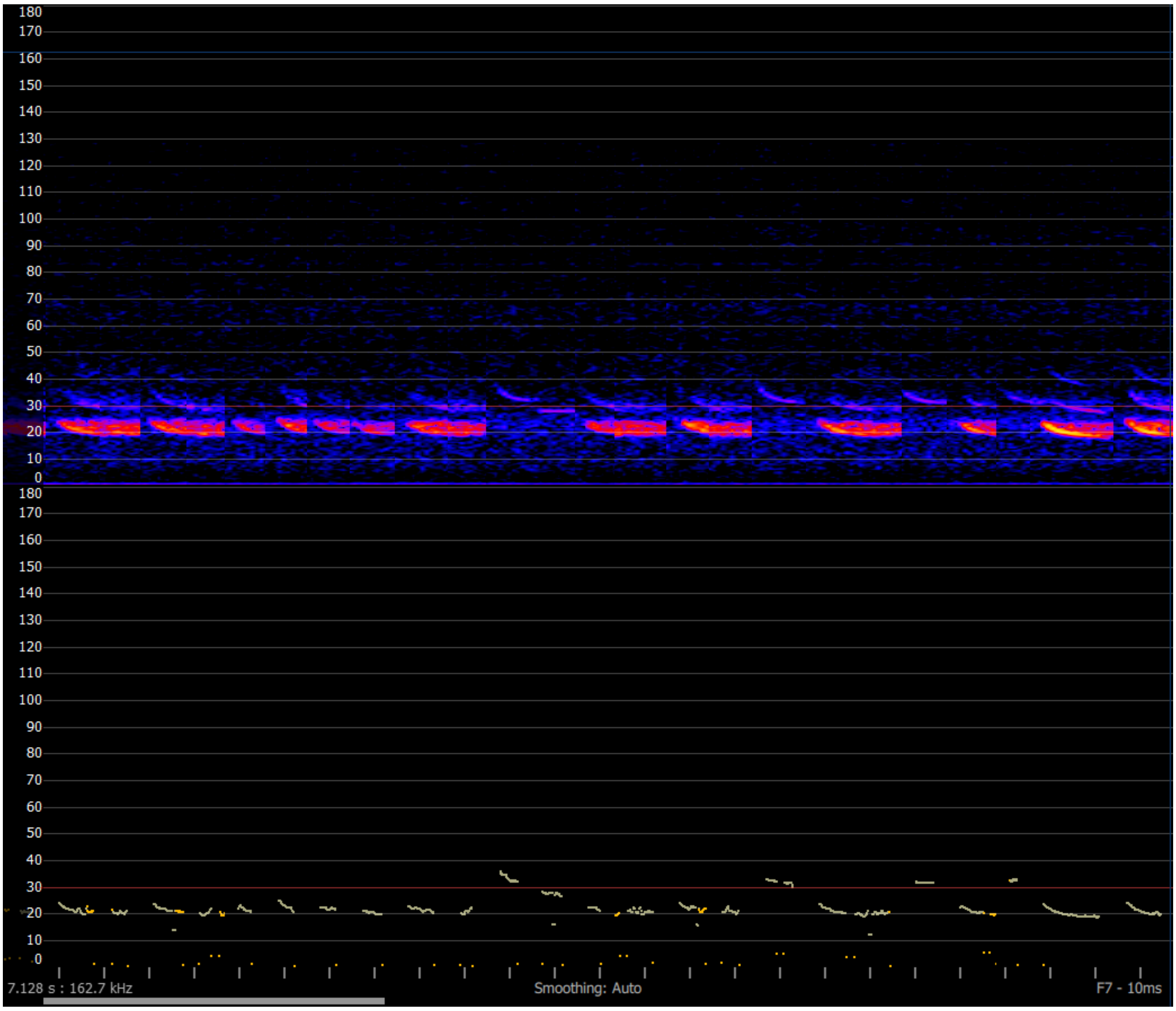
Appendix 19. Example call of *O. planiceps* at REF547C. Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F7 zoom level, time on the x-axis with ticks 10 ms apart and frequency on the y-axis.



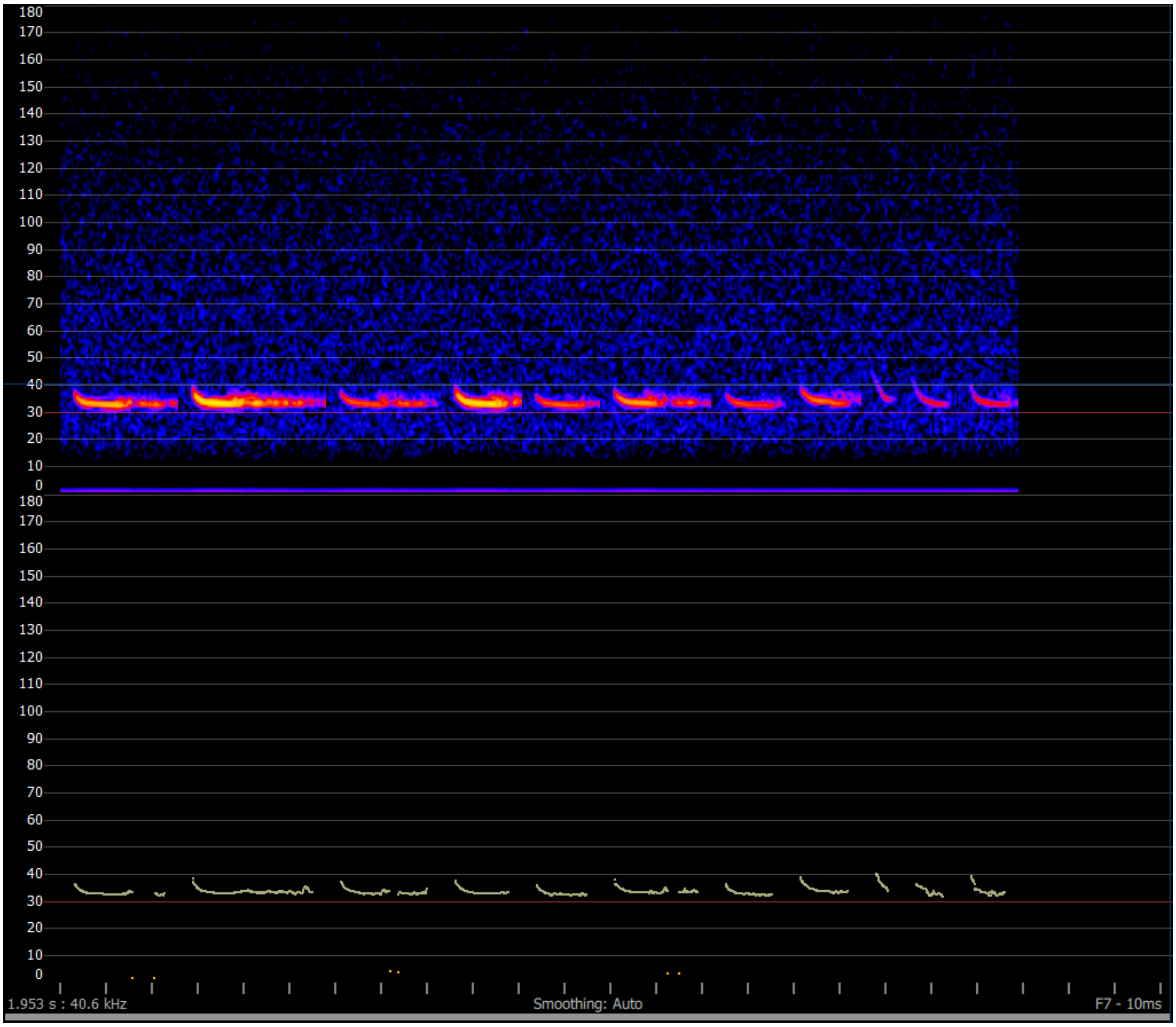
Appendix 20. Example call of *O. ridei*. at 547C Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F7 zoom level, time on the x-axis with ticks 10 ms apart and frequency on the y-axis.



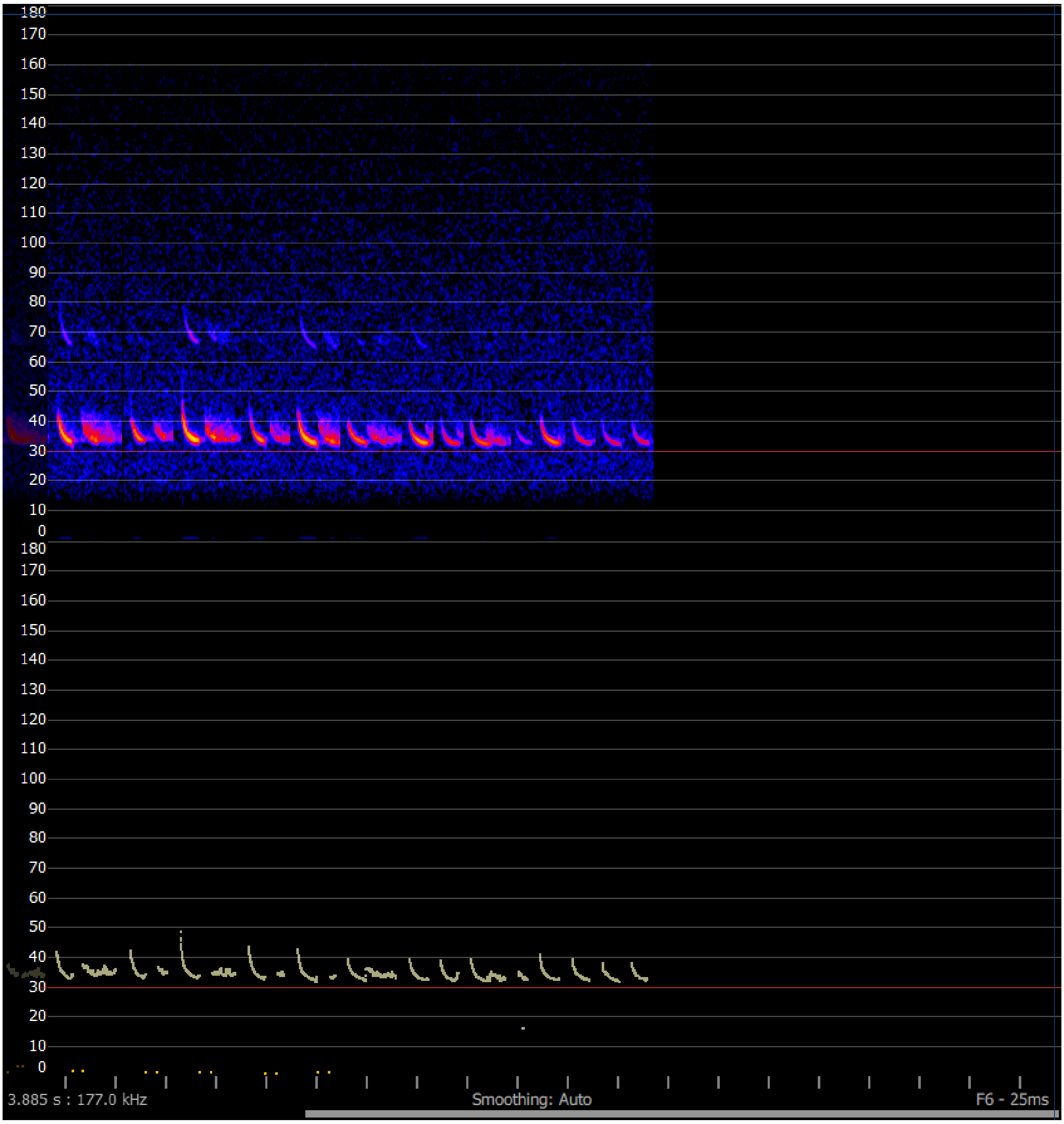
Appendix 21. Example call of *R. megaphylus*. at 547C Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F6 zoom level, time on the x-axis with ticks 25 ms apart and frequency on the y-axis.



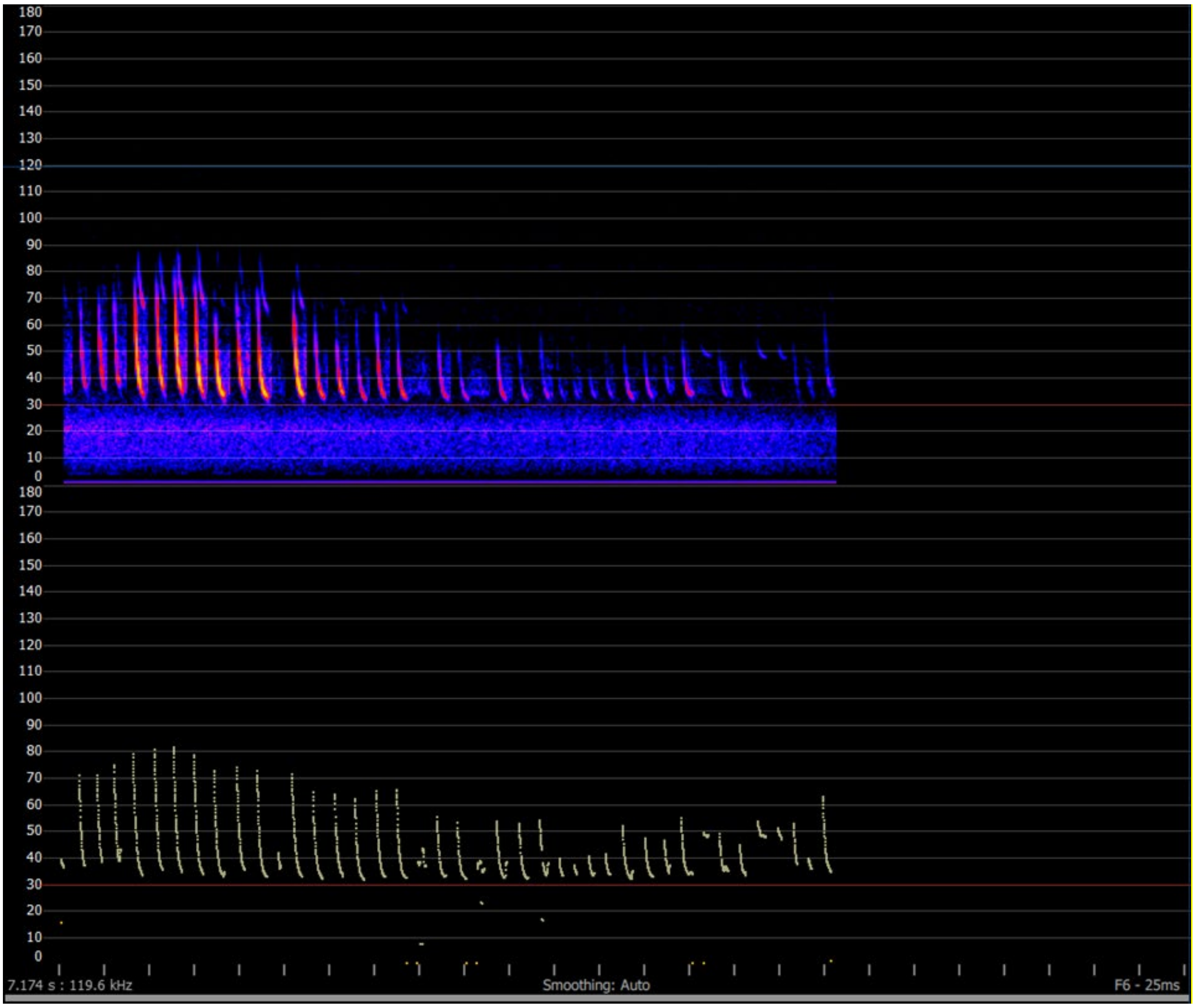
Appendix 22. Example call of potential *S. flaviventris* at 825C Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F7 zoom level, time on the x-axis with ticks 10 ms apart and frequency on the y-axis.



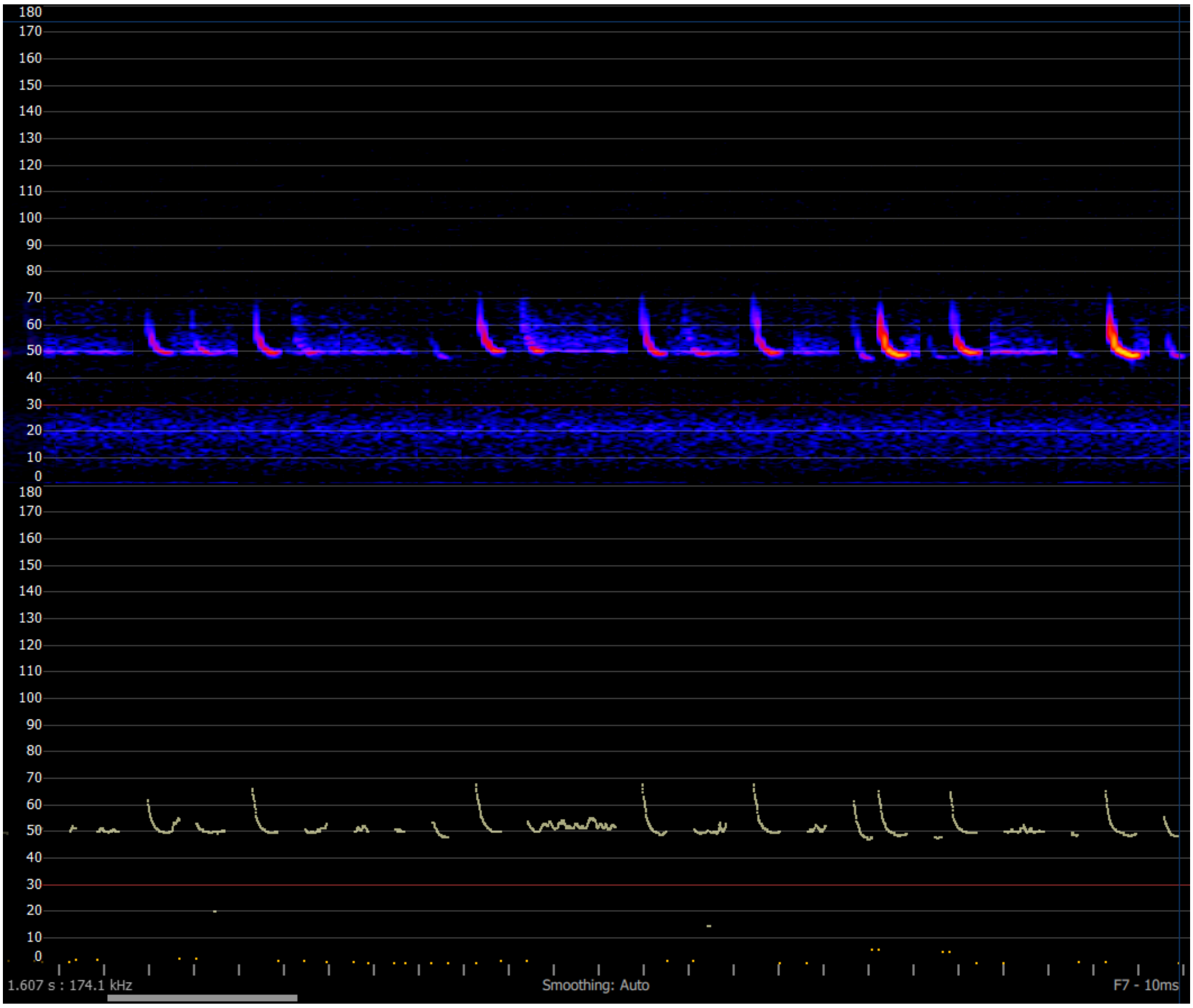
Appendix 23. Example species comples call of *S. rueppellii / S. balstoni*. at R6 Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F6 zoom level, time on the x-axis with ticks 25 ms apart and frequency on the y-axis.



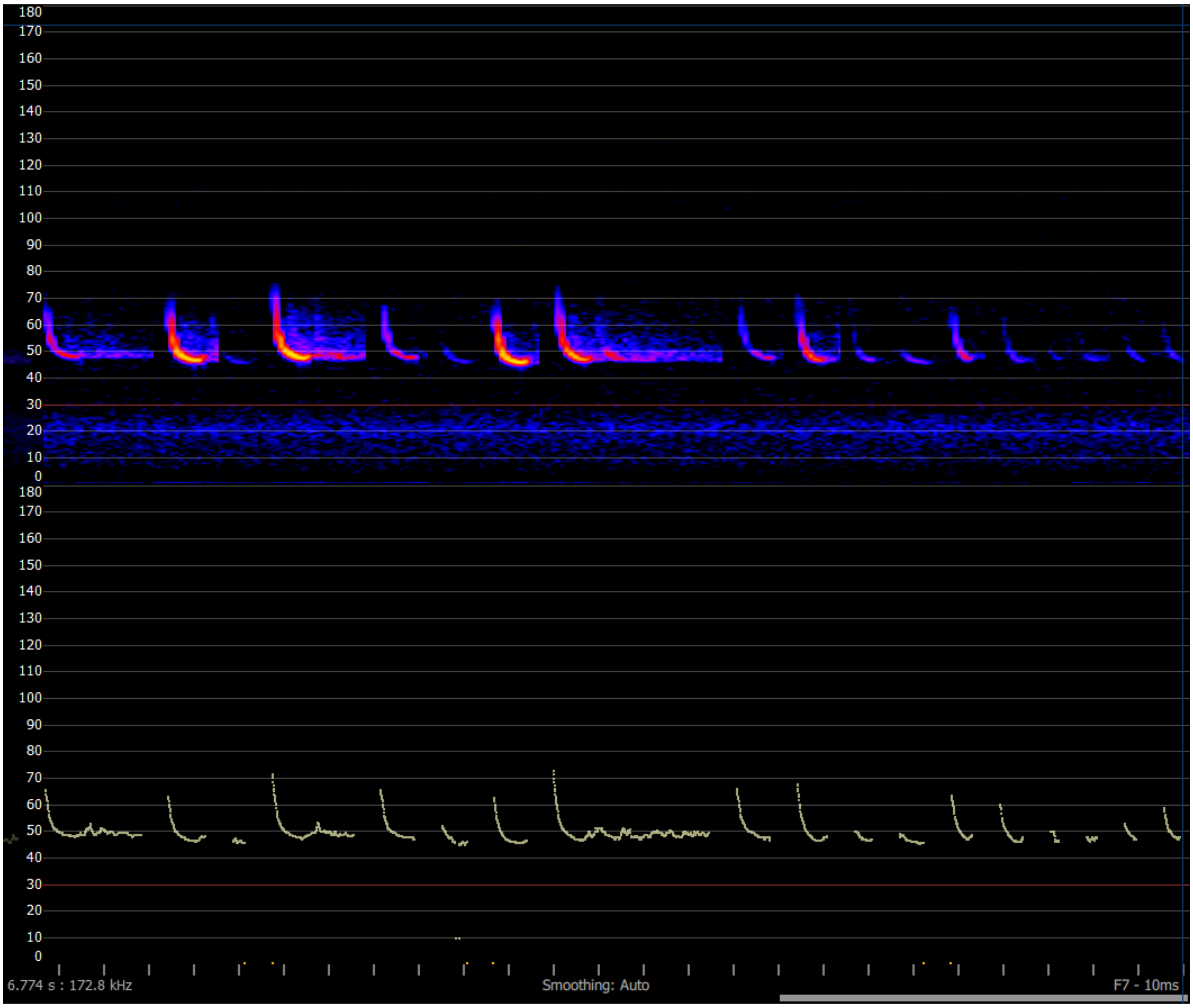
Appendix 24. Example call of *S. balstoni* at R6 Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F6 zoom level, time on the x-axis with ticks 25 ms apart and frequency on the y-axis.



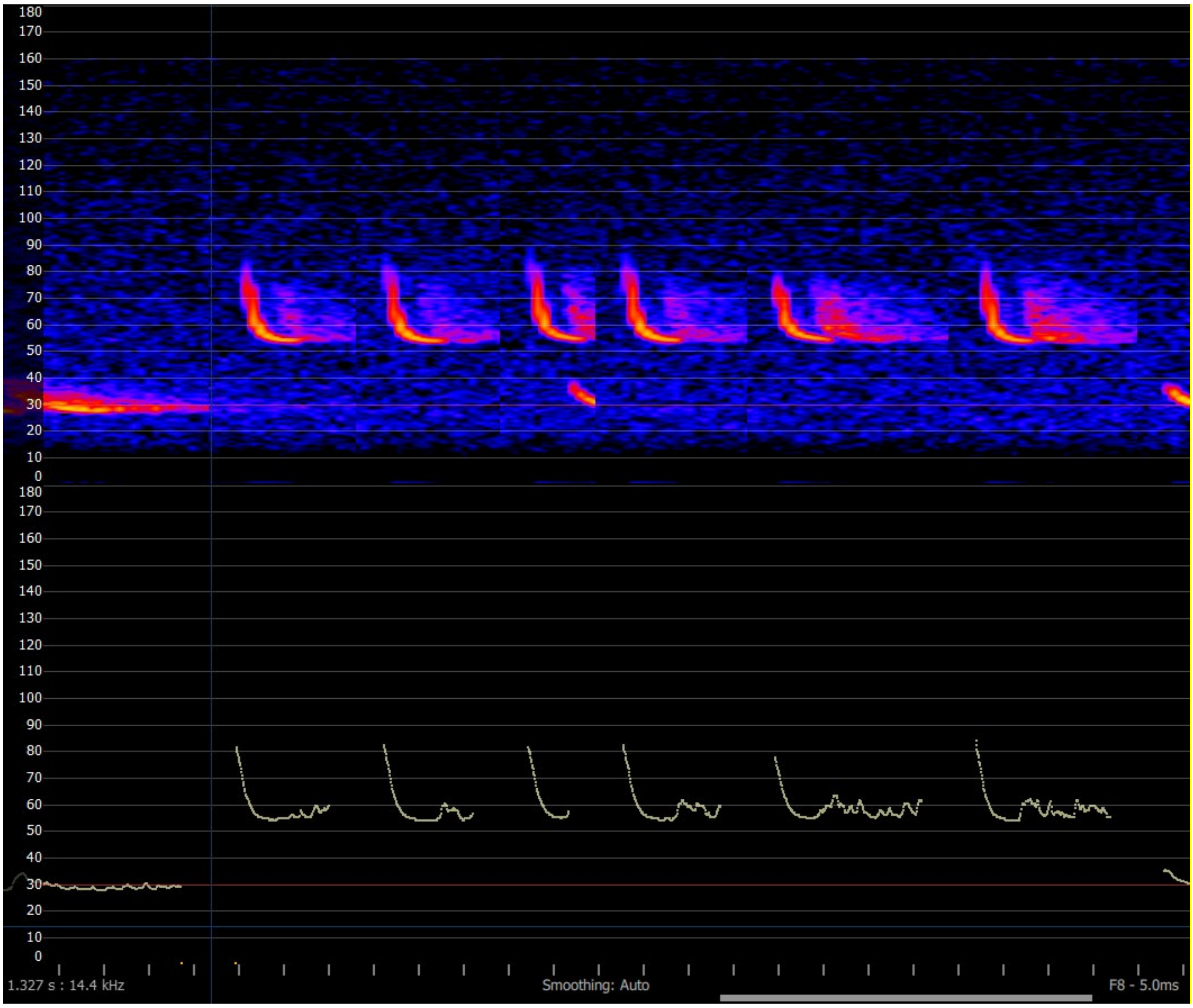
Appendix 25. Example call of *S. rueppellii / S. balstoni* at REF697C Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F6 zoom level, time on the x-axis with ticks 25 ms apart and frequency on the y-axis.



Appendix 26. Example call of *V. troughtoni* and *V. vulturnus* at REF732C Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F7 zoom level, time on the x-axis with ticks 10 ms apart and frequency on the y-axis.



Appendix 27. Example call of *V. vulturnus* at REF732C Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F7 zoom level, time on the x-axis with ticks 10 ms apart and frequency on the y-axis.



Appendix 28. Example species complex call of *V. troughtoni / V. pumilus* at R9 Top: full spectrum view of the call, bottom: zero crossing view of the call in Anabat Insight version 2.0.8-0-g4157d1f. Settings time compressed, F8 zoom level, time on the x-axis with ticks 5 ms apart and frequency on the y-axis.

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Review of BMP Management Schedule for 2023

Management Strategy	Objectives	2021	2022	2023	Comments 2023
Cultural Heritage Management	Cultural heritage items within the approved disturbance area, ECAs, Regeneration and Rehabilitation Areas are managed in accordance with the WCPL ACHMP (within DA boundaries) and Due Diligence Code of Practice for the Protection of Aboriginal Objects in NSW for areas elsewhere	• Continue implementation of WCPLs ACHMP, Due Diligence Code of Practice for the Protection of Aboriginal Objects in NSW and WCPLs GDP Process	• Continue implementation of WCPLs ACHMP, Due Diligence Code of Practice for the Protection of Aboriginal Objects in NSW and WCPLs GDP Process	• Continue implementation of WCPLs ACHMP, Due Diligence Code of Practice for the Protection of Aboriginal Objects in NSW and WCPLs GDP Process	• Implemented in 2023 (refer to Section 6.3 of the 2022 Annual Review
	Prevent unauthorised human access and exclude livestock from areas of native regeneration (unless being used as within management program i.e. crash grazing) to all Management Domains	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Annual & opportunistic inspections completed in 2023 • Inspections determined no further need for repairs • No livestock in sensitive areas
Fencing, Gates and Signage	Access to the Management Domains is retained for maintenance and safety purposes	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Annual & opportunistic inspections completed in 2023 • Inspections determined no further need for repairs • Adequate signage in place
Access Tracks	Reduce and rehabilitate unnecessary access tracks in all Biodiversity Offset Areas, ECAs and Regeneration Areas	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• No decommissioning of tracks required in 2023 (insitu tracks remaining are required for bush fire management) • One section of track within ECA-B needs repair due to wash outs, scheduled for repair in 2022

Management Strategy	Objectives	2021	2022	2023	Comments 2023
	Provide safe, unimpeded access for monitoring and maintenance, bushfire management, and asset protection in all Biodiversity Offset Areas, ECAs and Regeneration Areas	• Identify and map all access tracks required for safe and ongoing access, including tracks suitable for a CAT 1 tanker • Develop a repair and maintenance program for existing tracks that are proposed to remain • Seek relevant authorisation to enable construction of new access tracks (as required)	• Undertake annual and opportunistic access track inspection. Schedule and undertake necessary repairs	• Undertake annual and opportunistic access track inspection. Schedule and undertake necessary repairs	• No decommissioning of tracks required in 2023 (insitu tracks remaining are required for bush fire management) • One section of track within ECA-B needs repair due to wash outs, scheduled for repair in 2024
Waste Management	ECAs and Regeneration Areas are free of waste, disused buildings and redundant farm equipment	• Undertake annual and opportunistic waste inspections. Schedule and commission removal of all additional waste	• Undertake annual and opportunistic waste inspections. Schedule and commission removal of all additional waste	• Include disused building sites in annual and opportunistic inspections. Schedule and undertake necessary repairs	• Annual inspection completed in 2021, outstanding waste in ECA_B underwent partial removal during 2022 – partial completion in 2023.
Erosion, Sedimentation and Soil Management	High risk erosion, sediment or soil risks are identified and mapped in all ECAs and Regeneration Areas	• Undertake annual and opportunistic erosion, sediment and soil inspections. Update GIS database with necessary changes. • Undertake repairs as necessary to a stabilise high risk areas.	• Undertake annual and opportunistic erosion, sediment and soil inspections. Update GIS database with necessary change. • Undertake repairs as necessary to a stabilise high risk areas.	• Undertake annual and opportunistic erosion, sediment and soil inspections. Update GIS database with necessary changes. • Undertake repairs as necessary to a stabilise high risk areas.	• In 2019 high resolution mapping of Wilpinjong Creek (erosion profiling) was completed. • In 2023 ongoing targeted tree planting along sections of Wilpinjong Creek within ECA_B, ECA_A and Regen Area 2. • 2022 planting in Regen 1, plantings along LDP19 Wilpinjong Creek. • Annual inspections completed in late 2023 to monitor high risk erosion areas e.g., ECB_B. Ongoing development of suitable remediation plan in 2023.

Management Strategy	Objectives	2021	2022	2023	Comments 2023
	Exclude livestock from areas of native regeneration in all Biodiversity Offset Areas, ECAs and Regeneration Areas (unless being used as within management program)	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Annual & opportunistic inspections completed in 2023 • Inspections determined no further need for repairs • No livestock in sensitive areas
Seed Collection and Propagation	All seed collectors are appropriately qualified and trained	• Confirm training records for engaged seed collectors	• Confirm training records for engaged seed collectors	• Confirm training records for engaged seed collectors	• Seed collecting methodology and supplier details formed part of the 2020 seed tendering contract process. Changed seed supplier in 2023.
	Local species are included in revegetation and rehabilitation seed mixes	• Identify available seed species • Species collected to align with BVT species list and as required for site rehabilitation	• Identify available seed species • Species collected to align with BVT species list and as required for site rehabilitation	• Identify available seed species • Species collected to align with BVT species list and as required for site rehabilitation	• WCPL has maintained an ongoing seed collecting and seed storage program since 2015. • During 2021, applicable BVT seed species were identified from WCPL's seed bank and approximately 5,000 seedlings were propagated at a local nursey in Wollar. Propagation of this seed batch continued into 2023.
	Locally sourced seed is available for revegetation and rehabilitation works within all Management Domains	• Implement Seed Collection Program	• Implement Seed Collection Program	• Implement Seed Collection Program	• See above • During 2023 the seed collecting program continued (refer to Section 8 of the Annual Review)
Habitat Augmentation	Habitat augmentation opportunities are identified and assessed	• Implement Habitat Augmentation Procedure and recommendations where applicable	• Implement Habitat Augmentation Procedure and recommendations where applicable	• Implement Habitat Augmentation Procedure and recommendations where applicable	• Ongoing refer to **Section 8** of the Annual Review

Revegetation and Regeneration	Increase overall native plant species richness in ECAs, Regeneration and Rehabilitation Areas	**ECA-B** Revegetation of local native over-storey and shrub species within poor condition areas **Regeneration Area 1** Opportunistic supplementary tree planting **Regeneration Area 9** Opportunistic supplementary tree planting	**ECA-B** Continue revegetation works of local species **Regeneration Area 1** Opportunistic supplementary tree planting **Regeneration Area 2** Opportunistic undertakings of revegetation works of local native over-storey and shrub species within poor condition areas **Regeneration Area 4** Opportunistic undertakings of revegetation works of native over-storey and shrub species in areas of no to low resilience **Regeneration Area 5** Opportunistic undertakings of revegetation works of native over-storey and shrub species in areas of no to low resilience **Regeneration Area 9** Opportunistic undertakings of revegetation works of native over-storey and shrub species in areas of no to low resilience Undertake annual and opportunistic revegetation and regeneration inspections.	Undertake annual and opportunistic revegetation and regeneration inspections. Schedule and undertake necessary maintenance including reapplication of seed or supplementary tree and shrub planting.	• ECA_B (2019 & 2020) and Regen (2021) and 2023 have been replanted with tubestock species.

Management Strategy	Objectives	2021	2022	2023	Comments 2023
Weed Management	Noxious and environmental weeds are identified and mapped in all ECAs and Regeneration Areas	Undertake a detailed inspection of all Biodiversity Offset Areas, ECAs and Regeneration Areas and accurately map (GIS) noxious and environmental weeds	Undertake quarterly weed inspections. Update GIS database with necessary changes	Undertake quarterly weed inspections. Update GIS database with necessary changes	• ECA_A and ECA_B weed control incomplete due to access constraints caused by wet weather in 2022.
	A risk based weed management program is developed for all ECAs, Regeneration and Rehabilitation Management Domains	• Implement weed management program • Undertake weed inspections 1. Schedule and undertake necessary weed treatment	• Implement weed management program • Undertake weed inspections 2. Schedule and undertake necessary weed treatment	• Implement weed management program • Undertake weed inspections 3. Schedule and undertake necessary weed treatment	• Ongoing weed management assessments, based on annual and opportunistic inspections and Weed Management Plan developed by ELA (2020).

Wilpinjong Coal Mine 2023 Channel Stability Monitoring

Wilpinjong Coal Pty Ltd

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DOCUMENT TRACKING

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Contents

List of Figures

List of Tables

Abbreviations

Abbreviation	Description
ARI	Average Recurrence Interval
BEHI	Bank Erosion Hazard Index
BoM	Bureau of Meteorology
CSM	Channel Stability Monitoring
EIS	Environmental Impact Statement
ELA	Eco Logical Australia
EY	Exceedances per Year
IFD	Intensity-Frequency-Duration
LHB	Left Hand Bank
ML	Mining Lease
RHB	Right Hand Bank
WCM	Wilpinjong Coal Mine
WCPL	Wilpinjong Coal Pty Ltd

Executive Summary

Channel stability monitoring (CSM) was completed by Eco Logical Australia (ELA) on behalf of Wilpinjong Coal Pty Ltd (WCPL) between 18 December and 20 December 2023. The CSM program aims to provide quantitative and qualitative measures of channel stability along Wilpinjong and Cumbo Creeks. Monitoring was undertaken across a total of 59 permanent monitoring locations, including 49 on Wilpinjong Creek and 10 on Cumbo Creek. Consistent with previous monitoring, methods included surveying the designated reach of each monitoring site (approximately 100 m) and completing the Bank Erosion Hazard Index (BEHI) assessment, along with visual and photographic comparative assessment with data from previous years.

CSM results in 2023 were largely consistent with previous years, with only 10 sites seeing a change to BEHI scores, indicating the unchanged nature of the target creeks. For Wilpinjong Creek, BEHI ratings improved at five (5) sites, declined at (5) sites, and remained unchanged at 39 sites, whilst for Cumbo Creek, ratings remained unchanged at all 10 sites. Slight decreases in bank vegetation ground cover, as well as greatly reduced water levels and stream flow, were observed at most sites. Sites with a decline in channel stability between 2022 and 2023 are likely related to erosion caused by high flow events throughout 2022, combined with reduced vegetation cover following dry conditions in 2023. Despite this, some sites did experience an increase in channel stability BEHI scores, indicating that the impacts of preceding climatic conditions over the previous two years were not uniform throughout the catchment.

Identified historical erosion points were monitored in 2023, with some sites experiencing minor erosion in 2023, however all sites were largely stable. Overall, erosion points require ongoing monitoring, and additional revegetation and remediation works are recommended to allow for channel bank stability. Specifically, reshaping and contouring of the bank, followed by revegetation is recommended at multiple erosion points, including E1, E3, E4, E6, E9 and E11.

