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Dendrobium Areas 3A and 3B:
Terrestrial Ecology Monitoring Program
Annual Report 2022

Prepared for South32 Illawarra Metallurgical Coal | 24 July 2023

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Executive summary

In 2003 South32 Illawarra Metallurgical Coal (IMC) commissioned Biosis Pty Ltd (Biosis) to undertake terrestrial ecology monitoring for the Dendrobium Coal Mine in accordance with the *Flora and Fauna Environmental Management Program (Subsidence)* (Biosis, 2003) required by the Dendrobium Colliery Planning Approval, originally issued in 2001, and as modified in 2008 and 2010. As of 2020, Niche Environment and Heritage (Niche) have continued the Dendrobium Ecological Monitoring Program (the Program) replicating, as far as possible, the methods as previously implemented.

The 2022 iteration of the monitoring program has adopted a number of recommendations from the previous report (Niche 2022a), which represents a continuation of refinement in the monitoring approach with a number of existing assessment methodologies augmented by additional analyses, and the addition of Control sites commensurate with the change of pre-existing Control sites to Impact sites.

The Program is undertaken within the Metropolitan Special Area and Southern Coalfield of New South Wales and includes two mining domains (Dendrobium Area 3A and Dendrobium Area 3B) and associated Control sites.

Ecological values and indicators which are currently being monitored include:

- Coastal Upland Swamps in the Sydney Basin Bioregion (Upland Swamps) listed as Endangered under the NSW *Biodiversity Conservation Act 2016* (BC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
    - swamp extent
    - species composition
    - total species richness (TSR).
- Amphibians - with a focus on *Litoria littlejohni* (Littlejohn's Tree Frog), which is listed as Endangered under the EPBC Act and Vulnerable under the BC Act, and is known to breed within first and second (and occasionally third) order waterways within Dendrobium Areas 3A and 3B
    - population attributes (number of individual frogs within different life-stages)
    - habitat such as breeding pool characteristics.

Monitoring is undertaken each spring and autumn (Upland Swamps) and winter (Amphibians) with Upland Swamps and creeks being added to the Program according to longwall progression. As of 2022, there are seven Control swamps and nine Control creeks in the wider Catchment area, with ten Impact swamps, 14 Impact creeks across Dendrobium Areas 3A and 3B.

Within the Upland Swamp survey methodology all species present in each quadrat along three 15 metre transects were recorded, for TSR and species composition analysis in autumn and spring. Mapping of swamp extent (including sub-communities) using LiDAR imagery for ecosystem functionality analysis is also completed annually. Additionally, photo monitoring is taken at fixed point, direction and angle at all flora monitoring locations to assist in interpreting any on-ground changes.

Within the amphibian survey methodology, a targeted nocturnal survey for Littlejohn’s Tree Frog Adults, Tadpoles and Eggmass counts across both Control and Impact creeks is conducted. Since 2020, an additional assessment of habitat (breeding pool) condition (water capacity and water level on night of survey) has been reported to assist in determining suitable breeding habitat for Littlejohn’s Tree Frog in relation to the Trigger Action Response Plan (TARPs).

Upland Swamps

The 2022 iteration of the monitoring program has largely identified a continuation of the trends identified in recent monitoring years (Niche 2021, Niche 2022a). Trends across swamps indicate declining TSR post-mining for the majority of Impact swamps and Control swamps. Compositional changes show trends of the loss of flora species, generally (but not entirely) those with a preference for ‘wet environments’. While it is reasonable to expect natural species turnover to occur at a swamp, the overall patterns of change are suggestive of either declining swamp condition (die back or die off of swamp dependent species), or vegetation community transition.

The assessment of cumulative impacts considering longer periods has identified a number of significant trends in both TSR and species composition at the Impact monitoring sites. Although these are not necessarily consistent across the swamps and may be suggestive of die off of swamp dependent species, or vegetation community transition, depending on the swamp in question.

Additional breakpoint analysis has tended to present a more complex picture of temporal trends and their relationship to mining. Many trending declines in TSR and species detection appear to have commenced either pre- or at some years post-mining. In addition to this, the declining TSR levels and Swamp extents recorded at the Control swamps are indicative of other factors that may be contributing to declining swamp conditions, at least in terms of the metrics applied in this monitoring program.

The assessment of performance measures suggest that impacts are being detected at the Impact monitoring swamps utilised in the Program, although there is variation across the varying TARPs and TARP levels that have been triggered to date. All of the ten Impact monitoring swamps are considered at risk of potential impacts based upon their proximity to mining activity. In 2022, eight of the ten Impact monitoring swamps recorded at least one TARP trigger.

Threatened frogs – Littlejohn’s Tree Frog (*Litoria Littlejohni*)

The Control creeks in general have a higher quality of breeding habitat for Littlejohn’s Tree Frog and were presumably chosen at the beginning of the Program due to the known population of breeding adult records of Littlejohn’s Tree Frog and habitats. Analysis to date has identified that where pre-mining frog detection data is available, detection was statistically significantly lower at impact transects than the controls, indicating this disparity in control and impact transect pre-dates mining effects.

Significantly above average rainfall conditions in 2022 served to ameliorate some of the observed impacts previously recorded (e.g. flocculant and reduced pool levels). Despite this, the findings of the 2022 iteration of the monitoring program are largely consistent with previous years, with a number of Impact monitoring transects showing reduced habitat conditions, or reduced frog detection in the post-mining period.

In 2022, TARP levels have been triggered at seven of the fourteen Impact transects monitored as part of the Program.

Management actions and offsetting

The TARP system is to trigger corrective actions (which can include reporting, additional monitoring and assessment, mitigation or offsetting), once specified impacts are detected. A number of previously described management actions (e.g. grouting) are subject to ongoing research and trialling to demonstrate the expected level of effectiveness.

Offset areas have been established and research funding committed to the *Swamp Remediation Research Program* (SRRP). Similarly, after consultation with stakeholders, IMC and WaterNSW agreed to improve monitoring equipment. The consent conditions for Dendrobium Mine state that Biodiversity Offsets for Upland Swamp can be met as part of the *Strategic Biodiversity Offset*.

Impacts to Upland Swamps and watercourses have been offset via protection of lands elsewhere (e.g. Maddens Plains and Cataract River).

Table of Contents

List of Annexes

List of Figures

List of Tables

List of Graphs

Glossary and list of abbreviations

Term or abbreviation	Definition
AEMR	Annual Environmental Management Report
ANOVA	Analysis of Variance
BC Act	NSW *Biodiversity Conservation Act 2016*
BCD	Biodiversity Conservation Division of DPE
BGR-NIR	Blue Green Red – Near Infrared
BHPBIC	BHP Billiton Illawarra Coal (now South32 Illawarra Metallurgical Coal)
BSO EA	Bulli Seam Operations Environmental Assessment
CHM	Canopy height model
CMA	Corrective Management Action
Control site	Monitoring site (upland swamp or amphibian transect) selected to represent ecological features outside of the area of potential mining impacts.
Control Group	The collective monitoring sites (upland swamp or amphibian transect) selected to represent ecological features outside of the area of potential mining impacts.
CPUE	Catch per unit effort
DA3A	Dendrobium Area 3A
DA3B	Dendrobium Area 3B
DAWE	Commonwealth Department of Agriculture, Water and the Environment
DEE	Commonwealth Department of Environment and Energy (now DAWE)
DEM	Digital Elevation Model
DoPE	Department of Planning and Environment (now DPE)
DPE	NSW Department of Planning and Environment
DPIE	Department of Planning, Industry and Environment (formerly OEH/ DoPE, now DPE)
DSM	Digital Surface Model
EEC	Endangered Ecological Community
e.g.	exempli gratia, meaning “for example.
EP&A Act	NSW *Environmental Planning and Assessment Act 1979*
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
GEE	Generalised Estimating Equations
GLM	Generalised Linear Model
ha	Hectares
i.e.	id est, meaning "that is’’
IMC	South32 Illawarra Metallurgical Coal
IQR	Interquartile range
Impact site	Monitoring site (upland swamp or amphibian transect) selected to represent ecological features within the area of potential mining impacts.
Impact Group	The collective monitoring sites (upland swamp or amphibian transect) selected to represent ecological features within the area of potential mining impacts.
LAS	Laser
Littlejohn’s Tree Frog	Littlejohn’s Tree Frog

Term or abbreviation	Definition
m	Meters
mRL	Meters of reduced level (piezometer unit of measure)
NDVI	Normalised difference vegetation index
NPWS	National Parks and Wildlife Service
OEH	NSW Office of Environment and Heritage (now DPE)
RMZ	Risk Management Zone
Study Area	Dendrobium Area 3A and 3B
T&I	Trade and Investment
TARP	Trigger Action Response Plan
The Program	Dendrobium Ecological Monitoring Program
TSR	Total Species Richness
UAV Imagery	Unmanned Aerial Vehicles Imagery
USBT	Upland Swamp: Banksia Thicket
USTTT	Upland Swamp: Tea-Tree Thicket
USSHC	Upland Swamp: Sedgeland-heath Complex
USFEW	Upland Swamp: Fringing Eucalypt Woodland

1. Introduction

1.1 Background

In 2003 South32 Illawarra Metallurgical Coal (IMC) commissioned Biosis Pty Ltd (Biosis) to undertake terrestrial ecology monitoring for the Dendrobium Coal Mine in accordance with the *Flora and Fauna Environmental Management Program (Subsidence)* (Biosis, 2003) required by the Dendrobium Colliery Planning Approval, originally issued in 2001, and as subsequently modified.

The Approval included the requirement for a Before, After, Control, Impact (BACI) monitoring program, designed to identify ecological change within Dendrobium Areas 3A and 3B (hereafter referred to as the Study Area) as a result of mine subsidence by comparisons between control and impact areas before and after longwall mining (the Dendrobium Ecological Monitoring Program, hereafter referred to as the Program). Changes were measured against specific thresholds outlined in the trigger action response plans (TARPs) (Annex 7) (IMC 2020a, IMC 2020b, IMC 2020c). Monitoring was required to commence at least two-years prior to the start of mining in each affected area to gather baseline data at each site and continue once mining commenced. Monitoring is expected to continue throughout the duration of mining activities and for a period after the completion of mining.

In 2020, Niche Environment and Heritage (Niche) continued the Program replicating, as far as possible, the methods and monitoring approach as previously implemented. The 2020 monitoring report (Niche 2021) identified a number of potential improvements to the monitoring methods, which have been adopted for subsequent iterations of the monitoring program.

The Program is undertaken within the Metropolitan Special Area, part of the Southern Coalfield region of New South Wales (Figure 1). The area monitored includes two mining domains (Dendrobium Area 3A and Dendrobium Area 3B) and associated control sites.

Ecological values and indicators which are currently being monitored include:

- Coastal Upland Swamps in the Sydney Basin Bioregion (hereafter referred to as swamps) listed as Endangered under the NSW *Biodiversity Conservation Act 2016* (BC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
    - swamp extent
    - species composition
    - total species richness (TSR).
- Amphibians, with a focus on *Litoria littlejohni* (Littlejohn's Tree Frog) which is listed as Vulnerable under the BC Act and Endangered under the EPBC Act, and is known to breed within first, second and third order watercourses within Dendrobium Area 3A and Area 3B
    - Population attributes (number of individual frogs within different life-stages) and
    - habitat such as breeding pool characteristics.

Prior to the commencement of mining within Dendrobium Areas 3A and 3B, monitoring of swamp vegetation and amphibians commenced in spring 2003 within two swamps. Monitoring has continued each spring and autumn with swamps and creeks being added to the Program according to longwall progression.

1.2 Aim

The primary aim of the Program remains the same as previous years:

[...]to determine whether subsidence effects associated with longwall mining result in impacts to terrestrial ecological values located above the longwalls (Biosis 2020).

To assist in achieving the above aim, the TARP thresholds determined for Dendrobium Areas 3A and 3B (Section 1.5, Annex 7) are used to determine the significance of any direct or indirect impacts potentially caused by mining activity. The current report includes monitoring data collected during 2022 and provides analysis of data collected to date for the Program (2003-2022) where relevant to the identified aim.

Identification of opportunities to improve the Program are discussed in Section 3.

1.3 Monitoring design and definition of treatments

The monitoring design is structured around the BACI concept: Before, After, Control and Impact. Predicted impact areas are compared with control areas and measurements taken both before and after an impact event (longwall mining) occurs. Where measurable impacts occur, comparisons of before and after data should reveal changes at an impact site after mining. Control sites remain unimpacted before and after mining, where the mining plan evolves and has the potential to impact a previous Control swamp, this will be updated to reflect the on-ground works (e.g. the data that was previously listed as Control is now listed as pre-mining impact data (Before) and is no longer included in the analysis as a Control). Where both Control and Impact sites change in a similar manner, observed changes may be due to other wider-ranging factors such as above or below average rainfall.

Impacted areas are those within the 400 metre risk management zone (RMZ) which are sensitive to valley closure, uplifts, strains, and fracturing. This is in accordance with recommendations made by the Department of Planning (2008).

The Impact sites are referred to as pre-impact (Before) prior to mining activity, until the closest point of secondary extraction is located within the RMZ of the site. This allows for baseline (Before) data to be collected at each potential impact site. Once the point of secondary extraction is located within a RMZ the site is then referred to as post-impact but not yet mined beneath, this allows for the potential of observing any indirect impacts resulting from mining within the RMZ. Given that any observed impacts to natural features become most evident after the natural feature is mined beneath, the date the site has been mined beneath has also been considered in the assessment and analysis of trends over time. At this point the sites are referred to as post-impact and mined beneath.

Selected swamps and creeks located within each of the mining domains are generally monitored for a minimum of two-years prior to mining to gather baseline data (two swamps - Swamp 23 and Swamp 14 - were only monitored one year prior but include both autumn and spring seasons, with no pre-mining data available for amphibian transects WC17, DC(1) and WC21). The Upland Swamps and creeks being monitored are defined as either Control or Impact sites. There are some swamps and creeks that will remain in the RMZ, as they are not planned to be mined beneath.

Control sites are situated outside the RMZ (greater than 400 meters from mining activity). The data from Control sites is gathered to compare with Impact sites to determine whether there are any observable impacts as a result of mining or wider landscape scale changes in the Metropolitan Catchment (due to effects of drought, fire etc).

At the time of 2022 monitoring, there were seven Control swamps and ten Impact swamps, nine Control transects and fourteen Impact transects.

1.4 Survey sites and monitoring periods

Monitoring of swamps and creeks within Dendrobium Areas 3A and Area 3B continued in 2022 as detailed below. A summary of timing for all Impact sites and corresponding Control sites has been provided below in Table 1 and Table 2.

1.4.1 Dendrobium Area 3A

Dendrobium Area 3A includes Longwalls 6, 7, 8 and 19. Mining of Area 3A commenced in 2010 and concluded with Longwall 8 in December 2012. Mining re-commenced at Longwall 19 (situated south of Longwall 8) following the completion of Dendrobium Area 3B in June 2022. The Dendrobium Area 3A Impact Upland Swamps monitored as a part of the Program include Swamp 15A(1), Swamp 15A(2) and Swamp 15B (Figure 1, Table 1 and Table 9). All three swamps are also included in the LiDAR monitoring.

Monitoring along five Littlejohn’s Tree Frog transects was undertaken within two creek systems within Dendrobium Area 3A. Four transects were along Sandy Creek tributaries: SC10 (two sections, SC10(1) and SC10(2)), SC10C, 6CDL; and one along a tributary of Wongawilli Creek: WC17 (Figure 5, Table 2).

1.4.2 Dendrobium Area 3B

Dendrobium Area 3B includes Longwalls 9 through to 18. Mining of Area 3B commenced with Longwall 9 in February 2013 and has continued through to Longwall 18 which commenced in December 2021 and was completed in June 2022.

Seven Upland Swamps are currently monitored as a part of the Program (Swamp 1A, Swamp 1B, Swamp 5, Swamp 11, Swamp 13, Swamp 14 and Swamp 23), (Figure 3, Table 1 and Table 9). All swamps in Area 3B have now been mined beneath and are therefore Impact sites for the 2022 iteration of the Program. All Area 3B impact swamps are included in the LiDAR analysis.

Monitoring along nine Littlejohn’s Tree Frog transects was undertaken within three creek systems located within Dendrobium Area 3B. Two transects were along Donald Castles Creek tributaries: DC(1), DC13, two along Wongawilli Creek tributaries: WC15, WC21, two from Lake Avon tributaries: LA4A and LA2, and three along Native Dog Creek: NDC, ND1, ND2. The above creeks in Dendrobium Area 3B have now been mined beneath, or mining has entered within the RMZ of the transects and therefore are treated as Impact sites.

1.4.3 Control sites

A number of Control sites have been established for comparison with Impact sites that have or will be mined beneath. Control sites for vegetation monitoring include seven Upland Swamps; Swamp 131, Swamp 22, Swamp 33, Swamp 86 (previously named FT6X Swamp), Swamp 85 (monitored for LiDAR analysis only), Swamp 87 (previously named FT15E Swamp) and Swamp 88 (previously named Gallahers Creek Swamp). These sites were established to ensure an even mix of Impact and Control sites in the BACI experimental design (Figure 4, Table 1). Four control swamps are utilised in the LiDAR monitoring, including Swamp 85, which is not included in the transect vegetation monitoring component.

Monitoring of Control sites for Littlejohn’s Tree Frog was undertaken along nine transects in four stream networks, four Sandy Creek tributaries: SC7 (two sections SC7(1) and SC7(2)), SC7A, SC8, two Wongawilli Creek tributaries: WC10, WC11, one Donald Castles Creek tributary DC8, as well as CR29 and CR29D (tributary of the Cordeaux River) (Figure 5, Table 2).

Table 1: Mining progress and status of swamps

Swamp name	Nearest longwall	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Control – Outside Dendrobium 3A/3B areas																					
Swamp 22	-							🟩	🟩	🟩	🟩	🟩	🟩 L	🟩	🟩	🟩	🟩	🟩	🟩	🟩 L	🟩 L
Swamp 33	-							🟩	🟩	🟩	🟩	🟩	🟩 L	🟩	🟩 L	🟩 L	🟩 L	🟩 L	🟩 L	🟩 L	🟩 L
Swamp 85*	-												🟩 L		🟩 L	🟩 L	🟩 L	🟩 L	🟩 L	🟩 L	🟩 L
Swamp 86	-										🟩	🟩	🟩 L	🟩	🟩	🟩	🟩	🟩	🟩	🟩 L	🟩 L
Swamp 131	-																				🟩
Swamp 87	-										🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Swamp 88	-										🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Impact – 3A																					
Swamp 15A(1)	19			🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦 L	🟦	🟦 L	🟦 L	🟦 L	🟦 L	🟦 L	🟦 L	🟧 L
Swamp15A(2)	8, 19							🟦	🟦	🟦	🟧	🟧	🟧 L	🟧	🟧 L	🟧 L	🟧 L	🟧 L	🟧 L	🟧 L	🟧 L
Swamp15B	8	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟧	🟧	🟥	🟥	🟥 L	🟥	🟥 L	🟥 L	🟥 L	🟥 L	🟥 L	🟥 L	🟥 L
Impact – 3B																					
Swamp 11	13, 14	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦 L	🟦	🟧 L	🟥 L	🟥 L	🟥 L	🟥 L	🟥 L	🟥 L
Swamp 13	14, 15											🟦	🟦 L	🟦	🟦 L	🟧 L	🟥 L	🟥 L	🟥 L	🟥 L	🟥 L
Swamp 14	15, 16, 17												L		L	🟦 L	🟧 L	🟥 L	🟥 L	🟥 L	🟥 L
Swamp 1A	9, 10										🟦	🟧	🟥 L	🟥	🟥 L	🟥 L	🟥 L	🟥 L	🟥 L	🟥 L	🟥 L
Swamp 1B	9			🟦	🟦	🟦	🟦	🟦			🟦	🟧	🟥 L	🟥	🟥 L	🟥 L	🟥 L	🟥 L	🟥 L	🟥 L	🟥 L
Swamp 5	9, 10, 11										🟦	🟧	🟥 L	🟥	🟥 L	🟥 L	🟥 L	🟥 L	🟥 L	🟥 L	🟥 L
Swamp 23	15												L		L	🟦 L	🟧 L	🟥 L	🟥 L	🟥 L	🟥 L

Green cell = Control Site, Blue cell = Impact Site, pre-mining, Orange cell = Impact site Post-mining (mining within RMZ only), Red cell = Impact site Post-mining and directly mined beneath.
L = LiDAR monitoring.
***Swamp 85 has been assessed via LiDAR monitoring only.*

Table 2: Mining progress and status of amphibian monitoring transects

Transect	Nearest Longwall	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Control																		
SC7(1)	-	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
SC7(2)	-	⬜	⬜	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
SC7A	-	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
SC8	-	⬜	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
DC8	-	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
WC10	-	⬜	⬜	⬜	⬜	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
WC11	-	⬜	⬜	⬜	⬜	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
CR29	-	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟩
CR29D	-	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟩
Impact – 3A																		
6CDL	7	⬜	⬜	⬜	🟦	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧
SC10(1)	8	🟦	🟦	🟦	🟦	🟦	🟧	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
SC10(2)	8, 19	🟦	🟦	🟦	🟦	🟦	🟧	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
SC10C	8	🟦	🟦	🟦	🟦	🟦	🟧	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
WC17	7, 8	⬜	⬜	⬜	⬜	⬜	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Impact – 3B																		
WC15	14, 15	⬜	⬜	⬜	⬜	⬜	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟧	🟥	🟥	🟥	🟥
DC(1)	9	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧
LA4A	13	⬜	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟧	🟧	🟧	🟧	🟧	🟧	🟧
LA2	17	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟦	🟦	🟦	🟧	🟥	🟥
DC13	9	⬜	⬜	⬜	⬜	🟦	🟦	🟦	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
WC21	9, 10, 11	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
ND1	18	⬜	⬜	⬜	⬜	⬜	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟧
ND2	18	⬜	⬜	⬜	⬜	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟧
NDC	18	⬜	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟧

Green cell = Control Site, Grey cell = no monitoring, Blue cell = Impact Site (pre-mining), Orange cell = Impact site Post-mining (mining within RMZ only), Red cell = Impact site Post-mining and directly mined beneath. Note: Some creeks are within the RMZ of the LW but are not planned to be directly mined beneath due to the length of the survey transects and nature of the creek.

1.5 Trigger Action Response Plans (TARPs)

The approvals for Dendrobium Area 3A and Area 3B have set TARPs at specified levels which act as indicators of potential impacts from mining. Once a TARP is detected (or triggered) further investigation is required to determine whether the change is mining related and what management and/or corrective actions, if any, are required.

The purpose of the Program is to detect changes (if any) and investigate the mechanism of change using the data collected. The triggering of a TARP does not always indicate that immediate management actions are required. The approved TARP Level triggers (IMC 2020b; IMC 2020c; Annex 7) are used to determine required management actions or other responses for any particular Upland Swamp or creek being monitored. Dendrobium Area 3A was approved in 2012 and has a separate set of TARPs to Dendrobium Area 3B which was approved in 2013 and 2015 (and updated for each subsequent longwall in the domain) (Annex 7). Therefore, Niche have considered these TARP Level triggers separately. The relevant TARPs are detailed below.

1.5.1 Changes to TARP objectives

The TARP system (see Table 4 and Table 6) is to trigger corrective actions (which can include reporting, additional monitoring and assessment, mitigation or offsetting), once specified impacts are detected. A number of previously described management actions (e.g. grouting) are subject to ongoing research and trialling to demonstrate the expected level of effectiveness.

Offset areas have been established and research funding committed to the *Swamp Remediation Research Program* (SRRP) (IMC 2016a). Similarly, after consultation with stakeholders, IMC and WaterNSW agreed to improve monitoring equipment (IMC 2019). The most recent conditions for Dendrobium Mine state that Biodiversity Offsets for Upland Swamp can be met as part of the *Strategic Biodiversity Offset* (IMC 2016b).

TARP level 3 in Area 3A Upland Swamps relate to on-ground management actions such as grouting. As no grouting has been implemented in Area 3A to date, the monitoring and TARPs relate to an assessment of the health of the Upland Swamps and watercourses over time rather than initiating management actions. Impacts to swamps and watercourses have been offset via protection of lands elsewhere (e.g. Maddens Plains and Cataract River).

Niche have attempted to be consistent with the wording of the most up to date TARPs (Area 3B), hence the Upland Swamp Interpretation column in Table 4 that mentions species richness and species diversity with composition in brackets. Niche have noted that the purpose for the word “diversity” was likely to assess composition (as this is in line with the data available from the Program, i.e. diversity/abundance data is not collected as part of the monitoring methods, only composition data) and we have addressed it accordingly throughout the document. Niche notes composition is referenced in the “Potential Impacts” column to the TARPs, this indicator is not explained within the “Performance Triggers” (Swamp vegetation changes of IMC 2015a; Annex 7). As such, Niche have added composition (in brackets) to the Upland Swamp trigger levels in Table 6 to clarify where this is relevant.

1.5.2 Dendrobium Area 3A

For Dendrobium Area 3A, the terrestrial TARPs are combined for threatened flora and fauna as landscape impacts. The relevant Dendrobium Area 3A creeks and Upland Swamps to be considered are listed in Table 3. Dendrobium Area 3A TARPs are comparatively non-specific being limited to assessment of Upland Swamps and threatened fauna, namely threatened frogs. The TARP does not include any specific associated habitats or parameters for determining trigger levels/impacts. Niche have included habitat and other measurements within the interpretation of trigger levels for both Upland Swamps and threatened frogs

(Table 4). For example, assessment of habitat quality has been included within TARP interpretations as it is a key element of frog health, may respond more quickly to impacts and is usually more amenable to consistent/reliable measurement compared with direct measurements of frog populations.

Table 3: Impact sites being monitored under Dendrobium Area 3A TARPs

Upland Swamps Impact sites	Threatened frog transect Impact sites
Swamp 15A(1), Swamp 15A(2), Swamp 15B	6CDL, SC10(1), SC10(2), SC10C, WC17

Table 4: Dendrobium Area 3A TARPs and Niche interpretations for analysis

Trigger Levels	Trigger level - landscape impacts (IMC 2020a)	Upland Swamp interpretation	Threatened Frog interpretation
Level 1	Vegetation impacted by mining (by rockfalls, soil slippage, gas emissions) that is likely to naturally regenerate within the monitoring period.	No statistically significant difference between Before After Control Impact sites within previous year monitoring (2020-2021) but some observable adverse changes at Impact site (before and after mining) through photo point monitoring or UAV imagery. The same pattern is not detected at control sites.	Observed and measured adverse changes in habitat at site through pool water levels, stream appearance (e.g. iron flocculant, debris build up) or number of breeding pools available from the previous year *without* the same pattern at control sites.
Level 2	Vegetation impacted by mining (by rockfalls, soil slippage, gas emissions) that is unlikely to naturally regenerate within the monitoring period; or statistically significant difference of species richness and species diversity between Before After Control Impact sites as a result of mining.	Statistically significant difference for species richness and species diversity (composition) between Before After Control Impact sites as a result of mining within the previous year (2020-2021).	As per above Level 1 observational changes and the frog population changes (Tadpole, Eggmass or Adults) between Before After Control Impact Sites as a result of mining within the previous year (2020-2021).
Level 3	Vegetation impacted by mining that is not responding to Corrective Management Actions (CMAs).	Vegetation not responding to corrective management actions from the TARP Level 2 triggers and further declining impacts from the previous year.	Populations not responding to corrective management actions from the TARP Level 2 triggers and further declining impacts from previous years or for several years.

Note: TARP interpretations based on discussions with Gary Brassington of IMC on 16 April 2021.

1.5.3 Dendrobium Area 3B

The creeks and Upland Swamps to be assessed within Dendrobium Area 3B are detailed in Table 5. For Dendrobium Area 3B, the terrestrial TARPs considered are limited to the assessment of flora, ecosystem functionality (IMC 2015a) and fauna (IMC 2015b) (Table 6).

Table 5: Impact sites being monitored under Dendrobium Area 3B TARPs

Upland Swamps Impact sites	Threatened Frog transect Impact sites
Swamp 11, Swamp 13, Swamp 14, Swamp 1A, Swamp 1B, Swamp 5, Swamp 23	WC15, DC(1), LA4A, LA2, DC13, WC21, ND1, ND2, NDC

To maintain consistency with previous analysis and interpretation of the fauna and aquatic TARPs, Niche will continue to define the *reduction of aquatic habitat* for Littlejohn's Tree Frog, as a reduction in aquatic habitat (potential breeding habitat) by the number of dry pools along the transect. Additional metrics have been included since 2020 to assist in a more detailed examination of potential changes in key breeding habitats (pools).

The approved definition of ecosystem functionality from the SIMMCP (Section 3.9; IMC 2020b) stated *"ecosystem function of swamps is measured via the following attribute: the size of the groundwater dependent communities contributing to the swamps. Specifically, any changes in the proportion of Banksia Thicket, Tea-Tree Thicket and Sedgeland-heath Complex within the monitored swamps. Any change in area of a groundwater dependent community within a swamp will be compared to its pre-mining area and any change in area of that groundwater dependent community within reference swamps*" (IMC 2020b).

Table 6: Area 3B TARPs and Niche interpretations for statistical analysis

Trigger Levels	Upland Swamp trigger level (IMC 2020b) and interpretation (as dot points)*	Threatened Frog TARP (IMC 2020c) and interpretation (as dot points)	Swamp extent and ecosystem functionality TARP - LiDAR and UAV imagery (IMC 2020b)
Level 1	A 2% or otherwise statistically significant decline in species richness or diversity (composition) during a period of stability or increase in species richness/diversity in reference swamps for two consecutive years. • A Level 1 TARP would be triggered with a statistically significant difference (decline) in TSR or species composition over two consecutive impact years of data (i.e. impact detected between 2019-2020 and again 2020-2021 impact years). • The 2% change over two consecutive years was tested at a statistically significant level of 5% (p= ≤0.05).	Reduction in aquatic habitat for 1 year • Observed and measured changes in pool water levels and/or number of breeding pools available from the previous year without the same pattern at control sites.	**Extent** A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for two consecutive monitoring periods, greater than that observed in the Control Group, and exceeding the standard error (SE) of the Control Group. **Ecosystem functionality** A trending decline in the extent of any individual groundwater dependent community within a swamp for two consecutive monitoring periods, greater than that observed in the Control Group, and exceeding the SE of the Control Group.
Level 2	A 5% or otherwise statistically significant decline in species richness or diversity (composition) during a period of stability or increase in species richness/diversity in reference swamps for three consecutive years. • A level 2 TARP would be triggered with a statistically significant difference (decline) in TSR or species composition over three consecutive impact years of data (i.e. impact detected in each of 2018-2019, 2019-2020 and 2020-2021 impact years) (not 2018-2021 cumulative impact). • The 5% change over three consecutive years was tested at a statistically significant level of 5% (p= ≤0.05).	Reduction in aquatic habitat for two-years following the active subsidence period • Observed and measured changes in pool water levels and/or number of breeding pools available from two-years in a row without the same pattern at control sites.	**Extent** A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for **three** consecutive monitoring periods, greater than that observed in the Control Group, and exceeding the SE of the Control Group. **Ecosystem functionality** A trending decline in the extent of any groundwater dependent community within a swamp for three consecutive monitoring periods, greater than that observed in the Control Group, and exceeding the SE of the Control Group.
Level 3	An 8% or otherwise statistically significant decline in species richness or diversity (composition) during a period of stability or increase in species	Reduction in aquatic habitat for >two-years or complete loss of habitat following the active subsidence period. • Observed and measured changes in pool water levels and/or number of breeding pools	**Extent** A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for **four** consecutive monitoring periods,

Trigger Levels	Upland Swamp trigger level (IMC 2020b) and interpretation (as dot points)*	Threatened Frog TARP (IMC 2020c) and interpretation (as dot points)	Swamp extent and ecosystem functionality TARP - LiDAR and UAV imagery (IMC 2020b)
	richness/diversity in reference swamps for four consecutive years. • A level 3 TARP would be triggered with a statistically significant difference (decline) in TSR or species composition over four consecutive impact years of data (i.e. impact detected in each of 2017-2018, 2018-2019, 2019-2020 and 2020-2021 impact years) (not 2017-2021 cumulative impact). • The 8% change over four consecutive years was tested at a statistically significant level of 5% (p= ≤0.05).	available for greater than two-years in a row without the same pattern at control sites.	greater than that observed in the Control Group, and exceeding the SE of the Control Group. **Ecosystem functionality** A trending decline in the extent of any groundwater dependent community within a swamp for four consecutive monitoring periods, greater than that observed in the Control Group, and exceeding the SE of the Control Group.
Exceeding expectation	Mining results in a >10% or otherwise statistically significant decline in species richness or diversity (composition) during a period of stability or increase in species richness/diversity in reference swamps for five consecutive years. • Exceeding expectation TARP would be triggered with a statistically significant difference (decline) in TSR or species composition over five consecutive impact years of data (i.e. impact detected in each of 2016-2017, 2017-2018, 2018-2019, 2019-2020 and 2020-2021 impact years) (not 2016-2021 cumulative impact). • The >10% change over five consecutive years was tested at a statistically significant level of 5% (p= ≤0.05).	N/A	**Extent** Mining results in a trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for **five** consecutive monitoring periods, greater than that observed in the Control Group, and exceeding the SE of the Control Group. **Ecosystem functionality** Mining results in a trending decline in the extent of a groundwater dependent community within a swamp for five consecutive monitoring periods, greater than that observed in the Control Group, and exceeding the SE of the Control Group.

**Note: TARPs restart if a trigger is not detected for 1 year (impacts need to be consecutive to trigger escalating TARPs). TARP interpretations based on discussions with Gary Brassington of IMC on 16 April 2021.*

2. Methods

The baseline survey methodology, results of the statistical analysis and revised survey methodologies are detailed in previous annual monitoring reports (Biosis 2019, Niche 2021, Niche 2022a). The following is a brief description of the survey methodology used by Niche to carry out monitoring in 2022.

2.1 Summary of methods

Table 7 provides a summary of the survey methods implemented as a part of the Program.

Table 7: Summary of survey methodology

Survey type	Methods	Timing
Upland Swamp vegetation monitoring	Vegetation survey (30 quadrats of 0.5 m^2 along a fixed transect, three 15 m transects replicated per swamp), recording species present in each quadrat.	Annually in autumn and spring
Littlejohn's Tree Frog breeding habitat monitoring	Targeted nocturnal survey for Adults, Tadpoles and Eggmasses. An additional assessment of habitat (breeding pool) condition (water capacity, water level, iron flocculant on night of survey).	Annually in winter
Photo-point Monitoring	Photo taken at fixed point, direction and angle at all flora monitoring locations.	Annually in autumn and spring
LiDAR analysis	Mapping of swamp extent (including sub-communities) using LiDAR imagery.	Annually, aircraft survey following completion of latest longwall panel

2.1.1 Rainfall and hydrological data

Rainfall data recorded at the IMC DA3B rainfall gauge and Bureau of Meteorology (BoM) station 68018 are presented in this report.

Rainfall data from the IMC DA3B rainfall gauge is presented as the longest available record of Area specific rainfall measurements between 2013-2022. Niche (2022a) reported similar (for the purposes of this program) rainfall measurements recorded between DA3A and DA3B.

Longer term rainfall data (to cover the entire monitoring period and to generate long term averages) for the area has been obtained from BoM station 68018, which is situated within the Dendrobium mining lease. The BoM dataset is available for the 1909-1967 period only. This dataset has been combined with that available from SILO (hosted by the Queensland Department of Environment and Science), which may include data interpolated from daily observations for that date, representing a useful location specific source of information that is otherwise absent from any other nearby localities or meaningful timeframes.

Niche has incorporated the findings of hydrogeological reports made available by IMC, in particular (Watershed HydroGeo 2019 and Watershed HydroGeo 2021) to identify the likelihood of hydrological impacts to swamps based upon proximity of mining to ecological values.

Rainfall and hydrological data were used to correlate changes observed in swamp/frog data with changes to climate or ability of the swamps/creeks to retain water. These comparisons assist in determining if changes in swamps/creeks are likely a result of mining or a result of broader catchment/landscape scale changes.

2.1.2 LiDAR analysis

The LiDAR analysis method used in 2022 is the same as that detailed in Niche (2021, 2022a). These methods have also been retrospectively applied to previous LiDAR datasets to ensure valid comparisons are possible, reported in Niche (2022a). Table 9 identifies the Upland Swamps utilised in the LiDAR analysis in 2022.

Table 8: Swamps monitored as part of the LiDAR analysis

Upland Swamp LiDAR Impact sites	Upland Swamp LiDAR Control sites
15A(1), 15A(2), 15B, 1A, 1B, 5, 11, 13, 14, 23	22, 33, 85, 86

2.1.2.1 Upland Swamp extent mapping

Upland swamp extents for all years of the Program were detected by first modelling swamp boundaries based on a differential Canopy Height Model (CHM). The boundary was defined by the maximum height of the Banksia Thicket upland swamp vegetation sub-community in accordance with specifications within The Native Vegetation of the Woronora, O'Hares and Metropolitan Catchments (NPWS, 2003) and on-ground experience. The analysis generated comparable datasets from which to interpret change in upland swamp extents year on year.

The methods that describe how the spatial analysis was undertaken for mapping upland swamp extents year-on-year can be divided into the following workflow steps:

1. LAS (LiDAR) datasets were created for the relevant LiDAR returns for all supplied tiles for the Study Area.
    a. Ground
    b. Non-ground
2. LAS Datasets were then converted to rasters:
    a. Ground to Digital Elevation Model (DEM)
    b. Non-ground to Digital Surface Model (DSM)
3. A CHM raster was produced by subtracting the DSM from the DEM and symbolised using the height group classes detailed below.
4. Data generalisation was undertaken using statistical analysis to reduce the complexity of the dataset and average pixel relationships. This produced clear vegetation height group boundaries to work with. Discussions were held within the project team about how much generalisation was necessary and beneficial without compromising the results.
5. The CHM raster was reclassified into 1 value that represented the maximum height of the Banksia Thicket upland swamp vegetation sub-community of 6m. Any values greater than 6m were reclassified as no data.
6. A Shrink tool was run which reduces the size of all raster areas by 3 cells – this step reduces noise in the data by isolating clusters of cells outside the main swamp boundary that are low spots in non-swamp vegetation (e.g. spaces between tree crowns).
7. Conversion to polygon allowed for the 'islands' of non-contiguous cells described above to be selected by area size and removed.
8. The isolated swamp boundaries were converted back to raster format in order to run an Expand tool to increase the swamp boundaries by 3 cells – back to their original size.

9. Extenuating areas of low-lying vegetation posed as parts of swamp extent for all years and were trimmed to an agreeable edge with ecologists at the same location for all years to ensure datasets remained comparable and were not outlying due to data anomalies.

2.1.2.2 Upland Swamp vegetation sub-community mapping

Upland swamp extents were detected by first modelling swamp vegetation sub-community types based on a differential Canopy Height Model (CHM). The CHM classifies swamp vegetation by height according to specifications within The Native Vegetation of the Woronora, O'Hares and Metropolitan Catchments (NPWS, 2003) and on-ground experience.

The following vegetation types were classified as a part of the CHM:

- Banksia Thicket, 2.8 - 6 m
- Tea-Tree Thicket, 1.5 – 2.8 m
- Sedgeland-heath Complex, 0 - 1.5 m.

Spatial analysis of swamp vegetation sub-community boundaries (as a measure of ecosystem functionality) using LiDAR data (supplied by IMC) was completed by implementing the following workflow in ArcMap:

1. LAS (LiDAR) datasets were created for the relevant LiDAR returns for all supplied tiles for the Study Area.
    - Ground
    - Non-ground
2. LAS Datasets were then converted to rasters:
    a. Ground to Digital Elevation Model (DEM)
    b. Non-ground to Digital Surface Model (DSM)
3. A CHM raster was produced by subtracting the DSM from the DEM and symbolised using the height group classes detailed above.
4. Data generalisation was undertaken using the focal statistics tool to reduce the noise in the classified data and average pixel relationships. This produced clear vegetation height group boundaries for further processing. Discussions were held within the project team about how much generalisation was necessary and beneficial without compromising the results.
5. The CHM raster was reclassified into three values that represented the height group classes detailed above. Any values greater than 6 m were reclassified as no data to limit the dataset to relevant vegetation types only.
6. The reclassified CHM raster was converted to polygon without simplifying boundaries and the output coordinate system was defined at this step.
7. Data cleaning was undertaken by detecting polygons that were not neighbouring other polygons and removing them. This simplified manual data cleaning efforts by removing multiple polygons where they were not attached to the main swamp boundaries.

Given the structural (height) similarities within swamp vegetation sub-communities, analysis of canopy heights derived from LiDAR data could not be utilised alone to distinguish between these sub-communities. Therefore, the results of the analysis of canopy heights derived from LiDAR data were verified by Niche ecologists through visual interpretation of high-resolution aerial imagery captured during LiDAR flights or UAV. This involved discretionary manual editing of polygon boundaries to reflect vegetation sub-communities identified on the aerial imagery. This also allowed for attribution of reasons for changes in swamp extents detected in the analysis of canopy heights derived from LiDAR data.

Upon completion of verification using aerial imagery, the final version of the vegetation sub-communities spatial data was consolidated into single representative swamp extent polygons for each swamp. Area calculations were then run on the final swamp extents and final vegetation sub-community polygons. These calculations were graphed against previous years' results to determine changes in the total swamp size of upland swamps and extent of groundwater dependent upland swamp sub-communities within each swamp.

In 2022, additional workflow steps were included to verify areas of sub-community mapping identified as being 'lower confidence' due to limitations in the aerial imagery (i.e. shading, lower resolution) to swamp extent or ecosystem functionality identified by the LiDAR model, involving the following:

- Adding confidence intervals when undertaking swamp sub-community mapping using LiDAR model
- Low confidence areas are inspected in the field (where possible) during floristic monitoring.

2.1.3 Photo-point monitoring

Photo point monitoring was conducted at each site (Impact and Control) at a fixed location, designated by a star picket or wooden stake. Photographs are taken on handheld iOS devices in landscape orientation.

Every monitoring point had four photographs taken at each of the four main compass directions; north, east, south and west (0°, 90°, 180°, 270°).

The current photo points (2022) are provided in Annex 5 Photo point monitoring associated with previous monitoring seasons (2009-2021) is combined into a single document, also provided in Annex 5. Due to the size of the combined photo point monitoring document, no further additions are possible, future iterations of the monitoring program will continue to provide photo point documents for each monitoring year.

2.1.4 Upland Swamp vegetation monitoring

The swamp vegetation monitoring was conducted by Sian Griffiths (Practice Leader - Ecology), Luke Stone (Associate – Aquatic Ecology), Matthew Russell (Associate – Aquatic Ecology), David Wilkinson (Ecology Consultant), Amy Legge (Ecology Consultant) and Lily Cains (Graduate Ecologist). Autumn monitoring was undertaken between 09 June 2022 and 05 August 2022 and spring monitoring was undertaken between 18 October 2022 and 07 December 2022. A team of two qualified ecologists completed three transects within one swamp per day.

2.1.4.1 Transect monitoring program

Vegetation monitoring in swamps was undertaken along three 15 metre transects within each swamp (see Figure 2, Figure 3 and Figure 4). The presence of all species was recorded within thirty 0.5 x 0.5 metre quadrats positioned along the centre line of the 15 metre transect. A maximum score of 30 per transect for a species (or species complex) indicates it is present in all quadrats.

Consistent with the process in previous monitoring (Biosis 2020, Niche 2022a), where there was potential for misidentification, or where species cannot be reliably identified to species level in the field, species have been grouped into identification units for analysis. Each of these units is referred to as a species complex.

2.1.5 Littlejohn's Tree Frog monitoring

Targeted surveys for Littlejohn's Tree Frog were undertaken from mid-winter to early spring when the species is known to be breeding in the area and potentially most detectable by audible calls. Timing of surveys was developed with consideration of state and federal survey guidelines (DECC 2009 and CoA 2010), as applicable to Littlejohn's Tree Frog and years of site-specific experience with regard to frog surveys within the Metropolitan Special Areas and specifically, Dendrobium Area 3A and Dendrobium Area 3B. Sites may require repeated survey if seasonal climate conditions result in a lack of detection of the target species during peak calling periods, this was not required in 2022 as the weather was favourable for breeding and detection of species.

The Littlejohn's Tree Frog monitoring was conducted over ten nights, led by Luke Stone (Associate – Aquatic Ecology) and David Wilkinson (Ecology Consultant), assisted by Amy Legge (Ecology Consultant) and Lily Cains (Graduate Ecologist) from 2 August to 18 August 2022. A team of two qualified ecologists completed between one to three transects a night, dependent on transect length and amount of activity being recorded during survey.

Targeted surveys were undertaken along transects encompassing the breeding habitat and riparian zone of the creek (within pools and 5 m either side of the creek) within each of the 14 impact transects and 9 control transects in Table 2 (Figure 5). Transects involved counting all target amphibians at all life-stages (Eggmass, Tadpoles and Adults) observed or heard within the transect.

In 2021, extensive observations were made of discoloured Eggmass that were considered to be un-viable. This observation was made in minor amounts and limited locations in 2020 and it is not unusual for some eggs to be unviable either through not being fertilised or exposure to unsuitable environmental conditions. Due to the extensive observations in 2021, an additional recording item was added so that viable and un-viable Eggmass were recorded for analysis (Niche 2022a). Un-viable Eggmass were recorded where greater than half of an individual clutch of eggs were discoloured and considered un-viable. Eggmass totals have been included as the combined total of viable and non-viable Eggmass, as both indicate breeding activity. Non-viable Eggmass totals are also considered separately and will continue to be examined throughout future iterations of the Program as relevant to evaluate whether this is part of an emerging or ongoing trend.

Notable opportunistic sightings of all amphibian species were recorded, including threatened species such as the Giant Burrowing Frog (*Heleioporus australiacus*).

GPS accuracy limitations result in cases where georeferenced pools do not always match up exactly with a pool on the ground, likely due to GPS accuracy limitations in the field at the time of pool identification and also during the Littlejohn's Tree Frog surveys themselves. This is more difficult to discern during periods of high flow where connectivity along streams is greatest. Niche recorded each Littlejohn's Tree Frog breeding pool with the name of the closest previously recorded pool where present and recorded Littlejohn's Tree Frog activity within it. Where any individuals were recorded at distance from a previously identified pool, these were recorded as incidentals and each record georeferenced.

A suite of pool characteristics to augment the data analysis were also collected at each pool and for each incidental pool record. The objective of these recordings is to identify any physical impacts, consider differences in habitat structures between transects and provide an indication of how seasonal conditions may be reflected in habitat conditions. In this way, greater insight may be provided to interpret the biological data and allow for exploratory statistical testing of relationships between pool characteristics/impacts and Littlejohn's Tree Frog detection. The recording of pool characteristics has been formally incorporated into the Program since Niche first undertook the surveys in 2019, and these continue to be reviewed and developed based upon field observations, relevant published literature , and the analysis of detection and habitat relationships.

Pool characteristics were also recorded such as pool depth (overall depth capacity of pool, regardless of water level) categorised as: Very Shallow (<25cm), Shallow (25-50cm), Moderate (50-100cm) and Deep (>100cm) and also current depth (water level as a percentage of capacity).

2.2 Statistical analysis

Following data collection in the field, Upland Swamp vegetation and Littlejohn's Tree Frog monitoring data was reviewed and validated prior to analysis.

In BACI studies, the aim is to assess whether any trend in the response variable (e.g. TSR (Upland Swamps), species composition (Upland Swamps) or abundance (frogs) at sites that have been directly impacted (e.g., mining) differs after impact to that measured before and also differs to any global trend (i.e. trends observed at control sites that did not experience an impact). Potential outcomes in this survey design are numerous with trends potentially occurring suddenly as a pulse event, or as is more likely, gradually over time.

2.2.1 Treatments

As summarised in Section 1.3, one control and three impact site treatments are utilised in the survey design and data analysis approaches, detailed in Table 9 below. These treatments are applied across the swamp floristic transects, LiDAR and frog monitoring transect methodologies, consistent with previous iterations of the Program.

Table 9: Control and impact treatments

Treatment	Description
Control	Site is not subject to any potential impacts, with no mining within the 400 m Risk Management Zone (RMZ) of the feature (the distance at which effects on swamp hydrology are considered likely or possible).
Pre-mining	Data collected at Impact sites in the period prior to the post-mining status change is considered to be pre-mining data at this site. Once subject to potential impacts (within RMZ or mined beneath) sites are changed to post-mining status. Where Control sites are changed to Impact sites as a result of longwall progression, data is altered from Control to Pre-mining for the period prior to impact.
Post-mining - within RMZ	Site subject to potential impacts, with mining having occurred within the 400 m RMZ surrounding the ecological feature. Based on previous experience in Dendrobium, effects on water tables in mapped Upland Swamps have not been observed at distances greater than 60 m from a longwall panel (Watershed HydroGeo 2019).
Post-mining - mined beneath	Site subject to potential impacts, with mining having occurred directly beneath the ecological feature.

2.2.2 Upland Swamps

Mining-induced impacts to Upland Swamp vegetation may be evidenced by a change to TSR at different sites, or an overall change in the species composition, as some species may be less affected by impacts than others. In affected areas, these impacts may manifest as the following:

- Change in floristic TSR: the number of individual species, calculated by the total number of unique species detected at each monitoring transect during each season and year. This is a presence-absence measure and does not account for the abundance of each species.
- Changes in the floristic species composition: the assemblage of different individual plant species that make up a vegetation community.
- Changes in Upland Swamp extent: The contraction or expansion of the area of Upland Swamps and the communities that comprise them.

To maintain consistency with external data management and ensure a non-biased approach to data analysis was implemented, Niche engaged The Analytical Edge Statistical Consulting Pty Ltd (TAE) to undertake a review of the statistical analysis and data collection methodology of Upland Swamps following the completion of the 2020 program (Niche 2021). The analysis provides a statistical comparison of impact and control sites with the aim to identify, understand and manage any mining impacts through the implementation of a quantitative assessment against the relevant TARPs.

Statistical analysis was run for the 2022 dataset against one, two, three, four and five yearly comparisons. This was required to understand the TARP triggers and cumulative impacts. This approach was required as not all data are assessed in a single model, and therefore power is lost as data are omitted from the analysis. For example, a small change may never be statistically significant when comparing the data between two consecutive years (as is required to assess TARPs), but might be statistically significant at a different timescale, such as over the entire survey (TAE 2023a). To remedy this, an analysis of cumulative impact in TSR and species composition was undertaken over three, four and five years to enable detection of change over time.

The following methodology was designed and applied to the Dendrobium dataset by TAE (2023a,b,c,d,e) in consultation with Niche ecologists.

2.2.2.1 Total Species Richness (TSR)

TSR was calculated for swamp sites as the sum of individual taxa detected at each transect for each survey. Exploratory data analysis was conducted by creating boxplots of total species richness (TSR) at all swamps over the period of monitoring to determine any visually detectable yearly trend in TSR between swamp types (impact or control), any difference in TSR before and after impacts.

A complete analysis of all one, two, three, four and five yearly comparisons was undertaken across the entire historical dataset. The mean TSR of all two-consecutive-year pairs at impact swamps was contrasted against the mean TSR of all Control swamp data from prior to the impact.

Where applicable, a BACI style analysis was completed, whereby differences in group means before impact between the control and impact swamps, and after impact, were tested to explore whether they were different from zero (0). If there was only a single year of before-impact monitoring, a control-impact analysis was completed, whereby differences in group means after impact at the Control and Impact swamp was tested to explore whether they were different from 0. Conducting multiple testing such as this can lead to erroneous interpretation of results. Through statistical chance alone 5% of tests may be concluded statistically significant, and this chance is elevated when multiple tests are conducted. Methods exist for multiple correction (e.g. Holm 1979) but this will decrease the power to detect a difference, if one exists. All analyses were conducted in R (v. 4.1.2, R Core Team 2021) (TAE 2023a).

2.2.2.2 Species composition

A list of all unique species detected at each transect in each survey has been recorded. This data has been used to describe the species composition of each swamp and identify changes in species composition over time.

Flora data were used to determine species assemblages – or community composition – at each transect, within each swamp during each survey (i.e., simply a list of all unique species detected during each monitoring event). This multivariate data has been traditionally analysed within a distance-based framework, using methods like principal components analysis or non-metric multidimensional scaling (e.g., Symbolix, 2014). However, amongst other problems, these methods cannot offer a formal framework in which to test the hypothesis that treatment-effects influence species assemblages (Warton et al., 2012, Wang et al., 2012; TAE 2023b).

Instead, model-based approaches can be used when dealing with complex, multivariate data such as species assemblages. Here, multivariate presence-absence models were fitted using the 'manyglm' function in the 'mvabund' package (v.4.1.9, Warton, 2012) in program R (v. 4.1.2, R Core Team 2021). These models fit multiple presence-absence models to each detected species, correcting for the correlation between species (thus violating an assumption of standard Generalised Linear Models (GLMs) using generalized estimating equations (GEEs). Analysis of variance (ANOVA) was used to formally test the significance of explanatory variables (i.e., 'Mining Status'). Separate models were fitted to data collected at each swamp. If 'Mining Status' was found to be statistically significant, univariate tests were completed to determine which species were driving the change in flora community composition (TAE 2023b).

A complete analysis was undertaken across the entire historical dataset. Data were subset into two-consecutive year periods and analysed within a multivariate framework to determine if species composition differed between the two-year period after impact, compared to species composition prior to impact. For example, if a swamp was impacted in 2013, species composition in 2013 and 2014 at the impact swamp was compared to the species composition prior to the impact. This was then repeated for 2014-2015, 2015-2016, 2017-2018, 2018-2019, 2019-2020, 2020-2021 and 2021-2022. Three- and four-yearly comparisons were also undertaken, and for swamps in Area 3B, five-yearly comparisons were investigated (TAE 2023b).

In this approach, not all data are assessed in a single model, and therefore power is lost as data are omitted from the analysis. For example, a small change may never be statistically significant when comparing the data between two consecutive years, but might be statistically significant at a different timescale, such as over the entire survey.

2.2.2.3 Breakpoint analysis

In addition to the limitations in TSR outlined above, this approach doesn't identify any statistically significant 'change points' that might exist in the data. In this case knowledge about when the impact occurred and whether that impact date caused a change in the trajectory of TSR at each swamp. TAE has proposed alternative methods to analyse these data using a broken-stick approach (following Muggeo 2003; Muggeo 2017). This method has been included in the Program since 2021 (Niche 2022a).

TAE (2022c) explains that in a broken-stick model with a single breakpoint, the data are essentially split into two time series: one prior to and one after the breakpoint. A linear model is fit to each portion of the data (i.e., one linear model is fit to the data subset prior to the breakpoint, and one linear model is fit to the data subset after the breakpoint). The placement of the breakpoint is optimized to ensure the error for the fitted models within each segment of the data is minimal. As the number of breakpoints fit to the data is increased, so too is the number of linear models. That is, two breakpoints create three separate linear models (one before the first breakpoint, one between the first and second breakpoints, and one after the second breakpoint). The number of breakpoints fit to the data is a model selection issue, here based on Akaike's Information Criterion (AIC) (Buckland et al. 1997).

Once the final model of breakpoints is determined, the statistical significance of the linear models for each segment can then be explored. Here, the gradient of each segment is reported, along with statistical significance based on 95% confidence intervals. All analyses were conducted in R (v. 4.1.2, R Core Team 2021), using the 'segmented' packaged (v 1.4-0, Muggeo, 2008).

This additional analysis of the TSR data, breakpoint analysis has also been applied to a limited selection of 'target' species in each swamp with identified statistically significant differences in pre-post mining species composition. The same broken-stick methods were used as for the TSR analysis, however applied to the number of detection events for identified target species within specific swamps. As this is an exploratory analysis in order to examine the efficacy of the approach, two species were selected for breakpoint analysis in each swamp. Target species were primarily identified based on three criteria. First, species identified as experiencing the greatest degree of change in the species composition analysis (TAE 2023b). Second, species that have a clear preference for 'wet' or 'dry' soils or habitat associations. Third, species that show a clear trend of increasing or decreasing (or both) detection over the course of monitoring to optimise the likelihood of findings being conclusive.

2.2.2.4 Investigation of differences in seasonal monitoring

Exploratory analysis was recommended in Niche (2022a) to determine whether both seasons of data collection are essential to support the data analysis. If no difference is detected, the Program could potentially be adjusted to collect TSR and composition data once a year in spring, without reducing the validity of any statistical analysis. This would also reduce the effects of trampling alongside transect locations. Further discussed in Section 3.

Statistical analysis (Annex 3) of spring versus autumn TSR and species composition data was undertaken in 2021 and 2022 to determine if there is a difference between seasons (Niche 2022a, TAE 2023e). This analysis included visual analysis of boxplots of TSR for each control and impact swamp, contrasted by season. Multivariate generalized linear models were then fit to impact-swamp specific data to investigate seasonal differences in species composition. This analysis identified unique species detected in each season, per swamp. This list of unique species detected only in a single season at each swamp was then assessed by Niche Ecologists.

All analyses were conducted in R (v. 4.1.2, R Core Team 2021).

2.2.3 Littlejohn's Tree Frog

Niche have maintained the data collection and method to standardise the varying lengths of transects. As per previous reports, the total number of each life stage is standardised to represent a Catch-per- unit-of-effort (CPUE) per 100 metres of survey effort (n/100 m) along each transect.

For statistical analysis a linear model was fitted to the data of the form Count~Treatment*Year for each of Adults, Tadpoles and Eggmasses separately. This was to test for any interaction between year and treatment and the main effect of year and treatment. Count data were modelled as negative binomial instead of normal to account for the zero-truncated and integer-based nature of counting, and the zero-inflated dataset. For catchment level trends at Dendrobium Area 3A or Dendrobium Area 3B preliminary exploratory analysis examined homogeneity of variance. The variance was corrected by introducing a factorial variance structure, allowing different variance for each level of treatment. If these variances were unresponsive, a log(count+1) transform was conducted, if no effect, the raw data was then used. Site was included as a random term, and its significance was tested by an ANOVA by comparison to the factorial only model. In all cases, Site was not statistically significant and so removed from the final models.

For longer term effects the data were scored by treatment (Pre, RMZ, Mined under), at the Control and Impact sites. A GLM was fitted using a variance structure controlled for different variance between Control and Impact sites. For statistical analysis a linear model was fitted to the data in the form CPUE ~ Mine_status. This reads as: CPUE (catch per unit effort) as a function of Mine Status (Control/Pre-/RMZ/Mined under) and its significance was tested by an ANOVA. This was completed to test whether CPUE (of Adults/Tadpoles/Eggmass) was different between Control and Impact (whether Pre-, RMZ, or mined under) transects. Second to this analysis, a Tukey HSD test was completed to ask precisely which Mine Status were different from Control. The BACI style model was unique per creek site with the Control timing matching that of the Impact site timing in each case. In every case all Control sites were used as the Control. These models were run for Adults, Tadpoles, and Eggmasses separately.

All analyses were conducted in R (v. 4.1.2, R Core Team 2021).

2.3 Limitations

Limitations of the Program include the following:

General limitations:

- No two creeks or swamps are identical, and therefore eliminating all variables between Control and Impact sites is a complex task and not possible in this instance. A specific review and commentary around the selection of control sites and assessment approach initially included in the Program by Biosis has been previously undertaken in Niche (2022a).
- The amphibian transects had variable lengths and numbers of breeding pools, which are themselves variable in size and physical habitat. The data for number of breeding pools and length of creek was standardised to 100 metres for the purpose of data analysis (see section 2.2.3), consistent with previous iterations of the Program. The location of each count point for observations made during targeted nocturnal surveys and any other incidental sightings were recorded using a GPS.
- This is the third year Niche have undertaken the Program and as such, some methodologies may be slightly different to previous iterations of the Program or years of data collection (commencing in 2003), despite every effort to maintain consistency.
- Swamp and amphibian monitoring treatments were updated to reflect current mining activity (Section 2.4).
- In some cases, the Control Group for LiDAR comparisons of sub-communities are only represented by a single swamp, although isolated years from non-consecutive monitored swamps can be examined to assist in interpretation in these cases.

Restrictions to survey and timing

- WaterNSW administers access to the WaterNSW Metropolitan Special Areas and any closures (due to rainfall or fire danger) preventing access for survey are beyond the control of Niche. Significant and extended rainfall events throughout 2022 resulted in unprecedented extended closures to the WaterNSW Special Areas. No survey could be completed during these closures. These rainfall events also resulted in damage to fire trails and access routes that hampered field survey following the reopening of the Special Areas. Survey periods and closures are displayed in Table 10 and discussed below.

- Access to the WaterNSW Metropolitan Special Areas in 2022 was closed for the entirety of the autumn months of 2022, with these closures remaining in place between 10 January 2022 and 7 June 2022, due to significant and extended rainfall events. Further closures also occurred between 2 July 2022 and 2 August 2022 during the winter months. In total, the WaterNSW Metropolitan Special Area was closed for a total of 28 weeks, over the course of 2022.
- Once the Special Area closures were lifted, all efforts were made to complete the swamp surveys as soon as possible in order to maximise survey under as ‘autumn -like’ conditions, and as close together, as far as practicable.
- While not preferrable, the timing of some surveys outside of the programmed seasons was beyond the control of Niche, however is not considered a major limitation to the overall objectives of the Program. The following mitigating factors apply:
    - All monitoring sites were subject to the same survey timing limitation.
    - The potential for seasonal differences in the dataset is given special consideration in the data analysis and interpretation that forms the basis of the assessment against the relevant TARPs.
    - In previous years, swamp data collection has also extended into the winter months (June, July, August) in 2016, 2017, 2019, 2020 and 2021, presumably due to similar constraints to survey.
    - Statistical comparisons of the autumn and spring data completed in 2021 and 2022, identified that the autumn season is not as important to the analysis as the spring season (Niche 2022a).
    - A period of three months separated the autumn and spring flora surveys allowing for a suitable period of floristic change between the seasonal surveys.
- The 2021 and 2022 years of the Program have been completed during the COVID 19 pandemic. Disruptions to survey have included social restrictions dictated by the Australian and NSW Governments, unexpected infection of planned field team members and self-isolation requirements.

Table 10: Survey periods and WaterNSW closures in 2022

Season	Month	Autumn flora	Winter amphibian	Spring flora
Summer 2021/22	January			
		🟥	🟥	🟥
		🟥	🟥	🟥
		🟥	🟥	🟥
	February	🟥	🟥	🟥
		🟥	🟥	🟥
		🟥	🟥	🟥
		🟥	🟥	🟥
Autumn 2022	March	🟥	🟥	🟥
		🟥	🟥	🟥
		🟥	🟥	🟥
		🟥	🟥	🟥
	April	🟥	🟥	🟥
		🟥	🟥	🟥
		🟥	🟥	🟥
		🟥	🟥	🟥
	May	🟥	🟥	🟥
		🟥	🟥	🟥
		🟥	🟥	🟥
		🟥	🟥	🟥
Winter 2022	June	🟦		
		🟦		
		🟦		
		🟦		
	July	🟥	🟥	🟥
		🟥	🟥	🟥
		🟥	🟥	🟥
		🟥	🟥	🟥
	August	🟦	🟦	
			🟦	
			🟦	
Spring 2022	September			
		🟥	🟥	🟥
	October	🟥	🟥	🟥
		🟥	🟥	🟥
				🟦
		🟥	🟥	🟥
	November	🟥	🟥	🟥
				🟦
				🟦
				🟦
Summer 2022/23	December			🟦

Red shading indicates WaterNSW Special Area closures

Blue shading indicates survey periods undertaken in 2022

Upland Swamps:

- Control Sites are located within areas that are not expected to be impacted by mining operations. Survey within Control Sites was limited to lands that were accessible, and where safety concerns could be minimised.
- The Program employs the use of multiple Control sites to establish multiple lines of evidence to differentiate between catchment wide influences, such as low rainfall, and potential mining impacts. The Program also utilised long term monitoring data for many of these sites, and additional data sets such as groundwater monitoring conducted by IMC.
- The transect data only indicates the presence/absence of a species across the transect. This limits the ability to investigate some other aspects of vegetation monitoring such as diversity/abundance.
- Some plant species are cryptic or inconspicuous unless flowering or in fruit. Plant species complexes were developed that combine plant species that are known to be easily confused in the field. These species complexes are treated as one species in the data analysis, more commonly joining species of the same Genus and ecological function that are difficult to identify in the field across seasons and that occur in close proximity to one another.
- Though standards are employed to reduce the occurrence of observer bias (such as obtaining a list of species previously recorded at each swamp), there will inevitably be some observer bias that may result in different species recorded identified along transects. Particularity for closely related or similar species, this is maintained as the species complex to assist in eliminating risk to data.
- The sub-community mapping for Swamp 131 shown in Figure 4e is based on a combination of regional mapping (NPWS 2003) and limited ground-truthing. In 2022, the swamp extent and sub-community mapping could not be analysed through LiDAR data, given the swamp was added to the Program post collection of the LiDAR data and therefore the data extent did not cover Swamp 131. It is understood that South32 plan to capture LiDAR for Swamp 131 in 2023, and the mapping for this swamp will be updated as part of the 2023 monitoring program.

Littlejohn's Tree Frog:

- The limited dataset provided from previous iterations of the Program to 2019 for Littlejohn's Tree Frog analysis restricts the ability to analyse trends on the smaller scale as the data was represented as an average across standardised transects and presented as one number. Since 2020 the raw data has been maintained such that data can be examined at the individual pool level.
- Only visiting each site once across the survey period may not be a clear representation of the population in the system. This is also dependent on the temperature and rainfall throughout the breeding cycle. A general trend may be observed that if Adults are present, there will be fewer Tadpoles, and this may change over the course of the survey timing. Maturation times for Tadpoles of the species having been observed to take around 4 months (Anstis 2002) but are dependent on seasonal temperatures, and other factors. Klop-Toker et al. (2021) suggest between 3 to 4 months in summer and 5 to 11 months in winter.
- It is possible that, broadly speaking, surveys earlier in the breeding season may be more likely to detect more Eggmass and Adults compared to later in the season (at which time Eggmass may have metamorphosed into Tadpoles). However recent work by (Klop-Toker et al. 2021) suggests the species breeds nearly year-round, with breeding most typically triggered by rain events, with multiple breeding opportunities each year likely. Therefore, the relative timing of surveys across a season is not considered a major limitation in and of itself.
- To allow for potential variation in conditions described above, and to remain consistent with the previous monitoring approach, each survey night was planned wherever practicable to assess one control creek and one impact creek to further address the potential for lifecycle stage detection variation across the breeding season.

- Trends or results in lifecycle stages are not considered in isolation and form part of a weight of evidence approach whereby all lifecycle stages are considered, with analysis and interpretation of the biological data augmented by assessment of physical habitat conditions (e.g. water levels) and identification of gross indicators of environmental change (bedrock cracking, flocculant).

LiDAR

- The mapping of sub-communities was mainly undertaken via use of LiDAR, supported by aerial imagery interpretation. Minimal ground-truthing was undertaken to validate the mapping. There are therefore likely to be at least minor errors in the swamp extent mapping.
- The updated CHM developed for the 2020 analysis (Niche 2021) (as detailed in Section 2.1.2), was applied to the historic dataset in 2021 (Niche 2022a), to enable results of total swamp extent and swamp sub-community mapping to be compared to all previous years. Therefore, total swamp extents, swamp sub-community mapping and TARP triggers are likely to be different to that presented in previous monitoring reports (Niche 2021, Biosis 2020 and previous) and therefore may also differ to TARP levels reported in those reports. TARP levels presented for years prior to 2022 are reported in Niche (2022a).
- No LiDAR data for 2015, or the new Control Swamp 131 in 2022, was available and so has not been included in the analysis. It is understood that Swamp 131 will be included in the LiDAR data in 2023.
- Limited data for control swamps 86 and 22 is available (2014, 2021 and 2022 only). Data for these control sites are presented in this report and are used to inform the assessment of the results. To avoid unequal comparisons and biasing averages (i.e. higher averages in years where data is available compared to when it is not available) these sites are not included in the Control Group averages or standard error calculations used in the assessment against performance measures.

The current Program data collection and methods of analysis are considered suitable to address the relevant monitoring TARPs.

2.4 Niche team involved in the project

Niche has assembled a project team with significant experience monitoring ecological values and potential mining impacts in the Southern Coalfields and specifically the threatened biota known to occur within the Dendrobium area. The level of experience of the team is commensurate with the sensitivity of the ecological features/biota and complexity of the monitoring program itself. The 2022 field monitoring surveys, data analyses and reporting were completed by the Niche team described in Table 11.

Table 11: Niche team involved in the project

Personnel	Role	Experience
Luke Stone Associate - Ecology BSc, MRes	Project manager: • Vegetation monitoring • Littlejohn's Tree Frog monitoring • Data analysis • LiDAR analysis and interpretation • Program review • Reporting • Project management	Luke has over 7 years' experience as an ecological consultant undertaking ecological monitoring and assessment in the WaterNSW Metropolitan Special Areas. Luke has considerable experience in the delivery of large scale and long-term ecological monitoring programs. Of most relevance, this experience includes: • Project management, field survey, data analysis and reporting associated with upland swamps, threatened and non-threatened amphibians and the Giant Dragonfly *Petalura gigantea* within the Dendrobium, Cataract and Nebo mining areas. • Aquatic ecological monitoring, assessment and threatened fish survey within the Cataract, Nebo and Avon mining areas. • Preparation of monitoring and management plans associated with upland swamps, threatened amphibians and aquatic ecology.
Sian Griffiths Practice Leader -	Project director: • Vegetation monitoring	Sian is a highly experienced ecologist, ecological consultant and project manager, with over 18 years' experience in environmental consulting.

Personnel	Role	Experience
Ecology BEnvSc (Hons)	- Program review - LiDAR analysis and interpretation - Technical review and quality assurance - Project direction and oversight	Sian has extensive experience with application of the Biodiversity Assessment Method (BAM), biodiversity impact assessments under State and Commonwealth legislation, vegetation surveys and mapping, biodiversity management plans and long-term biodiversity monitoring programs. Sian is an accredited BAM Assessor under the *NSW Biodiversity Conservation Act 2016* (BAAS 17066). Sian has been involved in the Dendrobium monitoring program since 2019, and prior to this, was involved in the Program in its early years while working as an ecologist in a previous role with Biosis.
David Wilkinson Consultant Ecologist BSc (Environment)	Ecologist: - Vegetation monitoring - Littlejohn's Tree Frog monitoring - Data analysis - LiDAR analysis and interpretation - Field data quality assurance	David is an ecologist with five-years' experience in ecological field survey and assessment. David has worked on many ecological programs in the Sydney and Illawarra regions, including the Dendrobium Ecological monitoring program since 2019. David's skills include vegetation survey, plant species identification data management and targeted flora and fauna surveys. David also possesses considerable experience in the ecological monitoring and assessment of aquatic environments.
Amy Legge Ecologist BSc (Cons Bio)	Ecologist: - Vegetation monitoring - Littlejohn's Tree Frog monitoring - Field data quality assurance	Amy has been working in the environmental industry for over two-years, having previously undertaken volunteer work with Forestry Corporation NSW that spans over five-years. During this time, she developed her skills and understanding of plant communities, plant identification and restoration ecology. Amy has significant experience working in remote locations and collecting and analysing ecological data.
Lilly Cains Graduate Ecologist BSc	Ecologist: - Vegetation monitoring. - Littlejohn's Tree Frog monitoring	Lily graduated in 2019 and since that time has developed experience in flora, amphibian and aquatic surveys in Central Western NSW, Southern Highlands and the Illawarra region.
Matthew Russell Associate – Aquatic Ecology BSc	Senior Ecologist: - Ecological monitoring advice - Vegetation monitoring assistance	Matthew has over 20 years' experience specialising in aquatic ecology and river management. He has conducted large aquatic environmental impact assessments for mining, road/rail infrastructure, environmental flows, licenced discharges. Matthew also has significant experience in the development of aquatic and riparian management plans, as well as designing and implementing long term monitoring programs for regulatory requirements, including within the Southern Coalfields.
Loren Saiyanmontakul Experienced GIS Consultant BSc	GIS Consultant: - LiDAR analysis - GIS development - LiDAR analysis and interpretation - Multi-spectral analysis - Figure preparation - Spatial data management	Loren has over 7 years' experience in the provision of spatial services and advice for a range of disciplines including mining, environmental management, civil/geotechnical/environmental/water engineering and defence. Loren has managed large scale vegetation management data collection programs, utilising field and web applications and developed remote sensing procedures for ecological monitoring.
Matthew Harris Discipline Manager -GIS BA (Hons), PhD, GDip (GIS)	Senior GIS Consultant: - LiDAR analysis - GIS development advice	Matthew has extensive experience in a diverse range of GIS products, including remote sensing, spatial modelling, spatial data management and cartography. Matthew is also highly skilled in technical and scientific illustration and data visualisation and presentation. Matthew has worked since 2018 as a GIS specialist, and for the five years previous in cultural heritage in Queensland and New South Wales.
Dr Stefan Walker	Statistical Consultant: - Statistical analysis of	Stefan has over 20 years of experience undertaking research design, data analysis and teaching in the fields of biology, conservation and

Personnel	Role	Experience
Statistical consultant PhD	Littlejohn’s Tree Frog dataset	natural resource management.

To deliver the Program with the requisite levels of statistical expertise and to maintain consistency with previous iterations of the program, Niche has collaborated with TAE to provide specialist statistical analysis of the flora monitoring dataset, as described in section 2.2.2.

3. Review and updates to the Program in 2022

As part of the commitment to continuous improvement, Niche has reviewed the methodology and recommendations from the previous year's report in order to identify any areas of improvement or methods to augment the Program. Niche have undertaken the Program, as far as practicable, using the same methods as previous monitoring reports to ensure valid comparisons to previous years of data collection and analysis. Some changes to the approach have required updates relevant to the current year of mining activity within Dendrobium Area 3 and to improve the approach to data collection.

While the Program continuously evolves, major reviews and changes to the Program have been completed in specific years. The key changes or outcomes of each of these are briefly summarised in Table 12. Further detail can be found in the individual reports.

Table 12: Major program review outcomes summary

Program year	Major review items and outcomes
2013 (Biosis 2014)	• Stated justification of the inclusion of Native Dog Creek and the tributaries of Native Dog Creek (ND1 and ND2) as control sites (subsequently amended in 2021). • Discussion of baseline data collection timeframes and differences among sites.
2015 (Biosis 2016)	• Review of statistical analysis procedure previously applied and identification of limitations to the previous statistical analysis design. • Subsequent changes were made to the statistical analysis approach that form the basis of the ongoing Swamp statistical analysis. • The final round of Creek vegetation point-based monitoring was reported on.
2019 (Biosis 2020)	• The species complexes were reviewed and further refined in 2018 and 2019. • Species complexes were applied consistently across the entire flora monitoring dataset and analyses re-assessed in light of this change in approach. • The defined species list including species complexes was included as Appendix 1.
2020 (Niche 2021)	• Area 3A and Area 3B TARPs and approach to application of TARP levels defined. • Swamp treatments reviewed and defined. • Additional statistical analysis for Littlejohn Tree Frogs undertaken for long term trends with a BACI analysis via ANOVA. • Development of a new CHM for LiDAR analysis of swamp extent and mapping of sub-communities for use in 2020 and future monitoring reports due to uncertainty around the previous CHM. • Swamp sub-community Sedgeland Heath was combined into one community for the purpose of the LiDAR analysis. • The draft report and experimental design received feedback from the Biodiversity and Conservation Division (BCD), with all matters raised addressed and justified to the satisfaction of the Department of Planning Industry and environment (DPIE) (2021).
2021 (Niche 2022a)	• Consideration of paired vs pooled control site data for swamp floristic analysis. • Review and justify/re-designate control sites initially included in the Program by Biosis. • Review and amendment of control sites used for LiDAR analysis in line with recommendations (Niche 2021). • Inclusion of additional Littlejohn Tree Frog statistical analysis to assess the relationship of frog abundance at pools to the distance of the nearest longwall and the presence of flocculant. • Modification to the Littlejohn Tree Frog statistical analysis to assess Pre-impact collection data against controls. • Application of the updated CHM (Niche 2021) across previous years of LiDAR data. • Inclusion of additional breakpoint analysis to complement the existing statistical analysis applied to the Swamp floristic monitoring.