The results of the 2023 CSM support conclusions made in previous monitoring and assessments that ongoing mining operations are not causing stability issues within the target creek systems. Both Wilpinjong and Cumbo Creeks are typical of ephemeral creek systems in agricultural landscapes of the surrounding region, with channel stability issues within these creeks reflecting historical disturbances and land use practices, rather than contemporary mining operations.

1. Introduction

1.1. Background

Eco Logical Australia (ELA) was engaged by Wilpinjong Coal Pty Ltd (WCPL) to undertake annual channel stability monitoring (CSM) along Wilpinjong and Cumbo Creeks. CSM is required to satisfy Schedule 3, Condition 30 (d, iii) of the WCPL Development Consent (SSD 6764), and the CSM criteria detailed in Appendix 2 (Surface Water Management Plan) of the Wilpinjong Water Management Plan (WCPL 2018).

1.2. Regional Overview

The Wilpinjong Coal Mine (WCM) is located in the Mid-Western Regional Council Local Government Area, approximately 45 km north-east of Mudgee. The mine is owned and operated by WCPL, a wholly owned subsidiary of Peabody Energy Australia.

The WCM is located at the headwaters of the Goulburn River which is a major tributary of the Hunter River catchment. Wilpinjong Creek is the main drainage channel within the WCM. It is an intermittent creek with a narrow floodplain that has a history of cattle grazing. The northern edge of the floodplain is bordered by the sandstone escarpments of the Goulburn River National Park (NP). Wilpinjong Creek has three coal mines in its catchment, Moolarben, Ulan and Wilpinjong, with the latter positioned furthest downstream. WCPL discharges treated mine water into Wilpinjong Creek, treated by reverse osmosis, at a licensed discharge point (EPL24) directly adjacent to WCM.

Cumbo Creek flows north through land managed by WCPL, passing between Pit 3, Pit 2, Pit 7 and Pit 4, before joining Wilpinjong Creek north of the eastern pit area. Wilpinjong Creek continues to flow east, for approximately 4.5 km downstream where it joins Wollar Creek, which continues another 13 km through the Goulburn River NP before entering the Goulburn River.

1.3. Previous channel stability assessments

A baseline channel stability assessment of Wilpinjong and Cumbo Creeks was undertaken in 2005 as part of the Environmental Impact Statement (EIS) for the Wilpinjong Coal Project (WCPL 2005) to characterise the existing condition of the Wilpinjong and Cumbo Creek stream channels prior to mining. The Wilpinjong Creek survey included 49 sites and extended 12.5 km from the upstream gauging station to the confluence with Wollar Creek to the east. The Cumbo Creek survey included ten sites and extended 3 km from the southern boundary of the Mining Lease (ML) 1573 north to the confluence with Wilpinjong Creek.

The baseline surveys concluded both Wilpinjong and Cumbo Creeks have been affected by pre-mining land management practices dominated by sheep and cattle grazing. These land management practices involved the clearing of riparian vegetation on both creeks to maximise grazing areas and stock access to drinking water. The clearing of this vegetation is likely to have contributed significantly to bank instability. Disturbance from burrowing animals, both native (e.g. *Vombatus ursinus* (Common Wombats)) and introduced (e.g. *Oryctolagus cuniculus* (European Rabbit)), is also likely to have contributed to this instability.

Subsequent annual CSM has been undertaken in 2011, and 2014-2023, to assess the ongoing stability of the Wilpinjong and Cumbo Creeks during operational mining. Barnson (2017) developed a proforma to assist in the assessment of creek stability at each survey location and to enable comparisons to be made between annual survey periods. Annual CSM reports have concluded that overall riparian health is poor, with erosion and bank stability issues present, typical of historically cleared agricultural catchments. Data collected by annual CSM to date has indicated that mining activities are not contributing to further channel stability issues in Wilpinjong and Cumbo Creeks.

1.4. Objectives

This report details the findings from the 2023 CSM program and includes a comparison of the regeneration progress of both Wilpinjong and Cumbo Creeks against previous monitoring conducted since 2011.

The CSM program aims to provide qualitative measures of stream bed and bank erosion and channel instability along Wilpinjong and Cumbo Creeks.

The key objectives of the 2023 CSM program are to:

- Evaluate erosional or depositional features of the creek banks
- Record the details of permanent monitoring sites with written descriptions and photographs
- Assess the stability of Wilpinjong and Cumbo Creeks using a rapid assessment methodology
- Compare visual channel stability at each of the permanent monitoring sites against previous monitoring records.

2. Methodology

2.1. Field Survey – Channel stability monitoring and comparative assessment

The field survey was conducted by ELA ecologists Jack O'Sullivan and Tahnee Coull over three days between 18 December and 20 December 2023.

A total of 59 permanent monitoring locations were surveyed (49 on Wilpinjong Creek and 10 on Cumbo Creek; Figure 1). Consistent with previous monitoring, surveys involved surveying the designated reach of each site (approximately 100 m) and completing the Bank Erosion Hazard Index (BEHI) assessment. BEHI assessment involves scoring a site on eight quantitative categories outlined below and in Appendix A.

The eight BEHI indicators of channel stability that were used to evaluate erosion at each site include:

- Bank Height (m)
- Bank Angle (°)
- Percentage of Bank Height with a Bank Angle greater than 80°
- Evidence of Mass Wasting (% of Bank)
- Unconsolidated Material (% of Bank)
- Streambank Protection (% of Streambank covered in plant roots, vegetation, logs, branches, rocks, etc.)
- Established Beneficial Riparian Woody – Vegetation Cover
- Stream Curvature Descriptor

The BEHI indicators produce an activity rating that classifies each location from 'Highly Unstable', indicating the drainage line is experiencing severe ongoing erosion, to 'Highly Stable', indicating the drainage line is highly stable in function and form. This rating system enables any deterioration or improvement in bank stability to be detected over time. The classification system is detailed below in Table 1.

Table 1: BEHI score ratings for each rating class

Rating	BEHI Score
Highly Stable	0-25
Moderately Stable	26-35
Stable	36-45
Unstable	46-55
Moderately Unstable	56-65
Highly Unstable	66-85

Field notes and photographs were taken to allow qualitative assessment through comparisons between monitoring periods. This process included written site descriptions using the previous monitoring report (ELA 2022) to make comparisons in situ, as well as taking upstream and downstream photographs at each of the permanent monitoring sites. Site descriptions are provided in Section 3 and copies of site photos are provided in Appendix B. Comparisons of the monitoring site photographs (2011-2023) has been made by referring to previous reports prepared by Barnson (2017) and ELA (2020-2022).

Previously established erosion points along Wilpinjong Creek were also assessed (Figure 2). These are in areas with moderate to severe erosion and are monitored to determine the presence and extent of on-going erosion. Management issues and threatened species were recorded opportunistically throughout the surveys, to highlight areas where management intervention is recommended.

2.2. Rainfall and Flood Analysis

Previous WCPL CSM reports have included an analysis of rainfall Intensity-Frequency-Duration (IFD) and exceedance likelihood, with its effect on erosion (Barnson 2017). Rainfall data is included in Appendix C and shows that 2023 was a lot drier compared to the preceding three years (2020-2022) and was below the long-term average rainfall. Flow data for Wilpinjong and Cumbo Creeks is shown below in Figures 3 to 5, which demonstrates a significantly reduced flow throughout 2023 compared to previous years. Due to this below average annual rainfall and extremely low flow, coupled with an absence of significant or increased erosion events across the monitoring sites, it was determined that IFD and exceedance analysis would be of negligible benefit and therefore it has not been undertaken for the purposes of this report.

Figure 1: Channel Stability monitoring locations along Wilpinjong Creek and Cumbo Creek

Figure 2: Significant erosion locations along Wilpinjong Creek

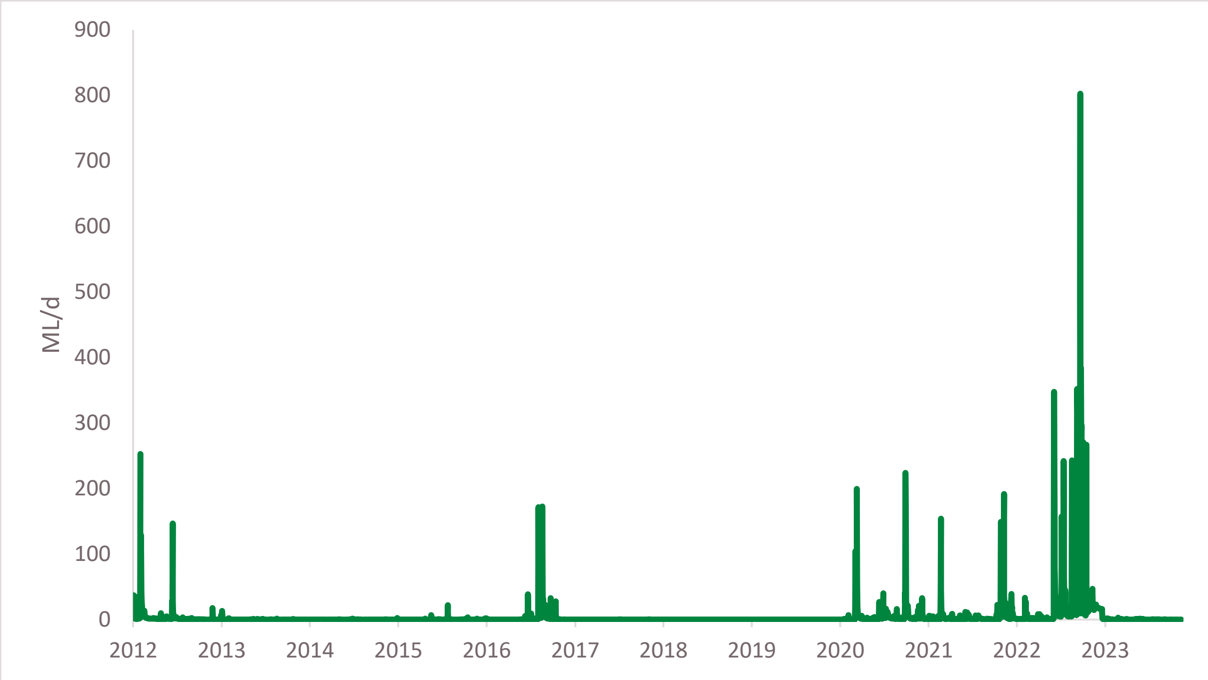

Figure 3: Wilpinjong Creek stream flow upstream of the WCPL mine discharge point EPL 24

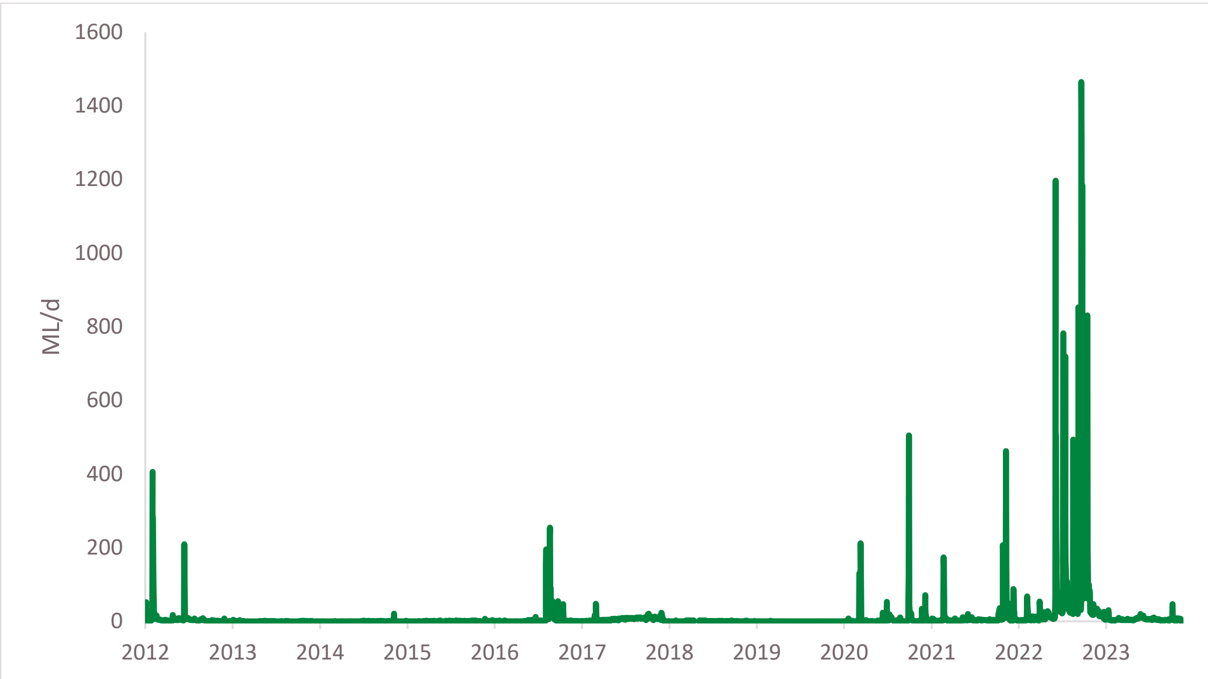

Figure 4: Wilpinjong Creek stream flow downstream of the WCPL mine discharge point EPL 24

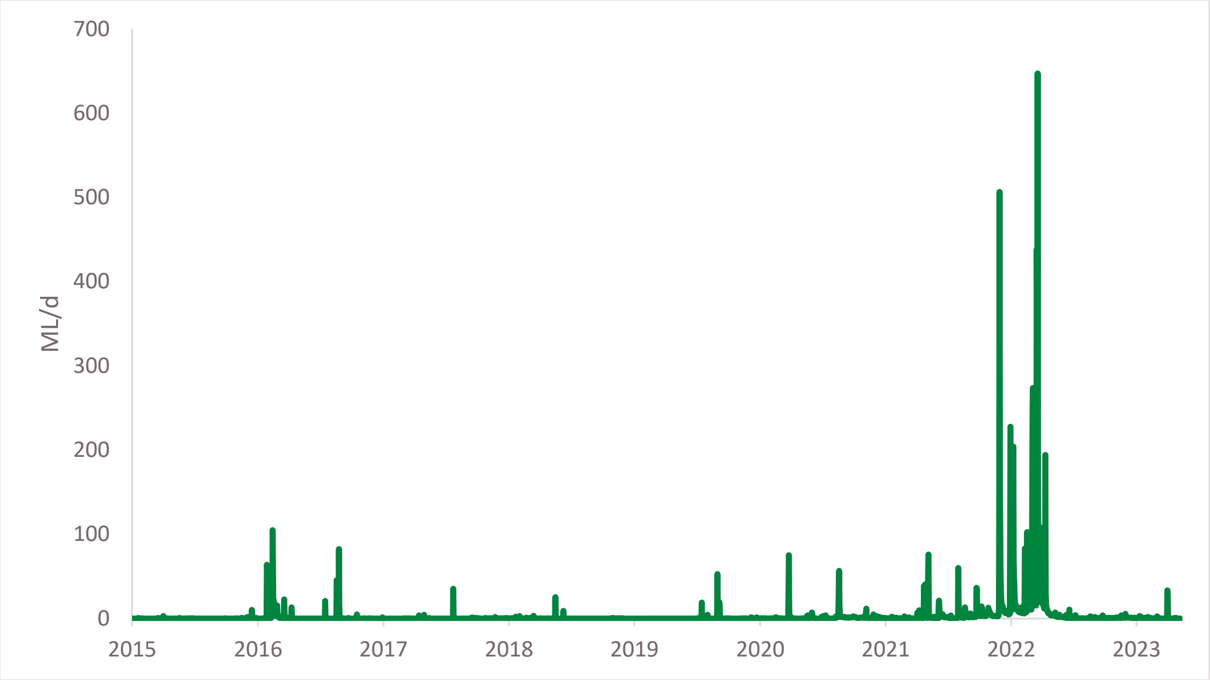

Figure 5: Cumbo creek stream flow downstream of the WCPL mine discharge point EPL 24

3. Results

3.1. Channel Stability Monitoring

The results of the BEHI assessments completed at sites along Wilpinjong Creek are presented below in Table 2, with results from Cumbo Creek sites presented in Table 3. Site descriptions and comparison notes can be found in Table 4. A range of priority weed species listed within the Central Tablelands Regional Strategic Weed Management Plan 2023-2027 (LLS 2023) were recorded, as well as priority pest animal species listed within the Central Tablelands Regional Strategic Pest Animal Management Plan 2018-2023 (LLS 2018), the locations of which are shown in Figure 6.

Table 2: 2023 BEHI data for Wilpinjong Creek

Site	Bank (L/R)	Bank Height (m)	Bank Face Length	BEHI Indicator								Total	Rating
				1	2	3	4	5	6	7	8		
WCk1	L	4	10	5	2	5	2.5	2.5	7.5	7.5	5	37	Stable
WCk2	R	3.5	9	5	2	5	2.5	2.5	7.5	10	0	34.5	Mod Stable
WCk3	L	3	12	5	2	2.5	7.5	5	10	12.5	5	49.5	Unstable
WCk4	L	3.5	7	5	2	7.5	5	7.5	10	12.5	0	49.5	Unstable
WCk5	L	3	7	5	2	2.5	5	5	2.5	7.5	0	29.5	Mod Stable
WCk6	L	3	6	2.5	2	2.5	0	2.5	7.5	7.5	2.5	27	Mod Stable
WCk7	L	2.5	6	2.5	2	2.5	0	2.5	7.5	7.5	0	24.5	Highly Stable
WCk8	L	5	12	7.5	2	0	2.5	0	2.5	15	2.5	32	Mod Stable
WCk9	R	2	9	2.5	2	7.5	5	2.5	10	15	2.5	47	Unstable
WCk10	R	1.5	15	2.5	0	0	0	0	2.5	15	2.5	22.5	Highly Stable
WCk11	R	1.5	18	0	0	0	0	2.5	0	10	2.5	15	Highly Stable
WCk12	R	2	12	2.5	2	0	0	2.5	2.5	12.5	5	27	Mod Stable
WCk13	L	4	8	5	4	0	0	2.5	0	10	5	26.5	Mod Stable
WCk14	L	1.8	7	2.5	2	0	0	2.5	2.5	12.5	0	22	Highly Stable
WCk15	L	1.8	6	2.5	2	2.5	0	2.5	2.5	10	2.5	24.5	Highly Stable
WCk16	L	2	7	2.5	2	5	0	2.5	7.5	7.5	0	27	Mod Stable
WCk17	R	1.8	4	2.5	2	0	0	0	0	15	2.5	22	Highly Stable
WCk18	R	2.5	5	2.5	2	5	2.5	0	0	15	2.5	29.5	Mod Stable
WCk19	L	2	4	2.5	2	2.5	2.5	0	0	15	0	24.5	Highly Stable
WCk20	L	1.8	5	2.5	2	5	7.5	2.5	7.5	12.5	0	39.5	Stable
WCk21	R	1.3	5	0	2	2.5	2.5	0	2.5	15	2.5	27	Mod Stable
WCk22	R	1.6	8	2.5	2	0	7.5	2.5	12.5	12.5	2.5	42	Stable
WCk23	R	2.5	12	2.5	2	0	2.5	5	12.5	15	5	44.5	Stable

Site	Bank (L/R)	Bank Height (m)	Bank Face Length	BEHI Indicator								Total	Rating
				1	2	3	4	5	6	7	8		
WCk24	R	1.7	10	2.5	0	2.5	0	2.5	2.5	15	2.5	27.5	Mod Stable
WCk25	L	1.7	7	2.5	2	2.5	7.5	2.5	10	15	2.5	44.5	Stable
WCk26	L	3.5	10	5	2	7.5	7.5	5	10	15	2.5	54.5	Unstable
WCk27	R	2.8	5	2.5	6	7.5	7.5	5	10	15	2.5	56	Mod Unstable
WCk28	L	2.5	5	2.5	2	7.5	5	2.5	7.5	12.5	2.5	42	Stable
WCk29	L	3.6	8	5	2	7.5	5	5	10	15	2.5	52	Unstable
WCk30	R	2.8	12	2.5	2	0	0	2.5	2.5	12.5	2.5	24.5	Highly Stable
WCk31	R	3	6	2.5	4	5	5	5	7.5	15	2.5	46.5	Unstable
WCk32	R	3.2	7	5	4	7.5	7.5	2.5	7.5	15	2.5	51.5	Unstable
WCk33	L	3.2	6	5	4	7.5	7.5	5	10	10	5	54	Unstable
WCk34	R	2.4	6	2.5	4	5	2.5	0	0	15	5	34	Mod Stable
WCk35	R	2.2	13	2.5	2	2.5	7.5	5	10	15	2.5	47	Unstable
WCk36	R	2	15	2.5	2	0	5	2.5	0	15	2.5	29.5	Mod Stable
WCk37	R	2	12	2.5	2	2.5	7.5	2.5	7.5	15	2.5	42	Stable
WCk38	L	3.1	6	5	2	2.5	0	2.5	0	10	5	27	Mod stable
WCk39	L	3.2	7	5	4	2.5	5	7.5	7.5	15	2.5	49	Unstable
WCk40	R	3.2	14	5	2	0	7.5	7.5	12.5	15	0	49.5	Unstable
WCk41	R	2.8	8	2.5	2	2.5	0	0	0	15	0	22	Highly Stable
WCk42	R	3.8	6	5	4	7.5	5	10	12.5	12.5	2.5	59	Mod Unstable
WCk43	L	3.1	5	5	4	7.5	2.5	0	2.5	15	2.5	39	Stable
WCk44	R	1.7	3	2.5	2	2.5	0	0	2.5	15	2.5	27	Mod stable
WCk45	L	3.5	7	5	4	2.5	2.5	0	2.5	7.5	5	29	Mod stable
WCk46	R	2.5	5	2.5	4	5	2.5	2.5	2.5	10	2.5	31.5	Mod Stable
WCk47	R	2.5	6	2.5	2	2.5	7.5	2.5	7.5	12.5	0	37	Stable
WCk48	L	2.7	8	2.5	2	2.5	2.5	5	2.5	12.5	2.5	32	Mod Stable
WCk49	L	4	10	5	4	2.5	0	5	7.5	10	2.5	36.5	Stable

Table 3: BEHI data for Cumbo Creek

Site	Bank (L/R)	Bank Height (m)	Bank Face Length	BEHI Indicator								Total	Rating
				1	2	3	4	5	6	7	8		
CCk1	L	1.8	10	0	0	0	0	0	0	15	0	15	Highly Stable
CCk2	R	1.3	8	0	2	2.5	5	2.5	7.5	15	5	39.5	Stable
CCk3	L	0.4	2	0	0	0	0	2.5	0	15	2.5	20	Highly Stable
CCk4	R	1	13	0	0	0	0	0	0	15	2.5	17.5	Highly Stable
CCk5	R	1	8	0	0	0	0	2.5	0	15	2.5	22	Highly Stable
CCk6	R	1.8	10	2.5	2	2.5	0	0	0	15	2.5	24.5	Highly Stable
CCk7	R	0.5	2	0	2	2.5	0	0	0	15	2.5	22	Highly Stable
CCk8	L	2	15	2.5	0	0	0	0	0	15	2.5	20	Highly Stable
CCk9	L	0.7	2	0	2	2.5	0	0	0	15	2.5	22	Highly Stable
CCk10	L	0.7	4	0	2	2.5	0	0	0	15	2.5	22	Highly Stable

Table 4: Monitoring site descriptions – Wilpinjong Creek and Cumbo Creek

Site	Upstream	Downstream
Wilpinjong Creek		
WCk1	• Water level is lower than 2022 with water pooled behind weir • No further dieback of *Angophora floribunda* (Rough-barked Apple) since 2021 • Livestock access to creek • Groundcover on bank heavily grazed • *Phragmites australis* (Common reed) present on bank and in channel in 2022 absent due to heavy grazing	• *Phragmites australis* present on bank and in channel in 2022 absent due to heavy grazing • Bare soil patches, erosion stabilising • Livestock access to creek • Groundcover on bank heavily grazed • No water within channel
WCk2	• Livestock access to creek • Groundcover on bank heavily grazed • Large decrease in vegetation cover within the channel due to livestock grazing • No water within channel • Minimal localised erosion, currently appears stable	• Livestock access to creek • Groundcover on bank heavily grazed • Erosion appears stable, however slight increase due to livestock access • No water within channel
WCk3	• Livestock access to creek • Groundcover on bank heavily grazed • *Phragmites australis* and *Juncus* sp. present in 2022 now absent due to grazing • No water within channel • Minimal localised erosion, slight progression	• Livestock access to creek • Groundcover on bank heavily grazed • *Phragmites australis* and *Juncus* sp. present in 2022 now absent due to grazing • Some progression of erosion and mass wasting • No water within channel
WCk4	• Livestock access to creek • Groundcover on bank and within channel heavily grazed • *Phragmites australis* now absent from channel • No water within channel • Active erosion on left hand bank (LHB) continues, with evidence of undercutting and mass wasting	• LHB steep with exposed roots • Vegetation cover on both banks is good • LHB erosion active still active, with undercutting and mass wasting • Vegetation in channel is high, dominated by Phragmites australis and Juncus sp. • No water within channel
WCk5	• *Phragmites australis* present in channel, high cover • LHB erosion active with mass wasting evident. Some bare soil patches on bank from erosion • Vegetation on banks is in good condition	• Vegetation in channel is high, dominated by Phragmites australis • Woody vegetation cover is good on both banks • Bank vegetation cover good, with mixed grasses including *Themeda triandra* • Minor localised erosion on LHB from animal tracks, however appears largely stable

Site	Upstream	Downstream
	• *Eucalyptus blakelyi* (Blakely's Red Gum) regeneration in channel • No water within channel • Erosion stable on LHB	
WCk6	• *Phragmites australis* in channel, high cover • Good vegetation on both banks bank • Eucalypt regeneration on LHB • No water within channel • Small *Rubus fruticosus* species aggregate (Blackberry) on LHB	• Vegetation in channel is high, dominated by *Phragmites australis* • Woody vegetation cover is good on both banks • Large *Rubus fruticosus* species aggregate on RHB and small *Rubus fruticosus* species aggregate along LHB
WCk7	• *Phragmites australis* present in channel, high cover • Good vegetation cover on both banks • Regeneration of *Eucalyptus blakelyi* on banks • Large woody debris (LWD), within channel, potential litter trap during high flow events • No water within channel	• Vegetation in channel is high, dominated by *Phragmites australis* • Good vegetation cover on bank, with groundcover on LHB contributing to stabilisation • Woody vegetation is good on both banks • Regeneration of *Angophora floribunda* and *Eucalyptus blakelyi* on both banks
WCk8	• High *Phragmites australis* cover within and edge of channel • Water ponding/pooling, no flow • Good woody vegetation cover on LHB, RHB has good groundcover	• High *Phragmites australis* cover within and edge of channel • Water ponding/pooling, no flow • Some bare patches on RHB, however no erosion • LHB has high groundcover
WCk9	• Erosion on right hand bank (RHB) has been active in past year, currently appears stable • High cover of *Phragmites australis* in channel • Debris washed up into trees from previous high flow events	• High cover of *Phragmites australis* in channel • Good vegetation cover on upper and lower bank • RHB is steep, with mid bank bare due to erosion • Erosion on RHB has been active within the past year, currently appears stable
WCk10	• High cover of *Phragmites australis* in channel and on bank • No water within channel • Eucalyptus regeneration on RHB • Good vegetation cover on RHB	• Good vegetation cover on both banks • High woody vegetation cover on RHB • High cover of *Phragmites australis* in channel • Debris from high flow events washed up onto trees on RHB • No water within channel
WCk11	• High vegetation cover in channel and on banks with *Phragmites australis, Arundinella nepalensis* (Reedgrass), and *Austrostipa verticillata* (Slender bamboo grass) present • *Cyperaceae* sp. in channel	• High cover of *Phragmites australis* in channel • High vegetation cover on both banks • Regeneration of *Eucalyptus blakelyi* in channel • No water in channel

Site	Upstream	Downstream
	• High woody vegetation cover on LHB • Young *E. camaldulensis* and *E. blakelyi* on RHB • No water within channel	
WCk12	• Young *Allocasuarina* species on LHB • Good vegetation cover on both banks • High *Phragmites australis* cover in channel • No water within channel	• High cover of *Phragmites australis* in channel • High woody vegetation cover on both banks • High vegetation cover on both banks, RHB dominated by *Lomandra confertifolia* • Regeneration of *Angophora floribunda* and *Eucalyptus blakelyi* on RHB • No water within channel
WCk13	• Good vegetation cover on banks, high cover of *Phragmites australis* within and on the edge of the channel • Debris washed up from high flow events in channel an on LHB • No water within channel • Eucalypt regengeneration present on both banks	• Regeneration of *Eucalyptus blakelyi* on both banks • Good vegetation cover on both banks • No water within channel
WCk14	• Debris washed up against base of tree from high flow events • High cover of *Phragmites australis* within and on the edge of the channel • Good groundcover and woody vegetation cover on both banks • Regeneration of *Eucalyptus blakelyi* on RHB • No water within channel • Fallow deer on RHB	• High cover of *Phragmites australis* within and on edge of channel • High groundcover on LHB • Regeneration of *Eucalyptus blakelyi* on LHB • No water within channel
WCk15	• High cover of *Phragmites australis* in channel • Good vegetation cover on both banks, which is stabilising LHB • Good groundcover on both banks • No water within channel	• LHB stable with good vegetation cover • High cover of *Phragmites australis* within and on edge of channel • No water within channel
WCk16	• No water within channel • High cover of *Phragmites australis* on the edge of the bank • Good vegetation cover on both banks	• *Phragmites australis* on the edge of RHB • Both banks well vegetated • LHB stable with good vegetation cover • Channel is bare with little vegetation • No water within channel
WCk17	• Highly vegetated with *Phragmites australis* in channel and extended onto bank	• Dense vegetation of *Phragmites australis* in channel at similar cover to 2022 monitoring, is preventing access to point

Site	Upstream	Downstream
	• Regen present on both banks	• *Eucalyptus blakelyi* regeneration on RHB • LHB stable with good vegetation cover
WCk18	• Good vegetation cover on RHB • Good woody vegetation on LHB • *Phragmites australis* on edge of channel • Water ponding/pooling • Erosion on RHB has been active over past year, small amounts of mass wasting	• High cover of *Phragmites australis* within in channel, extending to upper bank • Good vegetation cover on banks • Water ponding/pooling • Erosion on RHB has stabilised due to increased groundcover
WCk19	• High vegetation cover on bank, including *Lomandra confertifolia* (Mat-rush) and *Themeda triandra* • Minor erosion from animal tracks on LHB, currently appears stable • *Phragmites australis* within and on the edge of channel • Water ponding/pooling • Feral pig on LHB	• Good vegetation cover on LHB, dominated by *Lomandra confertifolia* and native grasses • High cover of *Phragmites australis* within in channel • Water ponding/pooling • Bare patches present on LHB, minor erosion has occurred but appears stable
WCk20	• High cover of *Phragmites australis* in channel • Mass wasting has continued on LHB over past year, for approximately 50 m upstream from point • Good groundcover vegetation on lower bank and upper bank, dominated by *Lomandra confertifolia* • Bare soil present mid bank on LHB from erosion	• High cover of *Phragmites australis* within in channel, extending to upper bank • Good vegetation cover on LHB, dominated by *Lomandra confertifolia* and native grasses • Regeneration of *Angophora floribunda* on LHB • *Rubus fruticosus* species aggregate on RHB • No water within channel
WCk21	• Vegetation cover on high, dominated by *Lomandra confertifolia* • High *Phragmites australis* cover within and on the edge of the channel • Eucalypt regeneration present on RHB • No water within channel	• High cover of *Phragmites australis* within in channel • *Angophora floribunda* regeneration on RHB • High groundcover on both banks, dominated by *Lomandra confertifolia*, which has helped stabilise erosion • No water within channel
WCk22	• Good vegetation cover on RHB • Some bare patches of ground on RHB, low bank angle, no active erosion • No riparian tree cover on LHB with only a small riparian zone on RHB	• Erosion on RHB has been active over the past year but currently appears stable • Minimal vegetation cover on RHB, dominated by bare ground • No riparian tree cover on RHB • High cover of *Phragmites australis* within channel • Good vegetation cover on LHB

Site	Upstream	Downstream
	• Eucalypt regeneration present RHB • High *Phragmites australis* cover within and on edges of channel • No water in channel	• No water within channel
WCk23	• High *Phragmites australis* cover within channel • Minor erosion on LHB, however there is good vegetation cover stabilising the bank and regeneration is occurring • Patches of bare soil on RHB, erosion is currently stable • No water in channel	• High cover of *Phragmites australis* within channel • Vegetation cover on RHB is similar to 2022 monitoring • Erosion on RHB appears to have stabilised, though bare ground present • *Rubus fruticosus* species aggregate present
WCk24	• High vegetaion cover on RHB • High cover of *Phragmites australis* in channel with *Juncus* sp. on edge of channel • Erosion on RHB stable • No water in channel	• High cover of *Phragmites australis* and *Typha* sp. within channel • Vegetation cover high on lower RHB • Sediment fence is gone
WCk25	• Bank well vegetated, however dry and dying off • High *Phragmites australis* cover within and on the edge of the channel • Eucalypt regeneration on LHB • Low cover of *Hypericum perforatum* on LHB • Some bare patches, however no active erosion • No water within channel	• High cover of *Phragmites australis* within channel • Bare soil patches on LHB, with active erosion • Good vegetation cover on the upper banks, mainly native grasses, however the groundcover is drying and dying off • *Hypericum perforatum* present on lower LHB
WCk26	• Good vegetation cover on LHB • High *Phragmites australis* cover within channel and extending to upper bank • *Rubus fruticosus* species aggregate present on LHB	• LHB is steep and continues to erode, with evidence of wasting and run off • High cover of *Phragmites australis* within channel • LHB mostly bare due to erosion • Groundcover on upper LHB dying off
WCk27	• High cover of *Phragmites australis* within channel • RHB continues to erode, mass wasting has progressed, undercutting from high flow events in 2022 • Vegetation on top of bank is dry and dying off • No water within channel	• RHB is steep and continues to erode through mass wasting • High *Phragmites australis* cover within channel • Patches of bare soil on lower and mid RHB • Groundcover on upper RHB dying off
WCk28	• Mass wasting on LHB has progressed slightly • Good vegetation cover on banks, slightly less than 2022	• High cover of *Phragmites australis* within channel • LHB steep with evidence of mass wasting erosion over the past year

Site	Upstream	Downstream
	• High cover of *Phragmites australis* in channel • Eucalypt regeneration at top of LHB	• Vegetation cover on upper LHB slightly less • Erosion on RHB currently appears stable however groundcover dying off
WCk29	• *Angophora floribunda* regeneration on LHB • Large *Rubus fruticosus* species aggregate present on LHB • High cover of *Phragmites australis* in channel • Slight increase in erosion around exposed tree root on LHB	• Signs of recent erosion on LHB, mass wasting active on steep bank face, top of bank held by native grasses • Lower and mid LHB is bare • High cover of *Phragmites australis* within channel
WCk30	• High cover of *Phragmites australis* in channel • Extensive wombat burrows on RHB, bank vegetation cover similar to 2022 • Good woody vegetation cover on both banks • Regeneration of *Angophora floribunda* on both banks • RHB dominated by *Lomandra confertifolia* • Water ponding/pooling	• High cover of *Phragmites australis* within channel • Vegetation cover is high on RHB with *Lomandra confertifolia* dominating RHB • *Rubus fruticosus* species aggregate on LHB • Regeneration of *Angophora floribunda* and *Eucalyptus blakelyi* and *Eucalyptus melliodora* on RHB • Water ponding/pooling
WCk31	• Erosion on RHB continues with undercutting and mass wasting, some sections stabilised by high groundcover • High cover of *Phragmites australis* in channel • Vegetation cover on banks is similar to 2022 • Water flowing in channel	• High cover of *Phragmites australis* within channel and extending to banks • Minor erosion on RHB, some evidence of mass wasting progression at top of RHB, however largely stable • Eucalypt regeneration on RHB
WCk32	• High cover of *Phragmites australis* in channel • RHB steep leading to exposed roots of Eucalypts on bank edge. Erosion is slowly progressing due to mass wasting • Bare patches mid bank on RHB, good vegetation cover on upper and lower bank • Very large *Rubus fruticosus* species aggregate at top of RHB which extends to the lower bank • Water ponding/pooled	• Erosion on RHB, largely stable but some evidence of mass wasting • High cover of *Phragmites australis* within channel • RHB dominated by native grasses • Slight increase in bareground on RHB • Very large *Rubus fruticosus* species aggregate at top of RHB which extends to the lower bank
WCk33	• Vegetation is lightly less in 2022 with more bare ground patches, particularly on mid bank • *High Lomandra confertifolia* cover on LHB • High cover of *Phragmites australis* in channel • Erosion has occurred on LHB over past year, currently appears stable in some sections but mass wasting active in some spots	• Active erosion on LHB, exposed root system with active mass wasting around it and increases in bare soil patches • Upper LHB has good vegetation cover • Good vegetation cover on RHB, dominated by *Lomandra confertifolia* • Lots of wombat burrows on RHB • Water ponding/pooling

Site	Upstream	Downstream
	• Water ponding in channel	• Two trees have fallen on LHB, with one over the channel • High cover of *Phragmites australis* within channel
WCk34	• High *Phragmites australis* within channel • Minimal localised erosion along animal tracks on RHB • Minor erosion on RHB, high vegetation cover is stabilising bank • High *Lomandra confertifolia* cover on RHB • Water ponding/pooling	• High cover of *Phragmites australis* within channel • Minor erosion on RHB has stabilised, however there are some bare patches of ground • Good vegetation cover on LHB • High groundcover on RHB dominated by L*omandra confertifolia*
WCk35	• High cover of *Phragmites australis* within channel • RHB bare patches and active erosion progressing slowly with mass wasting, however appears stable • Good vegetation cover on LHB and top of RHB	• High cover of *Phragmites australis* within channel • Vegetation cover on RHB is dominated by native grasses, however there is an increase in bare ground • *Rubus fruticosus* species aggregate within channel • Erosion on RHB has been active over the past year, though has largely stabilised • Good vegetation cover on LHB • No tree cover in riparian zone on RHB
WCk36	• High cover of *Phragmites australis* and *Typha* species within channel • Bare patches and minor erosion on both banks, currently appears stable • RHB vegetation includes a mix of *Verbena bonariensis,* native grasses and *Lomandra confertifolia*	• RHB erosion appears stable with good vegetation cover • Some bare ground on top of RHB • High cover of *Phragmites australis* and *Typha* sp. within channel • No tree cover in riparian zone on either bank • Both banks dominated native grasses and *Lomandra confertifolia*
WCk37	• Decrease in groundcover and increase in bare patches on RHB • Mass wasting progressing slowly • LHB remains well vegetated with minor lateral erosion • High cover of *Phragmites australis* and *Typha* species within channel • Water pooling and flowing slowly	• Vegetation cover high on RHB • Minor erosion on top of RHB, however stable due to good groundcover • High cover of *Phragmites australis* and *Typha* sp. within channel
WCk38	• Slight decrease in groundcover vegetation on banks, some bare ground however no erosion • *Phragmites australis* on edge of channel on LHB • Water ponding and flowing slowly • *Rubus fruticosus* species aggregate present on LHB	• Slight decrease in groundcover vegetation on banks, some bare ground however no erosion • Good woody vegetation cover on both banks • *Rubus fruticosus* species aggregate present on LHB • Water flowing slowly within channel

Site	Upstream	Downstream
WCk39	• Vegetation cover good on upper and lower LHB, however mid bank bare • *Juncus* sp. on edge of channel • Water flowing slowly within channel • Erosion progressing slowly on LHB with evidence of run off and mass wasting, currently appears stable • Regeneration of Eucalypt species on both banks, healthy and growing well • Grazing of channel and bank vegetation due to livestock	• Vegetation cover good on lower and upper LHB • Erosion on LHB recently active, some evidence of mass wasting but largely stable and vegetated • LHB steep with bare mid bank • Regeneration of Eucalypt species on both banks progressing well • *Rubus fruticosus* species aggregate present on RHB • Water flowing within channel • Grazing of channel and bank vegetation due to livestock
WCk40	• Vegetation cover on banks and in channel similar to 2022 • Regeneration of *Eucalyptus blakelyi* on both banks healthy and growing well • LHB erosion remains stable • RHB mostly bare ground with unconsolidated materials, some evidence of erosion but largely stable • Channel and bank vegetation cover high, but grazed due to livestock • Water flowing slowly • Cattle present on both banks and within channel	• Vegetation cover on banks and in channel similar to 2022 • Channel and bank vegetation cover high, but grazed due to livestock, *Juncus* sp. present • RHB mostly bare ground with unconsolidated materials, some evidence of erosion but largely stable • Regeneration occurring on both banks • Water flower slowly in narrow channel • Cattle present on both banks and within channel
WCk41	• RHB exposed tree roots, however vegetation cover is good and is assisting with bank stabilisation, no progression of erosion • RHB stock tracks and hoof prints, pugging on water edge • Macrophytes and *Juncus* sp. in channel • Water poonding/pooling • Channel and bank vegetation cover high, but grazed due to livestock	• Channel and bank vegetation cover high, but grazed due to livestock • Macrophytes and *Juncus* sp. in channel • Erosion on RHB stable • RHB stock tracks and hoof prints, pugging on water edge • Water pooled and moving very slowly
WCk42	• Veg in channel and on banks similar to 2022 • Bank vegetation cover high, but grazed due to livestock • High macrophyte and *Juncus* sp. cover within channel • RHB steep but appears stable, low groundcover • Water flowing in channel	• Erosion on RHB is still active, undercutting and mass wasting present, though overall less compared to previous years • LHB vegetation cover high, but grazed due to livestock • LHB is well vegetated with regeneration of Eucalypts present • High macrophyte and *Juncus* sp. cover within channel • Water flowing in channel

Site	Upstream	Downstream
WCk43	• High cover of macrophytes within channel • Good groundcover on RHB • LHB steep, some progression of mass wasting but appears stable • Water flowing slowly in channel	• High vegetation cover within channel and on the lower and upper LHB • LWD in channel with debris from flow events • LHB steep, some progression of mass wasting but appears stable due to good groundcover • Water flowing slowly in channel
WCk44	• Vegetation cover on RHB similar to 2022, some bare patches • Groundcover dominated by native grass species • Mass wasting on both banks stab due to good vegetation cover • *Juncus* sp. and other macrophytes on edge of channel • LHB appears stable • Water flowing slowly in channel	• Vegetation cover on RHB consistent with 2022, dominated by *Aristida ramosa* and *Bothriochloa macra* • *Phragmites australis* and *Typha* sp. within channel • LHB exposed steep bank appears stable due to good vegetation cover, erosion caused by wombats and animal tracks • Water pooling and flowing slowly
WCk45	• Vegetation cover is similar to 2022 • Water flowing in channel • LHB stable with vegetation cover improving stability • *Eucalyptus blakelyi* and *Eucalyptus melliodora* (Yellow Box) regeneration on both banks	• Vegetation cover similar to 2022, with high vegetation cover on both banks • *Rubus fruticosus* species aggregate on LHB • Regeneration of *Eucalyptus melliodora* and *Eucalyptus blakelyi* on RHB • LHB is steep, with erosion and mass wasting active over the previous year • Goody woody vegetation cover on LHB
WCk46	• High vegetation cover in channel and on banks • Water slowly flowing in channel • Large *Rubus fruticosus* species aggregate on LHB • Animal tracks on RHB causing localised erosion • Large *Angophora floribundas* on both banks with regen present	• High vegetation cover on both banks, including *Juncus* and *Cyperaceae* sp. on RHB • Good woody vegetation cover on RHB • Very slow flow of water • Fallen tree from LHB across channel, causing litter trap • LHB continues to be stabilised due to vegetation cover • RHB is steep with minor erosion but appears to have stabilised
WCk47	• High cover of *Phragmites australis* and *Typha* species within channel • Erosion and mass wasting has slowly progressed on RHB, however is currently stable • Regeneration of *Eucalyptus blakelyi* and *Angophora floribunda* on both banks • LHB is steep but stable with good groundcover • RHB good groundcover on lower and upper bank, dominated by *Lomandra confertifolia*	• High cover of *Phragmites australis* and *Typha* species within channel • Both banks have high cover of groundcover dominated by *Lomandra confertifolia* • Both banks have good woody vegetation cover • RHB is steep, erosion and mass wasting appears stable, mid bank is bare • Water in channel flowing slowly

Site	Upstream	Downstream
WCk48	• Vegetation cover is similar to 2022, with good cover on both banks • High cover of *Phragmites australis* and *Typha* species within channel • Animal tracks on LHB steep and causing localised erosion • Active erosion and undercutting under tree root on LHB, currently appears stable • Water flowing in channel	• *Phragmites australis* and *Typha* species on the edge of channel • Water flowing within channel • Good vegetation cover on both banks • LHB erosion currently stable and held by woody vegetation • Some bare ground on lower LHB • Erosion caused by animal tracks has stabilised
WCk49	• Vegetation cover on banks is similar to 2022 • LHB woody vegetation cover is high and stabilising bank • RHB lateral erosion is currently stable • *Rubus fruticosus* species aggregate on LHB • Water flowing in channel • Sediment and unconsolidated material present in channel	• Water flowing within channel • Good vegetation cover on both banks assisting with stabilising erosion • RHB some minor erosion and bare soil due to high flow events, however groundcover still high • Good woody vegetation cover on LHB stabilising erosion • LHB steep, with some erosion caused by animal tracks
Cumbo Creek		
CCk1	• Vegetation cover within channel similar to 2022, dominated by *Juncus* sp. • Vegetation cover on banks is similar to 2022 and is dominated by *Plantago lanceolata* (Lamb's Tongues) and native grasses • Some regeneration of Eucalypts present • Water pooling within channel	• Vegetation cover on bank and in channel is similar to 2022 • Channel vegetation cover is high, including *Juncus* sp. and *Cyperaceae* sp. • Bank dominated by *Plantago lanceolata* (Lamb's Tongues) and a mixture of native and exotic grasses • Eucalypt regeneration on LHB is healthy and growing well
CCk2	• Vegetation cover on bank and channel high, dominated by *Juncus* sp and native grasses including *Aristida ramosa* • Some bare patches on RHB • Erosion and mass wasting on bank continues to stabilise • Water pooling within channel	• Good vegetation cover in channel and on LHB • Bare soil on RHB, erosion currently appears stable • Channel vegetation cover is high, including *Juncus* sp. and *Cyperaceae* sp. • Mix of native and exotic grass species dominating bank, including *Aristida ramosa*
CCk3	• High vegetation cover on both banks, with a mix of native and exotic grasses • High cover of in stream vegetation, including *Cyperaceae* species • No water within channel • Pig diggings present	• Bank vegetation cover is high • Bank dominated by *Juncus* sp. and Cyperaceae sp. and a mix of native and exotic grass species • Small amounts of *Hypericum perforatum* also present • No water within channel

Site	Upstream	Downstream
CCk4	• Good groundcover within channel and on banks • Bank vegetation is dominated by *Plantago lanceolata* and *Sporobolus creber* (Western Rat-tail Grass) • Small amount of *Hypericum perforatum* • *Rosa rubiginosa* (Sweet Briar) in channel on RHB	• Two large *Rosa rubiginosa* on RHB • Site remains stable with good vegetation cover • Channel vegetation cover is high, including *Juncus* sp. and *Cyperaceae* sp. • Small amounts of *Hypericum perforatum* also present • No water within channel
CCk5	• High cover within channel, dominated by *Juncus* sp. • Groundcover on banks is similar to 2022, dominated by *Plantago lanceolata* and native grasses including *Sporobolus creber* and *Aristida ramosa* • Small amounts of *Hypericum perforatum* present • Bare ground on RHB	• Vegetation cover is high and similar to 2022 • Vegetation cover within channel is dominated by *Juncus* sp. • Upper bank dominated by *Plantago lanceolata, Paspalum dilatatum* and *Cynodon dactylon* • Small amounts of *Hypericum perforatum* also present • No water within channel
CCk6	• Channel vegetation cover high • Upper banks dominated by *Lomandra filiformis* (Wattle Mat-rush) as well as *Paspalum dilatatum* and *Cynodon dactylon* and *Juncus* sp. • No water within channel	• Channel is bare with no vegetation • Vegetation cover on banks is high and is dominated by *Lomandra filiformis* (Wattle Mat-rush) as well as *Paspalum dilatatum, Bromus* sp. and *Juncus* sp. • Small water pool within channel
CCk7	• Vegetation within channel and on banks very high, dominated by *Paspalum dilatatum*, *Bromus* sp. and *Plantago lanceolata* No water within channel	• Vegetation within channel and on banks very high, dominated by *Paspalum dilatatum*, *Bromus* sp. and *Plantago lanceolata* • No water within channel
CCk8	• High cover of *Phragmites australis* within channel • Vegetation on bank is dominated by *Paspalum dilatatum, Sporobolus creber* and *Plantago lanceolata* • Small amount of *Hypericum perforatum* present on LHB	• High vegetation cover in channel, with *Phragmites australis, Juncus* sp., and *Cyperaceae* sp. present • Good vegetation cover on banks, including *Paspalum dilatatum Bromus* sp. and *Sporobolus creber*
CCk9	• Vegetation cover is similar to 2022, • Vegetation cover is high and dominated by *Cyperaceae* sp. within the channel and mixed native and exotic grasses on both banks	• Vegetation cover is similar to 2022 • Erosion has been stabilised by vegetation cover • Bank is dominated by mixed native and exotic grass species • Channel vegetation cover is high and dominated by *Cyperaceae* sp.and *Typha* sp.
CC10	• Vegetation cover is similar to 2022, • Vegetation cover is high and dominated by *Cyperaceae* sp. within the channel and mixed native and exotic grasses on both banks • Water pooling/ponding	• Vegetation is similar to 2022 • Vegetation cover is high and dominated by *Cyperaceae* sp. within the channel and mixed native and exotic grasses on both banks • LHB erosion is currently stable • Water pooling/ponding

Figure 6: Location of listed weeds and feral animals along Wilpinjong Creek and Cumbo Creek

4. Discussion and Recommendations

Of the 49 sites surveyed along Wilpinjong Creek, 36 sites recorded scores in the stable range, whilst 13 sites recorded scores in the unstable range (Table 2). The lowest scoring sites (all Moderately Unstable) were WCk27 and WCk42, both of which have scored Moderately Unstable since 2018 and 2017 respectively. These sites were typified by mass sediment wasting, high cover of unconsolidated material, less than 50% streambank protection and limited to no riparian woodland.

The western section of Wilpinjong Creek (incorporating WCk1 to WCk16) contains good areas of natural regeneration, with overall moderate to good riparian woodland vegetation and habitat present. There was some regeneration of *Eucalyptus* sp. recorded along the banks. Overall groundcover declined slightly, due to drier conditions and grazing pressure in 2023, however, in stream vegetation cover of *Phragmites australis* (Common Reed) remained consistent despite significantly reduced water levels.

The middle section of Wilpinjong Creek (incorporating sites WCk17 to WCk44) is characterised by cleared adjacent paddocks and narrow, scattered riparian woodland (where present). Widespread historic clearing in this section of the creek has a pronounced influence on the channel stability scores, with unstable BEHI scores consistently recorded for Established Beneficial Riparian Woody Vegetation Cover. There was a slight decrease in groundcover at some sites, however this has had no impact to the overall score. A high cover of *Phragmites australis* within the channel was recorded at most sites.

The eastern section of Wilpinjong Creek (incorporating sites WCk45 to WCk49) is characterised by a relatively steep and narrow valley, which has resulted in a straight channel with an overall high bank height. All sites within this section are stable, with most sites in a moderately stable condition, in part due to the high groundcover and presence of woody vegetation on the banks which is assisting in stabilising the steep bank form erosion.

Of the ten sites surveyed along Cumbo Creek, all were in the Stable range, with 9 out of 10 sites Highly Stable (Table 3). The reach of Cumbo Creek is characterised by a shallow meandering channel with low stable banks. The adjacent paddocks have been historically cleared with only very sparse riparian vegetation woodland remaining. Despite the lack of woody riparian vegetation, the creek remains in a stable condition, primarily due to high groundcover. Groundcover species can assist in providing mid and upper bank sections with greater protection from scour, as they slow water flow close to the bank (Abernathy and Rutherford 1999).

4.1. Multi-year comparisons

Following on from the baseline channel stability assessment of Wilpinjong and Cumbo Creeks undertaken in 2005 as part of the WCPL EIS (WCPL 2005), annual monitoring has been undertaken during 2011, and 2014 – 2023. Annual monitoring since 2011 shows that the channel stability has remained relatively constant, both upstream and downstream of WCM. The following sections compare 2023 results to the results of previous monitoring years detailed above.

4.1.1. Site stability scores

Site channel stability data in the form of BEHI scores are available from 2016 – 2022 for direct comparison. Site stability ratings (based on BEHI scores) for Wilpinjong Creek sites are presented in

Table 5, with Cumbo Creek ratings presented in Table 6. Differences in ratings were only noted as 'Improved' or 'Declined' where a trend was observed over two consecutive years. If no differences were observed over three consecutive years (inclusive of 2023), the ratings were determined to be unchanged, indicating a consistent stability rating for that site. For Wilpinjong Creek, ratings improved at five sites, remained unchanged at 39 sites, and declined at five sites. For Cumbo Creek, ratings remained unchanged at all sites.

Three sites recorded stability improvements and four sites recorded declines along Wilpinjong Creek between 2022 and 2023, however, these will be assessed in the next monitoring period to determine any three yearly differences. The mostly consistent results from 2016 to 2023 at Cumbo Creek reflects the overall stable nature of this creek, with most sites classified as Highly Stable.

The five sites that recorded declines in stability ratings along Wilpinjong Creek between 2021 and 2022 maintained this difference in 2023. Declines observed during 2023 monitoring can be attributed to the impact of high flow events resulting from flooding in 2022, followed by drier conditions in 2023, leading to a reduction in groundcover vegetation. Decreased vegetation cover is directly linked to decreased scores for *Streambank Protection* and associated decreased scores for *Unconsolidated Material*. Of the 10 sites that recorded improvements in stability ratings along Wilpinjong Creek between 2021 and 2023, five maintained this difference in 2023. This indicates that decreased vegetation cover was not uniform throughout the catchment and had varying effects on different sites.

Table 5: Wilpinjong Creek site stability scores 2016-2023 comparisons

Site	2016 Rating	2017 Rating	2018 Rating	2019 Rating	2020 Rating	2021 Rating	2022 Rating	2023 Rating	Difference
WCk1	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Stable	Unchanged
WCk2	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk3	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unchanged
WCk4	Highly Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Unstable	Unstable	Unstable	Unstable	Unchanged
WCk5	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Highly Stable	Highly Stable	Moderately Stable	Moderately Stable	Declined
WCk6	Stable	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Moderately Stable	Unchanged
WCk7	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
WCk8	Stable	Stable	Stable	Unstable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk9	Unstable	Stable	Stable	Unstable	Stable	Stable	Unstable	Unstable	Declined
WCk10	Highly Stable	Highly Stable	Moderately Stable	Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
WCk11	Moderately Stable	Highly Stable	Highly Stable	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
WCk12	Moderately Stable	Highly Stable	Highly Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk13	Stable	Moderately Stable	Stable	Stable	Highly Stable	Highly Stable	Moderately Stable	Moderately Stable	Declined
WCk14	Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged

Site	2016 Rating	2017 Rating	2018 Rating	2019 Rating	2020 Rating	2021 Rating	2022 Rating	2023 Rating	Difference
WCk15	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Highly Stable	Highly Stable	Improved
WCk16	Highly Stable	Moderately Stable	Moderately Stable	Stable	Highly Stable	Highly Stable	Highly Stable	Moderately Stable	Unchanged
WCk17	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
WCk18	Stable	Stable	Stable	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk19	Unstable	Stable	Stable	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Highly Stable	Unchanged
WCk20	Unstable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Stable	Stable	Declined
WCk21	Unstable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk22	Moderately Unstable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Unchanged
WCk23	Moderately Unstable	Stable	Stable	Stable	Unstable	Unstable	Unstable	Stable	Unchanged
WCk24	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Moderately Stable	Moderately Stable	Improved
WCk25	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Stable	Unchanged
WCk26	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unchanged
WCk27	Stable	Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Unchanged
WCk28	Unstable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Unchanged
WCk29	Unstable	Stable	Stable	Unstable	Unstable	Unstable	Unstable	Unstable	Unchanged

Site	2016 Rating	2017 Rating	2018 Rating	2019 Rating	2020 Rating	2021 Rating	2022 Rating	2023 Rating	Difference
WCk30	Stable	Moderately Stable	Highly Stable	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
WCk31	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unchanged
WCk32	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Unstable	Unstable	Unstable	Unchanged
WCk33	Moderately Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unchanged
WCk34	Unstable	Unstable	Unstable	Unstable	Stable	Stable	Moderately Stable	Moderately Stable	Improved
WCk35	Stable	Moderately Stable	Stable	Stable	Stable	Stable	Unstable	Unstable	Declined
WCk36	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderatley Stable	Unchanged
WCk37	Stable	Stable	Stable	Stable	Unstable	Unstable	Stable	Stable	Unchanged
WCk38	Stable	Stable	Stable	Stable	Moderately Stable	Moderately Stable	Highly stable	Moderately Stable	Unchanged
WCk39	Stable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unchanged
WCk40	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unchanged
WCk41	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Highly Stable	Highly Stable	Improved
WCk42	Highly Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Unchanged
WCk43	Not surveyed	Unstable	Unstable	Unstable	Unstable	Unstable	Stable	Stable	Improved
WCk44	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Highly Stable	Moderately Stable	Unchanged
WCk45	Stable	Stable	Stable	Stable	Moderately Stable	Moderately Stable	Highly Stable	Moderately Stable	Unchanged

Site	2016 Rating	2017 Rating	2018 Rating	2019 Rating	2020 Rating	2021 Rating	2022 Rating	2023 Rating	Difference
WCk46	Stable	Moderately Stable	Moderately Stable	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk47	Stable	Moderately Stable	Stable	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Stable	Unchanged
WCk48	Stable	Stable	Stable	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk49	Stable	Stable	Stable	Unstable	Stable	Stable	Stable	Stable	Unchanged

Table 6: Cumbo Creek site stability scores 2016-2023 comparison

Site	2016 Rating	2017 Rating	2018 Rating	2019 Rating	2020 Rating	2021 Rating	2022 Rating	2023 Rating	Difference
CCK1	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
CCK2	Moderately Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Unchanged
CCK3	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
CCK4	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
CCK5	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
CCK6	Moderately Stable	Highly Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Highly Stable	Unchanged
CCK7	Not surveyed	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
CCK8	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
CCK9	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
CCK10	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged

4.1.2. Photographic comparisons

Photographic comparisons of sites across 2020 – 2023 monitoring are included in Appendix B. Photos taken from 2011 and 2014 – 2019 monitoring were also compared, however are not included in this report due to size. Previous reports can be referred to for photo comparisons with earlier years.

Comparisons indicate that there has been little observable change in the overall morphology of the stream channel and banks, with little evidence of any significant ongoing erosional features. The only notable feature is the level of groundcover on the banks has either remained consistent or decreased slightly compared to 2022, after a sustained, clear increase in vegetation cover recorded over the past three years. This is largely due to a decline in rainfall in 2023 (Appendix C) and an increase in livestock grazing pressure at sites within Wilpinjong Creek. Despite this, in stream cover of *Phragmites australis* and other macrophytes was largely maintained in 2023. Vegetation bank composition remained similar in 2023, with dominant groundcover species including a mixture of native and exotic species, such as *Aristida ramosa* (Purple wiregrass), *Sporobolus creber* (Western Rat-tail Grass), *Paspalum dilatatum* (Paspalum), and *Plantago lanceolata* (Lamb's Tongues).

Water levels were also notably lower within Wilpinjong Creek and Cumbo Creek in 2023 compared to 2022. Most CSM sites upstream of WCPL water discharge location were either completely dry or had water confined to pools/ponds at the time of monitoring. Downstream of the WCPL discharge point water levels were very low and slow flowing. There was no water flow within Cumbo Creek, with only isolated pools observed throughout its reach during monitoring.

Overall, reductions in vegetation cover and water levels visible in site photos observed both upstream and downstream of the WCPL water discharge location can be attributed to the below average rainfall recorded during 2023.

4.2. Erosion points

Table 7 provides photos of the significant erosion points along Wilpinjong and Cumbo Creeks (see Figure 2 above). These sites were identified as having moderate to severe historical erosion and the potential for continued erosion during times of downstream and lateral flow. Progression of erosion was minimal and only observed at half of the 2023 monitoring points, with all sites stable at the time of monitoring. Sites E1, E3, and E4 showed evidence of ongoing mass wasting. Site E7 displayed rilling and undercutting, with further mass wasting observed. Site E9 had further progression of bank undercutting and mass wasting. Sites E2, E6, E8, E10, and E11 all displayed evidence of erosion; however, they had largely stabilised over the previous year and showed no signs of obvious erosion progression at the time of monitoring.

Table 7: Significant erosion points and suggested remediation works

Erosion point	Image	Notes / suggested works
E1 (768557, 6422438)		Mass wasting has continued at top of bank. Reshaping and contouring of bank and revegetation (Section 4.3).
E2 (768469, 6422527)		Rills formed on exposed bare soil with mass wasting also evident. No evidence of active erosion at the time of monitoring. A reduction in groudcover on upper bank due to livestock grazing. Revegetation and mulching (Section 4.3).

Erosion point	Image	Notes / suggested works
E3 (768558, 6422432)		Evidence of continued mass wasting at top of bank and around tree roots. Reshaping and contouring of bank and revegetation (Section 4.3).
E4 (768614, 6422382)		Erosion has been active over the past year with some mass wasting evident at top of bank. Reshaping and contouring of bank and revegetation (Section 4.3).
E6 (772166, 6420287)		Erosion appears stable on the steep banks with no further mass wasting or undercutting observed at the time of monitoring. Reshaping and contouring of bank and revegetation (Section 4.3).

Erosion point	Image	Notes / suggested works
E7 (772431, 6420352)		Undercutting and rilling evident. A small amount of mass wasting has occurred over the past year. Revegetation (Section 4.3)
E8 (773014, 6420339)		Road continues to be stable with no further erosion evident. Some mass wasting evident on right side of the road heading upstream, which is largely stable. Continue to monitor rill.
E9 (773397, 6420376)		Erosion has continued to progress with evidence of undercutting and mass wasting. Tree roots on bank edge exposed. Reshaping and contouring of bank and revegetation (Section 4.3).

Erosion point	Image	Notes / suggested works
E10 (773772, 6420328)		Mass wasting and rilling on bank. Erosion appears to have stabilised over the past year. Not active at time of monitoring. Revegetation and mulching (Section 4.3)
E11 (771670, 6419956)		Mass wasting, undercutting, rilling and runoff of soil apparent. No evidence of further erosion at the time of monitoring. Reshaping of bank, revegetation and mulching (Section 4.3).

4.3. Revegetation and remediation

Revegetation work is recommended to target most of the erosion points, except for E8. The establishment of riparian vegetation can assist in stabilising banks and slow surface runoff (Abernathy and Rutherford 1999). Sites E1, E3, E4, E6 and E9 have very steep and exposed banks, which without intervention will continue to erode. This erosion can range from minor activity to gully retreat, bank collapse, and further root exposure. As these banks become higher, and the bank angle becomes greater, which will lead to further erosion. Therefore, it is recommended that these banks are initially reshaped to reduce the overall bank angle, before undertaking revegetation works.

Meanwhile, with site E2 showing evidence of rilling, the application of mulch to the bank sides (including hydro-mulch) is recommended to assist stabilisation until vegetation establishes, along with the installation of coarse-rock, large-woody debris, coir logs and/or hay bale check dams to reduce water flow in designated erosion points. Mulching is also recommended for sites E2, E10, and E11 before revegetation works to assist in stabilisation. Temporary fencing works in all areas will also assist in excluding native and introduced fauna from revegetation and remediation areas.

Previous revegetation works were undertaken in 2019 by WCPL on a 1.6 km section of Wilpinjong Creek, approximately between sites WCk25 and WCk27 (see Figure 1), and in 2020 along approximately 1.9 km of Cumbo Creek and 1 km of Wilpinjong Creek using tubestock of native species. Further survival assessments are recommended to determine the ongoing success of these revegetation works as well as an additional updates on ongoing or future revegetation works planned along these two channels.

4.4. Exclusion of livestock

Livestock (cattle) access to the riparian zone continues to impact on the overall stability and riparian health of Wilpinjong Creek. The impact of livestock was apparent in the far-western section of Wilpinjong Creek (incorporating sites WCk1 to WCk4), with heavy grazing observed of riparian and instream vegetation at each of these four sites. Evidence of stock presence was also observed in the eastern section of Wilpinjong Creek (incorporating sites WCk38 to WCk42), with grazing and pugging from livestock observed at sites WCk39 and WCk40. The preceding drier conditions in the lead up to 2023 monitoring likely exacerbated the impact of stock grazing in these two sections on Wilpinjong Creek. Excluding stock from the riparian zone in these areas, is recommended to improve creek stability and health and assist natural regeneration.

5. Conclusion

The channel stability of both Wilpinjong and Cumbo Creeks is characteristic of ephemeral systems in agricultural landscapes, and consistent with other creeks in the surrounding region. Both creek systems exhibit characteristic channel stability issues associated with agricultural landscapes including:

- Historically cleared and degraded riparian vegetation and the presence of exotic species, including Regional Priority Weeds such as *Rubus fruticosus* species aggregate, *Rosa rubiginosa* and *Hypericum perforatum*.
- Lateral gully-erosion at several locations, due to an increase in runoff velocity occurring perpendicular to the creek line from adjacent cleared paddocks.
- Continued livestock access contributing to bank instability, reducing in-stream and riparian vegetation and hampering natural regeneration.
- Introduced and native fauna (e.g. European Rabbit and Common Wombat) burrowing within the riparian zone.

The 2023 period recorded rainfall levels that were below the historical average leading to a large decrease in water flowing throughout the Wilpinjong catchment in comparison to the previous three monitoring periods (2020-2022). As a result, there was little evidence of erosion progression at the CSM sites, with the main impact being reduced riparian and instream vegetation cover due to the drier conditions and livestock grazing. Minor erosion was observed at half of the erosion monitoring points; however, they were all largely stable and not active during the monitoring period as a result of decreased rainfall and flow. Flow both upstream and downstream of the WCM was greatly reduced compared to 2022.

Erosion and bank stability issues within the Wilpinjong and Cumbo Creeks are the result of historic agricultural practices within the riparian zone, including widespread clearing and direct and ongoing stock access to the bank and channel. There is no evidence that mining activities are adversely impacting the channel stability of the target creeks surrounding the WCM.

6. References

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Appendix A BEHI Assessment Scoring

Indicator	Measure	Score
1. Bank Height (m)	0 - 1.5	0
	1.5-3	2.5
	3-4.5	5
	4.5-6	7.5
	6+	10
2. Bank Angle (°)	0-20	0
	21-60	2
	61-80	4
	81-90	6
	91-120	8
	> 120	10
3. Percentage of Bank Height with a Bank Angle Greater than 80°	0-10	0
	11 to 25	2.5
	26-50	5
	51-75	7.5
	76-100	10
4. Evidence of Mass Wasting (% of Bank)	0-10	0
	11 to 25	2.5
	26-50	5
	51-75	7.5
	76-100	10
5. Unconsolidated Material (% of Bank)	0-10	0
	11 to 25	2.5
	26-50	5
	51-75	7.5
	76-100	10
6. Streambank Protection (% of Streambank covered by plant roots, vegetation, logs, branches, rocks, etc.)	0-10	15
	11 to 25	12.5
	26-50	10
	51-70	7.5
	70-90	2.5
	90-100	0
7. Established Beneficial Riparian Woody – Vegetation Cover	0-10	15
	11 to 25	12.5

Indicator	Measure	Score
	26-50	10
	51-70	7.5
	70-90	2.5
	90-100	0
8. Stream Curvature Descriptor	Meander	5
	Shallow Curve	2.5
	Straight	0
Site Ratings (totals)	Highly Stable	0-25
	Mod Stable	26-35
	Stable	36-45
	Unstable	46-55
	Mod Unstable	56-65
	Highly Unstable	66-85

Appendix B Site Photo Comparisons

WCK 1

Figure B - 1: 2023 upstream

Figure B - 2: 2022 upstream

Figure B - 3: 2021 upstream

Figure B - 4: 2020 upstream

Figure B - 5: 2023 downstream

Figure B - 6: 2022 downstream

Figure B - 7: 2021 downstream

Figure B - 8: 2020 downstream

WCK 2

Figure B - 9: 2023 upstream

Figure B - 10: 2022 upstream

Figure B - 11: 2021 upstream

Figure B - 12: 2020 upstream

Figure B - 13: 2023 downstream

Figure B - 14: 2022 downstream

Figure B - 15: 2021 downstream

Figure B - 16: 2020 downstream

WCK 3

Figure B - 17: 2023 upstream

Figure B - 18: 2022 upstream

Figure B - 19: 2021 upstream

Figure B - 20: 2020 upstream

Figure B - 21: 2023 downstream

Figure B - 22: 2022 downstream

Figure B - 23: 2021 downstream

Figure B - 24: 2020 downstream

WCK 4

Figure B - 25: 2023 upstream

Figure B - 26: 2022 upstream

Figure B - 27: 2021 upstream

Figure B - 28: 2020 upstream

Figure B - 29: 2023 downstream

Figure B - 30: 2022 downstream

Figure B - 31: 2021 downstream

Figure B - 32: 2020 downstream

WCK 5

Figure B - 33: 2023 upstream

Figure B - 34: 2022 upstream

Figure B - 35: 2021 upstream

Figure B - 36: 2020 upstream

Figure B - 37: 2023 downstream

Figure B - 38: 2022 downstream

Figure B - 39: 2021 downstream

Figure B - 40: 2020 downstream

WCK 6

Figure B - 41: 2023 upstream

Figure B - 42: 2022 upstream

Figure B - 43: 2021 upstream

Figure B - 44: 2020 upstream

Figure B - 45: 2023 downstream

Figure B - 46: 2022 downstream

Figure B - 47: 2021 downstream

Figure B - 48: 2020 downstream

WCK 7

Figure B - 49: 2023 upstream

Figure B - 50: 2022 upstream

Figure B - 51: 2021 upstream

Figure B - 52: 2020 upstream

Figure B - 53: 2023 downstream

Figure B - 54: 2022 downstream

Figure B - 55: 2021 downstream

Figure B - 56: 2020 downstream

WCK 8

Figure B - 57: 2023 upstream

Figure B - 58: 2022 upstream

Figure B - 59: 2021 upstream

Figure B - 60: 2020 upstream

Figure B - 61: 2023 downstream

Figure B - 62: 2022 downstream

Figure B - 63: 2021 downstream

Figure B - 64: 2020 downstream

WCK 9

Figure B - 65: 2023 upstream

Figure B - 66: 2022 upstream

Figure B - 67: 2021 upstream

Figure B - 68: 2020 upstream

Figure B - 69: 2023 downstream

Figure B - 70: 2022 downstream

Figure B - 71: 2021 downstream

Figure B - 72: 2020 downstream

WCK 10

Figure B - 73: 2023 upstream

Figure B - 74: 2022 upstream

Figure B - 75: 2021 upstream

Figure B - 76: 2020 upstream

Figure B - 77: 2023 downstream

Figure B - 78: 2022 downstream

Figure B - 79: 2021 downstream

Figure B - 80: 2020 downstream

WCK 11

Figure B - 81: 2023 upstream

Figure B - 82: 2022 upstream

Figure B - 83: 2021 upstream

Figure B - 84: 2020 upstream

Figure B - 85: 2023 downstream

Figure B - 86: 2022 downstream

Figure B - 87: 2021 downstream

Figure B - 88: 2020 downstream

WCK 12

Figure B - 89: 2023 upstream

Figure B - 90: 2022 upstream

Figure B - 91: 2021 upstream

Figure B - 92: 2020 upstream

Figure B - 93: 2023 downstream

Figure B - 94: 2022 downstream

Figure B - 95: 2021 downstream

Figure B - 96: 2020 downstream

WCK 13


Figure B - 97: 2023 upstream


Figure B - 98: 2022 upstream


Figure B - 99: 2021 upstream


Figure B - 100: 2020 upstream


Figure B - 101: 2023 downstream


Figure B - 102: 2022 downstream


Figure B - 103: 2021 downstream


Figure B - 104: 2020 downstream

WCK 14

Figure B - 105: 2023 upstream

Figure B - 106: 2022 upstream

Figure B - 107: 2021 upstream

Figure B - 108: 2020 upstream

Figure B - 109: 2023 downstream

Figure B - 110: 2022 downstream

Figure B - 111: 2021 downstream

Figure B - 112: 2020 downstream

WCK 15

Figure B - 113: 2023 upstream

Figure B - 114: 2022 upstream

Figure B - 115: 2021 upstream

Figure B - 116: 2020 upstream

Figure B - 117: 2023 downstream

Figure B - 118: 2022 downstream

Figure B - 119: 2021 downstream

Figure B - 120: 2020 downstream

WCK 16

Figure B - 121: 2023 upstream

Figure B - 122: 2022 upstream

Figure B - 123: 2021 upstream

Figure B - 124: 2020 upstream

Figure B - 125: 2023 downstream

Figure B - 126: 2022 downstream

Figure B - 127: 2021 downstream

Figure B - 128: 2020 downstream

WCK 17

Figure B - 129: 2023 upstream

Figure B - 130: 2022 upstream

Figure B - 131: 2021 upstream

Figure B - 132: 2020 upstream

Figure B - 133: 2023 downstream

Figure B - 134: 2022 downstream

Figure B - 135: 2021 downstream

Figure B - 136: 2020 downstream

WCK 18

Figure B - 137: 2023 upstream

Figure B - 138: 2022 upstream

Figure B - 139: 2021 upstream

Figure B - 140: 2020 upstream

Figure B - 141: 2023 downstream

Figure B - 142: 2022 downstream

Figure B - 143: 2021 downstream

Figure B - 144: 2020 downstream

WCK 19

Figure B - 145: 2023 upstream

Figure B - 146: 2022 upstream

Figure B - 147: 2021 upstream

Figure B - 148: 2020 upstream

Figure B - 149: 2023 downstream

Figure B - 150: 2022 downstream

Figure B - 151: 2021 downstream

Figure B - 152: 2020 downstream

WCK 20

Figure B - 153: 2023 upstream

Figure B - 154: 2022 upstream

Figure B - 155: 2021 upstream

Figure B - 156: 2020 upstream

Figure B - 157: 2023 downstream

Figure B - 158: 2022 downstream

Figure B - 159: 2021 downstream

Figure B - 160: 2020 downstream

WCK 21


Figure B - 161: 2023 upstream


Figure B - 162: 2022 upstream


Figure B - 163: 2021 upstream


Figure B - 164: 2020 upstream


Figure B - 165: 2023 downstream


Figure B - 166: 2022 downstream


Figure B - 167: 2021 downstream


Figure B - 168: 2020 downstream

WCK 22

Figure B - 169: 2023 upstream

Figure B - 170: 2022 upstream

Figure B - 171: 2021 upstream

Figure B - 172: 2020 upstream

Figure B - 173: 2023 downstream

Figure B - 174: 2022 downstream

Figure B - 175: 2021 downstream

Figure B - 176: 2020 downstream

WCK 23

Figure B - 177: 2023 upstream

Figure B - 178: 2022 upstream

Figure B - 179: 2021 upstream

Figure B - 180: 2020 upstream

Figure B - 181: 2023 downstream

Figure B - 182: 2022 downstream

Figure B - 183: 2021 downstream

Figure B - 184: 2020 downstream

WCK 24


Figure B - 185: 2023 upstream


Figure B - 186: 2022 upstream


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Figure B - 192: 2020 downstream