A review of the existing Program has been made in 2022 in order to evaluate and where possible improve the robustness of the survey design, as well as improve consistency in assessment approach. These improvements build upon those identified and comprehensively described in the 2020 and 2021 iterations of the monitoring program (Niche 2021, Niche 2022a), which have been carried forward into 2022 and are not repeated in detail here. No major changes to the field data collection methodology or data analysis approaches have been made in 2022. Details of the outcomes of changes to the Program in 2022 and the review of monitoring approaches are provided in the following sections.

3.1 Swamp 15(A)1 treatment

Swamp 15(A)1 has been monitored as a control swamp since 2005. In 2022, the treatment of Swamp 15(A)1 has changed from Control to Impact (within RMZ). Consistent with the Program design, data collected at Swamp 15(A)1 between 2005 - 2021 is no longer considered Control data, but pre-mining data.

Following this change, the long-term statistical comparisons to past data and LiDAR comparisons may differ to those presented in previous reports, where Swamp 15(A)1 is no longer treated as part of the Control Group.

3.2 Additional Control sites

In accordance with the recommendations of Niche (2022a) and commensurate with the changes in monitoring site designations (pre-mining site status into post-mining site status), additional Control sites have been added to the Program. These sites were selected in consideration of:

- Available swamp sub-community mapping within the Dendrobium Area.
- Identification of swamps and streams within the Dendrobium mine lease area that are not impacted by current or future mining.
- Review of existing control and impact swamp/transect attributes and representation across monitoring sites.
- Identification of any other existing impacts such as inundation, easements or tracks.
- Presence of Bionet records and past survey results.
- Pool mapping provided by IMC.
- High resolution aerial imagery.
- Safe access.

Area 6 has been selected for the location of the new controls as it is understood this Area will not be mined.

3.2.1 Upland swamp control

An additional control swamp (Swamp 131) has been added to the vegetation transect and LiDAR monitoring components of the Program in 2022, commensurate with the re-designation of swamp 15(A)1 to an impact swamp following the progression of mining in 2022. Swamp 131 is located in Area 6 to the north of the DA3A and DA3B. The swamp is primarily comprised of Tea-Tree Thicket. This swamp will be included in LiDAR based sub-community mapping in future iterations of the monitoring program.

Location of the transects within the Swamp 131 was based upon:

- Representative sub-community composition.
- Safe access and ability to re-locate transect and photo point locations.
- Orientation.

3.2.2 Amphibian monitoring control transects

Two additional control transects (CR29 and CR29D) have been included in the Program in 2022, commensurate with the change in treatment of Native Dog Creek transects from Pre-mining/Control to within RMZ in 2022. With the aim being to identify comparable structural habitats to those in Native Dog Creek (similar pool sizes and physical characteristics) targeting potential breeding habitat for Littlejohn’s Tree Frog and Giant Burrowing Frog, as far as practical.

The transects and habitats were then inspected during daylight conditions to ascertain whether the objectives of selection were fulfilled. This was based upon habitats present, diurnal detection of life stages and broad pool characteristics. The transects were then surveyed under nocturnal conditions.

3.2.2.1 Transect CR29

Transect CR29 is characterised by permanent bedrock pools of relatively large size and elongate pool sections along the channel, separated by bedrock sheets or boulders. CR29 is part of a larger stream that is comparable to NDC/ND1 and associated stream network. The transect is set within a relatively steep valley with the upper stream extents fed via upland swamps, separated from the downstream half of the transect by a large waterfall. The downstream extent below the waterfall still retained structurally suitable habitat and comparable vegetation but the hillslope appears to be more sandy and consequently, vegetation structure more open. Very minor natural flocculant was recorded along the transect but this was evident in only minor amounts along bank sediments, diffuse in nature and not observed to be coating habitat. Evidence of high flows were observed along the stream section below the waterfall, as observed in many transects in 2022. Observation of freshwater shrimp were common below the waterfall, with juvenile native fish *Galaxias* sp. (Mountain Galaxias/Climbing Galaxias) individuals observed sporadically. Giant Burrowing Frog tadpoles and Littlejohn’s Tree Frog eggmass were observed along the extent of the transect, although the observations were most abundant upstream of the waterfall, especially for the Littlejohn’s Tree Frog. Adult and Tadpole observations were concentrated above the waterfall. This may be related to the relatively high flows prior to survey, reflect survey timing or habitat preferences. Pools 1 – 15 along CR29 were selected due to their similarity to NDC, in particular the large extended pools present along the lower half of that transect. It is recommended the detection data be reviewed in 2023 to ascertain whether it may be beneficial to extend the upstream limit of the transect and shorten the downstream limit of the transect in order to maximise detection, without significantly changing the physical characteristics.

3.2.2.2 Transect CR29D

Transect CR29D is a smaller stream characterised by closed dense vegetation that transitions between isolated bedrock dominated pool sections and small channel and pool sections among dense organic fine sediments. Natural flocculant is present in moderate to high levels throughout the transect and was observed in places to coat the majority of instream habitats along the bank, especially within smaller pools and outside of bedrock dominated sections. CR29D is also fed by upland swamps along its upstream extent and despite this and the density of vegetation, evidence of high flows through the upper valley were observed along much of the transect following a number of high rainfall events. Pools 1 – 15 along CR29 were selected due to their similarity to sections of ND1 and ND1, including the presence of natural flocculant that is not identified in many of the other Control transects utilised in the program.

3.3 Swamp autumn transect data collection evaluation

Preliminary comparative analyses investigating the potential of completing ‘spring only’ floristic surveys, as opposed to autumn and spring surveys was included in the 2021 annual report (Niche 2022a). Niche was requested to undertake this analysis to determine whether both seasons of data collection are essential to support the data analysis. If no difference is detected, the Program could potentially be adjusted to collect TSR and composition data once a year in spring, without reducing the validity of any statistical analysis.

Niche (2022a) identified that the argument to undertake transect (floristic) data collection only once per year in spring is supported by the fact that no seasonal differences were detected in TSR or in species composition for any swamp (across all monitoring years). No strong justification to maintain the autumn round of transect data collection was identified and the analysis undertaken suggests that ‘spring only’ data collection and analysis would not compromise the validity of the Program or fundamentally alter the monitoring results. In light of this, Niche (2022a) recommended that future data collection in spring only is considered for the transect (floristic) monitoring, with subsequent data analysis restricted to the spring seasons of data collection.

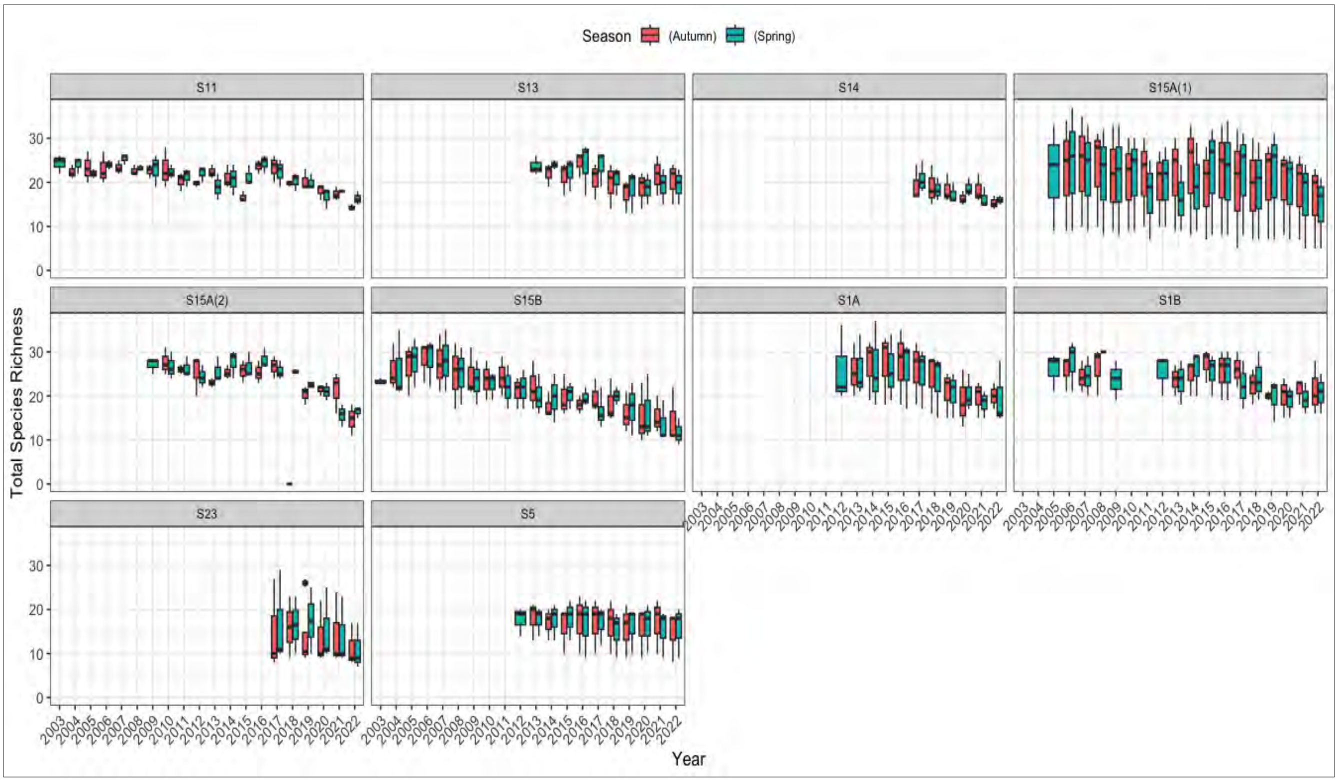
Niche have been requested to undertake further analysis of the autumn floristic dataset and whether it presents a significant contribution to the overall monitoring approach and assessment of the TARP’s. The outcome of this will be to provide a recommendation in answer to the question of:

> *Whether the autumn floristic surveys can be removed without impacting upon the assessment of trends in swamp composition or condition over time, based upon the dataset collected to date?*

To answer this question, additional statistical analyses have been completed in 2022 to augment those completed in 2021. The analyses undertaken in Niche (2022a) to investigate if any seasonal differences occur at monitored swamps were repeated as detailed in Annex 3, including the 2022 year of floristic data collection. In summary, this included:

- Visual assessment of boxplots of TSR for each year of monitoring (separated by season) for all control and impact swamps (Graph 1, Graph 2).
- Calculation and comparison of the number of unique species detected at each swamp within each season.
- A multivariate abundance model was fitted to all data, specifically testing for season effects.

Graph 1: Boxplot of the total species richness for each transect at each Control swamp, contrasted by season. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.



Graph 2: Boxplot of the total species richness for each transect at each Impact swamp, contrasted by season. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

The visual assessments of TSR boxplots (Graph 1, Graph 2) identified similar TSR results between autumn and spring data within impact and control monitoring swamps.

At every swamp, there was a subset of species that were detected in only one of the two seasons visited. Typically, more species were detected in spring and fewer species were detected only in autumn. This list of species for each swamp has been reviewed to identify any species that may have functional ecological requirements or life history stages that would make them suitable for detection in autumn alone (Table 13). The only such species was *Pterostylis parviflora* identified at Swamp 87 only which flowers in February–June, which presents a challenge to species level identification during spring. However, this species could be integrated into the orchid species complex. All other species (if present) should be detected in either spring or autumn seasons.

Table 13: Species identified as occurring in only autumn or spring within monitoring swamps

Species	**Upland Swamp**														
	15A(1)	**15A(2)**	**15B**	**11**	**13**	**14**	**1A**	**1B**	**5**	**23**	**86**	**87**	**88**	**22**	**33**
Acacia rubida						X			X						
Acacia terminalis				X						X					
Acianthus species complex			X												
Actinotus minor														X	X
Adiantum aethiopicum												X			
Allocasuarina littoralis			X		X						X				
Allocasuarina paludosa							X								
Almaleea paludosa			X												
Amperea xiphoclada								X							
Baeckea imbricata			X								X	X			
Baeckea linifolia										X					
Banksia ericifolia								X							
Banksia marginata							X								
Banksia spinulosa var. spinulosa		X				X									
Baumea acuta	X		X	X		X						X		X	X
Blandfordia Burchardia Caladenia Haemodorum Microtis Thelymitra species complex													X		X
Boronia parviflora														X	
Bossiaea heterophylla											X				
Bossiaea scolopendria										X					
Brachyloma Monotoca Lissanthe Leucopogon complex	X				X						X				
Callistemon citrinus					X										
Callistemon subulatus					X										
Calochilus campestris												X			
Calytrix tetragona															
Comesperma defoliatum	X						X	X	X			X			X
Comesperma ericinum f. A											X				
Comesperma sphaerocarpum								X							
Conospermum tenuifolium											X				X
Cryptandra ericoides									X						

Species	Upland Swamp														
	15A(1)	15A(2)	15B	11	13	14	1A	1B	5	23	86	87	88	22	33
Cryptostylis sp_complex			X						X						
Cyclosorus interruptus															X
Dampiera purpurea									X						
Dampiera stricta														X	
Dianella caerulea complex					X										
Dianella revoluta var. revoluta					X										
Dillwynia floribunda retorta complex													X		
Dodonaea camfieldii											X				
Drosera binata								X			X				
Drosera peltata											X		X		
Drosera spatulata													X		X
Epacris microphylla					X										
Epacris paludosa		X				X	X				X				X
Eriochilus cucullatus												X			
Eurychorda complanata											X				
Gahnia Sp_complex					X										
Genoplesium species complex			X												
Gompholobium minus pinnatum complex		X													
Gonocarpus sp_ complex												X			X
Goodenia hedercacea/ heterophylla Sp_ complex			X						X		X				
Grevillea sphacelata					X			X							
Gymnoschoenus sphaerocephalus											X				
Hakea dactyloides/ salicifolia Sp_ complex			X												
Hakea teretifolia/ sericea sp complex			X					X							
Hibbertia riparia species complex							X	X							
Hybanthus monopetalus											X				
Lachnagrostis filiformis												X			
Lagenifera stipitata								X							
Lepidosperma filiforme/urophorum complex	X					X									
Lepidosperma limicola											X				
Leptomeria acida											X				
Leptospermum lanigerum					X										
Leptospermum polygalifolium/trinervium complex												X			
Leptospermum rotundifolium										X	X				
Leptospermum squarrosum		X						X							
Lepyrodia cryptica				X											
Lomandra cylindrica/filiformis/micrantha sp complex	X		X	X									X		
Lycopodiella lateralis				X											

Species	Upland Swamp														
	15A(1)	15A(2)	15B	11	13	14	1A	1B	5	23	86	87	88	22	33
Melaleuca linariifolia											X				
Melaleuca thymifolia				X		X									
Micrantheum ericoides										X					
Mirbelia rubiifolia/ speciosa Sp_ Complex			X					X							
Mitrasacme polymorpha/ilosa species complex				X	X							X			X
Monotaxis linifolia						X									
Omphacomeria acerba														X	
Orchidaceae											X				
Panicum simile													X		
Parsonsia straminea								X							
Patersonia species complex					X		X	X							
Persoonia lanceolata								X			X				
Persoonia levis											X				X
Petrophile/Isopogon complex			X					X	X						X
Pittosporum undulatum															X
Plinthanthesis paradoxa															X
Poa Sp_ complex														X	
Pseuderantherum variable/ brunoniella sp complex			X												
Pterostylis parviflorat												X			
Pultenaea aristata					X							X			
Pultenaea divaricata											X				
Schizaea bifida										X					
Selaginella uliginosa					X	X									
Stylidium Sp_ complex										X				X	
Symphionema paludosum			X												
Tetraria capillaris							X			X		X			
Tetrarrhena juncea	X	X					X						X		
Thysanotus juncifolius	X				X			X		X					
Utricularia species complex				X										X	

Multivariate generalized linear models fit to impact-swamp specific data to investigate seasonal differences in species composition (Table 14) identified a significant difference between autumn and spring seasons at Swamp 14 (p-value: 0.030). The analyses did not identify any seasonal differences at any of the other impact swamps. Further data interrogation identified that the statistical seasonal difference in the Swamp 14 data may be explained by the narrow range of species richness at this swamp (with the variation in species detected at transects low in comparison to other transects), meaning analysis at this swamp is likely to be more sensitive to change. Looking more closely at the results, there are only two species at Swamp 14 that were only detected once each in autumn and not detected in spring (*Lepidosperma filiforme/urophorum* complex and *Selaginella uliginosa*). Both of these are perennial species that should be detectable at any time of year, i.e. there is no ecological reason that these species would not be detected during spring monitoring. Given that these two species were only detected once in autumn, they may have died out after one round of monitoring. Therefore, it is concluded that the significant difference at Swamp

14 is an artifact of the narrow range of species richness, rather than representing an ecologically functional pattern.

Table 14: ANOVA results of comparisons for each Impact swamp monitored in 2022

Swamp	Comparison	D.f.	Deviation	P-value
S15A(1)	Season	103	54.21609	0.435
S15A(2)	Pre-post	79	145.15090	0.044
	Season	78	52.57192	0.745
	Pre-post:season	77	37.98127	0.810
S15B	Pre-post	116	487.23839	**0.001**
	Season	115	62.52937	0.629
	Pre-post:season	114	30.18155	0.901
S11	Pre-post	114	276.41826	**0.001**
	Season	113	35.00562	0.669
	Pre-post:season	112	25.44648	0.984
S13	Pre-post	55	142.94940	**0.031**
	Season	54	57.78299	0.669
	Pre-post:season	53	18.93012	0.984
S14	Pre-post	35	73.49588	0.059
	Season	34	77.48308	**0.030**
	Pre-post:season	33	14.95730	0.774
S1A	Pre-post	61	53.22775	0.650
	Season	60	28.17037	0.975
	Pre-post:season	59	50.67004	0.381
S1B	Pre-post	82	308.69799	**0.001**
	Season	81	52.28988	0.894
	Pre-post:season	80	11.45411	0.999
S5	Pre-post	61	32.58030	0.628
	Season	60	32.54193	0.733
	Pre-post:season	59	10.61835	0.999
S23	Pre-post	32	37.76030	0.599
	Season	31	43.01401	0.515
	Pre-post:season	30	13.81843	0.939

When the outcomes of these three lines of assessment are considered together, it is concluded that the autumn floristic surveys could be removed without impacting upon the assessment of trends in swamp composition or condition over time, based upon the dataset collected to date. It is acknowledged that the removal of autumn surveying would mean some species detected only in autumn within induvial swamps could potentially be missed. However, the analysis of the 20 year dataset suggests that the potential number of species would be small (between one and seven at individual swamps) and there is no functional reason why these species would not be detected in spring only, where present.

It should be noted that this change to the Program would be likely to result in fine scale differences in the statistical analysis of previous years (assuming spring data alone forms the basis of ongoing statistical analysis), however given the factors previously established this would be unlikely to alter the overall results to any significant degree or represent a limitation to the Program.

On this basis, it is recommended that future data collection in spring only is considered for the transect monitoring (i.e. the autumn round of transect monitoring is removed from the Program), with subsequent data analysis restricted to the spring seasons of data collection.

Reducing the number of flora surveys is likely to have the additional benefit of reducing trampling effects adjacent to and along the fixed monitoring transects. As the transects and pathways into swamp transects are repeatedly accessed, trampling of swamp vegetation can be observed along some transects (Plate 1). This vegetation trampling has the potential to result in a degree of impact to swamp vegetation and soil compaction in these localised areas. Conceivably, these trampling effects alongside transects may have the potential to impact upon data collection.

Plate 1: Example of trampling along and adjacent to a flora monitoring transect.

3.4 Floristic species list

The current iteration of the monitoring program utilises the species list applied in Biosis (2020) as the last major refinement to the species list, in order to maintain consistency with previous iterations of the Program. The species list utilised in the floristic monitoring has been continually reviewed and adjusted throughout the Program, particularly in reference to the application of species complexes (section 2.1.4).

The review of floristic data detailed in Section 3.3 identified a number of species records that could be considered for incorporation into new species complexes. Across all the swamps overall, there are some species that are consistently and repeatedly showing up only in one season, with no ecological explanation as to why this may be happening, as they are perennial, long-lived species that should be identifiable all year. Examples include:

- *Grevillea sphacelata* was recorded in Swamp 1B 31 times in Autumn, but not in Spring. When this record is considered in the raw data, all of these 31 records were from the one year (2016), and so is likely to be an identification error. It appears that previous to 2016 and subsequently this species was included in the *Grevillea patulifolia/sericea/speciosa complex*.
- *Baumea acuta* was recorded 29 times in Spring 2022, but never in Autumn at Swamp 14, with all records from 2022. Inspection of the dataset identifies that it is likely that in previous years this species was recorded as part of the *Baumea articulata/ rubiginosa/ teretifolia* sp*. Chorizandra cymbaria/ sphaerocephalum* species complex. Similarly, this appears to be the case at Swamp 15A(1), where *B. acuta* was recorded 12 times in spring and never in autumn.
- *Tetrarrhena juncea* was recorded in Swamp 15A(1) 17 times, only in Spring 2019. Inspection of the raw data identifies that these records are likely to have been grouped with *Tetrarrhena turfosa / Hemarthria uncinata complex* in all other years.

These instances are examples of where the records should be merged with the related species complexes, to ensure that ID errors or inconsistencies are not contributing to data change. There may be other examples of where it would be beneficial to merge closely related species into complexes, which would become evident as part of a review of the entire long-term dataset where perennial species that should be identifiable year round are showing up only in one season (which are sometimes also only during one round of monitoring).

As the dataset now represents 20 years of floristic data collection, a review of the species application across the entire long-term dataset would be timely. It is recommended that the 2023 iteration of the monitoring program include a review of the species list applied and consideration of species complexes and refinements to species application across the entire long-term dataset.

3.5 LiDAR mapping trends in 2022

In 2022, a decrease in swamp extent and swamp community extent has been recorded across all swamps, in comparison to that recorded in 2021. Occurring at both the Impact and Control Groups. This finding was unexpected, due to the above average rainfall recorded in recent years. Under the conceptual monitoring approach, ‘wet’ conditions should favour upland swamp sub-communities.

Niche has undertaken a review and analysis of the LiDAR sensor utilised in data capture, swamp mapping workflow, application of different mapping software and has ruled out any technological feature as contributing to this uniform decrease.

The raw mapping outputs were then reviewed to identify areas of reduction in upland swamp sub-communities between 2021 and 2022 to explore this trend. The review identified that the decrease in upland swamp sub-communities primarily occurred around the margins of the upland swamps, particularly in areas with fringing eucalypt woodland occurring within the swamp margins (Plate 2, Plate 3). Occurring at both the Impact and Control Groups. It is suggested that this trend is driven by expansion of the fringing eucalypt woodland canopy (as the model is canopy-height driven), rather than a direct loss of upland swamp sub-community vegetation.

It is suggested that this expansion of the fringing eucalypt woodland has been driven by the above average rainfall conditions, in the years following the extended drought promoting growth (2017-2019). This is not to say that the conceptual monitoring approach is incorrect (i.e. reduced upland swamp sub-community extents indicate drying conditions). Rather that the conditions that have occurred under the timescale being considered have driven changes in other ecological processes (expansion of the fringing eucalypt canopy) that have manifested as decreased swamp sub-community extents, in part a result of the canopy height driven nature of the monitoring approach.

This trend should be considered in detail in subsequent monitoring reports to understand if this is part of an ongoing trend and the ecological consequences for upland swamp sub-community extents.

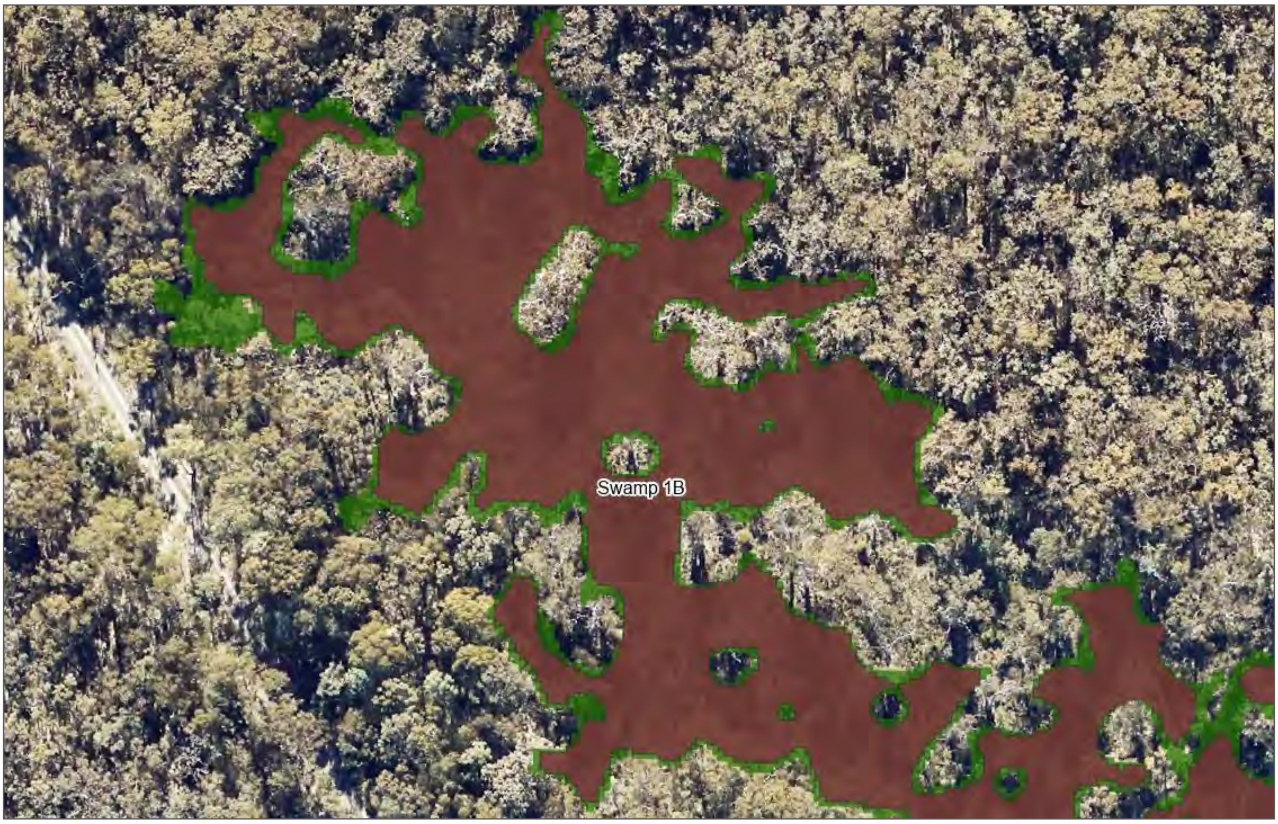


Plate 2: Comparison of upland swamp sub-community extents between 2021 (green), overlayed with 2022 (red) at Impact Swamp 1B

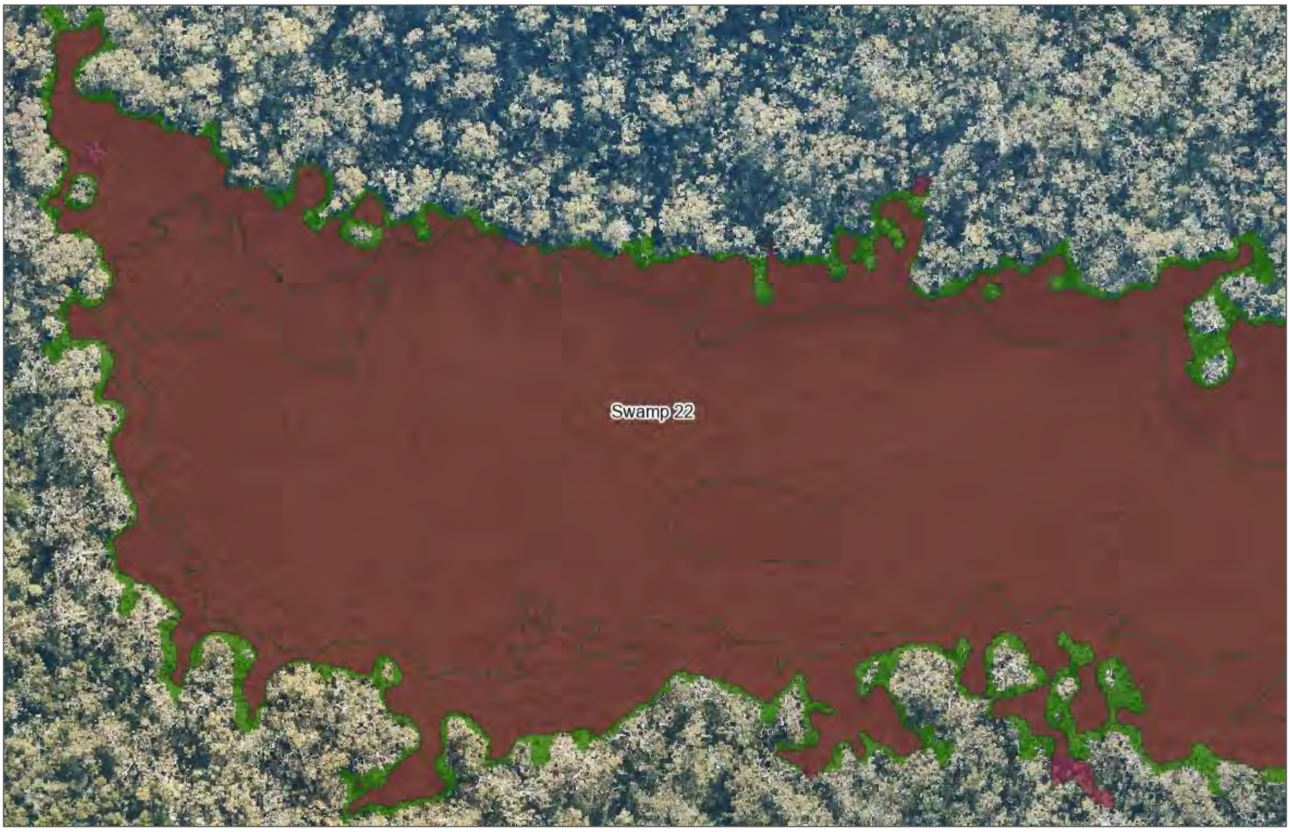


Plate 3: Comparison of upland swamp sub-community extents between 2021 (green), overlayed with 2022 (red) at Control Swamp 22

3.6 LiDAR analysis processing

Niche have undertaken preliminary investigation into potential additional data products that could be derived from LiDAR data to enhance the analysis workflow.

Niche (2022a) recommended consideration of developing a multi-criteria analysis workflow to augment the canopy-height model LiDAR analysis. Including consideration of incorporating moisture index and canopy density values. Specifically, to determine if the analysis could include a measure of 'vegetation health' and soil moisture to provide a more sensitive assessment of areas of potential dieback so that this indicator of potential impact can be considered in more detail and facilitate monitoring approaches e.g. installation of soil moisture probes in identified areas of drying.

A trial of the new model has been completed using data captured for Swamp 106 by IMC using UAVs in 2022. The new model allows multiple criteria analysis through overlay of canopy height and canopy density LiDAR derived products matched with Normalized Difference Vegetation Index (NDVI) index values acquired by IMC's new fleet of UAVs to better inform ecosystem functionality of the swamps. NDVI analysis of 5 band imagery returns moisture index values between –1 and 1, where no vegetation occurs at 0 values and values close to 1 represent the highest health values.

The trial identified that the NDVI data may be used to provide a determination of 'vegetation health', identifying areas of 'healthy vegetation' and 'vegetation trending toward unhealthy'. Further development would be required to understand how the relative health continuum may apply to different swamp sub-communities.

The canopy density analysis previously identified as an avenue of investigation as part of a multi-criteria analysis assessment method has become mute with the application of the NDVI assessment method. As where there is bare earth, the vegetation health assessment returns low values anyway.

This approach may also assist with sub-community boundary delineation, increasing efficiency in completion of the manual verification of the data and generate greater value from the data that IMC collects as it relates to usage and project outcomes.

It is recommended that the further development and integration of the NDVI assessment into the existing LiDAR analysis workflow for the monitoring swamps is considered.

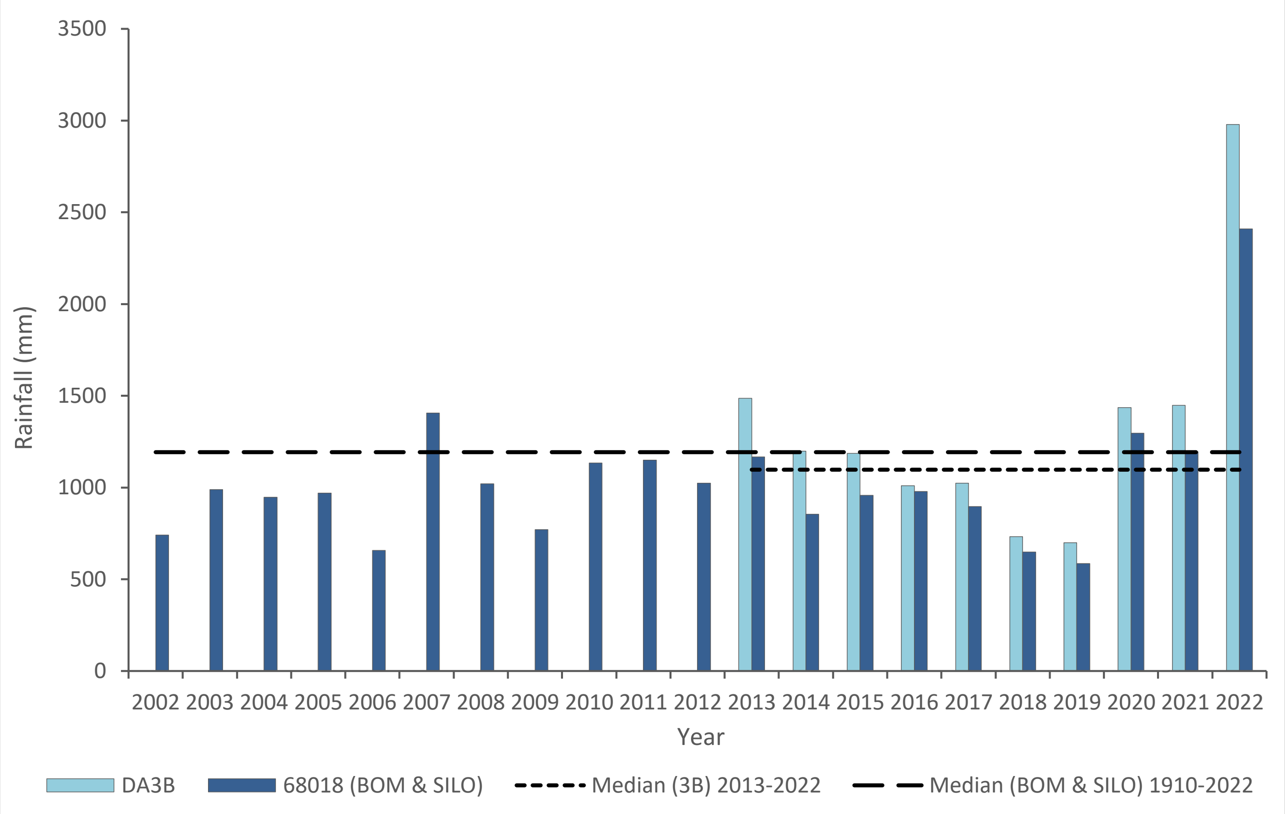
4. Results

The statistical analysis of Upland Swamps and Littlejohn's Tree Frog, raw threatened frog data and photo point monitoring are provided in Annexes 1 to 5. An overview and assessment of these results is provided in the following sections.

4.1 Rainfall

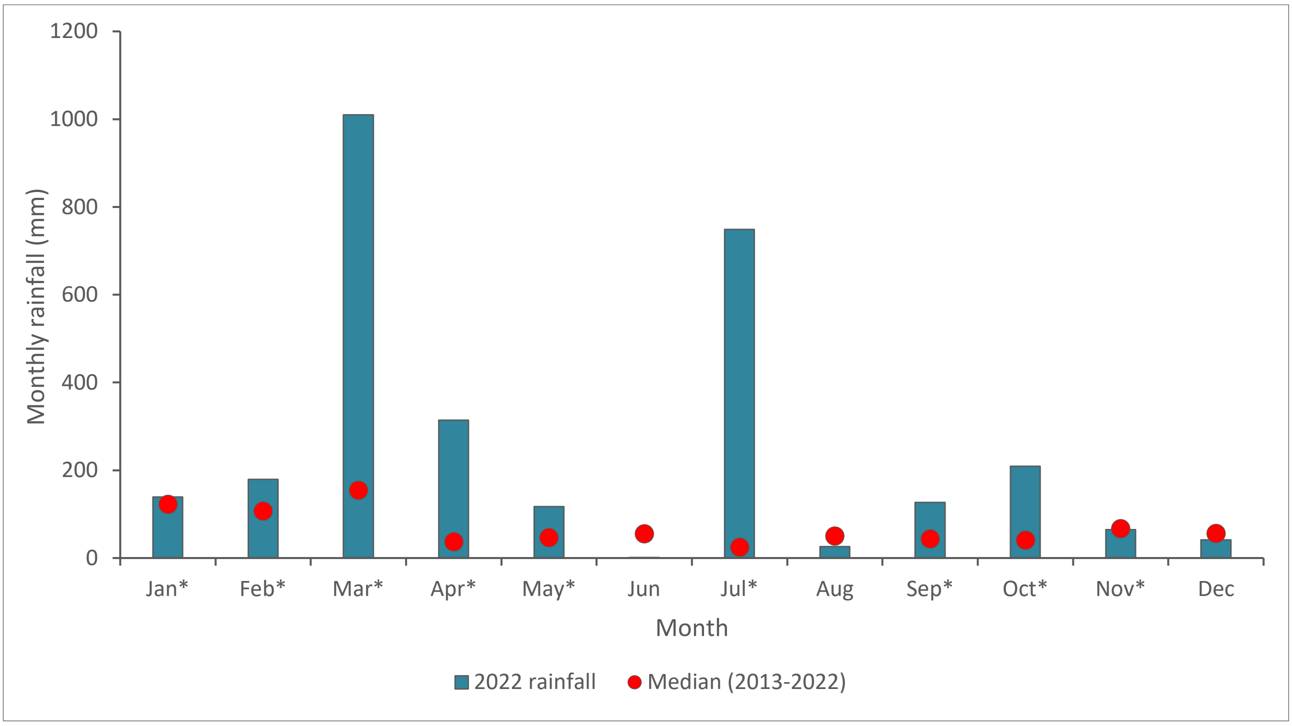
Rainfall is an important factor influencing change in Upland Swamps and creek habitat conditions. A visual analysis of rainfall data is useful when examining trends or changes to Upland Swamp or creek habitats at the catchment scale.

Available rainfall data recorded at the IMC DA3B rainfall gauge and BOM station 68018 is presented in Graph 3, showing annual rainfall recorded over the 20 years of the ecological monitoring program (2002 – 2022). Total annual rainfall during the 2022 iteration of the monitoring program (IMC DA3B: 2979 mm) was the highest level recorded at the IMC DA3B rainfall gauge and station 68018. This level of rainfall was not only significantly above average for the Program, but also above the long-term average recorded at station 68018 (1910 – 2002). Above average rainfall was also recorded in 2020 and 2021. This trend of above average rainfall marks a departure from the extended period of below average rainfall that occurred between 2016 and 2019, with the extended drought conditions being particularly acute in 2018 and 2019.



Graph 3: Annual rainfall data from 2002 to 2022 (IMC DA3B rainfall gauge and BOM station 68018)

The majority of rainfall in 2022 fell during the months of March and July (Graph 4), significantly exceeding the median rainfall values for these months. It is notable that July has typically been one of the lower rainfall months during the Program. Overall, median monthly rainfall levels were exceeded in eight of the twelve months in 2022. These results demonstrate prevailing wet conditions throughout the year, which were most intense during the autumn and winter survey seasons.



** denotes month wholly or partially effected by catchment closures*

Graph 4: Total monthly rainfall data recorded at IMC DA3B rainfall gauge during 2022

The swamp floristic monitoring data and frog monitoring data should be considered in the context of these results.

4.2 Hydrological review

Impacts to upland swamp communities may occur through a reduction in water level or an increased rate of drainage following subsidence. IMC have piezometers placed within the Upland Swamps as part of groundwater monitoring to monitor these pathways of potential impact.

Niche (2022) summarised information and expert assessment from IMCs consultants, which have undertaken a geographical review of mining effects on upland swamps associated with the mine (Watershed HydroGeo 2019, Watershed HydroGeo 2021). This expert assessment (Watershed HydroGeo 2019) and associated updated assessment (Watershed HydroGeo 2021) has informed the interpretation of the ecological upland swamp data detailed in this report. The major findings of the (Watershed HydroGeo 2019) report relevant to the Program are summarised below:

- The majority of impacts recorded occurred where swamps were mined under by a longwall.
- Most of the effects occurred when a longwall passed directly beneath or within 60 metres of the site.
- The maximum recorded distance at which a piezometer within a swamp recorded a response was 55 metres.
- Two piezometers that are lithologically similar detected effects at 95 and 125 metres from a longwall, however these were not located within swamps, and the majority of piezometers within that distance range did not record any effects.

- While the majority of upland swamp piezometers within 60 metres of a longwall showed a response to mining, conversely the effects of mining have not been detected in upland swamp piezometers that are greater than 60 metres from a longwall.

In summary, the associated updated assessment (Watershed HydroGeo 2021) found that swamp piezometers within 60 m of longwall secondary extraction are likely to exhibit a mining effect and almost certain to exhibit a mining effect when directly mined beneath, be that through a reduction in the water table to below pre-mining levels and/or increased recession (drainage) rate. Effects on swamp water tables were not reported (i.e. effects were considered nil or negligible) at distances greater than 60 m from a longwall panel (Watershed 2021).

Potential impacts to upland swamp communities identified or anticipated on the basis of hydrological information provided are summarised below for Dendrobium Area 3A and Dendrobium Area 3B in Table 15. In 2022 all impact swamps, with the exception of 15A(1) and 15A(2), have been mined beneath. Mining first occurred within 60 metres of Swamp 15A(1) and Swamp 15A(2) in June 2022, subsequent to the hydrological reviews. On the basis of the findings of these reviews, hydrological impacts have occurred, or are expected at all Impact swamps included in the Program.

Table 15: Impact treatment swamp hydrological impacts

Swamp	Distance from longwalls (2022)	Impact shown in any swamp piezometer (Watershed HydroGeo 2019, 2021)	Mining within RMZ	Mined beneath
1A	Directly mined under	Yes	February 2013	April 2013
1B	Directly mined under	Yes	February 2013	February 2013
5	Directly mined under	Yes	May 2013	July 2013
11	Directly mined under	Yes	May 2016	March 2017
13	Directly mined under	Yes	July 2017	November 2018
14	Directly mined under	Yes	December 2018	November 2019
15A(1)	55 m from longwall	Not available	June 2022	-
15A(2)	10 m from longwall	Yes	October 2012	-
15B	Directly mined under	Yes	September 2010	August 2012
23	Directly mined under	Not available	June 2018	June 2019

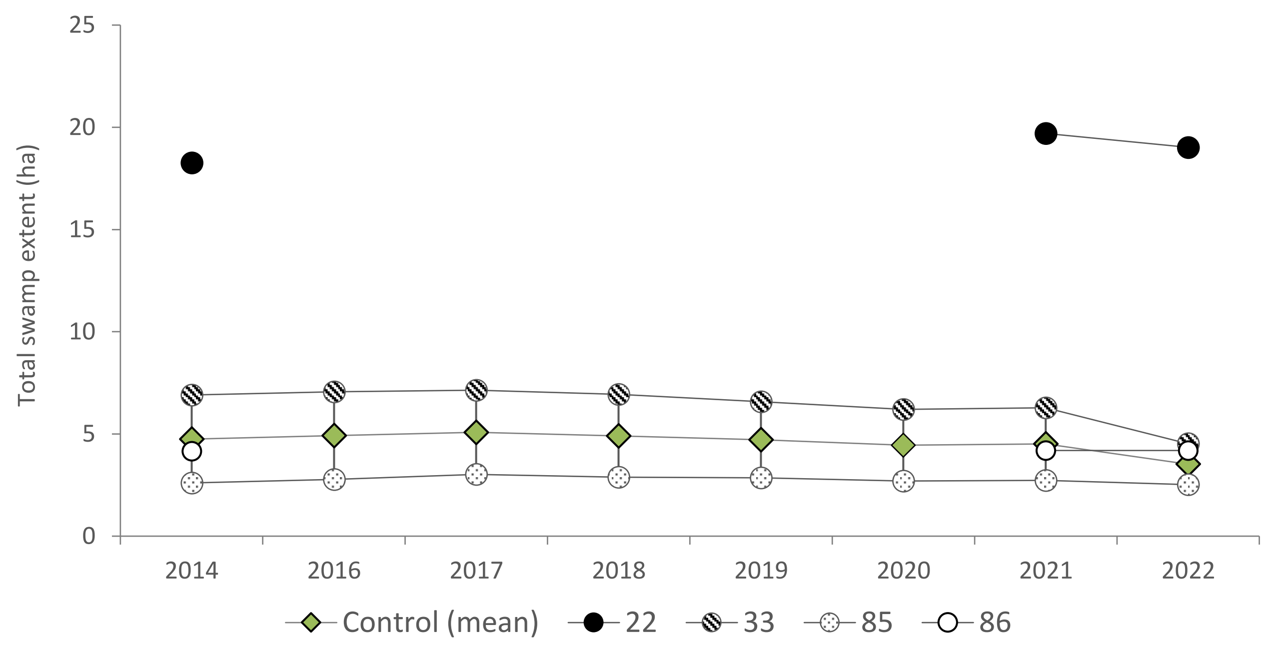
4.3 LiDAR mapping of upland swamp extents

The raw LiDAR monitoring results are presented in Annex 2. Trends across the upland swamps monitored during the entire monitoring period are graphically presented in following sections. Niche (2022a) discussed trends across the entire monitoring period following a review and updates to the LiDAR monitoring approach. This report focusses on change detected between 2021 to 2022 to provide an assessment against the relevant TARPs, provided in Section 5.

4.3.1 Total swamp extent

4.3.1.1 Control Group

The extent of each Control swamp is shown to fluctuate to some extent year on year (Graph 5), although the level of change is typically less than 0.5 hectares over each year, with the swamps extents at each site being overall relatively stable between 2014 and 2021. In 2022, all control swamps decreased in extent, except Swamp 86 which remained stable. Swamps 22 and 33 exhibited a greater degree of decreasing extent (-0.68 hectares and -1.76 hectares respectively) in 2022. The mean of the control sites plotted below reflects the broad trends of the individual control swamps, with a small decline evident between 2017 and 2020, following reduced rainfall in this period, before stabilising or increasing slightly in 2021, then declining again in 2022.

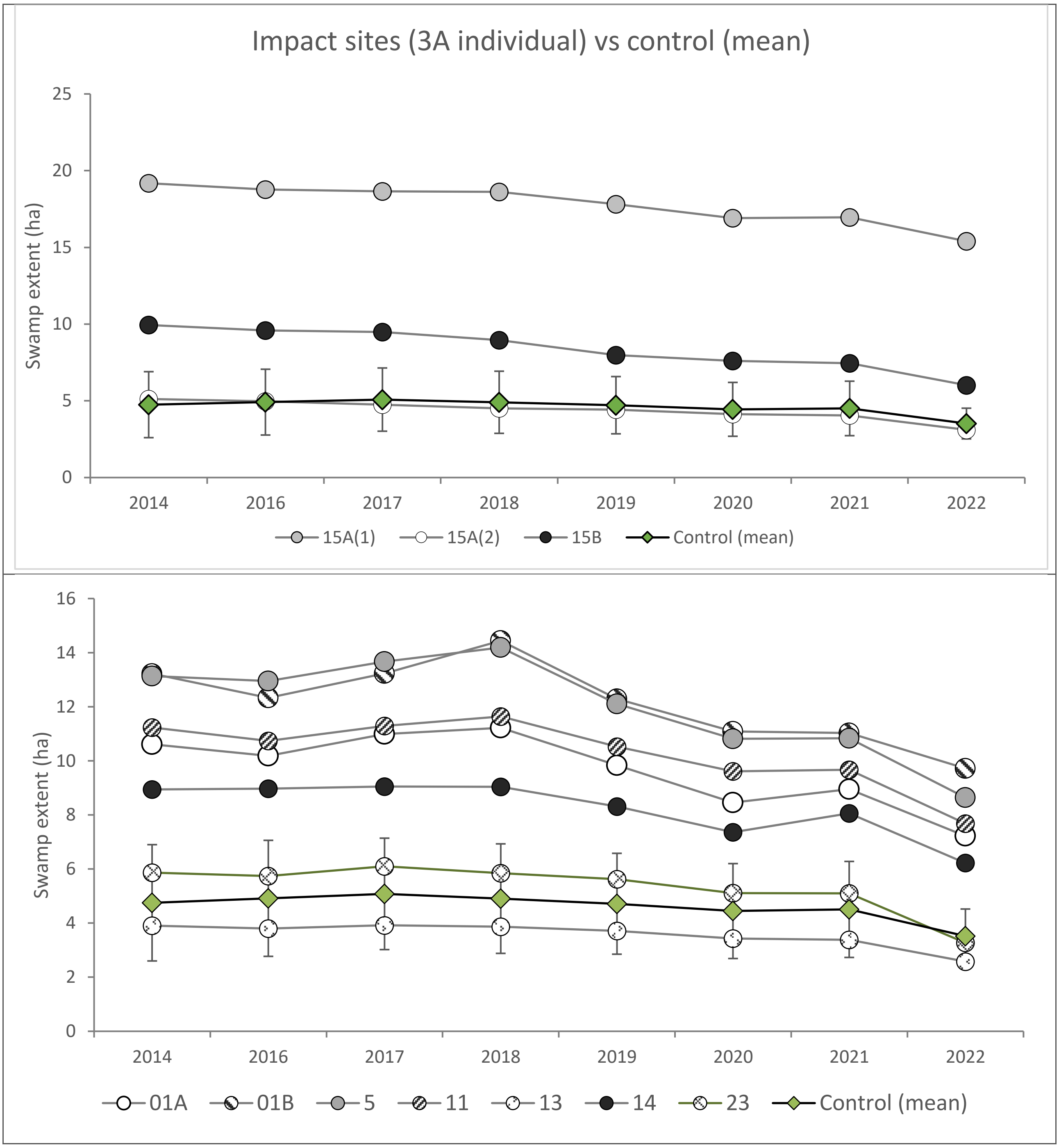


Data for swamps 22 and 86 is only available for 2014, 2021 and 2022, as such these sites are excluded from the Control Group mean to avoid skewing the data between years when there is data and years when there is no data for these sites.

Graph 5: Total swamp extent at Control Swamps from 2014 to 2022

4.3.1.2 Impact Group

Graph 6 displays the change in swamp extent across each of the individual impact swamps between 2014 and 2022 in Dendrobium Areas 3A and 3B. The majority of the impact swamps follow a similar trend to that of the control sites described above, although the degree of fluctuation and change year on year is typically greater than that observed at the Control Group so that a similar but more exaggerated pattern of change is observed at the impact sites. Including the decrease in swamp extent during 2022 observed at the Control Group. In addition, many of the impact sites record an increasing extent between 2016 and 2018, with the Control Group peaking in 2017. Swamps 15A(2) and 15B in Area 3A show a different trend, with a consistent decline over the 2014 to 2022 period. Between 2021 and 2022, all Impact swamps, and the Control Group, decreased in extent.



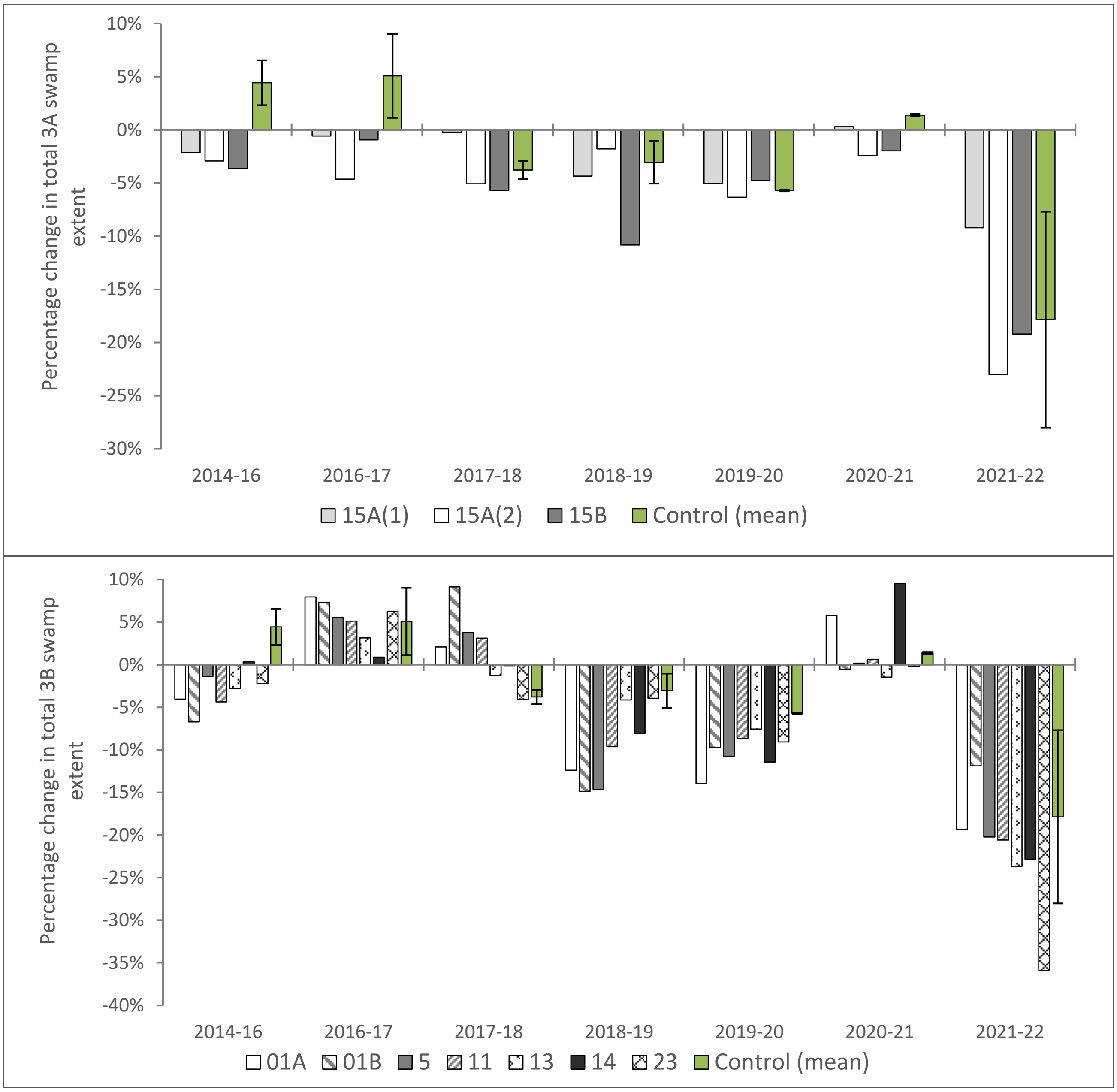
Graph 6: Total swamp extent at impact swamps from 2014 to 2022, impact swamps in Dendrobium Area 3A are shown above and Dendrobium Area 3B below

4.3.1.3 Percentage change in total swamp extent: 2021–- 2022

In 2022 in Dendrobium Area 3A, Impact swamps 15A(2) and 15B have recorded declines in swamp extent for each consecutive period (Graph 7). Swamp 15A (1), which changed status from Control to Impact swamp in 2022, has experienced declines in swamp extent in each consecutive period, except 2020 to

2021. However, the declines in the Impact swamps in Dendrobium Area 3A in 2021 to 2022 did not exceed that also identified at the Control Group (including the standard error of the group).

In Dendrobium Area 3B, changes in swamp extents over the entire monitoring period have been more variable. Between 2021 to 2022, all Impact swamps were observed to decrease in total extent (Graph 7). Swamp 23 was identified as declining in total swamp extent at a level that exceeded that of the Control Group (including the standard error of the group), while all other swamps were within this level. This is discussed further in Section 5 (assessment against performance measures).



Graph 7: Percentage change in total swamp extent at impact swamps, comparing consecutive years, impact swamps in Dendrobium Area 3A are shown above and Dendrobium Area 3B below.

4.3.1.4 Performance measure summary

A summary of the TARP levels over time are provided in Table 16, these are discussed in Section 5.

Table 16: Swamp extent TARP summary

Swamp name	2014-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
Swamp 11							
Swamp 13						2019-2020, 2020-2021	
Swamp 14					2018-2019, 2019-2020		
Swamp 1A							
Swamp 1B					2018-2019, 2019-2020	2018-2019, 2019-2020, 2020-2021	
Swamp 5							
Swamp 23						2019-2020, 2020-2021	2019-2020, 2020-2021, 2021-2022

Note: Level 1 = orange, Level 2 = red, Level 3 = purple. Consecutive periods of decline beyond that experienced at the Control Group and standard error of the group are provided. TARP levels pre-2022 are those presented in Niche (2022a).

4.3.2 Ecosystem functionality

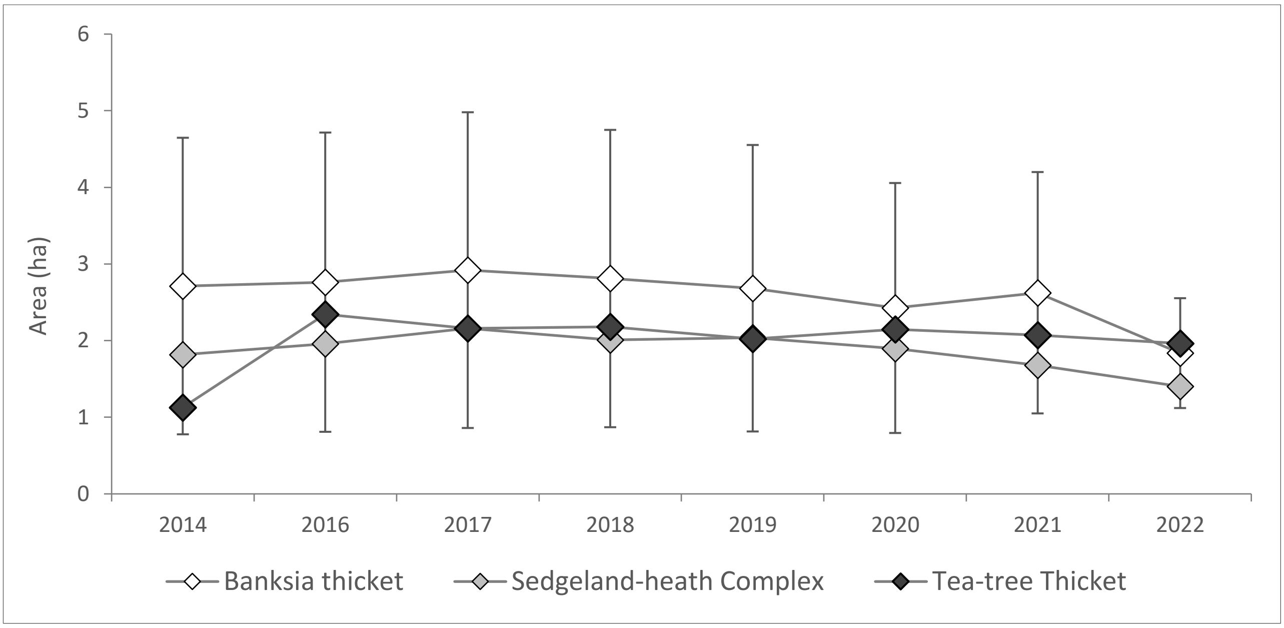
Upland Swamps within the Study Area are primarily comprised of three vegetation sub-communities:

- Upland Swamps: Banksia Thicket (MU42)
- Upland Swamp: Tea-Tree Thicket (MU43)
- Upland Swamp: Sedgeland-heath Complex (MU44) (Cyperoid Heath, Restioid Heath, Sedgeland).

In line with the TARPs, ecosystem functionality of the swamps is to be measured via the sizes of the groundwater dependent communities. Specifically, any changes in the proportion of Banksia Thicket, Tea-Tree Thicket and Sedgeland-heath Complex within the monitored swamps.

4.3.2.1 Control Group

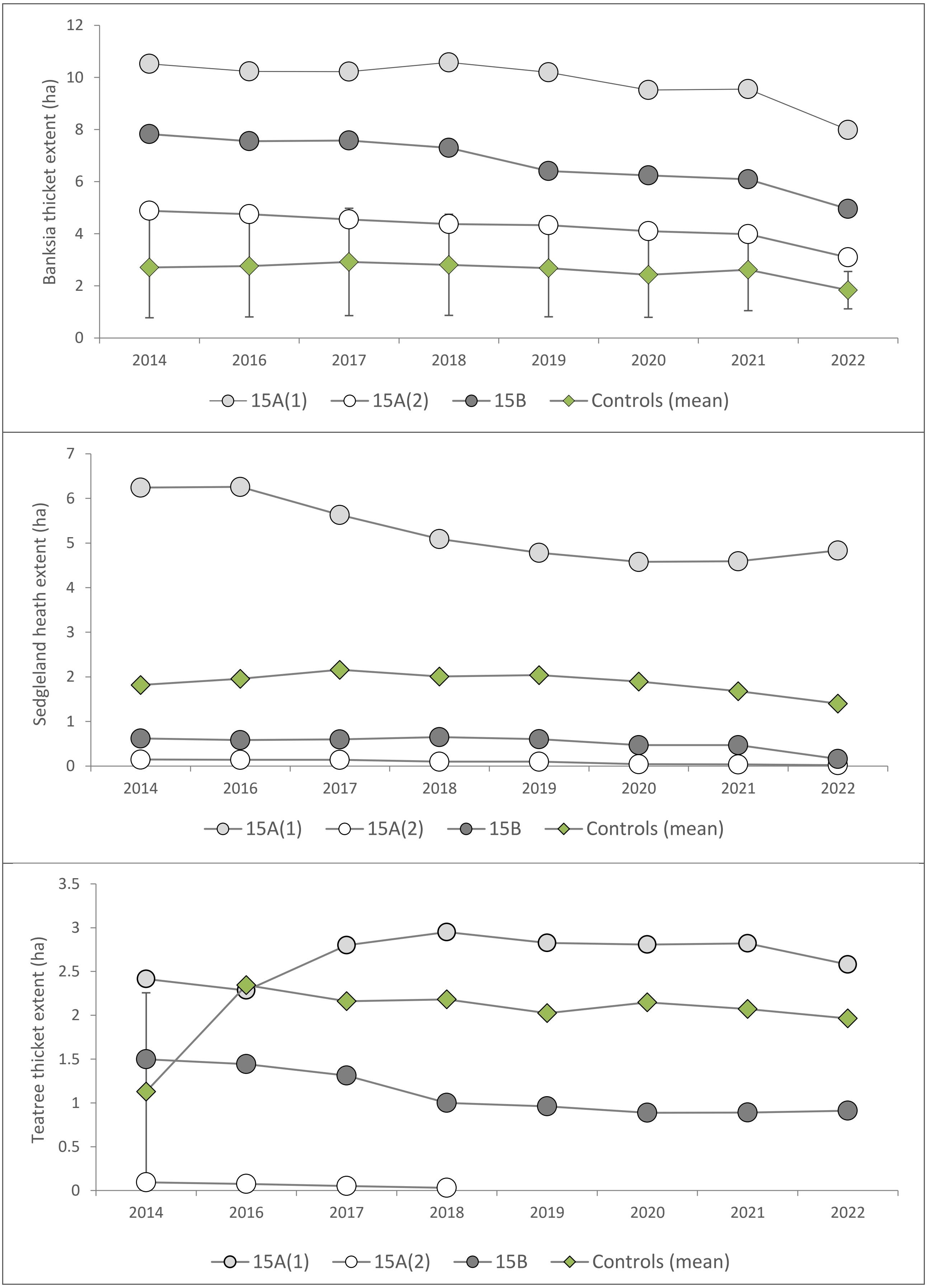
The average sub-community extent of the Control Group swamps are presented in Graph 8. Prior to 2022, Banksia Thicket recorded the greatest average proportional extent across the control swamps, this dipped below Tea-Tree Thicket in 2022. Both the Sedgeland-heath Complex and Tea-Tree Thicket sub-communities show differing patterns of change to each other and also to the Banksia Thicket sub-community over the entire monitoring period. There has been a consistent trending decline in average Sedgeland-heath Complex extent since 2019, which continued in 2022. A slight trending decline has also occurred in the Tea-Tree Thicket sub-community since 2020, which continued in 2022.



Graph 8: Average sub-community extents from the Control Group between 2014 and 2022

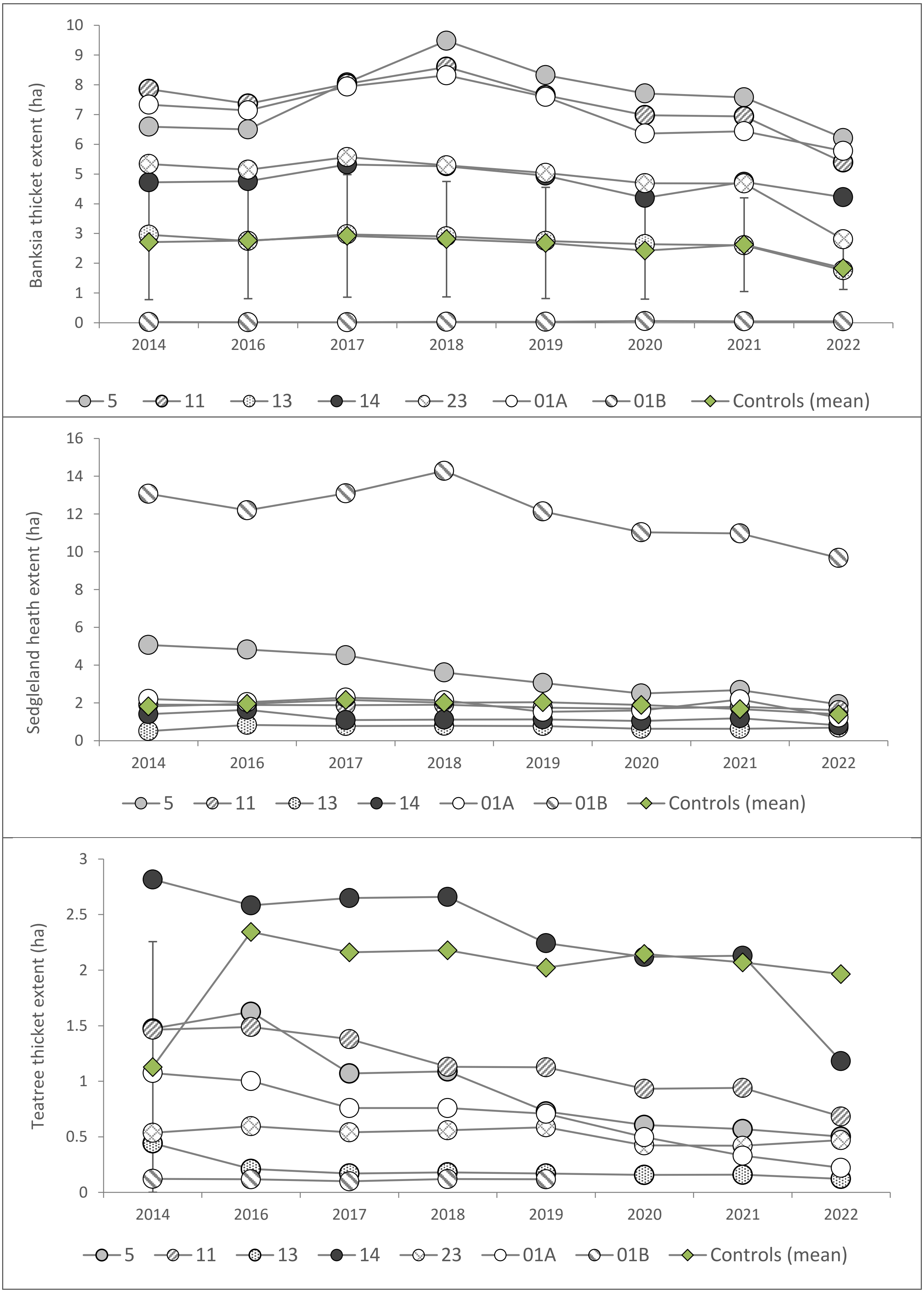
4.3.2.2 Impact Group

Dendrobium Area 3A swamps 15A(2) and 15B have recorded overall trending declines across each of the sub-communities between 2014 and 2022 (Graph 9), with swamp 15A recording an increase in Sedgeland heath extent in 2022 (although this remains part of an overall decline when compared to baseline). Tea-Tree Thicket is observed to decline in extent to the point that it is no longer represented at Swamp 15A(2) in 2018. It is important to note that this does not necessarily mean a wholescale change in the sub-community composition has occurred. It likely indicates that the vegetation in these areas is now dominated by taller growing species or individuals that have reached a height that better correspond with the Banksia Thicket definitions in the canopy height model applied, which may indicate a transition in vegetation community. In general terms, the pattern of change in sub-community extents are similar to that observed at the Control Group between 2021 and 2022.



Graph 9: Sub-community change in Dendrobium Area 3A impact swamps between 2014 and 2022, Banksia Thicket top, Sedgeland-heath Complex middle and Tea-Tree Thicket bottom

In Dendrobium Area 3B, the trajectories of change in the sub-communities in recent years have typically been similar to that of the Control Group (Graph 10), albeit with a greater degree of variability. This trend continuous into the 2021 and 2022 period, although the decline in Banksia Thicket at Swamp 23 and Tea-Tree Thicket at Swamp 14 are observed to be more acute when compared to the other swamps (Graph 10).

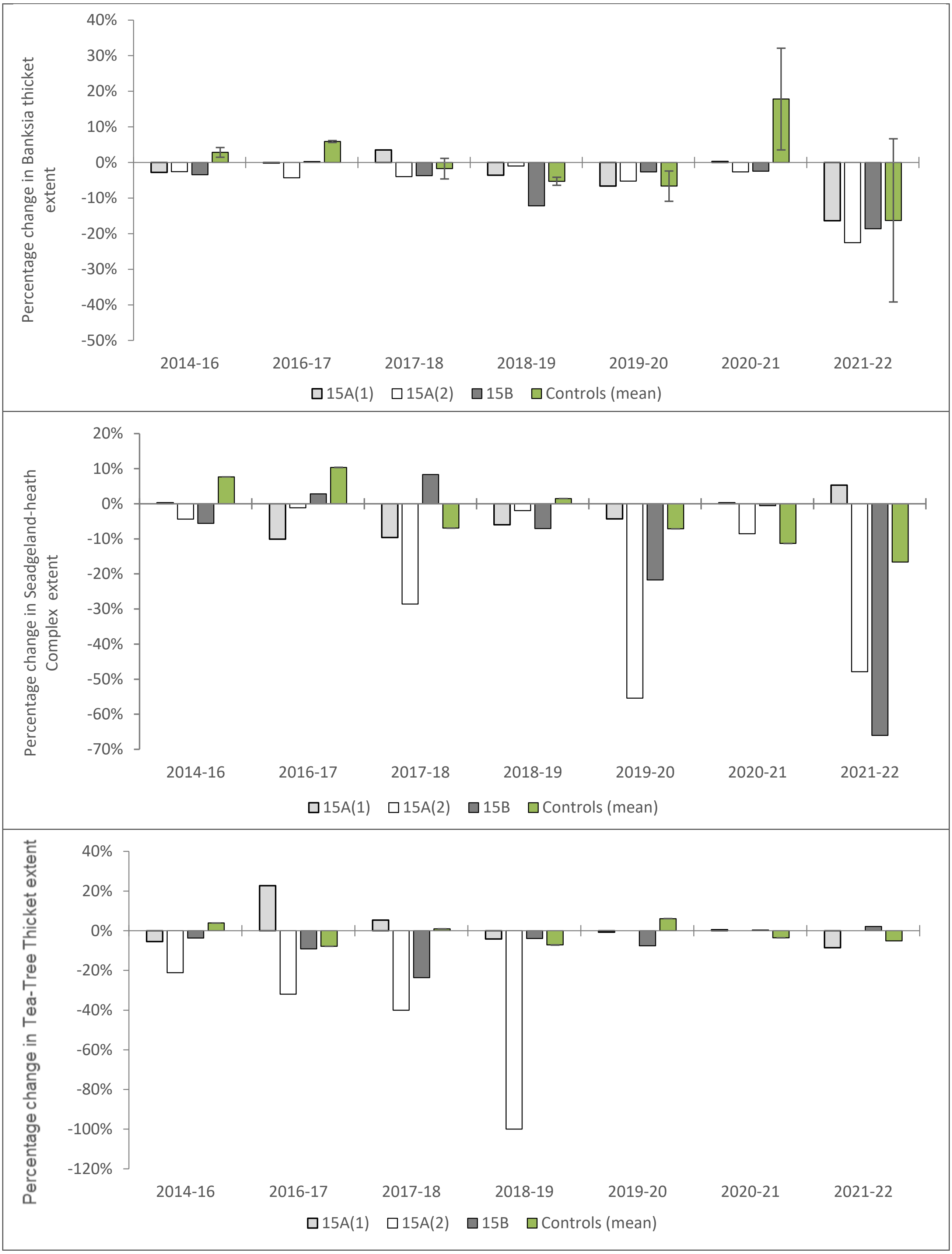


Graph 10: Sub-community change in the Dendrobium Area 3B impact swamps between 2014 and 2022, Banksia Thicket top, Sedgeland-heath Complex middle and Tea-Tree Thicket bottom

4.3.2.3 Percentage change in sub-community extent: 2021–- 2022

Graph 11 displays comparisons of the change in sub-community extents over consecutive years in Dendrobium Area 3A. In the 2021 to 2022 period:

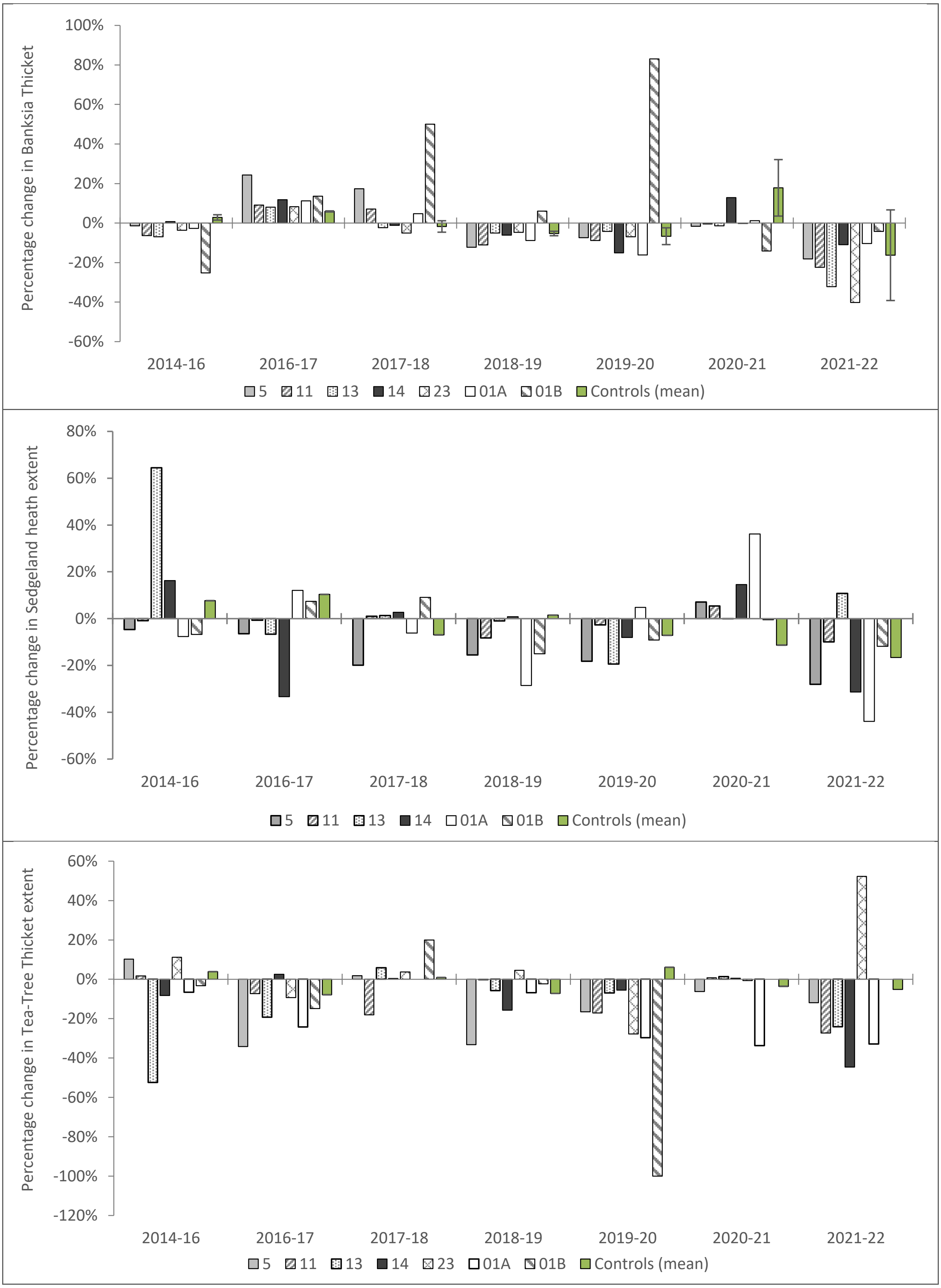
- All Impact swamps were within the percentage change of Banksia Thicket observed at the Control Group.
- Swamps 15A(2) and 15B showed a percentage decline in Sedgeland Heath greater than that observed at the Control Group, with an increase observed at Swamp 15A(1).
- Swamp 15A(1) showed a percentage decrease in Tea-Tree Thicket beyond that of the Control Swamp 33.