WCK 25

Figure B - 193: 2023 upstream

Figure B - 194: 2022 upstream

Figure B - 195: 2021 upstream

Figure B - 196: 2020 upstream

Figure B - 197: 2023 downstream

Figure B - 198: 2022 downstream

Figure B - 199: 2021 downstream

Figure B - 200: 2020 downstream

WCK 26

Figure B - 201: 2023 upstream

Figure B - 202: 2022 upstream

Figure B - 203: 2021 upstream

Figure B - 204: 2020 upstream

Figure B - 205: 2023 downstream

Figure B - 206: 2022 downstream

Figure B - 207: 2021 downstream

Figure B - 208: 2020 downstream

WCK 27

Figure B - 209: 2023 upstream

Figure B - 210: 2022 upstream

Figure B - 211: 2021 upstream

Figure B - 212: 2020 upstream

Figure B - 213: 2023 downstream

Figure B - 214: 2022 downstream

Figure B - 215: 2021 downstream

Figure B - 216: 2020 downstream

WCK 28

Figure B - 217: 2023 upstream

Figure B - 218: 2022 upstream

Figure B - 219: 2021 upstream

Figure B - 220: 2020 upstream

Figure B - 221: 2023 downstream

Figure B - 222: 2022 downstream

Figure B - 223: 2021 downstream

Figure B - 224: 2020 downstream

WCK 29

Figure B - 225: 2023 upstream

Figure B - 226: 2022 upstream

Figure B - 227: 2021 upstream

Figure B - 228: 2020 upstream

Figure B - 229: 2023 downstream

Figure B - 230: 2022 downstream

Figure B - 231: 2021 downstream

Figure B - 232: 2020 downstream

WCK 30

Figure B - 233: 2023 upstream

Figure B - 234: 2022 upstream

Figure B - 235: 2021 upstream

Figure B - 236: 2020 upstream

Figure B - 237: 2023 downstream

Figure B - 238: 2022 downstream

Figure B - 239: 2021 downstream

Figure B - 240: 2020 downstream

WCK 31

Figure B - 241: 2023 upstream

Figure B - 242: 2022 upstream

Figure B - 243: 2021 upstream

Figure B - 244: 2020 upstream

Figure B - 245: 2023 downstream

Figure B - 246: 2022 downstream

Figure B - 247: 2021 downstream

Figure B - 248: 2020 downstream

WCK 32

Figure B - 249: 2023 upstream

Figure B - 250: 2022 upstream

Figure B - 251: 2021 upstream

Figure B - 252: 2020 upstream

Figure B - 253: 2023 downstream

Figure B - 254: 2022 downstream

Figure B - 255: 2021 downstream

Figure B - 256: 2020 downstream

WCK 33

Figure B - 257: 2023 upstream

Figure B - 258: 2022 upstream*

Figure B - 259: 2021 upstream

Figure B - 260: 2020 upstream

Figure B - 261: 2023 downstream

Figure B - 262: 2022 downstream*

Figure B - 263: 2021 downstream

Figure B - 264: 2020 downstream

WCK 34

Figure B - 265: 2023 upstream

Figure B - 266: 2022 upstream

Figure B - 267: 2021 upstream

Figure B - 268: 2020 upstream

Figure B - 269: 2023 downstream

Figure B - 270: 2022 downstream

Figure B - 271: 2021 downstream

Figure B - 272: 2020 downstream

WCK 35

Figure B - 273: 2023 upstream

Figure B - 274: 2022 upstream

Figure B - 275: 2021 upstream

Figure B - 276: 2020 upstream

Figure B - 277: 2023 downstream

Figure B - 278: 2022 downstream

Figure B - 279: 2021 downstream

Figure B - 280: 2020 downstream

WCK 36

Figure B - 281: 2023 upstream

Figure B - 282: 2022 upstream

Figure B - 283: 2021 upstream

Figure B - 284: 2020 upstream

Figure B - 285: 2023 downstream

Figure B - 286: 2022 downstream

Figure B - 287: 2021 downstream

Figure B - 288: 2020 downstream

WCK 37

Figure B - 289: 2023 upstream

Figure B - 290: 2022 upstream

Figure B - 291: 2021 upstream

Figure B - 292: 2020 upstream

Figure B - 293: 2023 downstream

Figure B - 294: 2022 downstream

Figure B - 295: 2021 downstream

Figure B - 296: 2020 downstream

WCK 38

Figure B - 297: 2023 upstream

Figure B - 298: 2022 upstream

Figure B - 299: 2021 upstream

Figure B - 300: 2020 upstream

Figure B - 301: 2023 downstream

Figure B - 302: 2022 downstream

Figure B - 303: 2021 downstream

Figure B - 304: 2020 downstream

WCK 39

Figure B - 305: 2023 upstream

Figure B - 306: 2022 upstream

Figure B - 307: 2021 upstream

Figure B - 308: 2020 upstream

Figure B - 309: 2023 downstream

Figure B - 310: 2022 downstream

Figure B - 311: 2021 downstream

Figure B - 312: 2020 downstream

WCK 40

Figure B - 313: 2023 upstream

Figure B - 314: 2022 upstream

Figure B - 315: 2021 upstream

Figure B - 316: 2020 upstream

Figure B - 317: 2023 downstream

Figure B - 318: 2022 downstream

Figure B - 319: 2021 downstream

Figure B - 320: 2020 downstream

WCK 41

Figure B - 321: 2023 upstream

Figure B - 322: 2022 upstream

Figure B - 323: 2021 upstream

Figure B - 324: 2020 upstream

Figure B - 325: 2023 downstream

Figure B - 326: 2022 downstream

Figure B - 327: 2021 downstream

Figure B - 328: 2020 downstream

WCK 42

Figure B - 329: 2023 upstream

Figure B - 330: 2022 upstream

Figure B - 331: 2021 upstream

Figure B - 332: 2020 upstream

Figure B - 333: 2023 downstream

Figure B - 334: 2022 downstream

Figure B - 335: 2021 downstream

Figure B - 336: 2020 downstream

WCK 43

Figure B - 337: 2023 upstream

Figure B - 338: 2022 upstream

Figure B - 339: 2021 upstream

Figure B - 340: 2020 upstream

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Figure B - 343: 2021 downstream

Figure B - 344: 2020 downstream

WCK 44

Figure B - 345: 2023 upstream

Figure B - 346: 2022 upstream

Figure B - 347: 2021 upstream

Figure B - 348: 2020 upstream

Figure B - 349: 2023 downstream

Figure B - 350: 2022 downstream

Figure B - 351: 2021 downstream

Figure B - 352: 2020 downstream

WCK 45

Figure B - 353: 2023 upstream

Figure B - 354: 2022 upstream

Figure B - 355: 2021 upstream

Figure B - 356: 2020 upstream

Figure B - 357: 2023 downstream

Figure B - 358: 2022 downstream

Figure B - 359: 2021 downstream

Figure B - 360: 2020 downstream

WCK 46


Figure B - 361: 2023 upstream


Figure B - 362: 2022 upstream


Figure B - 363: 2021 upstream


Figure B - 364: 2020 upstream


Figure B - 365: 2023 downstream


Figure B - 366: 2022 downstream


Figure B - 367: 2021 downstream


Figure B - 368: 2020 downstream

WCK 47


Figure B - 369: 2023 upstream


Figure B - 370: 2022 upstream


Figure B - 371: 2021 upstream


Figure B - 372: 2020 upstream


Figure B - 373: 2023 downstream


Figure B - 374: 2022 downstream


Figure B - 375: 2021 downstream


Figure B - 376: 2020 downstream

WCK 48

Figure B - 377: 2023 upstream

Figure B - 378: 2022 upstream

Figure B - 379: 2021 upstream

Figure B - 380: 2020 upstream

Figure B - 381: 2023 downstream

Figure B - 382: 2022 downstream

Figure B - 383: 2021 downstream

Figure B - 384: 2020 downstream

WCK 49

Figure B - 385: 2023 upstream

Figure B - 386: 2022 upstream

Figure B - 387: 2021 upstream

Figure B - 388: 2020 upstream

Figure B - 389: 2023 downstream

Figure B - 390: 2022 downstream

Figure B - 391: 2021 downstream

Figure B - 392: 2020 downstream

CCK1

Figure B - 393: 2023 upstream

Figure B - 394: 2022 upstream

Figure B - 395: 2021 upstream

Figure B - 396: 2020 upstream

Figure B - 397: 2023 downstream

Figure B - 398: 2022 downstream

Figure B - 399: 2021 downstream

Figure B - 400: 2020 downstream

CCK2

Figure B - 401: 2023 upstream

Figure B - 402: 2022 upstream

Figure B - 403: 2021 upstream

Figure B - 404: 2020 upstream

Figure B - 405: 2023 downstream

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Figure B - 407: 2021 downstream

Figure B - 408: 2020 downstream

CCK 3

			
Figure B - 409: 2023 upstream	**Figure B - 410: 2022 upstream**	**Figure B - 411: 2021 upstream**	**Figure B - 412: 2020 upstream**
			
Figure B - 413: 2023 downstream	**Figure B - 414: 2022 downstream**	**Figure B - 415: 2021 downstream**	**Figure B - 416: 2020 downstream**

CCK 4


Figure B - 417: 2023 upstream


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CCK 5

			
Figure B - 425: 2023 upstream	**Figure B - 426: 2022 upstream**	**Figure B - 427: 2021 upstream**	**Figure B - 428: 2020 upstream**
			
Figure B - 429: 2023 downstream	**Figure B - 430: 2022 downstream**	**Figure B - 431: 2021 downstream**	**Figure B - 432: 2020 downstream**

CCK 6

Figure B - 433: 2023 upstream

Figure B - 434: 2022 upstream

Figure B - 435: 2021 upstream

Figure B - 436: 2020 upstream

Figure B - 437: 2023 downstream

Figure B - 438: 2022 downstream

Figure B - 439: 2021 downstream

Figure B - 440: 2020 downstream

CCK 7

Figure B - 441: 2023 upstream

Figure B - 442: 2022 upstream

Figure B - 443: 2021 upstream

Figure B - 444: 2020 upstream

Figure B - 445: 2023 downstream

Figure B - 446: 2022 downstream

Figure B - 447: 2021 downstream

Figure B - 448: 2020 downstream

CCK 8

Figure B - 449: 2023 upstream

Figure B - 450: 2022 upstream

Figure B - 451: 2021 upstream

Figure B - 452: 2020 upstream

Figure B - 453: 2023 downstream

Figure B - 454: 2022 downstream

Figure B - 455: 2021 downstream

Figure B - 456: 2020 downstream

CCK 9

Figure B - 457: 2023 upstream

Figure B - 458: 2022 upstream

Figure B - 459: 2021 upstream

Figure B - 460: 2020 upstream

Figure B - 461: 2023 downstream

Figure B - 462: 2022 downstream

Figure B - 463: 2021 downstream

Figure B - 464: 2020 downstream

CCK 10


Figure B - 465: 2023 upstream


Figure B - 466: 2022 upstream


Figure B - 467: 2021 upstream


Figure B - 468: 2020 upstream


Figure B - 469: 2023 downstream


Figure B - 470: 2022 downstream


Figure B - 471: 2021 downstream


Figure B - 472: 2020 downstream

Appendix C Monthly Rainfall Data

Table C - 1: Monthly rainfall from 2014-2023 (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2014	15.6	60.0	112.6	62.8	13.8	29.8	28.6	28.8	14.6	15.4	24.4	126.7	533.1
2015	127.6	11.6	9.4	108.4	42.8	42.8	38.0	53.8	7.8	61.0	59.0	118.4	680.6
2016	152.1	7.2	23.5	14.8	66.8	104.2	101.1	40.9	198.7	86.6	51.9	90.6	938.4
2017	27.8	34.2	146	23	32.4	10.4	5.8	25.2	3	28.4	92.6	102.6	531.4
2018	24.4	77	24.6	42.2	12.4	21.6	1.2	43.8	39.6	56.8	47.4	91.2	482.2
2019	54.8	7.4	108.8	0	17.6	10.6	2.6	10.2	23	5.6	22	3	265.6
2020	27.2	127	92	117	16	23.4	70	36.4	77.2	150.6	17.4	161.6	915.8
2021	52.6	126.6	159.8	1.8	9.4	84.4	66.8	25.4	44.2	40.8	249.2	81.4	942.4
2022	101.4	16	119.8	95	43.6	13	136.4	103.2	93.8	174.4	64	26.6	987.2
2023	48.6	24.6	64.6	47.8	2.8	28.8	23.2	29.8	18	36.2	94	59.6	478
Historical Mean	67.1	62.3	55.1	39.3	37	43.7	42.9	41.1	41.7	52.1	57	60.7	593.8

SOURCE: WCPL WEATHER STATION SENTINEX 34, AND BUREAU OF METEOROLOGY, 2023 (HISTORICAL AVERAGES) WOLLAR (BARRIGAN STREET) WEATHER STATION NUMBER: 62032 CLIMATE DATA ONLINE - MAP SEARCH (BOM.GOV.AU)

Wilpinjong Coal Mine Annual Biodiversity Monitoring Nest Box Inspections

Peabody Energy Australia

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DOCUMENT TRACKING

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Contents

List of Figures

List of Tables

1. Introduction

Wilpinjong Coal Pty Ltd (WCPL), a wholly owned subsidiary of Peabody Energy Australia Pty Ltd (Peabody), operates the Wilpinjong Coal Mine (WCM) located in the western coalfields of New South Wales (NSW) approximately 48 kilometres (km) north-east of Mudgee, within the Mid-Western Regional Council (MWRC) Local Government Area (LGA).

WCPL installed nest boxes within biodiversity management areas across the WCM site to provide enhanced habitat for native fauna species. The locations of the nest boxes is shown below in Figure 1.

ELA is contracted by WCPL to inspect each nest box annually to assess usage and provide advice on maintenance and management. The report presents the results of the nest box inspections completed in January 2024.

2. Methods

Sixty-nine nest boxes were inspected using a 12-metre-high pole and wireless hollow scope to investigate fauna presence or signs of use, as well as the overall condition of the nest box and any maintenance issues.

The condition of next boxes was divided into three categories:

- Fit for use;
- In need of repair; or
- Unserviceable

Nest box usage was determined by the presence of indicators such as nesting material, feathers, droppings, signs of chewing, scratching or a combination of these. An assessment of whether nest boxes had been currently or recently used was also made based on the nature and condition of the signs of use, including nest structure, age of droppings and the colour of leaves and plant material in the nest.

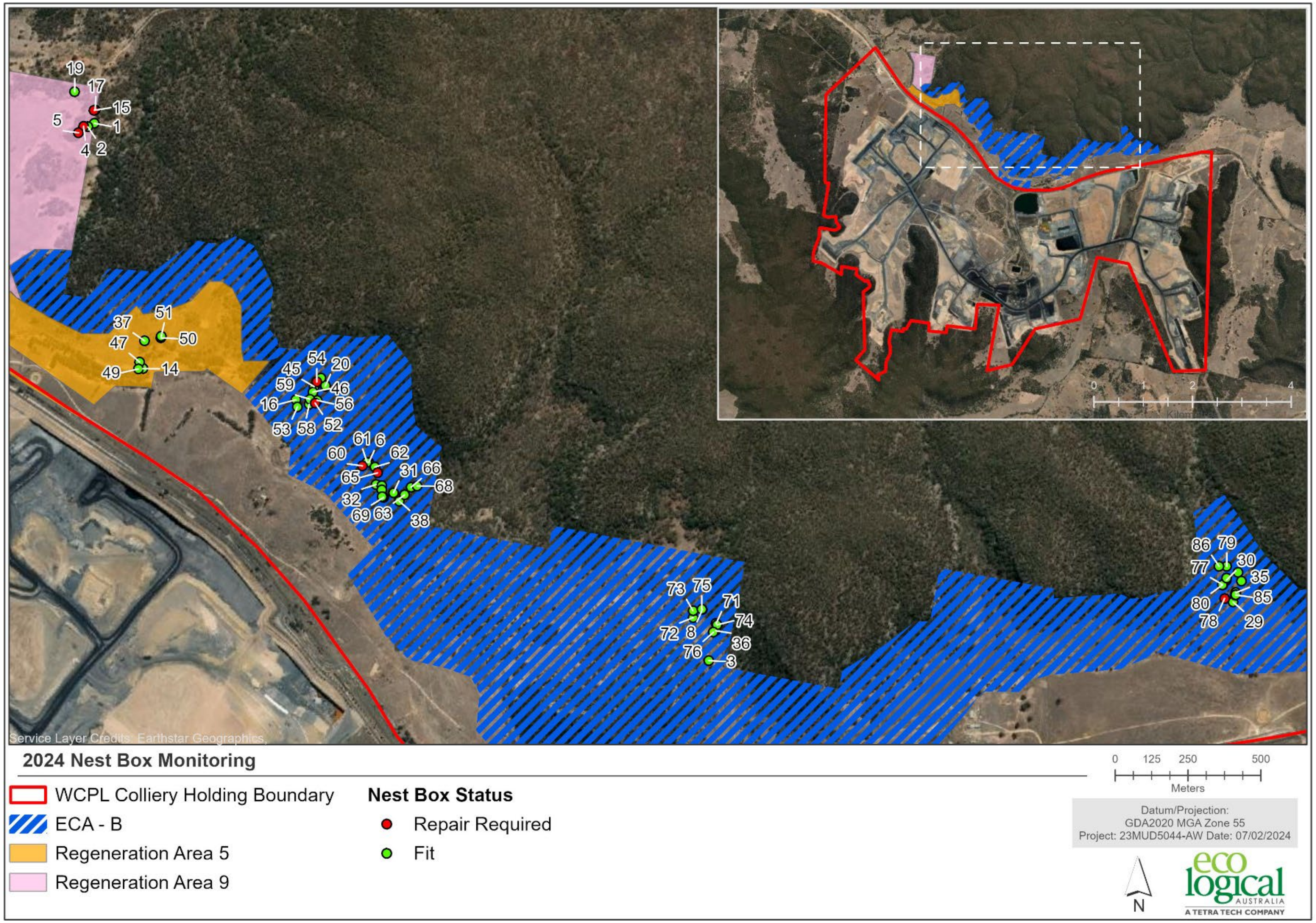

Figure 1: Nest Box Locations

3. Results

The results of the nest box inspections are summarized in Table 1 and detailed observations are provided in Appendix A. A total of 20 nest boxes demonstrated signs of use; six had fauna (*Trichosurus vulpecula* (Common Brushtail Possum)) present at the time of inspection, and a further 14 contained nesting material and/ or exhibited signs of use, i.e., chewings and scratches around entrance, feathers. This is consistent with the findings of the 2022 inspections.

Table 1: January 2024 Nest Box Monitoring Results

Installation Area	Condition			Fauna present (%)	Signs of use		
	Fit (%)	Repair (%)	Unserviceable (%)		Nest / nesting material (%)	Chewing present (%)	Other (e.g. feathers, scats, scratches) (%)
ECA-B	90	10	0	10	18	8	6
Regen 5	100	0	0	13	38	13	0
Regen 9	75	25	0	0	8	0	8

Insects (*Apis mellifera* [European HoneyBee] and *Paralastor* spp. [Potter Wasp]) were observed inhabiting six nest boxes and seven nest boxes had thick cobwebs covering the entrance, which could hinder use especially for microbats. Twelve of the 69 nest boxes were not able to be inspected due to deteriorating condition or height which prevented inspection by ELA's hollow scope.

Eight nest boxes were identified as needing repairs:

- Nest Boxes 5, 13, 54, 60, 65, and 78 require re-screwing to tighten panels, remove gaps in the floor and improve nest box integrity.
- Nest Box 52 is falling away from tree and will need to be resecured.
- Nest Box 4 has its entrance towards the back of the nest box, facing the trunk. The nest box has been screwed too tightly to the trunk, making it difficult for fauna to access. It is recommended to loosen the nest box off the trunk to allow for adequate fauna entry.
- Nest boxes with insect or arachnid signs should be cleaned out whilst other repair work is undertaken.

4. Conclusion

Nest box inspections demonstrated that they are being utilised by fauna species and the objective of providing habitat enhancement is being achieved. Repairs and maintenance as per the suggestions above is recommended, and the continuation of annual inspections is recommended.

Appendix A Nest Box Monitoring Observations

Table 2: Detailed Nest Box Monitoring Observations

Area	Nest Box ID	Northing	Easting	Condition	Fauna Present *	Signs of Use*
ECA-B	3	6420377	771218	Fit	N/A	N/A
	6	6421056	770052.4	Fit	None	None, spider webs
	8	6420553	771196.7	Fit	None	None, spider webs
	16	6421272	769802.2	Fit	None	None
	20	6421318	769902.5	Fit	N/A	N/A
	29	6420578	773016.9	Fit	None	None
	30	6420653	772993.4	Fit	None	None, Spider webs
	31	6420953	770137.2	Fit	None	Chewing around entrance, nesting material
	32	6420981	770077.2	Fit	None	None, spider webs
	35	6420610	773025.9	Fit	None	None
	36	6420480	771241.9	Fit	N/A	N/A
	38	6420924	770156.7	Fit	None	Scratches, feathers, leaves
	45	6421317	769864.8	Fit	None	None
	46	6421298	769861	Fit	None	None
	52	**6421260**	**769868.1**	**Repair**	**N/A**	**N/A**
	53	6421248	769807.9	Fit	None	None, leaves
	54	**6421333**	**769873.9**	**Repair**	**None**	**Nesting material**
	55	6421320	769903.3	Fit	None	None, remnants of beehive.
	56	6421270	769875	Fit	None	None
	57	6421346	769887.8	Fit	Bees	None, remnants of beehive.
	58	6421256	769848.1	Fit	None	Nesting material and feathers
	59	6421274	769850	Fit	Common Brushtail possum	Possum present
	60	**6421045**	**770030.8**	**Repair**	**None**	**None**
	61	6421057	770046.5	Fit	None	None, huntsman spider
	62	6421041	770073.1	Fit	N/A	N/A
	63	6420946	770175.6	Fit	N/A	N/A
	64	6420976	770096.5	Fit	None	Nesting material
	65	**6421021**	**770082.3**	**Repair**	**None**	**None**

Area	Nest Box ID	Northing	Easting	Condition	Fauna Present *	Signs of Use*
	66	6420971	770196.8	Fit	Common Brushtail Possum	Possum present
	67	6420963	770097	Fit	None	None
	68	6420976	770217.6	Fit	Common Brushtail Possum	Possum present
	69	6420936	770102.9	Fit	None	Nesting material
	70	6420939	770097.6	Fit	None	Scratching around entrance, leaves present
	71	6420505	771243.7	Fit	None	None
	72	6420525	771165.2	Fit	N/A	N/A
	73	6420548	771164.3	Fit	None	Scat, Wasp nest
	74	6420500	771247	Fit	None	None
	75	6420553	771194.5	Fit	None	None
	76	6420474	771234.5	Fit	None	None
	77	6420637	772980.9	Fit	Common Brushtail Possum	Possum present
	78	**6420590**	**772987.3**	**Repair**	**None**	**None**
	79	6420701	772994.7	Fit	Common Brushtail Possum	Possum present, chewing around entrance.
	80	6420637	772979.8	Fit	None	Chewings on entrance
	81	6420660	772993.7	Fit	None	Chewings on entrance and scratching, nesting material and feathers
	82	6420649	773044.5	Fit	None	Nesting material
	83	6420601	773024.8	Fit	None	nesting material
	84	6420680	773032.8	Fit	None	Nesting material and ants
	85	6420602	773025.2	Fit	None	None
	86	6420701	772968.5	Fit	None	None
Regen 5	14	6421378	769277.5	Fit	None	Scratches, nesting material
	21	6421474.461	769284.3198	Fit	N/A	N/A
	37	6421474	769283	Fit	None	None, spider webs
	47	6421401	769266	Fit	None	None, wasps present
	48	6421387.986	769272.4911	Fit	N/A	N/A
	49	6421377	769262	Fit	None	Nesting material
	50	6421484	769339	Fit	Common Brushtail Possum	Chewing around entrance
	51	6421489	769340	Fit	None	Nesting material

Area	Nest Box ID	Northing	Easting	Condition	Fauna Present *	Signs of Use*
Regen 9	1	6422219	769111	Fit	None	Nesting material
	2	6422207	769089	Fit	None	None
	4	**6422209**	**769074**	**Repair**	**N/A**	**N/A**
	5	**6422187**	**769057**	**Repair**	**None**	**None**
	7	6422277	769074	Fit	None	None, Spider webs
	11	6422219	769111	Fit	None	None
	12	6422279	769075	Fit	N/A	N/A, bees present
	13	**6422264**	**769110**	**Repair**	**None**	**None**
	15	6422208	769076	Fit	None	None
	17	6422266	769113	Fit	None	Scat, wasp nest
	18	6422337	769059	Fit	N/A	N/A
	19	6422327	769043	Fit	None	None

*N/A – data is not available; inspecting box was not possible
Bold – Repairs required

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Monitoring of Microbats at Slate Gully Adit (Pit 8), Wilpinjong Coal Mine, NSW for 2023

for

Peabody Energy Pty Ltd

Prepared for: James Heesterman
Prepared by: Biodiversity Monitoring Services
Date: 14 February 2024

Document History

Report	Version	Prepared by	Checked by	Submission Method	Date
Adit monitoring	Issue 1	Andrew Lothian	Glenn Hoye	email	14 Feb 2024

1.0 Introduction

An abandoned underground oil shale mine at Slate Gully, Wilpinjong NSW, supports colonies of two microbat species; Eastern Horseshoe-bat (*Rhinolophus megaphyllus*) and Large Bent-winged Bat (*Miniopterus orianae oceanensis*, formerly known as Eastern Bentwing-bat *Miniopterus schreibersii oceanensis*). Monitoring undertaken since April 2017 indicates that less than 50 Eastern Horseshoe-bats inhabit the mine workings throughout the year. From exit counts conducted to date, numbers of this species do not vary substantially throughout the year. Numbers of the Large Bent-winged Bat inhabiting the mine vary considerably more throughout the year.

Peabody Energy is approved to mine the valley (Slate Gully) adjacent to the adit. Topsoil stripping around the northern end of the ridgeline began in November 2019. Mining excavation works began in early 2020 approximately 600m to the northeast of the adit. Previous plans estimated the pit to come within 150m of the adit sometime in 2021, but by February 2023 only a clearwater drain existed within 150m of the adit. In February 2023 the main pit was approximately 430m away. By February 2024, the topsoil stripping is approximately 100m from the adit (to clearwater drain), and the main pit is approximately 350m east of the adit. Bats within the workings have been, or will be, subject to artificial lighting (Linley 2016), vibration and noise. There is also the potential for dust and fumes associated with the open cut operations.

Exit counts of bats leaving the adit, as well as capture of exiting bats[1], has been undertaken over the past seven years to determine what species are utilising the old oil shale mine and how their numbers and sexual composition change throughout the year (Fly By Night 2017; Fly By Night 2018; Fly By Night 2019). This has given a firm basis to monitor colonies of the two species roosting within the workings as the adjacent area is strip mined for coal. Previously we recommended that continual monitoring of bat activity via an ultrasonic bat call detector would provide a superior method to monitor the roost long term. This report details the results of automated monitoring over a 12-month period from January 2023 to December 2023, as well as concurrent monthly hand counts of bats exiting the workings.

[1] Harp trapping was conducted over the period 2017-2019 (autumn, winter, summer) and then discontinued at the request of the then OEH. Enough data was obtained to determine the site was not a breeding roost, but forms an important overwintering and seasonal roost, with composition of sex/age/individuals in the roost changing seasonally.

2.0 Survey Methodologies

Manual Exit Counts

Bats were counted leaving the adit by Andrew Lothian each month, with two months supplemented by a second counter (Matt Dobson, Elyse Tomkins). The counter was in position half an hour before sunset, and counts were conducted until no more bats exited for a period of 10 minutes. Due to differences in flight behaviour (speed and direction of travel upon exit), an assessment could be made of the species composition of those bats leaving the adit. Notes were made on the time of first bat leaving, the total number of bats leaving the adit, and the presence of each of the target species. This methodology has been published recently (Lothian and Hoye 2023).

Though the method has remained the same over time, the position of counting was forced to change in 2023 with the installation of a new steel tunnel creating multiple exit points for the bats. Instead of lying down near the entrance counting bats as they flew over (or to the side in the case of Horseshoe-bats), the counter has to sit further out from the entrance to allow observation of both the end of the tunnel and the natural aperture over the tunnel. It took a few months to choose the optimal position, so manual counts from April 2023 may be less accurate than previous counts. Using a torch to light the entrance created delays in exit by some individuals, and sitting side on to the adit made it difficult to pick out bats from the rock wall behind (as opposed to being back lit by the sky).

Automated Echolocation Call Detection

An Anabat Express detector (Titley Scientific) was placed twenty metres in front of the entrance of the mine adit to sample microbats on a nightly basis (**Figure 2-1**; **Plate 2-1**). The detector was powered via a 12 volt gel cell battery connected to a small solar panel. Files were downloaded monthly in conjunction with manual counts of bats exiting the workings. This allowed a nightly activity index of the two target microbat species to be determined. While the nightly activity cannot be directly compared to numbers of each species roosting within the workings, together with exit counts it provides an estimation/index of bat numbers.

Previous echolocation survey indicated that placement of a detector a distance of approximately 20 metres from the adit provided the best indicator of bat activity for the two species (Fly By Night 2019). The Eastern Horseshoe-bat undertakes circling behaviour when it exits the adit at dusk. Therefore, echolocation call activity undertaken at the adit gives inflated activity for this species. From presence during the counts, Eastern Horseshoe-bats tend to come and go frequently, particularly at the start of the night. Large Bent-winged Bat tend to all come out in a short space of time then return in smaller groups through the night.

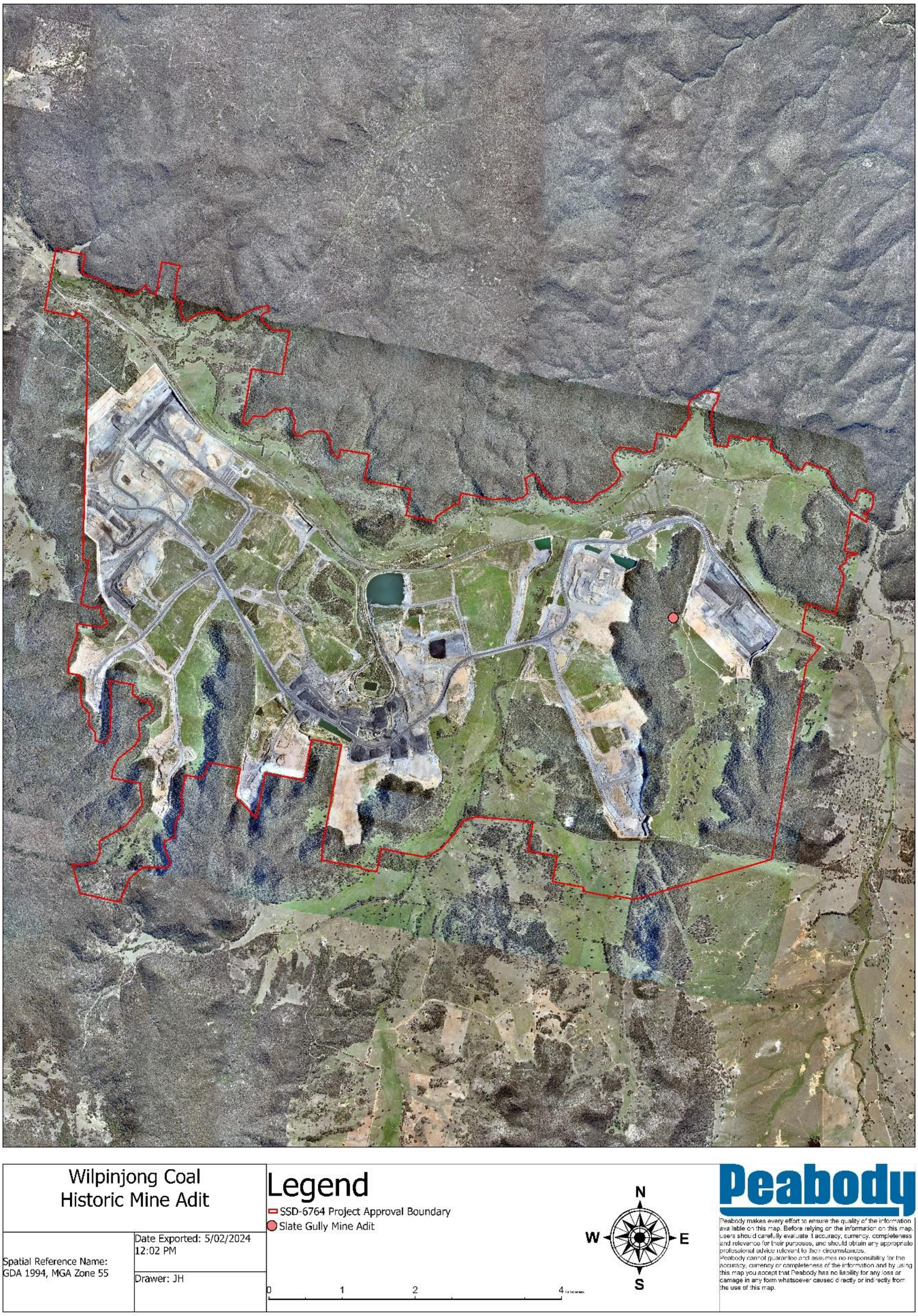


Figure 2-1: Location of Slate Gully Adit (Peabody 2024)

Plate 2-1: Slate Gully adit entrance prior to installation of steel pipe to maintain opening in the event of a collapse (mid 2019), also prior to installation of steel box tunnel (Apr 2023). Detector and solar panel setup 20m in front of adit.

3.0 Weather

Weather conditions on manual count nights (and the two nights prior) were recorded. Data was obtained from the Wilpinjong Meteorological Station, approximately 4.5km west of the adit.

Table 3-1: Weather conditions during survey (Peabody Energy 2023).

Date	Minimum Temperature (°C)	Maximum Temperature (°C)	Rainfall (mm)	Comments
07/01/2020	19.8	35.3	2.8	
08/01/2020	22.2	38.6	0.2	
09/01/2020	21.8	29.7	0	Hot, smoke haze, strong wind
17/02/2020	18.6	21.7	26.8	
18/02/2020	17.9	31.8	0	
19/02/2020	17.6	26.7	15	
21/03/2020	11.9	29.5	0	
22/03/2020	13.2	28.6	0	
23/03/2020	16.8	22	0	Cool, moderate wind
19/04/2020	5.1	21.1	0	
20/04/2020	6.8	20.4	0	
21/04/2020	10.3	23.4	0	Warm, overcast, no wind
16/05/2020	7.7	17.7	0	
17/05/2020	5.1	19	0	
18/05/2020	5.7	17.8	0	Cool, overcast, light wind
16/06/2020	2	17.4	0	
17/06/2020	1.7	17.4	0	
18/06/2020	8.2	16.6	0	Cold, overcast, light wind
23/06/2020	7.2	11.4	0.8	
24/06/2020	6.6	11	0	
25/06/2020	3.9	13.2	0	Cold, overcast, no wind
13/07/2020	1.8	12	0.2	
14/07/2020	4.7	16.4	0	
15/07/2020	3	15.4	0	Cold, clear sky, no wind
11/08/2020	4.3	15.8	0	
12/08/2020	5.9	20.2	0	
13/08/2020	6.5	20.2	0	Cool, clear sky, no wind
06/09/2020	7.5	24.4	0	
07/09/2020	7.6	27.3	0	
08/09/2020	14.1	19.5	0	Mild, clear sky, no wind
12/10/2020	7	25.5	0	
13/10/2020	9.1	28.4	0	

Date	Minimum Temperature (°C)	Maximum Temperature (°C)	Rainfall (mm)	Comments
14/10/2020	11.8	24.5	0	Mild, clear sky, moderate wind
16/11/2020	12.3	36.6	0	
17/11/2020	18.3	30.8	0	
18/11/2020	15.9	26.5	0	Warm, clear sky, moderate wind
21/12/2020	16.9	18.9	41.4	
22/12/2020	16.9	23.7	1.2	
23/12/2020	12.3	26.5	0	Mild, 50% cloud, moderate wind
26/01/2021	17.9	36.3	0	
27/01/2021	20.6	30.9	0	
28/01/2021	20.3	24.6	0	Mild, 100% cloud, high wind
22/02/2021	20.1	32.8	0	
23/02/2021	17.5	24.1	0	
24/02/2021	15.5	23.0	0	Mild, 100% cloud, high wind, thunderstorm
15/03/2021	11.1	22.2	0	
16/03/2021	14.4	22.2	0	
17/03/2021	16.2	19.3	0.4	Mild, 100% cloud, high wind, on/off rain
16/04/2021	11.3	19.9	0	
17/04/2021	9.1	16.4	1.4	
18/04/2021	7.5	20.7	0	Cool, 75% cloud, no wind, no rain
10/05/2021	7.8	21.6	0	
11/05/2021	8.5	18.7	0	
12/05/2021	4.1	19.5	0	Cold, clear sky, no wind, no rain
13/06/2021	4.7	14.6	0	
14/06/2021	0.3	15.0	0	
15/06/2021	0.5	16.6	0	Cold, clear sky, no wind, no rain
10/07/2021	4.5	17.0	0.2	
11/07/2021	0.8	15.6	0	
12/07/2021	1.2	17.6	0	Cold, 50% cloud, no wind, rain at end
02/08/2021	3.0	17.2	0.2	
03/08/2021	8.0	15.3	2.2	
04/08/2021	7.1	10.9	0.6	Cold, 100% cloud, no wind, rain squall at 18:25 caused a lot of bats to come back in. More rain at end
08/09/2021	2.2	22.3	0	
09/09/2021	2.7	22.5	0	
10/09/2021	3.7	24.8	0	Cool, 0% cloud, no wind, no rain
02/10/2021	9.1	18.6	1.4	
03/10/2021	11.1	22.4	0.2	
04/10/2021	9.2	20.8	0	Cool, 0% cloud, no wind, no rain
30/10/2021	7.5	22.2	0	
31/10/2021	6.7	22.2	0	

Date	Minimum Temperature (°C)	Maximum Temperature (°C)	Rainfall (mm)	Comments
01/11/2021	9.3	24.1	0	Mild, 100% cloud, no wind, no rain
30/11/2021	14.8	18.2	22.2	
01/12/2021	17.7	26.3	1.8	
02/12/2021	16.2	28.0	0	Warm, 0% cloud, no wind, no rain
17/01/2022	20.8	33.0	0	
18/01/2022	20.1	25.8	7.2	
19/01/2022	18.4	20.9	2.4	Cool, 100% cloud, mod wind, recent rain
15/02/2022	13.8	30.0	0	
16/02/2022	14.2	29.6	0	
17/02/2022	13.7	33.4	0	Warm, 100% cloud, no wind, humid, storm nearby, full moon
14/03/2022	13.3	25.9	0	
15/03/2022	15.8	24.7	0	
16/03/2022	16.1	26.7	0	Mild, 0% cloud, no wind, full moon
19/04/2022	10.0	26.7	6.6	
20/04/2022	9.4	20.2	0	
21/04/2022	5.5	22.2	0.2	Cool, 25% cloud, light-mod wind
14/05/2022	14.4	26.0	0.2	
15/05/2022	13.8	22.5	0	
16/05/2022	8.2	21.5	0.2	Cold, 0% cloud, no wind, recent rain
19/06/2022	2.5	16.7	0	
20/06/2022	3.3	16.7	0	
21/06/2022	2.4	18.9	0.2	Cold, 50% cloud, no wind, no rain
27/07/2022	5.8	13.8	0	
28/07/2022	2.4	15.9	0	
29/07/2022	2.1	16.1	0	Cold, 0% cloud, no wind, no rain
16/08/2022	6.7	14.6	0	
17/08/2022	1.2	18.8	0	
18/08/2022	4.1	19.9	0	Cool, 100% cloud, no wind, no rain but lots recently
25/09/2022	4.6	20.5	0	
26/09/2022	5.2	19.3	0.2	
27/09/2022	10.9	21.7	5.6	Cool, 75% cloud, no wind, warm sunny day with rain, humid
26/10/2022	14.6	25.1	0	
27/10/2022	13.7	23.7	1.2	
28/10/2022	9.8	20.6	0	Warm, 0% cloud, no wind, humid
05/12/2022	10.5	30.9	0.2	
06/12/2022	14	27.2	0	
07/12/2022	9.3	23.4	2.4	Warm, 100% cloud, no wind, very light rain
26/12/2022	15.3	32.4	0	

Date	Minimum Temperature (°C)	Maximum Temperature (°C)	Rainfall (mm)	Comments
27/12/2022	13.4	30.9	0	
28/12/2022	15.3	33.6	0	Hot, 25% cloud, no wind, humid
30/01/2023	20	23.8	5.4	
31/01/2023	19.8	28.5	0.4	
01/02/2023	17.9	32.6	0	Warm, 0% cloud, no wind, no rain
13/02/2023	19.7	29	0	
14/02/2023	18.2	25.2	0	
15/02/2023	16.9	29.5	0	Warm, 0% cloud, light wind, no rain
12/03/2023	17.5	30.7	12.6	
13/03/2023	18.8	24.1	0	
14/03/2023	18.8	24.9	0.2	Warm, 25% cloud, light wind, rain earlier today
24/04/2023	14.7	21.9	0	
25/04/2023	11.7	23.2	0	
26/04/2023	6.3	21.6	0	Cool, 0% cloud, no wind, no rain
20/05/2023	0.7	14.9	0	
21/05/2023	5.9	14.4	0	
22/05/2023	1	19.8	0	Cold, 0% cloud, no wind, no rain
16/06/2023	-1.1	17.9	0	
17/06/2023	-1.2	17.5	0	
18/06/2023	-1.5	17	0	Cold, 0% cloud, no wind, no rain
15/07/2023	1.8	20.2	0	
16/07/2023	4.7	18	0.2	
17/07/2023	8	18.5	0	Cool, 0% cloud, no wind, evidence of rain overnight
24/08/2023	4.2	18.2	0	
25/08/2023	1.9	23.3	0	
26/08/2023	1.4	21.7	0	Cold, 0% cloud, mod wind, no rain
17/09/2023	6.6	30.4	0	
18/09/2023	6.4	32.1	0	
19/09/2023	7.5	30.9	0	Warm, 0% cloud, no wind, no rain
23/10/2023	6.9	26.4	0	
24/10/2023	6.2	33	0	
25/10/2023	10.6	27.3	0	Warm, 100% cloud, light wind, no rain
21/11/2023	13.2	27.9	0	
22/11/2023	17	27.5	0	
23/11/2023	17.5	23.4	1	Warm, 100% cloud, strong wind, no rain but humid
16/12/2023	15.3	32.9	0	
17/12/2023	13.6	35.8	0	
18/12/2023	21.4	38.1	0	Hot, 0% cloud, no wind, no rain but humid

4.0 Results

Manual Exit Counts

Under the previous adit inspection/monitoring regime, exit counts were conducted over two nights alongside trapping of bats. Data comparing total exit counts over the last five years are presented in **Table 4-1**. Count data from monthly surveys since June 2019 are presented in **Table 4-2**.