Graph 11: Sub-community change in the Dendrobium Area 3A impact swamps between 2014 and 2022 comparing consecutive years with Banksia Thicket top, Sedgeland-heath Complex middle and Tea-Tree Thicket bottom

Graph 12 displays comparisons of the change in sub-community extents over consecutive years in Dendrobium Area 3B. In the 2021 to 2022 period:

- All Impact swamps showed a decline in Banksia Thicket, however this was within the level of change observed at the Control Group, except Swamp 23 which was beyond this level.
- Swamps 5, 14 and 01A showed a percentage decline in Sedgeland Heath greater than that observed at the Control Group, with an increase observed at Swamp 13.
- All Impact swamps showed a decline in Tea-Tree Thicket beyond that of the Control Swamp 33. The exception being Swamp 23, which showed an increase in this period.



Graph 12: Sub-community change in the Dendrobium Area 3B impact swamps between 2014 and 2022 comparing consecutive years with Banksia Thicket top, Sedgeland-heath Complex middle and Tea-Tree Thicket bottom

4.3.2.4 Performance measure summary

A summary of the TARP levels over time are provided in Table 17, these are discussed in Section 5.

Table 17: Swamp sub-community TARP summary

Swamp name	2014-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-2022
Swamp 11							
Swamp 13		TT: 2014-16, 2016-17.					
Swamp 14					TT: 2018-19, 2019-20.		
Swamp 1A		TT: 2014-16, 2016-17.			BT: 2018-19, 2019-20.	TT: 2019-2020, 2020-21.	TT: 2019-20, 2020-21, 2021-22.
Swamp 1B					SH: 2018-19, 2019-20	TT: 2019-20, 2021-21 (no longer recorded).	
Swamp 5				SH: 2017-18, 2018-19.	SH: 2017-18, 18-19, 2019-20. TT: 2018-19, 2019-20.	TT: 2018-19, 2019-20, 2020-21.	TT: 2018-19, 2019-20, 2020-21, 2021-22.
Swamp 23							BT: 2020-21, 2021-22.

Note: Level 1 = orange, Level 2 = red, Level 3 = purple. Consecutive periods of decline beyond that experienced at the Control Group and standard error of the group are provided. TARP levels pre-2022 are those presented in Niche (2022a).

4.4 Upland Swamps

The analysis of TSR and composition data of the Impact Upland Swamps is detailed in this section, with reference to TARPs. Initially an overview of Dendrobium Area 3 data is provided, followed by assessment against TARPs for Dendrobium Areas 3A and 3B and an analysis of TSR and composition trends at each swamp.

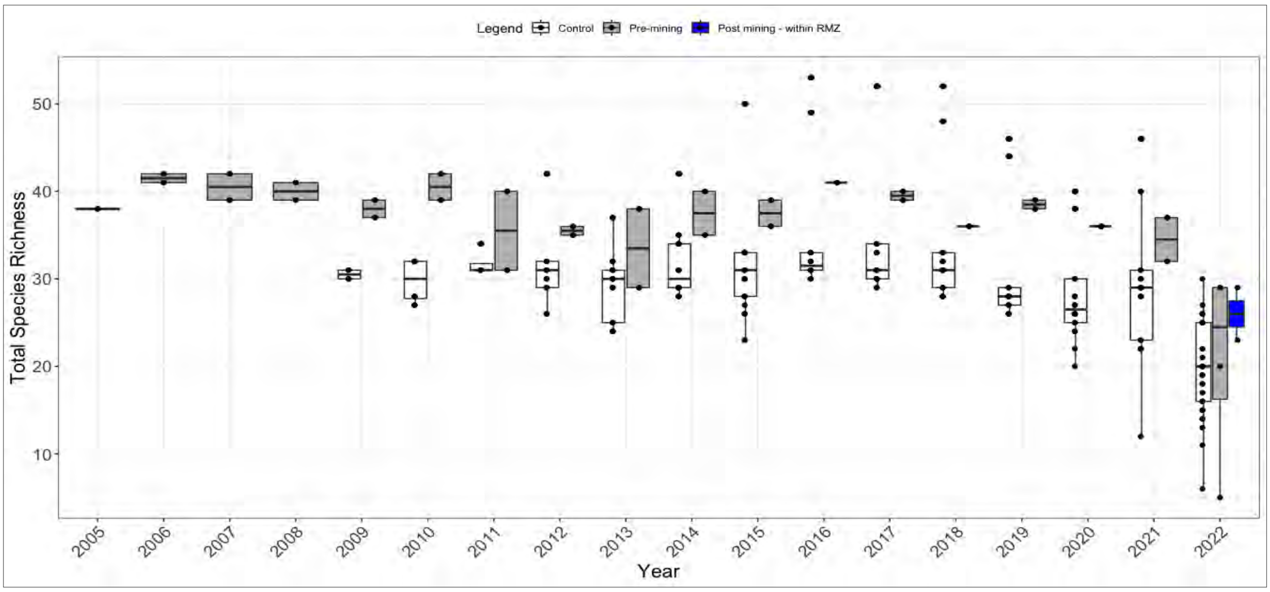
4.4.1 Dendrobium Area 3A

4.4.1.1 Swamp 15A(1)

Monitoring at Swamp 15A(1) began in 2005 and Longwall 19 entered the RMZ in 2022 (Table 1).

Since this swamp has only one year of monitoring post impact, no statistical analyses were undertaken for this swamp.

The boxplot of TSR data (Graph 13) shows that prior to impact, the TSR at the control sites were more variable (with a wider minimum and maximum TSR observation) and typically lower than TSR at the impact swamp.



The solid line within the boxes is the median (i.e., the 5⁰th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentile), and the whiskers of the boxplot cover 1.5 times the IQR of the data. Boxes shaded white are Control Upland Swamps, boxes shaded grey are Impact Upland Swamp 15A(1) that are Pre-mining, boxes shaded blue are Post-mining–-within RMZ. Solid black points are the observations (TAE 2021a). See Table 1 for mining progress, number and status of Upland Swamps at the year surveyed.

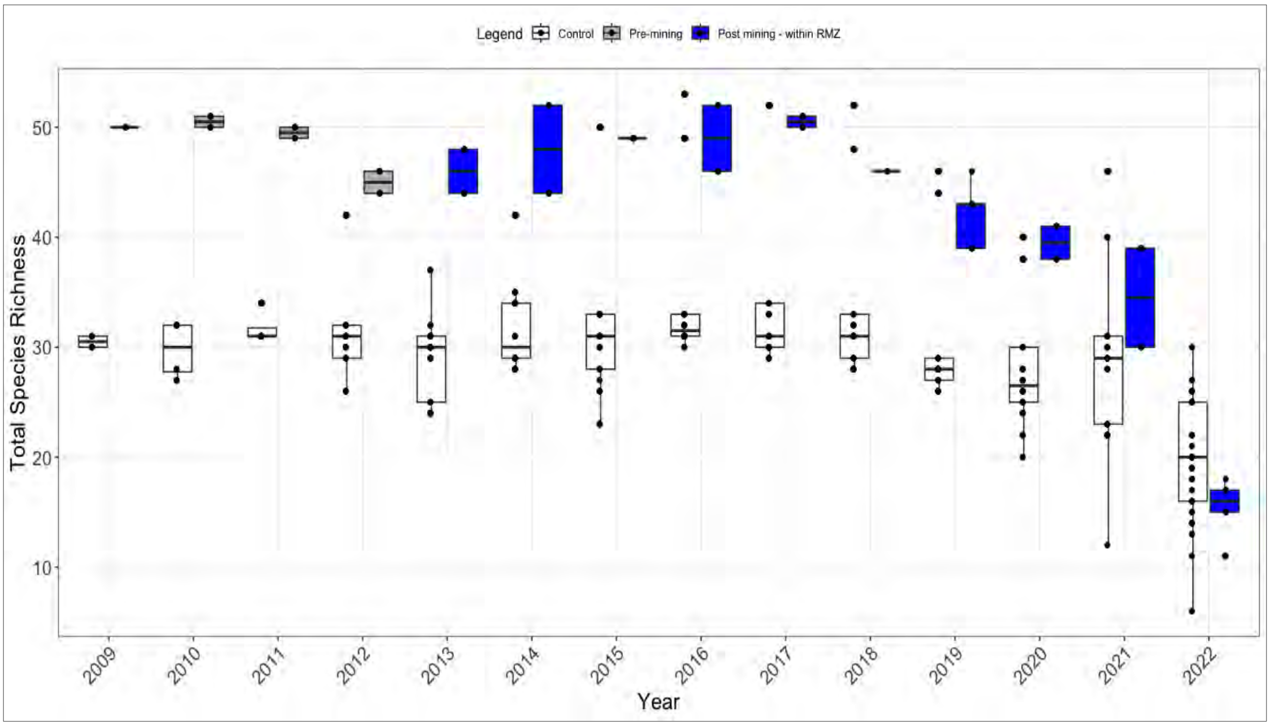
Graph 13: Boxplot of the TSR for each transect at Impact Upland Swamp 15A(1), contrasted against Control Upland Swamps

4.4.1.2 Swamp 15A(2)

Monitoring at Swamp 15A(2) began in 2009 and the swamp was impacted as Longwall 8 entered within the RMZ in 2013 (Table 1). A total of 67 unique species have been detected, of which 7% were detected only once.

4.4.1.2.1 TSR

Over the course of the monitoring period, TSR at Control sites was more variable, and generally lower, than TSR at the Impact swamp. An increase in TSR, proportionally similar to that experienced at the controls occurred post-impact (2014-2016). However since 2017, TSR at Swamp 15A(2) appears to have declined to lower levels than before impact, although a degree of decline is observed at the control sites in the 2017 to 2019 period also. In 2022, median TSR at Swamp 15A(2) is lower than that of the Control Group for the first time since monitoring began (Graph 14).



The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentile), and the whiskers of the boxplot cover 1.5 times the IQR of the data. Boxes shaded white are Control Upland Swamps, boxes shaded grey are Impact Upland Swamp 15A(2) that are Pre-mining, boxes shaded blue are Post-mining–-within RMZ. Solid black points are the observations (TAE 2021a). See Table 1 for mining progress, number and status of Upland Swamps at the year surveyed.

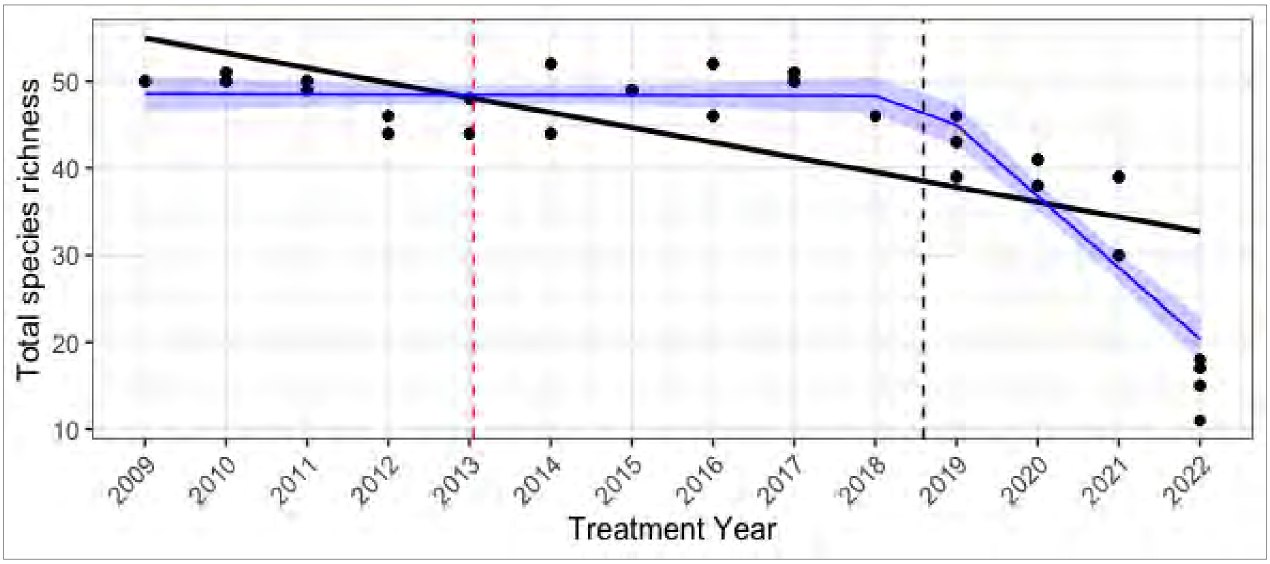
Graph 14: Boxplot of the TSR for each transect at Impact Upland Swamp 15A(2), contrasted against Control Upland Swamps

When the mean difference in TSR between Swamp 15A(2) and the control swamps are considered, TSR has declined to become more similar to the control swamps over time. A statistically significant difference between TSR at Swamp 15A(2) and the control swamps first occurred in 2018-2019 and 2019-2020 (Table 18). No statistically significant difference between TSR at Swamp 15A(2) and the control swamps was observed in the 2021-2022 period.

Table 18: Comparison of mean TSR between Swamp 15A(2) and control swamps over two-year periods

Comparison	Test statistic	D.f.	P-value
2013–2014	0.90	3.20	0.432
2014–2015	0.64	3.77	0.558
2015–2016	0.95	2.50	0.425
2016–2017	1.95	3.93	0.124
2017–2018	1.92	3.20	0.146
2018–2019	3.65	3.88	**0.023**
2019–2020	4.37	3.04	**0.022**
2020–2021	2.8	1.58	0.134
2021–2022	3.69	1.27	0.126

Additional breakpoint analysis found that the best fitting model based on AIC model selection had one breakpoint, although, model selection uncertainty was high, and the second-best fitting model is also shown. Prior to the break point in 2018 (Graph 15), no linear trend was found to be statistically significant, however after the break point, there was a significant linear decline in TSR at this swamp. This significant decline in TSR does not align with the date of impact, occurring some years post.



Best (A) and second-best (B) breakpoint analysis as determined by AIC model section (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Breakpoints indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years for visual clarity).

Graph 15: Breakpoint analysis showing best fitting models at Impact Upland Swamp 15A(2).

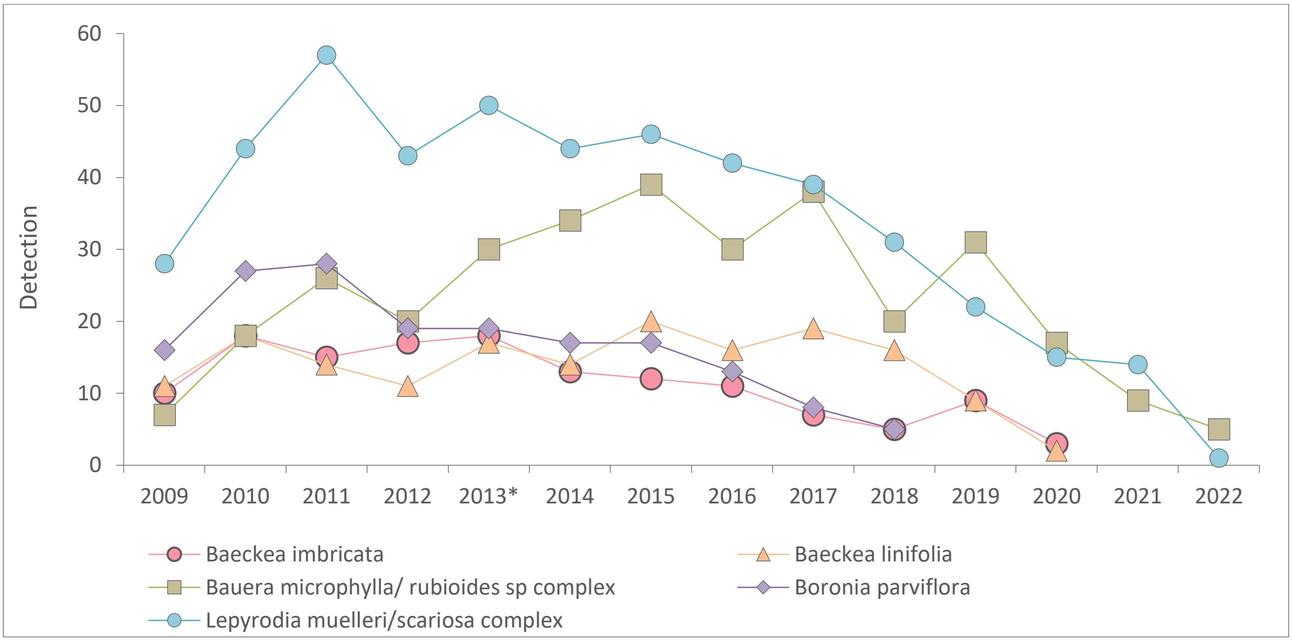
4.4.1.2.2 Species composition

Post-impact species composition data at Swamp 15A(2) was first identified as being statistically different to pre-impact data in 2018-2019 (Table 19). This continues into the latest (2021-2022) monitoring period (p-value: 0.001). The percentage of deviance relates to the five most influential species (species that have experienced the greatest level of change). In 2022 these species are *Baeckea imbricata, Boronia parviflora, Bauera microphylla rubioides* sp. complex*, Baeckea linifolia, Lepyrodia muelleri scariosa complex.* All of these species were found to be more common prior to the first date of potential impact, with three of these species no longer recorded. All of these species are known to grow in heath or damp areas.

Table 19: Species composition at Swamp 15A(2) over two-year periods

Comparison	P-value (pre-post mining)	Percentage of deviance
2013–2014	0.719	0.497
2014–2015	0.626	0.545
2015–2016	0.536	0.52
2016–2017	0.434	0.417
2017–2018	0.134	0.357
2018–2019	**0.034**	0.346
2019–2020	**0.034**	0.392
2020–2021	**0.013**	0.395
2021–2022	**0.001**	0.373

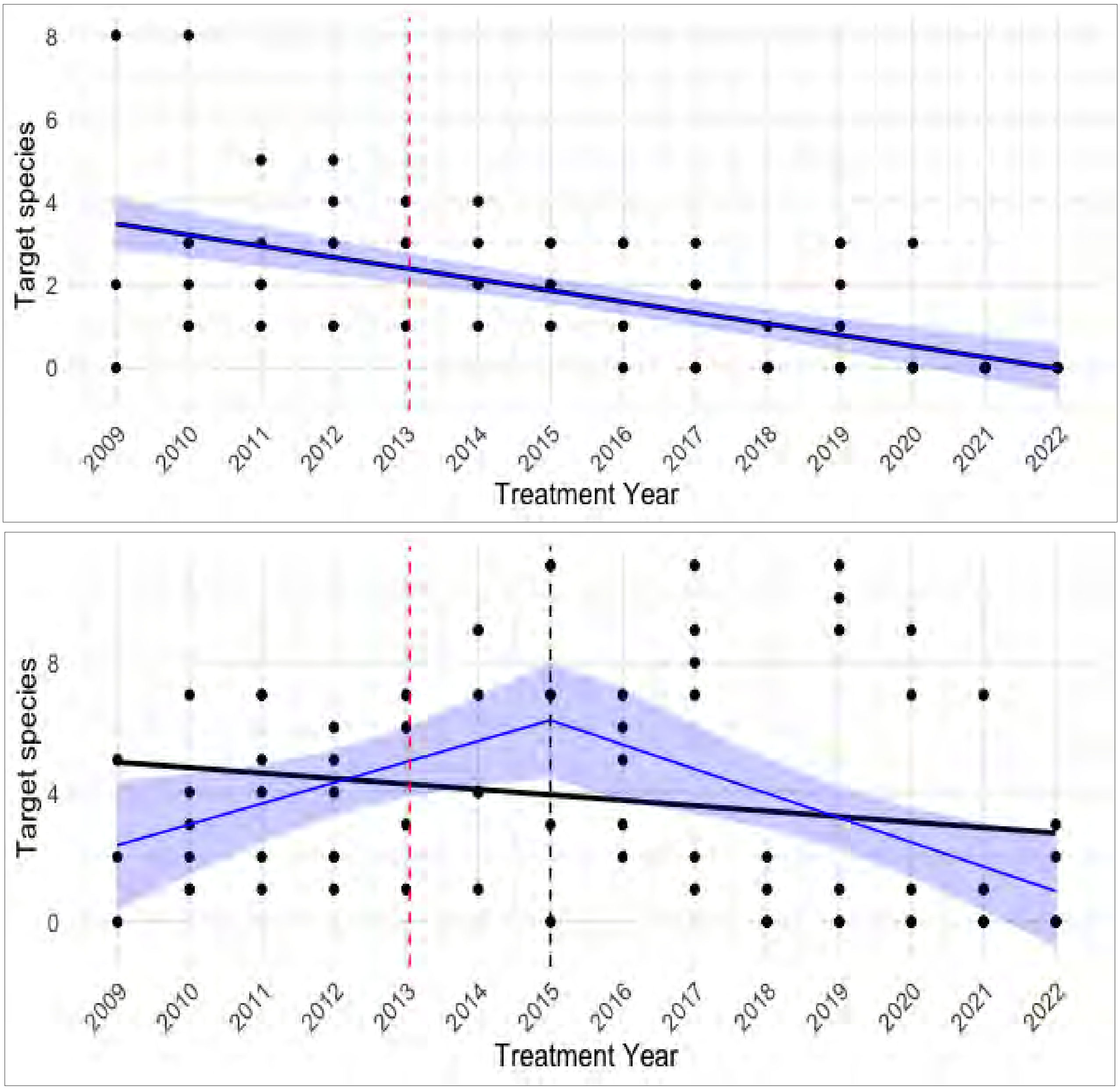
Graph 16 shows that detection of these species has been variable across the monitoring period, initially showing an increase in detection before experiencing overall declines. *Baeckea imbricata* detection is observed to decrease coincident with the date of the commencement of the mining period. Detection of *Lepyrodia muelleri scariosa complex* and *Boronia parviflora* however peaked in 2011 before declining, with this trending decline commencing pre-mining. While *Bauera microphylla rubioides* sp. complex is observed to generally increase through the commencement of the mining period before the trending decline commenced in 2017.



***** RMZ

Graph 16: Detection of five most influential species at Impact Upland Swamp 15A(2).

Target species *Baeckea imbricata* (Graph 17) was identified as a species that was more common prior to impact, compared to after impact, slowly trending to zero detection events by 2021. There has been a statistically significant decline in the number of detection events of this species since monitoring began, however the linear model was best fit to the data, indicating a trending decline pre-dating any mining activities (Graph 17). *Bauera microphylla/ rubioides* sp. complex was also identified as a species that was more common prior to impact, compared to after impact. The best fitting model suggests there is one breakpoint, whereby up to 2015 there was an increase in the number of detection events of this species, after which there has been a statistically significant decline. This breakpoint occurs approximately two-years following mining entering within the RMZ of Swamp 15A(2). While the fact that these breakpoints in these target species do not coincide with the first date of potential mining impacts does not rule out any mining impacts, it may be suggestive that factors other than mining may be primarily driving these trends.



Best break point analysis model (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Break points indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years for visual clarity).

Graph 17: Breakpoint analysis showing best fitting models for *Baeckea imbricata* (above) and *Bauera microphylla/ rubioides sp complex* (below) at Swamp 15A(2)

4.4.1.2.3 Performance measures summary

A summary of the TARP triggers identified throughout the life of the Program is provided in Table 20. Since 2014, a TSR Level 2 TARP has been triggered three times and a species composition Level 2 TARP triggered once. In 2017 a TSR Level 2 TARP was triggered. In 2019 there was a statistically significant difference in TSR, which triggered a Level 2 TARP for the second time. In 2020 there was another statistically significant difference which triggered the Level 2 TARP for a third time. This was not statistically significant in 2021 and has not triggered a continuing Level 2 TARP. A species composition TARP was first triggered in 2020 and has been triggered again in 2021 and 2022.

Table 20: TARP trigger summary (2014-2022) for Swamp 15A(2)

Years	TSR TARP	Composition TARP
2014	None	None
2015	None	None
2016	None	None
2017	**Level 2** • 2016-2017	None
2018	None	None
2019	**Level 2** • 2018-2019	None
2020	**Level 2 (two consecutive years)** • 2018-2019 • 2019-2020	**Level 2** • 2019-2020
2021	None	**Level 2 (two consecutive years)** • 2019-2020 • 2020-2021
2022	None	**Level 2 (three consecutive years)** • 2019-2020 • 2020-2021 • 2021-2022
Total times triggered	**3**	**3**

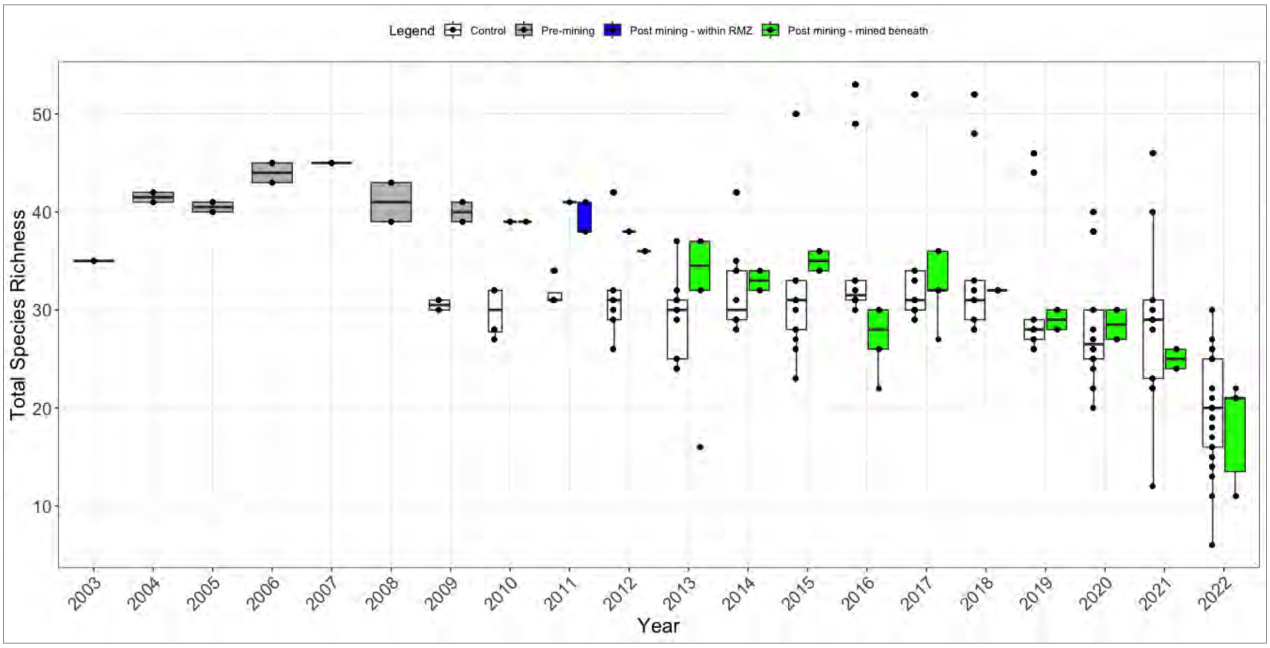
Note: TARP levels pre-2022 are those reported in Niche (2022a)

4.4.1.3 Swamp 15B

Monitoring at Swamp 15B began in 2003, and mining within the RMZ commenced in 2010, with the Upland Swamp directly mined beneath in 2012. A total of 69 unique species were detected in Swamp 15B across all monitoring periods, of which 20% were detected only once.

4.4.1.3.1 TSR

TSR recorded across the monitoring period at Swamp 15B is shown in Graph 18. TSR has been consistently more variable at the control sites than at Swamp 15B. Since impact, TSR at this swamp appears to have declined to lower levels than before impact. While year on year fluctuations in TSR at Swamp 15B are evident, there is a strong overall trend of decreasing TSR since 2017, including the post-impact period (2012-2022).



The solid line within the boxes is the median (i.e., the 5^{0t}h percentile), the margins of the box are the interquartile range (IQR, i.e., the 2^{5t}h and 7^{5t}h percentile), and the whiskers of the boxplot cover 1.5 times the IQR of the data. Boxes shaded white are Control Upland Swamps, boxes shaded grey are Impact Upland Swamps that are Pre-mining, boxes shaded blue are Post-mining–- within RMZ, and boxes shaded green are Post-mining–- mined beneath. Solid black points are the observations. See Table 1 for mining progress, number and status of Upland Swamps at the year surveyed.

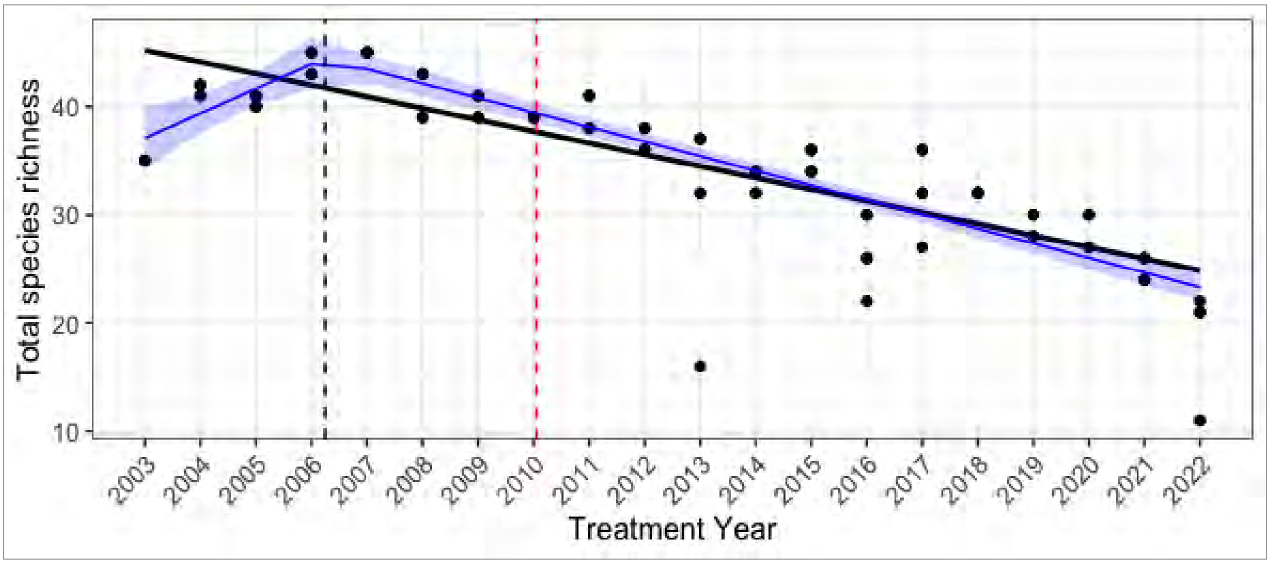
Graph 18: Boxplot of the TSR for each transect at Impact Upland Swamp 15B, contrasted against Control Upland Swamps

The TSR analysis (Table 21) shows a statistically significant difference in TSR between Swamp 15B and the control swamps in 2018-2019, but not in 2021-2022.

Table 21: Comparison of mean TSR between Swamp 15B and control swamps over two-year periods

Comparison	Test statistic	D.f.	P-value
2010–2011	-11.33	1	0.056
2011–2012	-5.68	1	0.111
2012–2013	-2.74	1	0.222
2013–2014	-2.54	1	0.239
2014–2015	-1.96	1	0.301
2015–2016	0.41	1	0.754
2016–2017	1.82	1	0.320
2017–2018	8.18	1	0.077
2018–2019	22.53	1	**0.028**
2019–2020	1.03	1	0.490
2020–2021	1.01	1	0.496
2021–2022	2.20	1	0.272

Additional analysis identified that the breakpoint in TSR data for Swamp 15B does not correspond to when the impact occurred, suggesting TSR was declining at this swamp prior to impact, and this trajectory has not changed (Graph 19).



Best breakpoint analysis model as determined by AIC model section (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Breakpoints indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years for visual clarity).

Graph 19: Breakpoint analysis showing best fitting models at Impact Upland Swamp 15B

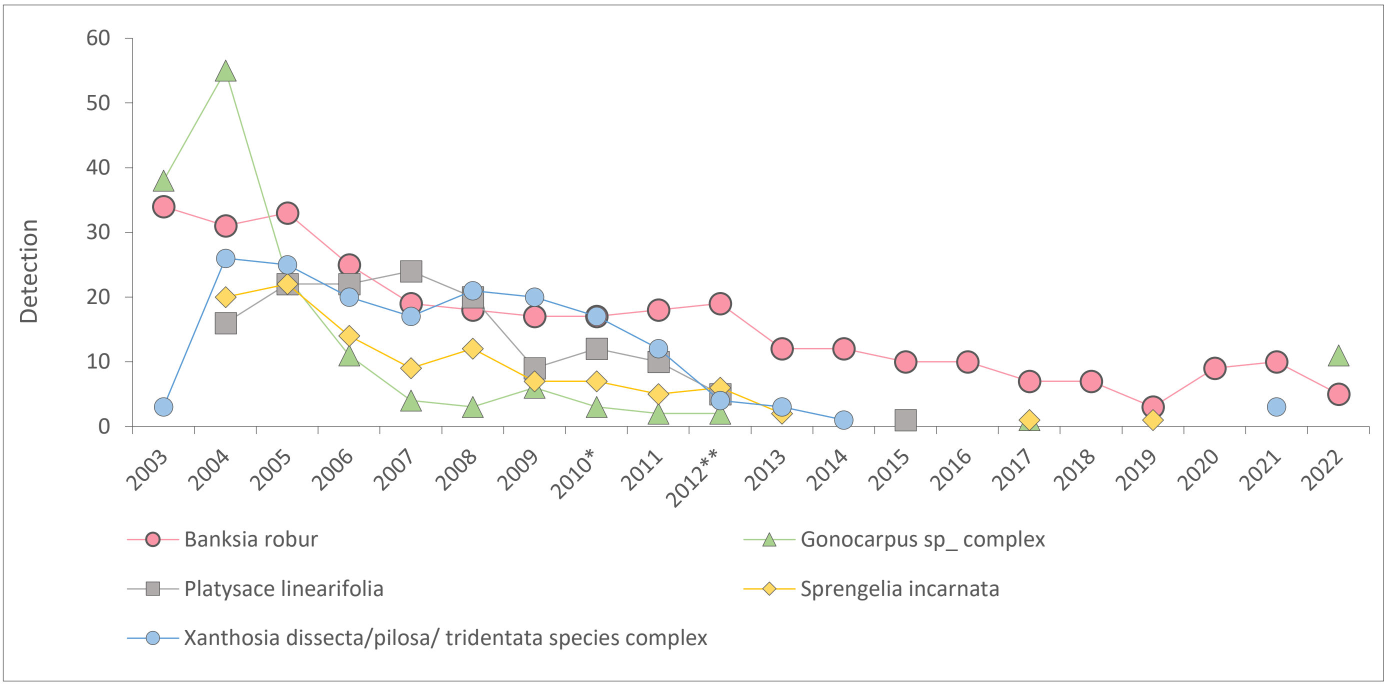
4.4.1.3.2 Species composition

Post-impact species composition data at Swamp 15B was first identified as being statistically different to pre-impact data in 2012-2013 after approaching the level of significance in 2011-2012 (the period following mining within the RMZ of the swamp in 2010). A statistically significant difference in species composition pre-post mining has continued to be detected in each two-year period since then, including in the 2021-2022 monitoring period (p-value: 0.001) (Table 22). The percentage of deviance relates to the five most influential species (species that have experienced the greatest level of change). In 2022 these species are *Gonocarpus* sp. complex, *Banksia robur*, *Sprengelia incarnata, Xanthosia dissecta pilosa tridentata species complex* and *Platysace linearifolia.*

Table 22: Species composition at Swamp 15B over two-year periods

Comparison	P-value (pre-post mining)	Percentage of deviance
2010–2011	0.137	0.481
2011–2012	0.066	0.463
2012–2013	**0.032**	0.44
2013–2014	**0.005**	0.438
2014–2015	**0.004**	0.437
2015–2016	**0.003**	0.465
2016–2017	**0.001**	0.409
2017–2018	**0.001**	0.361
2018–2019	**0.001**	0.392
2019–2020	**0.001**	0.376
2020–2021	**0.001**	0.334
2021–2022	**0.001**	0.326

All of these species were found to be more common prior to the first date of potential impact. As in previous years, this list of species includes those that are known to grow in heath or damp areas as well as those associated with dry sclerophyll forest and more sandy soils. Consideration of the trend in detection of these species suggests that these trending declines commenced during the pre-mining period (Graph 20).



* RMZ, ** directly mined beneath

Graph 20: Detection of five most influential species at Impact Upland Swamp 15B.

In 2020 it was concluded that the change in species composition does not appear to reflect the Upland Swamp drying and transitioning toward woodland, given the loss of both ‘wet’ and ‘dry’ species. Rather, the swamp may be experiencing some degree of die-back. As evidenced in the comparison of UAV imagery of the swamp vegetation in Plate 4 and Plate 5 below from 2020 (Niche 2021). The UAV imagery from the same locations in 2022 (Plate 6 and Plate 7) show dieback remains an issue in Swamp 15B, however there are potential signs of dieback recovery.

Plate 4: Control Upland Swamp 15A(1), showing healthy vegetation (2020)

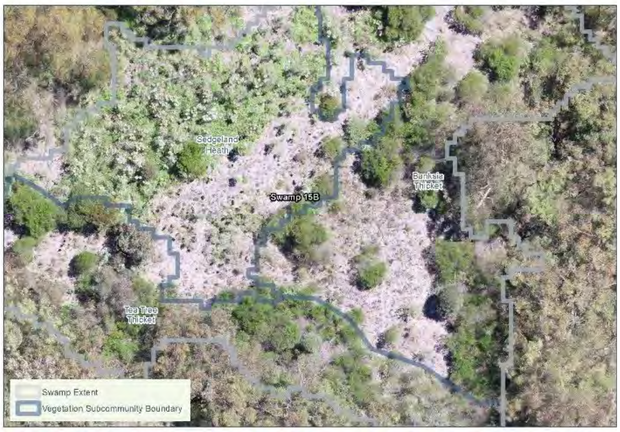
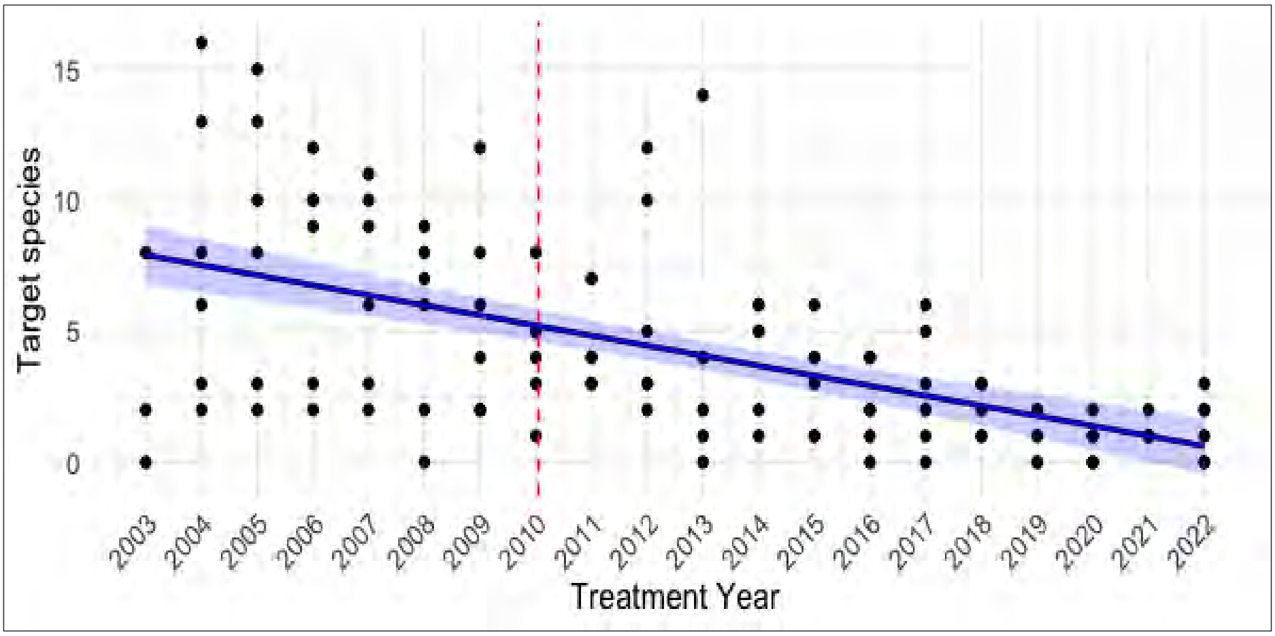


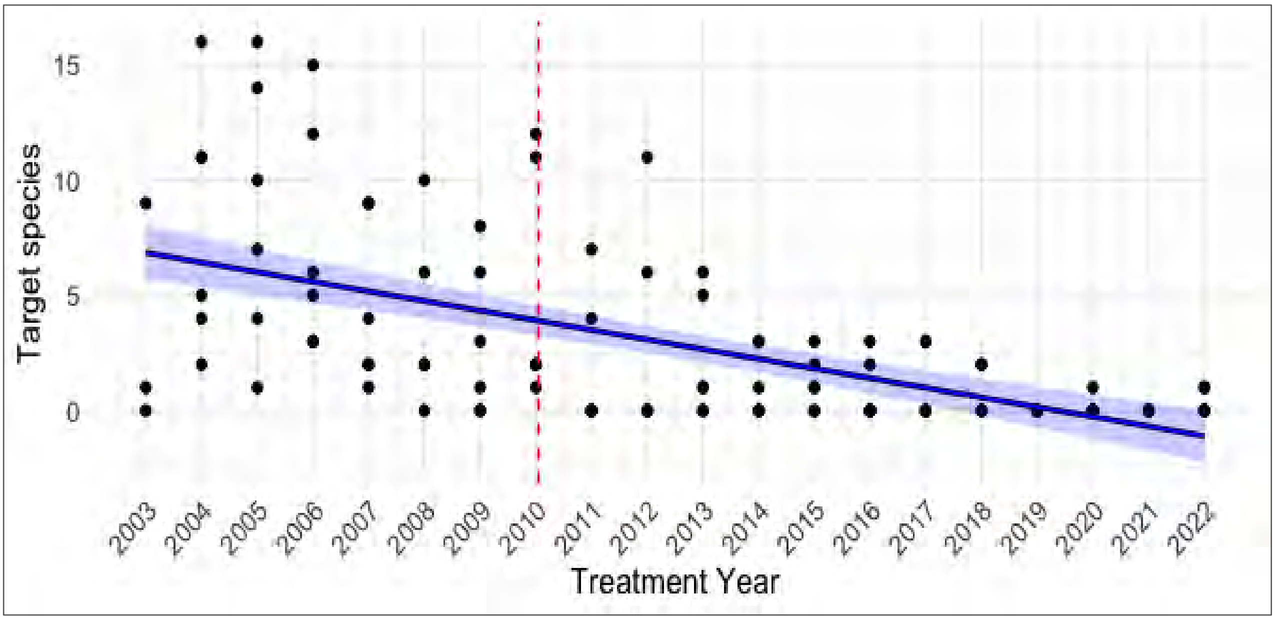
Plate 5: Impact Upland Swamp 15B, showing areas of die-back (2020)

Plate 6: Control Upland Swamp 15A(1), showing healthy vegetation (2022)

Plate 7: Impact Upland Swamp 15B, showing areas of die-back (2022)

Additional analysis of two key species identified as having strong trends over time at this swamp have been completed to examine whether the statistically significant breakpoints in these trends temporally align with mining activities (Graph 21). *Leptospermum juniperinum* was identified as steadily declining throughout the monitoring period. The best fitting model was the linear model (no breakpoints) representing a statistically significant linear decline in detection over the monitoring period. *Epacris obtusifolia* was identified as a species that was more common prior to impact, compared to after impact. The best fitting model was the linear model (no breakpoints) representing a statistically significant linear decline in detection over the monitoring period. Consideration of trends in these two species alone at this swamp, suggest factors other than mining may be primarily driving these trends, with significant declines pre-dating mining activities (Graph 21).





Best break point analysis model (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Break points indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years for visual clarity).

Graph 21: Breakpoint analysis showing best fitting models for *Leptospermum juniperinum* (above) and *Epacris obtusifolia* (below) at Swamp 15B

At impact Swamp 15B, regeneration of the *Gleichenia dicarpa / microphylla* sp. complex (Pouched coral fern) can be observed between spring 2020 and 2022 following three-years of above average rainfall, post the 2017-2019 drought (Plate 8, Plate 9 and Plate 10).

Plate 8: Swamp 15B -V1 Spring 2020

Plate 9: Swamp 15B -V1 Spring 2021

Plate 10: Swamp 15B -V1 Spring 2022

4.4.1.3.3 Performance measure summary

A TSR TARP has been previously triggered seven times at Swamp 15B (Niche 2022). In 2022, no TSR TARP has been triggered, with the breakpoint analysis suggesting the trending decline in TSR pre-dated mining activity.

A species composition TARP has been triggered nine times at Swamp 15B (Table 23). This was first triggered in 2013, one year since being mined beneath (2012), after approaching the adopted level of statistical significance in 2012.

The breakpoint analysis does suggest that this swamp may have been undergoing changes in floristic composition prior to mining occurring, although no trend other than decline is observed in the post-mining period.

When the TSR and species composition triggers are taken together with the observations of drying conditions (Niche 2022), trending decline in swamp extent and sub-communities (Section 4.3), these factors suggest a change in species present at the swamp and an impact due to mining. As discussed above, species composition is changing via loss of species with preferences for both wet and dry habitats with the breakpoint analysis suggestive of changes occurring pre-mining, nevertheless this indicates a continued loss of richness and change in community composition and hence continues to trigger a Level 2 composition TARP.

Table 23: Historical TARP triggers for Swamp 15B

Years	TSR TARP	Composition TARP
2011	None	None
2012 (mined beneath)	None	None
2013	Level 2 • 2012-2013	Level 2 • 2012-2013
2014	None	Level 2 (two consecutive years) • 2012-2013 • 2013-2014
2015	Level 2 • 2014-2015	Level 2 (three consecutive years) • 2012-2013 • 2013-2014 • 2014-2015
2016	None	Level 2 (four consecutive years) • 2012-2013 • 2013-2014 • 2014-2015 • 2015-2016
2017	Level 2 • 2016-2017	Level 2 (five consecutive years) • 2012-2013 • 2013-2014 • 2014-2015 • 2015-2016 • 2016-2017
2018	Level 2 (two consecutive years) • 2016-2017 • 2017-2018	Level 2 (six consecutive years) • 2012-2013 • 2013-2014

Years	TSR TARP	Composition TARP
		• 2014-2015 • 2015-2016 • 2016-2017 • 2017-2018
2019	Level 2 (three consecutive years) • 2016-2017 • 2017-2018 • 2018-2019	Level 2 (seven consecutive years) • 2012-2013 • 2013-2014 • 2014-2015 • 2015-2016 • 2016-2017 • 2017-2018 • 2018-2019
2020	Level 2 (four consecutive years) • 2016-2017 • 2017-2018 • 2018-2019 • 2019-2020	Level 2 (eight consecutive years) • 2012-2013 • 2013-2014 • 2014-2015 • 2015-2016 • 2016-2017 • 2017-2018 • 2018-2019 • 2019-2020
2021	Level 2 (five consecutive years) • 2016-2017 • 2017-2018 • 2018-2019 • 2019-2020 • 2020-2021	Level 2 (nine consecutive years) • 2012-2013 • 2013-2014 • 2014-2015 • 2015-2016 • 2016-2017 • 2017-2018 • 2018-2019 • 2019-2020 • 2020-2021
2022	No longer triggered	Level 2 (ten consecutive years) • 2012-2013 • 2013-2014 • 2014-2015 • 2015-2016 • 2016-2017 • 2017-2018 • 2018-2019 • 2019-2020 • 2020-2021 • 2021-2022
Total times triggered	**7**	**10**

Note: TARP levels pre-2022 are those reported in Niche (2022a)

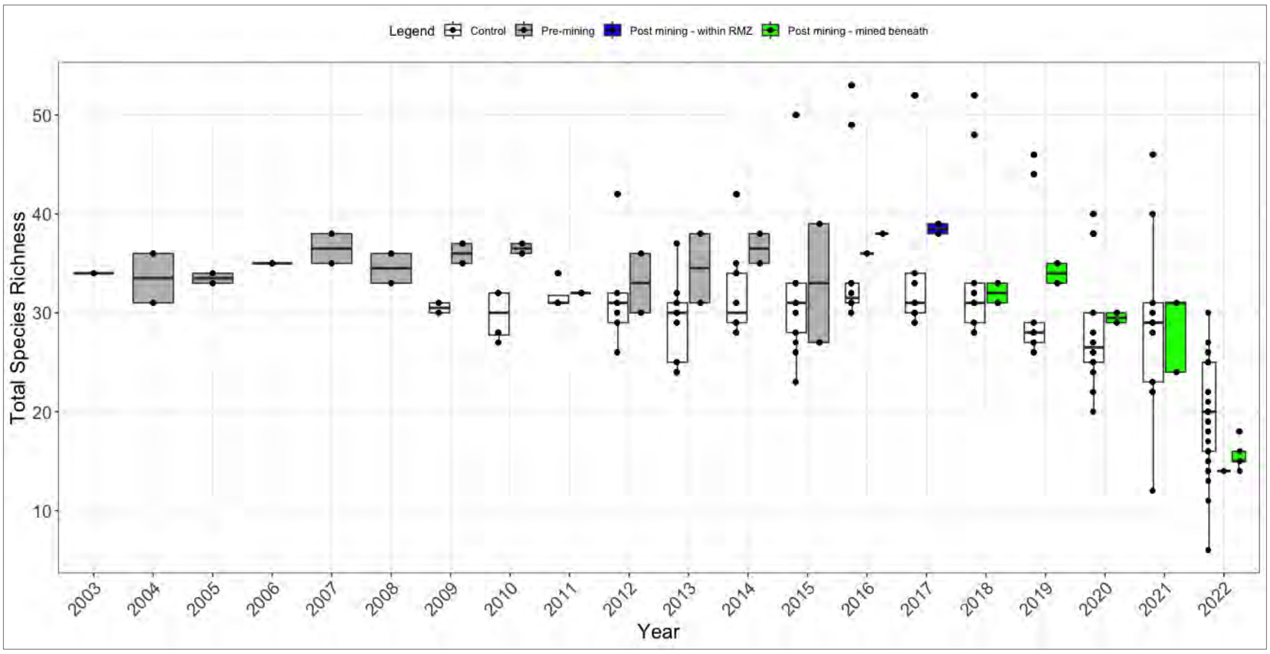
4.4.2 Dendrobium Area 3B

4.4.2.1 Swamp 11

Monitoring at Swamp 11 began in 2003 as a Control swamp for early Dendrobium Area 3A panels, reclassified when mining within the DA3B RMZ commenced in 2016 and was then directly mined beneath in 2017. A total of 61 unique species have been detected to date at Swamp 11, of which 8% were detected only once.

4.4.2.1.1 TSR

TSR at control sites has been more variable than that of Swamp 11 (Graph 22). An increase in TSR was recorded immediately following mining within the RMZ of the swamp in 2016 to the highest levels recorded at this swamp, which has since declined to levels recorded immediately before impact (2015).



The solid line within the boxes is the median (i.e., the 5⁰ᵗh percentile), the margins of the box are the interquartile range (IQR, i.e., the 2⁵ᵗh and 7⁵ᵗh percentile), and the whiskers of the boxplot cover 1.5 times the IQR of the data. Boxes shaded white are Control Upland Swamps, boxes shaded grey are Impact Upland Swamps that are Pre-mining, boxes shaded blue are Post-mining–- within RMZ, and boxes shaded green are Post-mining–- mined beneath. Solid black points are the observations. See Table 1 for mining progress, number and status of Upland Swamps at the year surveyed.

Graph 22: Boxplot of the TSR for each transect at Impact Upland Swamp 11, contrasted against Control Upland Swamps

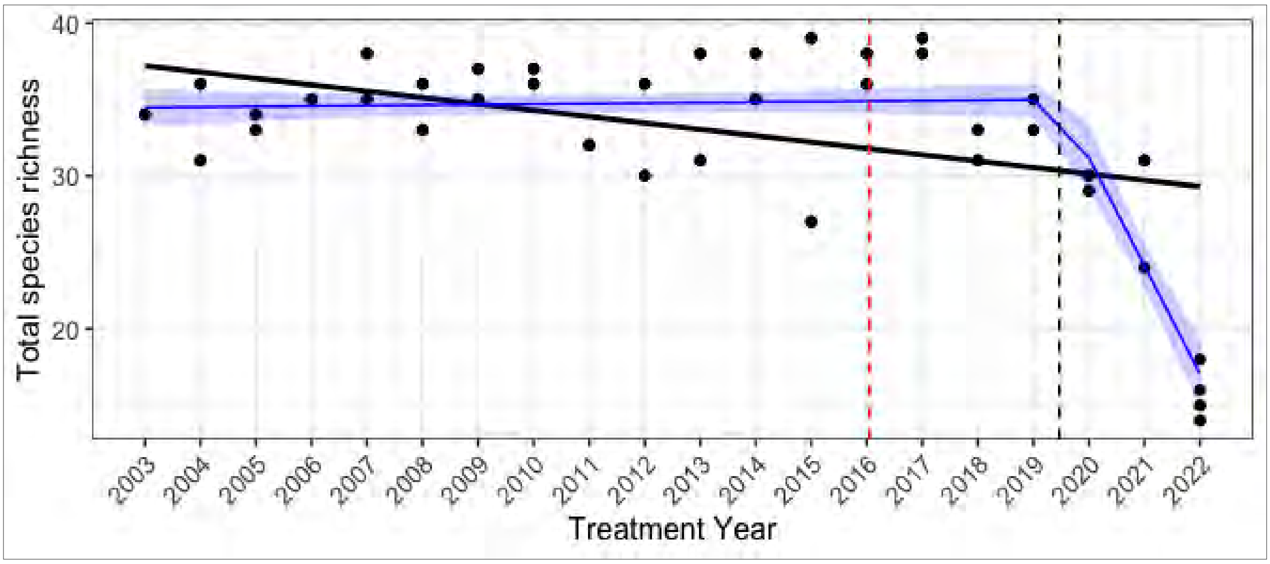
No statistically significant difference between pre- and post-impact TSR data has been detected (Table 24) at Swamp 11.

Table 24: Comparison of mean TSR between Swamp 11 and control swamps over two-year periods

Comparison	Test statistic	D.f.	P-value
2016–2017	0.98	4.51	0.375
2017–2018	1.10	1.31	0.435
2018–2019	1.16	1.33	0.414
2019–2020	1.15	3.12	0.329

Comparison	Test statistic	D.f.	P-value
2020–2021	2.48	2.43	0.109
2021–2022	3.83	2.08	0.058

Additional breakpoint analysis has identified that no significant linear trend was evident prior to the breakpoint in 2019, however the subsequent decline was found to be statistically significantly (Graph 23).



Best breakpoint analysis model as determined by AIC model section (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Breakpoints indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years for visual clarity).

Graph 23: Breakpoint analysis showing best fitting models at Impact Upland Swamp 11

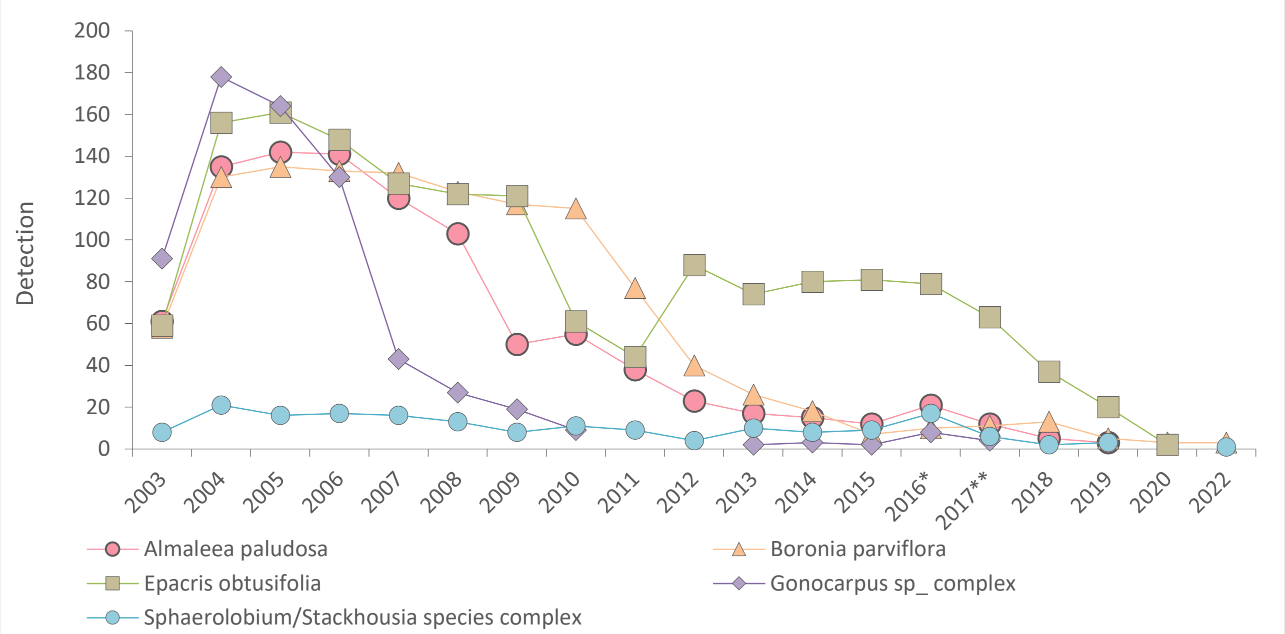
4.4.2.1.2 Species composition

A statistically significant difference between pre and post impact species composition data has been detected in each monitoring period since 2017-2018 (Table 25), including the most recent 2021-2022 period (p-value: 0.001).

Table 25: Species composition at Swamp 11 over two-year periods

Comparison	P-value (pre-post mining)	Percentage of deviance
2016–2017	0.251	0.35
2017–2018	**0.016**	0.334
2018–2019	**0.011**	0.462
2019–2020	**0.003**	0.494
2020–2021	**0.001**	0.606
2021–2022	**0.001**	0.57

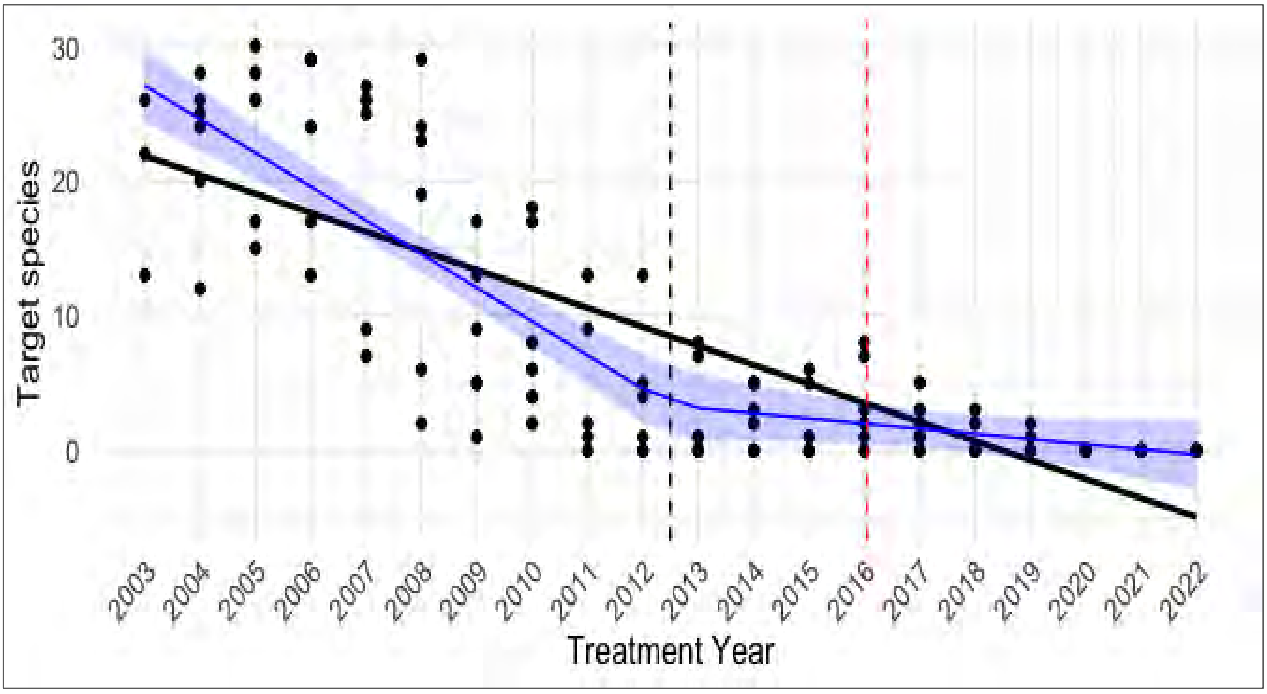
The percentage of deviance relates to the five most influential species (species that have experienced the greatest level of change). In 2022 these species are *Almaleea paludosa, Epacris obtusifolia, Boronia parviflora, Sphaerolobium Stackhousia* species complex and *Gonocarpus* species complex. All of these species were found to be more common prior to impact. As in previous years, this list of species includes those that are known to grow in heath or damp areas as well as those that may be associated with dry sclerophyll forest and more sandy soils. Consideration of the trend in detection of these species suggests that these trending declines commenced during the pre-mining period (Graph 24).

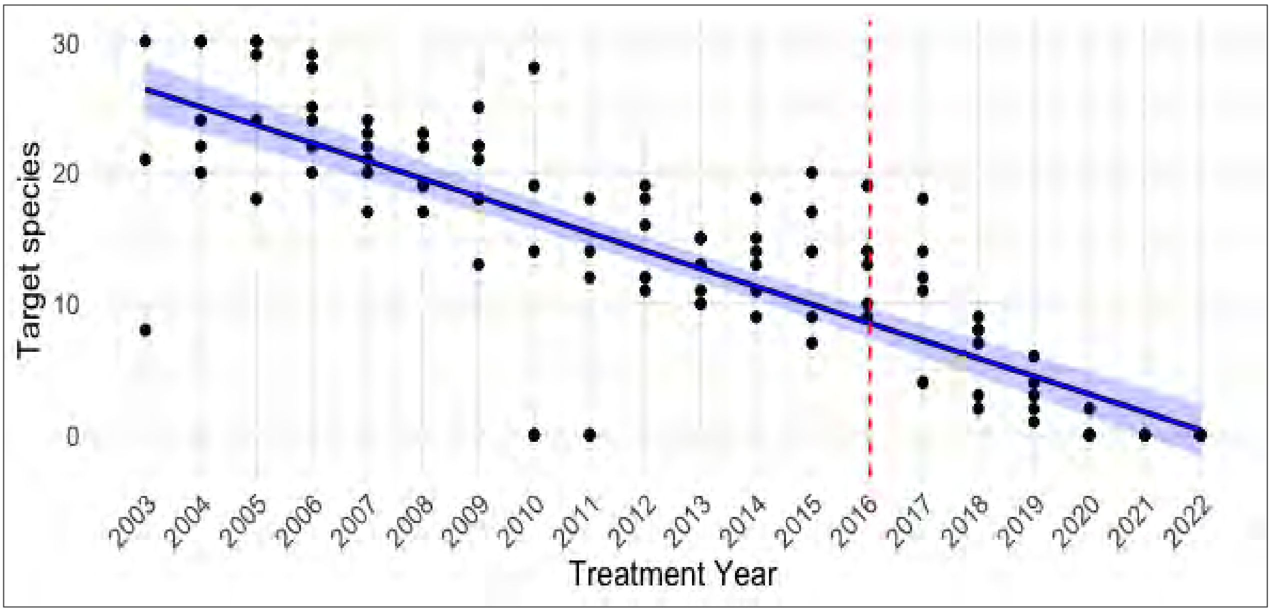


* RMZ, ** directly mined beneath

Graph 24: Detection of five most influential species at Impact Upland Swamp 11.

Additional analysis of two key species identified as having strong trends over time at this swamp have been completed to examine whether the statistically significant breakpoints in these trends temporally align with mining activities (Graph 25). *Almaleea paludosa* was identified as a species that was more common prior to impact, compared to after impact, with the species no longer detected in 2020. The period of decline between 2006 and 2012 was found to be statistically significant, which after the number of detection events for this species has been approximately stable. *Epacris obtusifolia* was also identified as a species that was more common prior to impact, compared to after impact. The best fitting model had no breakpoints (linear trend) and there was a statistically significant decline in number of detection events across the monitoring period. The statistically significant break points identified do not align with the commencement of mining, with declines pre-dating mining activity. Consideration of trends in these two species alone and at this swamp, suggest that factors other than mining may be primarily driving these trends in these two species.





Best break point analysis model (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Break points indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years for visual clarity).

Graph 25: Breakpoint analysis showing best fitting models for *Almaleea paludosa* (above) and *Epacris obtusifolia* (below) at Swamp 11

4.4.2.1.3 Performance measure summary

The statistically significant change in species composition does not necessarily indicate a mining induced negative change across Swamp 11, just that a change is occurring. The change in species composition is due to species that are generally restricted to wet or swamp environments, but also those that have a greater range of tolerances and may also be associated with dry sclerophyll or woodland environments. Given that many of the species that are experiencing the greatest change in composition can tolerate varying conditions, and the trending declines for target species appear to have commenced pre-mining, the change in occurrence of these species do not indicate a vegetation composition change that can be positively attributable to impacts from mining, i.e. from drying conditions.

In previous years, the change in species composition has not resulted in a statistically significant decline in TSR, indicating a shift in species assemblage, rather than dieback. While the comparison of TSR in 2021-2022 was not statistically significant, it is approaching the level of statistical significance. With the additional breakpoint analysis of TSR suggesting a significant decline commenced in 2019, some years post the first date of potential mining impact. This decline, and specifically the breakpoint, coincides with the end of the drought in 2017 – 2019, although no recovery has been identified in 2020 – 2022. A visual review of the pattern of change in TSR identifies similar pattens of change (of lower magnitude) at the control swamps. When this is taken together with swamp extent and sub-community LiDAR analysis which have not triggered any TARP's and as no visual indicators of gross environmental change (dieback) have been identified, the statistical difference in species composition identified in 2022 is not considered to trigger a TARP. However, this should be re-evaluated in detail in subsequent years to ascertain whether any indicators of mining impacts emerge in the dataset.

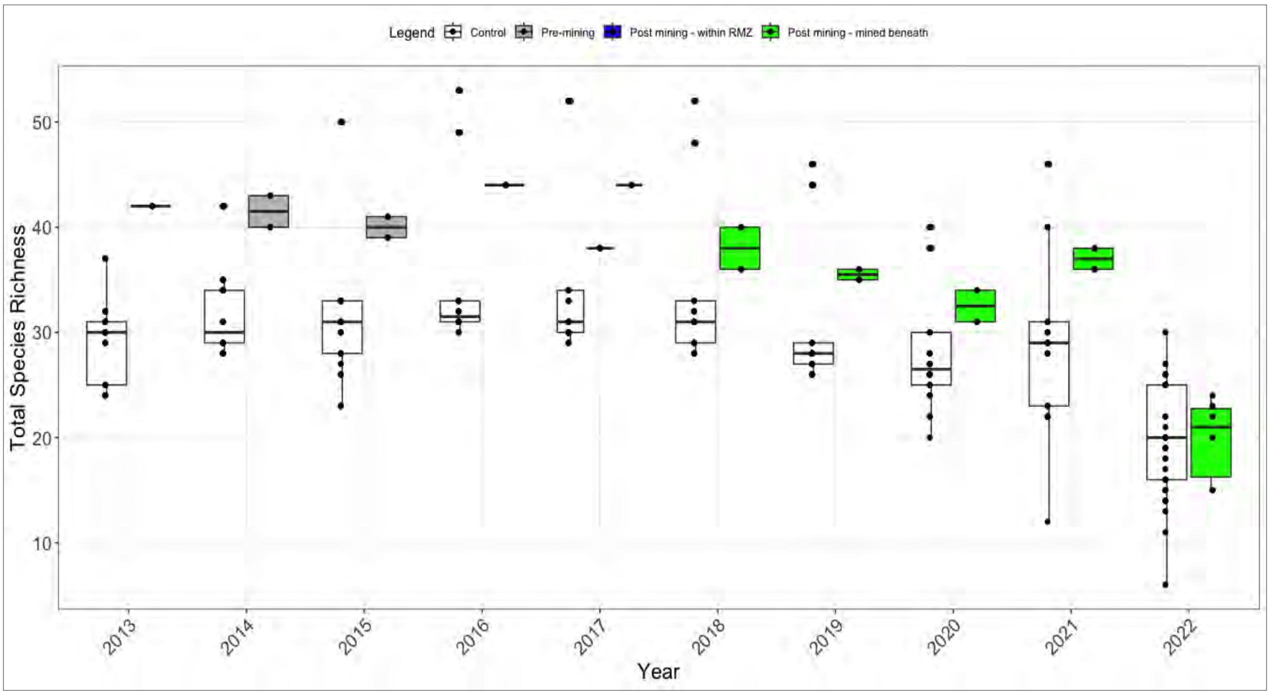
The change in species composition over time has resulted in a statistically significant difference in 2018, 2019 and 2020 (Niche 2022a), and also 2022. This change in species composition identified may be due to the variety of sub-communities within the swamp shifting in distribution. It is noted that the limited species assessed in the breakpoint analysis indicate significant trends that commenced prior to mining activity, as does the visual examination of detection of five most influential species identified in the species composition analysis. It is reasonable to expect natural species turnover to occur at a swamp, especially after an extended drought period. However, a statistically significant change in species composition indicates a long-term shift in the flora species comprising the swamp. As detailed above, the change in composition may be explained by the transects being within or along the border of a swamp sub-community in transition, where there are portions of swamp sub-communities present along the same transect, with potential drying out of some areas and moisture building in other areas across a complex Upland Swamp. When taken together, the multiple lines of assessment do not suggest an impact as a result of mining, as such a TARP for species composition is not considered to be triggered. However, changes in species composition at this swamp should be monitored in the coming years to determine if a differing trend emerges.

4.4.2.2 Swamp 13

Monitoring at Swamp 13 began in 2013. Mining within the RMZ commenced in 2017 and the swamp was directly mined beneath in 2018. A total of 68 unique species were detected in Swamp 13 across the monitoring period, of which 19% were detected only once.

4.4.2.2.1 TSR

The TSR at Control sites has been more variable than TSR at Swamp 13. Prior to impact, TSR at Swamp 13 was typically higher than the control swamps, and post-impact there has been a decline in TSR at Swamp 13 that has been greater than the control swamps (Graph 26). Overall declines in TSR at the impact swamp and control swamps have occurred since 2018.



The solid line within the boxes is the median (i.e., the 5⁰ᵗh percentile), the margins of the box are the interquartile range (IQR, i.e., the 2⁵ᵗh and 7⁵ᵗh percentile), and the whiskers of the boxplot cover 1.5 times the IQR of the data. Boxes shaded white are Control Upland Swamps, boxes shaded grey are Impact Upland Swamps that are Pre-mining, boxes shaded blue are Post-mining–- within RMZ, and boxes shaded green are Post-mining–- mined beneath. Solid black points are the observations. See Table 1 for mining progress, number and status of Upland Swamps at the year surveyed.

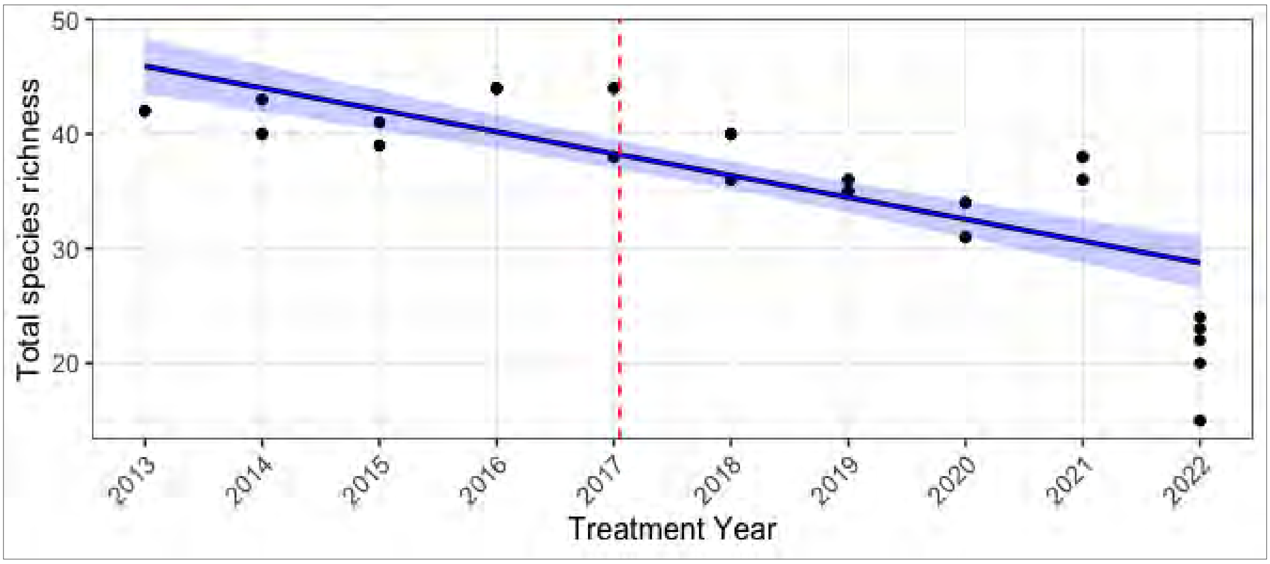
Graph 26: Boxplot of the TSR for each transect at Impact Upland Swamp 13, contrasted against Control Upland Swamps

No statistically significant difference between pre and post impact TSR data was detected in 2022 (Table 26). To date, a statistically significant difference has only been detected in the 2018-2019 monitoring period.

Table 26: Comparison of mean TSR between Swamp 13 and control swamps over two-year periods

Comparison	Test statistic	D.f.	P-value
2017–2018	3.95	3.76	0.019
2018–2019	5.45	3.16	**0.011**
2019–2020	5.44	3.39	0.009
2020–2021	2.14	1.75	0.184
2021–2022	1.64	1.16	0.322

Additional breakpoint analysis has identified that the linear declining trend in TSR at this swamp was best fit to the data (Graph 27) and was statistically significant. This trend commenced prior to mining and did not change trajectory post-mining (Graph 27).



Best breakpoint analysis model as determined by AIC model section (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Breakpoints indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years for visual clarity).