Table 4-1: Counts of bats exiting adit during April, June and December surveys from 2017-2023

	Apr 2017	Apr 2018	Apr 2019	Apr 2020	Apr 2021	Apr 2022	Apr 2023
Minimum count	603	640	460	55	289	527	221
Maximum count	669	705	603	55	289	527	221

	Jun 2017	Jun 2018	Jun 2019	Jun 2020	Jun 2021	Jun 2022	Jun 2023
Minimum count	665	1000	94	92	788	705	363
Maximum count	720	1029	94	246	823	705	363

	Dec 2017	Dec 2018	Dec 2019	Dec 2020	Dec 2021	Dec 2022	Dec 2023
Minimum count	10	9	12	20	15	15	3
Maximum count	10	9	12	20	15	22	5

Note: two counts were conducted in June 2020 due to a required maintenance visit. Access issues in 2022 meant there were two December counts due to a late November count. January count in 2023 was one day late, resulting in two February counts.

Table 4-2: Hand counts of bats exiting adit, and detector activity levels adjacent to the adit since monthly counts began in June 2019 – total (confident), raw # passes (all calls for all species). Detector located 20m from adit entrance in forest vegetation so more than just adit occupants are recorded.

Survey Date	Max. count	Min. count	First/last bat	Species present	# *R. megaphyllus* passes	# *M. orianae oceanensis* passes**	Total passes
24 Jun 2019	94	94	-	MIOR/RMEG	14 (11)	740 (487)	952
29 Jul 2019	93	93	-	MIOR/RMEG	42 (34)	850 (597)	1376
21 Aug 2019	99	99	17:45/18:45	MIOR/RMEG	114 (104)	707 (492)	1222
23 Sep 2019	267	267	18:15/19:30	MIOR/RMEG	88 (79)	873 (602)	1431
29 Oct 2019	80	80	19:44/20:29	MIOR/RMEG	NA	NA	569
22 Nov 2019	29	29	19:50/20:45	RMEG	Data Missing	Data Missing	Data missing
19 Dec 2019	12	12	20:20/21:20	RMEG	24 (14)	96 (59)	240
09 Jan 2020	8	8	20:29/21:15	RMEG	2 (1)	354 (274)	671
19 Feb 2020	59	59	19:56/21:00	MIOR/RMEG	Data missing	Data missing	Data missing
23 Mar 2020	17	17	19:33/20:20	RMEG	10 (10)	417 (311)	1365
21 Apr 2020	55	55	17:52/18:55	MIOR/RMEG	53 (45)	403 (225)	866
18 May 2020	66	66	17:25/18:35	MIOR/RMEG	Data missing	Data missing	Data missing
18 Jun 2020	92	92	17:21/18:20	MIOR/RMEG	10 (8)	354 (230)	612
25 Jun 2020*	246	246	17:19/18:32	MIOR/RMEG	18 (16)	570 (400)	816
15 Jul 2020	518	499	17:32/18:31	MIOR/RMEG	16 (13)	541 (332)	786
13 Aug 2020	682	682	17:43/18:55	MIOR/RMEG	18 (16)	580 (389)	845
08 Sep 2020	538	538	18:05/19:29	MIOR/RMEG	15 (10)	585 (440)	1012
14 Oct 2020	66	66	19:33/20:30	MIOR/RMEG	17 (13)	782 (727)	1362
18 Nov 2020	16	16	20:09/20:49	RMEG	5 (4)	261 (191)	508

Survey Date	Max. count	Min. count	First/last bat	Species present	# *R. megaphyllus* passes	# *M. orianae oceanensis* passes**	Total passes
23 Dec 2020	20	20	20:27/20:59	RMEG	7 (6)	229 (161)	511
28 Jan 2021	12	12	20:26/21:06	RMEG	22 (22)	436 (383)	1357
24 Feb 2021	27	1	19:57/19:37	VPUM?/RMEG	20 (16)	350 (283)	956
17 Mar 2021	47	28	19:32/20:21	MIOR/RMEG	14 (13)	284 (200)	1357
18 Apr 2021	289	270	17:52/19:02	MIOR/RMEG	15 (10)	698 (495)	942
12 May 2021	518	498	17:24/18:24	MIOR/RMEG	4 (4)	1092 (936)	1277
15 Jun 2021	823	788	17:16/18:26	MIOR/RMEG	1 (1)	794 (653)	979
12 Jul 2021	497	497	17:24/18:20	MIOR/RMEG	19 (17)	528 (399)	603
04 Aug 2021	419	419	17:45/18:40	MIOR/RMEG	29 (24)	548 (471)	787
10 Sep 2021	890	890	18:08/19:10	MIOR/RMEG	19 (17)	748 (588)	991
04 Oct 2021	624	624	19:15/20:20	MIOR/RMEG	37 (32)	897 (714)	1383
01 Nov 2021	28	28	19:44/20:30	MIOR(1)/RMEG	42 (37)	524 (439)	1037
02 Dec 2021	15	15	20:14/20:54	RMEG	7 (4)	398 (285)	706
19 Jan 2022	8	8	20:31/21:11	RMEG	21 (20)	751 (575)	1220
17 Feb 2022	17	17	20:05/20:45	RMEG	18 (12)	268 (146)	427
16 Mar 2022	29	29	19:35/20:25	VTRO?/RMEG	9 (5)	1013 (823)	1722
21 Apr 2022	527	527	17:47/18:27	MIOR/RMEG	4 (3)	1059 (908)	1594
16 May 2022	396	396	17:25/18:15	MIOR/RMEG	2 (1)	856 (705)	1026
21 Jun 2022	705	705	17:16/18:06	MIOR/RMEG	2 (2)	1068 (929)	1300
29 Jul 2022	661	661	17:30/18:30	MIOR/RMEG	15 (13)	651 (505)	866
18 Aug 2022	974	974	17:47/18:30	MIOR/RMEG	12 (6)	1199 (1017)	1497
27 Sep 2022	1050	1050	18:10/19:10	MIOR/RMEG	7 (6)	1124 (1013)	1435

Survey Date	Max. count	Min. count	First/last bat	Species present	# *R. megaphyllus* passes	# *M. orianae oceanensis* passes**	Total passes
28 Oct 2022	-	-	-	-	5 (4)	757 (605)	1046
7 Dec 2022*	22	22	20:13/20:43	MIOR(1)/RMEG	17 (15)	830 (761)	1281
28 Dec 2022	15	15	20:29/20:59	RMEG	8 (5)	327 (213)	444
01 Feb 2023*	6	6	20:24/20:54	RMEG	18 (15)	561 (371)	761
15 Feb 2023	19	17	20:10/20:40	RMEG	13 (11)	749 (640)	1305
14 Mar 2023	278	278	19:34/20:24	MIOR/RMEG	20 (16)	916 (747)	1484
26 Apr 2023***	221	221	17:36/18:46	MIOR/?	24 (22)	1101 (1027)	3829
22 May 2023***	323-388	288	17:03/18:13	MIOR/?	6 (5)	553 (394)	716
18 Jun 2023	363	363	17:05/18:14	MIOR/RMEG	14 (7)	502 (399)	643
17 Jul 2023	225	225	17:24/18:34	MIOR/RMEG	4 (2)	519 (405)	590
26 Aug 2023	666	666	17:47/19:16	MIOR/RMEG	0 (0)	1158 (999)	1432
19 Sep 2023	731	731	18:13/20:13	MIOR/RMEG	4 (2)	502 (415)	1707
25 Oct 2023	27	23	19:34/20:38	MIOR/RMEG	5 (4)	240 (178)	679
23 Nov 2023^	4	4	20:01?(20:15)/ 20:41	RMEG	1 (1)	59 (16)	1163
18 Dec 2023	5	3	20:29/20:59	RMEG	NA	NA	NA

*two counts were conducted in June 2020 due to a required maintenance visit. Access issues in 2022 meant the November count was pushed back into early December, resulting in two December counts. January count in 2023 was one day late, resulting in two February counts.

**# *M. orianae oceanensis* passes will include background level of *Vespadelus vulturnus* passes as data has been pooled for the two species whose call characteristics overlap in this region.

***New steel box culvert/tunnel installed 26 April 2023. New setup means counting location is further out from entrance, which makes it very hard to note presence or absence of RMEG unless they are observed during twilight. Also took a few months to work out the best counting position. Also took the bats a bit of time to acclimatise to and start using the tunnel.

^Access to adit was delayed. Previous nights data suggests bats first exit was at 20:01, but only got to adit at 20:15 to start count. May have missed a few bats at beginning.

Cells marked “Data missing” are nights/months where there has been an equipment failure that was not picked up until the next count. “NA” denotes data that is not yet available due to analysis not being completed.

Automated Echolocation Call Detection

The automated echolocation call detection equipment operated successfully throughout 2023 (with the exception of one night; 2 Nov). Issues in 2020 were rectified by more frequent formatting of memory cards. As with previous years, activity of the Eastern Horseshoe-bat (*Rhinolophus megaphyllus*) was generally low and relatively consistent (**Figure 4-1** to **4-5**). Wet weather caused mild conditions through much of 2021-2022, meaning activity was much more stable than earlier years, with no obvious seasonal change in activity. 2023started off with slightly elevated activity (though not comparable to that seen in 2019), but returned to low even activity levels from end of May. Historically, activity for this species declines over winter and increases between mid-September and late April. The 2020 October-December period was characterised by pulses of increased activity on occasional nights (50-100 passes over average), but few large spikes in activity were observed through 2021-2023. While oscillations in activity from night to night are seen, the overall picture is one of relative stability until the end of May 2023. From beginning of June 2023, activity levels rarely exceeded 10 passes per night. Monthly count data supports this with Eastern Horseshoe-bat numbers varying from 8 to 29 over the summer months from December 2017 to December 2022, but dropping to 3 to 5 over November-December 2023. Numbers from our monthly counts provide no evidence for gross changes in Eastern Horseshoe-bat numbers through spring-summer 2019. It could be that during the peak of the drought, individuals may have moved into the area either to escape bushfires to the east, or simply to access more permanent water sources in the vicinity of the adit. Though not resulting in increases in the Slate Gully adit occupation, other adits likely exist in the local area, particularly when considering the type of shelter used by this species (avens in boulders and caves with dark zones; *pers. obs.* author). Alternatively, bats could have needed to spend more time foraging for insects in the drought, leading to increased activity to satisfy energetic requirements. Steady activity through 2021-2022 could be a result of more stable climatic conditions, with weather generally milder than expected throughout the year. However, whilst relatively steady in the beginning of 2023, activity appears to decline from June-Dec. The removal of these water sources by the approaching mine pit may potentially explain the reduction in numbers by late 2023. Long-term averaged climatic data from site was not available at the time of writing. Gulgong Post Office monthly climate statistics show lower than average maximum temperatures over Jan-Jun and Sep-Dec 2022, higher than average minimum temperatures over Mar-May and Jul-Oct 2021, and lower minimum temperatures over Nov-Dec 2022 (BOM 2023, data based on 1970-2022). 2023 climate statistics show higher than average maximum temperatures for Jul-Dec, and higher than average minimum temperatures for Nov-Dec (BOM 2024, data based on 1970-2023). 2023 rainfall was generally lower than the long term average over 10 of 12 months, which was supported by the dry conditions experienced on site coming into the second half of the year. As above, good availability of insects in wet conditions may reduce activity demands in order to meet food requirements. Reductions in activity with no concurrent reduction in actual counts of individuals over the summer months could be indicative of reduced microphone sensitivity over time. This will be investigated going forward.

Activity levels of the Large Bent-winged Bat (*Miniopterus orianae oceanensis*) showed greater seasonal variation and the night to night variation was greater than that of the Eastern Horseshoe-bat (**Figure 4-6** to **4-10**). While activity increased during 2020 from February, the increase in activity during 2021 was seen in early April. 2022 saw an increase in activity in mid April, suggesting an even later return from summer maternity roosts with subadults than that seen in 2021. 2023 data shows an increase from late February. Monthly counts support this, suggesting that there is yearly variation, with Large Bent-winged Bats returning between mid-February and late March, with the majority arriving by mid-April. 2020 activity peaked in late August-September, while 2021 showed peaks in June and October. Peaks in 2022 occurred in April and June-July, while 2023 data shows peaks in April-May and August. In early years, there seemed to be a large decline in activity in mid-late October as bats leave for summer/maternity roosts. This decline pushed back to early November in 2022, whilst 2023 decline shifted forward to late September. By late November activity appears to be reduced to a level that indicates all bats are gone from the cave and only general foraging activity for the species is being picked up outside the cave entrance. This pattern mirrors that from counts of bats exiting the workings undertaken since April 2017, whereby Large Bent-winged Bats are gone by early November (Fly By Night 2017; Fly By Night 2018; Fly By Night 2019). Within this pattern, large oscillations in activity of this species did occur from night to night. While activity levels sometimes varied by only a few passes per night at other times it varied by up to 800 passes per night. 2022-2023 showed the most volatility in activity indices. This nightly variation could reflect changes in the number of individuals roosting within the workings, as well other factors including ambient temperature and prey abundance. Rain can interfere with the effectiveness of the microphone, so the volatility over 2021-2022 could be due to wet conditions. As La Nina subsides, we have not seen a reduction in volatility, suggesting this is not the cause of the night by night variation. The yearly pattern of use at Slate Gully is similar to that recorded at urban roosts in Sydney and Newcastle (Hoye & Spence 2004).

Data used to monitor Large Bent-winged Bat activity is a combination of call pulse identifications. Due to the huge volume of calls generated by continuous recording each year, we have used an automated call identification analysis program (Ana-lyse© A.J. Hoye) to label the data. In the region around Mudgee, call pulses for Large Bent-winged Bats in cluttered environments are very similar to those of the Little Forest Bat (*Vespadelus vulturnus*) and Chocolate Wattled Bat (*Chalinolobus morio*). Because of the overlap in call parameters, a combination of these species was used to generate various indices for Large Bent-winged Bat activity. The large numbers of cave roosting bats using the adit should dwarf the number of either of the other tree roosting species. As such, the background level of tree-roosting bat activity could be considered relatively constant through the year (noting tree roosting species will have reduced activity over winter). If we take that constant activity of Little Forest/Chocolate Wattled Bats away from the pooled activity figure, we should still be seeing seasonal variation in Large Bent-winged activity. This is why there is activity recorded for Large Bent-winged Bats over the summer period when there are none present in counts. By looking at recorded activity levels over the November-January 2020 period when Large Bent-winged are absent from the adit, we see a background level of activity of 50-250 call pulses.

This is likely to be the background level of Little Forest Bat activity. That activity was slightly higher in the summer months of 2021, and approached 400 pulses/night in summer months in 2022-2023. For consistency's sake, the correction factor has been retained at 150 pulses/night across all years (noting that background activity is likely to have increased on par with increases seen in Large Bent-winged Bat activity in the recent wet years). The low level of Large Bent-winged Bat activity seen over the summer months when individuals have vacated the mine workings probably represents males and non-breeding females present in a nearby roost that still forage over the site. Individuals can travel at least 10km (perhaps up to 30km) from a roost to feed in a night.

Correlation of bat activity with blast dates has the potential to reveal changes in activity as a result of "pulse" disturbance. "Pulse disturbance" is typically short term in nature and can often be of higher magnitude/intensity (e.g. blasting). Blast dates (Pits 3 and 8) from March 2020 to December 2023 were plotted against activity index of both species (**Figure 4-11**). Only Pit 8 blast dates were provided in 2020 which may explain the increase in blast occurrences in 2021. Pit 3 has not experienced a blast since April 2021 (*pers. comm*. James Heesterman). Pit 7 could also be close to the adit, but has not been included in these analyses. There does not appear to be any clear change in activity of either species relative to blast dates. Large Bent-winged Bat activity declined after some blasts, and increased after others. The magnitude of the changes also differed each time. Potential "press disturbance" (disturbance associated with constant long term phenomena which may not necessarily be high impact in nature) impacts as a result of increased activity within the vicinity of the adit will be analysed as mining advances toward the adits location. Examples of "press disturbance" include light spill from mine or noise from machinery.

As a requirement within the Biodiversity and Blast Management Plans, video surveillance and review of recorded footage is undertaken with each blast conducted in Pit 8 (Slate Gully). Footage is reviewed five minutes pre and post blast event to evaluate potential impacts to the adit and bat activity. Of the 2020 data collected and reviewed, blast activity was not seen to disturb or induce diurnal bat flight activity outside of the adit. No disturbances (bats leaving adit during daylight) were observed during 2021 or 2022 monitoring (pers. comm. Josh Frappell; pers. comm. James Heesterman). We have no data to assess whether bats are roused and undertaking diurnal flight within the adit. For blasts that were more than four days from other blasts, short term responses of Eastern Horseshoe-bat (**Figures 4-12**) and Large Bent-winged Bat (**Figures 4-13**) were plotted. Data is presented for the five days leading up to a blast, and the five days after. Data has been summarised into means with standard errors. Two potential hypotheses exist for disturbance of bats post blasting. The first is an increase in activity as bats have been roused into activity by the pressure/sound waves. The second could be a reduction in activity whereby bats are reluctant to leave the safety of the adit due to the recent disturbance. A lack of variation in activity after a blast, outside of the variation seen prior to the blast, would be considered an absence of impact.

We can see from raw data that in 26 of 59 blasts, Eastern Horseshoe-bat activity declined from the night before to the night of (after) the blast. Not only does this show mixed responses, but by looking at **Figure 4-12** we can see that on average the response is a decrease in activity on the night before the blast as well as the night of the blast (both of very small magnitude). Large Bent-winged Bat activity declined in 33 of 59 blast nights relative to previous nights, which is also seen in average data (**Figure 4-13**). Note again the decline in mean activity the night before the day of the blast. In the case of the Bent-winged Bat, the magnitude of this decline was no greater than variation seen in nights prior to the blast. The mixed results and small changes relative to normal nightly variation in activity suggest no impact from blasting in Pit 3 or 8 on the two bat species. The slight declining trend in Bent-winged Bats has not carried forward to 2023. Neither species' decline was more than what would be expected from nightly variation, and overlapping Standard Error bars suggest changes are not likely to be significant. One-way Repeated Measures ANOVAs were run on the activity data over the 11 nights. Neither Eastern Horseshoe-bat nor Large Bent-winged Bat activity were significantly different between any of the nights.

Additional analyses were conducted on Eastern Horseshoe-bat and Large Bent-winged Bat activity before and after blasts, but were restricted to the winter period when bats may utilise torpor to conserve energy. One-way Repeated Measures ANOVAs showed no significant differences between nightly activity before and after blasts, but power of both analyses were low due to small sample size (only 14 winter blasts). We will monitor this metric going forward as we get more data.

As bat activity did not seem to change in response to mine blasts, we looked at changes in bat activity with minimum nightly temperature. Minimum temperature was amplified so changes in temperature could be viewed at the scale of changes in bat activity. In 2021, there appeared to be an inverse response in bat activity with minimum temperature. As minimum temperature drops, bat activity is increased. However, in 2022 the relationship seemed to change seasonally, or when the Large Bent-winged Bat was present/absent. From early April to early October, Large Bent-winged Bat activity roughly correlated directly with minimum overnight temperature (i.e. as minimum temperature goes up, activity goes up). This happens to be the period in which Large Bent-winged Bat inhabit the adit as a non-breeding roost. 2023 saw a similar relationship to 2022, with activity correlated with minimum temperature over the early April to early September period. Over the warmer months, the relationship between temperature and activity was poorly defined. Whether this has to do with the absence of Bent-winged Bats, or if it is a product of minimum overnight temperature having no control over activity above a certain temperature threshold is unable to be determined. As there is no clear relationship seen, it is likely that other climatic variables contribute to bat activity each night (i.e. moon phase, wind speed, time of minimum temperature, etc.).

Regressions were run on confident Eastern Horseshoe-bat (R.megC) and Large Bent-winged Bat (M tot + Vvul P/Po) against minimum temperature. There was a very small positive correlation between R.megC and minimum temperature (r^2=0.0031). There was a small negative relationship between Large Bent-winged Bat activity and minimum nightly temperature (r^2=0.0197). This is not a surprising result, as the Bentwing-bats leaving over summer means there are less individuals present (hence less activity) when minimum temperatures are likely to be higher. When adjusted for the April to October period, the Bent-winged bat relationship changes to a very small negative relationship (r^2=0.0063). Overall this suggests the relationship between activity and temperature are very weak.