Graph 27: Breakpoint analysis showing best fitting models at Impact Upland Swamp 13

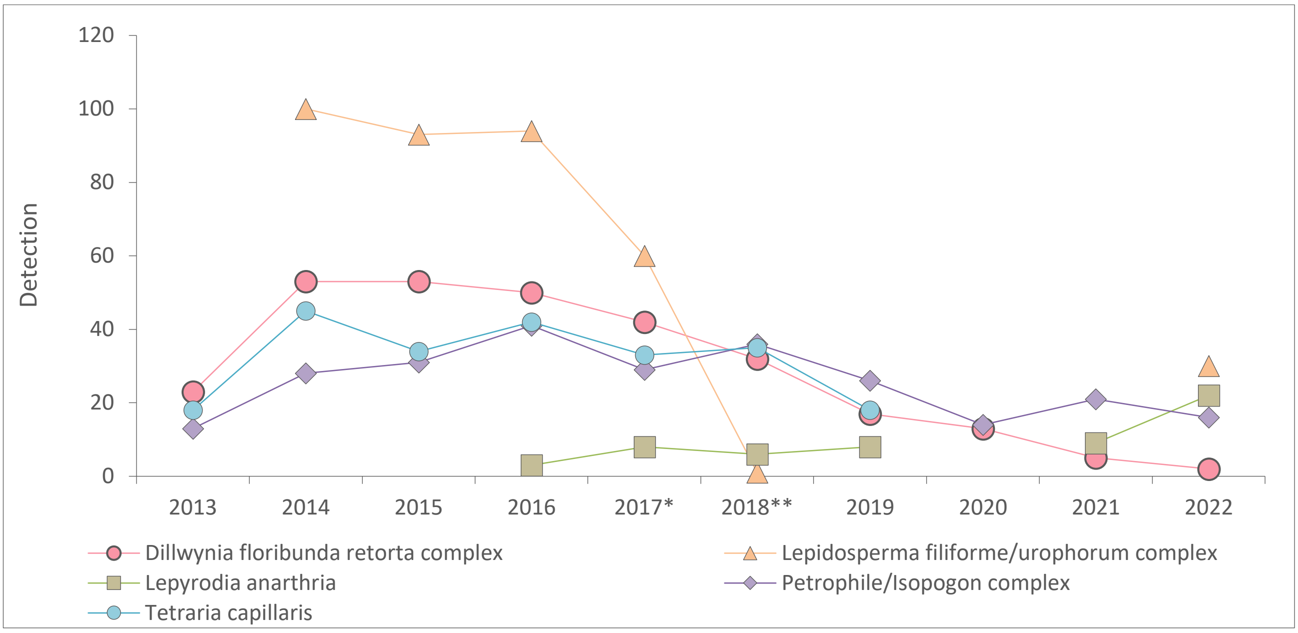
4.4.2.2.2 Species composition

A statistically significant difference between pre- and post-impact species composition was first detected in 2020 (Table 27). A statistically significant difference in species composition was detected for a third consecutive time in 2022 (p-value: 0.018).

Table 27: Species composition at Swamp 13 over two-year periods

Comparison	P-value (pre-post mining)	Percentage of deviance
2017–2018	0.57	0.534
2018–2019	0.169	0.476
2019–2020	**0.042**	0.367
2020–2021	**0.035**	0.334
2021–2022	**0.018**	0.396

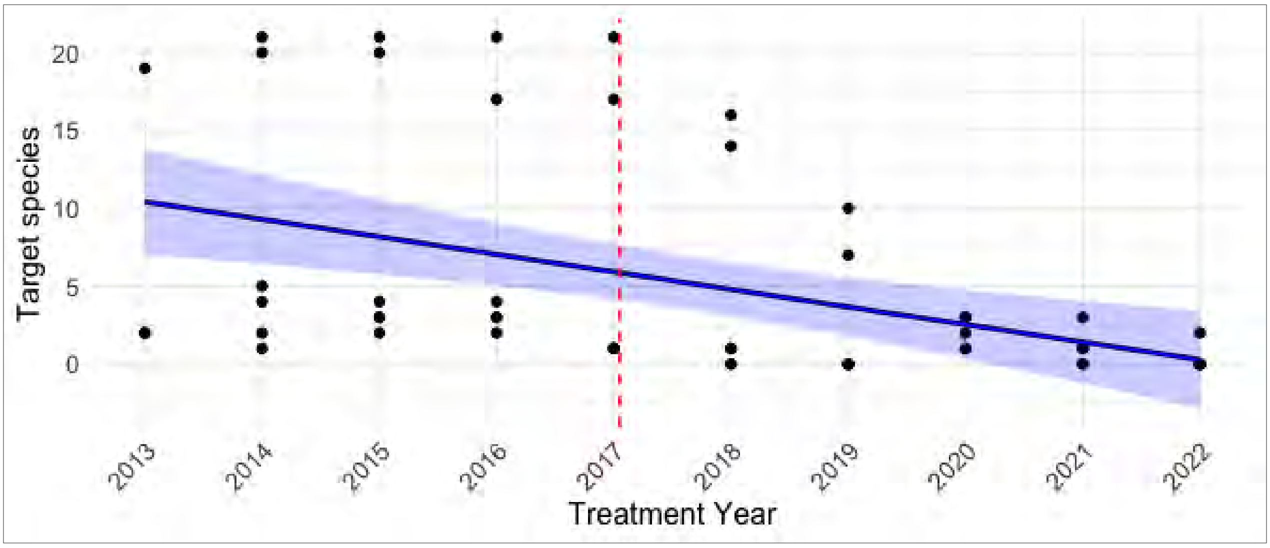
The percentage of deviance relates to the five most influential species (species that have experienced the greatest level of change). In 2022 these species are *Lepyrodia anarthria*, *Lepidosperma filiforme urophorum* sp. complex, *Tetraria capillaris*, *Dillwynia floribunda retorta* sp. complex and *Petrophile Isopogon complex* (Graph 28). All of these species were found to be more common prior to impact. As in previous years, while this group of species includes those most associated with ‘wet’ habitats, a number of these species are wide ranging and can tolerate varying conditions. As such, these species are not considered to be an overall indicator of changing swamp vegetation composition due to drying, thus the change in occurrence of the above species since the commencement of monitoring do not indicate a trend in vegetation composition change that can be attributable to impacts from mining and/or drying conditions.

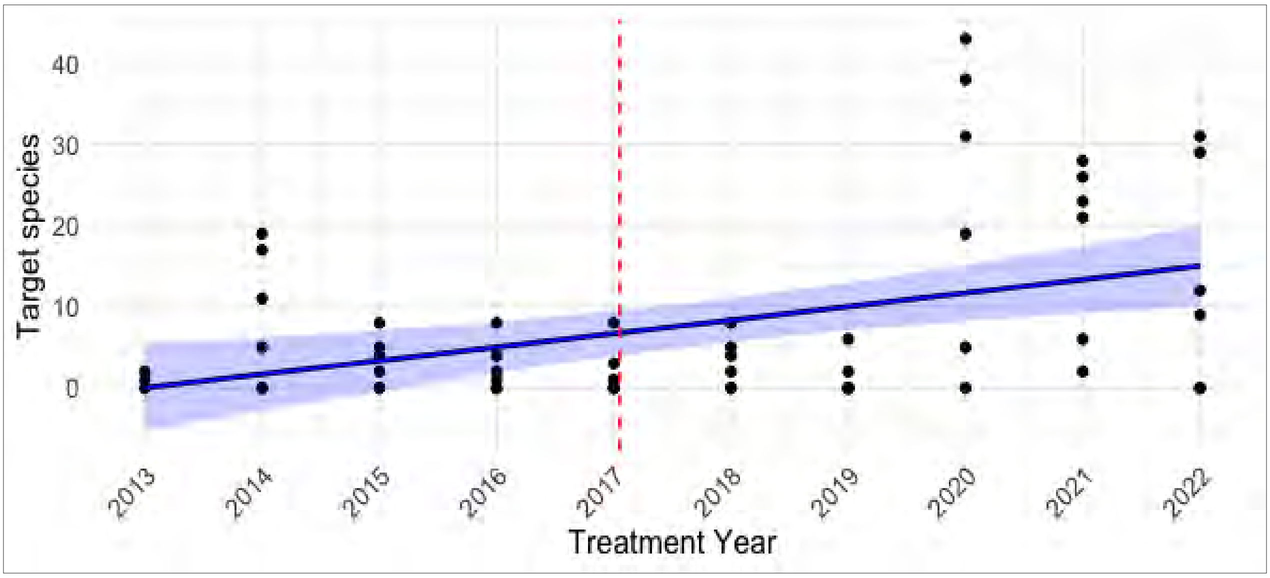


* RMZ, ** directly mined beneath

Graph 28: Detection of five most influential species at Impact Upland Swamp 13

Additional analysis of two key species identified as having strong trends over time at this swamp have been completed to examine whether the statistically significant breakpoints in these trends temporally align with mining activities (Graph 29). *Dillwynia floribunda retorta complex* was identified as a species that was more common prior to impact, compared to after impact, although there is high between-transect variability. The best fitting model was the linear model (i.e. no statistically significant breakpoints were identified). *Xyris species complex* was also selected for analysis with the number of detection events of *Xyris species complex* relatively stable until 2019, after which the number of detection events of this species were much higher. The best fitting model had no significant breakpoints (linear model). As the *Xyris species complex* has a preference for wetter conditions and *Dillwynia floribunda retorta complex* is more likely to be associated with dryer conditions, these findings do not indicate drying conditions within Swamp 13.





Best break point analysis model (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Break points indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years for visual clarity).

Graph 29: Breakpoint analysis showing best fitting models for *Dillwynia floribunda retorta complex* (above) and *Xyris species complex* (below) at Swamp 13

4.4.2.2.3 Performance measure summary

A TSR TARP has not yet been triggered to date (Niche 2022a) and has not been triggered in 2022. In 2019 TSR was statistically different to 2018, however a TARP was not triggered, as the statistically significant difference did not repeat in 2020 (two consecutive years of change required to trigger a Level 1 TARP). Additional breakpoint analysis has identified no statistically significant decline in TSR following mining, with the analysis suggesting declining TSR commenced in the pre-mining period and has not changed trajectory following mining.

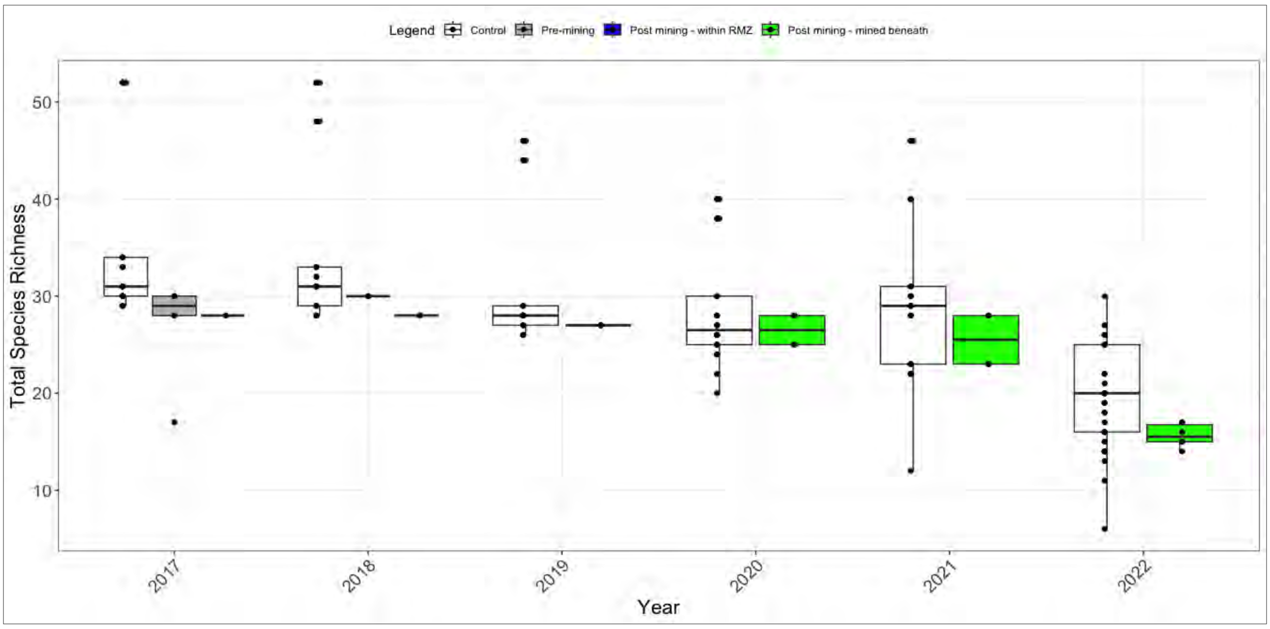
In 2022, a significant difference in species composition has been detected, following consecutive statistically significant differences being detected in 2020 and 2021. It is reasonable to expect natural species turnover to occur at a swamp, especially after an extended drought period, however, a statistically significant change in species composition indicates a likely long-term shift in the flora species comprising the Upland Swamp. The change in species composition has included a reduction in species able to tolerate a range of conditions and do not indicate an overall loss of species with preference for 'wet' habitats. Further, the breakpoint analysis of two species experiencing statistically significant trends in detection do not indicate drying conditions. As such, the change in occurrence of these species do not indicate a vegetation composition change that can be attributable to impacts from mining and/or drying conditions and no TARP is triggered.

4.4.2.3 Swamp 14

Monitoring at Swamp 14 began in 2017 with one year of pre-mining baseline monitoring, mining within the RMZ commenced in 2018 and Swamp 14 was mined beneath by 2019. A total of 42 unique species were detected, of which 12% were detected only once.

4.4.2.3.1 TSR

The combined data for all Upland Control Swamps were more variable than Swamp 14. TSR at Swamp 14 has been lower than that of the control swamps in each year of monitoring. The median TSR at the Control Group and Swamp 14 appear to be stable from 2019–- 2020 (Graph 30).



The solid line within the boxes is the median (i.e., the 5^{0t}h percentile), the margins of the box are the interquartile range (IQR, i.e., the 2^{5t}h and 7^{5t}h percentile), and the whiskers of the boxplot cover 1.5 times the IQR of the data. Boxes shaded white are Control Upland Swamps, boxes shaded grey are Impact Upland Swamps that are Pre-mining, boxes shaded blue are Post-mining–- within RMZ, and boxes shaded green are Post-mining–- mined beneath. Solid black points are the observations. TAE 2021a. See Table 1 for mining progress, number and status of Upland Swamps at the year surveyed.

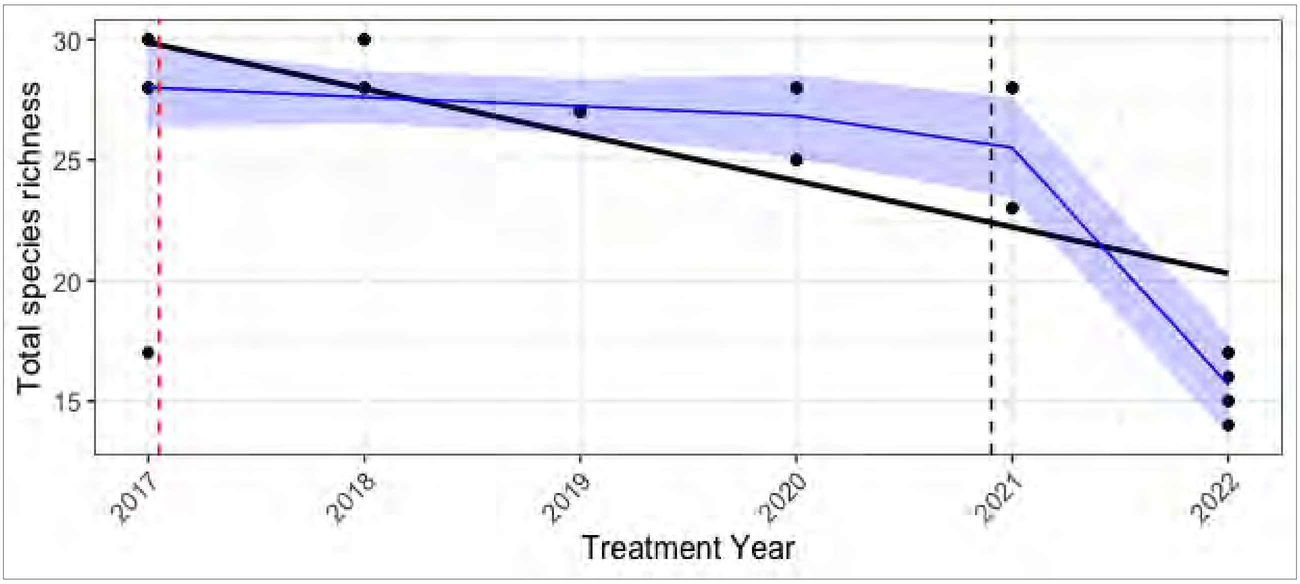
Graph 30: Boxplot of the TSR for each transect, at Impact Swamp 14, contrasted against Control Upland Swamps

No statistically significant difference between TSR at Swamp 14 and the control data was detected in 2022 (Table 28). To date, no statistically significant difference has been detected at Swamp 14, likely due to the limited data series.

Table 28: Comparison of mean TSR between Swamp 14 and control swamps over two-year periods

Comparison	Test statistic	D.f.	P-value
2018–2019	-1.29	2.50	0.305
2019–2020	-1.80	1.62	0.243
2020–2021	-1.71	1.70	0.250
2021–2022	-1.46	1.01	0.379

Breakpoint analysis has identified that the best fitting model had one break point, as shown in Graph 31. The initial trend prior to the breakpoint in 2021 was not statistically significant, however after the break point there was a significant decline in TSR at this swamp.



Best breakpoint analysis model as determined by AIC model section (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Breakpoints indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years for visual clarity).

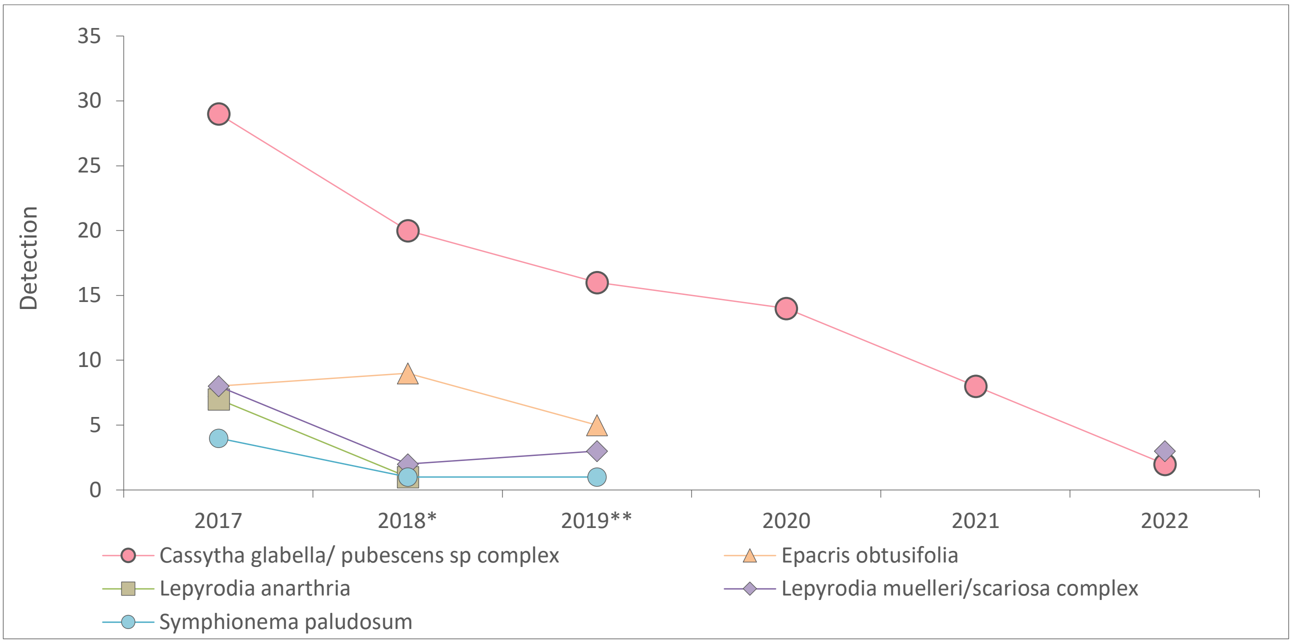
Graph 31: Breakpoint analysis showing best fitting models at Impact Upland Swamp 14

4.4.2.3.2 Species composition

In 2022, a statistically significant difference between pre and post impact species composition has been detected for the second consecutive time (p-value: 0.048), as shown in Table 29. The percentage of deviance relates to the five most influential species (species that have experienced the greatest level of change). In 2022 these species are *Lepyrodia muelleri scariosa* complex*, Epacris obtusifolia, Cassytha glabella pubescens* sp. complex*, Lepyrodia anarthria, Symphionema paludosum*, all of which were more common pre-mining. These species are generally associated with 'wet environments'. Consideration of the trend in detection of these species suggests that these trending declines coincided with the dates of mining within the RMZ and directly beneath the swamp, as well as the 2017-2019 drought. Although there is only one year of pre-mining data, as such establishing any trends prior to mining is not possible (Graph 32).

Table 29: Species composition at Swamp 14 over two-year periods

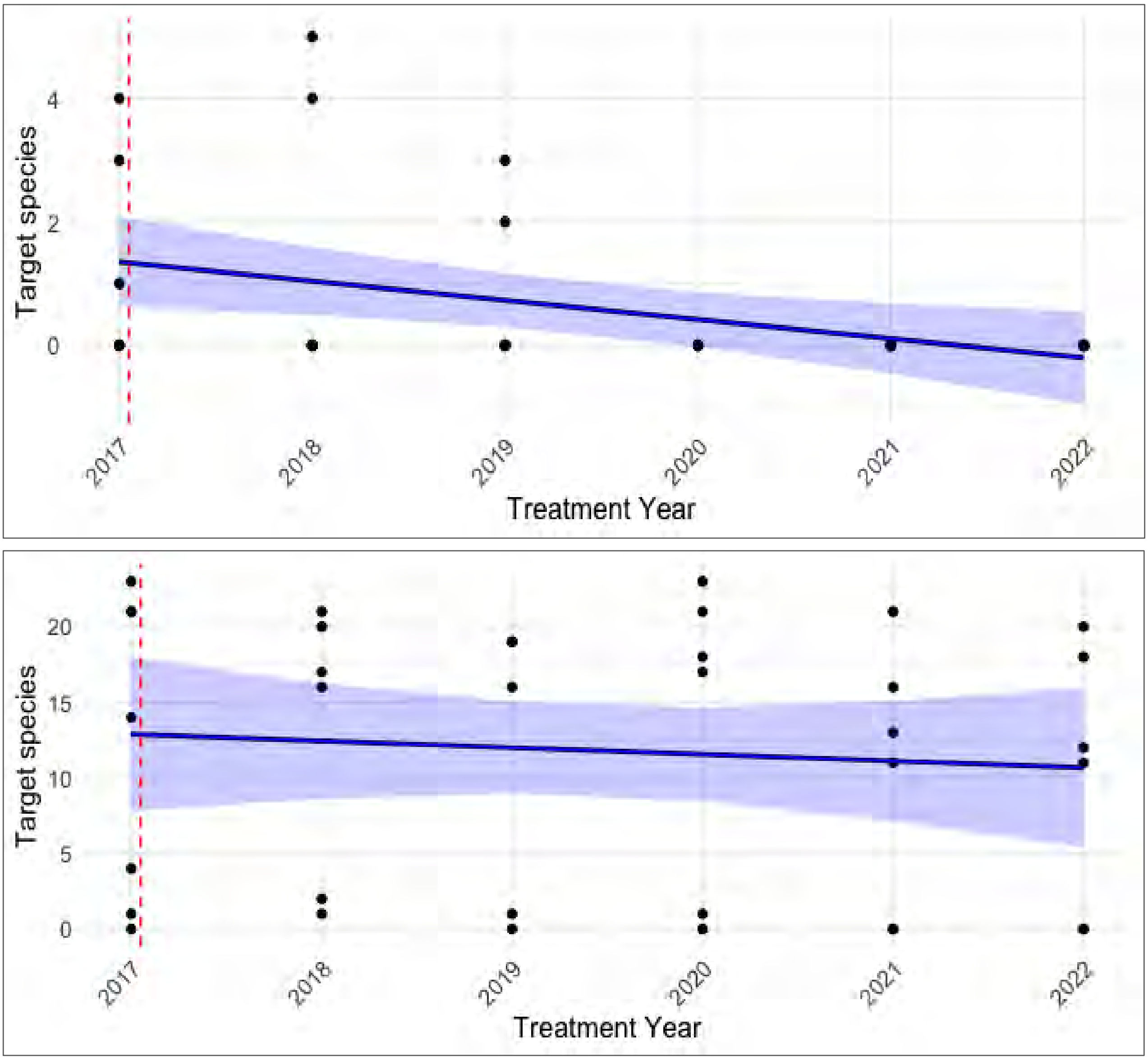
Comparison	P-value (pre-post mining)	Percentage of deviance
2018–2019	0.41	0.625
2019–2020	0.249	0.489
2020–2021	**0.045**	0.537
2021–2022	**0.048**	0.495



***** RMZ, ** directly mined beneath

Graph 32: Detection of five most influential species at Impact swamp 14

Additional analysis of two key species identified as having strong trends over time at this swamp have been completed to examine whether the statistically significant breakpoints in detection (Graph 33), although this is limited by the single year of pre-mining data. *Epacris obtusifolia* was identified as a species that was more common prior to impact, with this species not detected since 2020. The best fitting model was the linear model (i.e. no statistically significant breakpoints were identified). *Bauera microphylla/rubioides* species complex was also selected for analysis. The best fitting model had no significant breakpoints (linear model), with substantial inter-transect variation at this swamp.



Best break point analysis model (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Break points indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years for visual clarity).

Graph 33: Breakpoint analysis showing best fitting models for *Epacris obtusifolia* (above) and *Bauera microphylla/rubioides* species complex

4.4.2.3.3 Performance measure summary

No significant difference in TSR has been detected during the monitoring period to date.

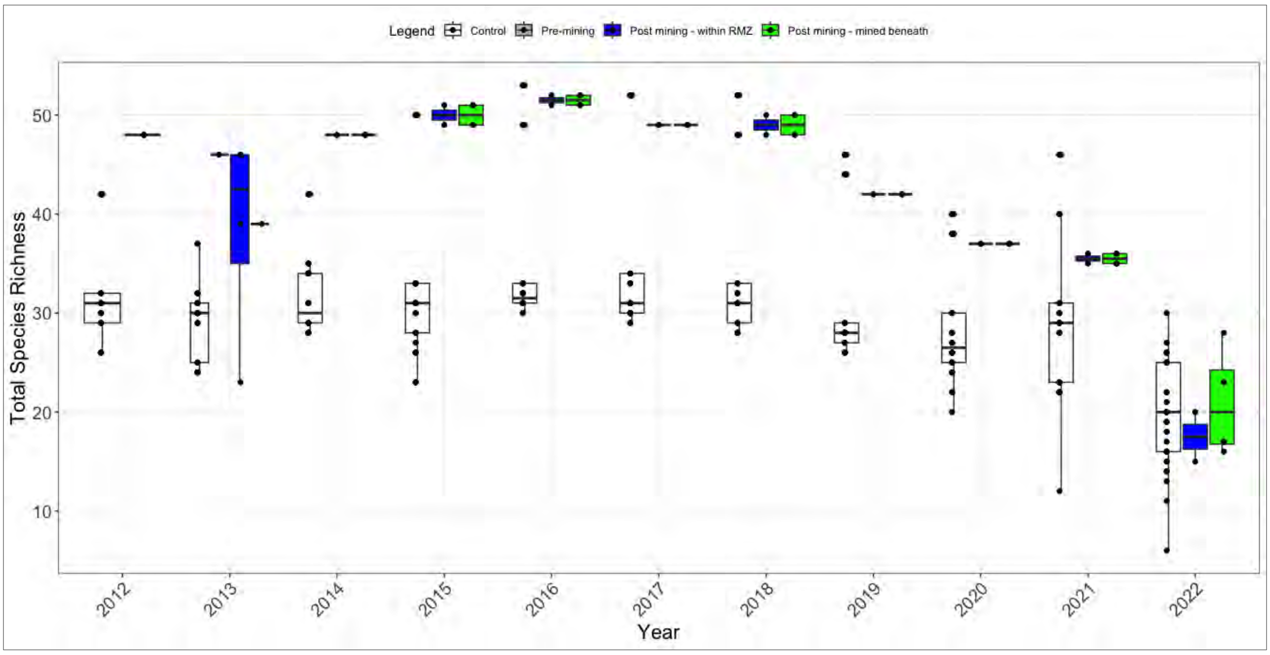
A statistically significant difference in species composition was detected in 2021, with a second consecutive statistically significant difference detected in 2022. As such a TARP level 1 is triggered for the first time at Swamp 14. With the trends in key species identified overall indicative of drying conditions. Monitoring should continue for Swamp 14, as trends may become more apparent with increased time since mining and/or increased availability of monitoring data.

4.4.2.4 Swamp 1A

Monitoring at Swamp 1A began in 2012, with one year of pre-mining baseline monitoring. Mining within the RMZ commenced in 2013 and Swamp 1A was mined beneath in 2014. A total of 69 unique species were detected, of which 9% were detected only once.

4.4.2.4.1 TSR

In the one year prior to impact, the TSR at the Swamp 1A was higher than of the control swamps (Graph 34). Overall, TSR at the control swamps has been more variable than TSR at Swamp 1A, and has been relatively stable across the monitoring period. In 2014, immediately after mining within the RMZ, post mining (within RMZ) TSR at Swamp 1A rose, before declining progressively.



The solid line within the boxes is the median (i.e., the 5^{0t}h percentile), the margins of the box are the interquartile range (IQR, i.e., the 2^{5t}h and 7^{5t}h percentile), and the whiskers of the boxplot cover 1.5 times the IQR of the data. Boxes shaded white are Control Upland Swamps, boxes shaded grey are Impact Upland Swamps that are Pre-mining, boxes shaded blue are Post-mining–- within RMZ, and boxes shaded green are Post-mining–- mined beneath. Solid black points are the observations. See Table 1 for mining progress, number and status of Upland Swamps at the year surveyed.

Graph 34: Boxplot of the TSR for each transect, at Impact Swamp 1A, contrasted against Control Upland Swamps

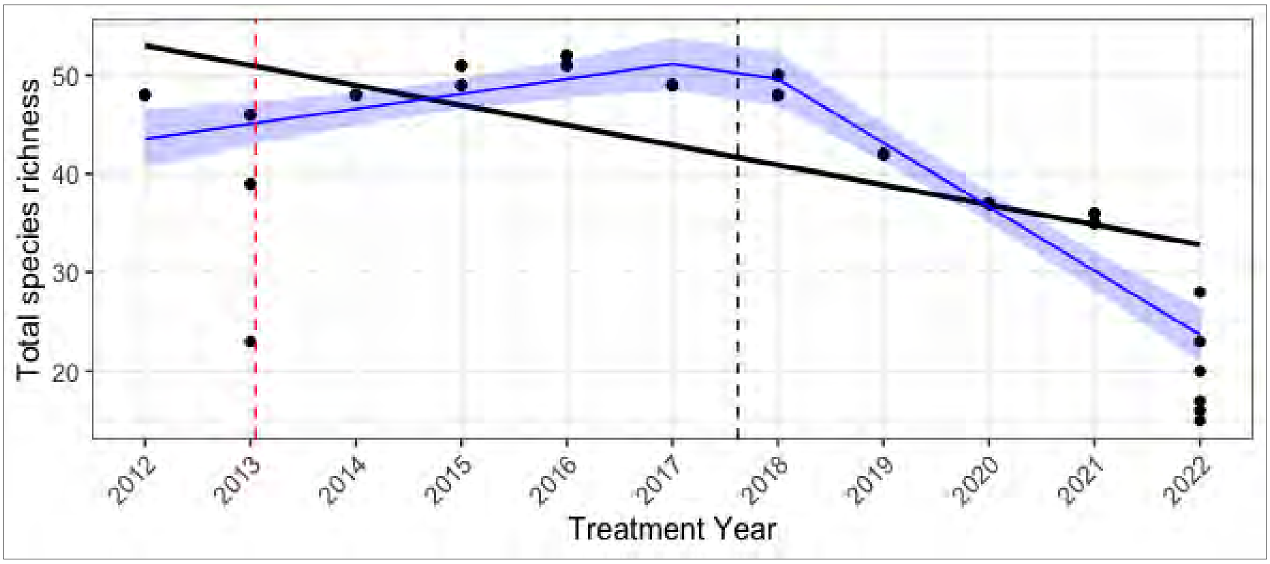
In 2015, TSR was statistically significantly different between Swamp 1A and the Control Group (Table 30), continuing into 2018. No further statistically significant differences have been detected, including in 2022.

Table 30: Comparison of mean TSR between Swamp 1A and control swamps over two-year periods

Comparison	Test statistic	D.f.	P-value
2013–2014	-4.78	1	0.131
2014–2015	-15.00	1	**0.042**
2015–2016	-15.00	1	**0.042**
2016–2017	-12.20	1	**0.052**
2017–2018	-19.09	1	**0.033**
2018–2019	-6.28	1	0.101

Comparison	Test statistic	D.f.	P-value
2020–2021	-5.42	1	0.116
2021–2022	-1.09	1	0.473

The best fitting breakpoint model had one break point in 2017-2018 (Graph 35). Prior to the break point there was a significant increase in TSR, and after the break point, there was a significant decline in TSR. The breakpoint identified did not coincide with the year of mining.



Best breakpoint analysis model as determined by AIC model section (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Breakpoints indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years for visual clarity).

Graph 35: Breakpoint analysis showing best fitting models at Impact Upland Swamp 1A

4.4.2.4.2 Species composition

No statistically significant difference in pre and post mining species composition data has been recorded to date, including in 2022 (Table 31). However, in 2022, the species composition is approaching the level of statistical significance (p-value: 0.062) as part of an ongoing trend and will be assessed in future monitoring.

Table 31: Species composition at Swamp 1A over two-year periods

Comparison	P-value (pre-post mining)	Percentage of deviance
2013–2014	0.763	0.483
2014–2015	0.916	0.538
2015–2016	0.847	0.504
2016–2017	0.739	0.447
2017–2018	0.597	0.409
2018–2019	0.614	0.407
2019–2020	0.253	0.338
2020–2021	0.095	0.298
2021–2022	0.062	0.284

4.4.2.4.3 Performance measure summary

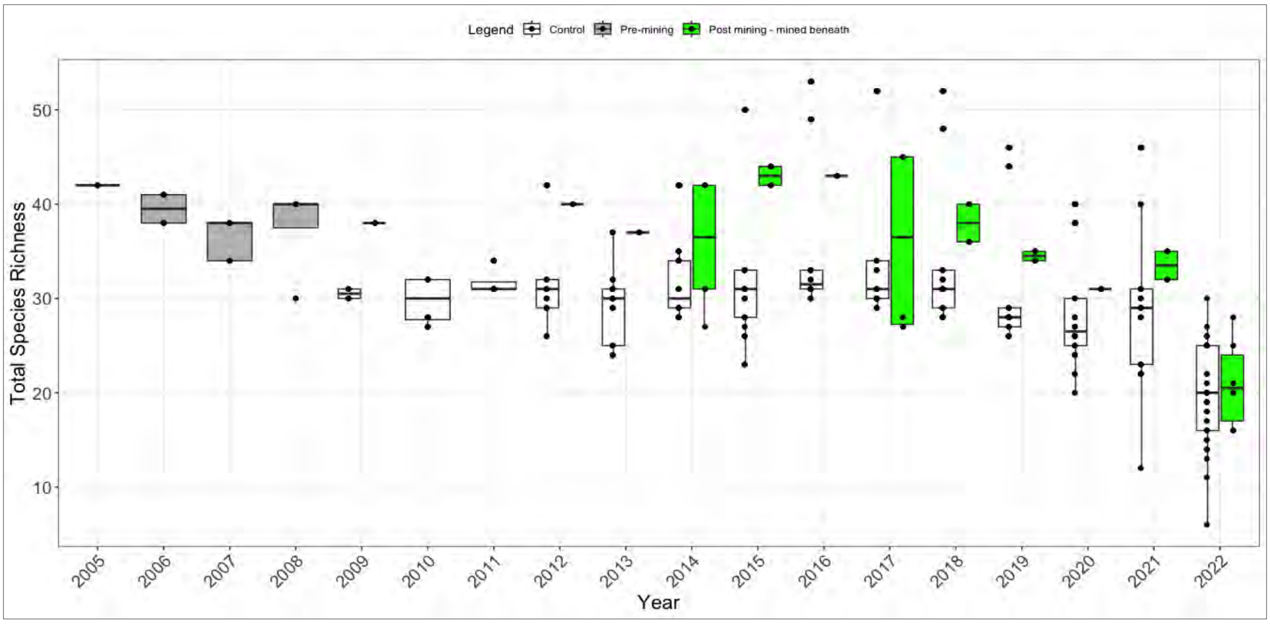
The statistically significant decline in TSR in 2014 to 2018 indicate a potential impact from mining, with Swamp 1A then appearing to continue to experience reduced TSR (Graph 34) more comparable with the Control Group. Although the breakpoint analysis demonstrates a pattern of increasing TSR post mining, before a significant decline occurring at some years post-mining. No TARPs have been triggered in 2022 for TSR and no statistically significant difference in species composition has been identified.

4.4.2.5 Swamp 1B

Monitoring at Swamp 1B began in 2005, with six years of pre mining baseline monitoring completed (2005-2009), followed by a gap of two-years not being monitored and then one year prior to mining being completed (2012). Mining entered within the RMZ of Swamp 1B in 2013 and was mined beneath in 2014. A total of 74 unique species were detected, of which 16% were detected only once.

4.4.2.5.1 TSR

Pre mining, the within year variability in TSR at control sites was more variable than at Swamp 1B, with this impact swamp often having a lower mean TSR than that of the control swamps. Since 2016, TSR at this swamp has declined to lower levels than before impact (Graph 36).



The solid line within the boxes is the median (i.e., the 5^{0t}h percentile), the margins of the box are the interquartile range (IQR, i.e., the 2^{5t}h and 7^{5t}h percentile), and the whiskers of the boxplot cover 1.5 times the IQR of the data. Boxes shaded white are Control Upland Swamps, boxes shaded grey are Impact Upland Swamps that are Pre-mining and boxes shaded green are Post-mining – mined beneath. Solid black points are the observations. See Table 1 for mining progress, number and status of Upland Swamps at the year surveyed.

Graph 36: Boxplot of the TSR for each transect at Impact Swamp 1B, contrasted against control swamps

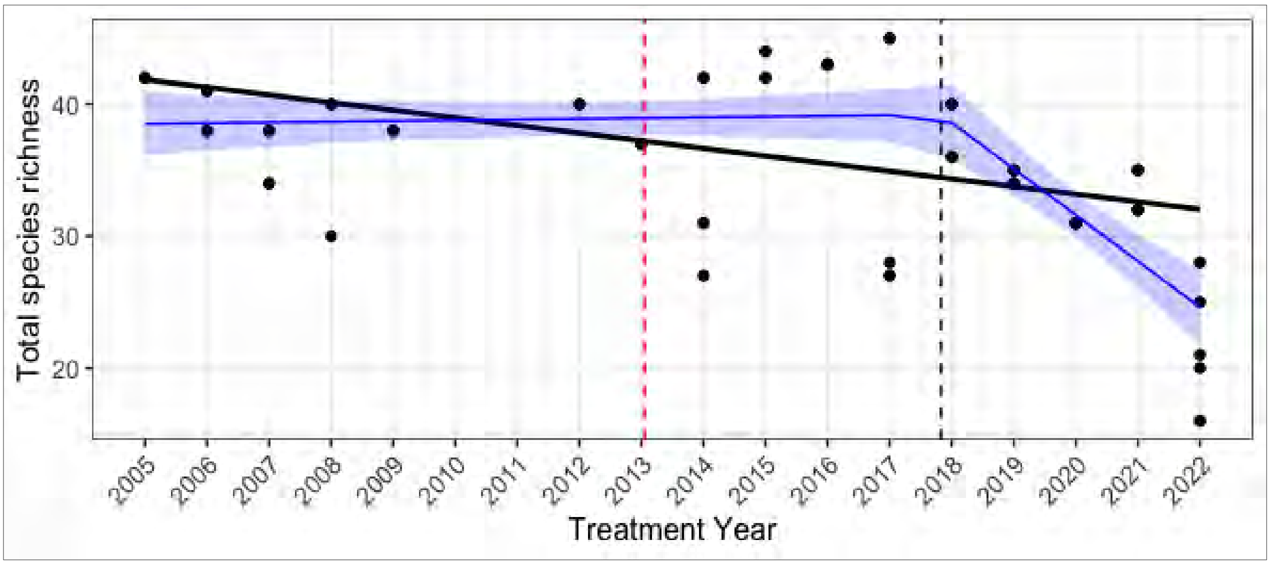
The mean TSR for Swamp 1B was statistically significantly different to that of control swamps between 2018 and 2021, but not in 2022 (Table 32).

Table 32: Comparison of mean TSR between Swamp 1B and Control swamps over two-year periods

Comparison	Test statistic	D.f.	P-value
2013–2014	1.11	1.12	0.452

Comparison	Test statistic	D.f.	P-value
2014–2015	0.08	1.03	0.949
2015–2016	-0.78	1.12	0.565
2016–2017	1.10	1.04	0.465
2017–2018	3.15	1.15	0.169
2018–2019	7.21	1.82	**0.024**
2019–2020	7.18	1.98	**0.019**
2020–2021	5.84	1.77	**0.037**
2021–2022	4.13	1.29	0.107

Additional breakpoint analysis identified that the best fitting model had one breakpoint in 2018 (Graph 37). TSR at this swamp was relatively stable until TSR declined statistically significantly from 2018, which did not coincide with the year of mining. Decline post 2018 coincides with the drought in 2017-2019, although no trend other than decline is currently observed in the data, including the 2020, 2021 and 2022 years.



Best breakpoint analysis model as determined by AIC model section (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Breakpoints indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years for visual clarity).

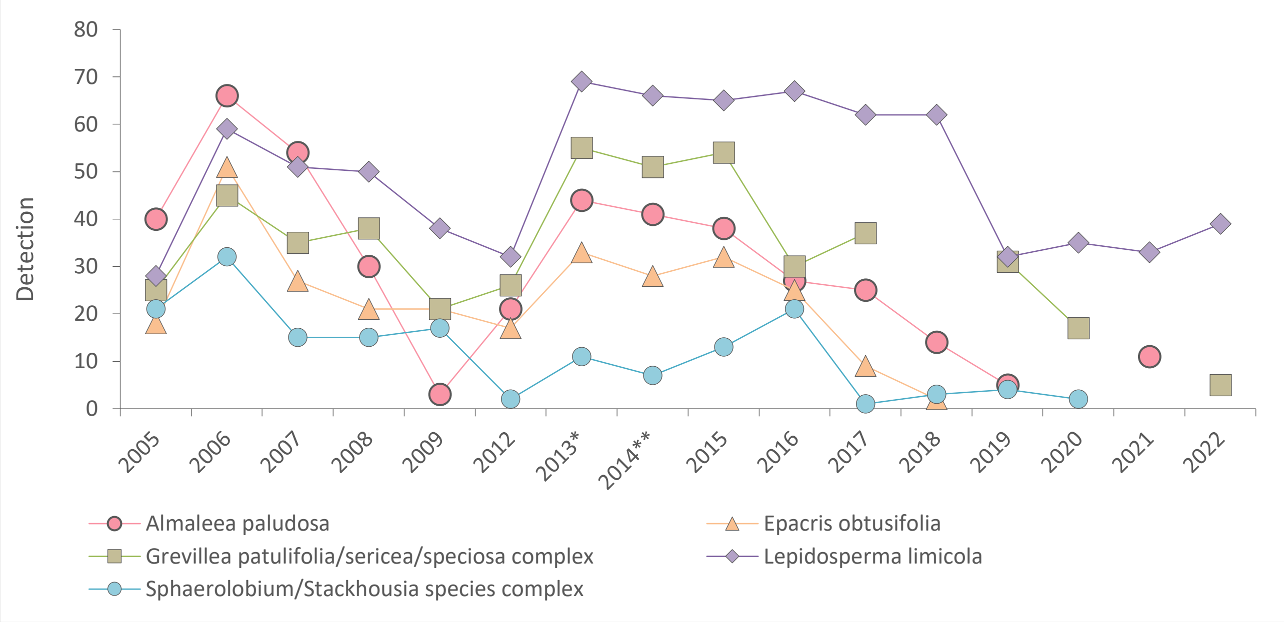
Graph 37: Breakpoint analysis showing best fitting models at Impact Upland Swamp 1B

4.4.2.5.2 Species composition

The species composition assessment shows a statistically significant change in species composition over eight consecutive years since 2015 (the year following being mined beneath), including 2022 (Table 33). The percentage of deviance relates to the five most influential species (species that have experienced the greatest level of change) (Table 33, Graph 38). In 2022, three of these species were *Lepidosperma limicola, Epacris obtusifolia* and *Almaleea paludosa,* all of which were more common prior to mining. These species are associated with ‘wet’ environments. The other two species were *Grevillea patulifolia sericea speciosa* complex and *Sphaerolobium Stackhousia* species complex, which were more common prior to mining. These species are associated with swamps and heath, but may also be associated with heath, or forested environments. The patterns of change identified in these species (Graph 38) are highly variable across all identified species, with both increases and decreases in detection recorded throughout the monitoring period. Overall trending declines for *Almaleea paludosa*, *Epacris obtusifolia, Grevillea patulifolia sericea* *speciosa* complex appear to have occurred since 2013 (coincident with mining activities), although these species also experienced trending declines in the pre-mining period before rebounding in 2013.

Table 33: Species composition at Swamp 1B over two-year periods

Comparison	P-value (pre-post mining)	Percentage of deviance
2013–2014	0.081	0.458
2014–2015	**0.03**	0.562
2015–2016	**0.007**	0.482
2016–2017	**0.004**	0.421
2017–2018	**0.003**	0.454
2018–2019	**0.002**	0.389
2019–2020	**0.001**	0.392
2020–2021	**0.001**	0.274
2021–2022	**0.001**	0.333



* RMZ, ** directly mined beneath

Graph 38: Detection of five most influential species at Impact Upland Swamp 1B

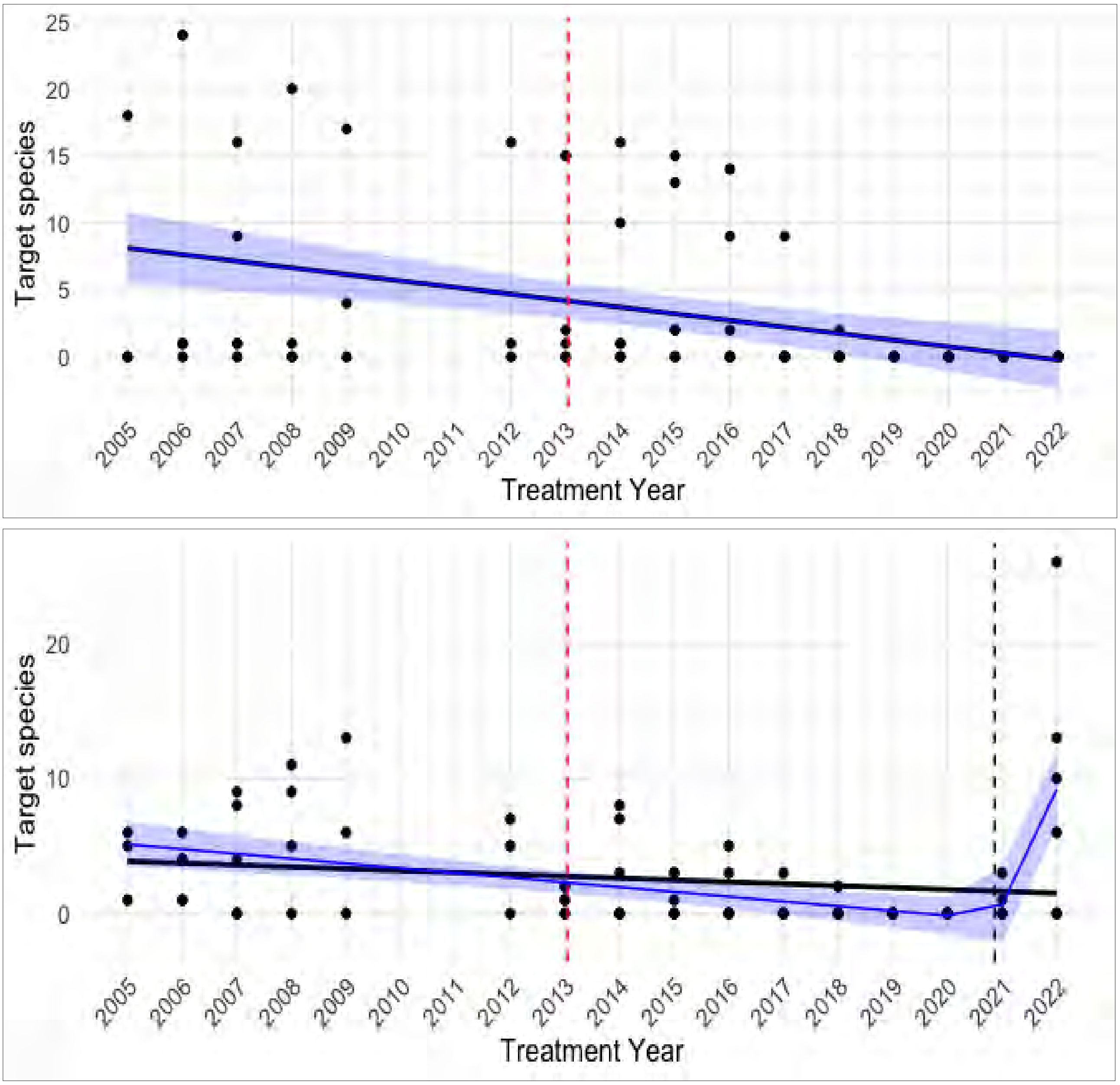
It is reasonable to expect natural species turnover to occur at the swamp, however, a statistically significant change in species composition has been detected over eight consecutive years, indicating a long-term shift in the flora species comprising Swamp 1B. The changes to species composition at Swamp 1B predominantly indicate a loss of species that prefer wet soils, progressively over time. Although, photo point monitoring in Swamp 1B (Plate 11, Plate 12 and Plate 13) does not show signs of gross visual trends of die-back of the Upland Swamp.

Plate 11: Swamp 1B F1 South Autumn 2015

Plate 12: Swamp 1B F1 South Autumn 2021

Plate 13: Swamp 1B F1 South Autumn 2022

Additional analysis of two key species identified as having strong trends over time at this swamp have been completed to examine whether the statistically significant breakpoints in these trends temporally align with mining activities. *Epacris obtusifolia* was identified as a species that was common prior to mining in 2013, but barely detected from 2017 onwards. The best fitting model was the linear model, showing a statistically significant decline but with no breakpoints (Graph 39). Detection of *Mitrasacme polymorpha/pilosa* species complex at Swamp 1B prior to impact was variable. Between 2017 and 2020 the number of detection events of this species became very uncommon (mostly zero) but in the past two-years it has been re-detected at this swamp. The best model had a single break point (Graph 39). There was initially a period of significant decline for this species, followed by the past two-years of a significant increase in detection events of this species. The certainty of this break point will become apparent in the coming years of data collection.



Best break point analysis model (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Break points indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years for visual clarity).

Graph 39: Breakpoint analysis showing best fitting models for *Epacris obtusifolia* (above) and *Mitrasacme polymorpha/ pilosa species complex* (below) at Swamp 1B

4.4.2.5.3 Performance measures summary

Table 34 details the historical TARP triggers for Swamp 1B. A statistically significant difference in TSR was not detected in 2022, as such no TSR TARP levels are triggered, following a Level one TARP in 2021 (Niche 2022a). Breakpoint analysis indicates the decline in TSR may align with the commencement of drought, however no recovery is evident in the post-drought period to date. Composition was statistically significantly different to pre-mining data, triggering a Level 1 TARP in 2016 (two consecutive years of impact), a Level 2 TARP in 2017 (three consecutive years impact), a Level 3 TARP in 2018 (four consecutive years impact), an exceeding TARP in 2019 onwards (eight years consecutive impact). TARPs were triggered for these years as the statistically significant difference in species composition was determined to be a result of a trend in loss of 'wet' species. Although the examination of the species identified as most influential in the composition analysis, and two species identified in the additional breakpoint analysis, suggest that factors additional to or other than mining may also be influencing swamp floristic change. Nevertheless, the species composition changes indicate an overall trend towards species more tolerant of dry soils in the post-mining period.

Table 34: Historical TARP triggers for Swamp 1B

Years	TSR TARP	Composition TARP
2014 (mined beneath)	None	None
2015	None	None
2016	None	Level 1 (two consecutive years): • 2014-2015 • 2015-2016
2017	None	Level 2 (three consecutive years): • 2014-2015 • 2015-2016 • 2016-2017
2018	None	Level 3 (four consecutive years): • 2014-2015 • 2015-2016 • 2016-2017 • 2017-2018
2019	None	Exceeding prediction (five consecutive years): • 2014-2015 • 2015-2016 • 2016-2017 • 2017-2018 • 2018-2019
2020	None	Exceeding prediction (six consecutive years): • 2014-2015 • 2015-2016 • 2016-2017 • 2017-2018 • 2018-2019 • 2019-2020
2021	Level 1 (two consecutive years): • 2019-2020 • 2020-2021	Exceeding prediction (seven consecutive years): • 2014-2015 • 2015-2016 • 2016-2017 • 2017-2018 • 2018-2019 • 2019-2020 • 2020-2021
2022	None	Exceeding prediction (eight consecutive years): • 2014-2015 • 2015-2016

Years	TSR TARP	Composition TARP
		- 2016-2017 - 2017-2018 - 2018-2019 - 2019-2020 - 2020-2021 - 2021-2022
Total times triggered	**1**	**7**

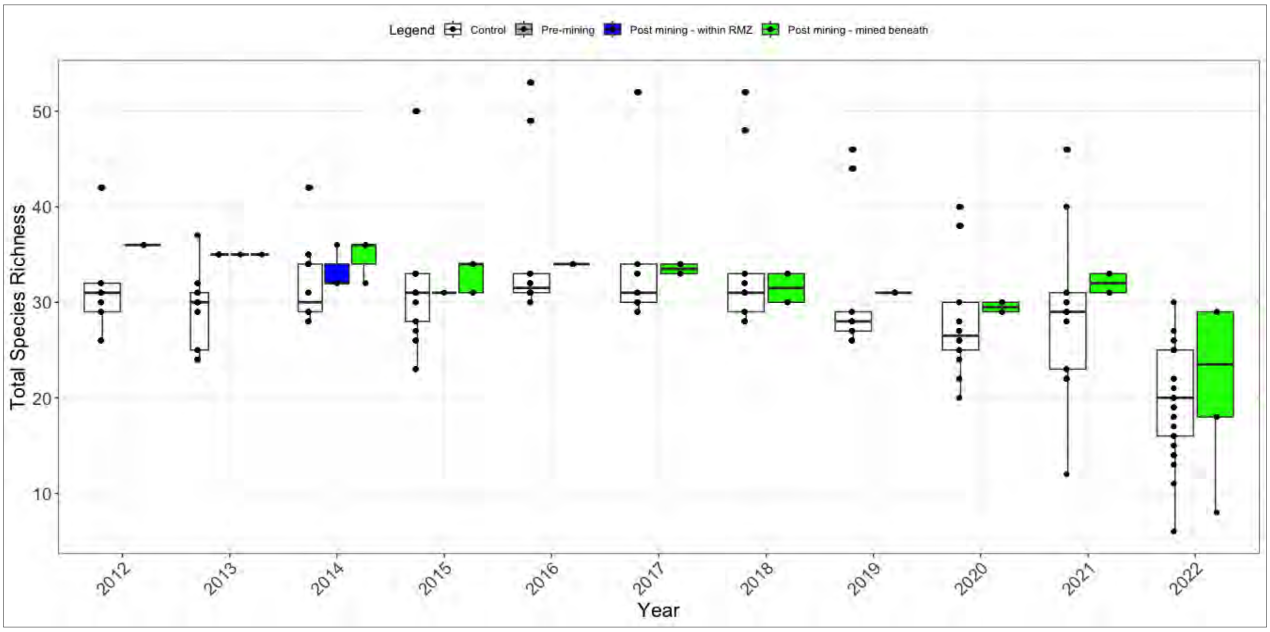
Note: TARP levels pre-2022 are those reported in Niche (2022a)

4.4.2.6 Swamp 5

Monitoring at Swamp 5 began in 2012 with two-years of pre mining baseline monitoring, mining within the RMZ commenced in 2013 with Longwall 9 and the swamp was mined beneath in 2014. A total of 49 unique species were detected, of which 12% were detected only once.

4.4.2.6.1 TSR

Graph 40 shows a boxplot of TSR data for Swamp 5 contrasted against Control Group. The combined data for all Control Swamps were more variable compared with Swamp 5. Visual assessment of the graph suggests that Swamp 5 has a slightly lower TSR since being mined beneath, but that this degree of reduction may be within the range observed at Control Upland Swamps (Graph 40).



The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentile), and the whiskers of the boxplot cover 1.5 times the IQR of the data. Boxes shaded white are Control Upland Swamps, boxes shaded grey are Impact Upland Swamps that are Pre-mining, boxes shaded blue are Post-mining - within RMZ, and boxes shaded green are Post-mining - mined beneath. Solid black points are the observations. See Table 1 for mining progress, number and status of Upland Swamps at the year surveyed.

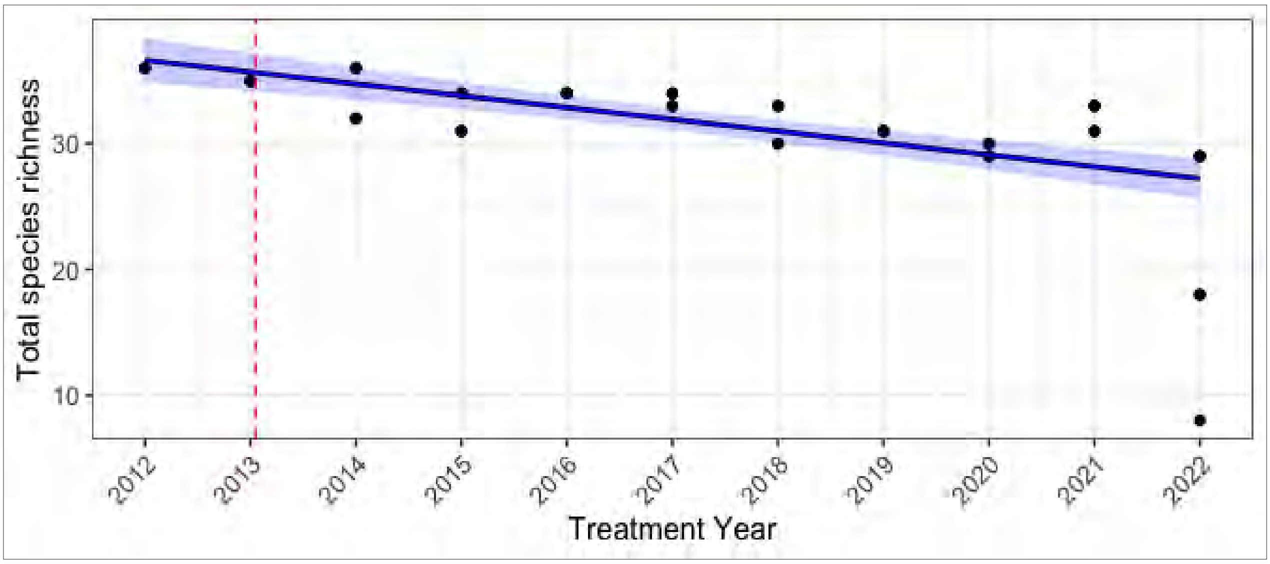
Graph 40: Boxplot of the TSR for each transect at impact Swamp 5, contrasted against control swamps

No statistically significant difference between TSR at Swamp 5 and control sites (Table 35) has been detected in 2022. Previous significant differences have been detected in 2017, 2018 and 2020.

Table 35: Comparison of mean TSR between Swamp 5 and control swamps over two-year periods

Comparison	Test statistic	D.f.	P-value
2014–2015	4.08	1.99	0.055
2015–2016	4.05	1.56	0.083
2016–2017	9.95	1.24	**0.039**
2017–2018	10.51	1.29	**0.033**
2018–2019	4.70	1.55	0.068
2019–2020	5.73	1.87	**0.034**
2020–2021	3.67	1.99	0.067
2021–2022	4.36	1.01	0.142

Additional breakpoint analysis identifies a trending decline in TSR at this swamp, with the most recent monitoring period having the lowest TSR levels since monitoring began (Graph 41).



Best breakpoint analysis model as determined by AIC model section (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Breakpoints indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years for visual clarity).

Graph 41: Breakpoint analysis showing best fitting models at Impact Upland Swamp 5

4.4.2.6.2 Species composition

The species composition analysis has not identified any statistically significant difference in the pre and post mining data to date (Table 35).

Table 36: Species composition at Swamp 5 over two-year periods

Comparison	P-value (pre-post mining)	Percentage of deviance
2013–2014	0.454	0.597
2014–2015	0.954	0.602
2015–2016	0.87	0.685
2016–2017	0.767	0.722
2017–2018	0.62	0.706
2018–2019	0.827	0.637
2019–2020	0.644	0.571

Comparison	P-value (pre-post mining)	Percentage of deviance
2020–2021	0.687	0.566
2021–2022	0.594	0.536

4.4.2.6.3 Performance measure summary

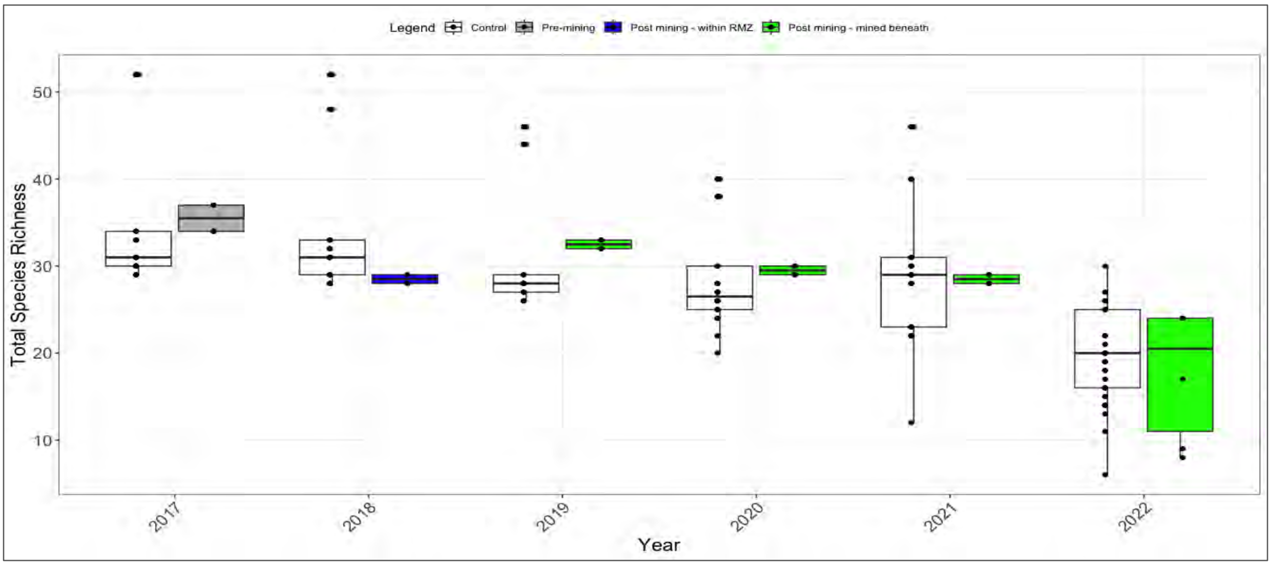
There were no TARPs triggered for Swamp 5 in 2022. Further, there are no statistically significant trends in the TSR or composition data, which appear to have little to no change when compared to data for Control sites. Swamp 5 is a long, narrow swamp, potentially indicating a potentially marginal/transitional Upland Swamp, with adjoining woodland species likely more prominent.

4.4.2.7 Swamp 23

Monitoring at Swamp 23 began in 2017 with one year of pre-mining baseline monitoring. Mining within the RMZ commenced in 2017 and the swamp was mined beneath by 2019. A total of 49 unique species were detected, of which 18% were detected only once.

4.4.2.7.1 TSR

Prior to mining, TSR at Swamp 23 was lower than that of the Control Group, which have also shown a greater degree of inter-year variability than that of Swamp 23 (Graph 42). There is an overall reduction in TSR observed at Swamp 23 over the course of the monitoring period, this is also seen at the control sites.



The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentile), and the whiskers of the boxplot cover 1.5 times the IQR of the data. Boxes shaded white are Control Upland Swamps, boxes shaded grey are Impact swamps that are Pre-mining, boxes shaded blue are Post-mining - within RMZ, and boxes shaded green are Post-mining - mined beneath. Solid black points are the observations. See Table 1 for mining progress, number and status of Upland Swamps at the year surveyed.

Graph 42: Boxplot of the TSR for each transect at Impact Swamp 23, contrasted against Control Upland Swamps

No statistically significant difference in TSR between Swamp 23 and the Control Group has been identified in 2022 (Table 37). Due to the limited data series, additional breakpoint analysis will be completed in future iterations of the monitoring program as more data is collected.

Table 37: Comparison of mean TSR between Swamp 23 and control swamps over two-year periods

Comparison	Test statistic	D.f.	P-value
2018–2019	0.56	1	0.675
2019–2020	-4.66	1	0.135
2020–2021	0.09	1	0.941
2021–2022	4.12	1	0.152

4.4.2.7.2 Species composition

No statistically significant difference in species composition pre and post mining at Swamp 23 has been detected, including in 2022 (Table 38).

Table 38: Species composition at Swamp 23 over two-year periods

Comparison	P-value (pre-post mining)	Percentage of deviance
2018–2019	0.731	0.617
2019–2020	0.541	0.627
2020–2021	0.395	0.54
2021–2022	0.341	0.462

4.4.2.7.3 Performance measure summary

Table 39 details the historical TARP triggers for Swamp 23, following Niche (2022a). There was a Level 1 TSR TARP triggered for Swamp 23 in 2020, this progressed to a Level 2 TARP in 2021. However, no significant difference was detected in 2022, as such the TSR TARP ceases to be triggered in 2022.

No statistically significant change in species composition has been detected. This Upland Swamp should continue to be monitored and allow more time since mining to observe if any further changes arise.

Table 39: Historical TARP triggers for Swamp 23

Years	TSR TARP	Composition TARP
2019	None	None
2020	Level 1 (two consecutive years) • 2018-2019 • 2019-2020	None
2021	Level 2 (three consecutive years): • 2018-2019 • 2019-2020 • 2020-2020	None
2022	None	None
Total times triggered	**2**	**0**

Note: TARP levels pre-2022 are those reported in Niche (2022a)

4.4.3 Cumulative impacts

Discussion of cumulative impacts to swamps is an important part of the analysis of impacts, as a small change may never be statistically significant when comparing the data between two consecutive years (as dictated by the TARPs), but might be statistically significant at a different timescale, such as over the entire survey (TAE 2023d).

To remedy this, an analysis of cumulative impact in TSR and species composition was undertaken over three, four and five years to enable detection of change over time. Testing across three, four and five years of data provides a larger magnitude and therefore greater ability to detect change over time (i.e. cumulative impacts).

Cumulative impacts have been observed at the following swamps, based upon the 2022 statistical analysis:

- Swamp 15A(2) (TSR and composition) – Cumulative analysis indicates a statistically significant decline in TSR over time over four-year periods (2016–2019, 2017–2020, 2018–2021, 2019–2022). Swamp composition has also been changing statistically significantly over four-year periods (2017-2020, 2018-2021, 2019-2022), this time period with 'wetter' species becoming less common post impact, suggesting a loss of species that prefer moist soils.
- Swamp 15B –A statistically significant change in composition over consecutive four-year periods is observed, commencing in 2010-2013, although this is detected for a range of species preferences.
- Swamp 11 - Cumulative analysis indicate statistically significant decline in TSR over the five-year period 2018–2022 and change in composition over consecutive five-year periods (2016-2020, 2017-2021, 2018-2022), with primarily 'wetter species becoming less common post impact.
- Swamp 13 – Cumulative analysis indicate statistically significant decline in TSR over consecutive five-year periods (2017–2021, 2018–2022) and change in composition over consecutive five year periods (2018-2021, 2019-2022), although this is detected for a range of species preferences.
- Swamp 14 – Cumulative analysis indicate statistically significant change in composition over the consecutive four-year period (2020-2023), with primarily 'wetter species becoming less common post impact.
- Swamp 1A – Cumulative analysis over five years show that the TSR is continually reducing over consecutive five year periods (2013–2017, 2014–2018, 2015–2019, 2016–2020, 2017–2021, 2018–2022). Species composition data does not identify a statistically significant trend.
- Swamp 1B – Cumulative analysis over five years show that the TSR is continually reducing over time (over consecutive five year periods (2016–2020, 2017–2021, 2018–2022)) and change in composition over consecutive five-year periods (2013-2017, 2014-2018, 2015-2019, 2016-2020, 2017-2021, 2018-2022). Overall, the changes to species composition indicate a loss of 'species that prefer wet soils, although not exclusively.
- Swamp 5 – Cumulative analysis shows a statistically significant decline in TSR over consecutive five-year periods (2014–2018, 2015–2019, 2016–2020, 2017–2021, 2018–2022).
- Swamp 23 – Cumulative analysis shows a statistically significant decline in TSR over consecutive four-year periods (2018–2021, 2019–2022).

4.5 Photo point monitoring

Photo point monitoring over time can be a visual indicator of change. The current photo points are provided in Annex 5 and may be compared to previous monitoring reports. Photo point monitoring has been utilised where relevant to further describe trends observed in other data analysis (see Section 3.5).

Previous reports have observed that when Control swamps are compared with Impact Swamps over the same time period (five years), there is a noticeable difference in the growth of many of the shrubs from small and barely in the photograph to now dominant in the image (Niche 2021), at both the Control and Impact swamps. For example, in Swamp 86 (Control Swamp) the shrub layer present can be observed to have grown in size and appears to have encroached inwards towards the swamp, with sedgeland species appearing to be giving way to more shrub species in 2019 (through to 2022). These comparisons over time suggest a change in composition for this swamp, at least in the margins, with more *Banksia ericifolia* and fewer sedges (Plate 14, Plate 15, Plate 16).

Plate 14: Swamp 86 F3 South Spring 2015

Plate 15: Swamp 86 F3 South Spring 2021

Plate 16: Swamp 86 F3 South Spring 2022

4.6 Littlejohn's Tree Frog monitoring

The following sections describe the biological and physical data collection results for 2022 in the context of previous years of monitoring and detail the outcomes of statistical analysis to test for trends in Littlejohn's

Tree Frog counts associated with mining and habitat characteristics. The detection data for all transects across the Program is presented in Annex 3, with statistical outputs tabulated in Annex 4.

An assessment against performance measures for the relevant TARP's is provided in Section 5.

4.6.1 Monitoring results summary across Dendrobium Area 3

A summary of the Littlejohn's Tree Frog data for all lifecycle stages (i.e. Adult, Tadpole or Eggmass) that were recorded across the entire monitoring program, noting that more sites were added over time, is provided in Table 40. When considered in the context of previous years of monitoring, 2022 recorded relatively high levels of detection across the Eggmass and Adult life stages, but low levels of Tadpole detection.

Table 40: Total Littlejohn's Tree Frog abundance by life stage for all years of monitoring

Year	Total number of transects	Number of impact transects	Number of Control transects	Number of pre-mining transects	Eggmass*	Tadpoles	Adults
2006	5	3	1	1	0	7	79
2007	8	4	2	2	14	162	104
2008	9	5	2	2	95	261	41
2009	10	5	3	2	198	464	54
2010	14	8	4	2	930	1036	86
2011	16	8	6	2	155	362	172
2012	16	8	6	2	325	283	106
2013	21	11	8	2	368	950	110
2014	21	11	8	2	387	956	148
2015	21	11	8	2	644	1061	149
2016	21	11	8	2	2664	6147	273
2017	21	11	8	2	481	1166	169
2018	21	11	8	2	385	1082	129
2019	21	11	8	2	305	3290	242
2020	21	11	8	2	140	4756	230
2021	21	11	8	2	477	2358	61
2022	23	14	9	0	1090	518	173

**Includes both viable and non-viable Eggmass, as evidence of breeding activity (section 2.1.5)*

A summary of the detection results for the 2022 season are provided in Table 41 below. Littlejohn's Tree Frog were detected in at least one lifecycle stage at eleven of the fourteen post-mining (mined beneath and within RMZ) impact sites. No Littlejohn's Tree Frogs were recorded at three impact transects (LA4A, LA2 and ND2). At least one lifecycle stage was detected at all nine control sites monitored in 2022.

Table 41: Littlejohn's Tree Frog detection results for 2022

Transect	Treatment	Area	Life stage			Transect attributes	
			Total Eggmass*	Total Tadpoles	Total Adults	Transect length	Breeding pools**
Control							
SC7(1)	-	3A	53	0	6	474	20
SC7(2)	-	3A	13	130	13	436	9
SC7A	-	3A	159	79	9	453	22
SC8	-	3A	7	0	7	315	21
DC8	-	Outside	0	0	9	432	3
WC10	-	Outside	83	45	11	346	19
WC11	-	Outside	9	0	5	176	6
CR29	-	6	19	7	2	837	15
CR29D	-	6	7	14	0	351	9
Impact							
6CDL	RMZ	3A	4	95	2	89	8
SC10(1)	Mined beneath	3A	9	0	19	539	15
SC10(2)	Mined beneath	3A	599	81	33	950	36
SC10C	Mined beneath	3A	3	2	8	481	12
WC17	Mined beneath	3A	3	1	4	177	7
WC15	Mined beneath	3B	30	17	1	478	16
DC(1)	RMZ	3B	5	0	3	642	17
LA4A	RMZ	3B	0	0	0	209	3
LA2	Mined beneath	3B	0	0	0	593	23
DC13	Mined beneath	3B	25	0	4	641	17
WC21	Mined beneath	3B	26	2	4	1399	35
ND1	RMZ	3B	36	45	31	742	26
ND2	RMZ	3B	0	0	0	123	7
NDC	RMZ	3B	0	0	2	555	18

**including non-viable Eggmass*

***Previously marked breeding pools only, i.e. not including incidental records*

A total of 1090 Eggmass were recorded during the 2022 surveys across the monitoring transects (Table 42). Of these, 53 were considered non-viable based upon field observations (section 2.1.5), equating to approximately 5% of all Eggmass detected. Non-viable Eggmass were observed at two control transects and three impact transects. The greatest number of non-viable Eggmass (40) were recorded at SC10(2), however a significant number of viable Eggmass (559) were recorded at this site, with non-viable Eggmass representing only a fraction of the total number of Eggmass detected (approximately 7%).

Table 42: Littlejohn's Tree Frog Eggmass detection results for 2022

Transect	Treatment	Area	Viable Eggmass	Non-viable Eggmass	Total Eggmass
Control					
SC7(1)	-	3A	53	0	53
SC7(2)	-	3A	13	0	13
SC7A	-	3A	159	0	159
SC8	-	3A	7	0	7
DC8	-	Outside	0	0	0
WC10	-	Outside	76	7	83
WC11	-	Outside	9	0	9
CR29	-	6	19	0	19
CR29D	-	6	5	2	7
Impact					
6CDL	RMZ	3A	2	2	4
SC10(1)	Mined beneath	3A	9	0	9
SC10(2)	Mined beneath	3A	559	40	599
SC10C	Mined beneath	3A	3	0	3
WC17	Mined beneath	3A	3	0	3
WC15	Mined beneath	3B	30	0	30
DC(1)	RMZ	3B	5	0	5
LA4A	RMZ	3B	0	0	0
LA2	Mined beneath	3B	0	0	0
DC13	Mined beneath	3B	25	0	25
WC21	Mined beneath	3B	26	0	26
ND1	RMZ	3B	34	2	36
ND2	RMZ	3B	0	0	0
NDC	RMZ	3B	0	0	0

When considered as broad groups (Table 43), the total and average number of Eggmass and Adults recorded in 2022 were greater at the Impact Group than the control transect group. The significant number of Eggmass recorded at transect SC10(2) was a major factor in this. In contrast, the total and average number of Tadpoles was greater at the Control Group.

Table 43: Summary Littlejohn's Tree Frog detection results for 2022

Treatment		Detection results 2022			Transect attributes (total)	
		Total Eggmass*	Total Tadpoles	Total Adults	Transect length	Breeding pools**
Control summary	Total:	350	275	62	3820	124
	Average:	39	31	7	424	14
Impact summary	Total:	740	243	111	7618	240
	Average:	53	17	8	544	17

Includes both viable and non-viable Eggmass. Includes only pools marked in previous pool mapping.*

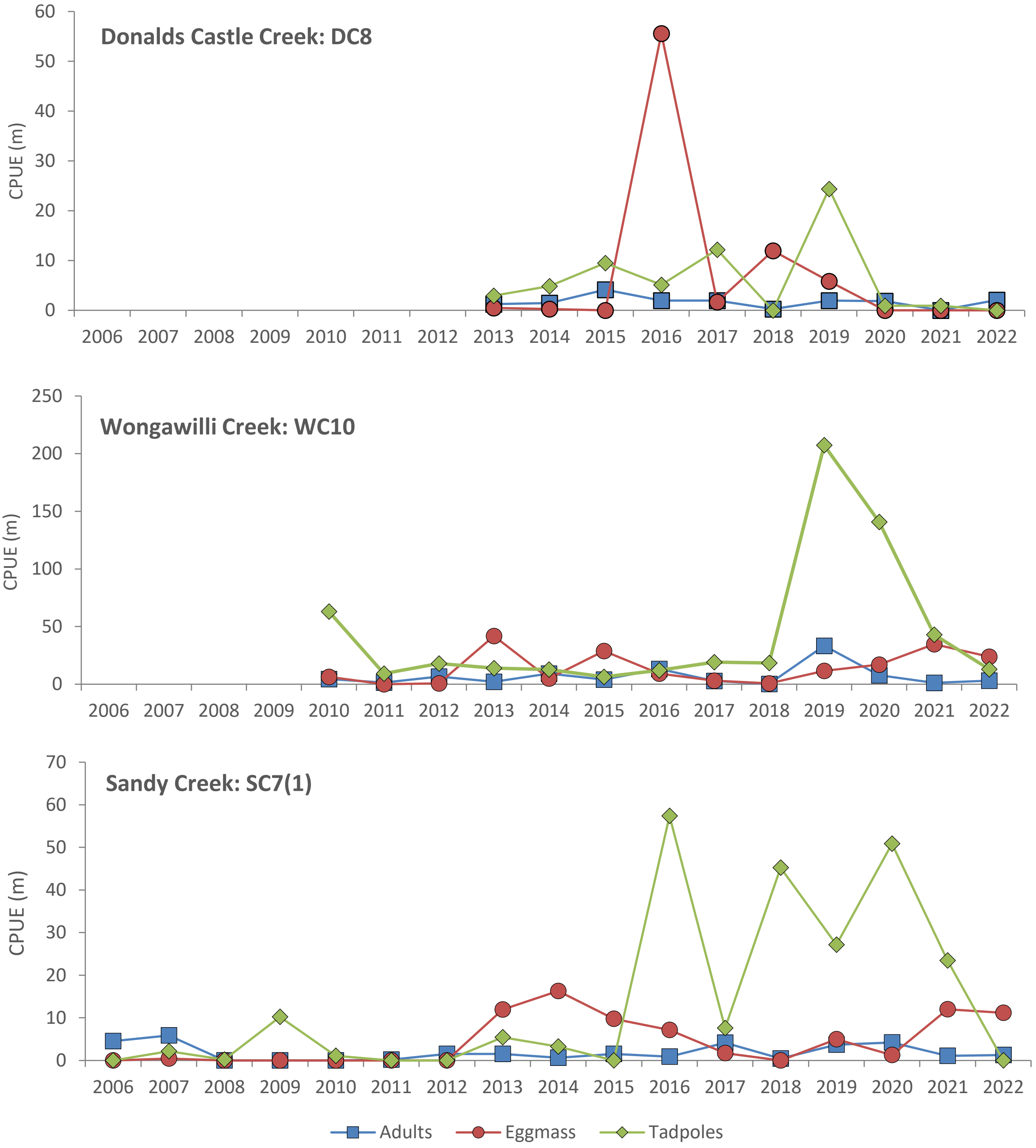
4.6.2 Patterns of abundance across un-impacted sub-catchment areas

Dendrobium Area 3 occurs across four main sub-catchments. The Donalds Castle Creek and Wongawilli Creek sub-catchments flow northwards out of Area 3 and join before flowing to the Cordeaux River. Native Dog Creek flows west to Lake Avon, having a relatively smaller sub-catchment area to the others. The Sandy Creek sub-catchment flows north-east into Lake Cordeaux. Each of these sub-catchments are represented by control and impact transects, except Native Dog Creek where in 2022, mining has entered within the RMZ of each transect.

A summary of the data collected at each of the Donalds Castle Creek, Wongawilli Creek and Sandy Creek sub-catchments over time is presented in the following series of graphs (Graph 43). Each sub-catchment is represented by one control transect, selected based on the highest or most consistent level of detection. This series of graphs is presented in order to establish whether there are any general patterns of change across un-impacted areas of Dendrobium Area 3 to provide context for the presentation and interpretation of data from the impact sites, and comparisons between the impact and control transects.

Graph 43 demonstrates a high degree of variability across years, lifecycle stages and across sub-catchments. The datasets are characterised by typically low levels of detection with some peaks in individual years. These peaks in detection are generally not consistent across the sub-catchments and do not necessarily follow predictable patterns i.e. peaks in adult detection do not typically align with peaks in Eggmass detection, nor does Tadpole detection appear to peak following relatively high numbers of Eggmass being recorded. Interestingly, while a reduction in detection is apparent across transects and lifecycle stages there is also no uniform response (in terms of scale or timing) to the recent drought evident (2017-2019) with some peaks in detection also occurring during this period. Furthermore, peaks in detection do not necessarily occur in the subsequent above average rainfall years (2020 -2022).

These graphs presented serve to underline the unpredictability in detection of this species, complex relationship between lifecycle-stages and their likely connection to environmental variables at a population scale. These complex and unpredictable patterns may be suggestive of several factors beyond the scope of this program to investigate, including a propensity in the species for movement across sites, breeding activity occurring over an extended period of the year and possibly differing fine scale environmental conditions, and responses in the species, across the sub-catchments or transects to prevailing conditions. To a limited extent this may also reflect a limitation of single survey approach in the Program. The interpretation of the results detailed in the following sections must be considered in this context and supported by assessment of habitat features as well as frog detection.



Graph 43: Littlejohn's Tree Frog detection between 2007 - 2022 at control sites DC8, WC10 and SC7(1)

4.6.3 Pool characteristics and trends recorded across Dendrobium Area 3

The pool characteristics across the monitoring transects have been considered in detail in Niche (2021, 2022a). Overall, these results indicate potentially more favourable pool sizes at the Control sites, but also that the environmental conditions (water availability and absence of flocculant) are also generally more favourable for the Littlejohn's Tree Frog at the Control sites. Previous reports have established a statistically significant relationship between detection and pool size, with more Adults and Tadpoles being detected in deep pools, with Eggmasses more evenly spread (Niche 2021, 2022a).

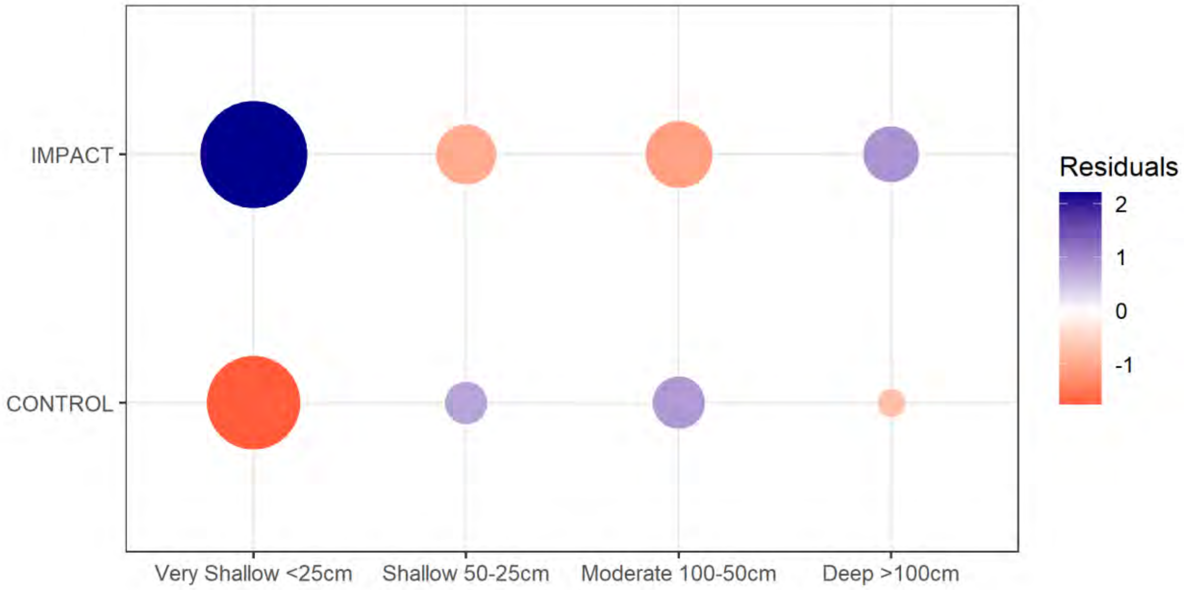
4.6.3.1 Analysis of pool characteristics: 2022

Statistical analyses has been completed to explore the difference between impact and control transect pool characteristics for Dendrobium Area 3A and 3B, to provide further context for the interpretation of the biological frog detection data. Note that these analyses only consider maximum pool depth as a proxy for pool size, to understand underlying potential habitat conditions, this does not take into account the water level within the pool which may be influenced by other factors (e.g. rainfall or mining impact).

These exploratory analyses indicate that there are statistically significant differences between pool characteristics at the area level between Dendrobium Area 3A and 3B, as well as the Native Dog Creek transects (becoming Impact sites in 2022), when compared to the Control sites. Across the Dendrobium Area 3A impact transects there is a greater proportion of very deep and very shallow pools, indicating a potentially greater degree of habitat variation along these transects. Across Dendrobium Area 3B moderate pools were more common at the Control Group than at the impact sites, with the impact sites having a greater number of very shallow pools. As this is the first year of 'RMZ' monitoring for the Native Dog Creek transects, these have also been considered in detail. There were more very shallow pools at the Native Dog Creek transects and more moderate pools at the Control transects.

4.6.3.2 Dendrobium Area 3A pool characteristics

There were statistically significantly different pool characteristics between Control Group and the Impact sites at Dendrobium Area 3A (χ^2 = 12.499, df = 3, p = 0.0059). When considering the Dendrobium Area 3A impact transects against the control transects, very shallow and also very deep pools were overrepresented at the impact transects (Graph 44).

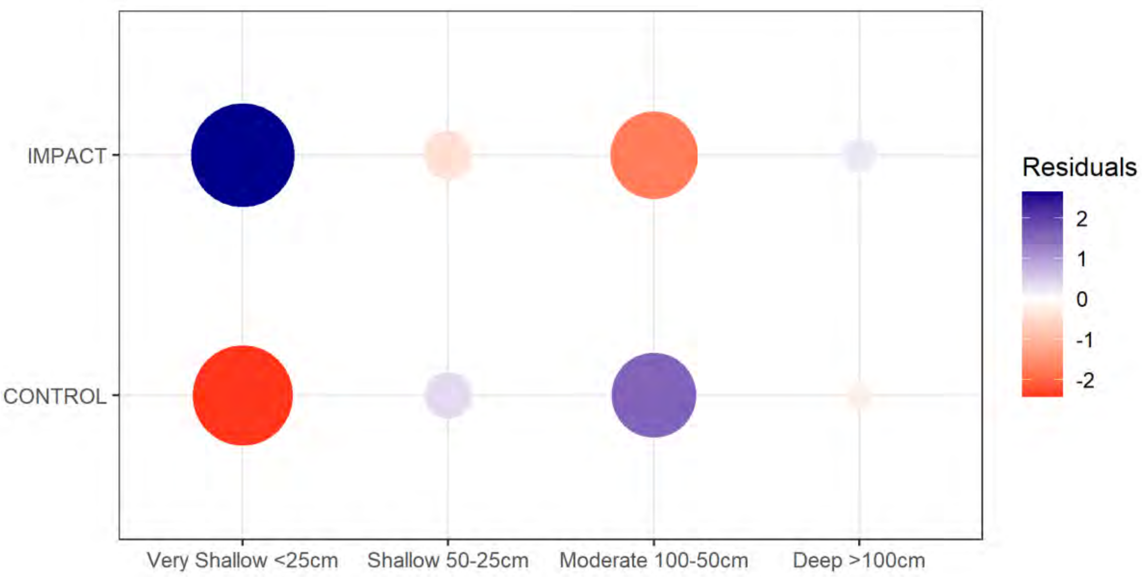


The colour scale, blue-red indicates overrepresented-underrepresented, while size of the circle indicates the degree. For example, a small red circle means slightly underrepresented, while a large blue circle means strongly overrepresented.

Graph 44: Residual scores from χ^2 test of independence for pools size distribution amongst control (n=120) and impact (n=75) transects at Dendrobium Area 3A.

4.6.3.3 Dendrobium Area 3B pool characteristics

There were statistically significantly different pool characteristics between Control and the Impact sites at Dendrobium Area 3B ($\chi^2 = 18.837$, DF = 3, $p < 0.001$) (Graph 45), noting that the Native Dog Creek transects are considered separately below. When considering the Dendrobium Area 3B impact transects against the control transects, there were more moderate pools at the Control transects and more very shallow pools at the Impact transects (Graph 45).

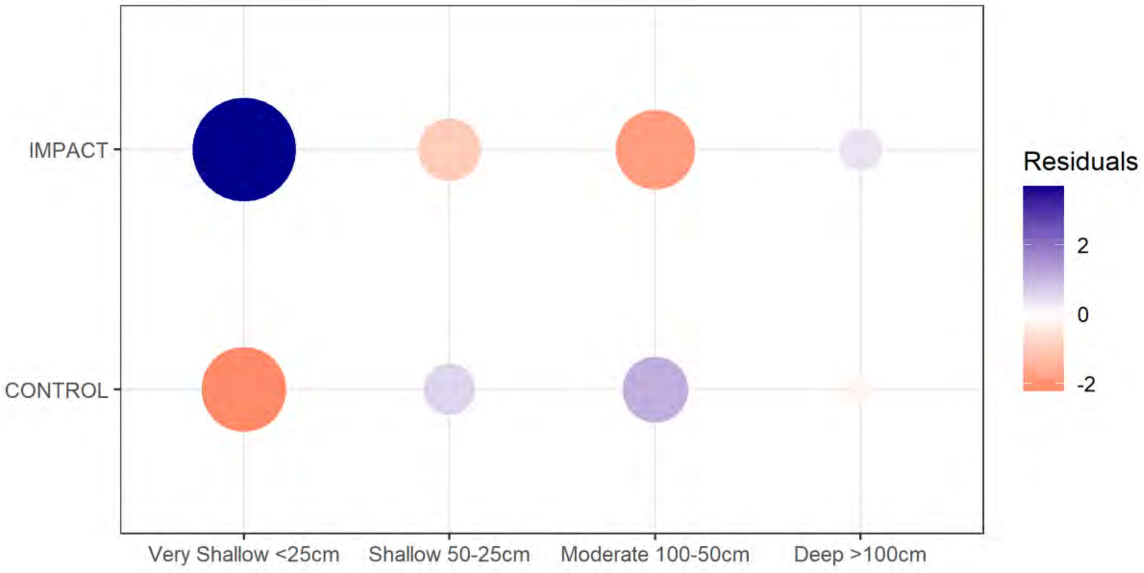


The colour scale, blue-red indicates Overrepresented-Underrepresented, while size of the circle indicates the degree. For example, a small red circle means slightly underrepresented, while a large blue circle means strongly overrepresented.

Graph 45: Residual scores from χ^2 test of independence for pools size distribution amongst control (n=120) and impact (n=137) transects at Dendrobium Area 3B.

4.6.3.4 Native Dog Creek pool characteristics

There were statistically significantly different pool characteristics between Control and the Impact sites at the Native Dog Creek transects ($\chi^2 = 24.793$, DF = 3, $p < 0.0001$) (Graph 46). When considering the Native Dog Creek impact transects against the control transects, there were more moderate pools at the Control transects and more very shallow pools at the Impact transects (Graph 46).



The colour scale, blue-red indicates Overrepresented-Underrepresented, while size of the circle indicates the degree. For example, a small red circle means slightly underrepresented, while a large blue circle means strongly overrepresented.

Graph 46: Residual scores from χ^2 test of independence for pools size distribution amongst control (n=120) and impact (n=43) transects at Native Dog Creek.

4.6.4 Dendrobium Area 3A

Within Dendrobium Area 3A two main creeks and selected tributaries are monitored, with both Control and Impact sections (Figure 5):

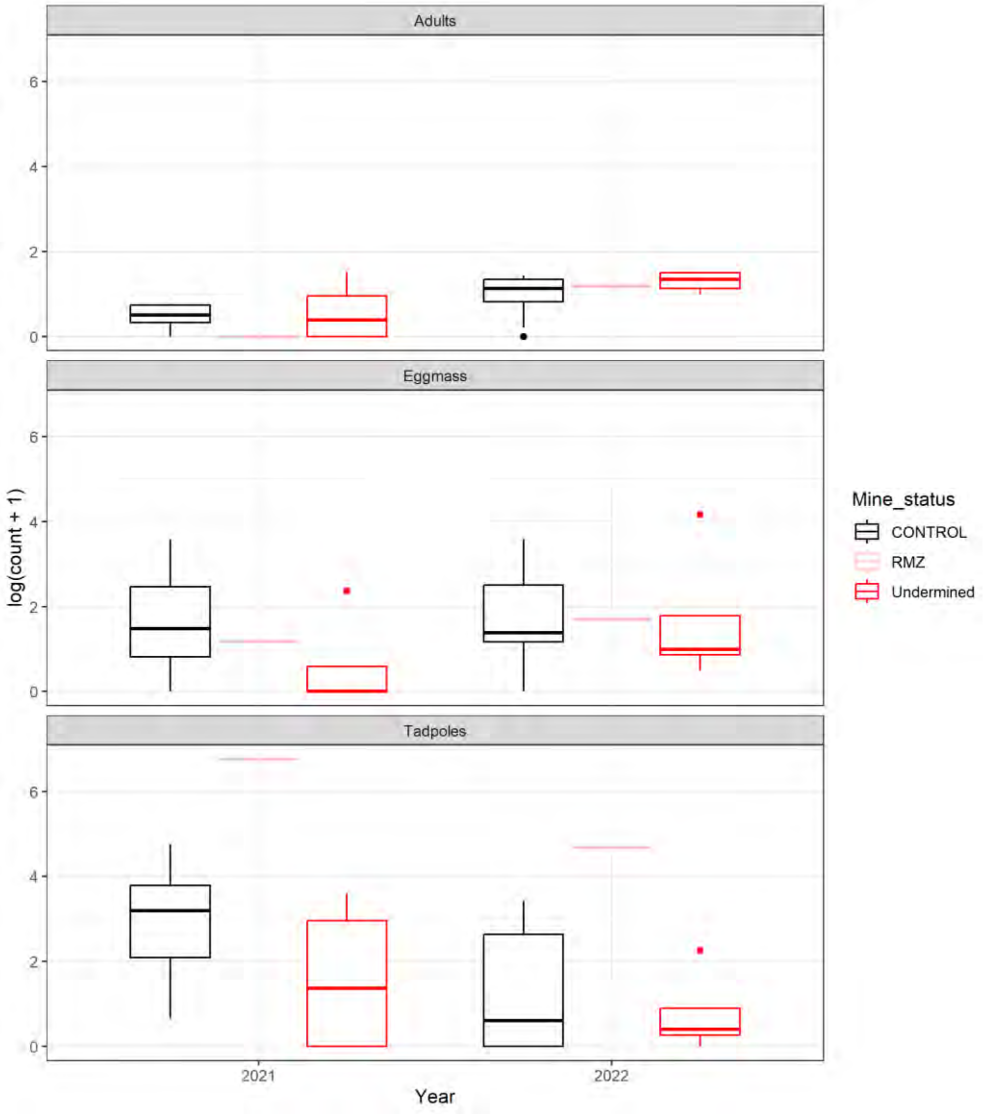
- Sandy Creek first and second order tributaries SC10C, SC10(1), SC10(2), 6CDL, SC7(1), SC7(2), SC7A and SC8
- Wongawilli Creek (third order or higher) and tributaries WC10, WC11 and WC17.

Many of these waterways and transects are interconnected, so it is likely that Littlejohn's Tree Frog move throughout these catchments in response to a number of environmental and seasonal variables which may influence breeding, recruitment and migration.

4.6.4.1 Overall trends

When comparing frog detection results from 2021 to 2022, a significant difference (p-value < 0.001) between the overall impact and Control Groups in Area 3A was detected for the Tadpole life stage, with lower counts recorded at the impact sites. No other statistically significant difference in detection of any other lifecycle stage was identified between the overall impact and Control Groups in Area 3A.

When considering the results regardless of treatment, there was a statistically significant difference in Adult counts (p-value = 0.012) and Eggmass (p-value = 0.029), with Adult and Eggmass detection increased in 2022 in comparison to 2021. The interaction between 'treatment' and 'year' was also significant for Tadpoles (P-value <0.0001) in the 2021-2022 period, with decreased detection in 2022 (Graph 47).



Graph 47: Boxplots of counts of Adults, Tadpoles, Eggmasses at Dendrobium Area 3A, 2021-2022 (left-right), and between Treatments (Control (n=9), black, Impact (n=5), red)

4.6.4.2 6CDL

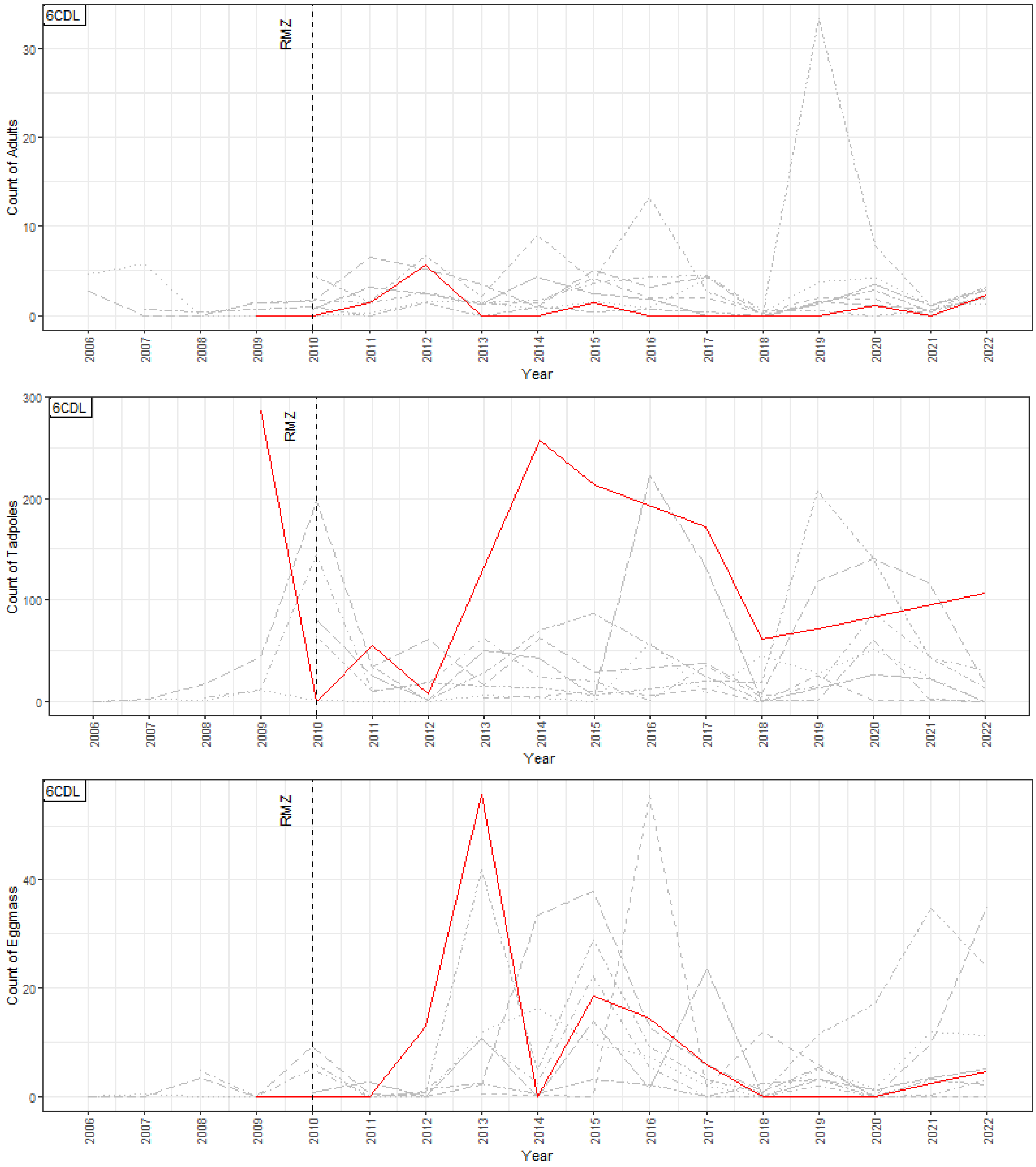
6CDL had one year of pre-mining data in 2009 and within the RMZ in 2010, due to the location of the longwalls this tributary is not planned to be mined beneath. It will remain in the RMZ and experience potential indirect impacts from the nearby Longwall 7 which is approximately 40 – 60 m away (Figure 5g). No visual indicators of impact were observed in 2022.

Two Adults, four Eggmass and a large number of Tadpoles (n = 95) were observed at 6CDL during the 2022 survey. Adults were heard and Eggmass were incidentally observed upstream of the transect at the time of survey.

The statistical test for trends over long-term before and after mining effects at this tributary has not been identified as statistically significant for any lifecycle stage (Appendix 4). While there are statistically significant differences between detection of Adults and Tadpoles at 6CDL in comparison the Control Group, these are for the pre-mining and RMZ. Meaning that differences between 6CDL and the Control Group pre-date mining.

Observable changes in populations have also largely happened at the Control sites (Graph 48). Detection levels, while variable, have not been observed to decline post mining.

On the basis of the above factors, no TARP levels have been triggered at 6CDL in 2022.



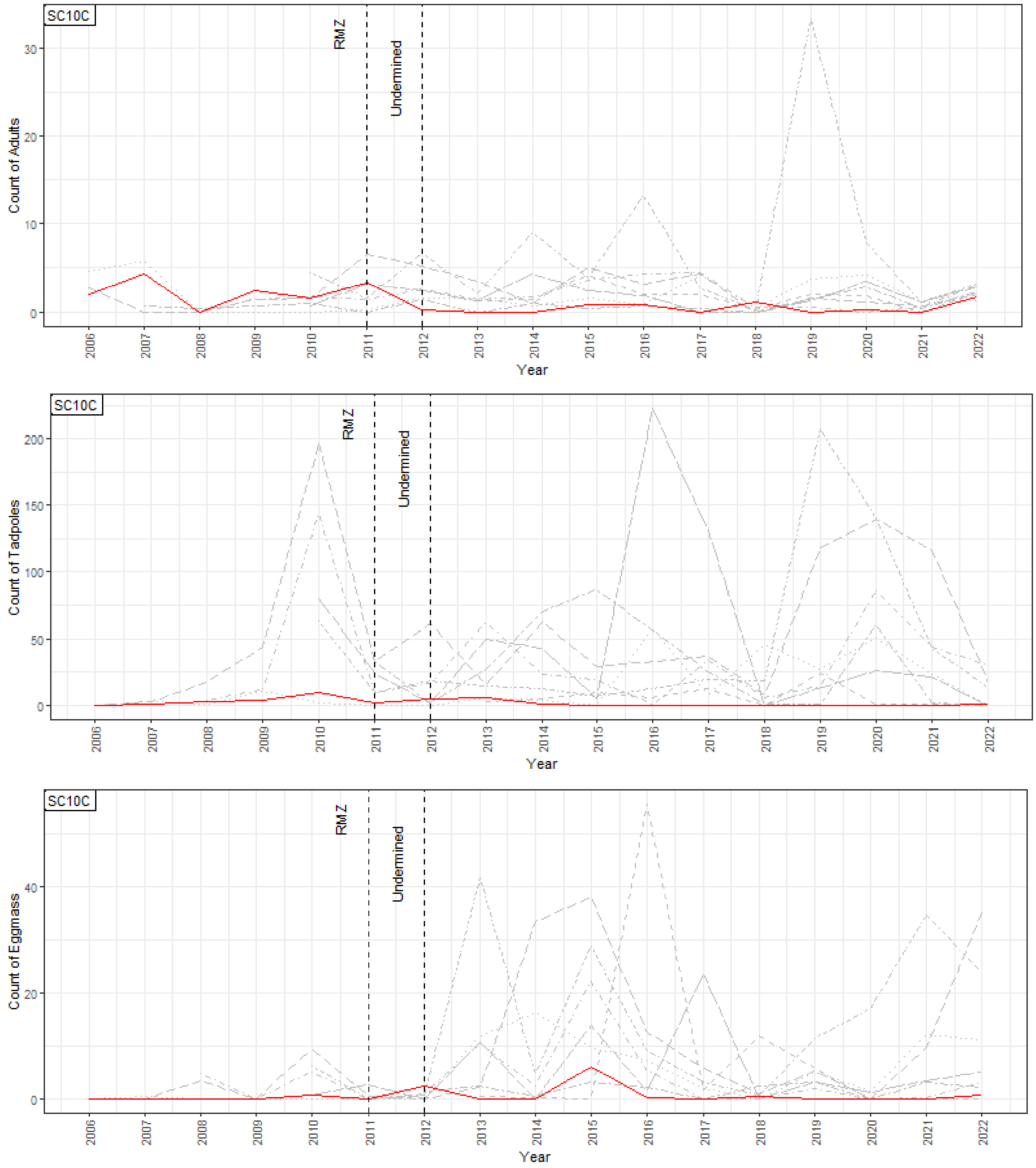
Graph 48: 6CDL mean +- SE count of Adults, Tadpoles, and Eggs at Control sites (n=9) and 6CDL for all years 6CDL has been monitored. See Table 2 for mining progress, number and status of Creeks at the year surveyed.

4.6.4.3 SC10C

Monitoring at SC10C commenced in 2006, with the extraction of Longwall 7 occurring within the transect's RMZ in 2011 and Longwall 8 mining beneath the transect in 2012. All lifecycle stages were recorded in

2022, the first time all lifecycle stages have been recorded since 2012. Eight Adults, three Eggmass and two Tadpoles were recorded in 2022.

A statistically significant difference in detection of Adults, Eggmass and Tadpoles were identified based on mining treatment (P-values <0.0001). Post hoc tests identified that for each lifecycle stage, significant differences were identified between the pre-mining data and Control Group. Indicating that while all counts were statistically significantly higher at Control sites than the Impact site, this occurred both before and after mining. However, for the Adult life stage, a significant difference was also identified between the pre-mining and both mined beneath and RMZ data. Indicating that there has been a decline in the Adult lifecycle stage at SC10C post-mining.



Graph 49: SC10C mean +- SE count of Adults, Tadpoles, and Eggs at Control sites (n=9) and SC10C for all years SC10C has been monitored. See Table 2 for mining progress, number and status of Creeks at the year surveyed.

Previous monitoring reports indicated fractured bedrock and iron flocculant at this site. On ground observations in 2022 recorded pools with high levels of iron flocculant in the first five pools of the transect (at the downstream end), with each of these pools recorded to be overflowing (i.e. 100% capacity). However, pools upstream of this section of the transect were largely dry, or held only some water. This is consistent with observations in 2020 and previous observations (Biosis 2020) with most pools remaining dry.

Optimal habitats are likely to have been somewhat limited pre-mining with predominantly shallow pools present across the transect when compared with Control sites. The relatively higher slope of the upstream half of the transect may also reduce the residence time of water in these shallower pools. These factors may be suggestive of a naturally low carrying capacity of the transect, as seen in the pre-mining detection data.

Within both 2018 and 2019, previous monitoring reports indicate a Level 3 trigger from the DA3A TARP, stating *a decline in the abundance of adult frogs was observed following subsidence impacts detected at SC10C following extraction of Longwall 7 and Longwall 8 during 2011 and 2012 (two-years after the initial mining within the RMZ), and numbers have not recovered* (Biosis 2020).

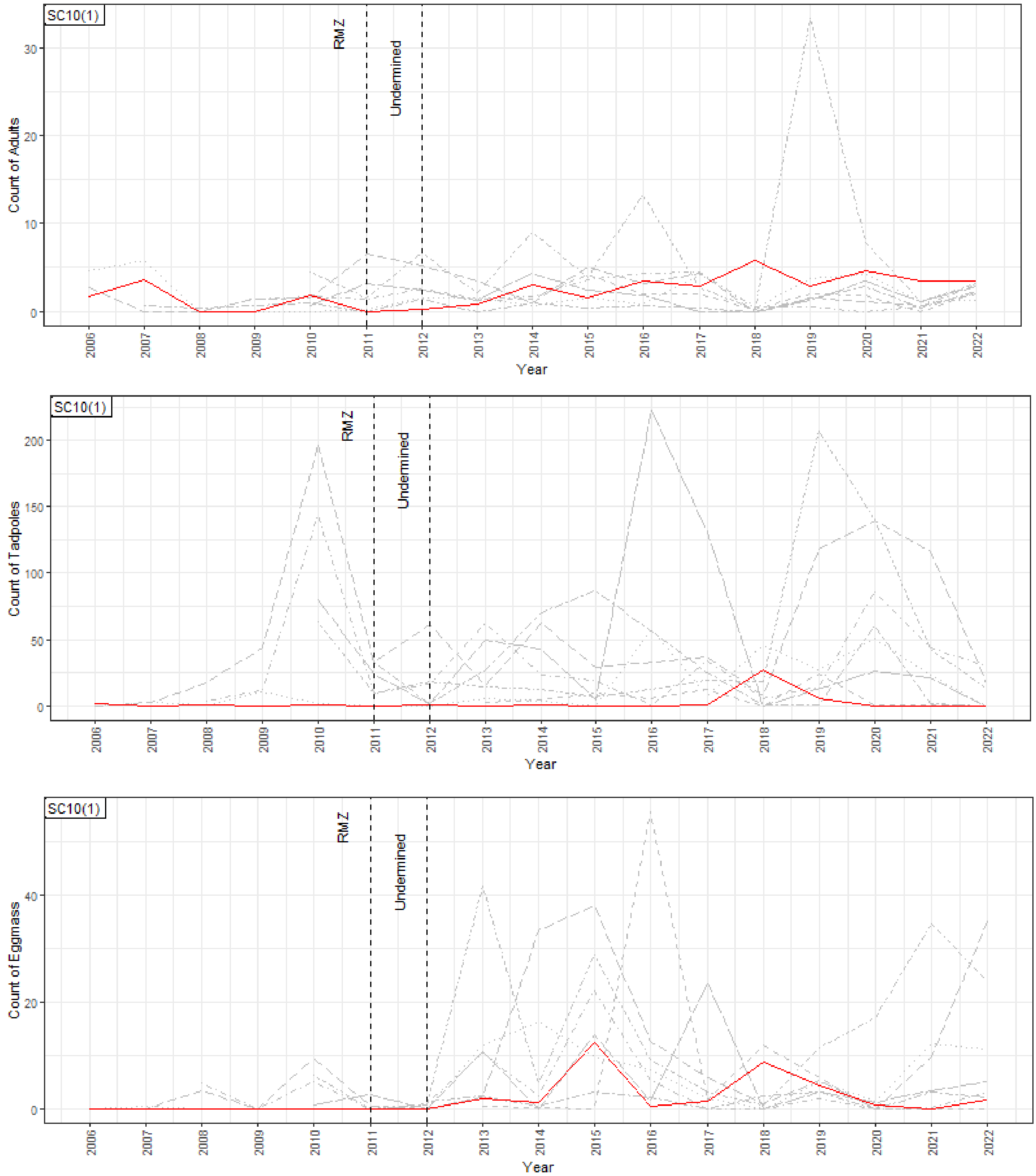
It is determined that SC10C has triggered a Level 2 Landscape Monitoring TARP due to the appearance decline and being unlikely to naturally regenerate within the monitoring period, with reductions in habitat conditions along this transect evident in the post-mining period. Additionally, a statistically significantly lower level of detection of Adults has been identified in the post mining period.

4.6.4.4 SC10(1)

Sandy Creek tributary, SC10(1), was first impacted by Longwall 7 RMZ in 2011 and a small section mined beneath by Longwall 8 in 2012 (Figure 5g).

In 2022, 19 Adult Littlejohn's Tree Frogs were recorded, with 9 Eggmass and no Tadpoles observed. All pools recorded 100% water holding capacity and the presence of a number of moderate and deep pools. Although iron flocculant was observed at 14 of the 15 incidental and monitoring pools.

While all counts were statistically significantly higher at Control sites than the Impact site (Graph 50), this occurred both before and after mining. The post hoc tests identified that there was no statistically significant effect of mining for any life stage, with detection being generally higher in the post mining period.



Graph 50: SC10(1) mean +- SE count of Adults, Tadpoles, and Eggs at Control sites (n=8) and SC10(1) for all years SC10(1) has been monitored. See Table 2 for mining progress, number and status of Creeks at the year surveyed.

The previous monitoring reports state:

- *[…] 2017 is the first year that site SC10(1) has triggered the Dendrobium Area 3 Watercourse TARP […] due to build-up of iron flocculant covering all stream surfaces during the 2017 winter survey, and is considered likely to reduce productivity, and therefore suitability, of the pools for Tadpoles* (Section 4.3.4 Biosis 2019).

- *There has been a slow decrease in Eggmass and Tadpoles at SC10(1) in the past three-years [...] SC10(1) is a relatively large stream and is likely to experience the impacts of dry conditions to a lesser extent than other streams, thereby providing refuge habitat during dry periods* (Biosis 2019).

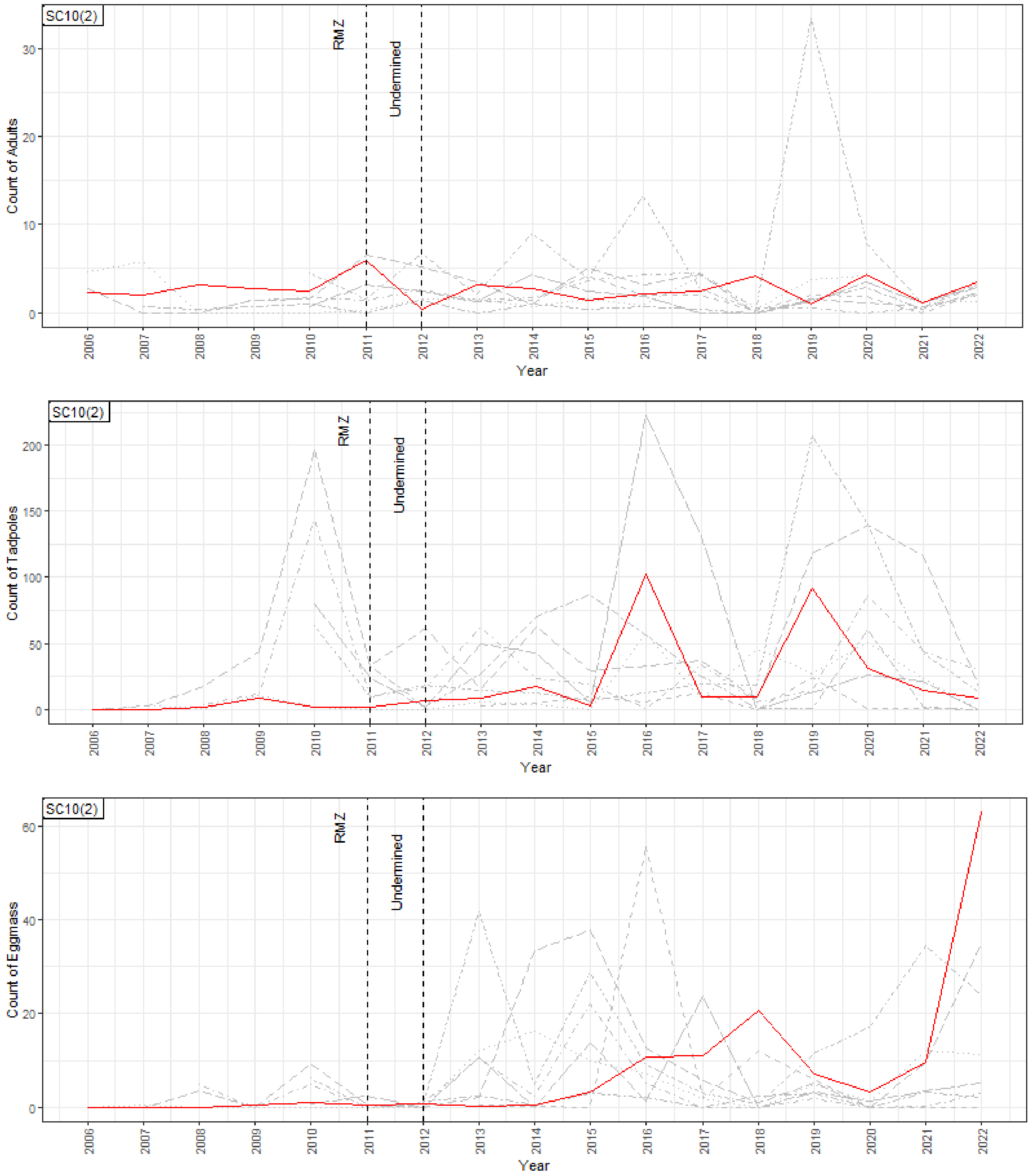
While the statistical test for trends before and after mining effects at this tributary have not been significant with regards to mining over time, a Level 1 Landscape Monitoring TARP was triggered in 2017 due to iron flocculant observed on the bedrock. Similar observations were made in the 2020, 2021 and 2022 surveys. Due to observed changes of decline in tributary appearance (e.g. iron flocculant, debris build up) representing a reduction in available habitat, and as the transect is unlikely to naturally regenerate within the monitoring period, the Level 2 TARP is triggered.

4.6.4.5 SC10(2)

The upstream transect of SC10, SC10(2), has been monitored since 2006. The transect was first impacted by Longwall 7 (within RMZ) in 2011 and a small section mined beneath by Longwall 8 in 2012 (Figure 5g,m,w). Longwall 19 has also entered within the RMZ of SC10(2) in 2022.

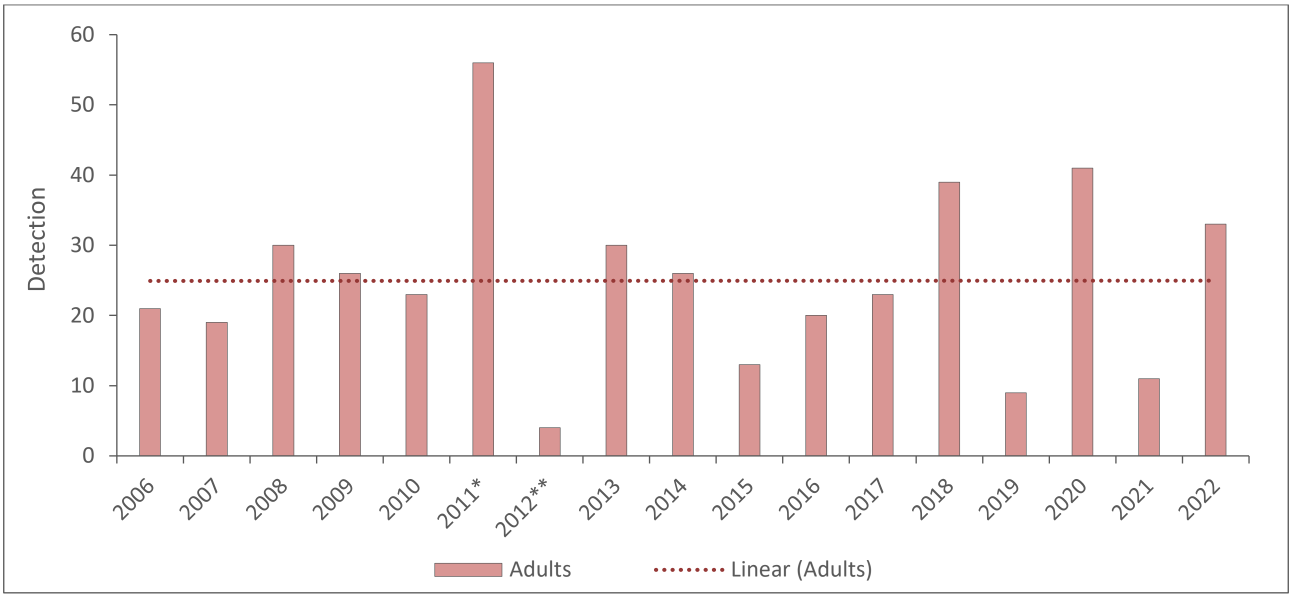
The Littlejohn's Tree Frog individuals observed in 2022 comprised 81 Tadpoles, 33 Adults and 599 Eggmasses. The SC10(2) section of SC10 was flowing and pools were typically at 100% capacity on the night of survey. Iron flocculant was not observed.

There was a statistically significant difference between the detection of Adults when comparing the within RMZ monitoring period to pre-mining (p-value < 0.001) and also to mined beneath (p-value < 0.001) period, in line with the findings of Niche (2022a). The Adult counts were found to increase during the within RMZ period (2011 only) before falling to levels just below the pre-mining data in the mined under monitoring period (2012 onwards), illustrated in (Graph 51).



Graph 51:SC10(2) mean +- SE count of Adults, Tadpoles, and Eggs at Control (n=9) and the SC10(2) Impact site for all years SC10(2) has been monitored. See Table 2 for mining progress, number and status of Creeks at the year surveyed.

Previous monitoring reported no statistically significant decline in Littlejohn's Tree Frog at SC10(2) since mining began in 2011 (Biosis 2020). While there have been statistically significant differences in Littlejohn's Tree Frog Adult lifecycle stage at this tributary with regards to mining over time in 2022, these findings do not indicate overall reduced counts following mining, rather differences between the high counts in the single year of monitoring when mining was within the RMZ of the tributary. As this is represented by a single year of monitoring, the value of the difference may appear artificially high.



** RMZ, ** directly mined beneath*

Graph 52: Adult life cycle stage detection over time at SC10(2) also showing linear trend line.

While the Adult lifecycle stage has been subsequently lower than the within RMZ period in the statistical analysis, the levels of detection in the mined beneath period are comparable to that of the pre-mining period (Graph 52). No long-term trending decline of Adult detection is apparent in the data. 2022 represented a high level of Adult detection, with the significant number of Eggmass recorded in 2022 also reflective of a high level of Adult breeding activity.

The transect appearance has not changed and no iron flocculant or cracking was observed in 2022. On the basis of the biological data and habitat observations, no TARPs have been triggered for this transect in 2022.

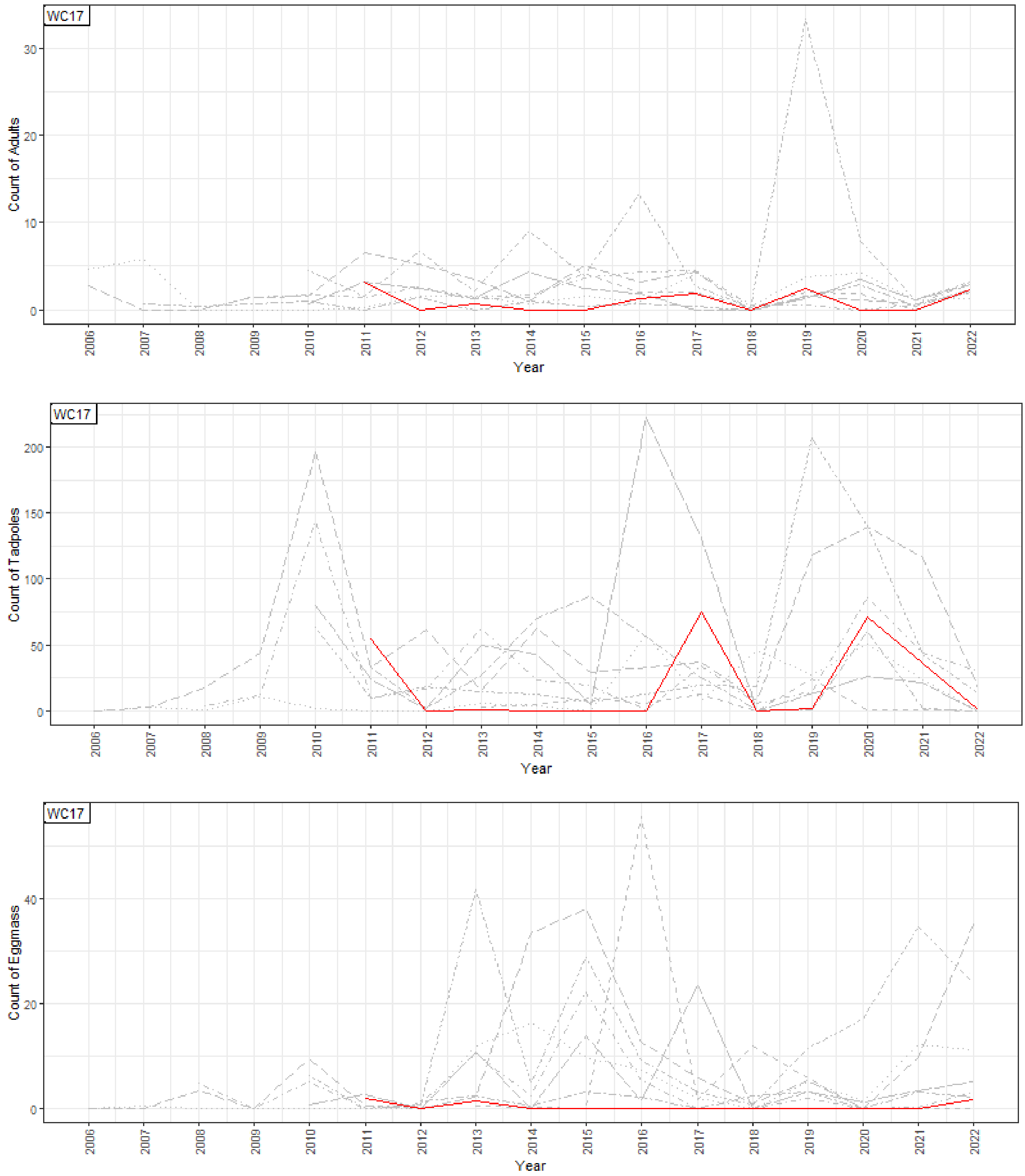
4.6.4.6 WC17

No pre-mining monitoring of WC17 (Figure 5o) was carried out. While significant differences were detected between Adults and Eggmass at WC17 and the Control Group, it is unclear whether the level of detection is comparable to pre-mining periods (as is the case at many other transects) and this cannot be tested.

The initial survey in 2011 recorded relatively high numbers of Littlejohn’s Tree Frogs in all life stages (relative to subsequent data at WC17) (Graph 53). This tributary has consistently recorded low numbers of Littlejohn’s Tree Frog in the Adult and Eggmass lifecycle stages, post the year of being mined beneath (also in 2011), with no Littlejohn’s Tree Frog recorded in any life stage in the first year of post-mining monitoring (2012), and also in the 3rd, 4th and 7th year of mining.

In 2022 one Tadpole was recorded within the tributary, with four Adults and three Eggmass observed. This represents a relatively high level of detection for transect WC17, despite the single Tadpole being observed.

All eight pools were at 100% of their water holding capacity in 2022, in contrast to 2020 when only three pools held water but recorded the highest number of Tadpoles (n = 125) detected. Tadpole numbers have varied significantly over time, with sporadic detection of Adults and Eggmass recorded only during three surveys.



Note: No pre mining data is available.

Graph 53: WC17 mean +- SE count of Adults, Tadpoles, and Eggs at Control sites (n=9) and WC17 for all years WC17 has been monitored. See Table 2 for mining progress, number and status of Creeks at the year surveyed.

Although the presence of Tadpoles and other lifecycle stages indicates at least episodic breeding activity. Iron flocculant was recorded in every pool in 2020, 2021 and 2022, with visible bedrock cracking recorded in the most downstream pools of the transect.

Previous monitoring reports indicated the following:

- *In 2017, it was determined that WC17 no longer triggered the Landscape Monitoring – Terrestrial Flora and Fauna TARP triggered in 2016 […] as frog numbers had returned to pre- mining levels. In 2018 Littlejohn's Tree Frog was not detected within the WC17 transect at any life stage, the transect was dry during the survey, with no pools containing water* (Biosis 2019).

With regards to mining over time, it can only be concluded that detection is highly variable and it cannot be ascertained how this would compare to pre-mining detection. However, it is observed that there has been a relative increase in Tadpoles counts in 2020, and 2021 compared to recent years, with relatively high detection of Adults and Eggmass in 2022 indicative of ongoing breeding activity in recent years.

The stream appearance has been altered since 2017 with every pool having iron flocculant indicating a reduction in habitat conditions, also observed in 2022. Due to observed changes of decline in tributary appearance (e.g. iron flocculant, debris build up) and as it is unlikely to naturally regenerate within the monitoring period, the Level 2 TARP is triggered.

4.6.5 Dendrobium Area 3B

Within Area 3B four main creeks or their tributaries are monitored, with both Control, Impact and pre-mining sections (Figure 5):

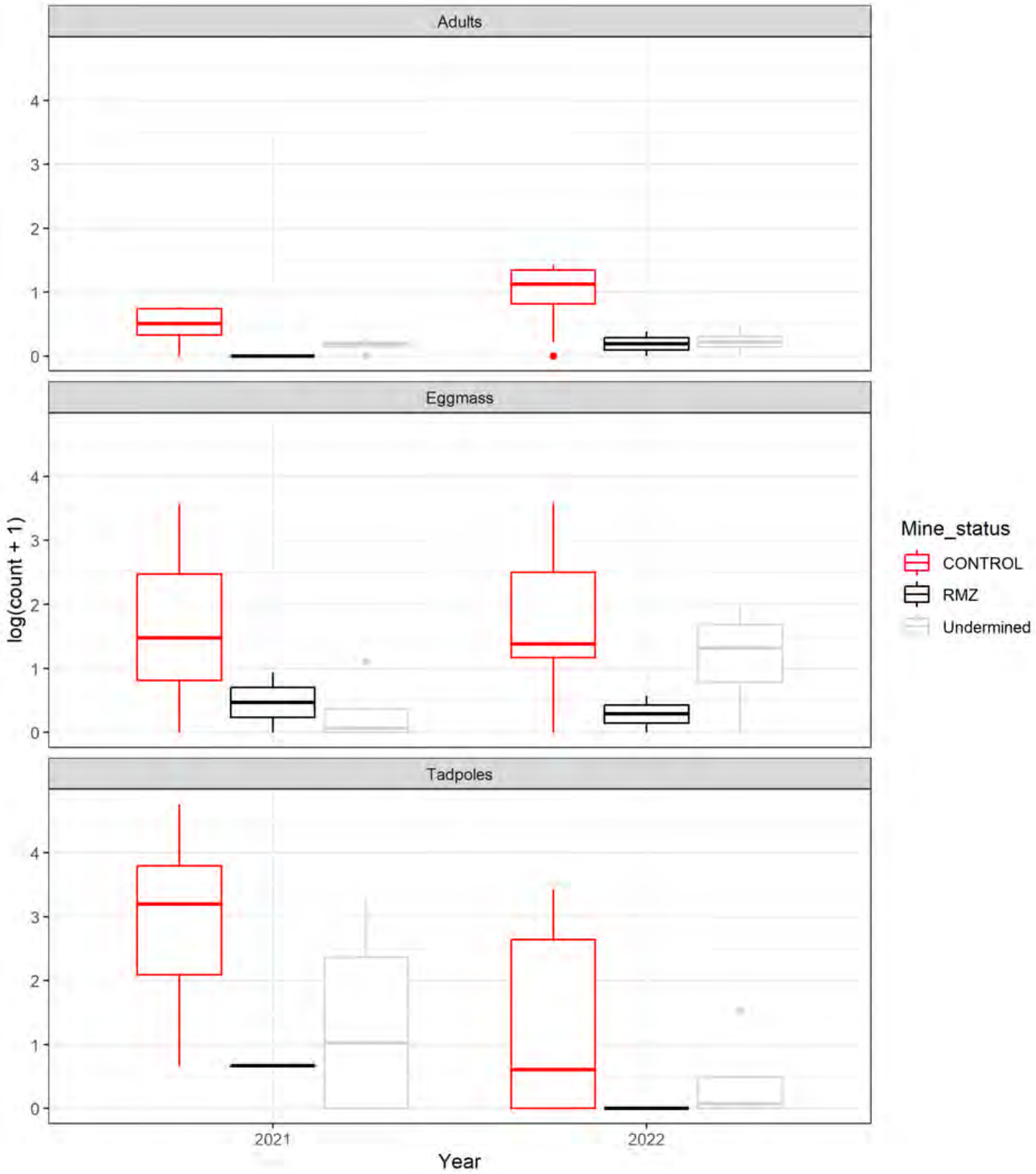
- Wongawilli Creek first and second order tributaries: WC15 and WC21
- Donald's Castle Creek first, second and third order tributaries: DC(1), DC13, DC8
- Native Dog Creek: ND1, ND2 and NDC
- Lake Avon (LA) tributaries: LA4 and LA2.

Waterways within Dendrobium Area 3B are not as interconnected as those within Dendrobium Area 3A. As such, it is possible that Littlejohn's Tree Frog dispersal throughout this area is more limited.

4.6.5.1 Overall trends

When comparing frog detection results from 2021 to 2022, regardless of Treatment, there was a statistically significant difference in count of Tadpoles (p-value <0.0001), being lower in 2022, which was also observed among the Control Group (Graph 54).

When considering the effect of mining Treatment on frog detection results from 2021 to 2022, there was a statistically significant effect of Treatment on the counts of Adults (p-value <0.0001), Tadpoles (p-value = 0.017) and Eggmass (p-value = 0.02). All lifecycle stages had higher counts at Control transects than Impact Transects (Graph 54).



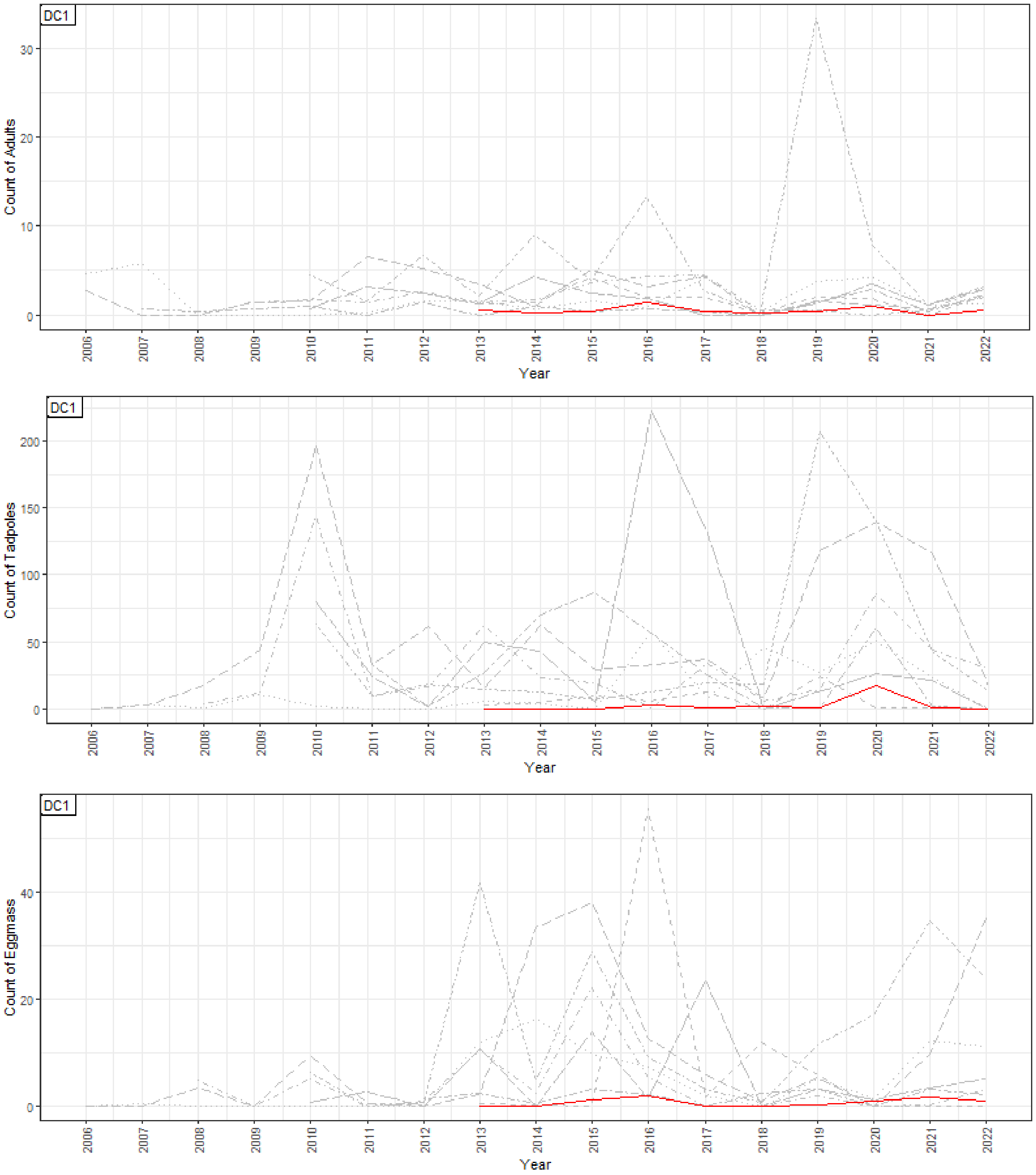
Graph 54: Boxplots of counts of Adults, Tadpoles and Eggmasses at Dendrobium Area 3B, 2021-2022 (left to right), and between mining status

4.6.5.2 DC(1)

Monitoring at DC(1) commenced in 2013, with mining entering the RMZ of the tributary in 2013. Due to the location of the longwalls, this tributary is not planned to be mined beneath and will remain in the RMZ, however there is potential for indirect impacts from the nearby Longwall 9 (Figure 5q). No pre-mining baseline data was collected for this tributary and therefore implementation of the BACI analysis design is not applicable.

In 2022, three Adults were detected, with 5 Eggmass and no Tadpoles observed. Iron flocculant was not observed in any of the 17 pools and water levels were high (all pools at or above holding capacity).

Assessment of available data indicates a statistically significant difference between the Controls and DC(1) across all lifecycle stages, with higher Littlejohn’s Tree Frog counts for all life stages at Control sites than at DC(1), (Graph 55). It cannot be determined whether this pattern existed pre-mining.



Graph 55: DC(1) mean +- SE count of Adults, Tadpoles, and Eggs at Control sites (n=8) and DC(1). See Table 2 for mining progress, number and status of Creeks at the year surveyed.

Following the extraction of Longwall 9 in 2013, changed pool water levels at DC(1) were recorded by the Illawarra Coal Environmental Field Team (Biosis 2020) and have continued to 2021 (Niche 2022a).

The level 1 TARP was triggered in 2017 and 2018 and the Level 2 TARP was triggered in 2019 due to a reduction in habitat for two-years following the active subsidence period (Biosis 2020). An improvement in this trend was not recorded in 2020 or 2021 and therefore due to a reduction in habitat for greater than two-years following the active subsidence period, the Level 3 TARP was triggered (Niche 2022a). No observations of flocculant were made in 2022, with all pools at or above water holding capacity, or flowing.

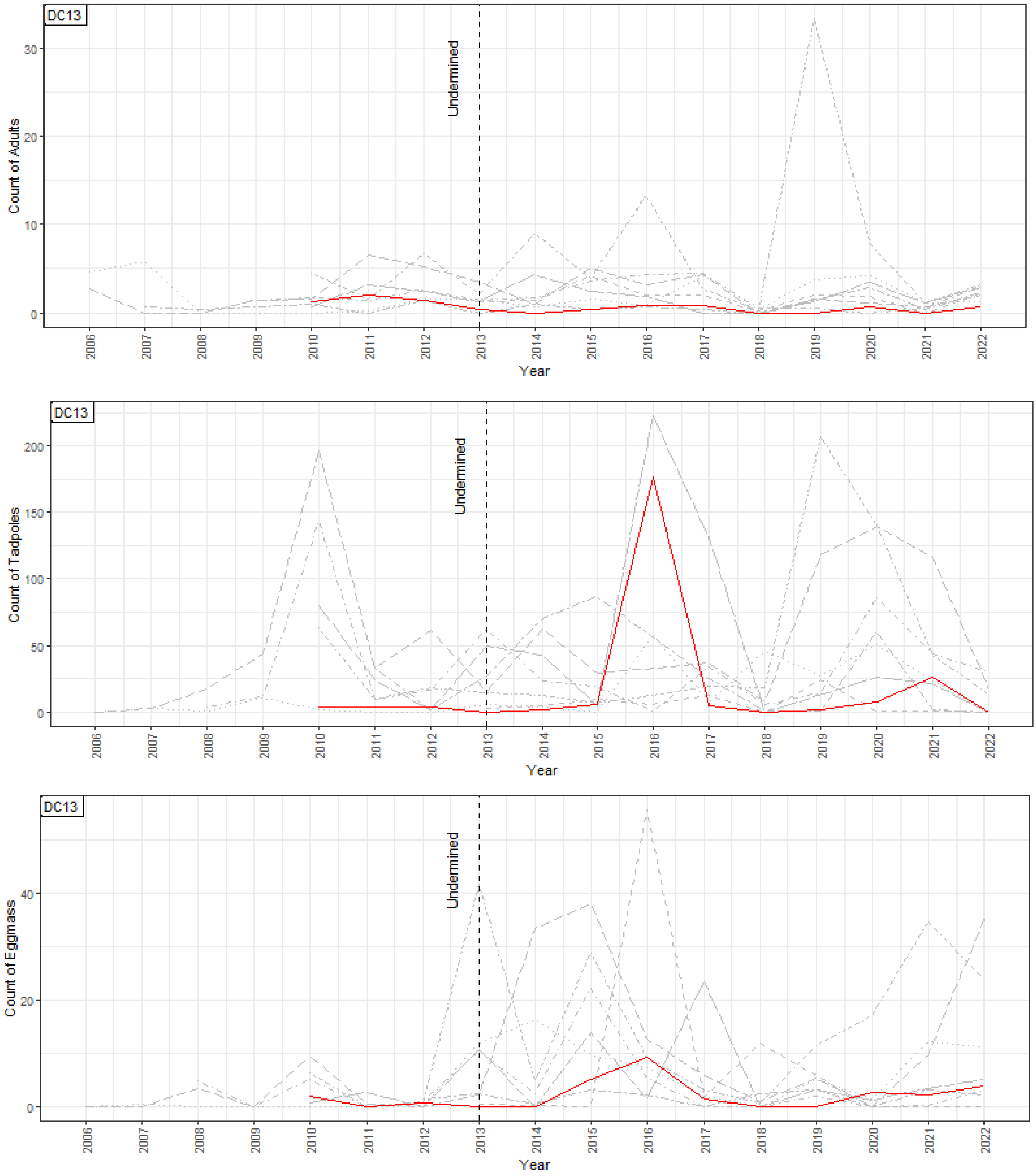
These observations are likely to be driven by the high rainfall, however they do represent an improvement in habitat conditions. Graph 55 shows continued low detection of life cycle stages, although both Eggmass and Adults were detected in 2022, indicative of breeding activity. On the basis of these two factors, the Level 3 TARP is not triggered at DC(1) in 2022. It should be acknowledged that this may represent only a temporary amelioration driven by high rainfall conditions rather than a persisting long-term improvement. This transect should be considered in detail in 2023 to resolve this question.

4.6.5.3 DC13

DC13 is located to the west of DC(1) and flows north from Longwall 9 (Figure 5q, a). DC13 has been monitored since 2010, with mining within the RMZ and beneath the transect both occurring in 2013.

In 2022, four Adults were detected, with no Tadpoles but 25 Eggmasses detected. All pool levels were high along the transect, except Pool 21 at the upstream end of the transect (mined beneath section), which was dry. Bedrock cracking was observed in Pool 20 although the pool was full at the time of survey. There was evidence of high flows along much the transect with observations of associated erosion recorded along many pools.

While the counts for all lifecycle stages were statistically significantly different at Control sites than the Impact site (Graph 56), this occurred both before and after mining. The detection of Adults have been statistically reduced post – mining (p-value <0.0001), but not for any other lifecycle stages.



Graph 56: DC13 mean +- SE count of Adults, Tadpoles, and Eggs at Control Sites (n=9) and DC13 Impact site. See Table 2 for mining progress, number and status of Creeks at the year surveyed.

Previous monitoring reports stated:

> "[..] *fracturing of bedrock was observed within the transect. It is determined that Level 3 […] remains triggered and should be re-evaluated in 2019.*" (Biosis 2019).

> *"[..] many of the identified breeding pools had experienced a significant reduction in water, and were no longer appropriate habitat for Littlejohn's Tree Frogs to survive to metamorphosis.[…]"* (Biosis 2020).

The Level 3 TARP was first triggered in 2017 and then again in 2018 due to a reduction in habitat for greater than two-years following the active subsidence period (Biosis 2020). While the majority of pools held high water levels during 2022 as a result of the high rainfall, the detection of the Adult lifecycle stage remains statistically lower than that of the pre-mining years and therefore due to a reduction in habitat for greater than two-years following the active subsidence period the Level 3 TARP remains triggered. This should be re-evaluated in 2023 to determine whether water levels persist, or whether this is part of a temporary amelioration driven by above average rainfall, and whether the detection of the Adult lifecycle stage responds accordingly.

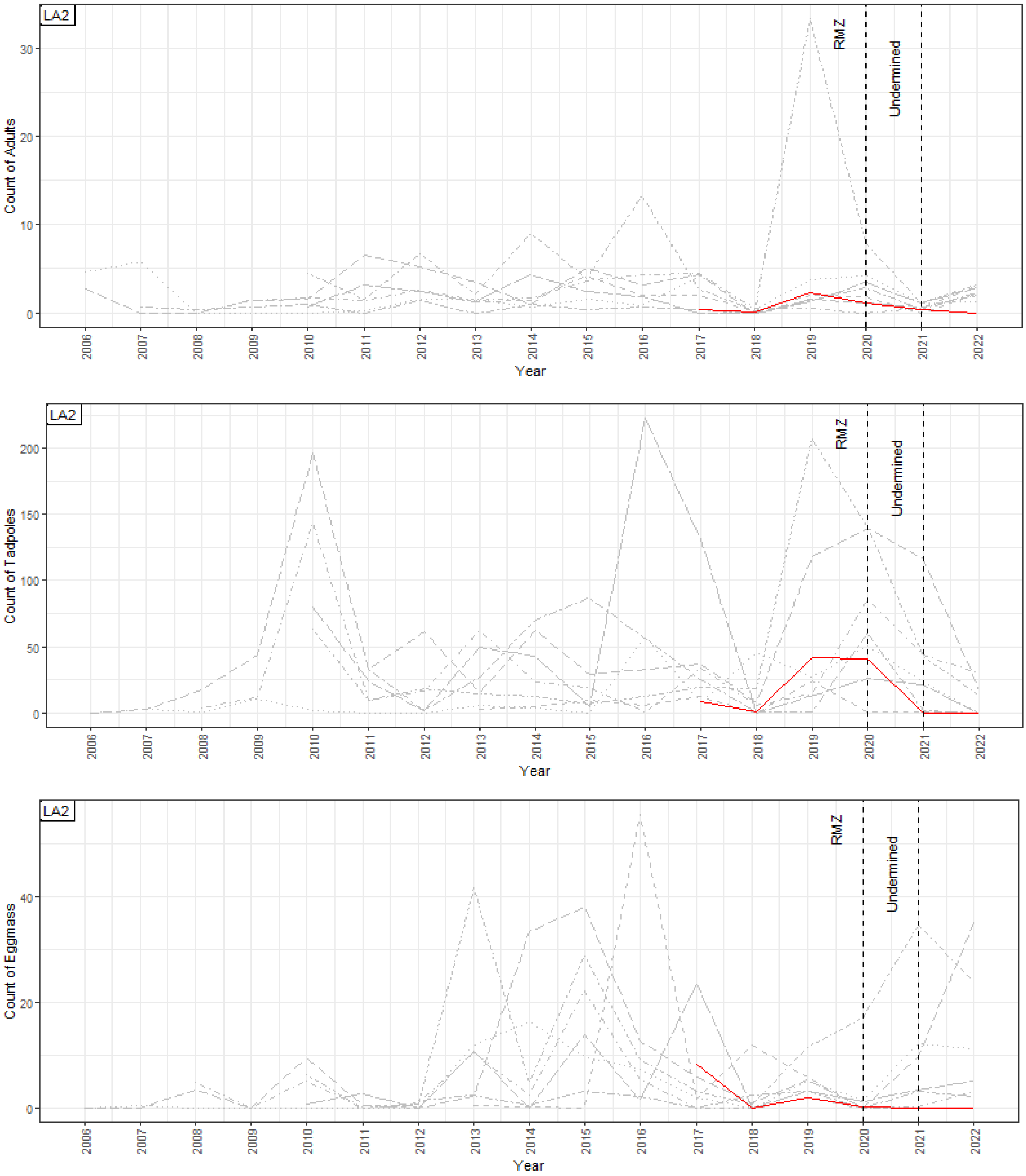
4.6.5.4 LA2

LA2 is situated above Longwall 17 and was mined beneath in 2021, following mining within the RMZ by Longwall 16 in 2020 and by Longwall 18 in 2021 (Figure 5r). Notably in 2021, all identified pools along the transect were directly mined beneath and as such are most likely to experience subsidence impacts.

In 2022, no individuals of any lifecycle stage were detected, following the trend of significantly reduced detection (despite above average rainfall). This is in contrast to the relatively high numbers of all lifecycle stages recorded in 2017, 2019 and 2020. These low levels are comparable, and even below, that of the height of the drought in 2018 (pre-mining) when the transect was extremely dry with the majority of pools empty (Biosis 2020).

A statistically significant difference between the pre-mining detection of Adults and Eggmass was identified between LA2 and the Control Group, indicating that detection of these lifecycles stages were lower at this transect than the Control Group prior to mining effects (Graph 57). This was not observed for Tadpoles. A statistically significant difference was identified for Tadpoles between the RMZ and mined beneath period, but not between the pre-mining and mined beneath period. This may be explained by the relatively high detection during the RMZ year (2020), which is comparable to the pre-mining years (2017 and 2019). In addition, the very low detection at the height of the drought in the pre-mining year of 2018 provides a comparable year of monitoring in the baseline dataset as a result of the naturally low water levels.

In 2022, only one of the 18 pools held water, and at only 50% of its capacity. This is despite the very high rainfall in 2022 and presence of moderate and deep pools along the transect. This represents a marked shift from 2020 when all pools were recorded as being at 100% of their water holding capacity. This is consistent with the findings of Niche (2022a) and suggests a loss of water from the transect in 2021 and 2022, coinciding with reduced detection of the Littlejohn's Tree Frog.



Graph 57: LA2 mean +- SE count of Adults, Tadpoles, and Eggs at Control Sites (n=9) and LA2. See Table 2 for mining progress, number and status of Creeks at the year surveyed.

Conditions and detection in the 2018 year of monitoring suggest that habitats in LA2 are susceptible to water loss/stress, this may in part reflect the degree of sandy substrates present along much of the upper tributary sections and catchment position, although the bottom section of the transect is bedrock dominated. Habitats for the species in this tributary may be naturally somewhat cyclical, reflecting the prevailing weather conditions at the time. These factors notwithstanding, the comparable conditions and detection levels were recorded in 2018 at the height of the drought, whereas 2022 was a record rainfall year, with above average rainfall also recorded in 2020 and 2021.