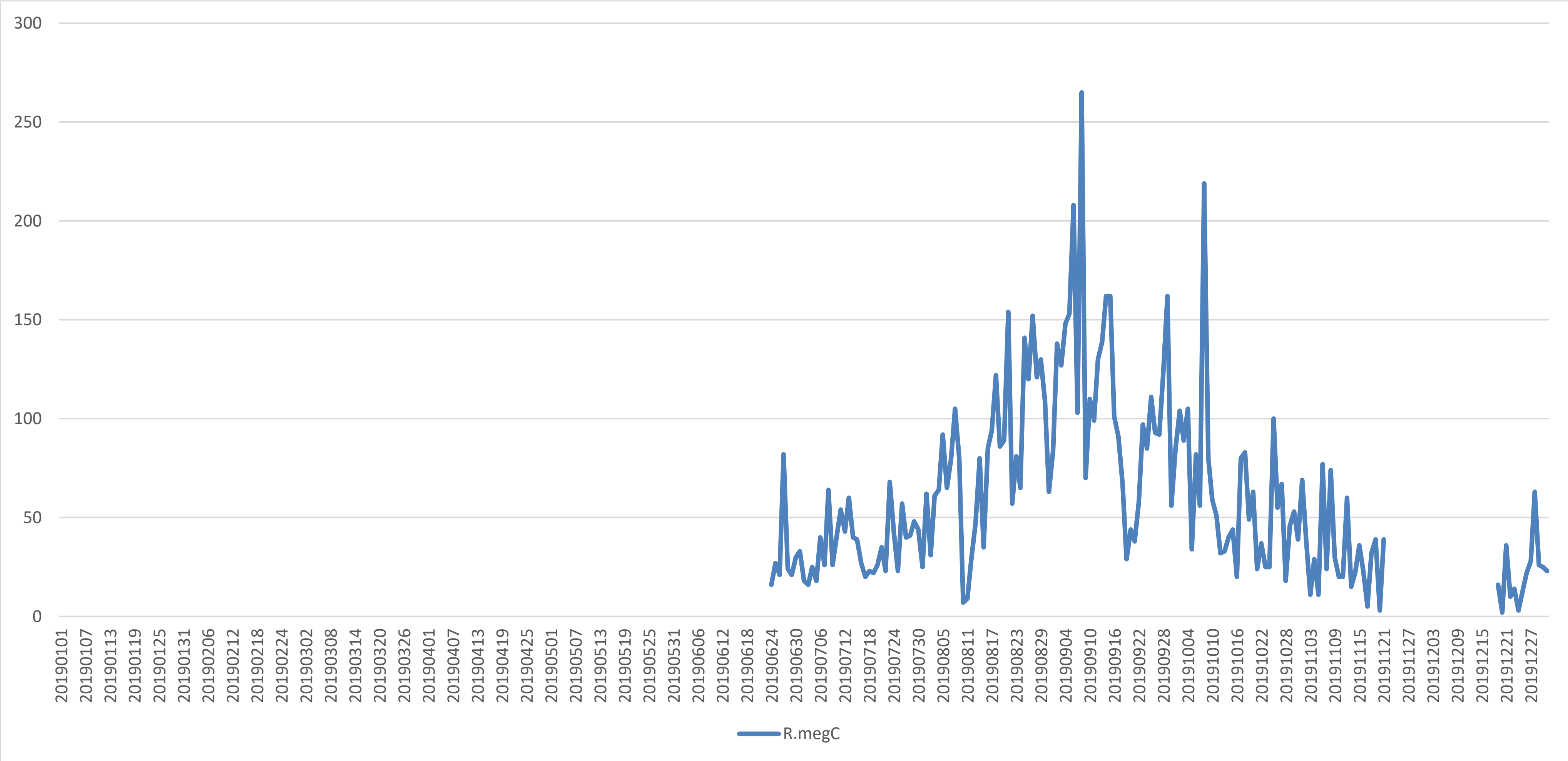


Figure 4-1: Nightly Eastern Horseshoe-bat activity in 2019

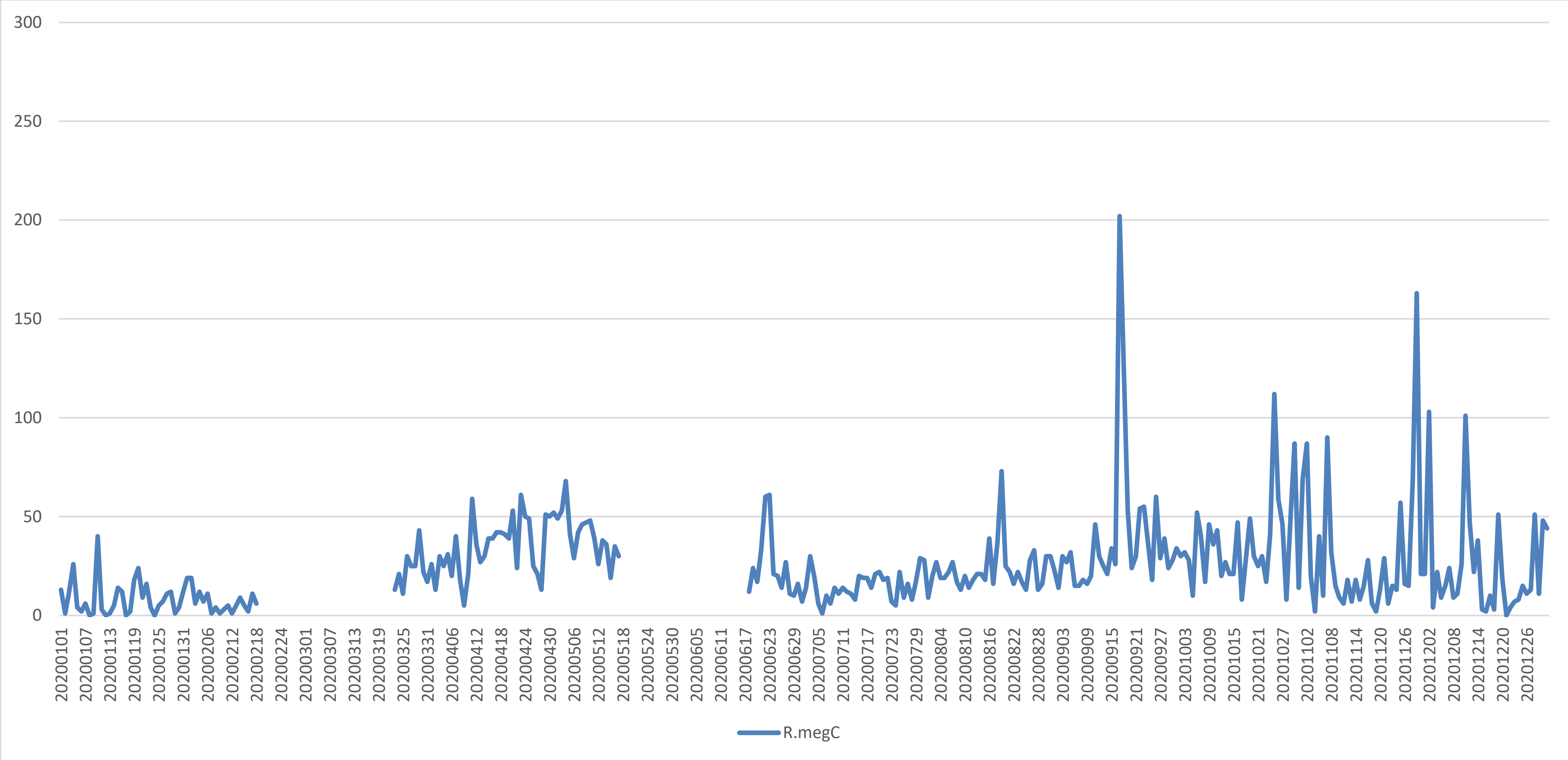


Figure 4-2: Nightly Eastern Horseshoe-bat activity in 2020

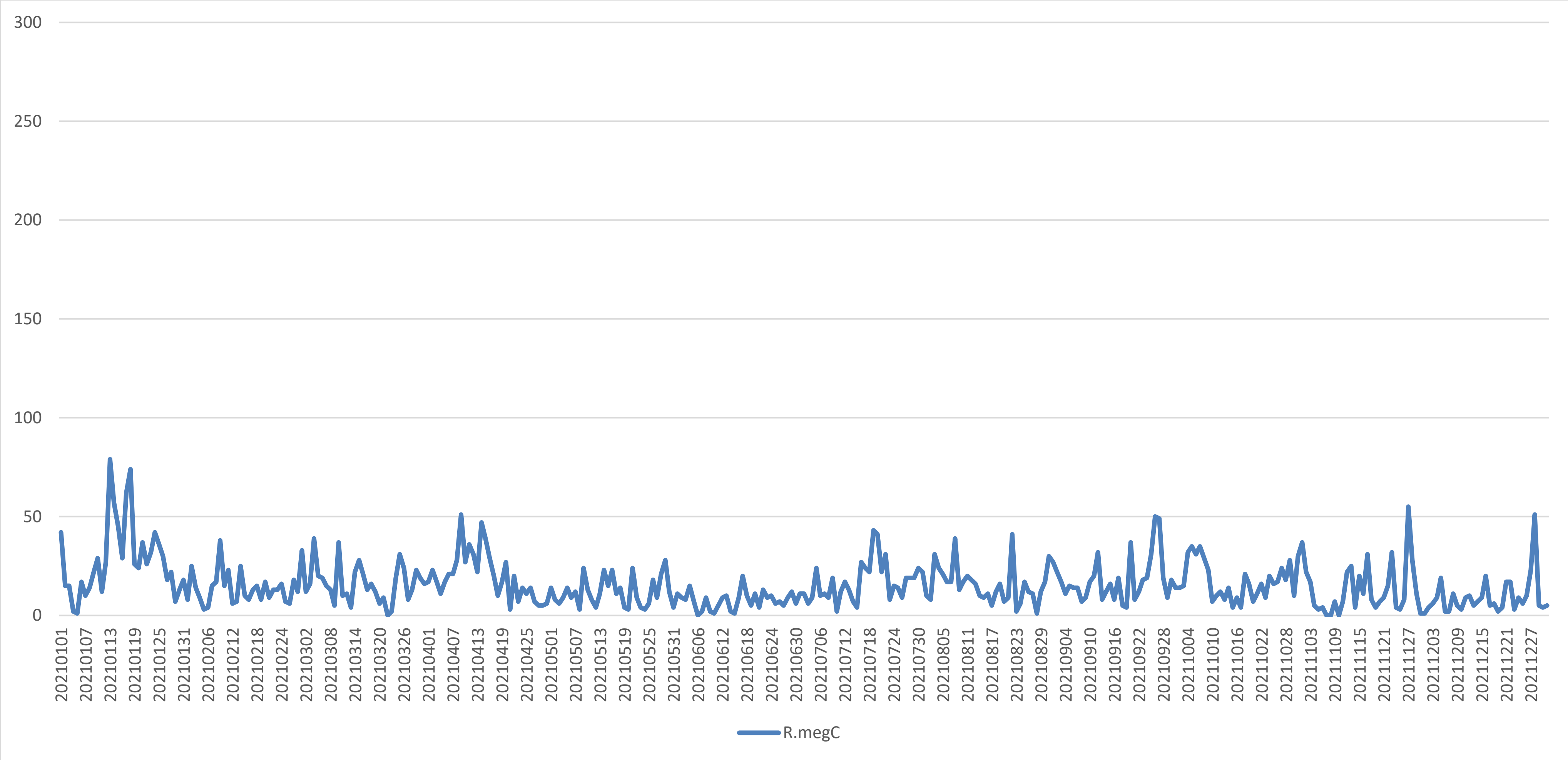


Figure 4-3: Nightly Eastern Horseshoe-bat activity in 2021

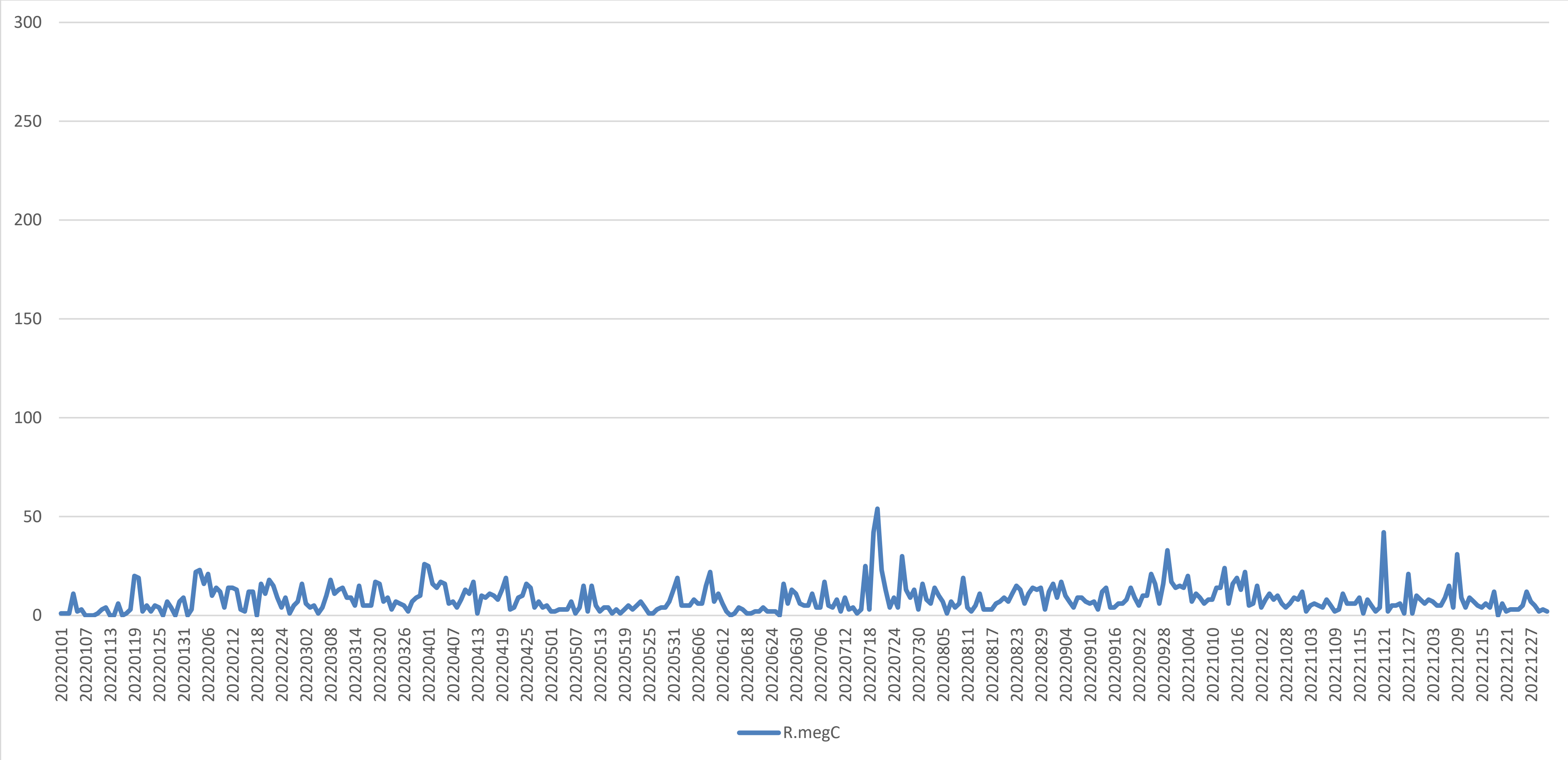


Figure 4-4: Nightly Eastern Horseshoe-bat activity in 2022

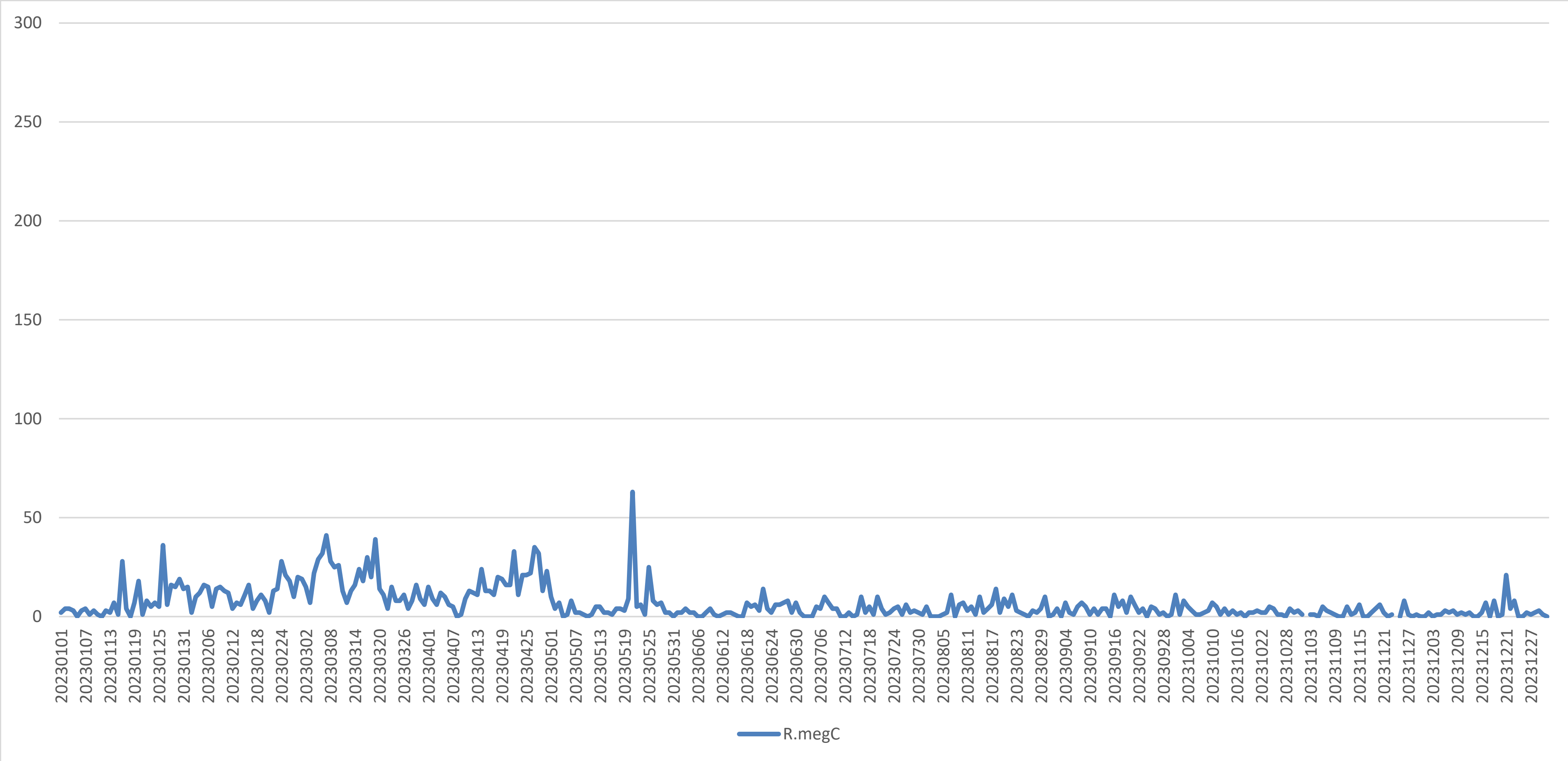


Figure 4-5: Nightly Eastern Horseshoe-bat activity in 2023

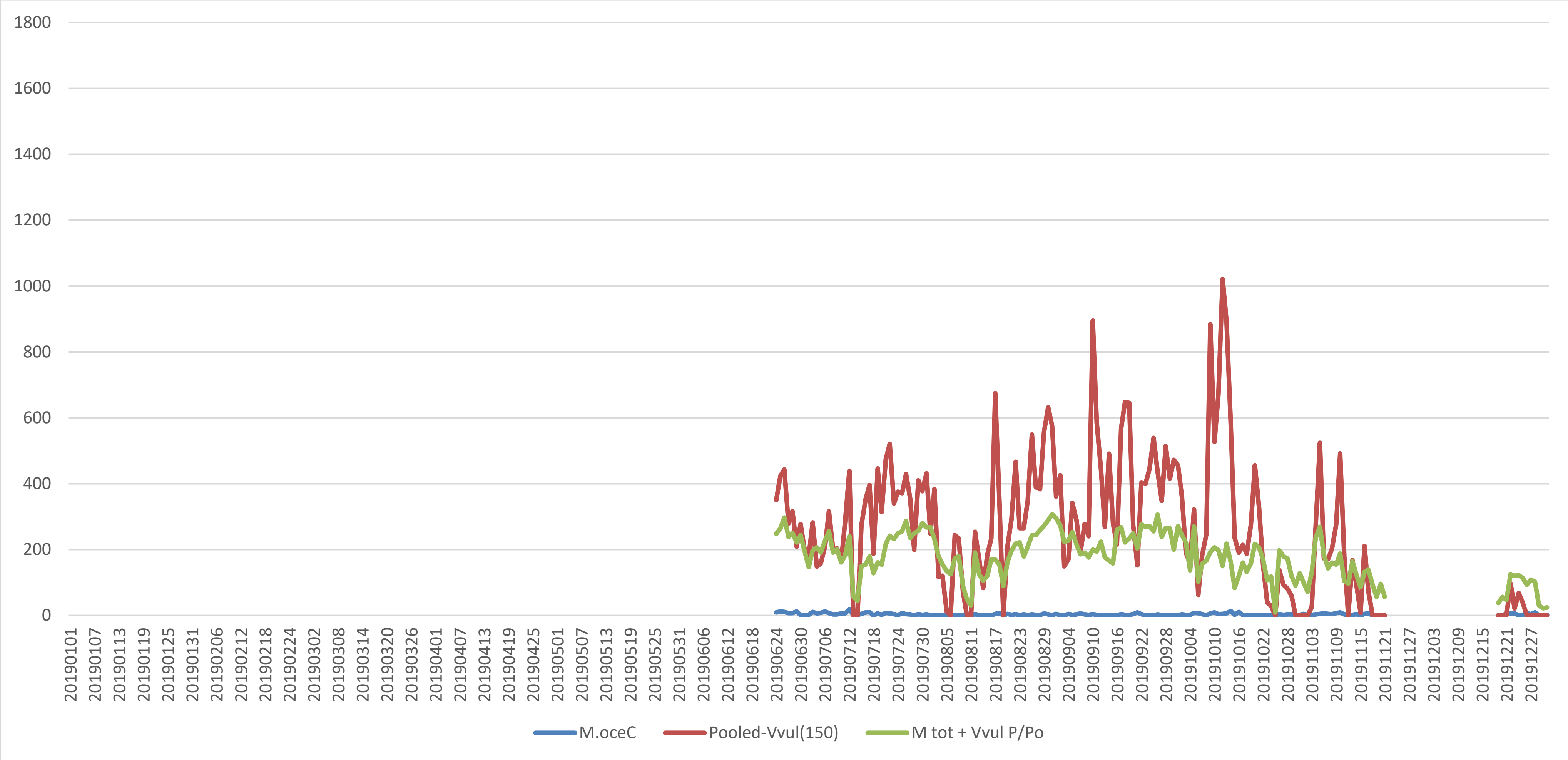


Figure 4-6: Nightly Large Bent-winged Bat activity in 2019. *M.oceC* represent the number of confident open space Large Bent-winged Bat calls. *Pooled-Vvul(150)* represent the number of pooled confident calls for Large Bent-winged and Little Forest Bats which have similar call parameters (i.e. M.oceC + VvulC – 150). *Mtot+VvulP/Po* represent the number of total Large Bent-winged Bat calls plus calls of Little Forest Bat that were not identified confidently as Little Forest Bat.

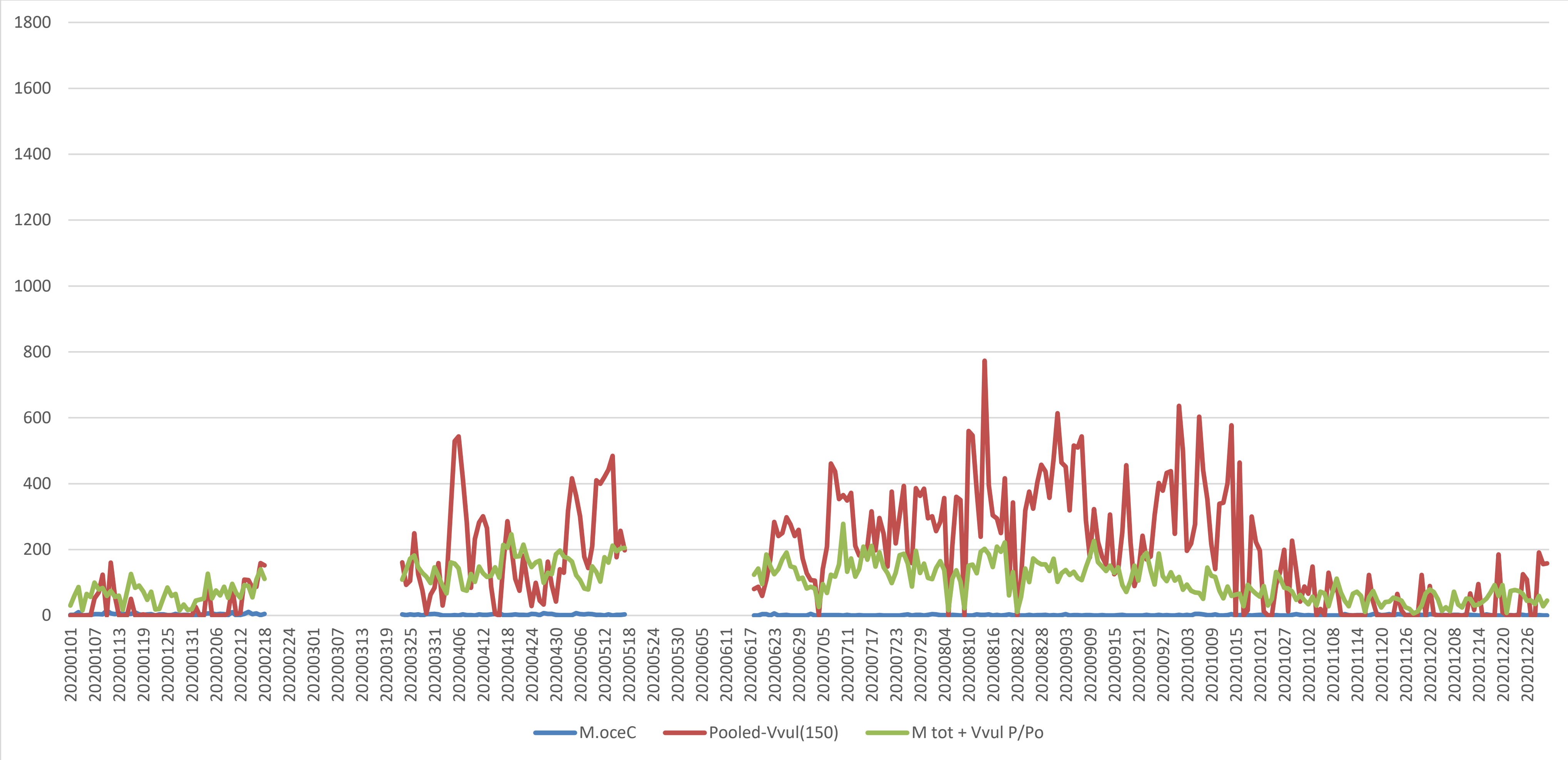


Figure 4-7: Nightly Large Bent-winged Bat activity in 2019. *M.oceC* represent the number of confident open space Large Bent-winged Bat calls. *Pooled-Vvul(150)* represent the number of pooled confident calls for Large Bent-winged and Little Forest Bats which have similar call parameters (i.e. M.oceC + VvulC – 150). *Mtot+VvulP/Po* represent the number of total Large Bent-winged Bat calls plus calls of Little Forest Bat that were not identified confidently as Little Forest Bat.

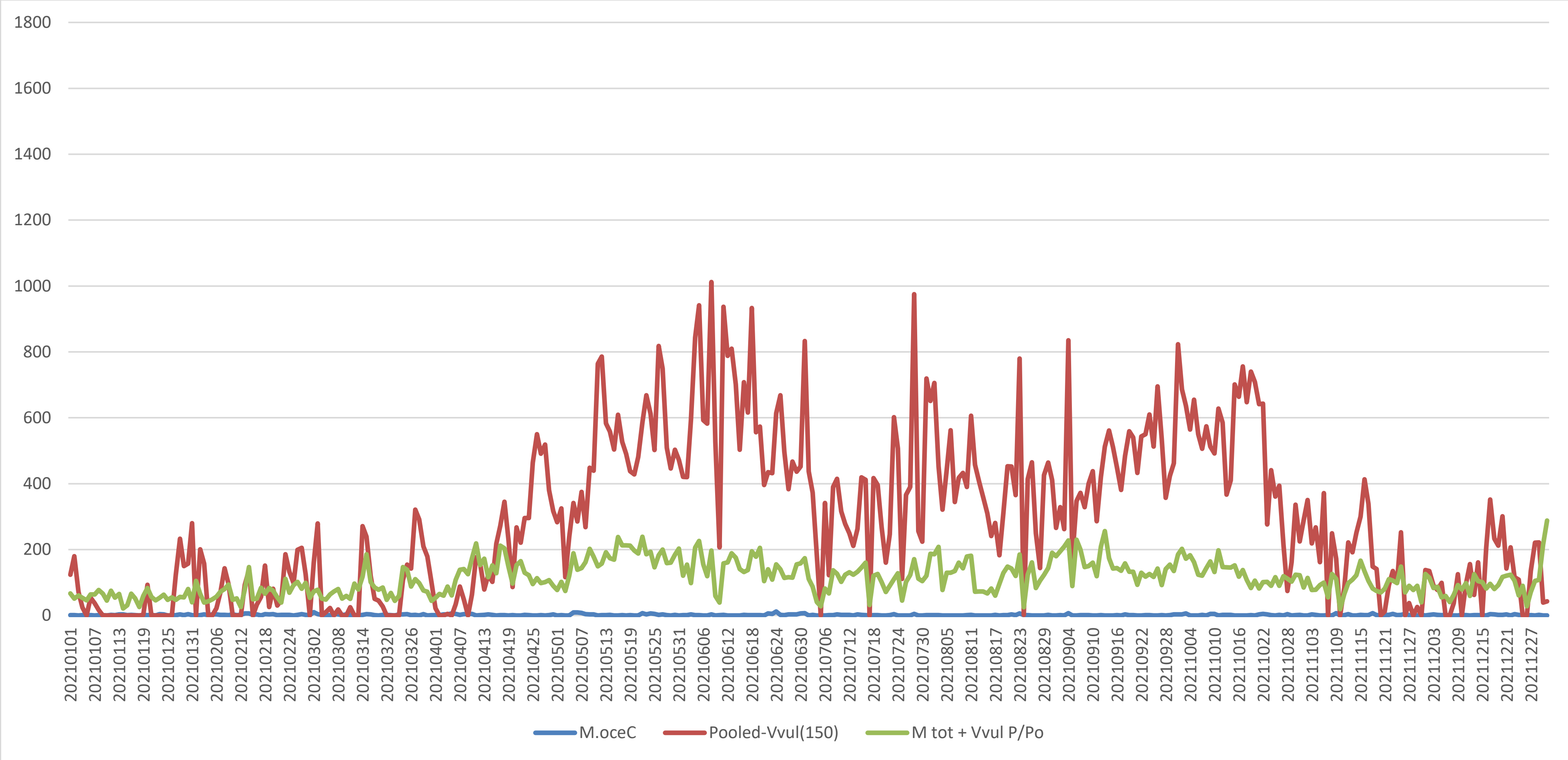


Figure 4-8: Nightly Large Bent-winged Bat activity in 2019. *M.oceC* represent the number of confident open space Large Bent-winged Bat calls. *Pooled-Vvul(150)* represent the number of pooled confident calls for Large Bent-winged and Little Forest Bats which have similar call parameters (i.e. M.oceC + VvulC – 150). *Mtot+VvulP/Po* represent the number of total Large Bent-winged Bat calls plus calls of Little Forest Bat that were not identified confidently as Little Forest Bat.

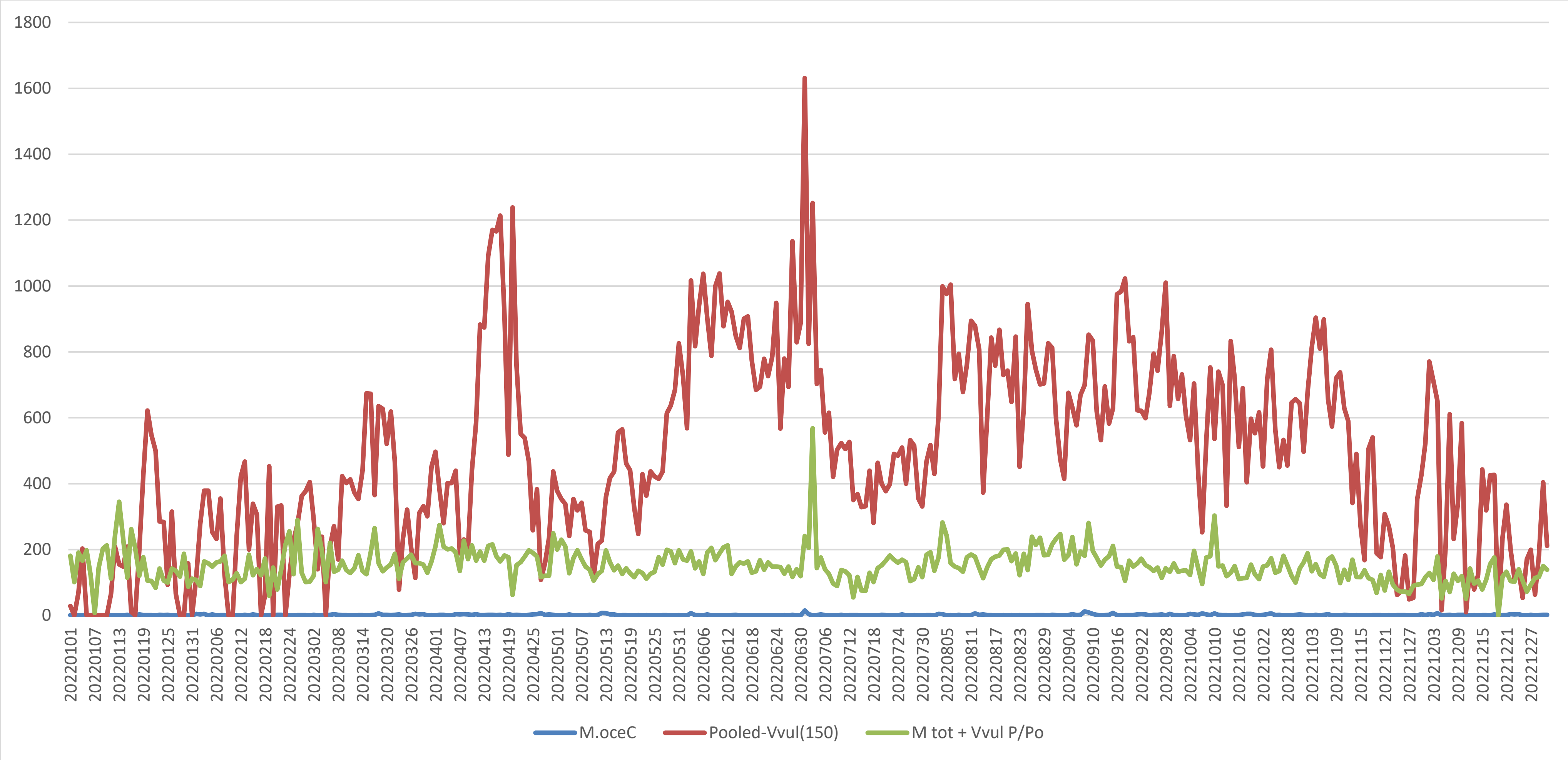


Figure 4-9: Nightly Large Bent-winged Bat activity in 2019. *M.oceC* represent the number of confident open space Large Bent-winged Bat calls. *Pooled-Vvul(150)* represent the number of pooled confident calls for Large Bent-winged and Little Forest Bats which have similar call parameters (i.e. M.oceC + VvulC – 150). *Mtot+VvulP/Po* represent the number of total Large Bent-winged Bat calls plus calls of Little Forest Bat that were not identified confidently as Little Forest Bat.

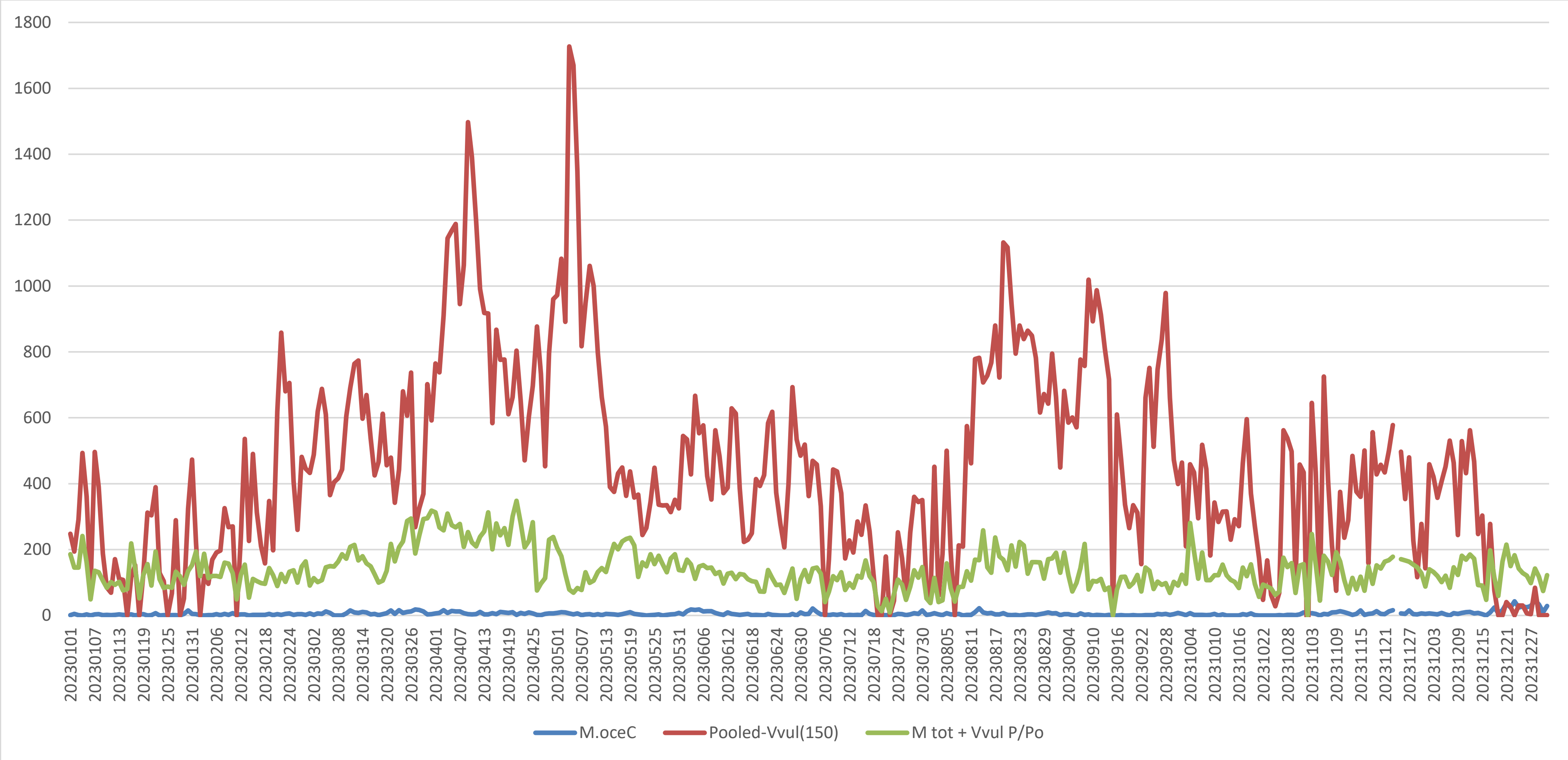
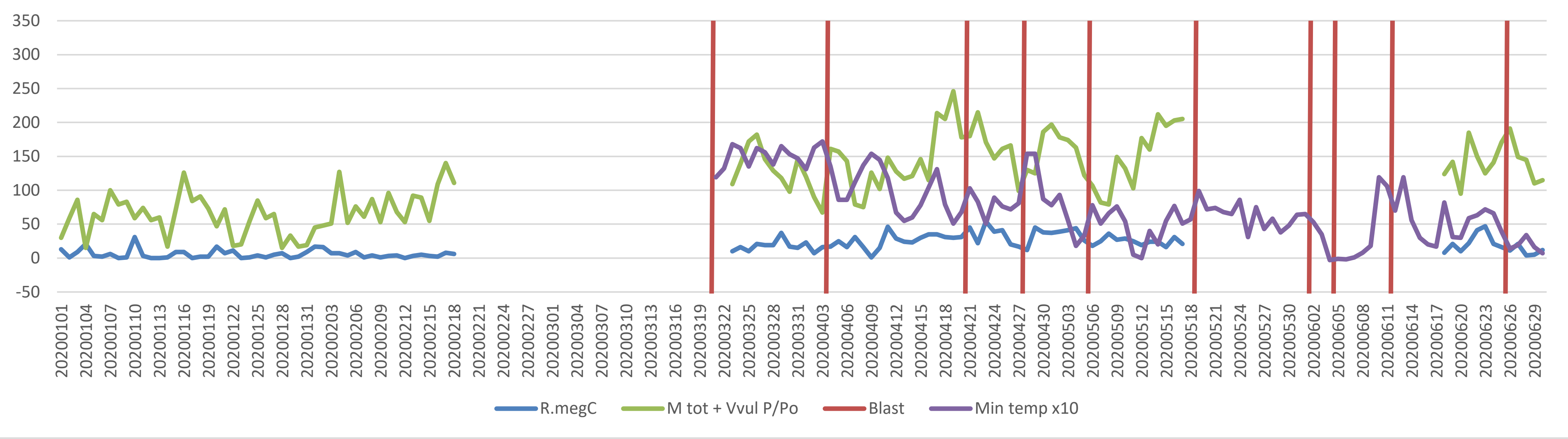
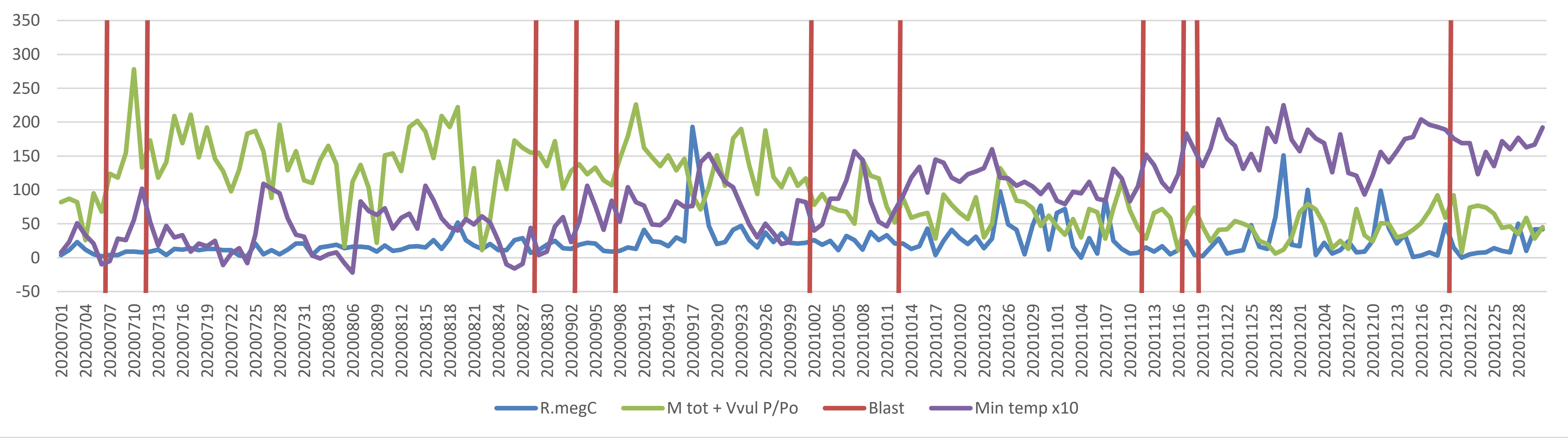


Figure 4-10: Nightly Large Bent-winged Bat activity in 2019. *M.oceC* represent the number of confident open space Large Bent-winged Bat calls. *Pooled-Vvul(150)* represent the number of pooled confident calls for Large Bent-winged and Little Forest Bats which have similar call parameters (i.e. M.oceC + VvulC – 150). *Mtot+VvulP/Po* represent the number of total Large Bent-winged Bat calls plus calls of Little Forest Bat that were not identified confidently as Little Forest Bat.


R.megC
M tot + Vvul P/Po
Blast
Min temp x10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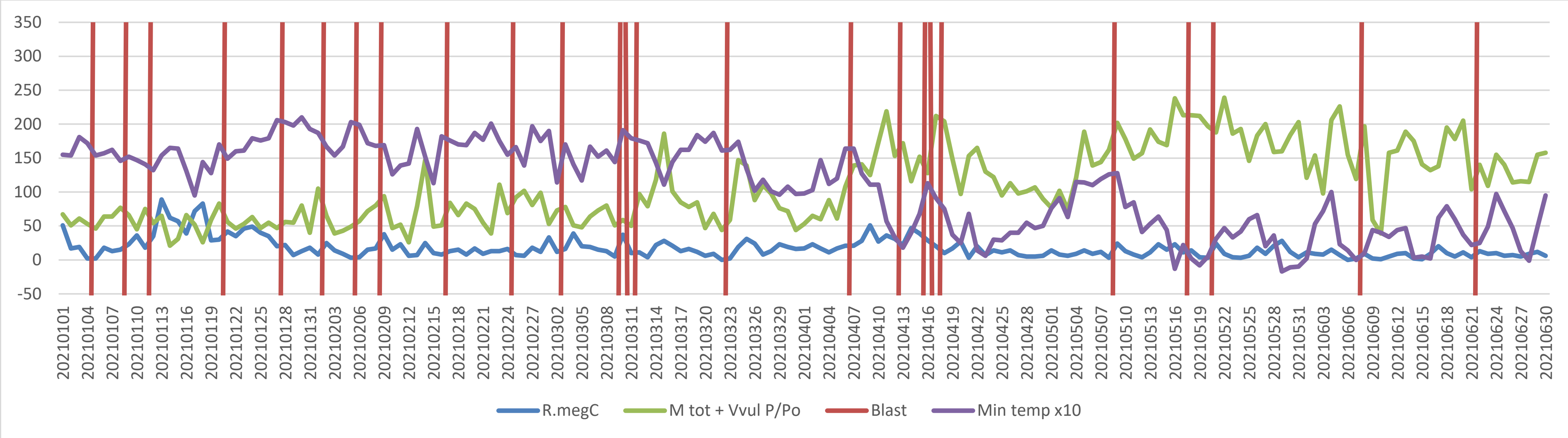
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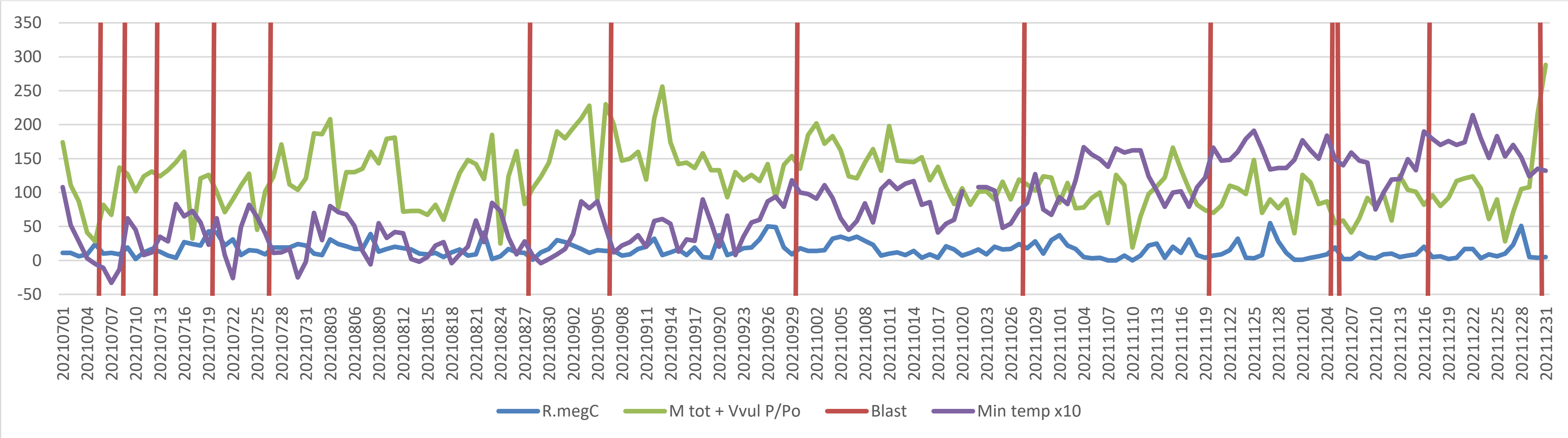
M tot + Vvul P/Po
Blast
Min temp x10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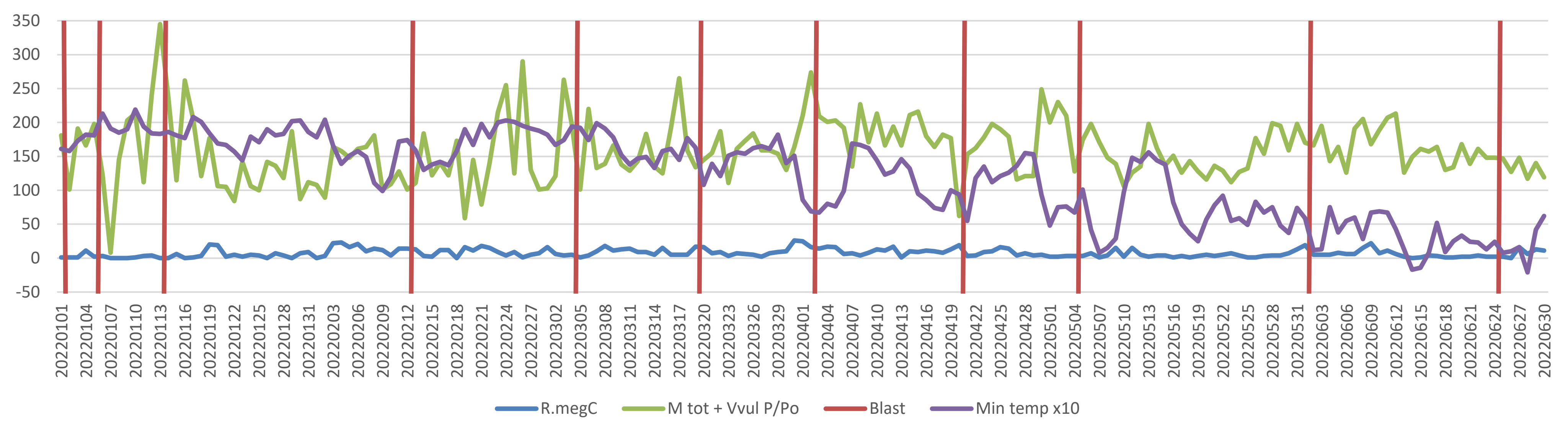
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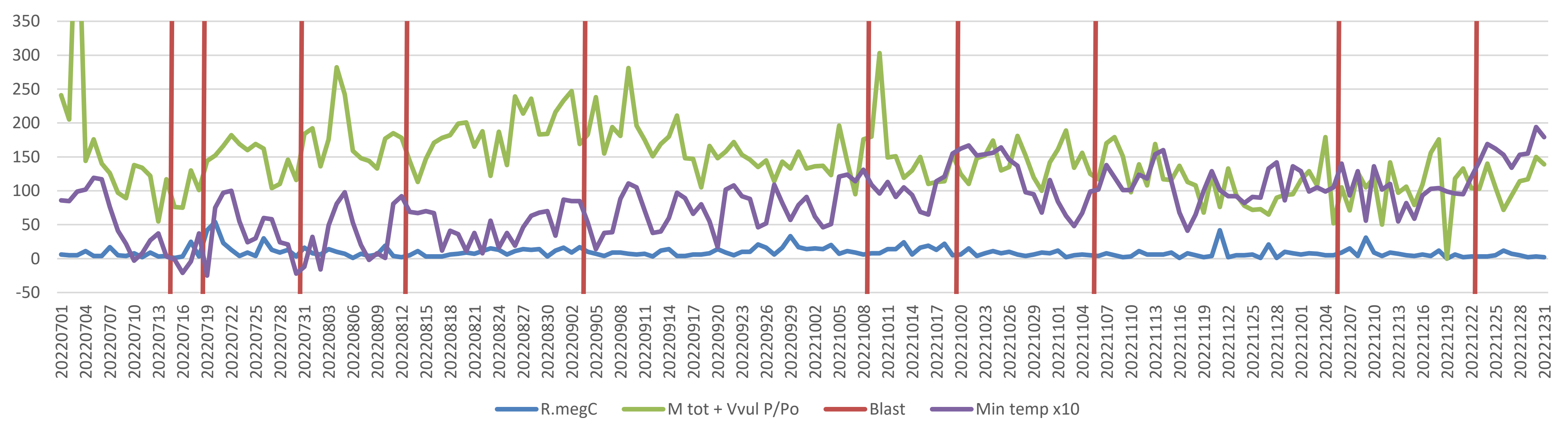
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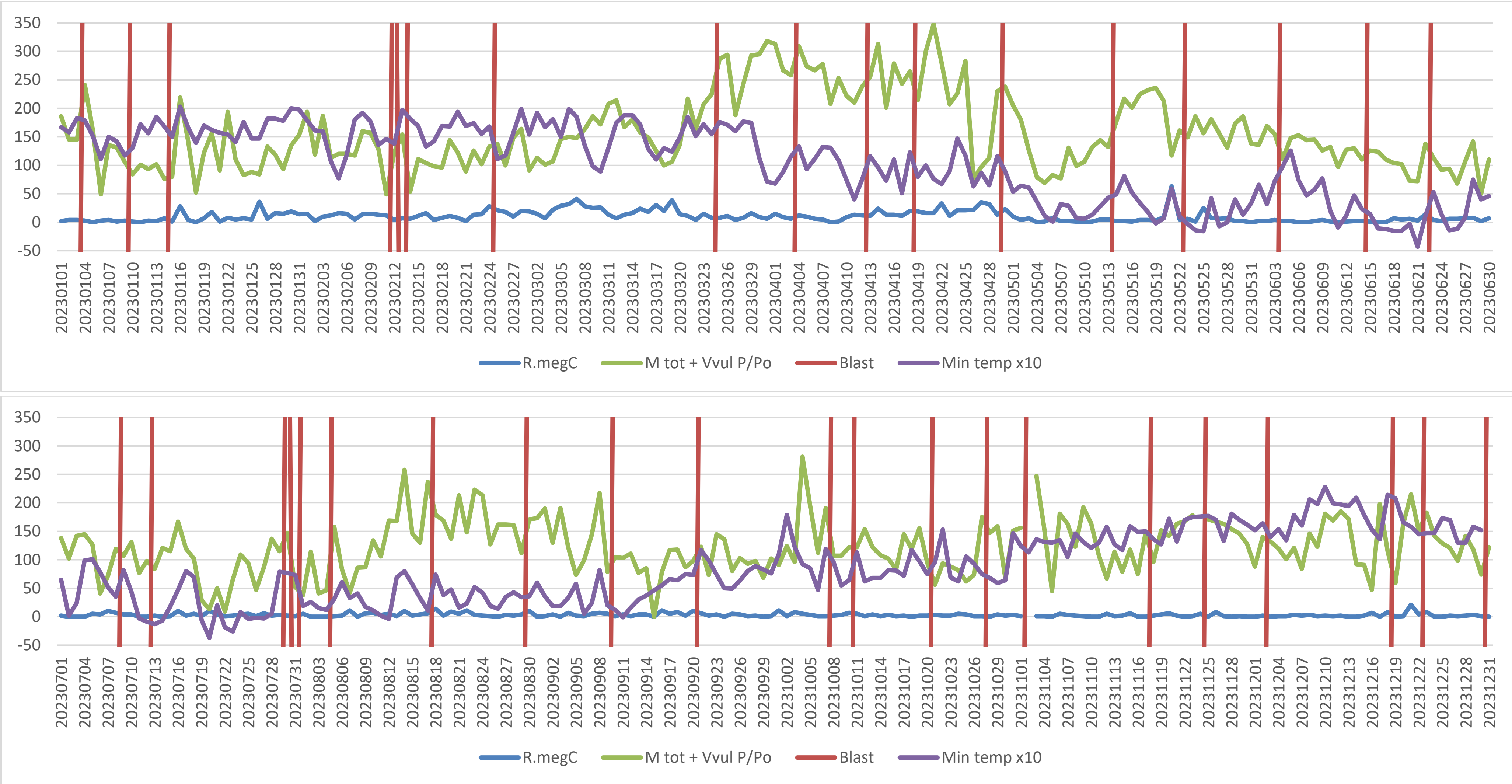