When taken together the declining detection results and assessment of physical conditions suggest a loss of habitat associated with mining when compared to the pre-mining period. As such, a Level 2 TARP is triggered for the first time at this transect, aligning with the interpretation identified in Table 6:

"Reduction in aquatic habitat for two-years following the active subsidence period

- Observed and measured changes in pool water levels and/or number of breeding pools available from two-years in a row without the same pattern at control sites."

Incidental observations of Littlejohn's Tree Frog were made downstream of the survey transect in 2022, approximately 70 metres downstream of the extent of extraction in Longwall 17. The shallow incidental pool held water to approximately 90% of its capacity, with eight Eggmass and 60 Tadpoles. It is recommended that this pool is re-visited in subsequent iterations of the monitoring program to determine if persistent habitat and breeding activity remains through more nominal rainfall conditions.

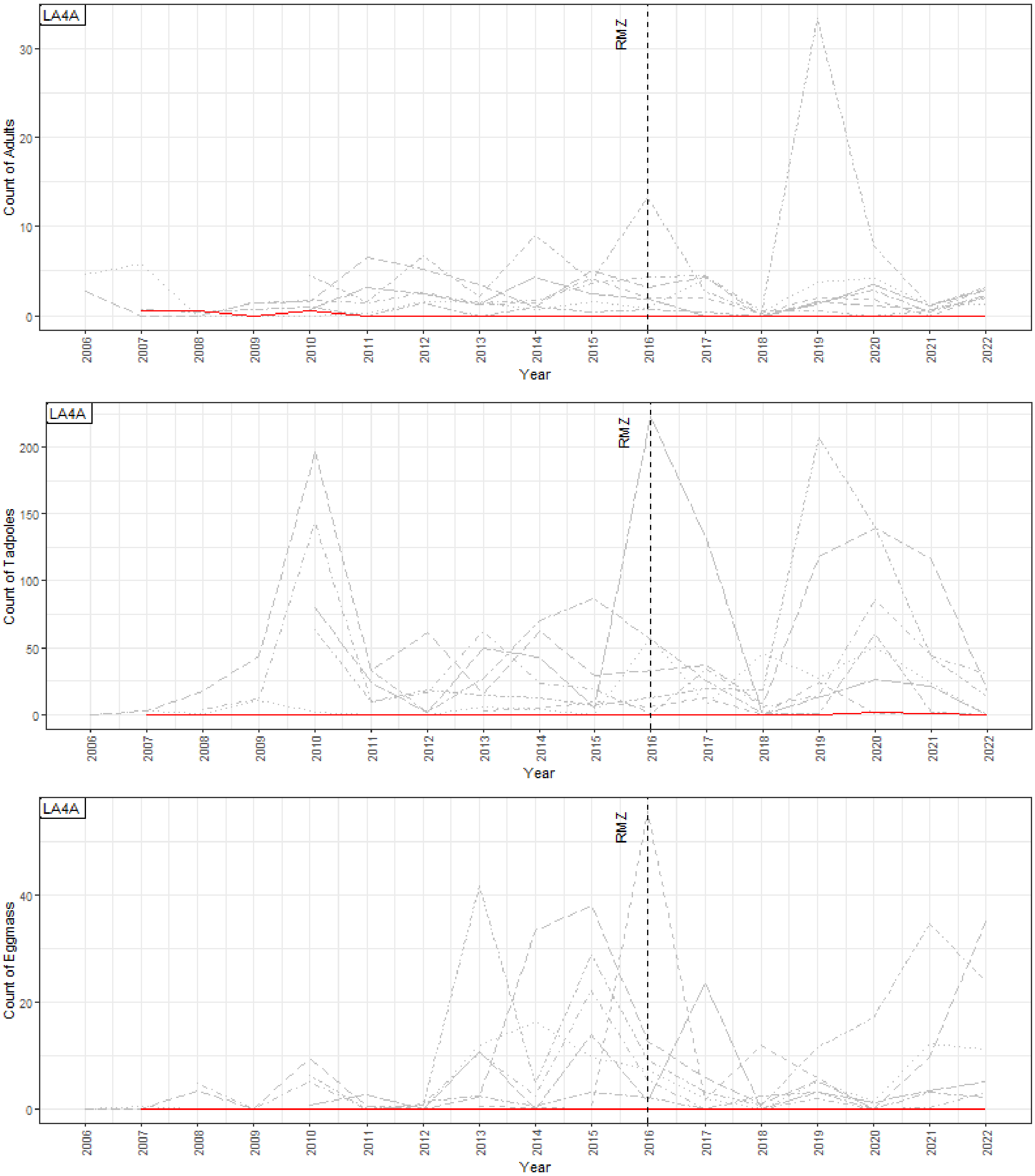
Known areas of rockfall and treefall were observed along the upper half of the transect, presenting hazards to the field survey team during nocturnal survey due to the densely vegetated nature of the stream preventing observations at distance from the field team. The value of completing survey along this extent of the transect, in light of the known impacts and continued lack of detection, and potential hazards should be reviewed. It is recommended that future surveys focus on the transect between Pools 7 and 19 and areas downstream of the transect that may present suitable habitat for Littlejohn's Tree Frog.

4.6.5.5 LA4A

Due to the location of the longwalls, tributary LA4A (Figure 5k) is not planned to be mined beneath and will remain as within RMZ for Longwall 12 and 13, starting in 2016.

There are only three pools within this short section of tributary. Across the transect, all pools were observed to hold water in 2022. No individuals of any lifecycle stages were detected in 2022. This is not unusual, with no individuals recorded in the majority of monitoring years.

No statistically significant difference in pre-post mining detection was identified in the Adult or Tadpole detection data (Graph 58). While all counts were statistically significantly higher at Control sites than the Impact site (Graph 58), this occurred both before and after mining.



Graph 58: LA4A mean +- SE count of Adults, Tadpoles at Control sites (n=9) and LA4A. See Table 2 for mining progress, number and status of Creeks at the year surveyed.

The general lack of Littlejohn's Tree Frog records noted for LA4A suggests the tributary supported sub-optimal, or episodic, habitat before mining began. The key difference at LA4A is that in the pre-mining data Adults are detected sporadically and in very low numbers, and in the within RMZ data Tadpoles are detected sporadically and in very low numbers. Overall, no change in species activity during the monitoring is apparent and as such, no TARPs have been triggered at LA4A.

4.6.5.6 WC15

WC15 stretches across Longwalls 14 and 15 (Figure 5l). Monitoring commenced at WC15 in 2011 and this transect was first within the Longwall 14 RMZ in 2018 and then mined beneath in 2019. Cumulatively, Longwall 15 also entered into the RMZ in 2019 and the transect was also mined beneath by Longwall 15 in 2020.

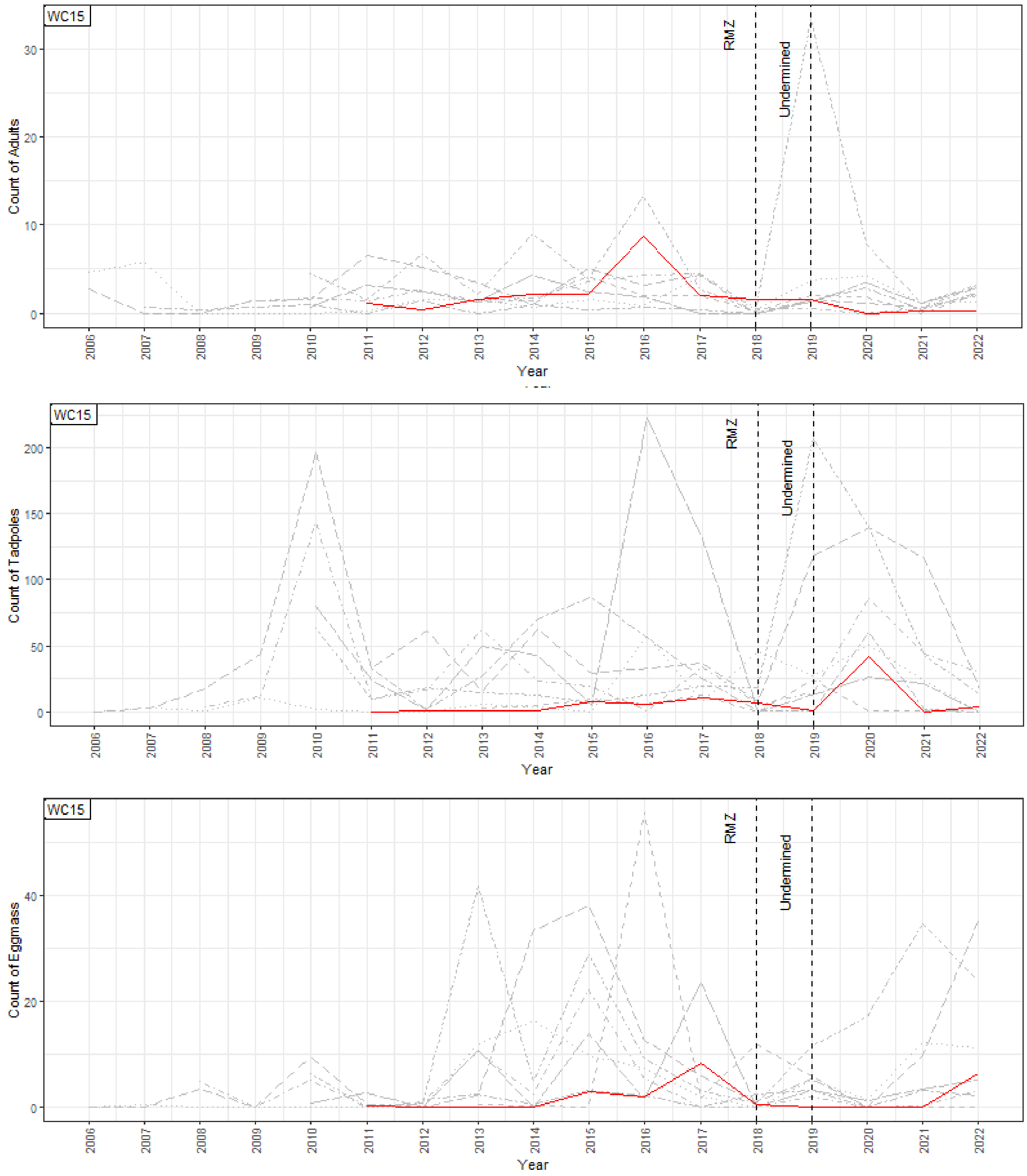
In 2022 there was only water in five out of 16 pools along the transect, at typically low levels, despite the above average rainfall conditions, this is similar to the trends observed in 2020 and 2021. Visible cracking of bedrock between Pools 18 and 22 (Plate 17 and Plate 18), also observed in 2020 and 2021. Water levels in 2022 were low with the majority of pools dry.

Plate 17: WC15 bedrock cracking

Plate 18: WC15 sandstone rocks from nearby cracking

One Adult, 30 Eggmass and 17 Tadpoles were recorded in 2022. This represents an improvement on detection when compared to recent post-mining years (2019 – 2021), with all lifecycle stages represented, although in low to moderate abundances. All observations were from a single pool (Pool 18), which is the largest pool in the transect and was at its water holding capacity, with all other pools empty or holding only approximately 5% of their capacity.

No statistically significant effect of mining on any lifecycle stage was detected in the 2022 analysis. While the counts of Adults and Eggmass were statistically significantly different at Control sites compared with the Impact site (Graph 59), this occurred both before and after mining.



Graph 59: WC15 mean +- SE count of Adults, Tadpoles, and Eggs at Control (n=9) and WC15. See Table 2 for mining progress, number and status of Creeks at the year surveyed.

Due to observed bedrock cracking within WC15 and limited water present, WC15 has triggered a Level 3 TARP due to a reduction in habitat (dry pools for extended time) for three-years following the active subsidence period.

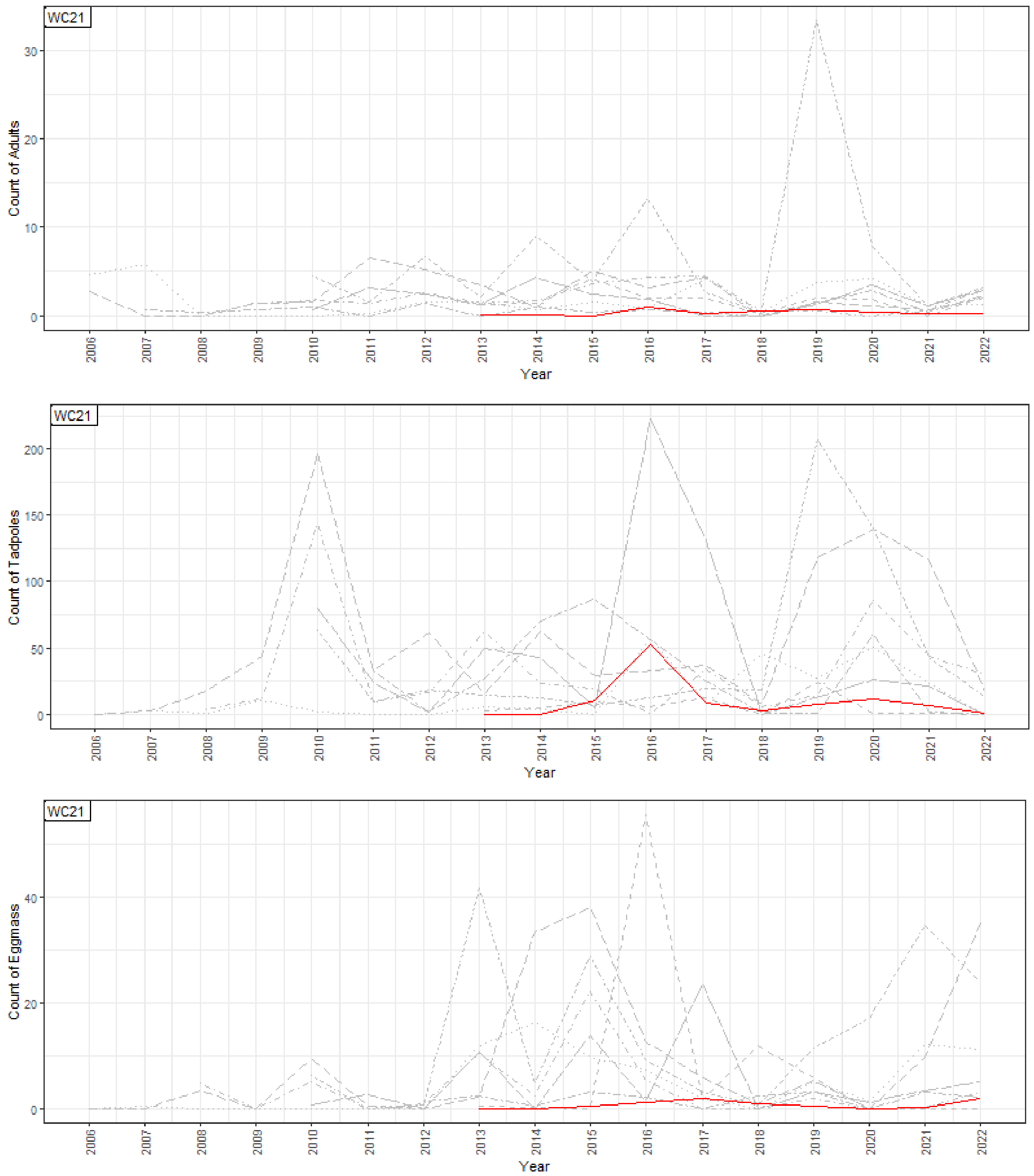
4.6.5.7 WC21

WC21 (Figure 5s) stretches across three longwalls (Longwall 9, Longwall 10 and Longwall 11). Monitoring commenced at WC21 in 2013, when mining was already within the RMZ which then extended beneath the transect (Longwall 9) in 2013. Cumulatively, Longwall 10 also extended into the RMZ of the tributary in

2014, which was then mined beneath in 2014. Longwall 11 also entering into the RMZ of the tributary in 2015, which then extended beneath the tributary in the same year. There is no pre-mining baseline data for this tributary, therefore implementation of the BACI design is not applicable.

While the transect includes a number of deeper pools, these are located at the downstream end of the transect which are also affected by iron flocculant. In contrast to recent years of observations, water levels remained quite high along the length of the transect in 2022, driven by the significant rainfall conditions. Evidence of high flows and varying levels of erosion were observed at the majority of pools in 2022.

The counts of Adults and Eggmass were statistically significantly different at Control sites compared with the Impact site (Graph 60), although there is no pre-data against which to test detection against.



Graph 60: WC21 mean +- SE count of Adults, Tadpoles, and Eggs at Control (n=9) and WC21. See Table 2 for mining progress, number and status of Creeks at the year surveyed.

Previous monitoring reports state:

> *"Impacts to WC21 were previously recorded by the Illawarra Coal Environmental Field Team between Pool 10 and the end of the transect to Pool 31, following the extraction of Longwall 9, Longwall 10, Longwall 11 and Longwall 12, and these included fracturing of bedrock, cracking, uplift and flow diversion"* (Biosis 2020).

> *[…] reduction in habitat at WC21 has now been recorded for five monitoring periods (four-years), thus triggering Level 3 TARP […] 57% of the potential breeding habitat along this stream is experiencing a reduction in water levels (between Pool 11 and Pool 30) including three confirmed breeding pools."* (Biosis 2019).

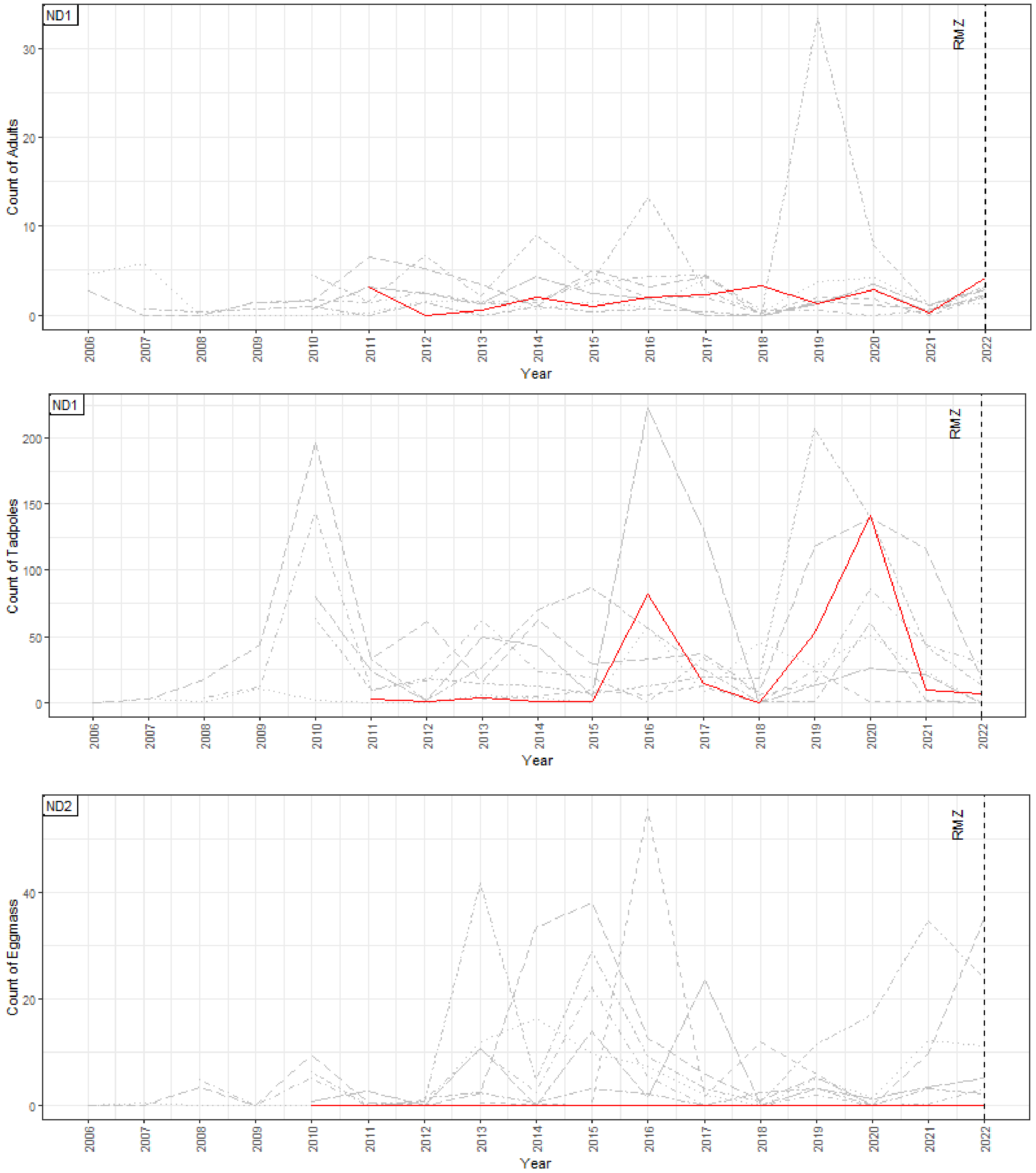
The Level 3 TARP was triggered in 2017, 2018 and 2019 due to a reduction in aquatic habitat for > two-years (three-years in a row). No improvement in this trend was detected in 2020, 2021 or 2022, therefore the Level 3 TARP remains triggered.

4.6.5.8 ND1

ND1 drains west into Native Dog Creek, which flows into Lake Avon. The upper reaches of the tributary runs adjacent to Longwall 18, with the transect itself located approximately 225 metres from the longwall (Figure 5d).

Monitoring commenced at ND1 in 2011 and this transect was first impacted by Longwall 18 (within RMZ) in 2022. In 2022, a total of 31 Adults, 36 Eggmass and 45 Tadpoles were detected.

While the counts of Adults and Eggmass were statistically significantly different at Control sites compared with the Impact site (Graph 61), this occurred both before and after mining. No statistically significant effect of mining on any lifecycle stage was detected in the 2022 analysis.



Graph 61: ND1 mean +- SE count of Adults, Tadpoles, and Eggs at Control (n=9) and ND1. See Table 2 for mining progress, number and status of Creeks at the year surveyed.

No evidence of cracking, or flocculant were observed along ND1 in 2022, with the majority of pools at their water holding capacity.

On the basis of the above factors, no TARP levels have been triggered at ND1 in 2022.

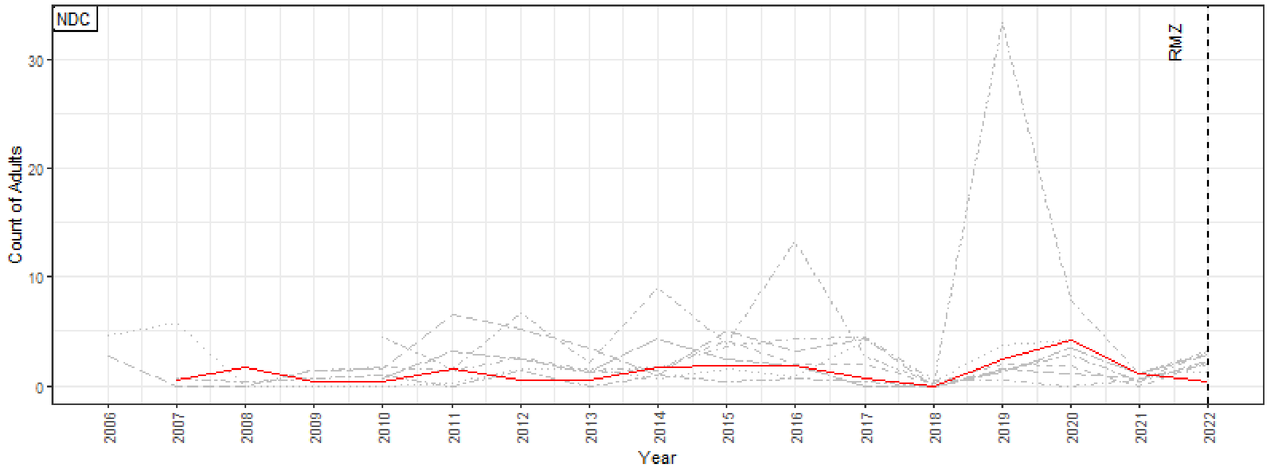
4.6.5.9 NDC

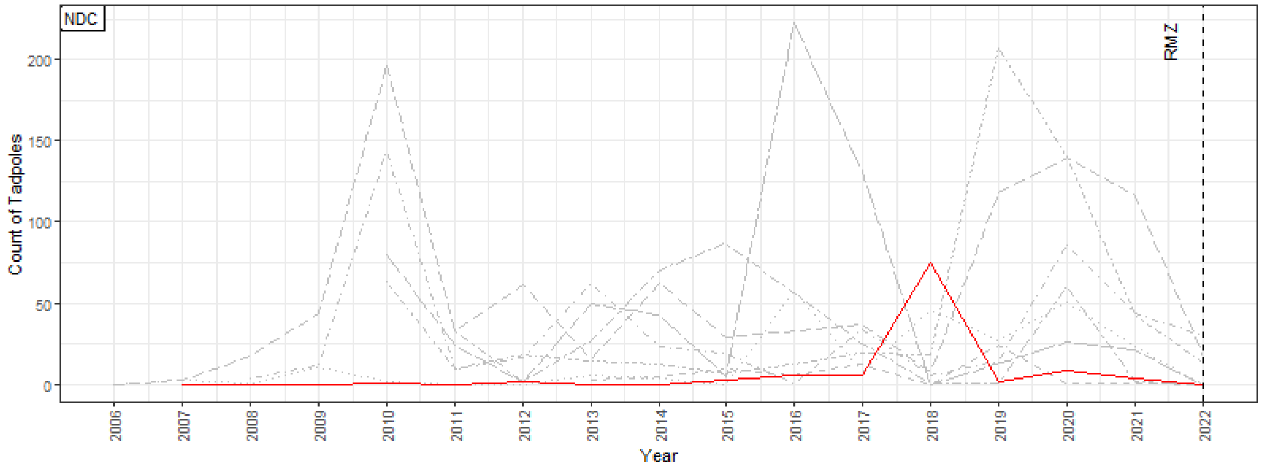
Transect NDC runs along Native Dog Creek, up to the confluence of ND1, downstream of which Native Dog Creek flows into Lake Avon (Figure 5d).

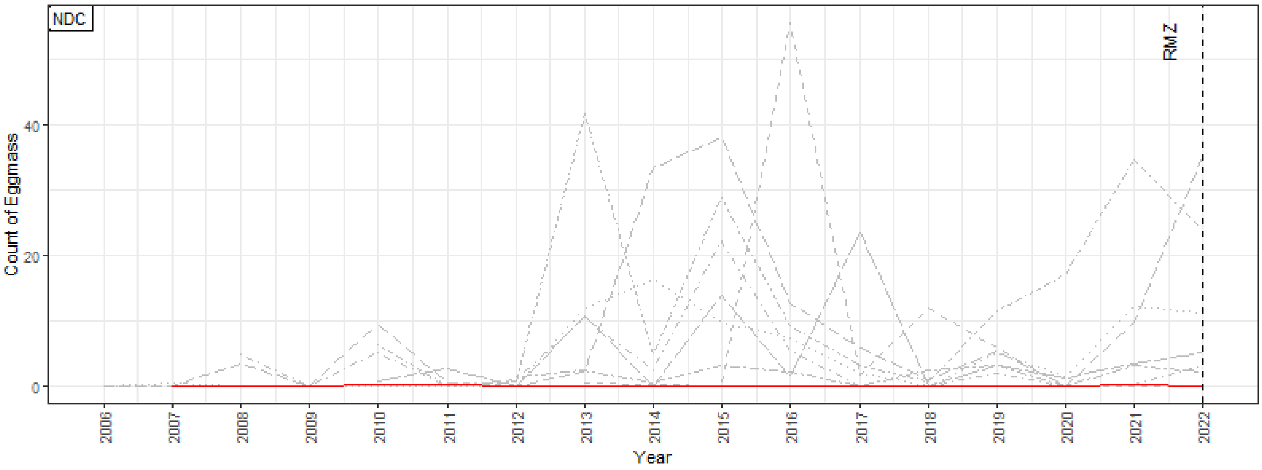
Native Dog Creek has been subject to prior impacts from the Elouera Colliery, pre-2007 (Niche 2022a), including prevalent flocculant levels observed in the pre-mining data (Niche 2022a). The lack of data prior to impacts along these transects associated with the Elouera Colliery is a limitation to examining post Elouera impact detection data.

Monitoring commenced at ND1 in 2007 and this transect was first impacted (in this program) by Longwall 18 (within RMZ) in 2022. In 2022, a total of 2 Adults were detected.

While the counts of Adults and Eggmass were statistically significantly different at Control sites compared with the Impact site (Graph 62), this occurred both before and after mining. No statistically significant effect of mining on any lifecycle stage was detected in the 2022 analysis.







Graph 62: NDC mean +- SE count of Adults, Tadpoles, and Eggs at Control (n=9) and NDC. See Table 2 for mining progress, number and status of Creeks at the year surveyed.

No evidence of cracking was observed along NDC in 2022, with all pools at or above their water holding capacity. Flocculant was observed at all pools, in levels visually similar to 2021 (pre-mining as part of this program).

High flows were observed along Native Dog Creek in 2022, with the level of dam influence encroaching into the most downstream pools along the transect. It is anticipated that this may partly explain the lack of detection of Tadpole and Eggmass lifecycle stages. Although Niche (2022a) previously described low levels of detection of these lifecycle stages at NDC, apparent across the monitoring program. Niche (2022a) considered the detection results from NDC in the context of the most similar control sites (transect length, number of breeding pools and pool size distribution), as well as ND1 where impacts have not been observed, to assess whether the level of detection is suggestive of any impacts to Littlejohn's Tree Frog along transect ND1 and ND2. While it is true that the detection of the adult lifecycle-stage of Littlejohn's Tree Frog at NDC appears consistent with that recorded at similar control sites, the detection of Tadpoles was found to be somewhat lower. On average, approximately half that of the similar control with the lowest level of detection. Although lower, this does indicate that some degree of reproduction is occurring at NDC. However, the detection of Eggmass was much lower when compared to the similar controls. This low level of detection is not only typified by no detection at all in most years but also lacks the occasional peaks in detection seen at similar control sites over the 15 years of monitoring at NDC. This is despite the presence of larger pools and relatively high water availability at this transect which, in theory, are favourable for breeding. These lower levels of detection may represent generally reduced habitat conditions associated with the Elouera Colliery.

The level of detection was low in 2022, however this may be in part due to the high level of flows and encroachment of the level of dam influence into the transect. Despite this, overall detection level was comparable to pre-mining years 2007, 2009 and 2013 at NDC. While it is difficult to disentangle observations of physico-chemical impact (flocculant) between recent longwall activity and that which may have resulted from the Elouera Colliery, especially during a high flow year, no indicators of gross visual change from 2021 were observed. On the basis of these factors, no TARP levels have been triggered at NDC in 2022.

4.6.5.10 ND2

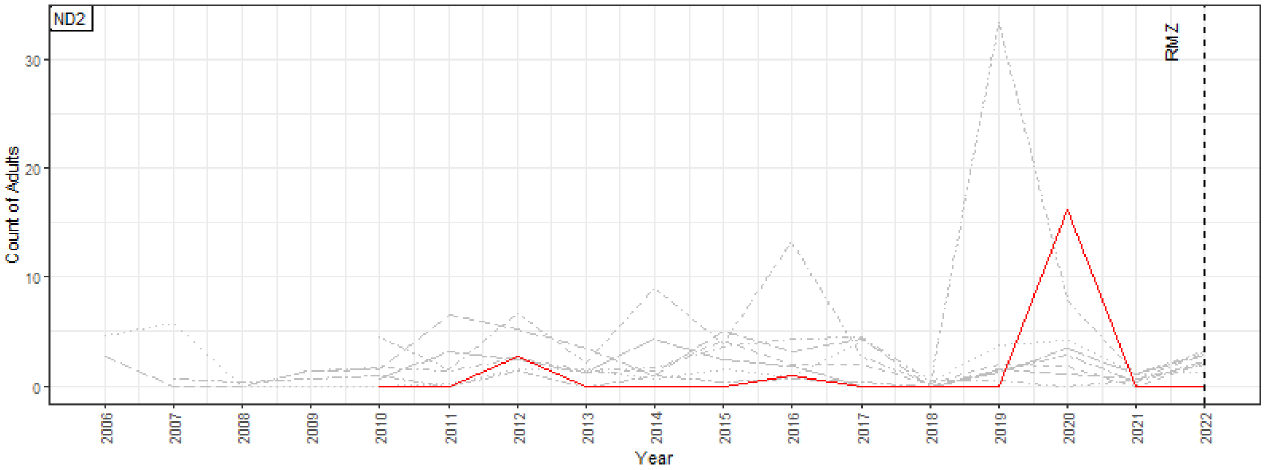
Transect ND2 drains north east along a small tributary into Native Dog Creek, meeting just upstream of the confluence of ND1 and Native Dog Creek (Figure 5d). ND2 is a relatively short and steep transect.

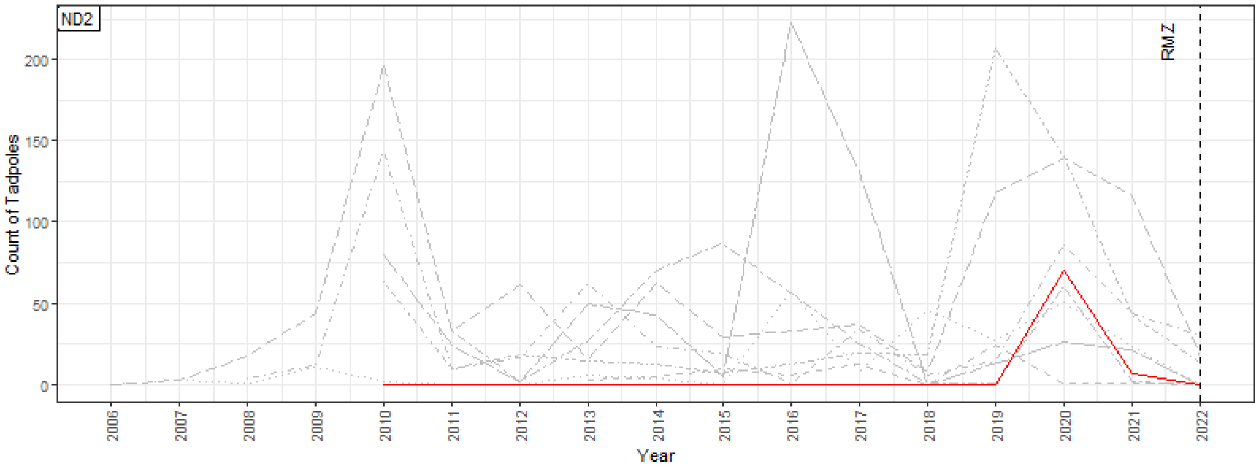
ND2 has been subject to prior impacts from the Elouera Colliery, pre-2007 (Niche 2022a), including prevalent flocculant levels observed in the pre-mining data (Niche 2022a). The lack of data prior to impacts along these transects associated with the Elouera Colliery is a limitation to examining post Elouera impact detection data.

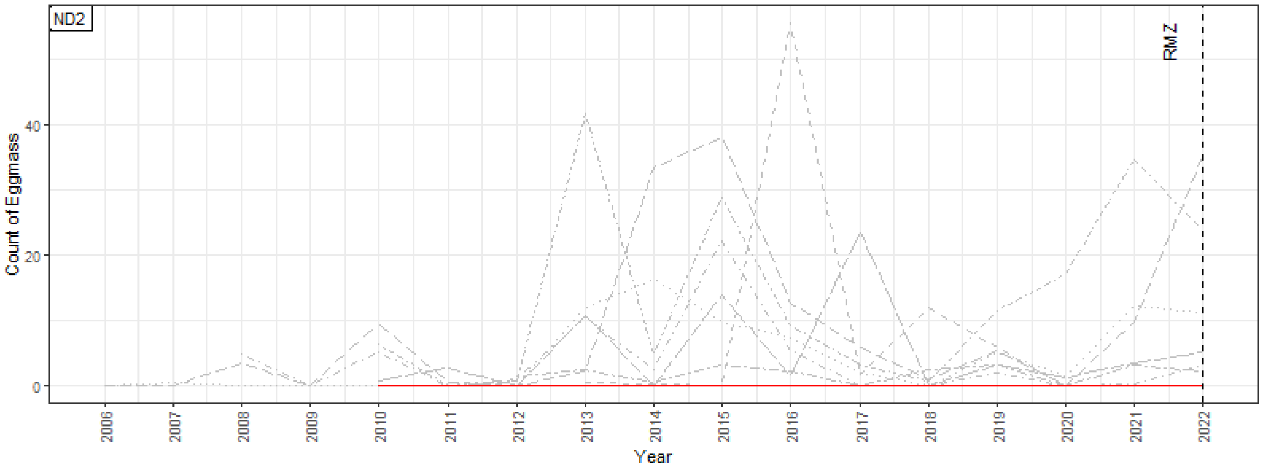
The review of Native Dog Creek monitoring transects by Niche (2022a) identified that the observations of flocculant at ND2 were more comparable to that of the post-mining transects than control transects. It was noted that while it was difficult to disentangle potential impacts at transect ND2 from the likely more transient and less utilised habitat conditions pre-mining, when considered overall the data are suggestive of observations that are more aligned with those at the impact transects than control transects.

Monitoring commenced at ND1 in 2010 and this transect was first impacted (in this program) by Longwall 18 (within RMZ) in 2022. In 2022, no individuals of any lifecycle stage were detected, also occurring in 2010, 2011, 2013, 2014, 2015, 2017, 2018 and 2019. No Eggmass have been detected along this transect across all years of monitoring.

While the counts of Adults and Tadpoles were statistically significantly different at Control sites than the Impact site (Graph 63), this occurred both before and after mining. No statistically significant effect of mining on any lifecycle stage was detected in the 2022 analysis.







Graph 63: ND2 mean +- SE count of Adults, Tadpoles, and Eggs at Control (n=9) and ND2. See Table 2 for mining progress, number and status of Creeks at the year surveyed.

No evidence of cracking was observed along ND2 in 2022, with all pools at or above their water holding capacity. Flocculant was observed at Pool ND2-P01, in levels visually similar to pre-mining (as part of this program) observations.

While no individuals were detected in 2022, this is not unusual for this transect. While it is difficult to disentangle observations of physico-chemical impact (flocculant) between recent longwall activity and that which may have resulted from the Elouera Colliery, especially during a high flow year, no indicators of gross visual change from 2021 were observed. On the basis of these factors, no TARP levels have been triggered at ND2 in 2022.

5. Assessment against performance measures summary

5.1 Upland Swamp vegetation monitoring

Hydrological impacts have occurred or are anticipated to occur at all Impact swamps part of the Program, on the basis of the findings of Watershed HydroGeo (2019, 2021), as summarised in Section 4.2, areas of upland swamp within 60 metres of longwall panels in DA3A and DA3B have been identified as 'potentially impacted' or may become potentially subject to impacts, shown in Figure 6.

All of the ten Impact monitoring swamps are considered at risk of potential impacts based upon their proximity to longwall panels (within 60 metres). In 2022, eight of the ten Impact monitoring swamps recorded at least one TARP trigger (Table 44). At Swamp 15A(1), the TARPs cannot be formally assessed until 2023, when sufficient data has been collected to allow time series comparison. Swamp 11 was the only other swamp not to record a TARP level in 2022.

Additional calculations have been completed in 2022 to identify areas of upland swamps within the monitoring program that are potentially subject to impacts (Figure 6, Table 44).

Table 44: TARP monitoring summary: 2022

Swamp	Area of swamp within 60 m of Longwall panels (%)	LiDAR TARP		Floristic monitoring TARP	
		Total extent	Ecosystem functionality	TSR	Composition
DA3A					
15A(1)	1.90	N/A	N/A	-	-
15A(2)	28.86	N/A	N/A	None	**Level 2**
15B	99.35	N/A	N/A	**Level 2**	**Level 2**
DA3B					
11	92.38	None	None	None	None
13	100.00	None	None	None	**Level 2**
14	100.00	None	None	None	**Level 1**
1A	67.96	None	**Level 2**	None	**Level 2**
1B	72.56	None	None	None	**Exceeding expectation**
5	89.26	None	**Level 3**	None	None
23	100.00	**Level 2**	**Level 1**	None	None

Note: The TARPs for Dendrobium Area 3A do not include an assessment of LiDAR.

The full area calculations accompanying Figure 6 are provided in Table 45, based upon available swamp mapping and longwall mining activity in the 2022 year of the Program. The total area of swamp within DA3A and DA3B is 85.42 ha, of which 53.70 is within 60 m of longwall panels and therefore potentially subject to impacts.

Table 45: Area calculations accompanying Figure 6.

Swamp	Area of swamp within 60 m of Longwall panels (ha)	Area of swamp within of Longwall panels (%)	Total area of swamp (ha)
DA3A			
15A(1)	0.29	1.90%	15.40
15A(2)	0.90	28.86%	3.11
15B	5.98	99.35%	6.02
12	5.37	100.00%	5.37
95	0.93	86.31%	1.08
146	0.60	100.00%	0.60
147	0.00	0.00%	0.45
148	0.79	92.16%	0.86
33	0.00	0.00%	3.38
34	0.00	0.00%	2.58
95	0.00	0.00%	1.08
96	0.00	0.00%	0.17
DA3B			
11	7.10	92.38%	7.68
13	2.58	100.00%	2.58
14	6.22	100.00%	6.22
1A	4.91	67.96%	7.22
1B	7.05	72.56%	9.72
5	7.71	89.26%	8.64
23	3.27	100.00%	3.27

5.1.1 Dendrobium Area 3A

A summary of the results against TARP triggers (identified in Table 4) for Dendrobium Area 3A in 2022 is presented in Table 46. If a TARP is triggered it may not necessarily require corrective management actions (CMAs). This trigger system allows detection of change and indicates where to focus further investigation to determine what has triggered the TARP. The higher the TARP trigger is, the more severe the level or duration of change is and greater the implications to the health of the swamp.

Level 1 TARPS in Dendrobium Area 3A cannot be retrospectively reported on as these apply to visual trends observed on the ground with regards to Upland Swamp vegetation and not statistically significant differences in the data collected.

In 2022 both swamps 15A(2) and 15B have recorded TARP triggers. The only change from the 2021 iteration of the monitoring program (Niche 2022), is that a Level 2 TSR TARP at Swamp 15A(2) is no longer triggered.

Table 46: Summary of TARP triggers for Upland Swamps in Dendrobium Area 3A in 2022

Swamp	Results 2022	Details
Swamp 15A(1)	• Not formally assessed	Section 4.4.1.1
Swamp 15A(2)	• TSR: None • Composition: **Level 2 TARP** triggered	Section 4.4.1.2
Swamp 15B	• TSR: **Level 2 TARP** triggered • Composition: **Level 2 TARP** triggered	Section 4.4.1.3

5.1.2 Dendrobium Area 3B

A summary of the results against TARP triggers for Dendrobium Area 3B in 2022 are presented in Table 47, inclusive of the outcomes from the LiDAR assessment.

The trigger system allows detection of change and indicates where to focus further investigation to determine what has triggered the TARP. The higher the TARP trigger the more severe the impact with greater implications to the health of the swamp as impacts are detected over longer timeframes.

In 2022, TARPs have been triggered at Swamps 13, 14, 1A, 1B, 5 and 23 (Table 47). Only Swamp 11 has not recorded any TARP triggers in 2022, although this swamp continues to be reviewed in detail to determine whether the community change that appears to be occurring may be indicative of potential mining effects.

Changes from the 2021 iteration of the monitoring program (Niche 2022) include the following:

- Swamp 13: the swamp extent TARP Level 2 has ceased to trigger
- Swamp 14: a Level 1 species composition TARP has been triggered in 2022 for the first time.
- Swamp 1A: the ecosystem functionality TARP has progressed to Level 2.
- Swamp 1B: an exceeding expectation species composition TARP remains triggered. The TSR and swamp extent TARPs triggered in 2021 are no longer triggered. The decline in Tea-Tree Thicket previously reported cannot be assessed in 2022 as this community is no longer mapped at this swamp based upon the canopy height model.
- Swamp 5: the ecosystem functionality TARP has progressed to Level 3.
- Swamp 23: the TSR TARP is no longer triggered. The swamp extent TARP has progressed to Level 2. A Level 1 ecosystem functionality TARP has also been triggered in 2022.

Table 47: Summary of TARP triggers for Upland Swamps in Dendrobium Area 3B in 2022

Swamp	TARP	2022	Summary
11	TSR	None	A statistically significant difference was not detected in the 2022 analysis, although the trend over monitoring years is approaching the level of significance. Breakpoint analysis identified a statistically significant decline post-mining, although this also coincided with the drought. Currently, no TARP has been triggered however this will be re-examined in 2023.
	Composition	None	Statistically significant differences between pre and post mining have been detected since 2018, however the species experiencing the greatest degree of change display a mix of preferences for wet and dry conditions, with no unified pattern of increasing dry preference species or declining wet preference species. With trending declines in a number of these species commencing pre-mining. Target species selected for breakpoint analysis indicate statistically significant trends that commenced in the pre-mining period or part of a linear trend.
	Extent	None	No TARP triggers to date.
	Ecosystem functionality	None	No TARP triggers to date.
13	TSR	None	No statistically significant difference in TSR has been identified.
	Composition	**Level 2**	Level 2 TARP Triggered in 2022.
	Extent	None	
	Ecosystem functionality	None	No TARP triggered in 2022.
14	TSR	None	No TARP triggers to date.

Swamp	TARP	2022	Summary
	Composition	**Level 1**	Level 1 TARP triggered in 2022 for the first time.
	Extent	None	No TARP triggered in 2022.
	Ecosystem functionality	None	No TARP triggered in 2022.
1A	TSR	None	No TARP triggers to date.
	Composition	None	No TARP triggers to date.
	Extent	None	No TARP triggers to date.
	Ecosystem functionality	**Level 2**	A continuing decline in Tea-Tree Thicket greater than that experienced at the Control Group in 2019-2020, 2020-2021, 2021-2022 has been identified in 2022.
1B	TSR	None	A Level 1 TARP is no longer triggered.
	Composition	**Exceeding expectation**	An exceeding expectation TARP has been triggered following seven consecutive years of species composition data being different to pre-mining data. Consistent with Niche (2022).
	Extent	None	A Level 2 TARP is no longer triggered.
	Ecosystem functionality	None	The decline in Tea-Tree Thicket greater than that experienced at the Control Group in 2019-2020 and 2020-2021 identified in 2021 (Niche 2022), cannot be assessed in 2022 as this community is no longer mapped at this swamp based upon the canopy height model. South32 Environment Team undertook an inspection on 5 May 2023 of the area where Tea-tree Thicket was previously mapped in Swamp 1B. Evidence of some die-back was present (mostly appeared to be dead *Hakea dactyloides* and some patches of bare ground), however the area was found to be supporting a canopy of *Banksia ericifolia, B. robur, Hakea dactyloides, H. tereifolia* and a ground cover supporting *Gleichenia dicarpa, Empodisma minus, Lepidosperma limicola* and other sedges. Regrowth of Tree-Tree plants (*Leptospermum polygalifolium*) were observed within the patches of bare soil (ranging from 30 cm to 2 m in height). Woodland species such as *Isopogon anemonifolius* and *Persoonia levis* were also recorded. Mapping of this area will be reviewed in the 2023 monitoring program, as it appears that this area is transitional between the adjoining woodland and Sedgeland Heath, with some elements of Tea-Tree Thicket is still present and potentially recovering from previous die-back.
5	TSR	None	No TARP triggers to date.
	Composition	None	No TARP triggers to date.
	Extent	None	No TARP triggers to date.
	Ecosystem functionality	**Level 3**	A decline in Tea-Tree Thicket greater than that of the Control Group was detected in 2018-19, 2019-20, 2020-21 and 2021-22.
23	TSR	None	No TARP triggered in 2022.
	Composition	None	No TARP triggers to date.
	Extent	**Level 2**	A Level 2 TARP has been triggered for the first time.
	Ecosystem functionality	**Level 1**	A Level 1 TARP has been triggered, with a decline in Banksia Thicket greater than that of the Control Group detected in 2020-21 and 2021-22.

5.2 Amphibian monitoring

A range of impacts to streams have been identified at impact monitoring transects as part of the Program to date. Additional calculations have been completed in 2022 to identify the length of streams within DA3A and DA3B that are potentially subject to impacts (Figure 7). The mapping of stream length at risk of impacts has been completed using advice from the Biodiversity Conservation Division (BCD) on the Dendrobium

Mine Extension Project Biodiversity Development Assessment Report (Niche 2022c) (received 1 August 2022) regarding the development of a species polygon for the Littlejohn's Tree Frog:

"The species polygon should therefore be assumed to occur downstream of all watercourses underneath longwalls, until that watercourse joins another watercourse (at least a second order stream which is un-impacted by mining)."

This advice has been adopted in the mapping of the length of streams within DA3A and DA3B that are potentially subject to impacts (Figure 7). This acknowledges that the extent of impacts that are possible (e.g. normal hydrology not re-instated beyond the 400 m RMZ buffer and iron staining of downstream pools). On the basis of these calculations, a total of 25.65 km of stream within DA3A and DA3B are potentially subject to impacts. Noting, that the level and severity of impact to stream features and aquatic environments has been observed to be highly variable down to the pool scale, indicated by differing TARP levels at the transect scale (Figure 7).

Table 48: Stream lengths potentially impacted in DA3A and DA3B (Figure 7)

Strahler order	Stream length (km) – Dendrobium Area 3A	Stream length (km) – Dendrobium Area 3B
1	6.03	11.51
2	2.08	6.03
Total	8.11	17.54

It should be noted that this calculation is likely to be a conservative measure of potential impacts to Littlejohn's Tree Frog habitat, as this is applied as a general measure for desktop analysis based upon the longwall panel layout. It should also be considered that not all streams, or stream sections, may represent suitable habitat for this species, and that the species typically has a low population density and distribution across the landscape. Occupancy of suitable stream habitats within the Dendrobium Mine lease area has been investigated with modelled estimates of approximately one third of each 50 m stretch of stream examined containing tadpoles (Klop-Toker et al. 2021). A range of biotic and abiotic factors influence breeding pool selection for this species, with the result that not all pools suitable for breeding within the landscape are in fact occupied by the species, with the pattern of pool occupancy typically not uniform.

5.2.1 Dendrobium Area 3A

A summary of the results against TARP triggers for Dendrobium Area 3A is presented in Table 49. No changes to TARP Level triggers have occurred in 2022 relative to those in 2021 (Niche 2022a).

Table 49: Summary of TARP triggers for Amphibian Transects in Dendrobium Area 3A

Transect	Results and TARP justification 2022	Additional details
6CDL	**No TARP** triggered	See section 4.6.4.2 This tributary has been within the RMZ since 2010, 50 m away from goaf of Longwall 7. No decline in frog detection post mining has been identified.
SC10C	**Level 2 TARP** triggered due to appearance at SC10C (fractured bedrock and iron flocculant) and habitat unlikely to naturally regenerate within the monitoring period. A statistically significant decrease in the detection of Adults has occurred in the post mining period.	See section 4.6.4.3 This tributary is almost completely mined beneath by Longwall 8

Transect	Results and TARP justification 2022	Additional details
SC10(1)	**Level 2 TARP** triggered due to appearance at SC10(1) (fractured bedrock (upstream in SC10C) and iron flocculant present at 13 of the 14 pools recorded) and habitat unlikely to naturally regenerate within the monitoring period.	See section 4.6.4.4 Longwall 8 has extended into the RMZ of the tributary across the majority of the transect. Observed indirect impacts (flocculant) were recorded.
SC10(2)	**No TARP** levels triggered.	See section 4.6.4.5 Longwalls 8 and 19 have entered into the RMZ of the tributary across much of the transect, with a small section mined beneath in 2021. As in previous years, limited observations of indirect impacts (flocculant) were made at the most downstream end of the transect, but no observable pattern of adverse impacts is observed in the biological data.
WC17	**Level 2 TARP** triggered due to appearance at WC17 (iron flocculant and fractured bedrock since 2017 at WC17) and habitat unlikely to naturally regenerate within the monitoring period.	See section 4.6.4.6 Much of this tributary is mined beneath by Longwalls 7 and 8.

5.2.2 Dendrobium Area 3B

A summary of the results against TARP triggers for Dendrobium Area 3B is presented in Table 50. The following changes have occurred relative to the 2021 Program year (Niche 2022a):

- DC(1): The Level 3 TARP is no longer triggered.
- LA2: the TARP level has progressed to Level 2.
- WC15: the TARP level progressed to Level 3.
- WC21: the Level 3 TARP remains triggered.

Table 50: Summary of TARP triggers for Amphibian transects in Dendrobium Area 3B

Transect Name	Results and TARP justification 2022	Details
DC(1)	No TARP triggered. Both Adults and Eggmass were detected in 2022. No observations of flocculant were made in 2022, with all pools at or above water holding capacity, or flowing. On the basis of these two factors, the Level 3 TARP is not triggered at DC(1) in 2022. It should be acknowledged that this may represent only a temporary amelioration resulting by high rainfall conditions rather than a persisting long-term improvement.	See Section 4.6.5.2 Tributary is within the RMZ and continues outside of the RMZ greater than 400 m from Longwall 9. Impacts to pool levels apparent up to 200 m from mined beneath area.
DC13	**Level 3 TARP** remains triggered. The detection of the Adult lifecycle stage remains statistically lower than that of the pre-mining years and there has been a reduction in habitat for greater than two-years following the active subsidence period.	See Section 4.6.5.3 Tributary is mined beneath and within RMZ. Impacts are predominantly observed within the mined beneath section, improving within the RMZ.
LA2	**Level 2 TARP** triggered due to a reduction in habitat (reduction in aquatic habitat, contrary to that observed at the controls) for 1 year following the active subsidence period.	See Section 4.6.5.4 The first year of mined beneath monitoring has recorded the transect transitioning from having all pools at full capacity in 2020 to having only a single pool holding water in 2022. Frog detection results

Transect Name	Results and TARP justification 2022	Details
		have also declined to levels commensurate to those recorded at the height of the recent drought in 2018.
LA4A	No TARP triggered. Sub-optimal habitats are present along this tributary both pre and post mining with no change in detection identified, or observation of impacts recorded.	See Section 4.6.5.5 Tributary is entirely within RMZ (Longwall 13). Some observed impacts however the habitats are limited and sub-optimal, with frog detection consistent with pre-mining levels.
WC15	**Level 3 TARP** triggered due a reduction in habitat (dry pools for extended time and bedrock cracking) for three-years following the active subsidence period.	See Section 4.6.5.6 The transect has both mined beneath sections of the stream and sections within the RMZ. Impacts are clearly apparent in mined beneath section and become less pronounced within the RMZ.
WC21	**Level 3 TARP** triggered due a continued reduction in habitat (fractured bedrock) at WC21 for more than two-years following the active subsidence period.	See Section 4.6.5.7 Tributary has sections mined beneath, within RMZ and outside of RMZ. Hydrological impacts are notable in mined beneath sections. Indirect impacts within the RMZ sections have included the presence of iron flocculant.
ND1	No TARP triggered.	See Section 4.6.5.8 The upper reaches of the tributary runs adjacent to Longwall 18, with the transect itself located approximately 225 metres from the longwall (within RMZ).
NDC	No TARP triggered.	See Section 4.6.5.9 Longwall 18 extends into the RMZ of Native Dog Creek, with approximately half of the transect within RMZ. Native Dog Creek has been subject to prior impacts from the Elouera Colliery, pre-2007, including prevalent flocculant levels observed in the pre-mining data (Niche 2022a).
ND2	No TARP triggered.	See Section 4.6.5.10 Longwall 18 extents into the RMZ of the tributary, with approximately half the transect within RMZ. ND2 has been subject to prior impacts from the Elouera Colliery, pre-2007 (Niche 2022a), including prevalent flocculant levels observed in the pre-mining data (Niche 2022a)

6. Discussion and recommendations

At the completion of the 2022 iteration of the ecological monitoring program, approximately 20 years of data has been collected for Dendrobium Area 3A; and 9 years of data collected for the majority of Dendrobium Area 3B (aside from Swamp 11 where monitoring has been undertaken for 16 years).

6.1 Trends across Upland Swamps

Trends across swamps indicate declining TSR post-mining for the majority of Impact swamps and Control swamps. Compositional changes show trends of the loss of flora species, generally (but not entirely) those with a preference for 'wet environments'. Although it is reasonable to expect natural species turnover to occur at a swamp, especially after an extended drought period, the overall patterns of change are suggestive of either declining swamp condition (die back or die off of swamp dependent species), or vegetation community transition. The assessment of performance measures suggest that impacts are being detected at the Impact monitoring swamps utilised in the Program, although there is variation across the varying TARPs and TARP levels that have been triggered to date. This level of inconsistency presents difficulties in the interpretation of trends and may serve to emphasise the swamp specific nature of impacts and how these manifest in the monitoring results.

The assessment of cumulative impacts considering longer periods has identified a number of significant trends in both TSR and species composition at the Impact monitoring sites. Although similarly to the two-year comparisons described above, these are not necessarily consistent across the swamps and may be suggestive of die off of swamp dependent species, or vegetation community transition, depending on the swamp in question.

Additional breakpoint analysis has been completed since 2021 for the TSR data and target species experiencing strong trends within swamps. This analysis has tended to present a more complex picture of temporal trends and their relationship to mining. Many trending declines in TSR and species detection appear to have commenced either pre- or at some years post-mining. Generally speaking, the trends occurring pre-mining have not appeared to be exacerbated by mining, although no recovery or trending increases are seen in the post-mining data at individual swamps, and do not appear to be strongly correlated to rainfall, although this has not been specifically tested and future monitoring may be able to better address this question. Statistically significant trends or breakpoints that have occurred in the post-mining data are more difficult to interpret with certainty. In some cases, these align with the drought but do not show a recovery in the post-drought period (2020-2022) to date. Possible explanations may include that there is a lag time generally in vegetative response following acute and extended drought conditions that may take several years to manifest. Impacted swamps may have a lower resilience to drought and therefore may take longer to recover, or the vegetative response will manifest as a different stable state to the pre-drought condition, or recovery potential will be limited. Further monitoring will be required to address these temporal patterns of change. Completing the broken stick analysis for the control swamps during the same period may assist in the interpretation of these trends.

Impact Upland Swamps occurring in the RMZ and not directly mined beneath appear to take longer to show impacts at the surface. For example, Swamp 15(A)2 (the only swamp remaining in the RMZ) has taken five years since impact to detect changes in TSR and composition with observed impacts less severe than swamps mined beneath (given changes in groundwater levels are generally not detected until longwalls are within 60 m of a swamp as discussed in Section 4.2, the causal effect here is unclear). In contrast, changes are detected in TSR or composition for swamps directly mined beneath, typically within 1-two-years of impact. This suggests that swamps that are not directly mined beneath are less impacted than those directly mined beneath with compositional changes in vegetation not readily observed for some years.

It should be noted that between 2016 and 2019 was the most significant drought on record for the area, peaking in 2018/2019 (see Graph 1), the effect of which can be seen through contraction in both control and impact swamp size in 2019 and 2020 (as demonstrated by LiDAR analysis). The drying of the Impact Upland Swamps over time since impact may be exacerbated by the effect of the drought, though the correlation between impact of mining and drying of the Impact Upland Swamps was evidenced by the greater magnitude of change experienced at the Impact Upland Swamps compared to Control Upland Swamps over the drought period (Biosis 2020, Niche 2021). Continued monitoring will assist in determining whether any recovery occurs following the above average rainfall period post-drought, and whether this differs in timing or scale when compared to control swamps.

Interestingly in 2022 (following significantly above average rainfall years), a decline in swamp extent through the LiDAR monitoring has been recorded, across both Impact and Control monitoring swamps. It is suggested that this trend is driven by expansion of the fringing eucalypt woodland canopy (as the model is canopy-height driven), rather than a direct loss of upland swamp sub-community vegetation. It is suggested that this response in the fringing eucalypt woodland has been driven by the above average rainfall conditions, in the years following the extended drought promoting growth (2017-2019). Over a longer time scale, it is possible that prolonged above average rainfall conditions (into the future) would benefit the upland swamp vegetation and result in a general increase in swamp extent, however it is unclear over what timescale this may occur.

Detecting change in Coastal Upland Swamp vegetation and habitat change from subsidence is confronted with many limitations and variables, and as such, results have not been conclusive to date around the severity and scale of impacts. This is largely attributed to the time over which change may be observed in vegetation as a result of subsidence, influences of the surrounding landscape, current limitations of monitoring (in particular current LiDAR and aerial interpretation models), influence of climatic factors (drought and rainfall), as well as the unique nature of each swamp and its subsidence impacts.

The above factors notwithstanding, this report concludes that impacts to swamp communities are apparent in the post-mining period. This is anticipated based upon the proximity of these swamps to the longwalls and the outcomes of the review identifying hydrological impacts within 60 metres of longwall activity (Sections 4.2 and 5.1). While the impacts (assessed as part of the TARP framework) noted in 2022 appear to be suggestive of vegetation transition, it has not been tested whether the loss or decline of specific species are being replaced by commensurate increases in other species, although the general trend of declining TSR does not suggest the recruitment of different species (at the monitoring transects). It is also noted that no areas of gross visual change (dieback) observed during the drought (Biosis 2020), were recorded in 2022, with some evidence of continued recovery. Another open question is what are the driving factors behind the trends in species detection that pre-date mining activity, and the decline in TSR observed in the control swamps?

Two factors that have been identified as potential contributors in driving these trends (outside of mining influence) are time since bushfire, and climate change. It should be considered that the swamps experiencing impacts associated with mining may be at greater risk of change associated with these phenomena, or have lower resilience to the influence of these environmental perturbations. This is based upon a growing body of evidence developed in recent years following widespread bushfires in NSW. Mason et al. (2020) recorded that mined wetlands were persistently drier and retained water for shorter durations than unmined wetlands. Baird et al (2020) observed a lack of resprouting of swamp flora following bushfire at mined swamps at Newnes Plateau. Similarly, Krogh et al. (2022) contrasted the relatively rapid vegetative recovery observed at unimpacted upland swamps on the Newnes Plateau after the Gospers Mountain bushfire with evidence of extensive combustion and oxidization of peat soils in swamps located above the footprint of prior longwall coal mining operations. Keith et al. (2022) concluded that mined swamps showed symptoms of post-fire ecosystem collapse, while reference swamps regenerated vigorously.

Over the longer term, it has been suggested by Keith et al. (2006) that an increased fire frequency of around 15 years may not be compatible with the persistence of Coastal Upland Swamp vegetation. An increased fire regime from climate change may result in a decline of resprouting shrubs and sedges, which may lead to more prolonged exposure of soils after fires, especially if fires consume all ground fuels. This is because resprouting plants restore groundcover more rapidly than new seedlings. Prolonged or enhanced soil exposure could lead to accelerated decay of organic matter and/or accelerated erosion of surface soils, particularly if heavy rainfall events occur in the early post-fire years (Keith et al 2006). Erosion and reductions in the organic content of swamp soils are likely to increase the turbidity and mineral content of discharge waters and reduce the water retention capacity of the swamps (Young 1986). It is possible that subsidence may have a role in exacerbating the process through drying soils as a result of a changed groundwater regime.

6.2 Littlejohn’s Tree Frog ecology

Recent research into the Littlejohn’s Tree Frog biology and ecology has shed further light on the distribution, populations and ecology of the species as a whole. As well as the Woronora population, which includes those within the Dendrobium Mining Domain and ecology of the species in this area specifically. The most relevant findings are synthesised in this section to inform the discussion of results of the monitoring program in 2022 and with reference to previous years of monitoring.

6.2.1 Distribution and populations

Following recent work by Mahony et al. (2020) the species has been split. The taxonomic review has therefore restricted Littlejohn’s Tree Frog to the northern-end of its previously accepted distribution range, halving the species Area of Occupancy (AoO).

The revised distribution of the Littlejohn’s Tree Frog now considers the species as restricted to three regions in the Sydney Basin, being the Watagan Mountains, the Blue Mountains National Park and the Woronora Plateau. It has been suggested that the key driver behind the inferred recent reductions in the extent and occurrence of this species is Chytridiomycosis, although the species has received relatively little study to date (Mahony et al. 2020) and additional threats to the species have also been identified, including subsidence from longwall mining. The Cordeaux area was found to have the highest population size out of three populations surveyed as part of a recent study by Klop-Toker et al. (2021).

6.2.2 Lifecycle and ecology

Within the Study Area, the species relies upon semi-permanent to permanent pools for tadpole development (Biosis 2016, Daly and Craven 2007), with maturation times for tadpoles of the species having been observed to take around 4 months (Anstis 2002) but dependent on seasonal temperatures, and other factors. Klop-Toker et al. (2021) suggests between 3 to 4 months in summer and 5 to 11 months in winter.

Anstis (2017) notes that metamorphosis occurs mainly in December and January. Pools of sufficient depth and hydroperiod within the Study Area are generally located along second and third order streams or first order streams downstream of headwater swamps.

Work by Klop-Toker et al. (2021) and Stock et al. (N.D) suggest movement across catchment boundaries appears to be relatively limited, however causal factors are not well known and the level of movement between frogs within the Dendrobium and Avon catchments into adjacent areas has not been tested. Klop-Toker et al. (2021) also found that that the species is able to disperse significant distances moving between mined and un-mined areas within the Dendrobium Mine lease, although the authors suggest the species may have a high level of site fidelity.

6.2.3 Habitats

The species typically has a low population density and distribution across the landscape. Occupancy of suitable stream habitats within the Dendrobium Mine lease area has been investigated with modelled estimates of approximately one third of each 50 m stretch of stream examined containing tadpoles (Klop-Toker et al. 2021).

Swamps act as a buffer allowing for more continuous and even water flows along streams after rain events (Young 2017, NSW Scientific Committee 2012) and thus greater hydroperiods (or permanency) within pools along smaller streams. This may influence tadpole development for species with lengthy periods of metamorphosis. Therefore, while swamps are not considered required for tadpole development, they aid in providing suitable conditions downstream for tadpole development to occur, particularly along 1st and 2nd order streams. However, many locations where the species is found do not have upland swamps present and there is no known associated vegetation type that the species relies on specifically. The species (as presently listed) has been recorded in coastal woodland, heaths and in disturbed and undisturbed woodlands (DoE 2022). Swamps and heath may aid in providing suitable conditions to forage and shelter, facilitated through moisture availability and abundance of debris. However, the species is known to shelter in a range of habitats. The extent to which drying of swamps might impact the capacity of swamp sites to provide ideal sheltering conditions is unknown, however it seems likely that swamps are more important in regard to enhancing opportunities for tadpole development downstream rather than providing ideal sheltering habitat given the variety of sheltering habitats reportedly used.

Within the Dendrobium Mine lease area the species is restricted to smaller streams, below a stream order of 4, within dry sclerophyll or heath forest vegetation, often but not exclusively in association with upland swamps (Biosis 2016, Klop-Toker et al. 2021). Fine scale pool attributes selected for breeding include water quality that is low in salinity and slightly acidic, sizes between 1 m^2 to 3000 m^2, pools with a depth of < 1.5 metres (Klop-Toker et al. 2021). Monitoring of the species undertaken by Niche (2021, 2022a) has identified a preference for deeper pools over shallower pools within Dendrobium Areas 3A and 3B. Niche (2022a) also concluded that while each lifecycle stage may be detected in pools with flocculant, both Adults and Eggmass are statistically significantly less likely to occur in pools with flocculant present. A preference for pools containing high levels of leaf litter and an absence of algae, fish and iron flocculant have also been established (Klop-Toker et al. 2021).

A range of biotic and abiotic factors influence breeding pool selection for this species, with the result that not all pools suitable for breeding within the landscape are in fact occupied by the species, with the pattern of pool occupancy typically not uniform.

6.2.4 Impacts within Dendrobium

The monitoring program has identified an ecological response detected at several impact sites within Dendrobium Areas 3A and 3B, with observed impacts most frequent and acute in areas that have been directly mined beneath (Niche 2021, 2022a). The reports described observed patterns of limited water retention at impact monitoring sites post-mining, indicating that mining is having an impact on the species due to decreased tadpole survivorship (Niche 2021, 2022a). Similarly, Klop-Toker et al. (2021) found that recruitment has been reduced within mined areas of the Dendrobium Mine Lease area, due to a loss of habitat after subsidence. Despite this, Littlejohn's Tree Frogs have been observed consistently from both Control and Impact sites during annual monitoring since monitoring began in 2006 (Niche 2021, 2022), indicating breeding habitats may continue to be utilised despite impacts in some areas, at least in the short term (less than 10 years) and albeit at reduced abundances.

However, the ability of Littlejohn's Tree Frog to persist on a long-term basis in areas that are directly mined beneath by longwall mining should be considered questionable based on conclusions from recent studies (Klop-Toker et al. 2021). Although, studies (e.g. Klop-Toker et al. 2021) have noted that areas of un-impacted habitat within the mined areas continue to support high numbers of tadpoles and regular recruitment. Ongoing monitoring will assist in understanding these long-term trends post-impact.

6.3 Trends across Littlejohn's Tree Frog populations in 2022

In 2022, relatively high levels of detection across the Eggmass and Adult lifestages were recorded when compared to previous years, but low levels of Tadpole detection. This may be an artifact of survey timing (given the high number of Eggmass), possibly in relation to rainfall breeding cues, or an effect of the significantly above average rainfall and elevated flows.

6.3.1 Control and Impact transect habitat comparisons

It is considered that as a group the Control transects within the Program generally support higher quality breeding habitat for Littlejohn's Tree Frog, with the Control transects typically featuring overall deeper pools with less variation than the Impact sites. Whilst Littlejohn's Tree Frog amplexus and egg deposition may occur within pools of any size, Adult Littlejohn's Tree Frog generally indicate a preference for deeper pools (Niche 2021, 2022a), which are more likely to support Tadpole metamorphosis due to longer hydroperiods. Klop-Toker et al. (2021) also found that the presence of Tadpoles were positively correlated with the number of pools per transect and pool depth, with Tadpole abundance being positively correlated with pool volume.

The Control transects were presumably incorporated into the Program due to the presence of known Littlejohn's Tree Frog habitat and breeding populations. The design of longwall mining layouts is also biased towards lower order streams with smaller pools to avoid larger watercourses and thereby reduce potential impacts to these ecological features. The same bias has not applied to Control site selection. This bias may also be observed in the statistical analysis in 2022, which identified that where pre-mining detection data is available for impact transects, this is typically statistically significantly lower than that of the Control Group.

Regardless of the observed bias in pools depth (as a readily estimated proxy for pool size), Littlejohn's Tree Frog have been observed consistently from both Control and Impact sites and therefore changes due to longwall mining at Impact sites remain observable and valid comparisons are able to be made between Control and Impact sites. Relatively longer hydroperiods occur in small pools downstream of large swamps (compared with where swamps are absent) due the inherent water retention capacity. Therefore, pool size is not the only factor determining hydroperiod and other factors such as catchment position, stream geomorphology and underlying geology are also key factors in determining pool hydroperiod.

Due to the significant levels of rainfall, the prevailing environmental conditions (water availability and absence of flocculant) within habitats were not typically any more favourable for the Littlejohn's Tree Frog at the Control sites than the Impact sites. Notable exceptions to this occur where impacts are severe (e.g. LA2) and pool water holding capacity has been significantly reduced.

6.3.2 Direct and indirect impacts

Littlejohn's Tree Frog may preferentially select smaller breeding pools associated with upstream swamps due to the limited number of suitable pools in other streams across the mining domain (Klop-Toker 2020). Given observed patterns of limited water retention at Impact sites post-mining, it is likely that mining is having an impact on frog reproduction due to decreased Tadpole survivorship and a reduction in the extent of preferred habitats.

Observed patterns of cracking and limited water retention as well as analysis of swamp piezometric data indicates greater and more obvious hydrological impacts within areas directly mined beneath. Whereas indirect impacts, specifically flocculant, are more typically detected in sections where mining has entered within the RMZ of the stream and water levels are maintained, but in close proximity to mining activity (Niche 2022a). The distance of the creeks or tributaries from being directly mined beneath and within the RMZ either upstream or downstream appear to have a general trend. Directly mined beneath areas have more observable changes to aquatic habitat with dry pools or limited water retention. This becomes less obvious as the transect moves away from the longwall. This is evident in transects that contain sections that are mined beneath, within the RMZ and/or sections greater than 400 m from the longwalls (i.e. DC(1) or WC21). An additional example may be the pool identified downstream of transect LA2, approximately 70 metres downstream of Longwall 17.

Previous monitoring events reported: *Subsidence related impacts, including cracking of bedrock, lowering of water levels and build-up of iron flocculant ….at sites SC10C, SC10(1), WC17, WC21, DC(1) and DC13, with each of these sites triggering either Level 1 (SC10(1), DC(1)) or Level 3 (WC21 and DC13) of the relevant TARP* (Biosis 2020). These effects were also evidenced at these sites, and with the addition of LA2, as a part of the 2022 monitoring year. In 2022, TARP levels have been triggered at seven of the fourteen Impact monitoring transects as part of the Program.

The significant levels of above average rainfall in 2022 may have ameliorated impacts at some transects.

6.3.3 Incidental observations

Incidental observations of Littlejohn's Tree Frog tadpoles were made during the ecological restoration monitoring surveys for Survey 16 borehole infrastructure (Niche 2022b). Tadpoles were observed to be present within the footprint of borehole site S17-22. Approximately 20 Littlejohn's Tree Frog tadpoles were identified within a pool of water in a sandstone rock cut-out at the base of the borehole monitoring station. The man-made pool located on site is not part of the usual breeding habitat for the species and is located approximately 250 metres from the nearest stream and key breeding habitats. The artificially created habitat at site S17-22 is considered poor for breeding (having limited connectivity to other waterways in the landscape and being upslope of the nearby streams in a small, cleared area). However, the site does fulfill the basic requirements of the species (an intermittent pool in sandstone topography). It is considered likely that this artificially created habitat had been opportunistically utilised while adult individuals of the species had been moving throughout the landscape. This observation is suggestive of the species capacity to move across terrestrial environments and it may also present promising indications that the provision of simplistic artificial habitats that fulfil basic breeding requirements in otherwise marginal areas could be utilised by the species.

The Giant Burrowing Frog (listed as Vulnerable under the BC Act and EPBC) is not specifically included in ongoing monitoring to date in Dendrobium Areas 3A and 3B due to inaccessibility of the catchment during optimal survey times (i.e. after periods of heavy rain), and as such, observations are recorded incidentally as part of the Littlejohn's Tree Frog monitoring. While impacts to habitats within some of the impact monitoring streams have been detected, potential impacts to Giant Burrowing Frog populations have not been tested, and observations of the species have been highly sporadic across control and impact monitoring streams, and years, throughout the Program. In 2022, Giant Burrowing Frog tadpoles were recorded at both Control transects CR29 and CR29D. A total of 20 Giant Burrowing Frog tadpoles were recorded across 4 pools at CR29, and one pool along CR29D.

6.4 Corrective management actions and offsets

Area 3A CMAs relevant to TARP triggers are outlined in Table 51, Table 4; and Area 3B CMAs relevant to TARP triggers for Upland Swamps are outlined in Table 52 and watercourses in Table 53.

It should be noted that CMAs (e.g. grouting trials) have commenced. In addition, offsets were provided for loss of water quality or loss of water flows (subject to Condition 14 of Schedule 3 of the Development Consent) via the transfer of 33 ha of land adjacent to the Cataract River to WaterNSW (IMC 2017). Further, the Strategic Biodiversity Offset (IMC 2016b) includes frog habitat within Maddens Plains and was considered a suitable offset for impacts on watercourses that have exceeded those predicted in the SMP (IMC 2017).

The impacts and declines in health of the Upland Swamps and aquatic habitat are described in this report.

Table 51: Area 3A Landscape TARP Actions table summary (IMC 2020a)

TARPs	Actions
Area 3A Landscape TARP	
No TARP	• Continue monitoring program • IMC to report in the End of Panel Report
Level 1	• Continue monitoring program • IMC to report in the End of Panel Report
Level 2	• Actions as stated for Level 1 • Review monitoring frequency • Notify relevant technical specialists and seek advice on any Corrective Management Actions (CMA) required • Implement agreed CMAs as approved
Level 3	• Actions as stated for Level 2 • Immediately notify OEH, DoPI, DPI, SCA, other resource managers and relevant technical specialists and seek advice on any CMA required • Site visits with stakeholders if required • Review monitoring program and modify if necessary within 1 month • Implement increased monitoring if required within 2 weeks • Develop site CMA in consultation with key stakeholders within 1 month, (pending stakeholder availability) and seek approvals • Completion of works following approvals • Issue CMA report within 1 month of works completion

TARPs	**Actions**
Area 3A Landscape TARP	
	• Conduct initial follow up monitoring & reporting within 2 months of CMA completion • Review the relevant TARP and Management Plan in consultation with key stakeholders
Exceeding TARP (Swamp 15A only)	• Actions as stated for Level 3 • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation

Table 52: Area 3B Swamp TARP Actions table summary (IMC 2020b)

TARPs	**Actions**
Area 3B Swamp TARP	
Level 1	Management strategies • upfront mine planning • vegetation monitoring • water spreading • seeding/planting • weeding • fauna monitoring • fire management • grouting of controlling of controlling Offsets • Offset required immediately, if no remediation considered practicable. Offset required five-years following remediation, if it is ineffective. This period can be extended to 10 years, with the agreement of the Secretary. Other Actions: • Monitoring period for swamp size is related to capture of LiDAR data at the end of each longwall ~ 1 year. • Triggers for groundwater decline result in increased intensity and frequency of vegetation monitoring of vegetation monitoring
Level 2	
Level 3	
Exceeding TARP (Swamp 15A only)	

Table 53: Area 3B Watercourses TARP Actions table summary (IMC 2020c)

TARPs	**Actions**
Area 3B Watercourses TARP	
No TARP	N/A
Level 1	• Continue monitoring program • IMC to submit an Impact Report to OEH (DPIE), DoPE (DPIE), T&I, WaterNSW and other relevant resource managers • IMC to report in the End of Panel Report • Summarise action and monitoring in AEMR
Level 2	• Actions as stated for Level 1 • Review monitoring frequency • Notify relevant technical specialists and seek advice on any Corrective Management Actions (CMA) required • Implement agreed CMAs as approved (subject to stakeholder feedback)
Level 3	• Actions as stated for Level 2 • Site visits with OEH (DPIE), DoPE (DPIE), T&I WaterNSW, other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders

TARPs	Actions
Area 3B Watercourses TARP	
	- Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with OEH (DPIE), DoPE (DPIE), T&I, WaterNSW and other stakeholders - Completion of works following approvals and at a time agreed between BHPBIC (IMC), DoPE (DPIE), T&I and WaterNSW (i.e. may be after mining induced movements and impacts complete), including monitoring and reporting on success.

6.5 Recommendations for future monitoring

The 2022 iteration of the monitoring program has adopted a number of recommendations from the previous report (Niche 2022), this represents a continuation of refinement in the monitoring approach with a number of assessment methodologies augmented by additional analyses.

The following recommendations are made in relation to future monitoring carried out as a part of the Program.

6.5.1 Seasonal data collection: removal of autumn flora transect monitoring

As described in Section 3, the argument to undertake transect (floristic) data collection only once per year in spring is supported by the fact that no seasonal differences were detected in TSR or in species composition for any swamp (except Swamp 14 which was identified to be an artifact of the narrow range of species richness at his swamp, rather than representing an ecologically functional pattern), and general lack of species depending on autumn survey for detection. With spring representing the more important of the two seasons for the analysis in terms of species detection. No strong justification to maintain the autumn round of transect data collection was identified and the analysis undertaken suggests that 'spring only' data collection and analysis would not compromise the validity of the Program or fundamentally alter the monitoring results.

It is recommended that future data collection in spring only is considered for the transect (floristic) monitoring, with subsequent data analysis restricted to the spring seasons of data collection.

6.5.2 Statistical analysis

It is recommended that the additional breakpoint analysis undertaken in 2022 should also be applied to the control swamp floristic data to enable direct comparison to trends at impact and control swamps, rather than just within impact swamps. It is also recommended that statistical analysis also incorporate time since bushfire to determine how bushfire impacts may affect changes to TSR and composition at a landscape scale. This will also allow a greater consideration of global trends that are apparent in the monitoring results.

6.5.3 Additional monitoring sites

One additional Control swamp and two additional Control amphibian monitoring transects have been added to the Program in 2022 in line with the recommendations of Niche (2022a).

While Littlejohn's Tree Frog was detected along the extent of CR29, detection was more concentrated along the upstream sections of the transect. It is recommended the detection data be reviewed in 2023, in unison with a diurnal inspection of upstream habitats, to ascertain whether it may be beneficial to extend the upstream limit of transect CR29 and shorten the downstream limit of the transect. With the aim to maximise the potential for detection, without significantly changing the physical characteristics present along the transect.

6.5.4 Transect LA2

Incidental observations of Littlejohn's Tree Frog were made downstream of the survey transect in 2022, approximately 70 metres downstream of Longwall 17. This pool should be re-visited in subsequent iterations of the monitoring program to determine if persistent habitat and breeding activity remains through more nominal rainfall conditions.

Known areas of rockfall and treefall were observed along the upper half of the transect, presenting potential hazards to the field survey team during nocturnal survey due to the densely vegetated nature of the stream preventing observations at distance from the field team. In light of the limited value of completing survey along this extent of the transect, considering the known impacts, continued lack of detection, and potential hazards, it is recommended that future surveys focus on the downstream end of the transect between Pools 7 and 19 (area of highest detection, including during the pre-mining period).

6.5.5 LiDAR analysis

Niche have undertaken preliminary investigation into potential additional data products that could be derived from LiDAR data to enhance the analysis workflow.

The new model allows multiple criteria analysis through overlay of canopy height LiDAR derived products matched with NDVI moisture index values acquired by IMC's new fleet of UAVs to better inform ecosystem functionality of the swamps and in particular provide an indication of 'vegetation health' and identification of any areas of dieback.

This new multiple criteria approach may also assist in sub-community boundary delineation which would increase efficiency to complete manual verification of the data and generate greater value from the data that IMC collects as it relates to usage and project outcomes.

It is recommended that further development and integration of the NDVI assessment into the existing LiDAR analysis workflow for all monitoring swamps is considered.

7. Conclusion

Following the 2022 analysis of impacts to swamps and creeks against TARPs, an ecological response had been detected at the majority of Impact sites within Dendrobium Areas 3A and 3B, where a decline in ecological values have been observed.

For Area 3A, TARPS were triggered in two Impact swamps and three tributaries. For Area 3B, TARPS were triggered for four tributaries and six swamps.

Ongoing decline in ecological condition have been identified through this monitoring program, although potential resilience and recovery may be observed after above average rainfall seasons in 2020-2022.

The additional assessments of both swamp floristic data and Littlejohn’s Tree Frog detection data in 2022 have shed further light on the complex relationships between suitable and optimal habitats, prevailing environmental conditions, and the interplay of these factors with mining effects.

A number of recommendations to improve the monitoring program have been detailed in Section 6.5 to further refine the analysis.

References

Anstis, M 2002. Tadpoles of South-eastern Australia: A Guide with Keys. Sydney: Reed New Holland.

Anstis, M. 2017. Tadpoles and Frogs of Australia. Second Edition. New Holland Publishers Pty Ltd.

Baird, I.R & Benson, D. 2020. Serious impacts of longwall coalmining on endangered Newnes Plateau Shrub Swamps, exposed by the December 2019 bushfires. Australasian Plant Conservation: Journal of the Australian Network for Plant Conservation, Vol 29 No 1 June to August 2020.

Biosis 2014. Dendrobium Ecological Monitoring Program: Annual Report for Spring 2013. Prepared for BHP Billiton Illawarra Coal. Biosis Pty Ltd, Wollongong. Dated 31 July 2014.

Biosis 2016. Dendrobium Terrestrial Ecology Monitoring Program: Annual Report for 2015. Prepared for Illawarra Coal. Biosis Pty Ltd, Wollongong. Dated 6 May 2016.

Biosis 2020. Dendrobium Area 2, 3A and 3B: Terrestrial Ecology Monitoring Program: Annual Report for 2019. Report for Illawarra Metallurgical Coal. Biosis Pty Ltd, Wollongong. Dated 8 July 2020.

Bureau of Meteorology (BoM) 2023. Climate data online: Cordeaux No.1 Dam (68018O): Monthly rainfall. Accessed at: http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=139&p_display_type=dataFile&p_stn_num=68018

Buckland S., Burnham K., Augustin N. 1997. Model Selection: An Integral Part of Inference. Biometrics 53:603–618.

CoA (Commonwealth of Australia) 2010. Survey guidelines for Australia's threatened frogs: Guidelines for detecting frogs listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999. https://www.environment.gov.au/resource/survey-guidelines-australias-threatened-frogs-guidelines-detecting-frogs-listed-threatened. Last accessed April 2021.

Daly, G. and Craven, P. 2007. Monitoring populations of Heath Frog *Litoria littlejohni* in the Shoalhaven region on the south coast of New South Wales. *Australian Zoologist* 34 (2).

Department of the Environment 2022. *Litoria littlejohni* in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: http://www.environment.gov.au/sprat. Accessed September 2022.

Department of Environment and Science (DES) Queensland 2023. SILO - Australian climate data from 1889 to yesterday. Accessed at: https://www.longpaddock.qld.gov.au/silo/point-data/

Department of Planning 2008. Impacts of underground coal mining on natural features in the Southern Coalfield: strategic review. NSW Department of Planning, Sydney.

Department of Planning Industry and Environment 2021. Dendrobium Mine (DA60-03-2001-PA-77) Terrestrial Ecology Report Revision. Letter dated 22/09/2021.

Holm, S. 1979. A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics* 6, 65–70.

Keith, D., Rodoreda, S., Holman, L. and Lemmon, J. 2006. Monitoring change in upland swamps in Sydney's water catchments: the roles of fire and rain. Department of Environment and Conservation, Sydney.

Keith DA, Benson DH , Baird IRC, Watts L, Simpson CC, Krogh M, Gorissen S, Ferrer-Paris JR and Mason TJ 2022. Interactions between anthropogenic stressors and recurring perturbations mediate ecosystem resilience or collapse. Conservation Biology, 37(1).

Klop-Toker, K. 2020. *Litoria littlejohni* (Littlejohn's tree frog) Research Report 2019-20 South32 Dendrobium Mine, School of Environmental and Life Sciences, The University of Newcastle. Prepared for South32 IMC in August 2020.

Klop-Toker, K., Stock, S., Wallace, S., Hayward, M. and Mahony, M. 2021. *Litoria littlejohni* (Littlejohn's tree frog) Research Report 2020-21 South32 Dendrobium Mine. School of Environmental and Life Sciences, The University of Newcastle.

Krogh, M., Gorissen, S., Baird, IRCC. And Keith, D.A. 2022. Impacts of the Gospers Mountain Wildfire on the flora and fauna of mining-impacted Newnes Plateau Shrub Swamps in Australia's Eastern Highlands Australian Zoologist (2022) 42 (2): 199–216.

Mason, T.J., Krogh, M., Popovic, G.C., Glamore, W. and Keith, D.A. 2020. Persistent effects of underground longwall coal mining on freshwater wetland hydrology. Science of the Total Environment.

Mahony, M., Moses, B., Mahony, S., Lemckert, F. and Donnellan, F. 2020. A new species of frog in the *Litoria ewingii* species group (Anura: Pelodryadidae) from south-eastern Australia. *Zootaxa*, vol. 4858 (2), pp. 201 – 230.

Muggeo, V. 2003. Estimating regression models with unknown breakpoints. Statistics in Medicine, 22, 3055-3071.

Muggeo, V. 2008. segmented: an R Package to Fit Regression Models with Broken-Line Relationships. R News, 8/1, 20-25. URL https://cran.r-project.org/doc/Rnews/.

Muggeo, V. 2017. Interval estimation for the breakpoint in segmented regression: a smoothed score-based approach. Australian & New Zealand Journal of Statistics, 59, 311-322.

Niche 2021. Dendrobium Areas 3A and 3B: Terrestrial Ecology Monitoring Program Annual Report 2020. Prepared for South32 Illawarra Metallurgical Coal. Project number 5805. Dated 29 April 2021.

Niche 2022a. Dendrobium Areas 3A and 3B: Terrestrial Ecology Monitoring Program Annual Report 2021. Prepared for South32 Illawarra Metallurgical Coal. Project number 6639. Dated 28 April 2022.

Niche 2022b. Survey 16 Proposed surface exploration in Dendrobium Area 5, Survey 16 addendum, Survey 16 addendum 2 and Survey 16 addendum 3. Ecological Restoration Plan – Year 2 monitoring. Prepared for South32 Illawarra Metallurgical Coal. Project number 7274. Dated 14 September 2022.

Niche 2022c. Dendrobium Mine Extension Project: Biodiversity Development Assessment Report. Prepared for Illawarra Metallurgical Coal. Rev2. Project number 6624. Dated 29/08/2022.

NPWS 2003. The Native Vegetation of the Woronora, O'Hares and Metropolitan Catchments, NSW National Parks and Wildlife Service, Sydney.

NSW Scientific Committee 2012. Coastal Upland Swamp in the Sydney Basin Bioregion - endangered ecological community listing.

R Core Team 2021. V. 4.1.2. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria.

South32 Illawarra Metalogical Coal (IMC) 2016a. Swamp Rehabilitation Research Program (SRRP), Dendrobium Area 3B. Prepared in August 2016.

South32 Illawarra Metalogical Coal (IMC) 2016b. Strategic Biodiversity Offset. Illawarra Coal Prepared by IMC in August 2016.

South32 Illawarra Metalogical Coal (IMC) 2017. Dendrobium Area 3B rehabilitation plan: WC21 and Donalds Castle Creek rehabilitation plan. Dated September 2017.

South32 Illawarra Metalogical Coal (IMC) 2019. Correspondence letters with WaterNSW for amendments to SRRP. Ref: D2019/109161.

South32 Illawarra Metalogical Coal (IMC) 2020a. Dendrobium Area 3B Subsidence Management Plan (SMP) Volume 2. Appendix A: Trigger Action Response Plan, Area 3A. Prepared by IMC August 2020.

South32 Illawarra Metalogical Coal (IMC) 2020b. Area 3B Swamp Impact, Monitoring, Management and Contingency Plan (SIMMCP) Prepared by IMC August 2020.

South32 Illawarra Metalogical Coal (IMC) 2020c. Area 3B Watercourse Impact, Monitoring, Management and Contingency Plan (WIMMCP) Prepared by IMC August 2020.

South32 Illawarra Metalogical Coal (IMC) 2021a. Dendrobium Mine – Annual Terrestrial Ecology Monitoring. Letter dated 30 August 2021.

Stock, S.E., Klop-Toker, K., Wallace, S., Kelly, O., Callen, A., Hayward, M.W., and Mahoney, M. N.D. Genome-wide SNPs reveals inbreeding, small populations, and genetic isolation in a threatened and understudied frog (*Litoria littlejohni*). Draft paper for publication. School of Environmental and Life Sciences, The University of Newcastle, University Drive, Callaghan, 2308, Australia.

Symbolix 2014. Dendrobium Flora and Fauna Analysis 2013 Calendar Year. Version1.0. Report prepared Commercial in-Confidence for Biosis.

The Analytical Edge Statistical Consulting (TAE) 2023a. Task 1A - Analysis of total flora species richness at swamps within the Dendrobium region. Data collected up to and including 2022. Dated 15 March 2023.

The Analytical Edge Statistical Consulting (TAE) 2023b. Task 1B - Analysis of flora species composition at impact swamps within the Dendrobium region. Data collected up to and including 2022. Dated 15 March 2023.

The Analytical Edge Statistical Consulting (TAE) 2023c. Task 2A - Breakpoint analysis of total flora species richness at swamps within the Dendrobium region. Data collected up to and including 2022. 20 March 2023.

The Analytical Edge Statistical Consulting (TAE) 2023d. Task 2B - Breakpoint analysis of priority species richness at swamps within the Dendrobium region. Data collected up to and including 2022. 20 March 2023.

The Analytical Edge Statistical Consulting (TAE) 2023e. Task 3 - Investigation of differences in seasonal monitoring at swamps within the Dendrobium region. Data collected up to and including 2022. 31 March 2023.

Wang, Y., Naumann, U., Eddelbuettel, D., Wilshire, J. and D. Warton. 2021. *mvabund: Statistical Methods for Analysing Multivariate Abundance Data*. R package version 4.1.9.

Warton, D. I., S. T. Wright, and Y. Wang 2012. Distance-based multivariate analyses confound location and dispersion effects. *Methods in Ecology and Evolution*, 3(1): 89-101

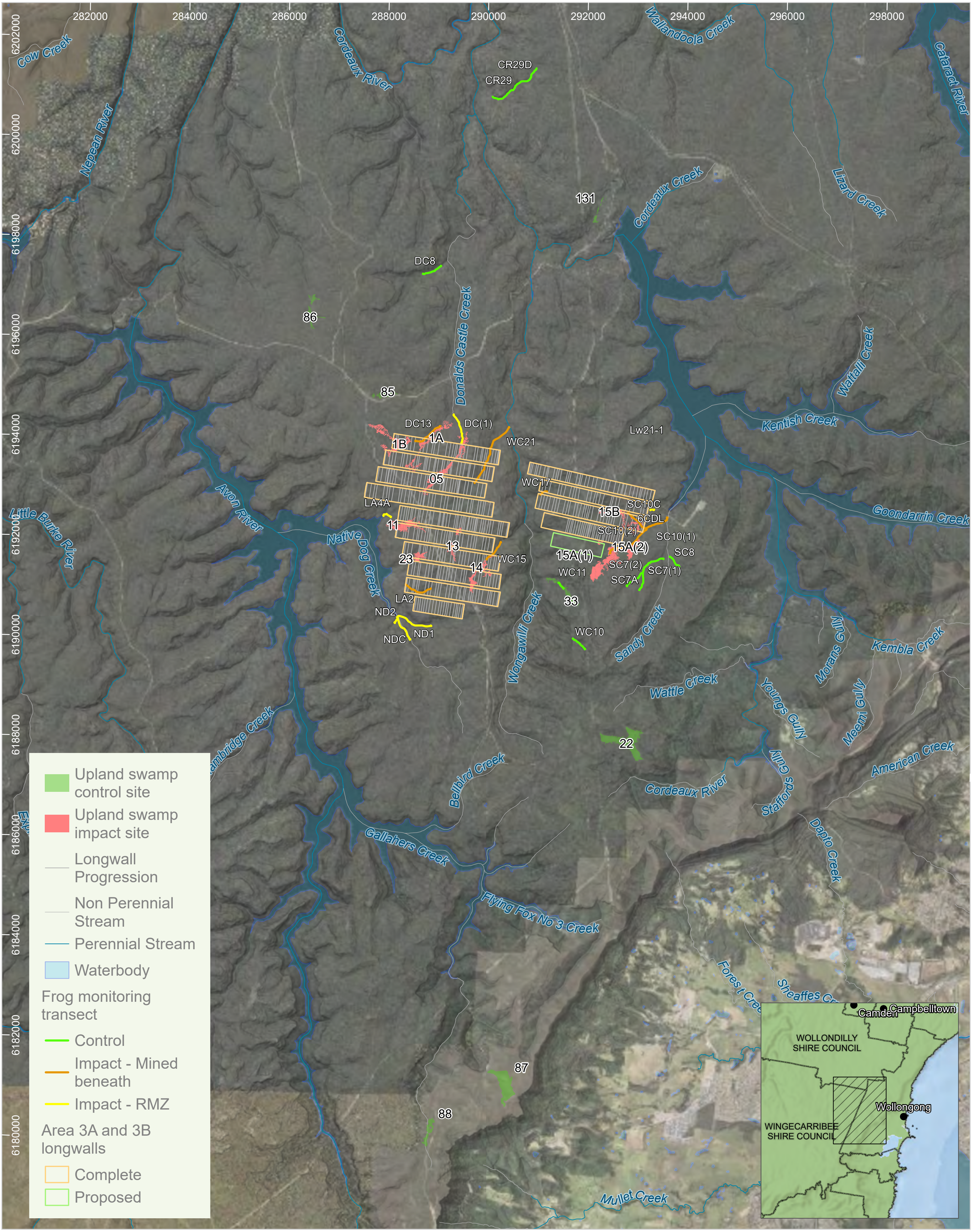
Watershed HydroGeo 2019. Dendrobium Mine Geographic review of mining effects on Upland Swamps at Dendrobium Mine. Unpublished Report for Illawarra Coal.

Watershed HydroGeo 2021. South32 Illawarra Metallurgical Coal Dendrobium Mine Extension Project Update to geographic review of mining effects on Upland Swamps at the Dendrobium Mine September 2021.

Young, A. 1986. The geomorphic development of dells (upland swamps) on the Woronora plateau, N.S.W., Australia. Zeitschrift fur Geomorphologie 30, 317–327.

Young, A.R.M 2017. Upland Swamps in the Sydney Region. Published by Anne Young 2017.

Figures



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Location of the study area

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
Annual Report 2022

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Figure 1a

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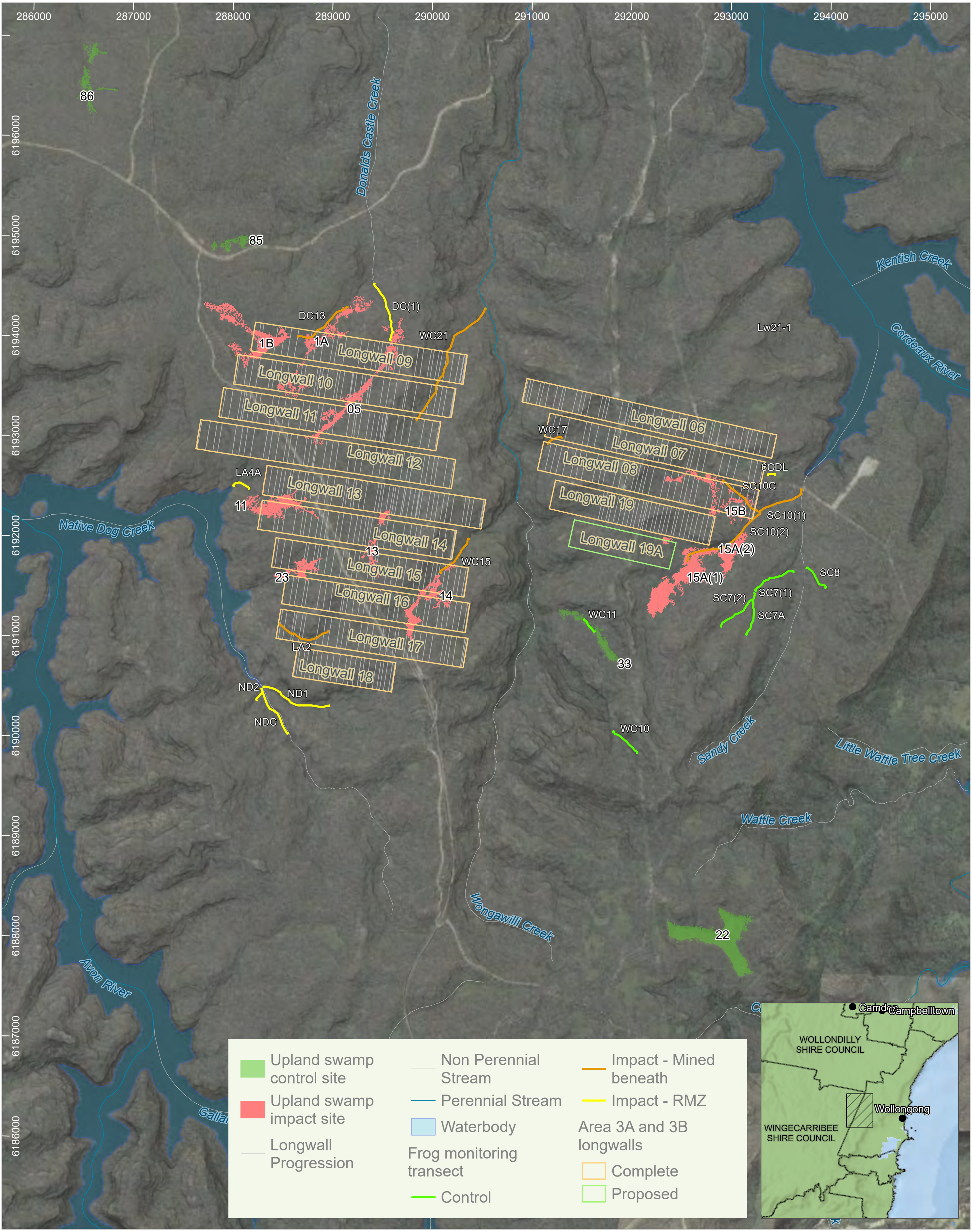

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Location of the study area

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Figure 1b

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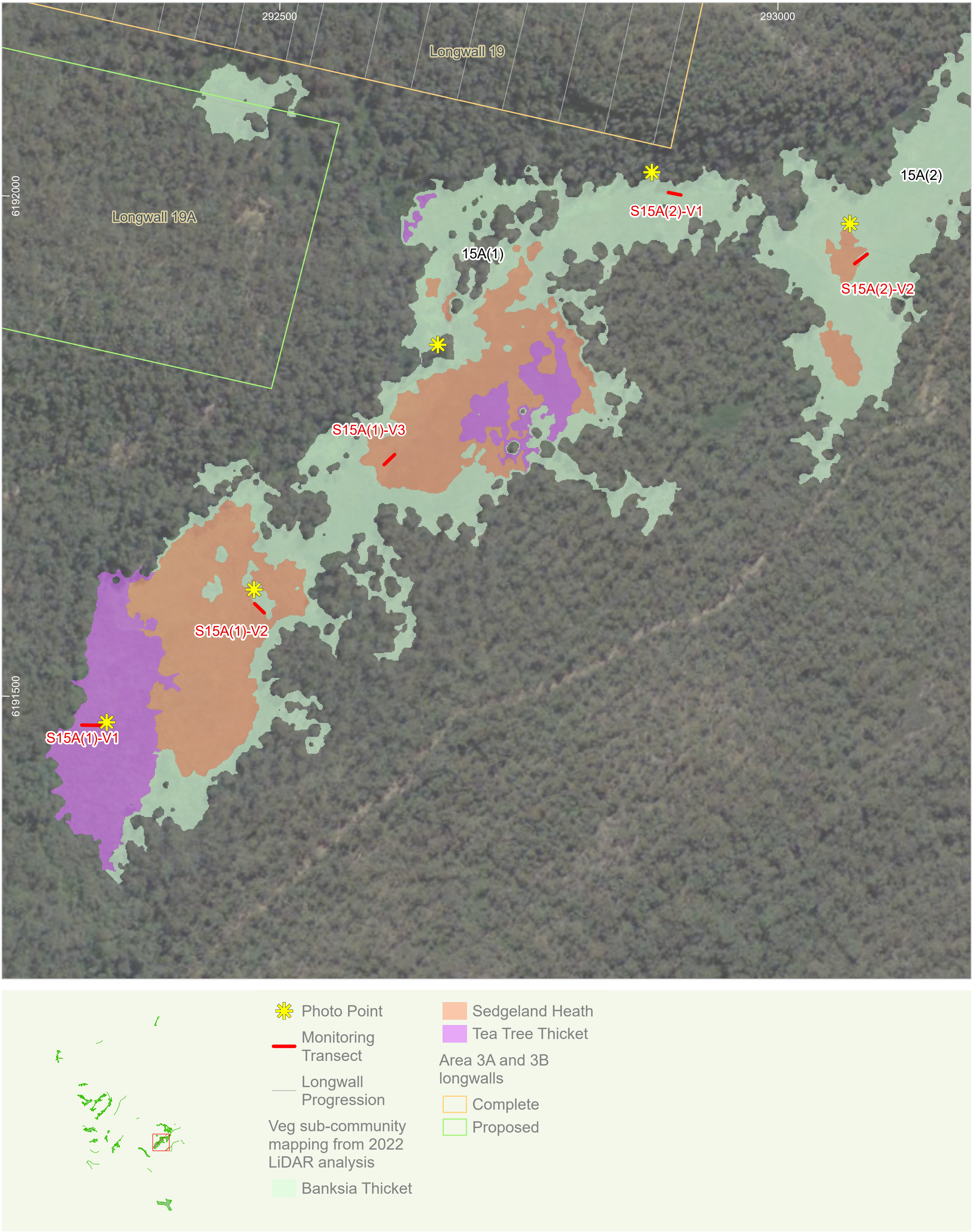

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Location of flora monitoring impact sites surveyed in Dendrobium Area 3A - 15(A)1: Impact

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
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Figure 2a

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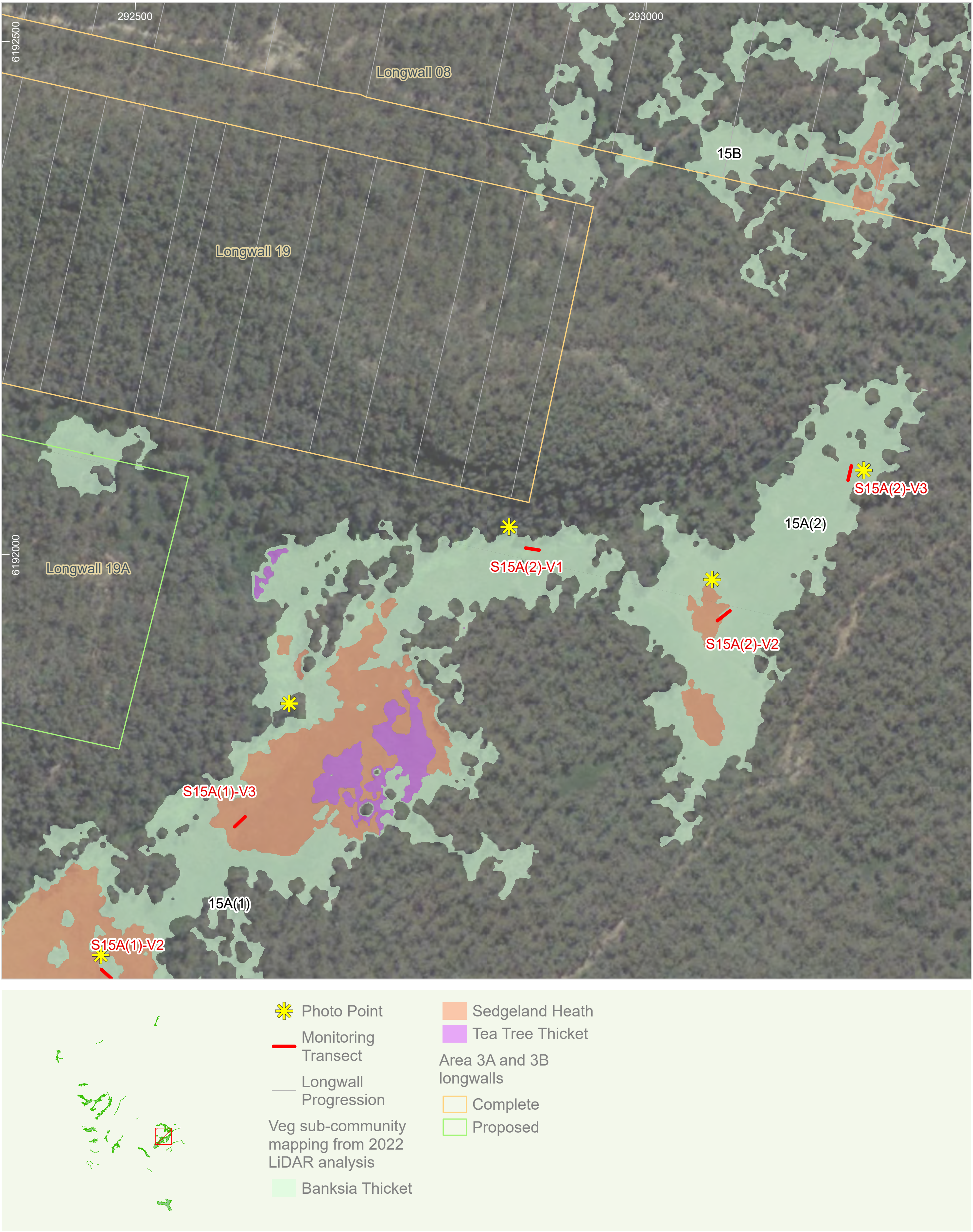

Location of flora monitoring impact sites surveyed in Dendrobium Area 3A - 15(A)2: Impact

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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Figure 2b

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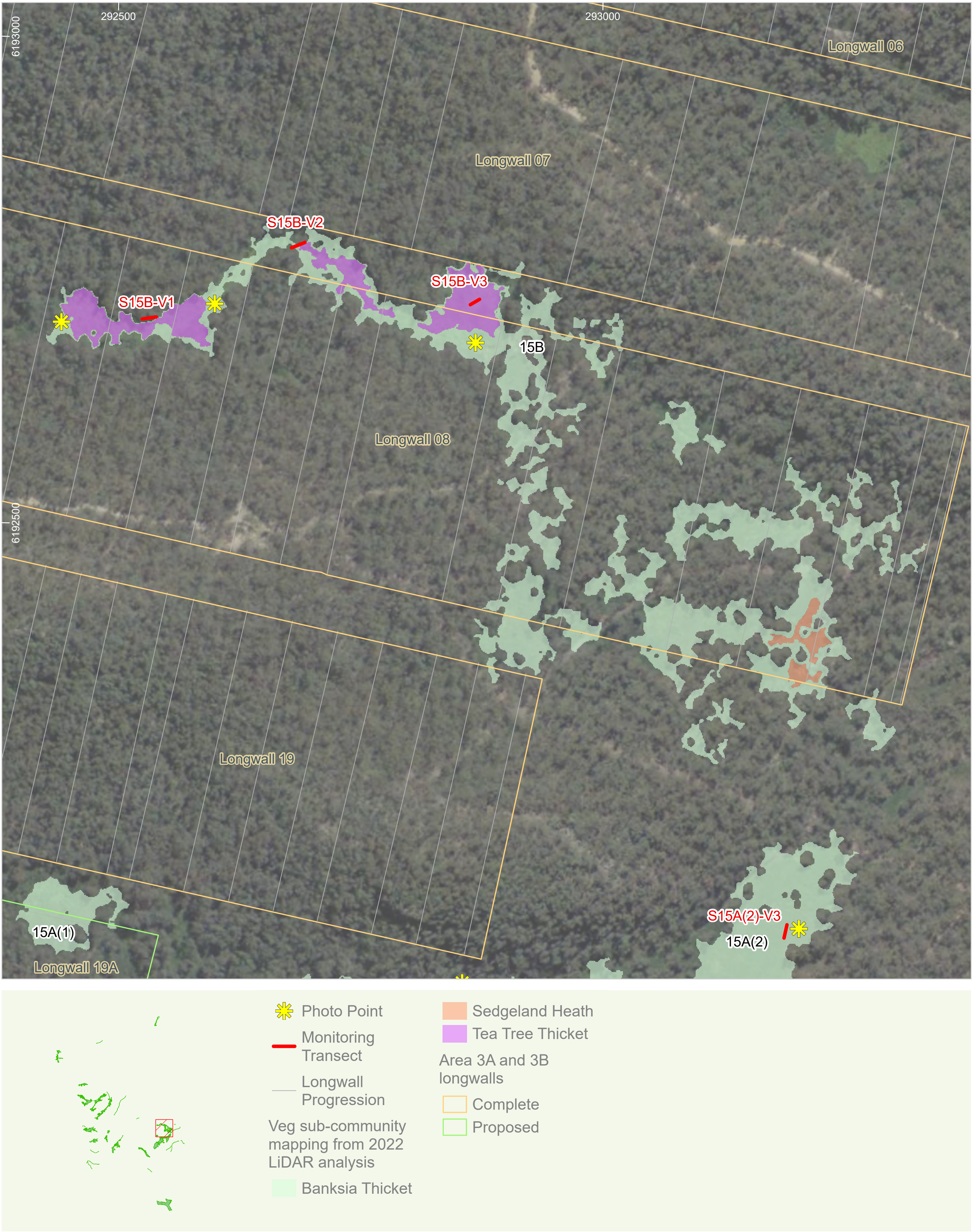

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Location of flora monitoring impact sites surveyed in Dendrobium Area 3A - 15B: Impact

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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Client: South32

Figure 2c

public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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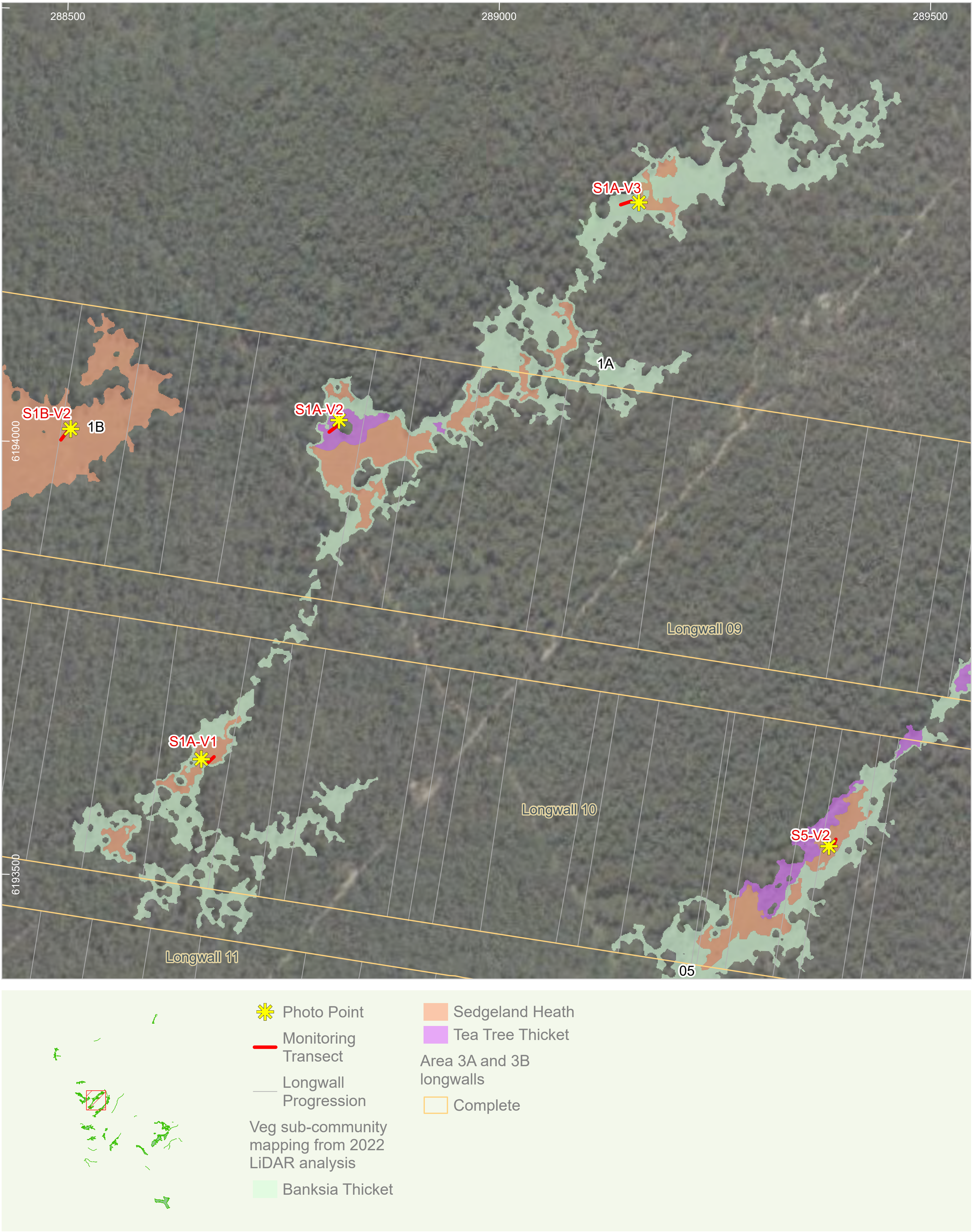

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WGS 1984 Web Mercator

Location of flora monitoring impact sites surveyed in Dendrobium Area 3B - 1A: Impact

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
Annual Report 2022

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Figure 3a

public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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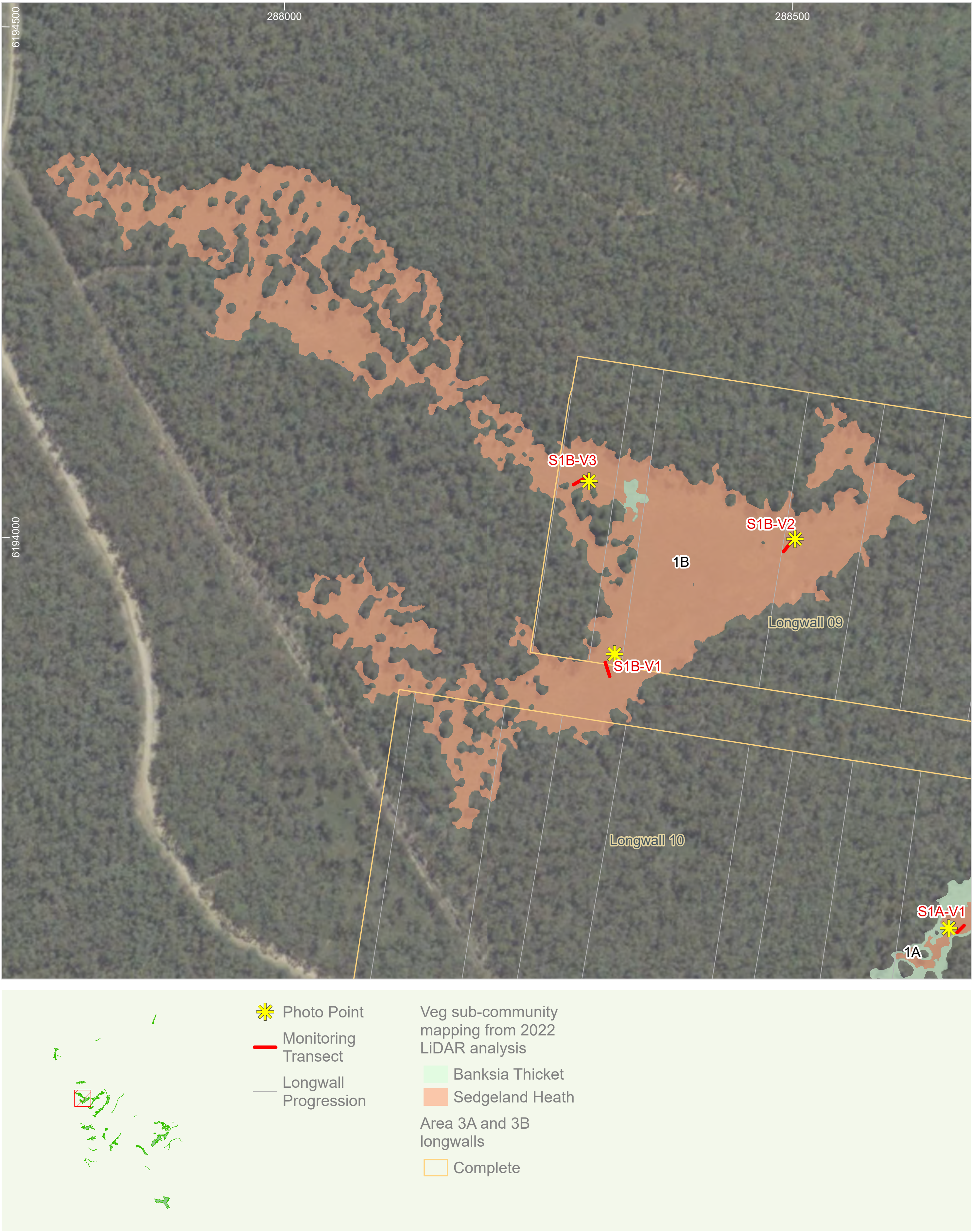

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Environment and Heritage

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WGS 1984 Web Mercator

Location of flora monitoring impact sites surveyed in Dendrobium Area 3B - 1B: Impact

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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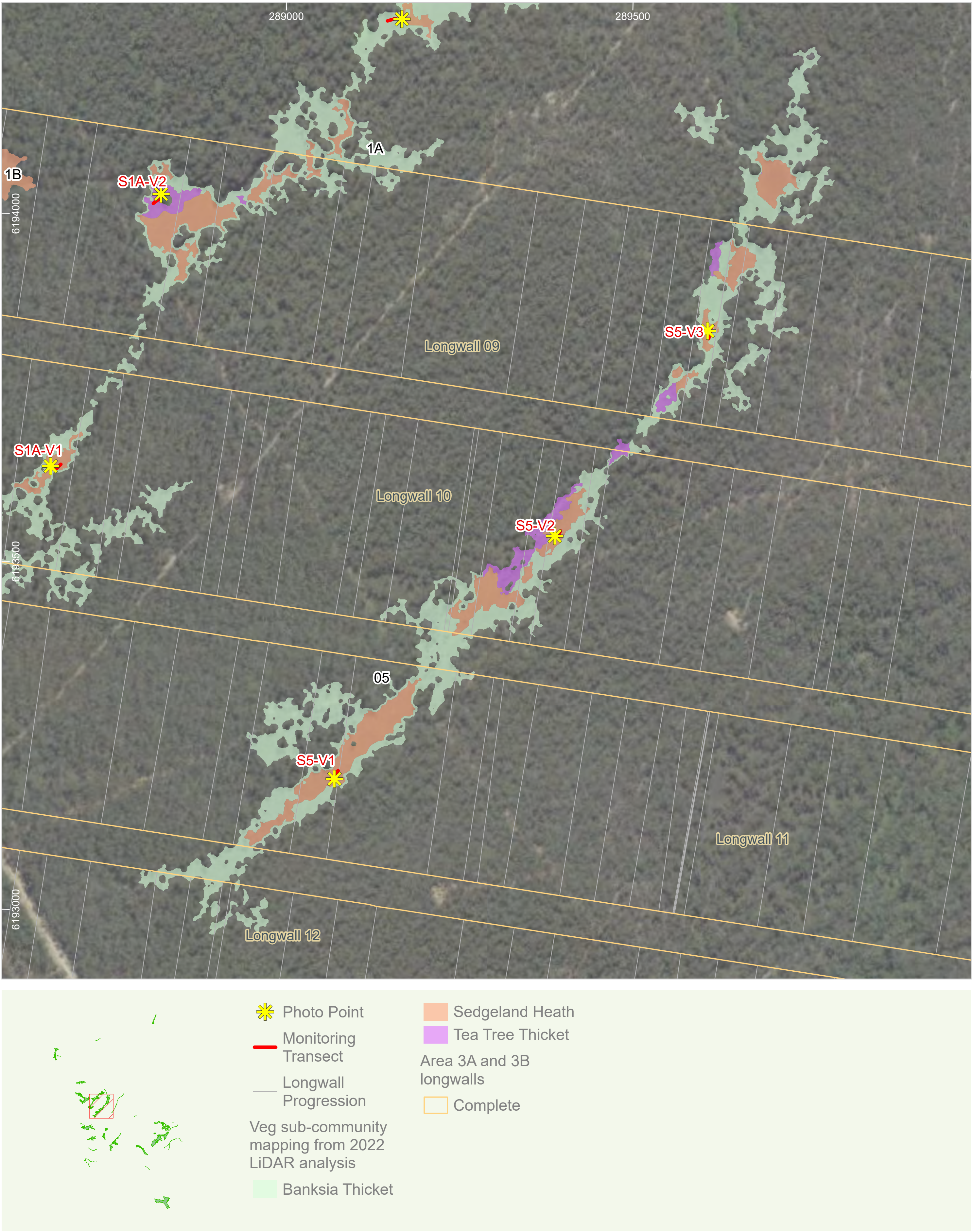
Niche Proj. #: 7290
Client: South32

Figure 3b

public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.



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WGS 1984 Web Mercator

Location of flora monitoring impact sites surveyed in Dendrobium Area 3B - 05: Impact

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
Annual Report 2022

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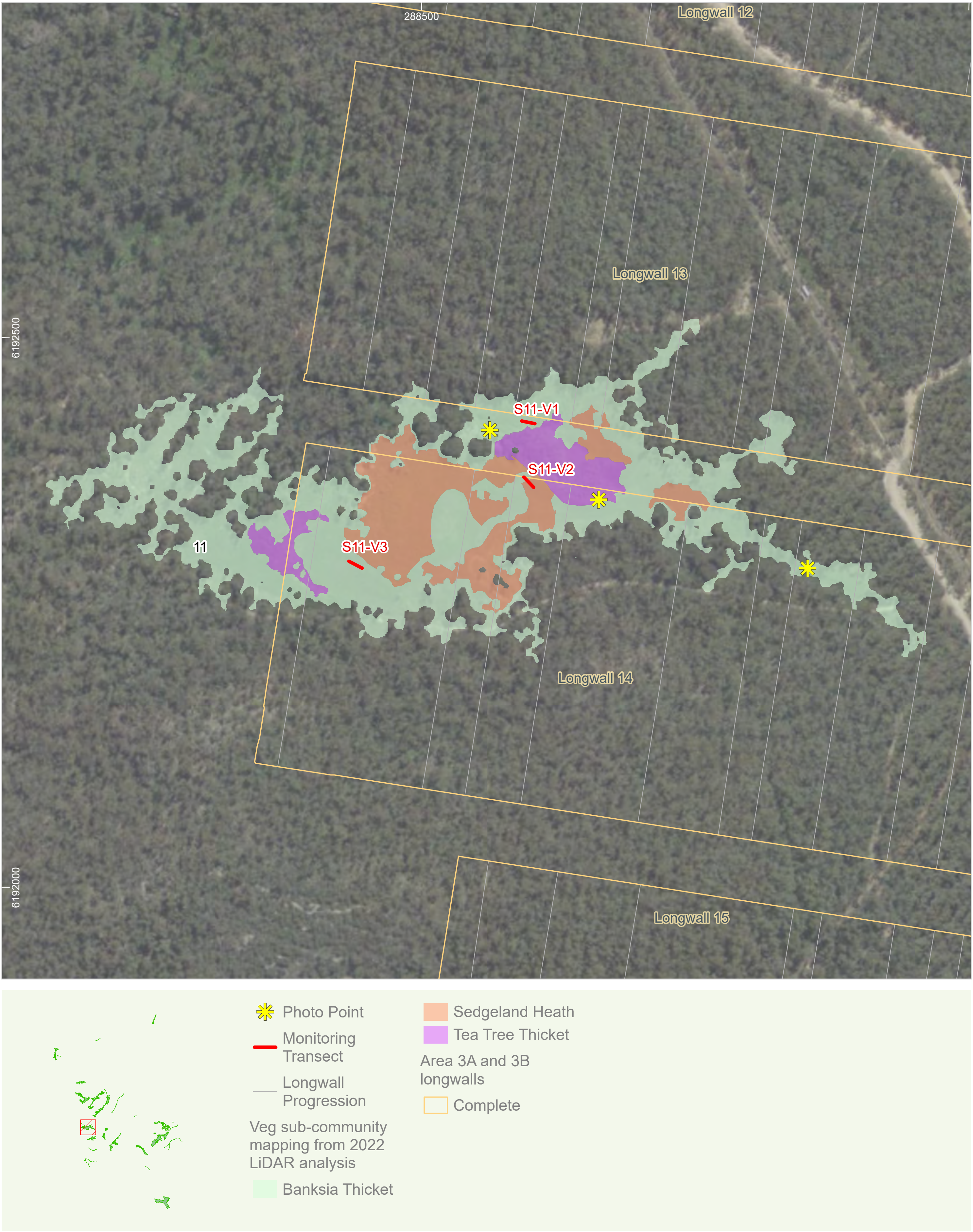
Figure 3c

public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.



Location of flora monitoring impact sites surveyed in Dendrobium Area 3B - 11: Impact

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
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Niche Proj. #: 7290
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Figure 3d

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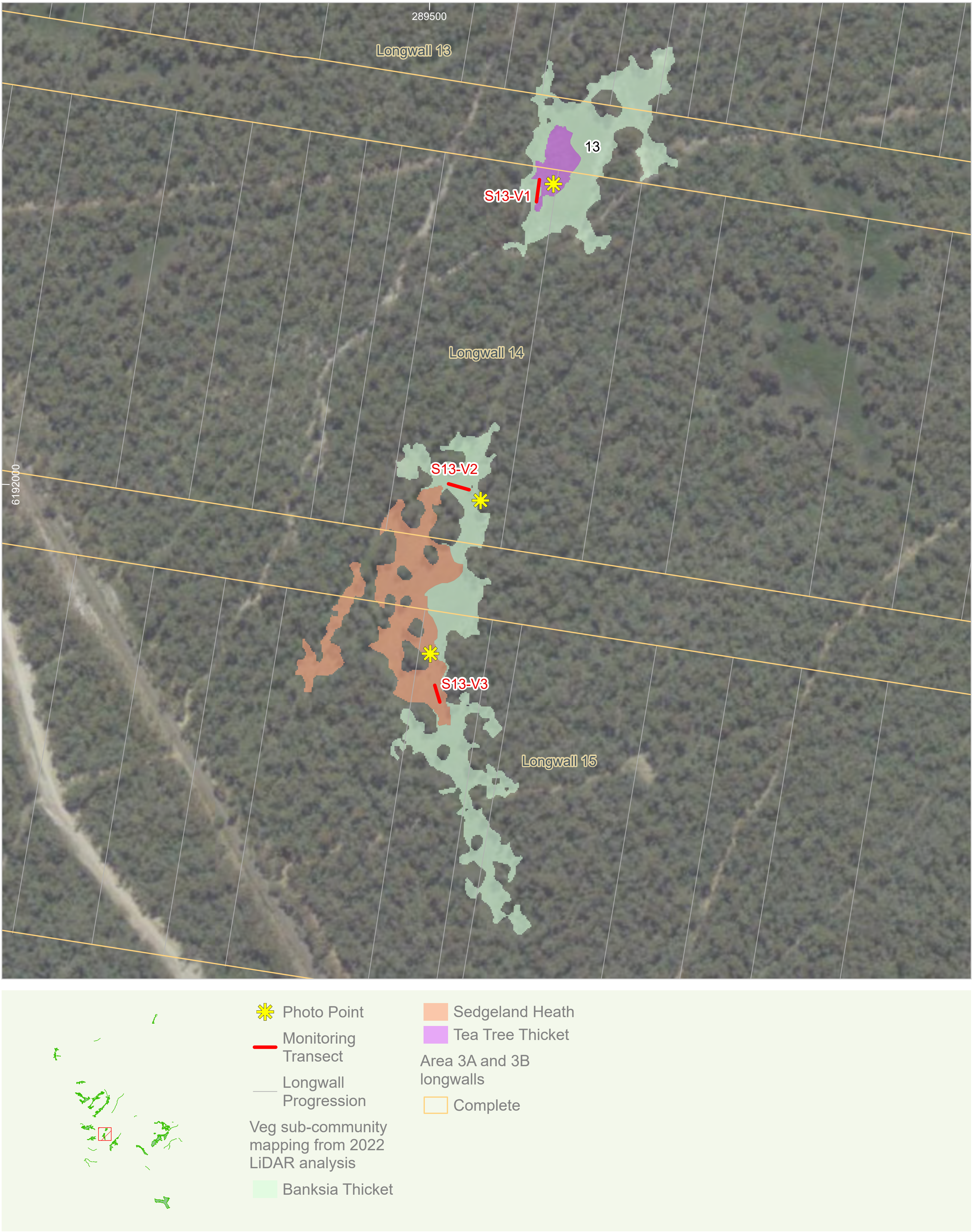

Location of flora monitoring impact sites surveyed in Dendrobium Area 3B - 13: Impact

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
Annual Report 2022

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Client: South32

Figure 3e

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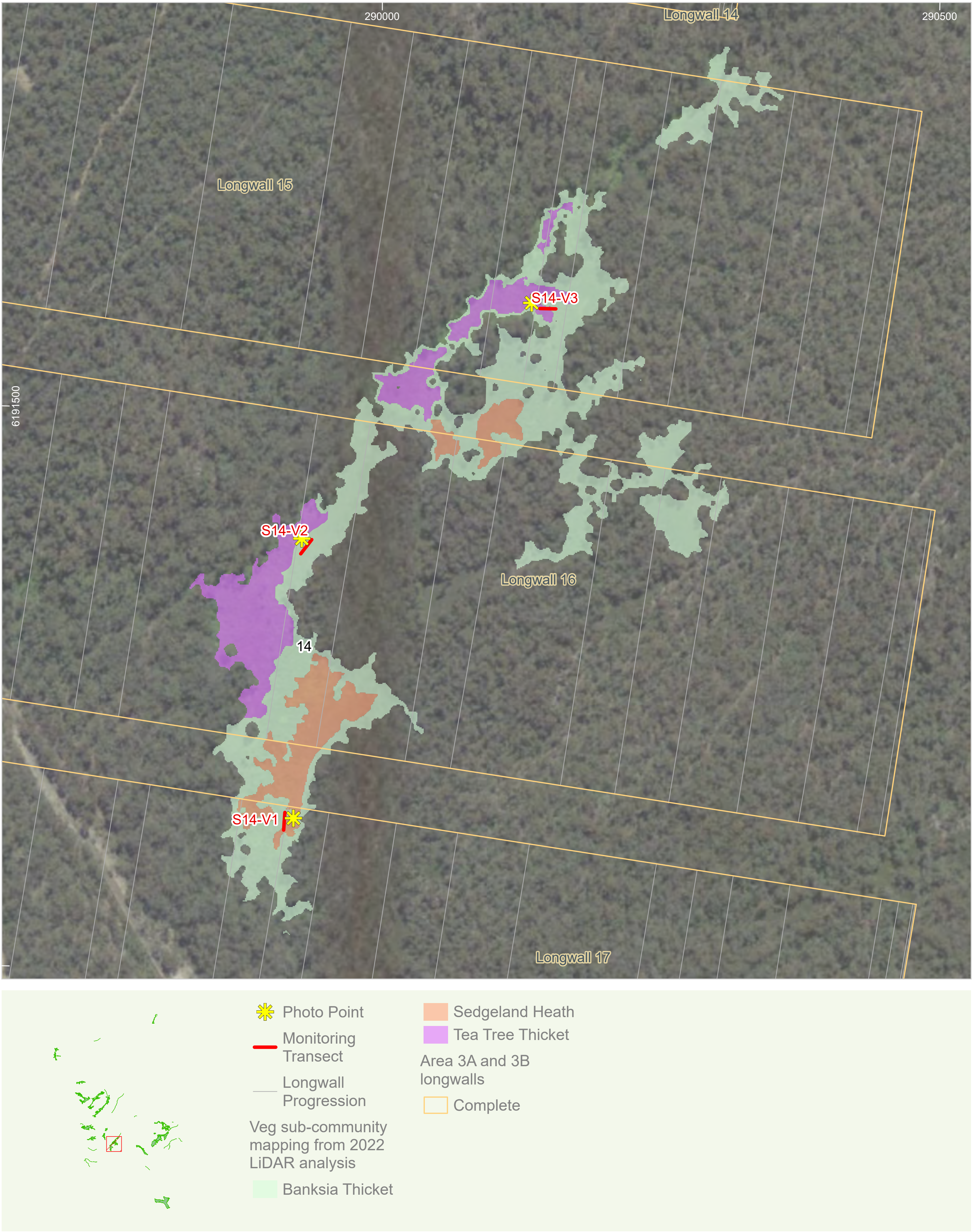

Environment and Heritage

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WGS 1984 Web Mercator

Location of flora monitoring impact sites surveyed in Dendrobium Area 3B - 14: Impact

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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Figure 3f

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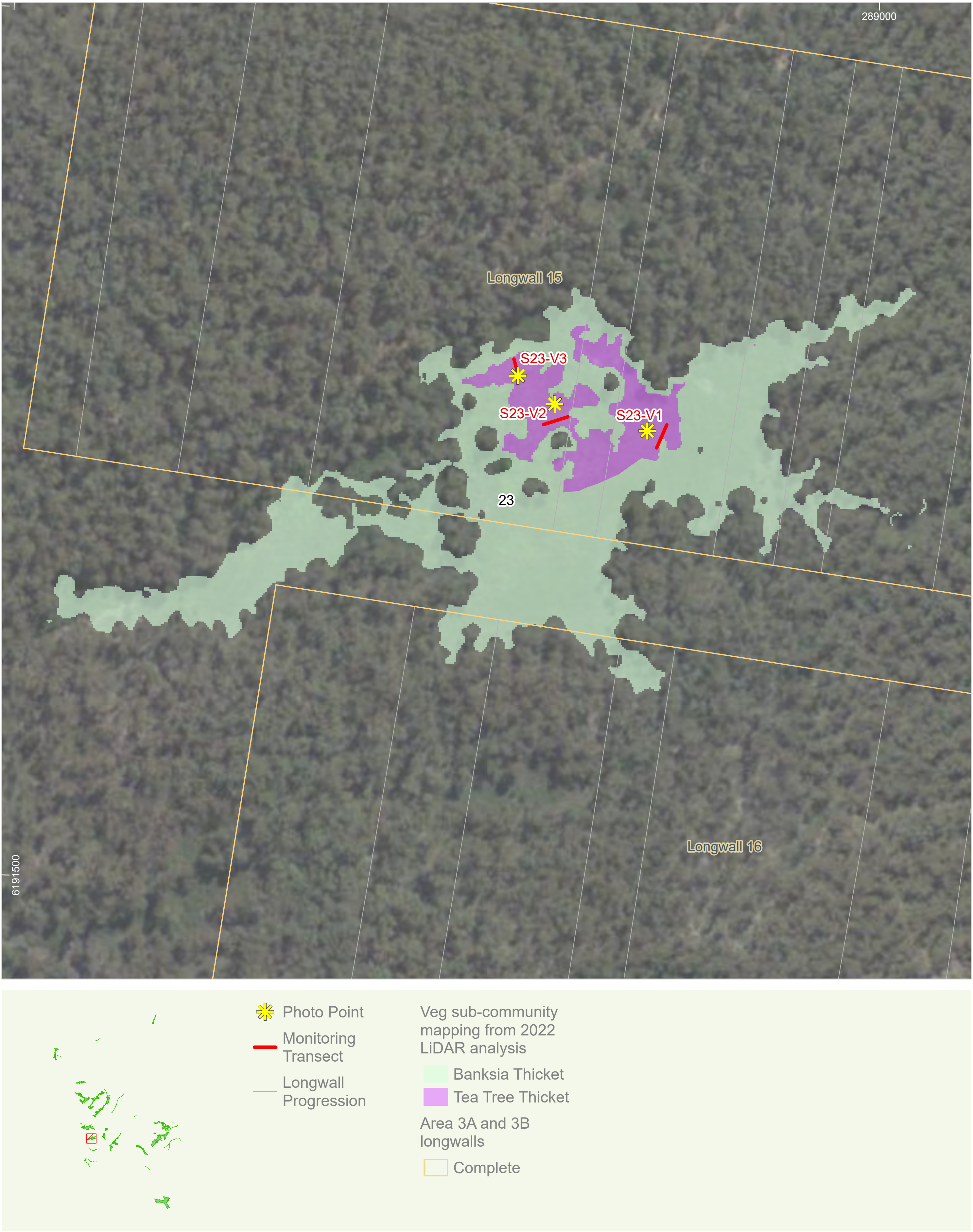

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WGS 1984 Web Mercator

Location of flora monitoring impact sites surveyed in Dendrobium Area 3B - 23: Impact

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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Figure 3g

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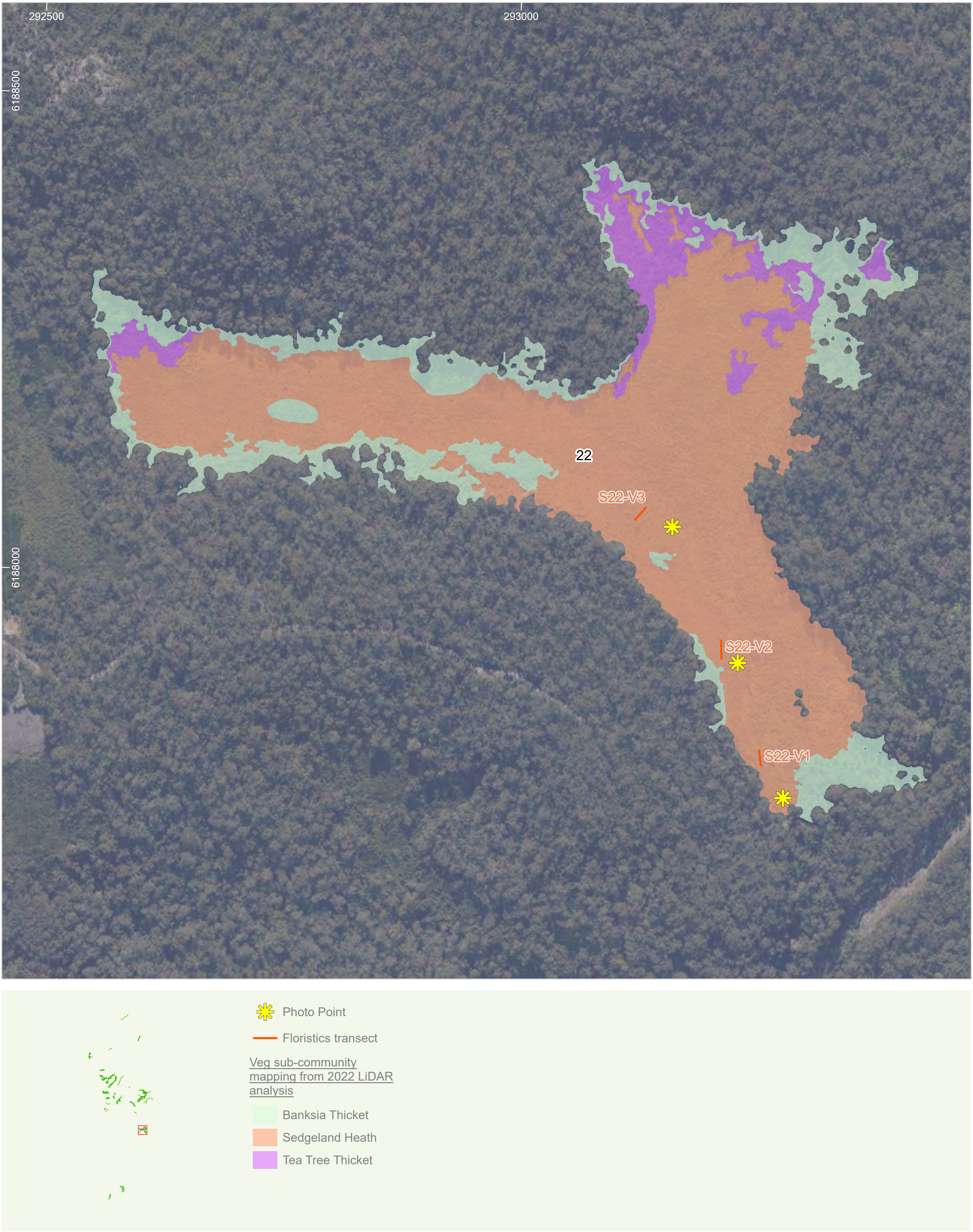

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WGS 1984 Web Mercator

Location of flora monitoring control sites surveyed in the 2022 program - 22: Control

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
Annual Report 2022

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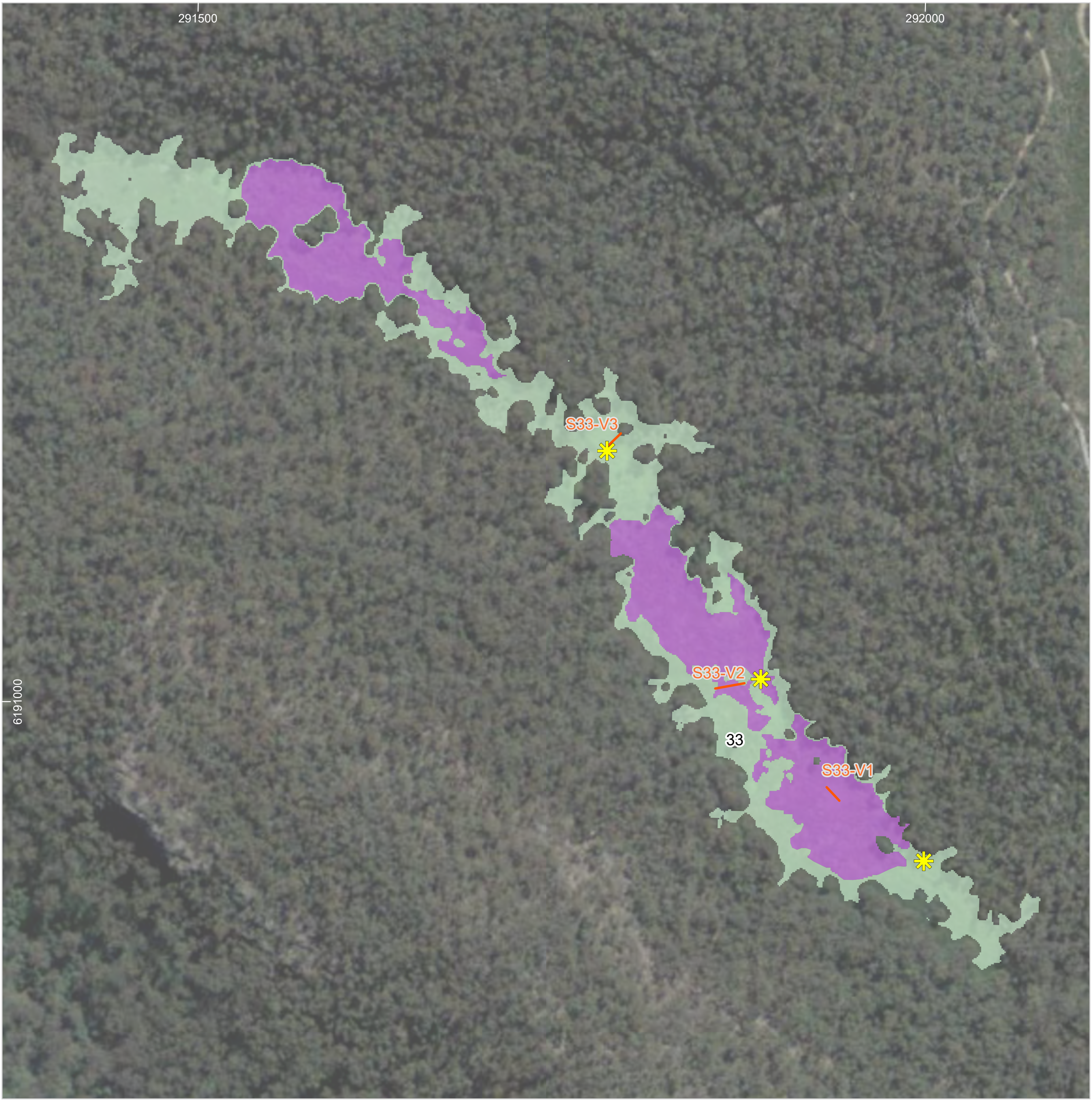
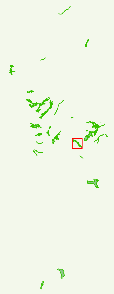
Figure 4a

public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.





✳ Photo Point

― Floristics transect

Veg sub-community mapping from 2022 LiDAR analysis

🟩 Banksia Thicket

🟪 Tea Tree Thicket

niche Environment and Heritage

WGS 1984 Web Mercator

Location of flora monitoring control sites surveyed in the 2022 program - 33: Control

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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Figure 4b

public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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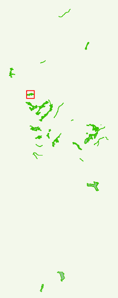

Veg sub-community mapping from 2022 LiDAR analysis

- 🟩 Banksia Thicket
- 🟧 Sedgeland Heath

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Environment and Heritage

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WGS 1984 Web Mercator

Location of flora monitoring control sites surveyed in the 2022 program - 85: Control

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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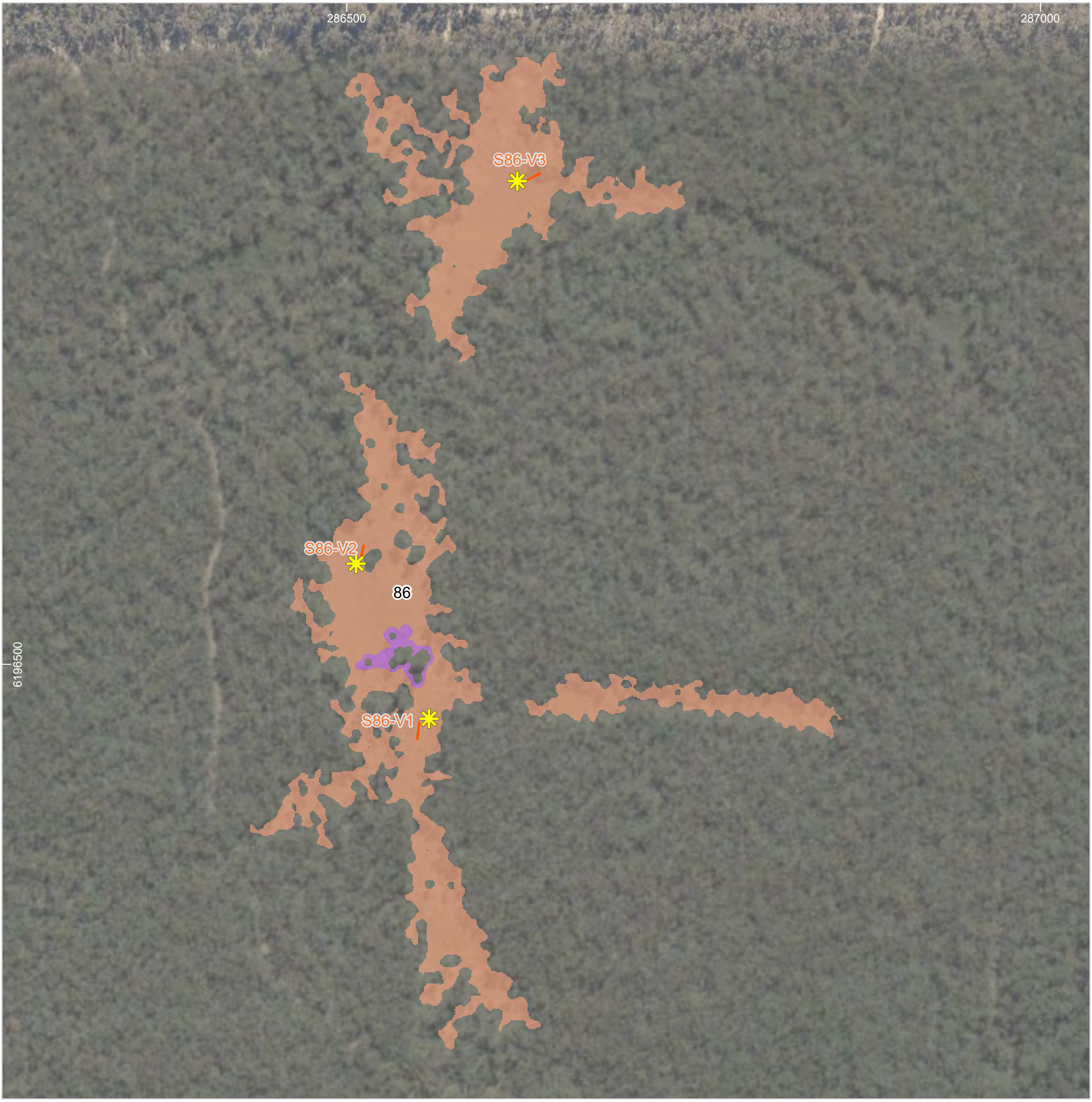
Client: South32

Figure 4c

public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.