Figure 4-11: Eastern Horseshoe-bat and Large Bent-winged Bat numbers through time with blast dates marked as vertical lines

Minimum temperatures presented as degree Celsius x10 so change in temperature is visible against change in bat activity

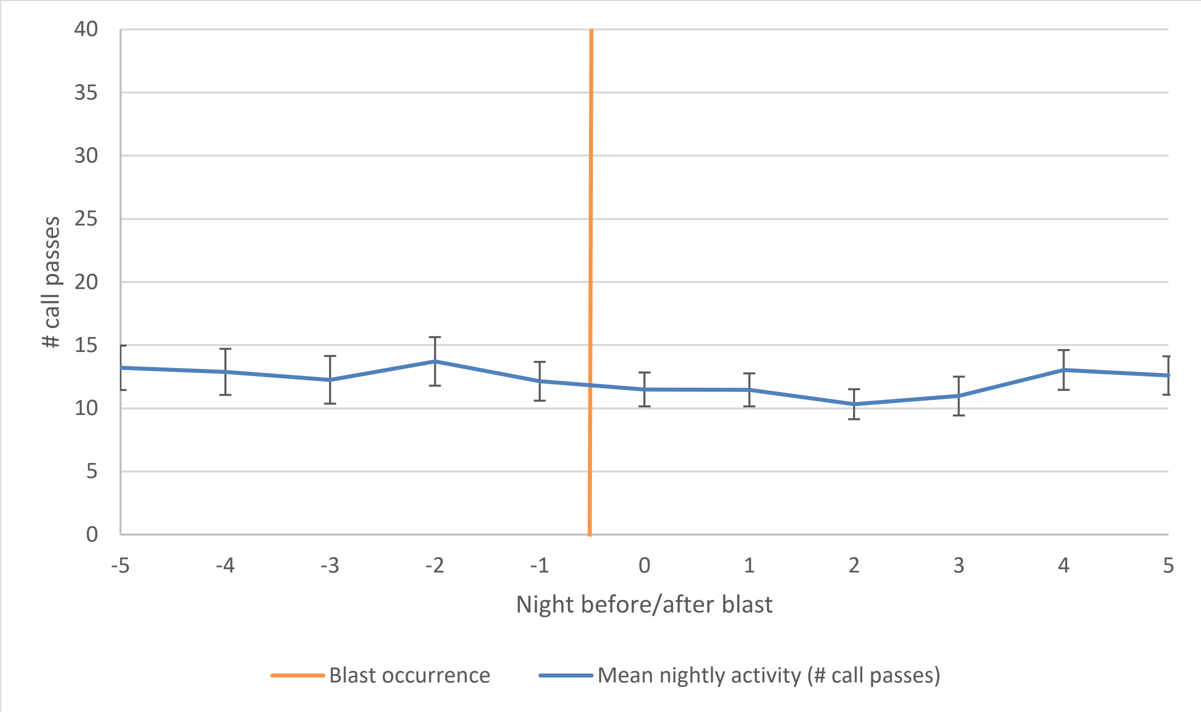

Figure 4-12: Mean short term response by Eastern Horseshoe-bat (R.megC) 2020-2023

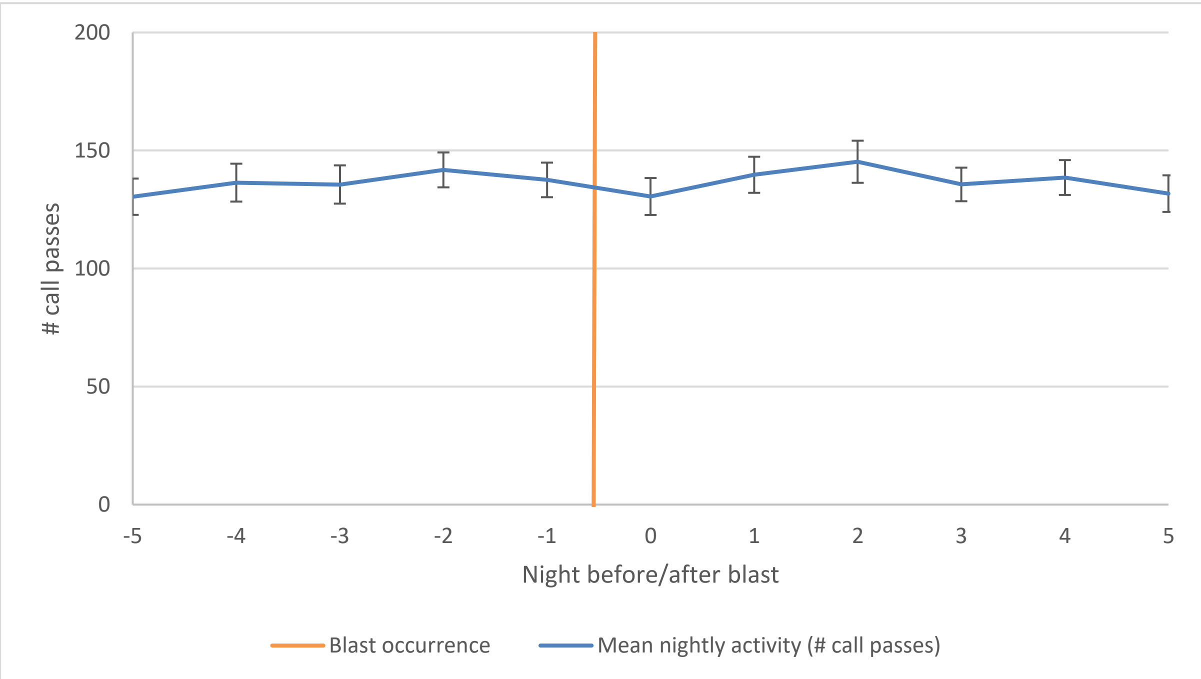

Figure 4-13: Mean short term blast response by Large Bent-winged Bat (M tot + Vvul P/Po) 2020-2023

5.0 Discussion

November 2019 saw the installation of a 900mm diameter steel pipe in the entrance of the adit. Collapsed material was removed, a 20m section of pipe pushed into the entrance, and material back filled around the pipe. The aim of this was to ensure an opening is maintained in the event of an entrance collapse. Modifications to this work were conducted in April 2020 in response to concerns raised via email in March 2020, regarding the height of the backfill material reducing the size of the adit opening. Low numbers of Large Bent-winged Bats were recorded in March 2020, after individuals were found to have returned in February. While the extreme drought and heat conditions experienced through 2019 could explain the large reduction in bat numbers, the fact that numbers had declined since the February count indicated there could be a localised issue. It was postulated that this reduction could be due to the small gap left after material was back filled over the pipe. This material was reduced, increasing the opening to approximately 1.0m in height. By June 2020 numbers were back to where they were in June 2019, and by August 2020 the number of Large Bent-winged Bats counted indicated numbers were back to levels seen in winter 2017.

On 26 April 2023, the steel pipe was removed from the adit and replaced with a larger aperture square steel box tunnel (see **Plate 5-2**). This was in response to the beginning of signs of rock fracture around the adit entrance. The rock around the adit entrance was sprayed with marking paint in September 2022 to facilitate identification of rock that had dislodged from the adit entrance. Minor rock falls (football sized) were observed in December 2022, February 2023, August 2023 and September 2023. A larger block (esky sized) was observed to have dislodged from the right hand side of entrance in March 2023. The new tunnel (measuring 1.1m high x 1.3m wide) was constructed of steel plate with the inner surface a combination of painted and bare steel. The old pipe had a sectional area of approximately 0.64m2, while the new tunnel had a sectional area of 1.43m2. This better suits the requirements of Large Bent-winged Bat flight, with few (if any) bats ever observed using the round pipe. The April 2023 count was conducted on the night of the tunnel installation. Dirt had been piled up on top of the tunnel in an attempt to stabilise the tunnel and close the adit in (forcing bats to use the tunnel). On counting the exit, a small aperture was obviously present in the top of the dirt pile, as approximately 90% of the bats exiting the adit that night used the top rather than the tunnel. Forcing large numbers through a small aperture also meant the exit took longer than it had previously. The author proposed that the mine remove some of the dirt on top of the pipe to allow bats to use their preferred flight path, and reduce the risk of predation by a cat or fox standing in front of the small aperture.

In May 2023, the space above the tunnel had been expanded to avoid funnelling bats through a tiny aperture. The bats must have become accustomed to the tunnel by this stage as the majority were observed exiting via the tunnel rather than the space over the top (though multiple instances of bats exiting via the tunnel and returning via the aperture were observed). Again, the exit took longer than it had previously, and I was still trying to find a counting location that let me effectively count the bats exiting from the bottom and top (the tunnel extends out from the entrance of the adit, so if you sit in front of the tunnel, it is hard to observe bats leaving via the top). Observing from the side also meant having to use a torch to count the bats as they were now flying against a complex rock background, rather than being backlit by a sky lit up with the glow of light spill from the nearby mine. Counting was ceased once no new bats had exited the adit in a 10 minute period. Upon packing up, bats were noted streaming out of the tunnel. Returning to the entrance to aurally count bats exiting via the tunnel counted another 35 bats in a 5 minute period. It would appear light from counting was preventing the bats from exiting the adit. It should be noted that few Eastern Horseshoe-bats were counted during this period, but it could be a result of poor visibility of their preferred exit route from the end of the tunnel.

From June, a few different observation setups were trialled. Shining a torch out and up from the end of the tunnel allowed counting of the bats exiting the tunnel, but made it hard to pick up bats exiting via the top (or out to the side where Horseshoe-bats prefer to come and go). Lowering the light intensity still allowed counting without preventing the bats from exiting (assessed by turning the light off at the end and listening for bats exiting). The smaller aperture of the tunnel has still resulted in slowing the emergence of the bats. Exit counts previously peaked in the 10 minute period 10-30 minutes after first exit, and most bats had exited by 40-50 minutes after first exit. With the new tunnel installed, exits were observed as a steadier stream but a peak at about 20-40 (June) or 30-50 (May and September) minutes after the first exit. It now takes 90-120 minutes for the colony to exit with the new setup. Note: counting was stopped at 2 hours rather than when no bats were observed exiting for 10 minutes as they kept dribbling out slowly.

By January 2023 I think I have a counting protocol sussed out, but will only know if it is successful once Large Bent-winged Bats return to the adit. Looking at December counts from 2017-2023, the number of Eastern Horseshoe-bats was the lowest on record in 2023. The dry conditions experienced over the last 6 months may be partly responsible, but the removal of farm dams for the mine may also explain the reduction in counts/activity. Blast data does not indicate any obvious impact.

April 2023 counts (both species) were half the 2022 numbers, and the second lowest on record with only 2020 being lower. Note both these years were very dry. June counts were the third lowest on record, again being half last years numbers. Numbers peaked for 2023 in September at 731. This is lower than the peaks in 2021 and 2022, but higher than the peaks in 2019 and 2020. The September 2022 count (1050) remains the highest that has been recorded in the adit since investigations and monitoring began. Absence of Large Bent-winged Bat activity over summer reconfirms the absence of maternity roost in the adit.

Automated echolocation call detection worked successfully at Slate Gully for estimating the activity of the two microbat species roosting within the disused oil shale mine workings. A fault in the detector caused loss of data over several weeks in March and June 2020, but the equipment has functioned without fail throughout 2021-22. One night in 2023 (2 November) recorded no call passes, but it is impossible to tell if this was a glitch in the detector or a genuine absence of activity over one night. The pattern of activity broadly mirrored numbers of bats recorded leaving the adit from hand counts undertaken over several years (Fly By Night 2017; Fly By Night 2018; Fly By Night 2019), with the absence of Large Bent-winged Bats in March 2020 counts the only anomaly. There are some complications with separating Large Bent-winged Bat calls from Little Forest Bat calls in the area, though the overall trends seen in the pooled data make ecological sense. With such large amounts of data to analyse from nights call recording, this is considered sufficient to monitor changes in the two cave-dwelling species utilising the adit.

The activity of the Large Bent-winged Bat recorded at the detector was broadly comparable with the hand counts undertaken simultaneously at the adit. Activity of the Eastern Horseshoe-bat recorded at the detector correlated much more poorly with the hand counts. This can be attributed to the small population of Eastern Horseshoe-bats resident in the workings throughout the year compared with that of the Large Bent-winged Bat. The activity patterns of the Eastern Horseshoe-bat (lots of coming and going) also impacts the suitability of the index for this species. From all the data collected, we estimate the population of Eastern Horseshoe-bats within the adit to be stable at 5-30 individuals. Early years have shown activity of the Eastern Horseshoe-bat peaking during the autumn and spring months, with minor activity declines over winter and summer. This species' activity was relatively consistent over 2021 and 2022. 2023 saw consistent activity over the first half of the year and very ow activity since May. Conversely, Large Bent-winged Bat activity fluctuated more in 2023 than during previous years. Activity peaked in April-May and August-September (April and July in 2022), with declines in activity over summer as females migrate to select maternity roosts to give birth (Hoye & Hall 2008). Patterns of activity do not appear to coincide with noted blasts (data March 2020 to December 2023). The index tracking the number of total Large Bent-winged Bat calls added to those attributed to Little Forest Bat with low confidence (*M tot + Vvul P/Po*, **Figures 4-6** to **4-10**) give the best representation of Large Bent-winged Bat numbers in the adit. Looking at bat activity before and after blasts showed mixed (increase/decrease) results. The small changes relative to normal nightly variation in activity suggest no impact from blasting in Pits 3 or 8 on the two bat species.

Results suggest that monitoring of the colony at Slate Gully through nightly recording of echolocation calls provides a feasible means of monitoring use of the disused workings by the two microbat species. Mean monthly activity for the two species can be compared prior to mining taking place in adjacent areas with that post mining. As of February 2024, mining activity is approximately 350m from the adit. As the mine moves closer in 2024, we should be able to detect any potential impacts to occupation/activity of the two cave dwelling microbat species. Images from monthly monitoring (**Plates 5-1** and **5-2**) show the adit entrance has maintained integrity despite the nearby blasting in Pits 3 and 8 (and potentially Pit 7). However, some football sized rocks were dislodged from the entrance in the last half of 2022. One larger rock fell from the eastern side of the entrance in 2023.

Plate 5-1: Periodic monitoring photo of adit entrance from February 2021 (top), January 2022 (middle) and December 2022 (bottom) showing lack of substantial change

Plate 5-2: Monitoring photos of adit entrance pre culvert instillation (March 2023 – top left), afternoon of installation (April 2023 – top right), three months after installation (July 2023 – bottom left), and nine months after installation (January 2024 – bottom right). This shows progression of pipe to tunnel with small aperture, tunnel with large aperture.

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14 February 2024

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WCPL 2023 Stream Health Monitoring Report

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Contents

List of Figures

List of Tables

Abbreviations

Abbreviation	Description
AUSRIVAS	Australian Rivers Assessment System
DO	Dissolved oxygen
EC	Electrical conductivity
ELA	Eco Logical Australia
EPL	Environmental Protection Licence
NP	National Park
NTU	Turbidity
RCE	Riparian, Channel and Environmental
RO	Reverse osmosis
SHM	Stream health monitoring
SIGNAL2	Stream Invertebrate Grade Number - Average Level
WCM	Wilpinjong Coal Mine
WCPL	Wilpinjong Coal Pty Ltd

Summary of Key Findings

Stream health monitoring (SHM) was undertaken during spring 2023 within the catchments surrounding Wilpinjong Coal Mine (WCM). A total of nine permanent sites were monitored along Wilpinjong, Wollar and Cumbo creeks, as well as one control site located along Barigan Creek. One site along Wilpinjong Creek and one control site along Barigan Creek had no surface water at the time of surveying, therefore water quality testing and macroinvertebrate sampling were not undertaken there.

The monitoring results were largely consistent with previous years' results. Most sites recorded mid-range RCE (Riparian, Channel and Environmental) scores, typical of catchments in the region.

Water quality results were recorded for various parameters and differed markedly across most sites in comparison with previous years. Parameters were inside Australian and New Zealand Environmental and Conservation Council (ANZECC) guidelines at all sites for pH and were within or close at eight sites for turbidity, likely as a result of decreased runoff and stream flow leading up to the monitoring period.

Water quality results for temperature, electrical conductivity (EC), and dissolved oxygen (DO) fluctuated considerably across monitoring years, during times of variable stream flow and at sites both upstream and downstream of the WCM licensed discharge point. As such, these results indicate that natural factors and fluctuating climatic conditions, rather than mining operations are the primary influences on water quality in the catchments surrounding the WCM.

Across all monitoring sites, a total of 15 macroinvertebrate Orders and 51 Families were recorded. Stream invertebrate grade number average level (SIGNAL2) scores were generally low in 2023, with all sites but one showing a decrease in comparison to the 2022 SHM period. A combination of low levels of flowing water, higher water temperature, and low DO likely limited the diversity of macroinvertebrate communities. In line with previous years, SIGNAL2 scores were <4.0 for all sites, which is indicative of severely disturbed systems. The overall temporal and spatial consistency of these macroinvertebrate results indicate that historical disturbances, combined with fluctuating climatic conditions within the larger catchments surrounding the WCM, are the main factors responsible for current stream health conditions.

The 2023 SHM was conducted under prevailing dry conditions in the lead up to and during the monitoring period. To ensure an accurate representation of water quality and macroinvertebrate community health, it is recommended that where practicable, future SHM be conducted when the condition is not extreme.

1. Introduction

1.1. Background

Wilpinjong Coal Pty Ltd (WCPL) is required to undertake annual stream health monitoring (SHM) to satisfy the updated requirement of Development Consent SSD 6764 Condition 29 & 30 (ii) (previously under Schedule 3, Condition 32 of WCPL's Project Approval (05-0021)) and the SHM criteria detailed in Appendix 2 of the Wilpinjong Water Management Plan (WCPL 2018). Eco Logical Australia (ELA) was engaged by WCPL to undertake SHM in the 2023 monitoring period.

1.2. Regional Overview

The Wilpinjong Coal Mine (WCM) is located in the Mid-Western Regional Council Local Government Area, approximately 45 km north-east of Mudgee. The mine is owned and operated by WCPL, a wholly owned subsidiary of Peabody Energy Australia.

The WCM is located at the headwaters of the Goulburn River which is a major tributary of the Hunter River catchment. Wilpinjong Creek is the main drainage channel within the WCM. It is an intermittent creek with a narrow floodplain that has a history of cattle grazing. The northern edge of the floodplain is bordered by the sandstone escarpments of Goulburn River National Park (NP). Wilpinjong Creek has three coal mines in its catchment, Moolarben, Ulan, and Wilpinjong, with the latter positioned furthest downstream. WCPL discharges water, treated by reverse osmosis (RO), into Wilpinjong Creek at Environment Protection Licence (EPL) point 24 (EPL 24) directly adjacent to WCM.

Barigan Creek flows north through agricultural land as a tributary to Wollar Creek, joining south of the town of Wollar. Cumbo Creek flows north through land managed by WCPL, passing between Pit 3 and Pit 4, before joining Wilpinjong Creek north of the eastern pit area. Wilpinjong Creek continues to flow east, for approximately 4.5 km downstream where it joins Wollar Creek, which continues another 13 km through the Goulburn River NP before entering the Goulburn River.

1.3. Objectives

The ongoing SHM program for WCM is aimed to assist in determining the need for any maintenance and/or contingency measures. The objectives of annual SHM within Wilpinjong, Cumbo, Wollar and Barigan Creeks include:

- Survey of aquatic macroinvertebrate assemblages in spring if streamflow or ponded water is present and access to the creeks is safe, paired with *in situ* surface water quality sampling at each sampling site.
- An assessment of environmental condition at each site based on a variety of ecological indices.
- Comparisons of site indices against previous survey data to assess changes through time, and comparisons to trigger levels that would prompt further investigation.

2. Methodology

2.1. Survey Overview

The 2023 SHM was undertaken by ELA ecologists Cheryl O'Dwyer, Jack O'Sullivan, and Kacey Tada from 4 December to 6 December 2023. A total of ten permanent monitoring sites were surveyed along Wilpinjong, Cumbo and Wollar Creeks, along with two control sites at Barigan Creek established in 2020 (**Table 1**). In 2023, macroinvertebrate and water sampling did not occur at BC2 along Barigan Creek, nor at WC2 along Wilpinjong Creek because they were dry. Two survey sites WO3 and WO4 along Wollar Creek were inaccessible in 2022, but revisited this year.

Monitoring locations reflect a balance of sites both upstream and downstream of WCPL discharge point (EPL Point 24), as well as the various creeks (including external creeks) within the surrounding catchment (**Figure 1**). Photographs of each site are included in **Appendix A**.

Table 1: 2023 monitoring sites

Creek	Site	Upstream / Downstream*	Inundation Status	Easting	Northing
Wilpinjong Creek	WC1	Upstream	Wet	767680	6422970
	WC2**	Upstream	Dry	768490	6422490
	WC6	Downstream	Wet	774580	6420860
	WC8	Downstream	Wet	775860	6420820
Cumbo Creek	CC1	Upstream	Wet	772710	6418130
	CC2	Upstream	Wet	772980	6418950
Wollar Creek	WO1	Upstream	Wet	777940	6418170
	WO2	Upstream	Wet	777780	6418950
	WO3	Downstream	Wet	777790	6420100
	WO4	Downstream	Wet	778030	6420596
Barigan Creek	BC1	Upstream	Wet	778704	6409493
	BC2**	Upstream	Dry	779830	6403765

*Indicates Upstream / Downstream of EPL Point 24)

**Sampling was not possible at these sites during the 2023 monitoring period

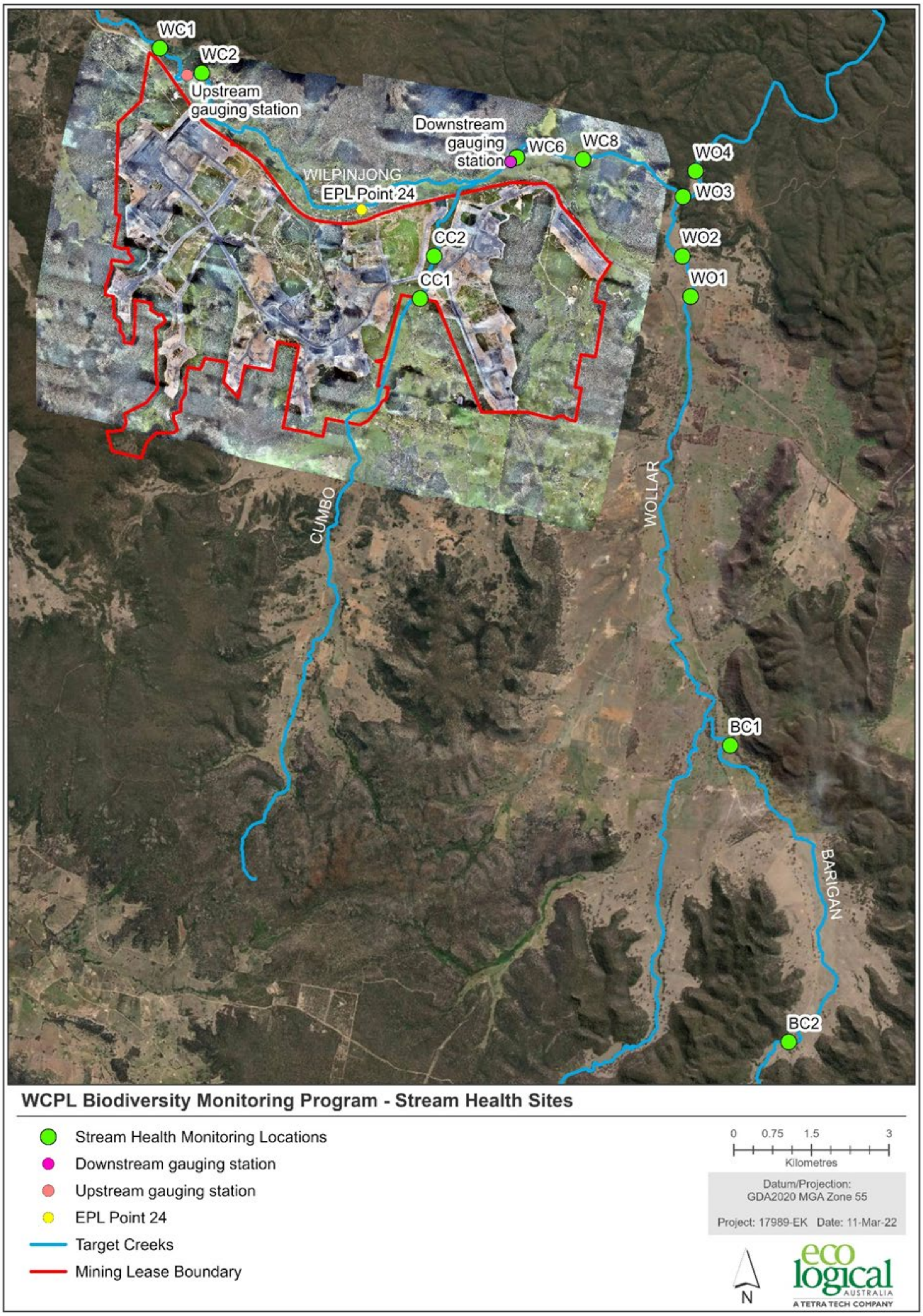

Figure 1: 2023 monitoring sites along Wilpinjong, Cumbo, Wollar and Barigan Creeks

2.2. Survey Methods

2.2.1. Aquatic habitat assessment

Aquatic habitat assessments were based on the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI Fisheries 2013), which outlines the features important for fish habitat in freshwater, estuarine, and marine areas. Habitat assessments allow the significance of river reaches to be determined, regardless of whether target fish species are present permanently, or for brief periods of time.

Aquatic habitat variables (environmental data) were noted for each site, with observations made from the bank on the following characteristics:

- General signs of disturbance
- Habitat type
- Channel topography
- Current water level
- Bank and bed slope
- Degree of river shading
- Amount of detritus
- Macrophyte type and extent
- Riparian zone width
- Snags and large woody debris coverage
- Stream width and depth
- Surrounding land use
- Description of the natural substrate
- Extent of bank overhang
- Amount of trailing bank vegetation.

Riparian condition was assessed using a version of the Riparian, Channel and Environmental (RCE) inventory (Peterson 1992) that was modified for Australian conditions (Chessman et al. 1997). The modified RCE has 13 descriptors, each with a score from one (poor condition) to four (good condition).

Descriptors included width and condition of the riparian zone, surrounding land use, extent of bank erosion, stream width, water depth, occurrence of pools, riffles and runs, substratum type, presence of snags and woody debris, in-stream and emergent macrophytes, algae, and barriers to fish passage. The total score for each site was derived by summing the score for each descriptor and calculating the result as a percentage of the highest possible score (up to 52).

Sites with a high RCE score indicate that the riparian zone is largely undisturbed, while those with a low score have undergone substantial modification. Based on the original classification established by Peterson (1992), site condition was rated as follows:

- Poor for RCE scores of 0-24%
- Fair for RCE scores of 25-43%

- Good for RCE scores of 44-62%
- Very Good for RCE scores of 63-81%
- Excellent for RCE scores of 82-100%.

RCE results from 2023 were compared with results from previous monitoring years dating to 2016, when RCE was introduced to the WCPL SHM program (**Section 4.1**).

2.2.2. Water quality

Complementing documented biological data, the following physicochemical parameters were measured at all sites:

- Temperature
- Dissolved oxygen (DO)
- Electrical conductivity (EC)
- Turbidity (NTU)
- pH

Water quality results from 2023 were compared with previous year's results for DO, EC, turbidity and pH (Section 4.2). Results date back to 2006, however, not all parameters have results available for each year. Water quality parameters measured during surveys were compared with the ANZECC and ARMCANZ (2000) guidelines for the protection of aquatic environments. The ANZECC and ARMCANZ guidelines provide different ranges for upland and lowland streams, with upland streams being those above 150 m altitude. All sites surveyed for this project are considered upland stream sites.

2.2.3. Macroinvertebrate communities

Macroinvertebrate samples were collected at each site using the Australian Rivers Assessment System (AUSRIVAS) protocols (Turak et al. 2004). Three representative samples were collected at each site. Samples were collected from 10 m of representative edge, pool and/or riffle habitats using a standard AUSRIVAS kick net with 250 µm mesh. The net was bounced along the bottom to disturb resting invertebrates, and then rapidly passed again through the water column to collect the disturbed taxa. Edge habitats were defined as adjacent to the creek bank in areas of little or no flow, including alcoves and backwaters, with abundant leaf litter, fine sediment deposits, macrophyte beds and overhanging bank vegetation (Turak et al. 2004).

Macroinvertebrate samples were live-sorted in the field for a minimum of 40 minutes. If new taxa were collected in the period from 30 to 40 minutes, picking continued for 10 minutes. If no new taxa were found after the additional 10 minutes, sorting stopped. The maximum sorting time was 60 minutes. All picked animals were preserved in 70% ethanol solution and transported to the laboratory for identification. Specific care was taken to ensure cryptic, fast-moving taxa were represented.

Macroinvertebrates were identified to family level, except for Copepoda, Ostracoda, Oligochaeta, Platyhelminthes, Hirudinea, and Collembola which were identified to order.

The Stream Invertebrate Grade Number - Average Level (SIGNAL2) is a biotic index that allocates a value to each macroinvertebrate family based upon their sensitivity to pollution. A macroinvertebrate family with a value of 10 indicates high sensitivity, while a value of 1 indicates low sensitivity (i.e. high pollution tolerance) (Chessman et al. 1997). The SIGNAL2 score for the entire site is calculated by summing the

SIGNAL2 grades for each family collected at that site and then dividing by the total number of families collected. SIGNAL2 scores are used to grade aquatic health into the following categories:

- SIGNAL2 Score > 6: Healthy Habitat
- SIGNAL2 Score 5-6: Mild Pollution
- SIGNAL2 Score 4-5: Moderate Pollution
- SIGNAL2 Score < 4: Severe Pollution.

Average SIGNAL2 scores for 2023 were compared with scores from previous years, dating back to 2006 (where available) (**Section 4.3**). SIGNAL2 scores from 2011 to 2013 (Landline Consulting 2011; 2012; 2013) were calculated using abundance weighting of macroinvertebrate taxa which resulted in slightly higher average SIGNAL2 scores for sites with relatively abundant macroinvertebrates. Since 2014, SIGNAL2 scores were calculated on presence/absence data. Whilst this method differs slightly from that undertaken in previous years, the results are largely consistent and valid for comparison.

2.3. Climate data

During the three days of the 2023 stream health monitoring period, air temperature was high and above historical averages, and there was no rainfall (**Table 2**). In the preceding four months prior to monitoring, rainfall was well below average, which was only 60% of the historical average for July-October (**Table 3**). **Table 4** summarises monthly flow data measured at three gauging stations near WCL. Due to this consistent dry trend, there was generally very little or no flow at many sites.

Table 2: Temperature and rainfall data for the Spring 2023 monitoring period

Date	Min. temp (°C)	Max. temp (°C)	Rainfall (mm)
4 Dec 2023	15.4	29.9	0
5 Dec 2023	13.4	35	0
6 Dec 2023	17.9	38.4	0

Source: WCPL Weather Station Sentinex 34

Table 3: Temperature and rainfall preceding 2023 monitoring period

Month	2023 Averages (WCPL)			Historical Averages		
	Mean min. temp (°C)	Mean max. temp (°C)	Total Rainfall (mm)	Mean min. temp (°C)	Mean max. temp (°C)	Total Rainfall (mm)
January	16.2	30.4	48.6	16.1	30.9	67.1
February	15.6	30.6	24.6	15.6	29.4	62.3
March	15.3	29.5	64.6	12.9	26.9	55.1
April	9.5	22.0	47.8	7.9	22.9	39.3
May	2.5	18.3	2.8	4.0	18.6	37.0
June	2.9	16.2	28.8	2.4	15.0	43.7
July	3.0	17.2	23.2	1.2	14.6	42.9
August	3.4	19.6	29.8	1.6	16.2	41.1
September	5.2	24.4	18	4.3	19.7	41.7
October	9.0	25.7	36.2	7.8	23.2	52.1

Month	2023 Averages (WCPL)			Historical Averages		
	Mean min. temp (°C)	Mean max. temp (°C)	Total Rainfall (mm)	Mean min. temp (°C)	Mean max. temp (°C)	Total Rainfall (mm)
November	14.5	27.7	94	11.2	26.3	56.7
December	17.0	32.1	59.6	13.7	28.9	60.7

Source: 2023 data from the WCPL Weather Station Sentinex 34, historical data from the BoM weather stations at Mudgee Airport (temp) and Wollar-Barigan St weather station (rainfall) (BOM 2023)

Table 4: Monthly flow data at three gauging stations

Month	Wilpinjong Creek Upstream			Wilpinjong Creek Downstream			Cumbo Stream Upstream		
	Flow (cumecs)	EC (us/cm)	pH	Flow (cumecs)	EC (us/cm)	pH	Flow (cumecs)	EC (us/cm)	pH
January	0.12	1754.5	7.61	0.15	1672.6	7.56	0.02	2188.5	7.36
February	0.00	791.4	7.11	0.09	1145.4	7.50	0.01	2409.3	7.50
March	0.00	1039.7	7.26	0.05	1098.2	7.38	0.00	3056.4	7.44
April	0.00	786.9	7.07	0.05	1310.7	7.55	0.01	3086.9	7.59
May	0.00	728.0	7.18	0.05	1351.6	7.78	0.01	2965.4	7.73
June	0.01	585.5	7.18	0.11	1370.0	7.82	0.01	3008.1	7.49
July	0.00	568.5	7.06	0.09	1311.9	7.81	0.01	2875.0	7.53
August	0.00	708.0	7.09	0.08	1233.6	7.79	0.01	3037.4	7.38
September	0.00	934.9	7.31	0.04	1057.1	7.87	0.01	3255.1	7.43
October	0.01	1209.2	7.42	0.14	804.5	7.74	0.05	3777.4	7.83
November	0.00	1338.1	7.70	0.14	936.3	7.46	0.06	3531.5	7.54
December*	0.00	1431.4	7.37	0.05	702.7	7.34	0.00	3866.6	7.29

Source: WCM.

*As of 11 Dec 2023

3. Results

3.1. Aquatic Habitat Assessment

Results of the habitat assessment, including water, substrate, vegetation, land use, and how these elements contribute to the RCE score are detailed below. A breakdown of how the 13 RCE parameters scored for each site is included in **Table 5**.

Table 5: Site results for the 13 RCE parameters

Descriptor	WC1	WC2 *	WC6	WC8	WO 1	WO 2	WO 3	WO 4	BC1	BC2 *	CC1	CC2
Land use pattern beyond immediate riparian zone	3	3	2	3	2	3	3	4	3	3	2	3
Width of riparian strip of woody vegetation	3	3	3	3	3	3	3	4	3	3	2	1
Completeness of riparian woody strip of vegetation	2	2	2	3	2	2	2	4	3	1	1	1
Vegetation of riparian zone within 10 m of channel	4	4	2	2	3	3	3	4	3	1	2	1
Stream bank	2	2	3	3	3	3	3	3	3	3	3	3
Bank undercutting	3	3	3	4	3	3	3	3	3	3	4	4
Channel form	2	3	3	3	3	3	3	3	3	3	2	3
Riffle/pool sequence	2	3	3	3	3	3	3	3	3	3	2	2
Retention devices in stream	1	1	1	1	4	3	3	3	2	2	1	1
Channel sediment accumulations	4	3	4	4	3	4	3	3	3	3	4	4
Stream bottom	2	2	2	2	2	2	2	2	2	2	2	2
Stream detritus	2	2	2	2	2	2	3	3	2	2	2	1
Aquatic vegetation	2	2	2	2	2	2	2	2	2	2	2	2
Total	32	33	32	35	35	36	36	41	35	31	29	28
Total %	62	63	62	67	67	69	69	79	67	60	56	54
Condition classification	G	VG	G	VG	VG	VG	VG	VG	VG	G	G	G

G = Good; VG = Very Good

*Due to lack of water, scores were adopted from the assessment in 2022, assuming that conditions will recover to the previous level as water returns

All sites continue to record an RCE classification of 'Good' (five of twelve sites) or 'Very Good' (seven of twelve sites), consistent with that recorded in 2022.

3.2. Water Quality

The results of water quality sampling for temperature, EC, DO, pH *in situ* and Turbidity *ex situ* are detailed in **Table 6**. Water temperatures at the time of sampling ranged between 19.3°C and 29.9°C.

Variation in water temperature generally reflected the time of day as well as the stream morphology of the monitoring sites, with samples collected later in the day (e.g. WC1 and WO2) and/or from shallower profile streams (e.g. WC1 and BC1) recording higher temperatures.

EC levels increased across all sites except WC6 and WC8 in 2023 compared to the result from 2022. None of the sites had EC values within the ANZECC and ARMCANZ (2000) guidelines. The lowest EC recorded was at WC8 (666 µS/cm). The highest two EC values were recorded at CC1 (4026 µS/cm) and CC2 (3994 µS/cm), both of which are located within the WCPL mining lease, with the EC values at these sites substantially higher than all other monitoring sites, analogous to the previous two years' trend.

DO ranged between 30.0% saturation at WO1 to 77.6% saturation at WO3 and CC2. All ten sites were much lower than the recommended ANZECC and ARMCANZ (2000) guideline range. The pH ranged between 6.85 at WC1 and 7.84 at CC2, resulting in all sites being within the ANZECC and ARMCANZ (2000) guidelines. Turbidity ranged from 1.6 NTU at CC2 to 69.7 NTU at WC1 (**Table 6**). WC1, BC1, CC2 did not meet the recommended ANZECC and ARMCANZ (2000) guideline for turbidity, with only WC1 exceeding the guidelines by a significant degree.

Table 6: Water quality results. Red figures are outside of ANZECC Guidelines

Variable	Guideline Range	WC1	WC2*	WC6	WC8	WO1	WO2	WO3	WO4	BC1	BC2*	CC1	CC2
Temperature (°C)	N/A	29.9	-	19.3	20.7	20.4	29.0	27.0	25.4	25.8	-	21.0	27.6
Conductivity (µS/cm)	30-350	1563	-	708	666	1549	1553	917	966	889	-	4026	3994
DO (% saturation)	90-110	33.1	-	53.6	59.2	30.0	72.2	77.6	67.8	37.4	-	44.6	77.6
DO (mg/L)	N/A	2.47	-	4.95	5.29	2.69	5.47	6.07	5.56	3.06	-	3.87	6.1
pH	6.5-8.0	6.85	-	7.33	7.26	7.48	7.61	7.68	7.67	6.96	-	7.67	7.84
Turbidity (NTU)	2-25	69.7	-	5.3	19.2	17.6	6.1	10.2	13.5	29	-	2.9	1.6

*Sites were not sampled during the 2023 monitoring period

3.3. Macroinvertebrate Communities

A summary of macroinvertebrate results is presented in **Table 7**, with the full results for each site detailed in **Appendix B**. A total of 15 macroinvertebrate Orders/Classes and 51 Families were recorded during 2023 monitoring. The most observed taxa were Atyidae from the Order Decapoda, Chironomidae from the Order Diptera, Baetidae from the Order Ephemeroptera, three families from the Order Hemiptera, and Coenagrionidae from the Order Odonata, all of which were recorded across eight out of ten monitoring sites. Across individual sites, macroinvertebrate taxonomic richness ranged from 9 to 31 taxa, with WC1 recording the least number of taxa and WO1 recording the most. CC2 resulted in the second lowest richness with 10 taxa despite that it recorded the highest richness in 2022, implying that richness may be highly impacted by the abundance of flowing water. At the time of sampling, these sites had a variety of available micro-habitat for macroinvertebrates, including macrophytes, woody debris and riffles. However, the water level was generally low across all sites, harnessing limited macroinvertebrate communities.

Pollution sensitivity ratings for each Family/Order were used to calculate the average SIGNAL2 score for each site. Where Families/Orders have no assigned SIGNAL2 sensitivity rating, they were not included in the averages, however, are still represented in results for taxa richness. Average SIGNAL2 scores range from 2.4 (severely polluted) at WC6 to 3.6 (severely polluted) at WO2 and WO3 (**Table 7**). All the sites had an average SIGNAL2 score of less than 4.0 and as such, are classified as severely disturbed. Overall, the score declined compared to the result in 2022.

Section 6.2 of the WCPL Surface Water Management and Monitoring Plan (WCPL, 2018) outlines the following trigger conditions for SHM:

- Minimum taxon richness: 15 taxa; and
- Minimum SIGNAL2 index: 3.0.

WO3, WC8, and WO1 scored above the minimum trigger conditions for both SIGNAL2 and taxa richness scores. Sites WC6 and WO4 did not reach either minimum taxa richness or minimum SIGNAL 2 index.

Table 7: SIGNAL2 scores for 2023 monitoring sites

Measure	BC1	CC1	CC2	WC1	WC6	WC8	WO1	WO2	WO3	WO4
Taxa richness	24	23	10	9	12	21	31	13	19	8
Average SIGNAL2 score	2.8	2.6	3.3	3.0	2.4	3.1	3.5	3.6	3.6	2.8
SIGNAL2 pollution condition	S	S	S	S	S	S	S	S	S	S

S = Severe

*Sites were not sampled during the 2023 monitoring period

4. Discussion

4.1. Aquatic Habitat Assessment

All sites recorded either 'Good' or 'Very Good' classifications for their RCE indices during 2023 monitoring. This puts them in the mid-range for riparian and channel habitat quality. Overall, habitat conditions within Wilpinjong, Wollar, Cumbo, and Barigan Creek sites were consistent with those recorded since2016, both upstream and downstream of the WCPL licensed discharge point (**Figure 2**).

The stream bed structure (Stream bank, Stream bottom and Stream detritus) scored low overall, due to lack of vegetation cover and the presence of loose and mobile sediments along the stream bed at most sites. This is typical in a highly modified agricultural landscape where sites have reduced bank stability leading to increased erosion and sedimentation. Temporal differences were largely restricted to changes in stream bank, stream bottom, and stream detritus. However, this is not reflective of an overall deterioration in water quality, and therefore habitat quality, but was caused by extremely low flow levels in the region.

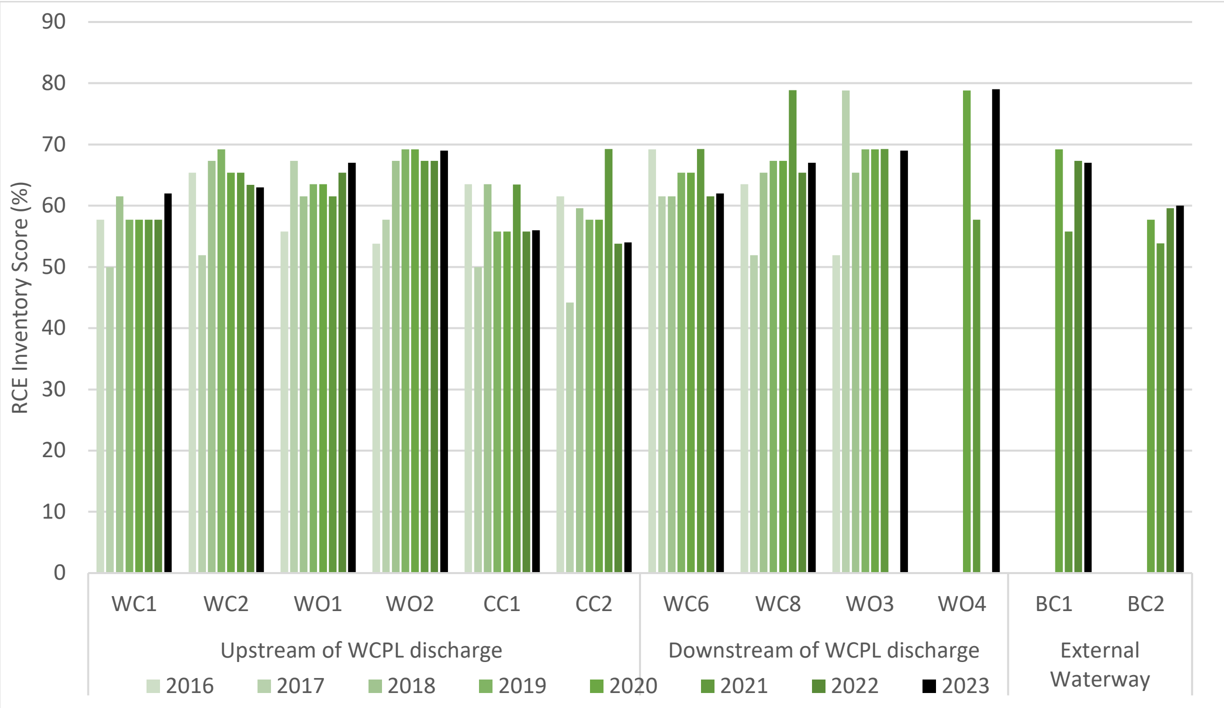

Figure 2: RCE scores across all sites and years

4.2. Water Quality

Water temperature overall was higher than in previous years, with an average temperature of 24.6°C compared to 16.4°C in 2022. The higher water temperature was influenced by survey timing. Specifically, the survey occurred a month later than the previous year when the ambient temperature was higher. The flow level was extremely low at each creek due to a recent decline in precipitation. Two sites were completely dry of surface water, whilst multiple other sites had stagnant flow in which trapped water was readily heated by radiation. Further fluctuations in water temperature are expected at each site in line with the generally shallow stream depth, minimal riparian shading, algal growth and turbidity reducing transparency of water, and variable flow.

DO concentrations in 2023 were below the ANZECC and ARMCANZ (2000) guideline range across all sites, showing a significant decline from 2022. DO concentration in 2022 was high likely due to the increased flow, turbulence, and mixing, resulting from high rainfall and flooding. DO concentrations also fluctuate due to a range of factors including water temperature, organic and bacterial activity, wind, water flow and circulation, and time of day. In 2023, still water, warmer temperatures, and the lack of sufficient water flow may have caused the decreased DO. This is exemplified by the comparison of sites such as WO3 and WO4 which had higher flow rates and sites WC1, WO1 and CC1 where the water was stagnant, and channels seemed disconnected. Over time, DO concentrations have fluctuated considerably across sites and years, and have frequently been outside of ANZECC and ARMCANZ (2000) guidelines (**Figure 3**). These results have been recorded not only both upstream and downstream of the WCPL discharge point, but the two control sites located along the external Barigan Creek. This suggests that DO concentrations and fluctuations may be a result of catchment-scale processes and are not linked to mining operations.

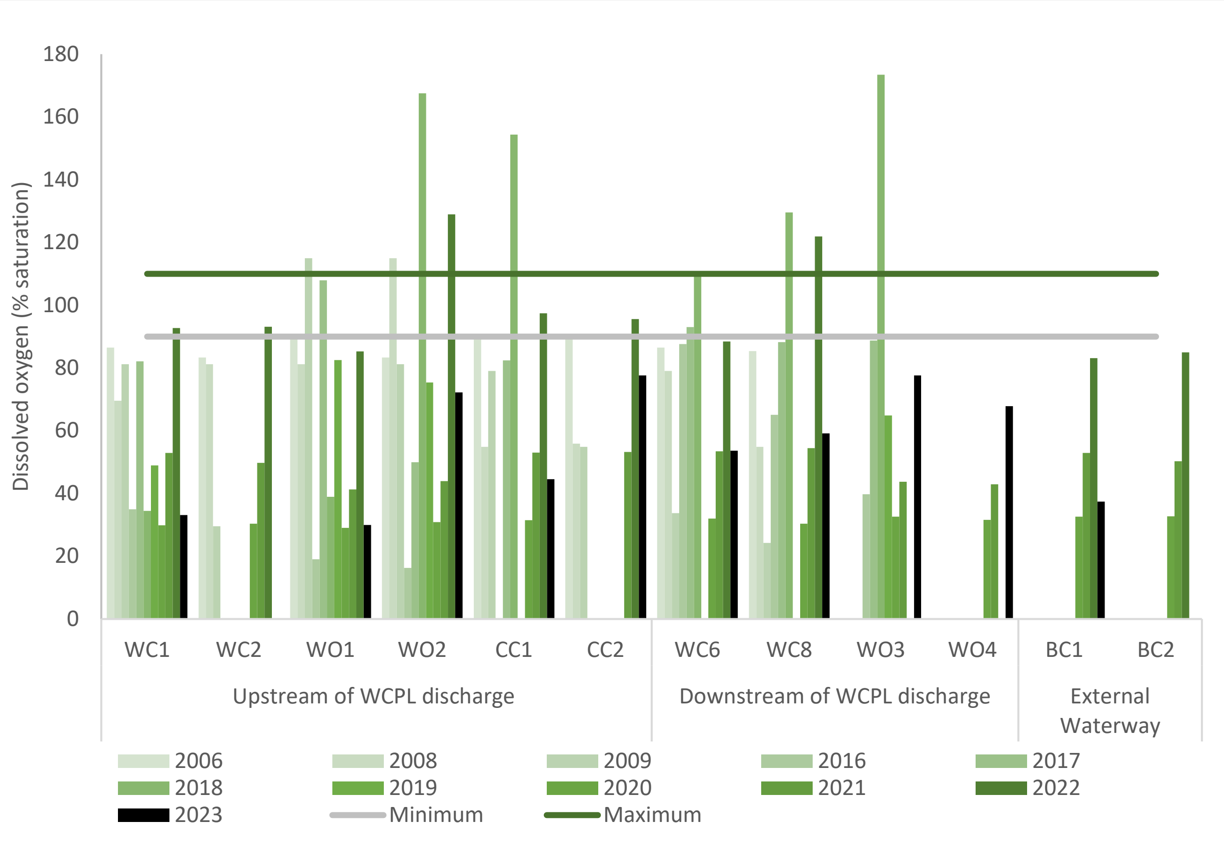

Figure 3: DO (% saturation) results across all sites and years

EC was higher in 2023 at all the sites upstream of WCPL discharge compared to results from 2021 and 2022 (**Figure 4**). In contrast, EC at downstream sites was similar to that of previous years. This may indicate that natural variables, rather than mining operations are the main factors that influence EC in the sampled catchments. EC measurements at control sites BC1 and BC2 during 2020–2023 were generally lower than those in Wilpinjong and Wollar Creeks, whilst Cumbo Creek sites (CC1 and CC2) recorded substantially higher EC values than all other sites for many years. The region is known to have naturally occurring saline groundwater (BIO-ANALYSIS 2015), which likely contributed to baseflow in all creeks. Decreased EC downstream of the Cumbo Creek confluence is potentially a result of a dilution by the licenced discharge of RO water at EPL 24 and an increasing proportion of influx of freshwater from the surrounding basin as water travels downstream.

EC was outside of the recommended ANZECC guideline range (30-350 µS/cm), although the trend appears to be improving, with EC in 2023 generally lower at most sites compared to values in 2016-2020. Exceptions to this were at CC1 and CC2 upstream of the discharge location, where EC was around 4000 µS/cm. This is potentially due to higher salinity groundwater inputs to Cumbo Creek.

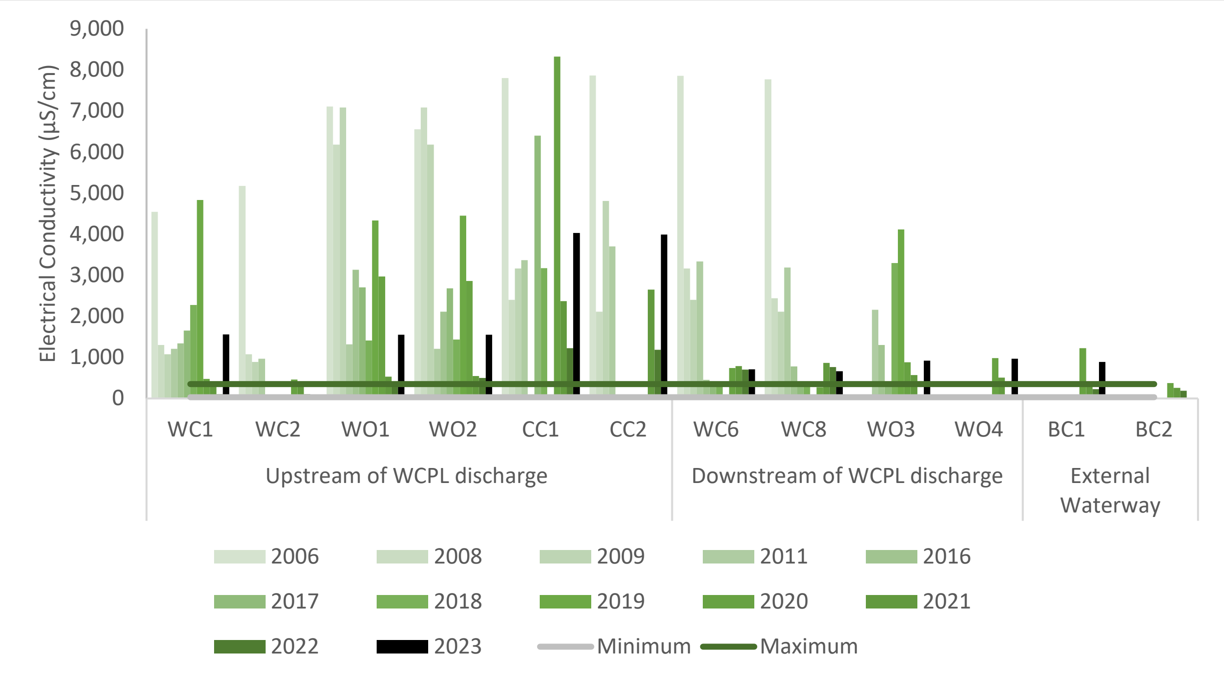

Figure 4: EC (µS/cm) results across all sites and years

Seven of ten site meet the recommended ANZECC and ARMCANZ (2000) guideline range for turbidity. Overall, turbidity was much lower compared to previous monitoring years, likely due less rainfall and lower volumes of sediment and organic matter transported by the river in the dry condition both before and during the 2023 monitoring period (**Figure 5**).

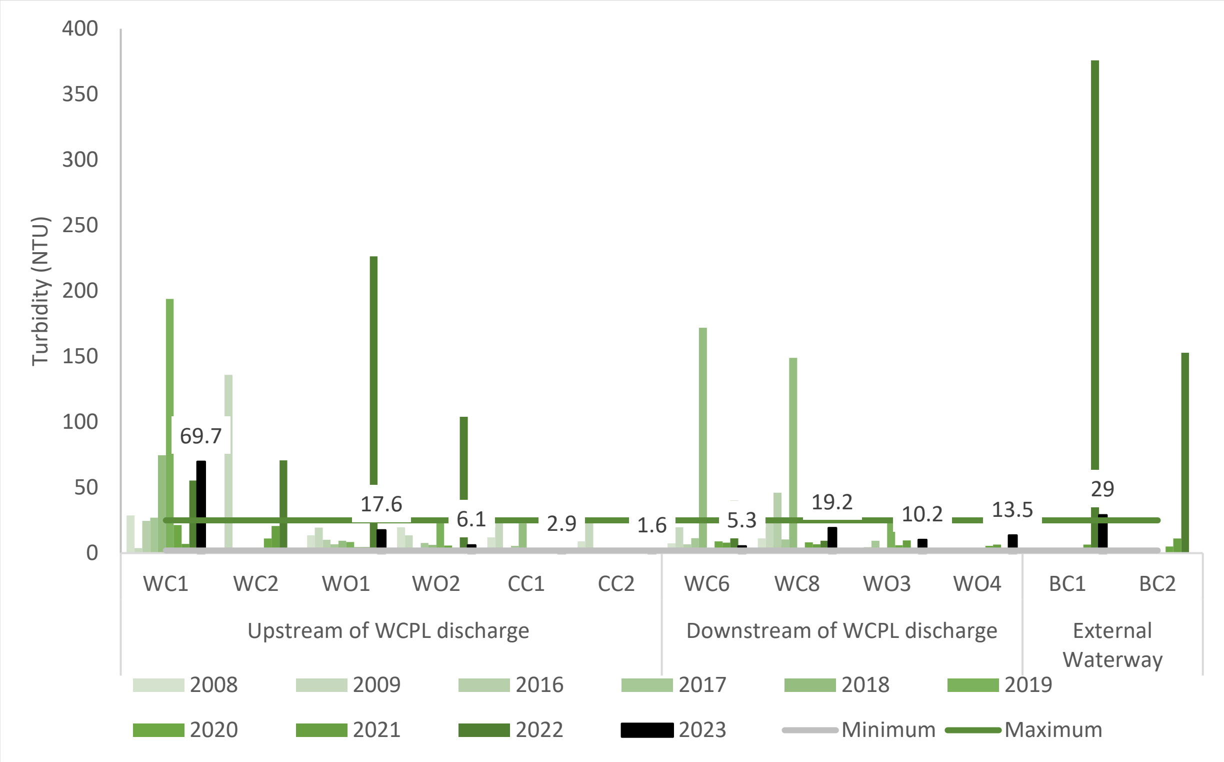

Figure 5: Turbidity (NTU) results across all sites and years (Scores for 2023 are labelled for better readability)

The pH for all sites monitored in 2023 were within ANZECC guidelines despite large changes in the other parameters discussed above (e.g. DO). Across all sites and monitoring years, pH has remained highly consistent (**Figure 6**).

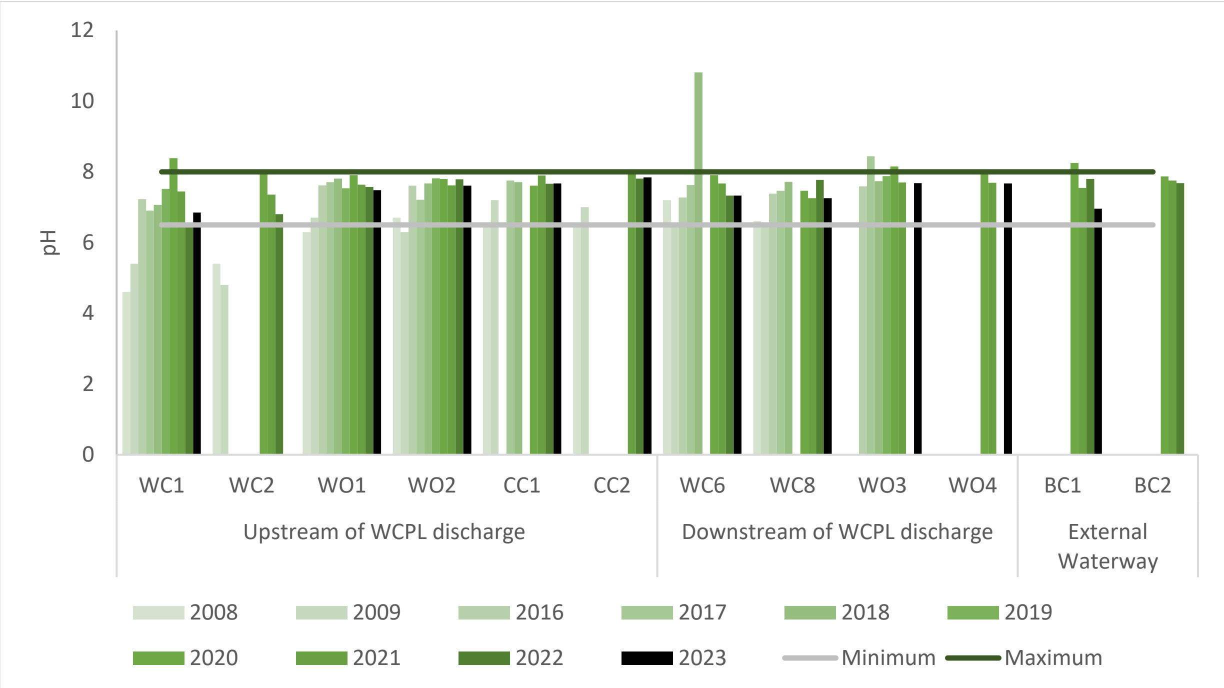

Figure 6: pH results across all sites and years

4.3. Macroinvertebrate Communities

Across all monitoring years, the average SIGNAL2 score for each site is <4.0 with these scores indicative of severely disturbed systems (**Figure 7**). Low SIGNAL2 scores have been consistently recorded during periods of variable surface water availability and at sites both upstream and downstream of the WCM, including the two control sites located in Barigan Creek. Such results therefore reflect the overall disturbed nature of the catchment, largely attributable to historical agricultural and land use practices.

SIGNAL2 scores decreased across all sites except one (WO1) from 2022. WO3, WC8, and WO1 still scored above the minimum trigger conditions for both SIGNAL2 and taxa richness scores. In contrast, sites WC6 and WO4 did not reach either minimum taxa richness or minimum SIGNAL 2 index, which should trigger an investigation into the cause of this as outlined in the WCPL SWMMP (WCPL, 2018). However, it is likely that the prevailing climatic conditions during monitoring (i.e. low rainfall and water levels throughout the catchment) and relevant parameters (higher water temperature, lower DO) have strongly influenced the score, and therefore it is recommended that subsequent monitoring is to be conducted under closer to average rainfall conditions.

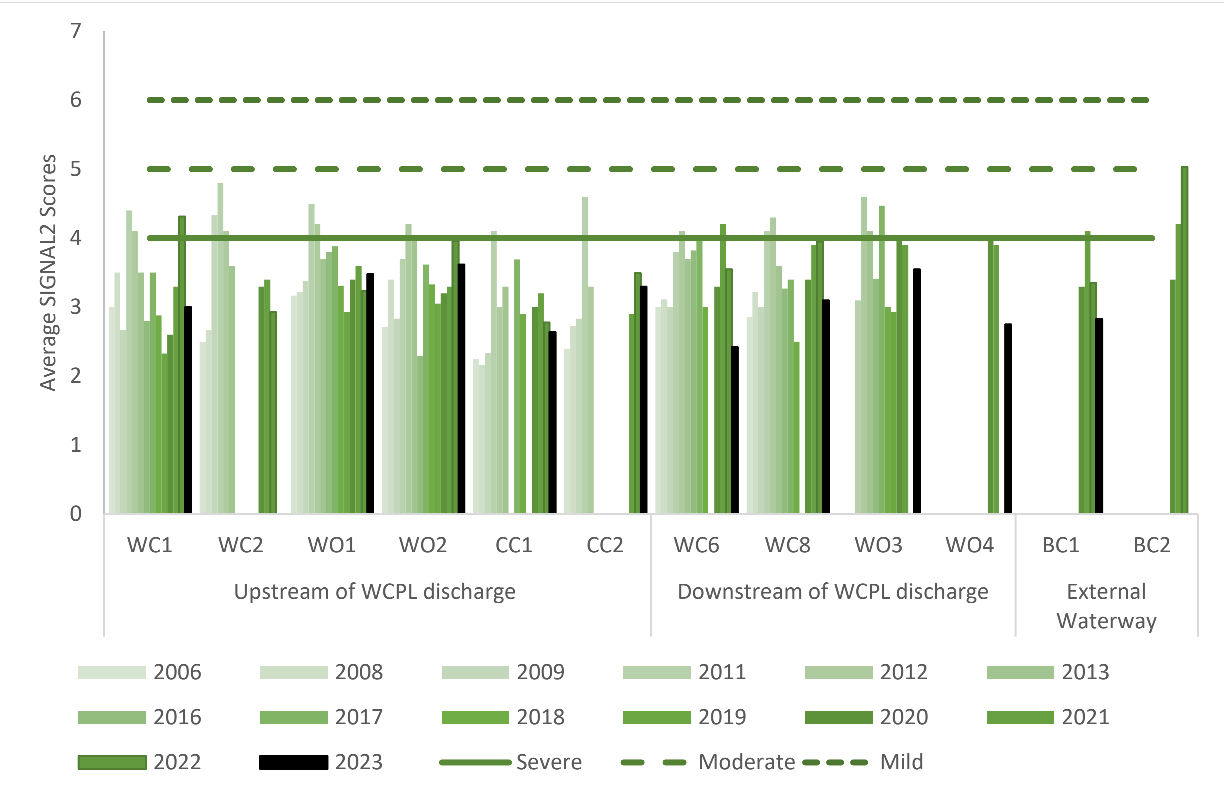

Figure 7: Average SIGNAL2 macroinvertebrate scores across all sites and years

5. Conclusions and Recommendations

A total of nine permanent sites along Wilpinjong, Wollar, and Cumbo Creeks were sampled in 2023, along with one control site at Barigan Creek. Two sites (WC2 and BC2) were completely dry in the survey period, and therefore not sampled. Due to the below-average rainfall in 2023, all the other sites were easily accessible but had low water levels for sampling. Overall, having one control site made it difficult to determine what benchmark settings are appropriate for evaluating local stream health conditions.

The habitat conditions at all ten sites were classified as either good or very good using the RCE inventory, which places the sites in the mid-range of aquatic habitat scores, typical of catchments in the surrounding region. Overall, aquatic habitat results have remained largely consistent across survey years, with differences primarily relating to changes in stream bed macrophyte and groundcover, because of fluctuating water levels after heavy rainfall and flooding in 2022 and dry conditions in 2023. There is the capacity to improve instream habitat through the re-introduction of logs and boulders as instream retention devices, particularly after the widespread flooding events that occurred during 2022. These works would also help limit downstream erosion and can be tied in with ongoing revegetation and rehabilitation works along Cumbo and Wilpinjong Creeks.

Water quality parameters have fluctuated considerably across years and varying stream flow levels, at sites both upstream and downstream of the WCPL licensed discharge point. The results also showed some improvement compared to recent years, with all the sites falling within the ANZECC and ARMCANZ (2000) guidelines for pH. Most of the sites met the guidelines for turbidity, likely due to the lower amounts of sediment and organic matter being washed into the stream during the period of low rainfall in the lead up to the 2023 monitoring. EC and DO did not meet the guideline across all sites including one control site. This is likely due to decreased rainfall in most months leading up to the monitoring period, as well as higher water temperatures, algae growth, and decomposition of organic matter in the water. EC was generally better at sites downstream of WCPL discharge. Hence, water quality results overall indicate that natural variables, rather than mining operations are the main factors which influence water quality in the sampled catchments. It is possible that the guidelines for these measures, excluding pH, are not appropriate at the local and/or regional catchment level.

A total of 15 macroinvertebrate Orders and 51 Families were recorded across all sites. SIGNAL2 scores showed decreasing trends both upstream and downstream of the WCPL licensed discharge point in 2023. Taxa richness was also variable across the ten sites, and was often not related to SIGNAL2 scores (i.e. WO2 vs BC1). In line with previous years, SIGNAL2 scores were <4.0 for all sites, indicative of severely disturbed sites. Two sites, WC6 and WO4, scored below the minimum trigger conditions for both SIGNAL2 and taxa richness scores. A combination of low levels of flowing water, higher water temperature, and low DO likely limited the diversity of macroinvertebrate communities. Due to the prevailing abnormal climatic conditions in the lead up to, and during the SHM period in 2022 (wet) and 2023 (dry), it is recommended that the site be re-sampled during normal conditions. Future surveys may be conducted earlier in summer when water temperatures are not extremely high and macroinvertebrate diversity and abundance are likely to be greatest. It is also strongly recommended to undertake surveys when there is sufficient water flow at each monitoring site.

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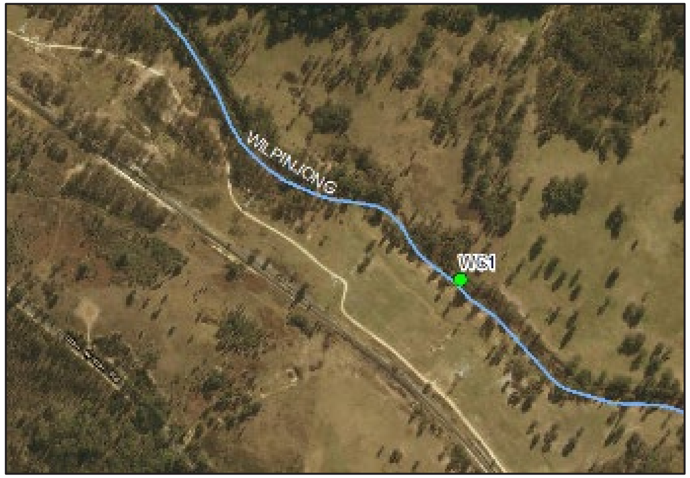
Appendix A Site Photos




Site WC1 (from left to right: site location, upstream, downstream (04/12/2023))


Site WC2 (from left to right: site location, upstream, downstream (04/12/2023))


Site WC6 (from left to right: site location, upstream, downstream (05/12/2023))

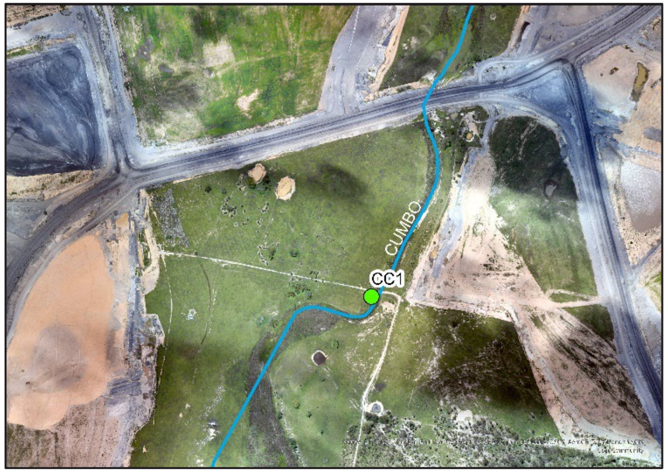

Site WC8 (from left to right: site location, upstream, downstream (5/12/2023))


Site WO1 (from left to right: site location, upstream, downstream (6/12/2023))


Site WO2 (from left to right: site location, upstream, downstream (5/12/2023))


Site WO3 (from left to right: site location, upstream, downstream (5/12/2023))


Site WO4 (from left to right: site location, upstream, downstream (5/12/2023))




Site CC1 (from left to right: site location, upstream, downstream (4/12/2023))


Site CC2 (from left to right: site location, upstream, downstream (4/12/2023))


Site BC2 (from left to right: site location, upstream, downstream (6/12/2023))


Site BC2 (from left to right: site location, upstream, downstream (6/12/2023))

Appendix B Macroinvertebrate Data

Order/Class	Family	SIGNAL2	BC1	CC1	CC2	WC1	WC6	WC8	WO1	WO2	WO3	WO4
Coleoptera	Corixidae	2						33				
	Dytiscidae	2	4	7		6	1	16	7			
	Elmidae	7	10		5				2	1		
	Gyrinidae	4						3				
	Hydrochidae	4		1		3						
	Hydrophilidae	2	2	6			1		9			
	Hygrobiidae	1	2						1			
Decapoda	Atyidae	3		2	4		32	8	15	77	36	35
Diptera	Ceratopogonidae	4	3					4	2		4	
	Chironomidae	3	28	10		10	6	4	19	5		2
	Culicidae	1		1				4				
	Dixidae	7		2								
	Dolichopodidae	3	1	7				4				
	Psychodidae	3									1	
	Simuliidae	5							1		13	
	Stratiomyidae	2	2	1								
Ephemeroptera	Baetidae	5	1		3		17	5	17	19	74	16
	Caenidae	4						3	6		1	
	Leptophlebiidae	8						4	3		1	
Gastropoda	Lymnaeidae	1	2					4				
	Physidae	1	7	16		2	4	3	2		1	

Order/Class	Family	SIGNAL2	BC1	CC1	CC2	WC1	WC6	WC8	WO1	WO2	WO3	WO4
	Planorbidae	2	5		2				4	1	6	
Hemiptera	Corixidae	2	17	5		3	2		40	80	99	49
	Mesoveliidae	2							1			1
	Micronectidae	2	2	11			87	15	30	98	105	31
	Naucoridae	2							6			
	Nepidae	3	1			1						
	Notonectidae	1		4	3		4	1	22	14	46	18
	Veliidae	3							2		2	
Hirudinea		1	4	1				1				
Lepidoptera		2							4			
Nematoda		3		1								
Nemertea		3		2							1	
Odonata	Aeshnidae	4	1	1	1		2	2	12			
	Austrocorduliidae	10			1	1	1	6	6			
	Coenagrionidae	2	1	1	6	1		1	35	3	1	
	Diphlebiidae	6							7			
	Gomphidae	5		1							3	
	Hemicorduliidae	5			5				2			
	Lestidae	1		1								
	Libellulidae	4		3				1	1			
	Odonata Sp.	3	1		1		1		12	1		
	Telephlebiidae	9				1		6		1		
Oligochaeta		2	1									

Order/Class	Family	SIGNAL2	BC1	CC1	CC2	WC1	WC6	WC8	WO1	WO2	WO3	WO4
Ostracoda		None	2	1								
Platyhelminthes		2	7	2					7		1	
Trichoptera	Calamoceratidae	7	2						10		1	
	Ecnomidae	4								1		
	Glossosomatidae	9							1			
	Hydropsychidae	6									2	
	Hydroptilidae	4	1						5	1		1

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