✳ Photo Point

— Floristics transect

Veg sub-community mapping from 2022 LiDAR analysis

🟧 Sedgeland Heath

🟪 Tea Tree Thicket

niche Environment and Heritage

N

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m

WGS 1984 Web Mercator

Location of flora monitoring control sites surveyed in the 2022 program - 86: Control

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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Figure 4d

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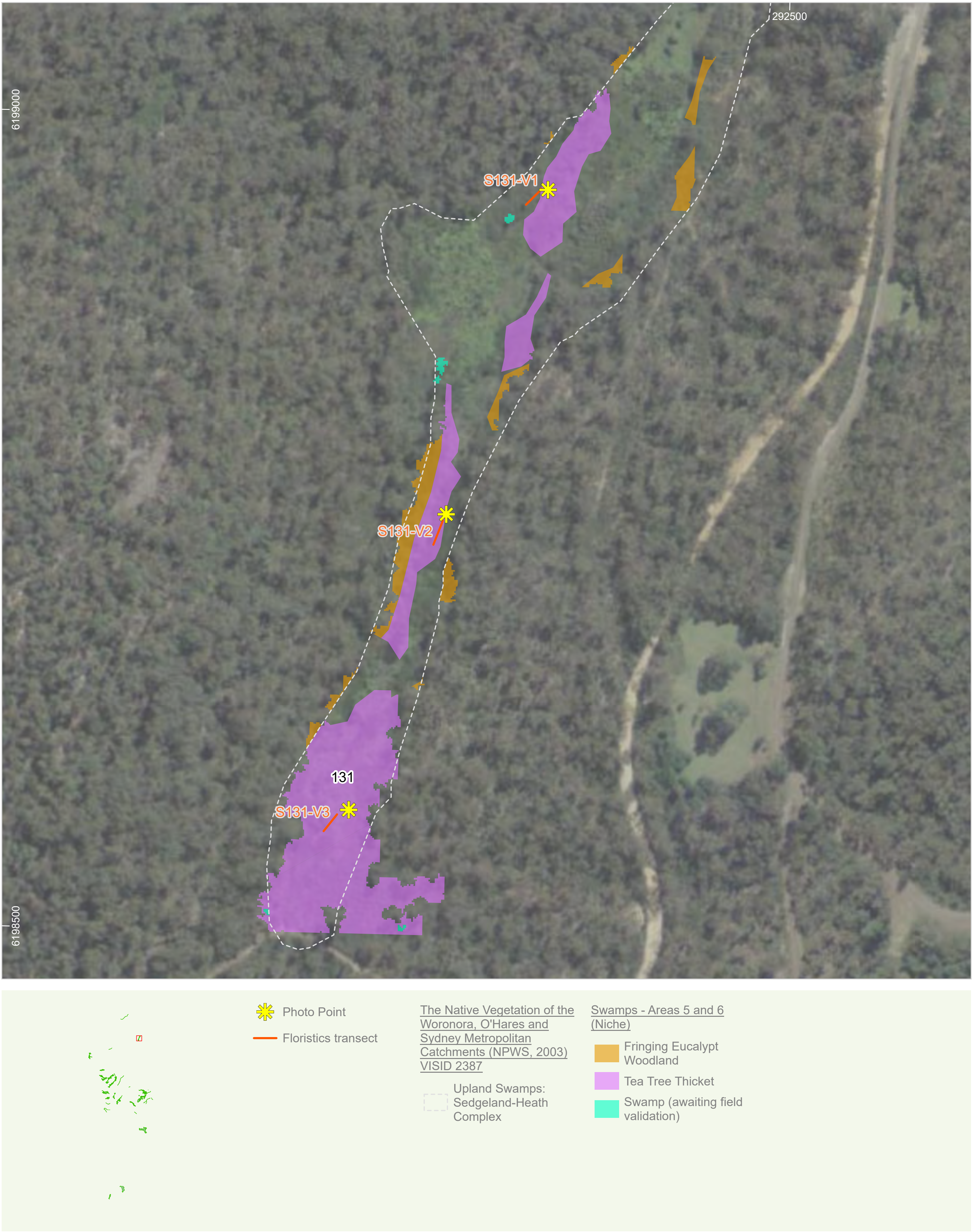

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Location of flora monitoring control sites surveyed in the 2022 program - 131: Control

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
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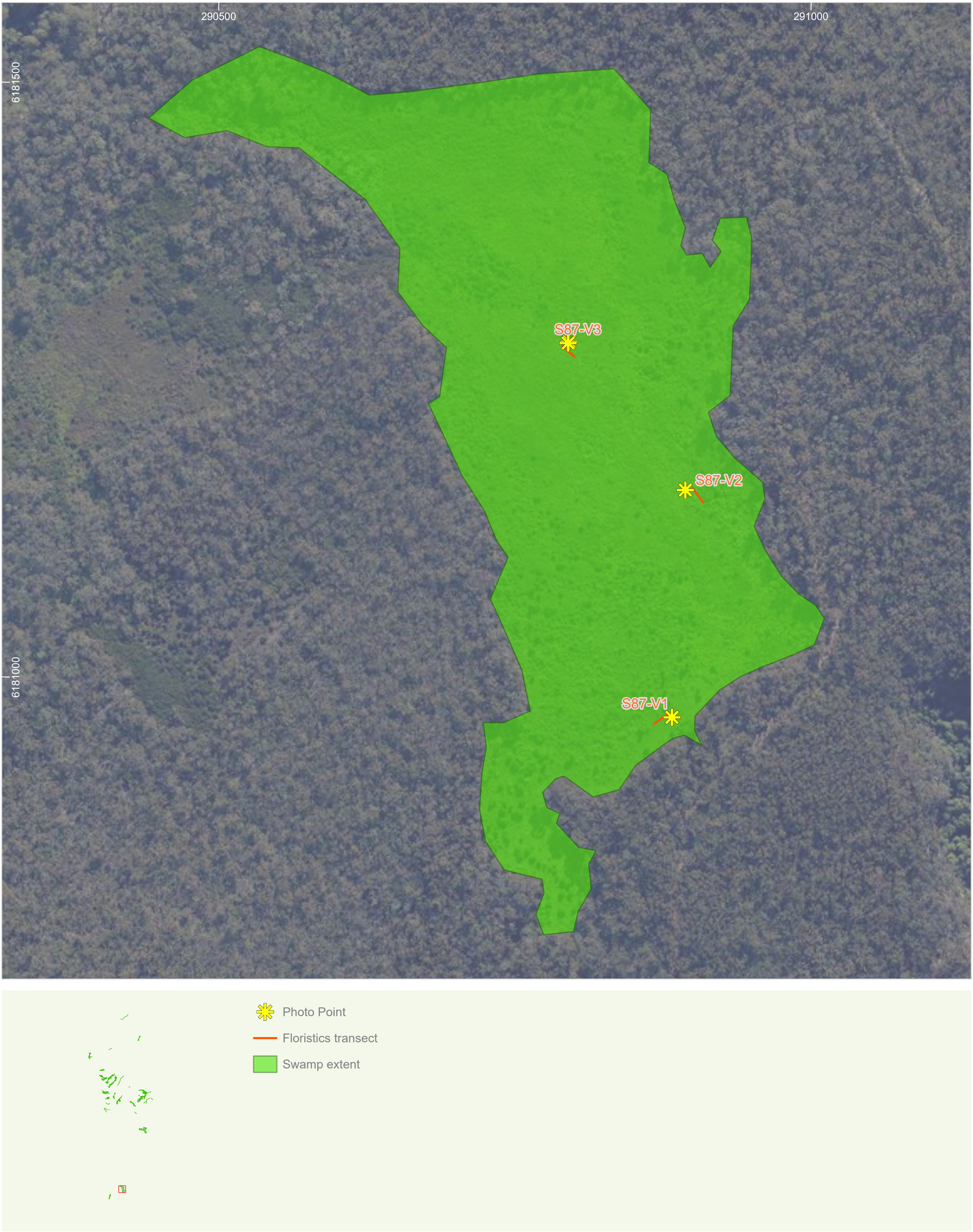
Client: South32

Figure 4e

public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.



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WGS 1984 Web Mercator

Location of flora monitoring control sites surveyed in the 2022 program - 87: Control

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
Annual Report 2022

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Client: South32

Figure 4f

public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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niche
Environment and Heritage

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WGS 1984 Web Mercator

Location of flora monitoring control sites surveyed in the 2022 program - 88: Control

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
Annual Report 2022

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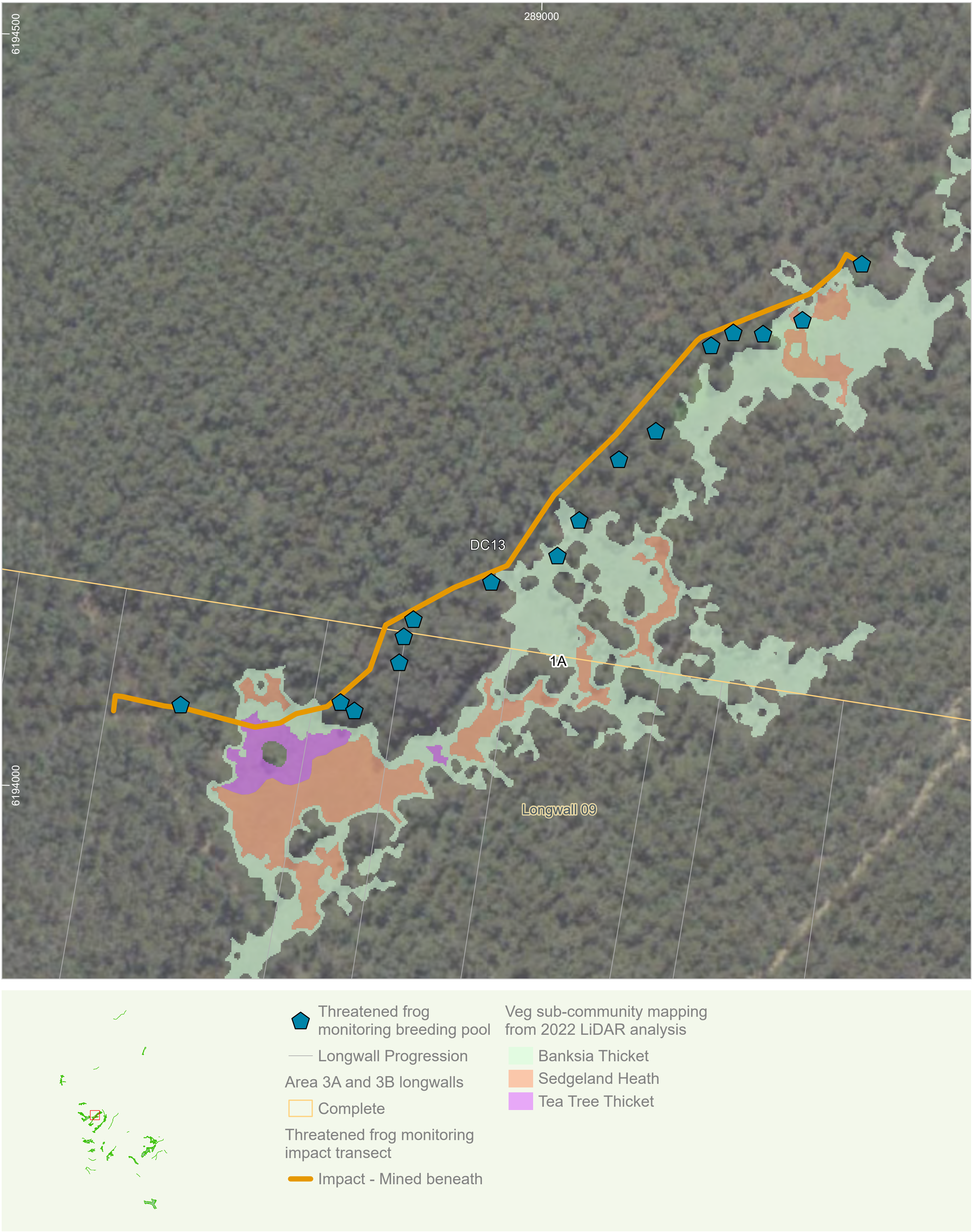
Client: South32

Figure 4g

public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.



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niche Environment and Heritage

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WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - DC13: Impact (mined beneath)

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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Figure 5a

World Imagery: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

⬟ Threatened frog monitoring breeding pool

Threatened frog monitoring impact transect

🟩 Control

Niche Environment and Heritage

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WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - WC10: Control

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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Client: South32

Figure 5b

World Imagery: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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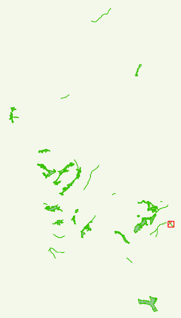

⬟ Threatened frog monitoring breeding pool

Threatened frog monitoring impact transect

🟩 Control

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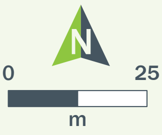
Environment and Heritage



WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - SC8: Control

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
Annual Report 2022

Niche PM: Sian Griffiths
Niche Proj. #: 7290
Client: South32

Figure 5c

World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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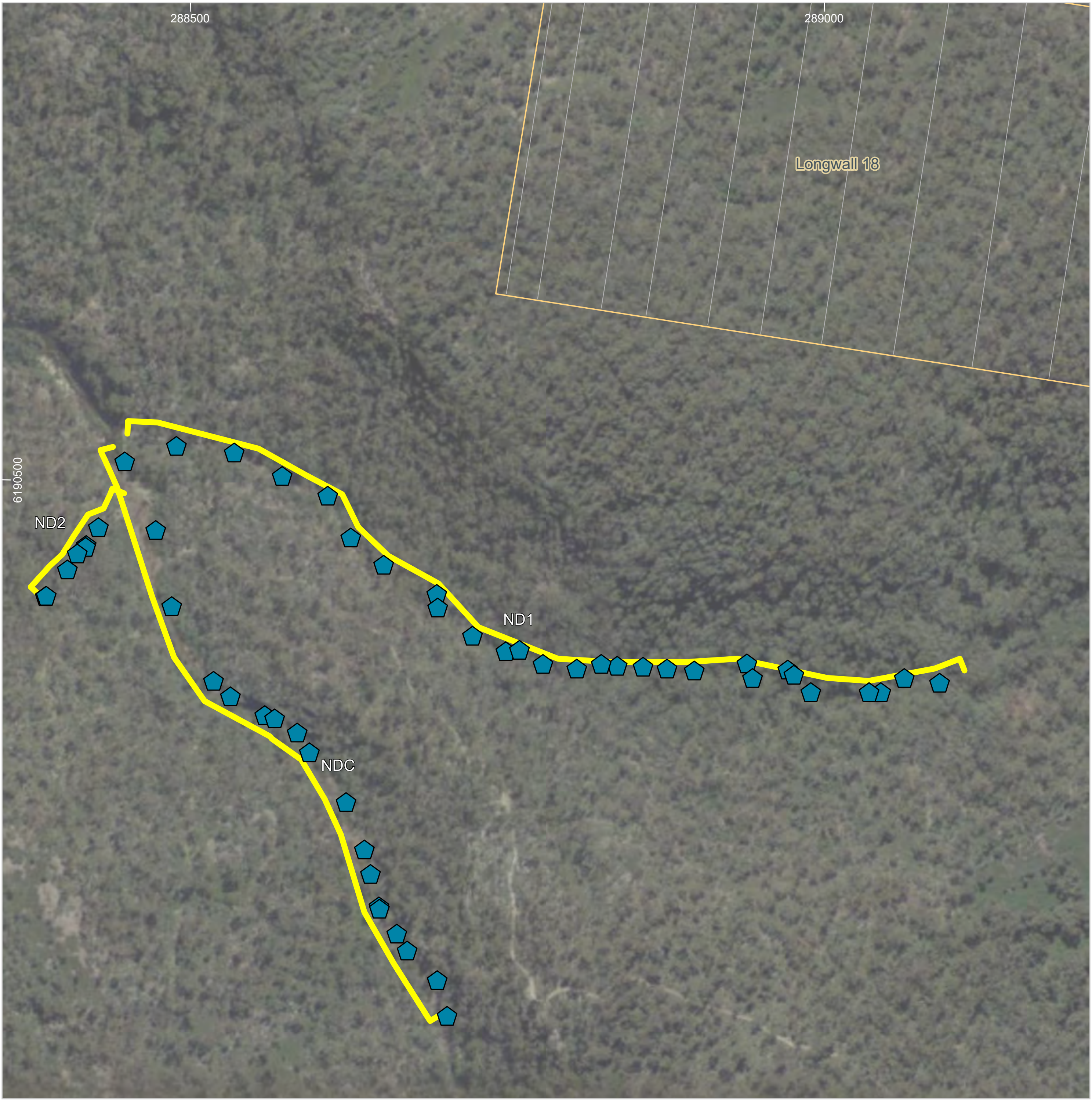

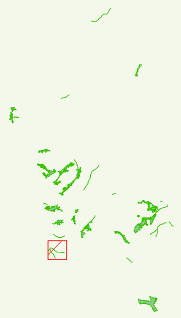

⬟ Threatened frog monitoring breeding pool

— Longwall Progression

Area 3A and 3B longwalls

☐ Complete

Threatened frog monitoring impact transect

▬ Impact - RMZ

Environment and Heritage

0 90

m

WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - ND1: Impact (RMZ)

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

Niche PM: Sian Griffiths
Niche Proj. #: 7290
Client: South32

Figure 5d

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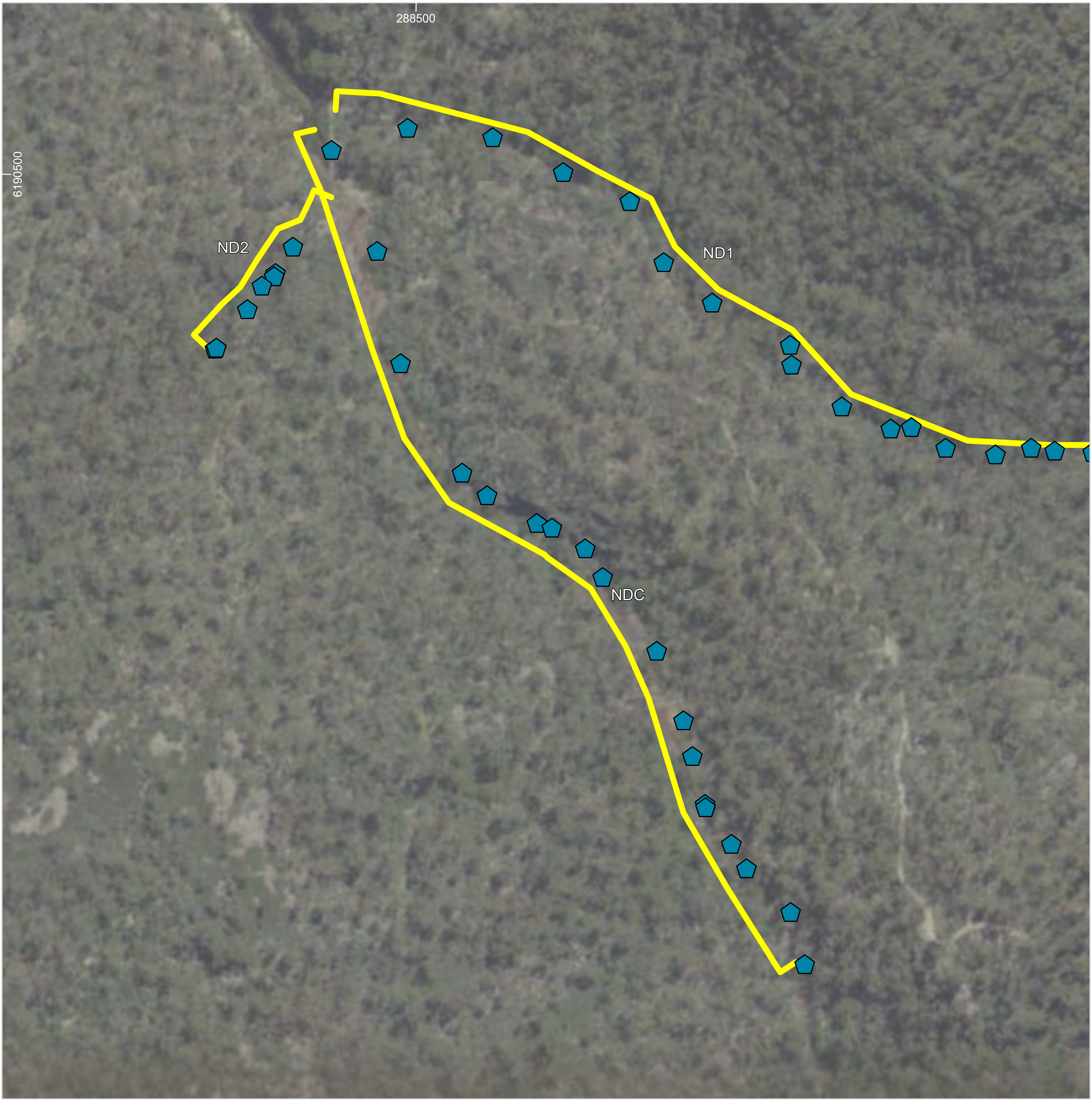
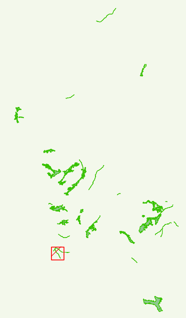
World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.





⬟ Threatened frog monitoring breeding pool

Threatened frog monitoring impact transect

▬ Impact - RMZ

Niche Environment and Heritage

0 60
m
WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - NDC: Impact (RMZ)

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

Niche PM: Sian Griffiths
Niche Proj. #: 7290
Client: South32

Figure 5e

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World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

⬟ Threatened frog monitoring breeding pool

Threatened frog monitoring impact transect

━ Impact - RMZ

niche Environment and Heritage

N

0 10

m

WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - ND2: Impact (RMZ)

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
Annual Report 2022

Niche PM: Sian Griffiths
Niche Proj. #: 7290
Client: South32

Figure 5f

World Imagery: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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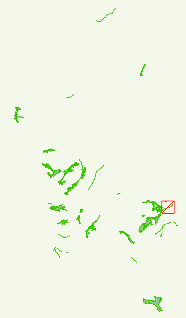

⬟ Threatened frog monitoring breeding pool

— Longwall Progression

Area 3A and 3B longwalls

☐ Complete

Threatened frog monitoring impact transect

— Impact - Mined beneath

— Impact - RMZ

Veg sub-community mapping from 2022 LiDAR analysis

🟩 Banksia Thicket

niche Environment and Heritage

0 50 m

WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - SC10(1): Impact (mined beneath)

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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Niche Proj. #: 7290
Client: South32

Figure 5g

World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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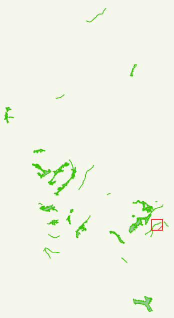

⬟ Threatened frog monitoring breeding pool

Threatened frog monitoring impact transect

🟩 Control

Niche Environment and Heritage

0 50
m
WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - SC7(1): Control

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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Niche Proj. #: 7290
Client: South32

Figure 5h

World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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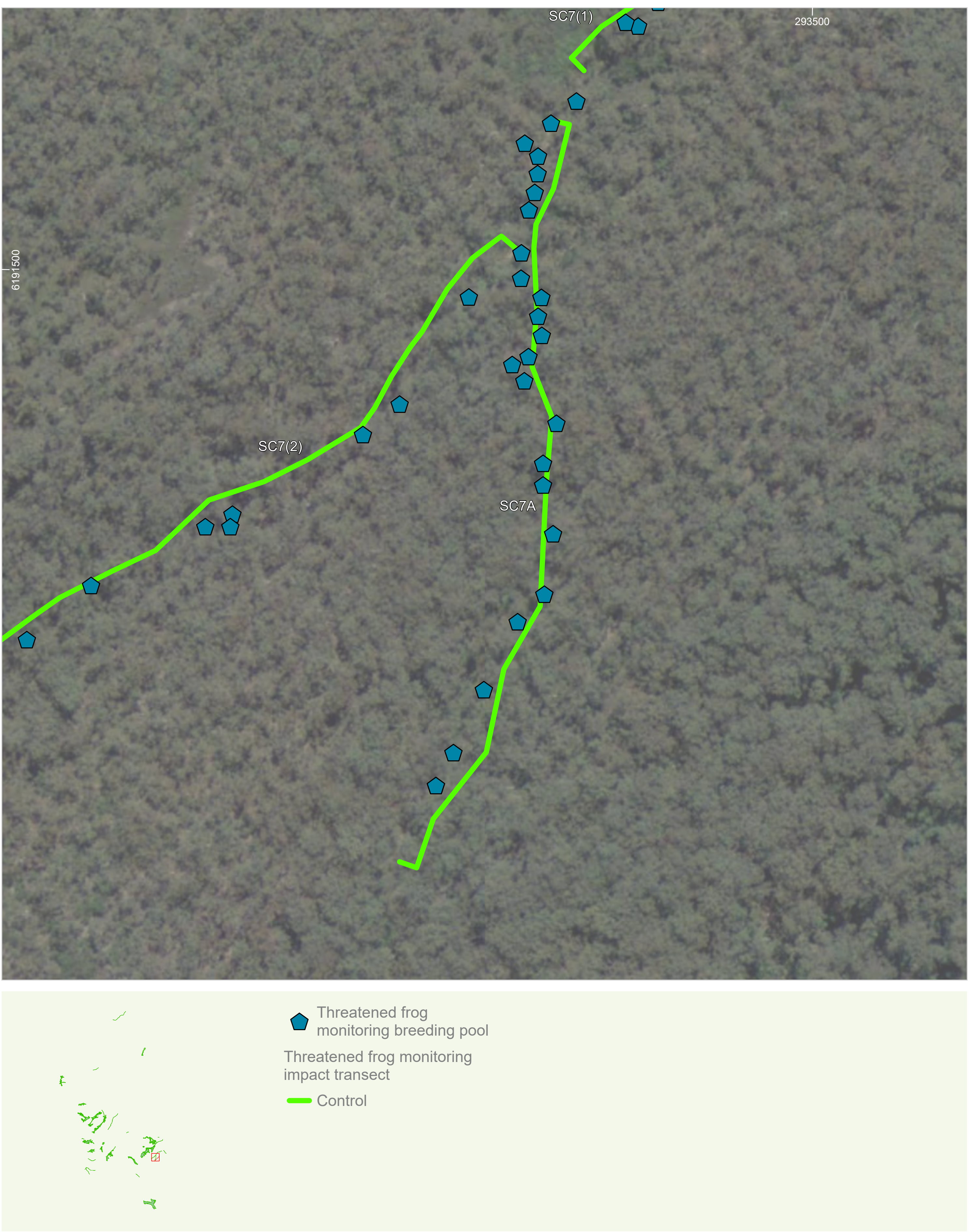

WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - SC7A: Control

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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Figure 5i

World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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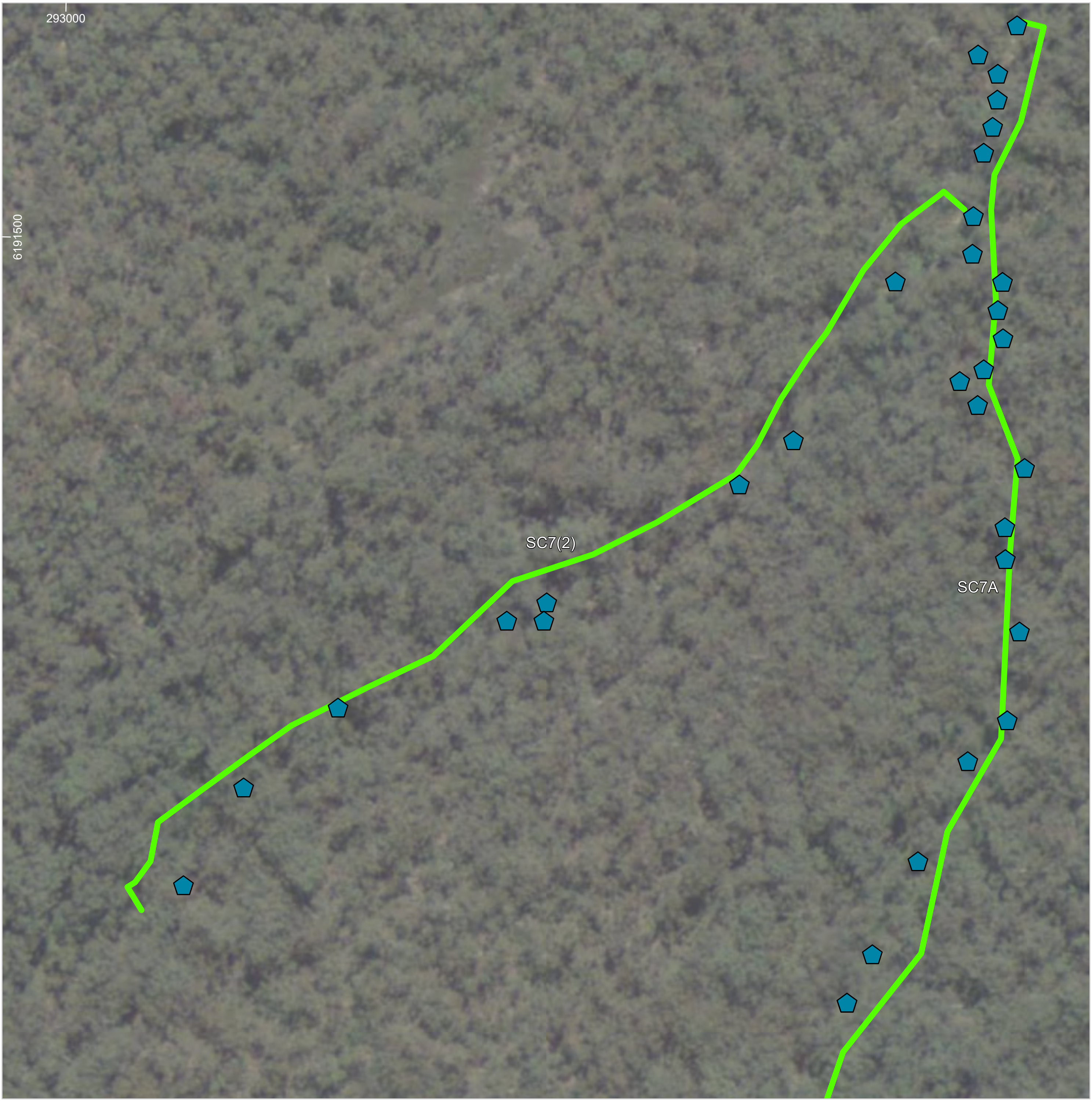

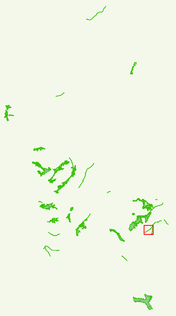

⬟ Threatened frog monitoring breeding pool

Threatened frog monitoring impact transect

🟩 Control

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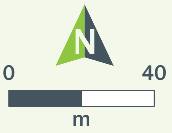

WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - SC7(2): Control

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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Client: South32

Figure 5j

World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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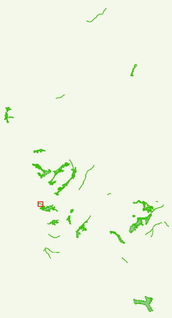

🔵 Threatened frog monitoring breeding pool

Threatened frog monitoring impact transect

🟨 Impact - RMZ

Veg sub-community mapping from 2022 LiDAR analysis

🟩 Banksia Thicket

Niche Environment and Heritage

0 20
m
WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - LA4A: Impact (RMZ)

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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Figure 5k

World Imagery: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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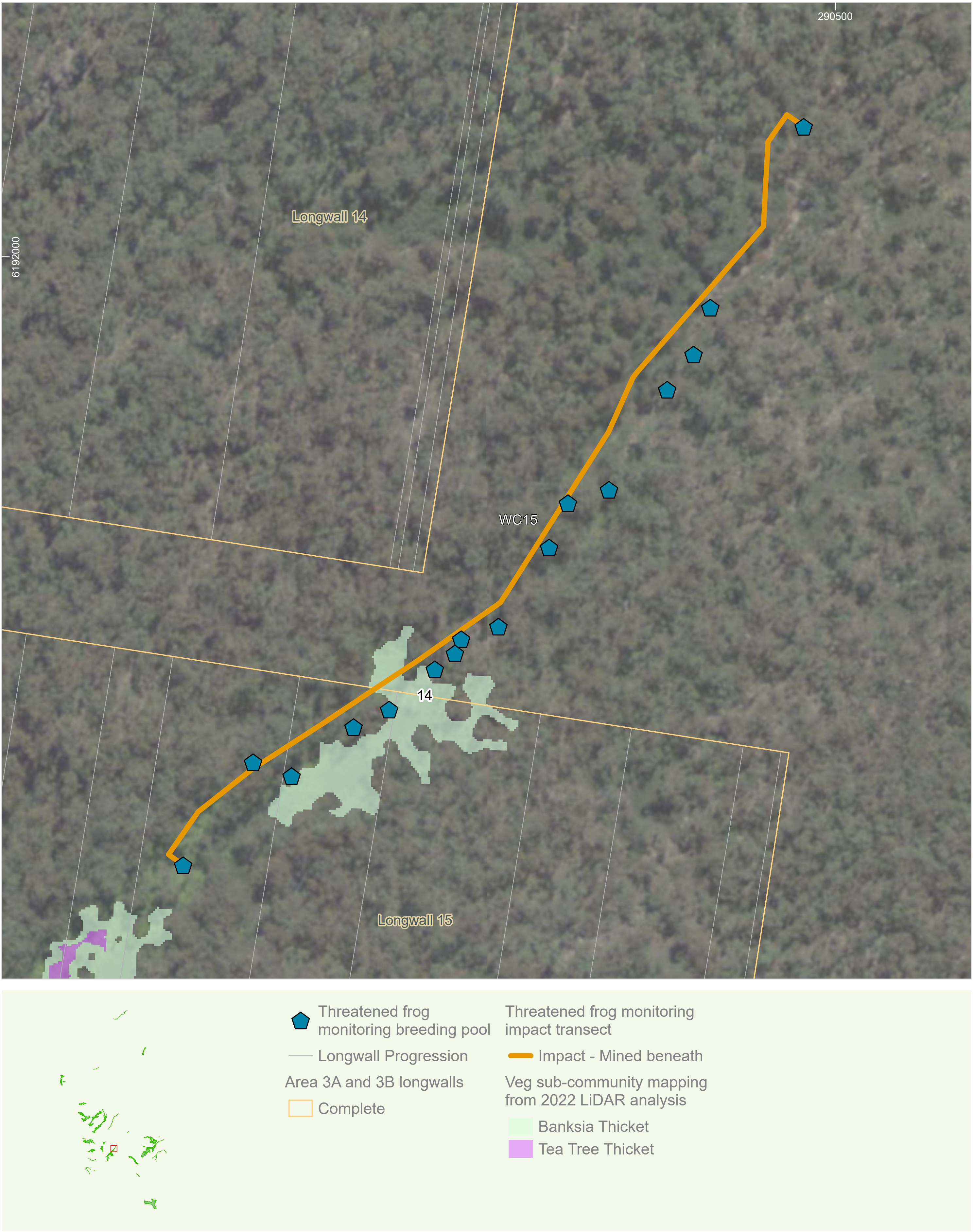

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0 40
m
WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - WC15: Impact (mined beneath)

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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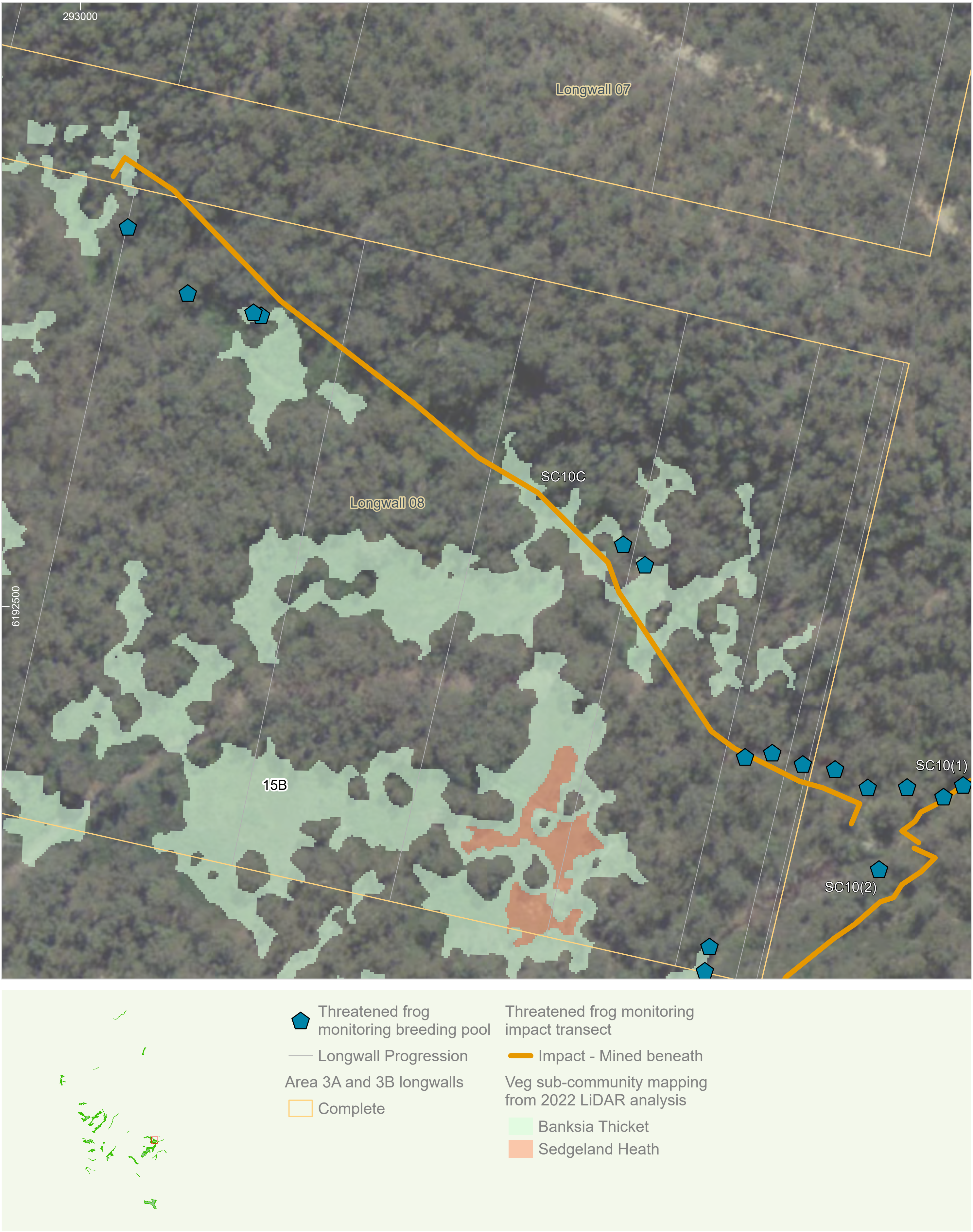
Niche Proj. #: 7290
Client: South32

Figure 5l

World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.



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WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - SC10C: Impact (mined beneath)

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
Annual Report 2022

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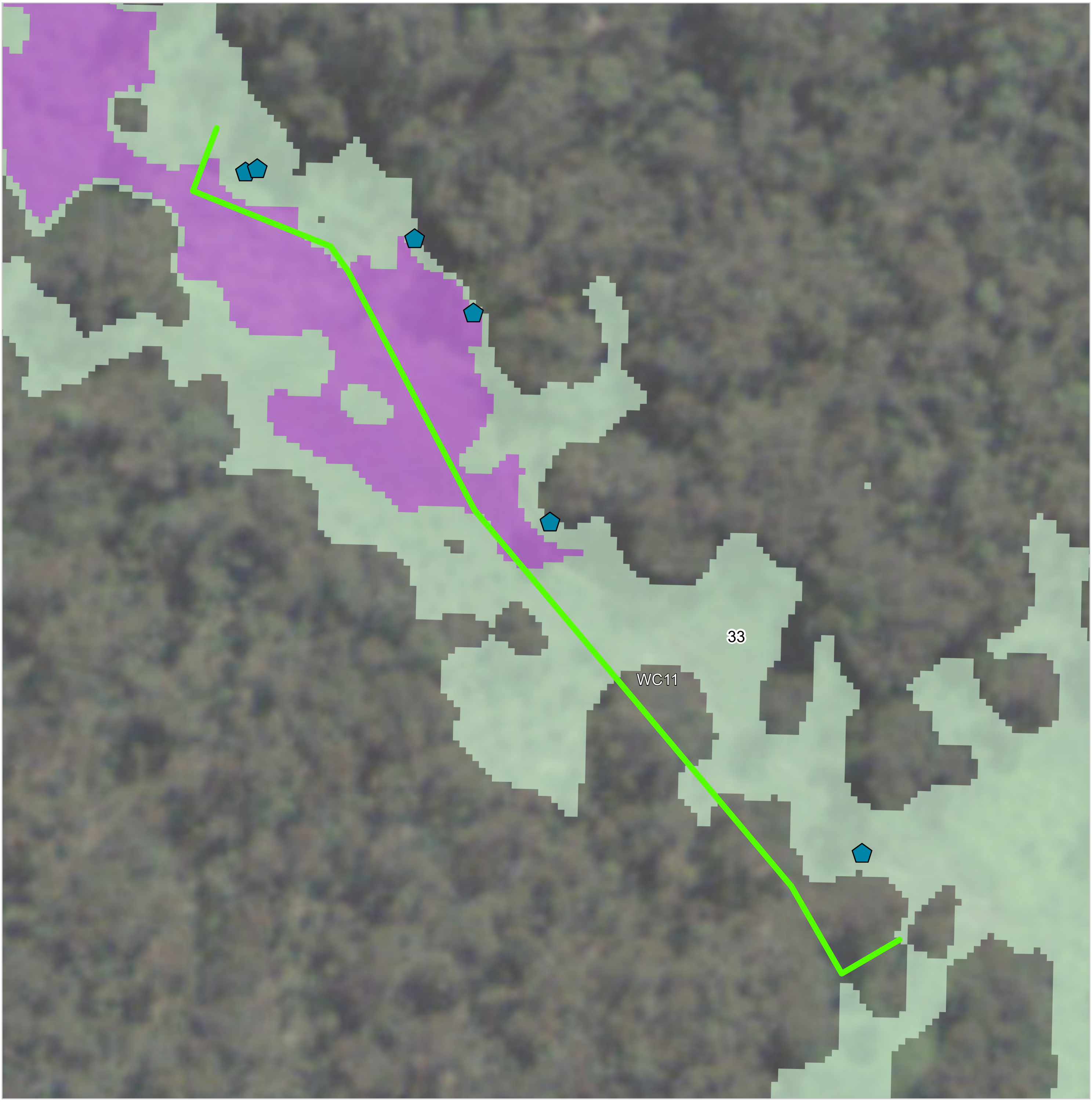
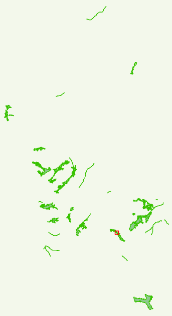
Client: South32

Figure 5m

World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

v2.0





⬟ Threatened frog monitoring breeding pool

Threatened frog monitoring impact transect

— Control

Veg sub-community mapping from 2022 LiDAR analysis

🟩 Banksia Thicket

🟪 Tea Tree Thicket

niche
Environment and Heritage

0 10
m

WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - WC11: Control

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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Niche Proj. #: 7290
Client: South32

Figure 5n

World Imagery: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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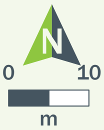
Niche Environment and Heritage



WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - WC17: Impact (mined beneath)

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
Annual Report 2022

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Niche Proj. #: 7290
Client: South32

Figure 5o

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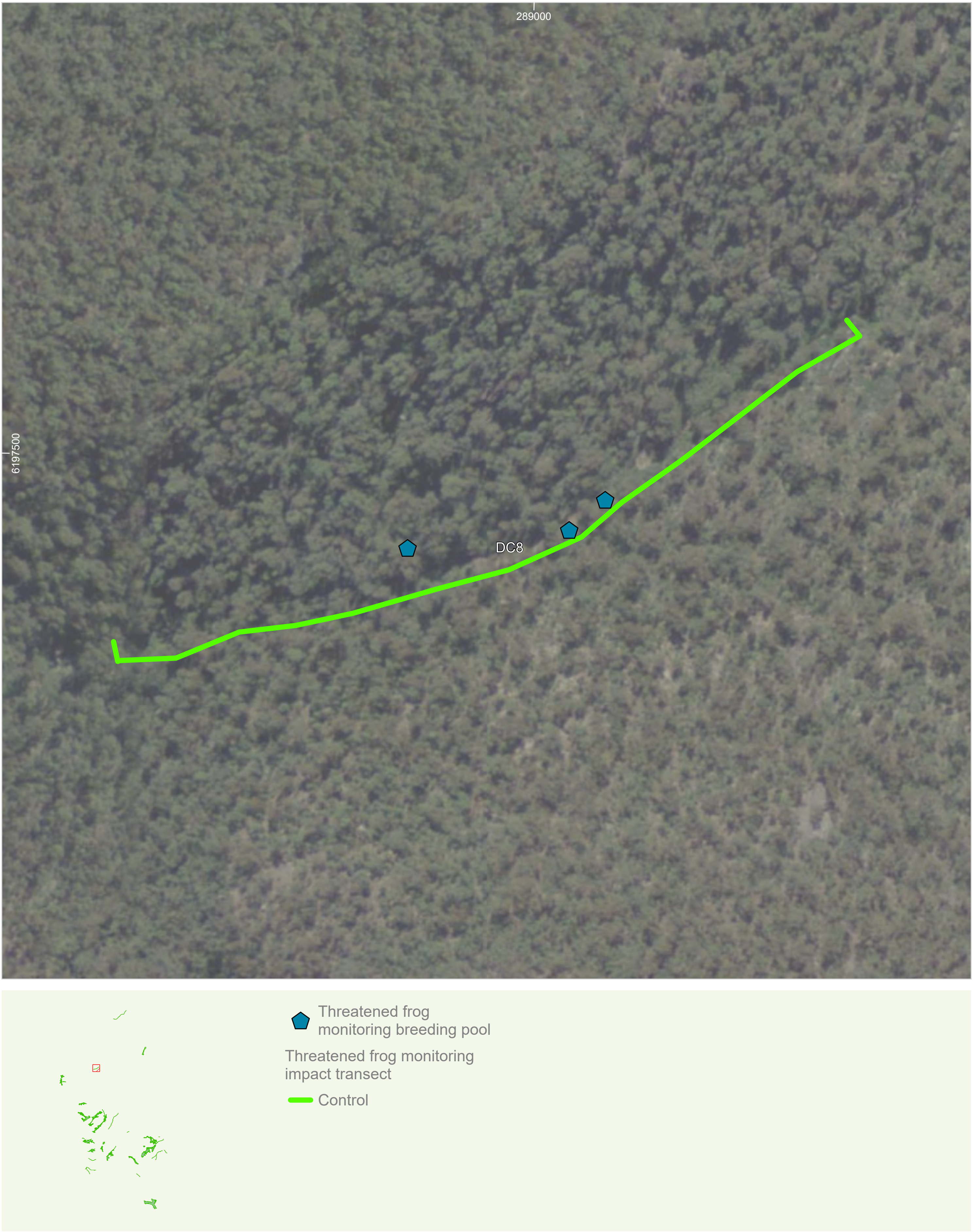
World Imagery: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.



niche
Environment and Heritage

0 50
m
WGS 1984 Web Mercator

Location of threatened frog monitoring transects used in the 2022 program - DC8: Control

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
Annual Report 2022

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Niche Proj. #: 7290
Client: South32

Figure 5p

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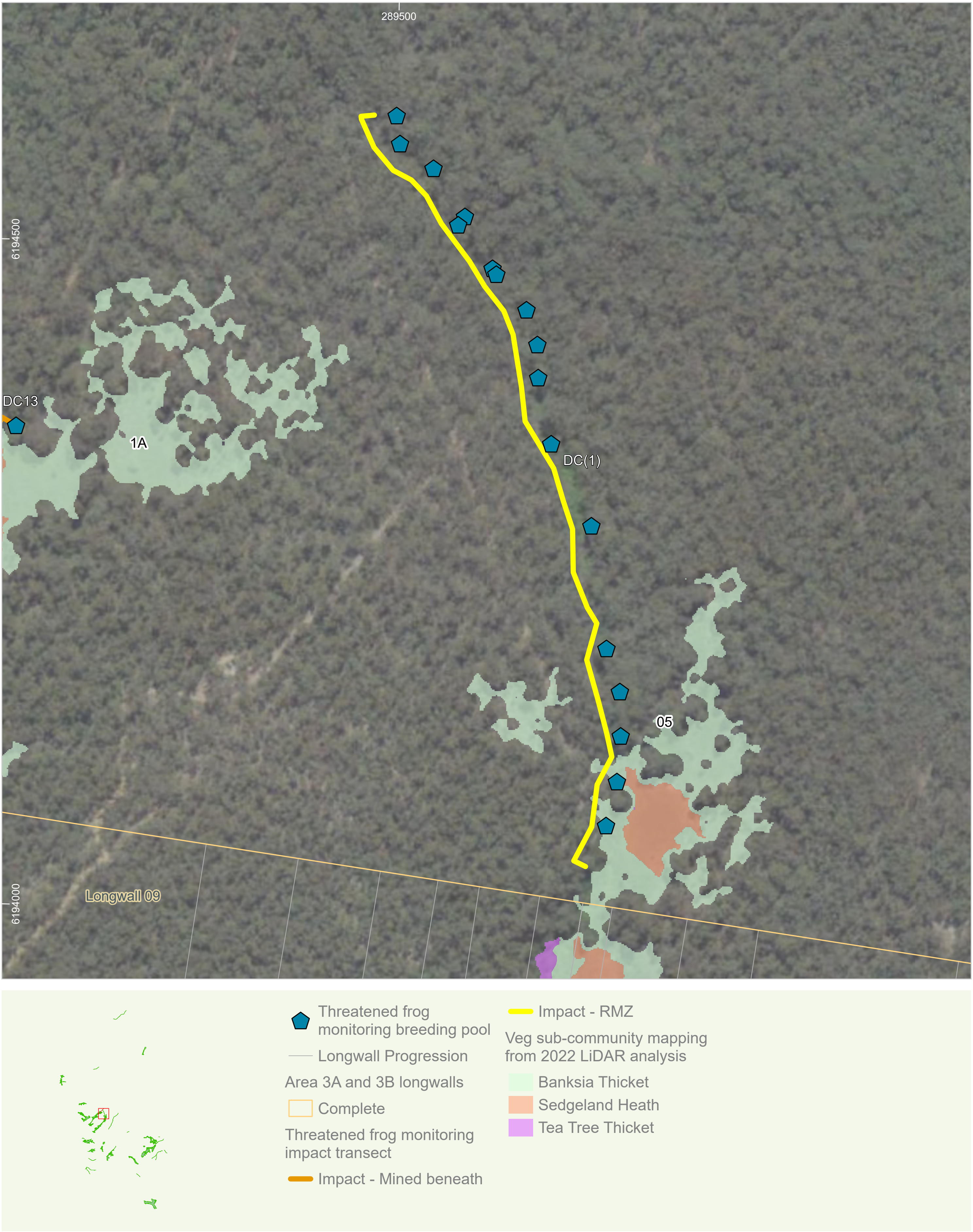
World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.



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Location of threatened frog monitoring transects used in the 2022 program - DC(1): Impact (RMZ)

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
Annual Report 2022

Niche PM: Sian Griffiths
Niche Proj. #: 7290
Client: South32

Figure 5q

World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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niche
Environment and Heritage

0 70
m
WGS 1984 Web Mercator

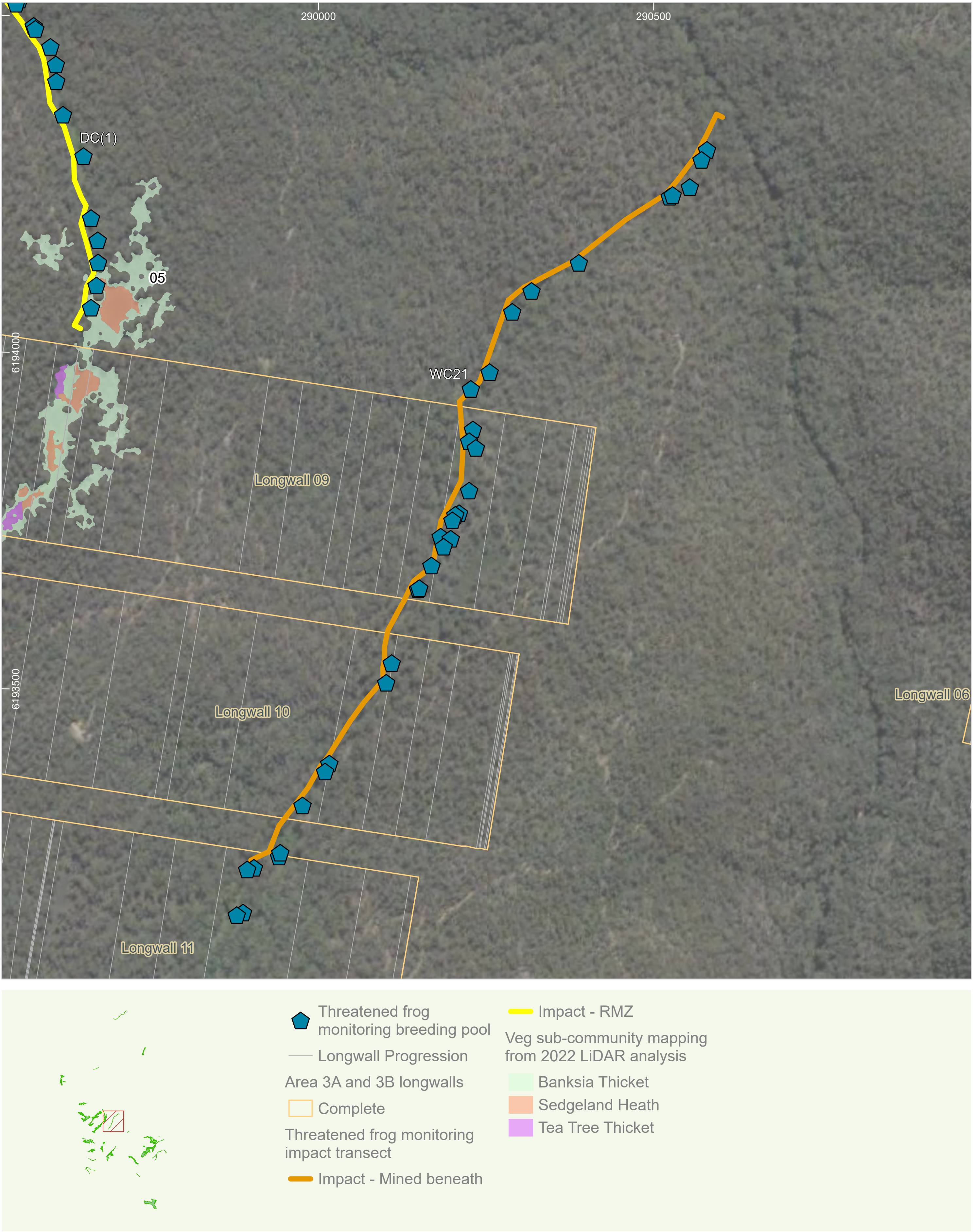
Location of threatened frog monitoring transects used in the 2022 program - LA2: Impact (mined beneath)

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
Annual Report 2022

Niche PM: Sian Griffiths
Niche Proj. #: 7290
Client: South32

Figure 5r

World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.



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Location of threatened frog monitoring transects used in the 2022 program - WC21: Impact (mined beneath)

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Figure 5s

World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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Location of threatened frog monitoring transects used in the 2022 program - 6CDL: Impact (RMZ)

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Figure 5t

World Imagery: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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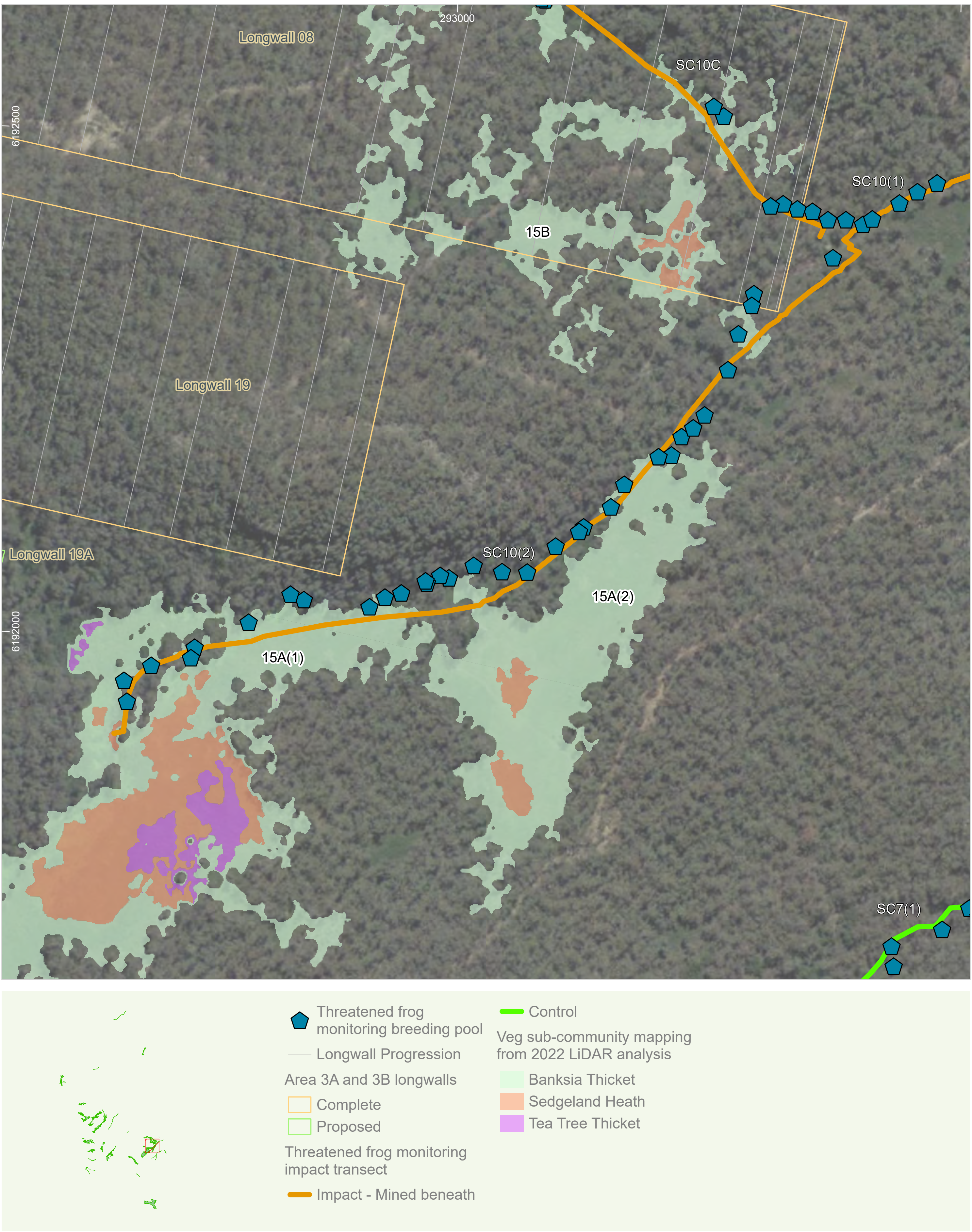

Location of threatened frog monitoring transects used in the 2022 program - SC10(2): Impact (mined beneath)

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Figure 5u

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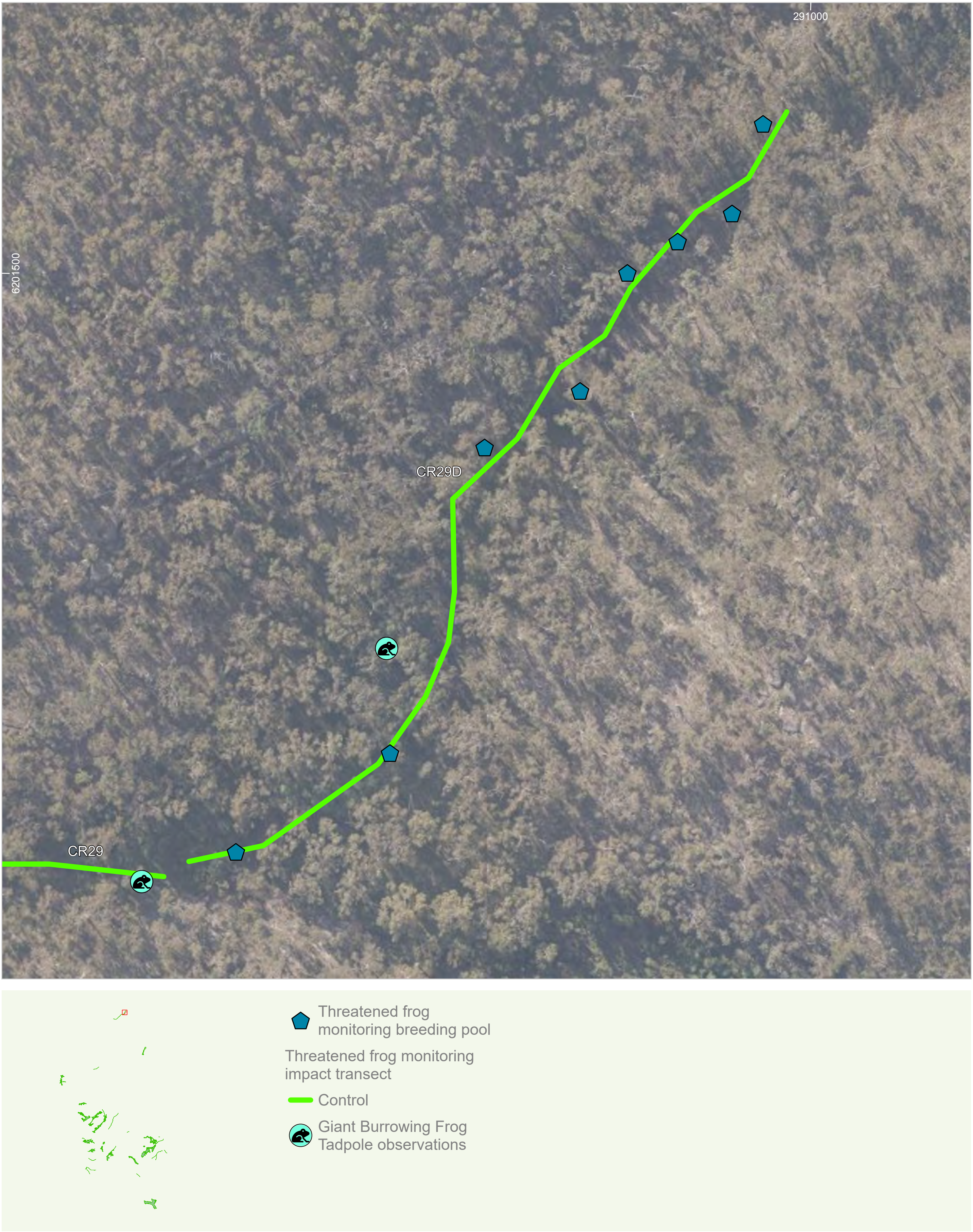
World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.



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Location of threatened frog monitoring transects used in the 2022 program - CR29D: Control

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Figure 5v

World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

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Location of threatened frog monitoring transects used in the 2022 program - CR29: Control

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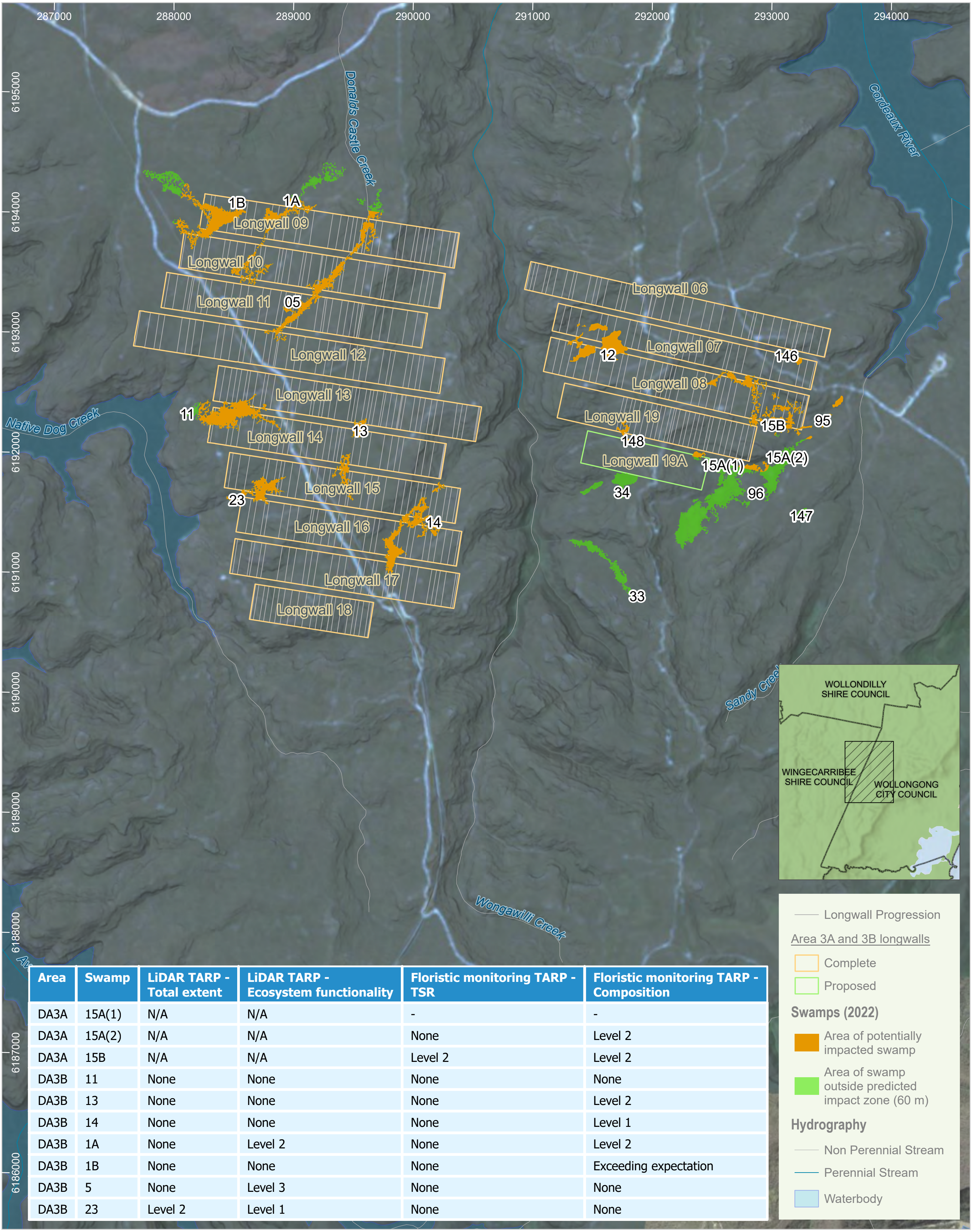
Figure 5w

World Imagery: Maxar/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.



Area	Swamp	LiDAR TARP - Total extent	LiDAR TARP - Ecosystem functionality	Floristic monitoring TARP - TSR	Floristic monitoring TARP - Composition
DA3A	15A(1)	N/A	N/A	-	-
DA3A	15A(2)	N/A	N/A	None	Level 2
DA3A	15B	N/A	N/A	Level 2	Level 2
DA3B	11	None	None	None	None
DA3B	13	None	None	None	Level 2
DA3B	14	None	None	None	Level 1
DA3B	1A	None	Level 2	None	Level 2
DA3B	1B	None	None	None	Exceeding expectation
DA3B	5	None	Level 3	None	None
DA3B	23	Level 2	Level 1	None	None

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Upland Swamp TARPs
Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program Annual Report 2022

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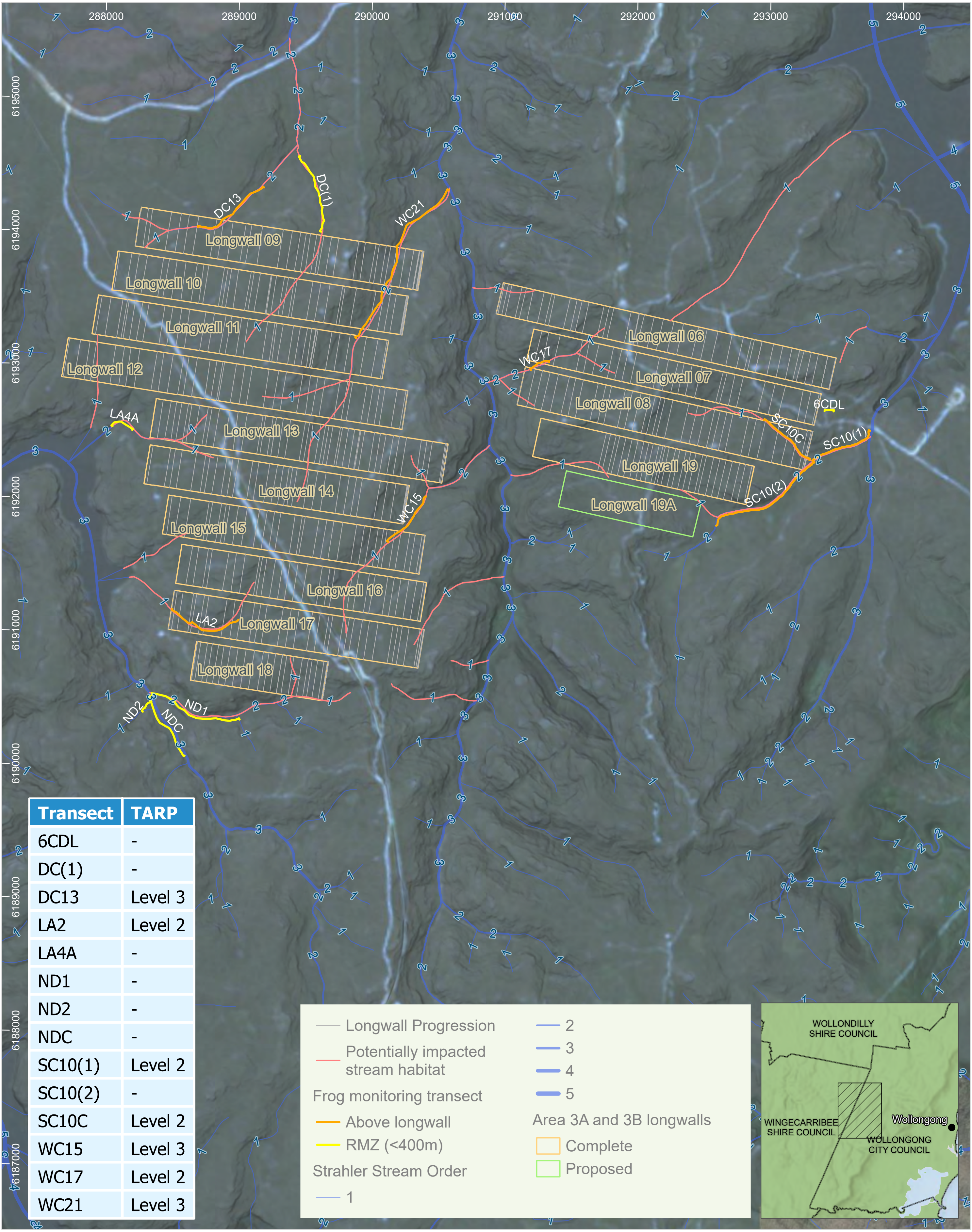
Figure 6

public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community/World_Ocean_Base: NIWA, GeosciencesAustralia, Esri, GEBCO, DeLorme, NaturalVue/World Hillshade: Esri, USGS | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.



Transect	TARP
6CDL	-
DC(1)	-
DC13	Level 3
LA2	Level 2
LA4A	-
ND1	-
ND2	-
NDC	-
SC10(1)	Level 2
SC10(2)	-
SC10C	Level 2
WC15	Level 3
WC17	Level 2
WC21	Level 3

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Amphibian monitoring TARPs

Dendrobium Areas 3A and 3B - Terrestrial Ecology Monitoring Program
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Client: South32

Figure 7

World Hillshade: Esri, CGIAR/public/NSW_Imagery: © Department of Customer Service 2020/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community/World_Ocean_Base: NIWA, GeosciencesAustralia, Esri, DeLorme, NaturalVue | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

Annex 1 LiDAR analysis results – Upland Swamps

Table 54: LiDAR analysis results: 2022

Swamp	Sub-community	Area (ha)							
		2014	2016	2017	2018	2019	2020	2021	2022
Control swamps									
22	Banksia Thicket	-	-	-	-	-	-	3.50	4.24
	Sedgeland Heath	18.27	-	-	-	-	-	15.15	13.18
	Tea Tree Thicket	-	-	-	-	-	-	1.05	1.60
	Total	18.27	-	-	-	-	-	19.70	19.02
33	Banksia Thicket	4.65	4.72	4.98	4.75	4.55	4.06	4.20	2.55
	Tea Tree Thicket	2.26	2.34	2.16	2.18	2.02	2.15	2.07	1.96
	Total	6.90	7.06	7.14	6.93	6.58	6.20	6.27	4.52
85	Banksia Thicket	0.78	0.81	0.86	0.87	0.81	0.79	1.05	2.52
	Sedgeland Heath	1.82	1.96	2.16	2.01	2.04	1.89	1.68	1.12
	Tea Tree Thicket	0.00	-	-	-	-	-	-	1.40
	Total	2.60	2.77	3.02	2.88	2.85	2.69	2.73	
86	Banksia Thicket	0.00	-	-	-	-	-	-	-
	Sedgeland Heath	4.06	-	-	-	-	-	4.11	4.12
	Tea Tree Thicket	0.10	-	-	-	-	-	0.08	0.07
	Total	4.15	-	-	-	-	-	4.19	4.19
3A Impact swamps									
15A(1)	Banksia Thicket	10.52	10.23	10.22	10.58	10.20	9.52	9.55	7.99
	Sedgeland Heath	6.24	6.26	5.63	5.09	4.78	4.58	4.59	4.83
	Tea Tree Thicket	2.41	2.28	2.80	2.95	2.83	2.81	2.82	2.58
	Total	19.18	18.77	18.65	18.62	17.81	16.91	16.96	15.40
15A(2)	Banksia Thicket	4.88	4.76	4.55	4.37	4.33	4.10	3.99	3.09
	Sedgeland Heath	0.15	0.14	0.14	0.10	0.10	0.04	0.04	0.02
	Tea Tree Thicket	0.09	0.07	0.05	0.03				
	Total	5.12	4.97	4.74	4.50	4.42	4.14	4.03	3.11
15B	Banksia Thicket	7.83	7.56	7.58	7.30	6.41	6.24	6.09	4.96

Swamp	Sub-community	Area (ha)							
		2014	2016	2017	2018	2019	2020	2021	2022
	Sedgeland Heath	0.62	0.58	0.60	0.65	0.60	0.47	0.47	0.16
	Tea Tree Thicket	1.50	1.44	1.31	1.00	0.96	0.89	0.89	0.91
	Total	9.94	9.58	9.49	8.95	7.98	7.60	7.45	6.02
3B Impact swamps									
11	Banksia Thicket	7.86	7.36	8.03	8.60	7.64	6.97	6.94	5.39
	Sedgeland Heath	1.91	1.89	1.88	1.90	1.74	1.70	1.79	1.61
	Tea Tree Thicket	1.46	1.49	1.38	1.13	1.13	0.93	0.94	0.68
	Total	11.23	10.74	11.29	11.63	10.52	9.61	9.67	7.68
13	Banksia Thicket	2.96	2.75	2.97	2.90	2.75	2.64	2.60	1.76
	Sedgeland Heath	0.51	0.84	0.78	0.79	0.78	0.63	0.63	0.70
	Tea Tree Thicket	0.44	0.21	0.17	0.18	0.17	0.16	0.16	0.12
	Total	3.91	3.80	3.92	3.87	3.71	3.43	3.39	2.58
14	Banksia Thicket	4.72	4.76	5.32	5.26	4.94	4.20	4.74	4.22
	Sedgeland Heath	1.41	1.63	1.09	1.12	1.13	1.04	1.19	0.82
	Tea Tree Thicket	2.82	2.58	2.65	2.66	2.24	2.12	2.13	1.18
	Total	8.94	8.97	9.06	9.04	8.31	7.36	8.06	6.22
01A	Banksia Thicket	7.33	7.14	7.94	8.32	7.59	6.36	6.44	5.78
	Sedgeland Heath	2.20	2.03	2.28	2.14	1.53	1.60	2.18	1.22
	Tea Tree Thicket	1.07	1.00	0.76	0.76	0.71	0.50	0.33	0.22
	Total	10.61	10.18	10.98	11.22	9.83	8.46	8.95	7.22
01B	Banksia Thicket	0.02	0.02	0.02	0.03	0.03	0.06	0.05	0.05
	Sedgeland Heath	13.07	12.20	13.10	14.29	12.14	11.03	10.98	9.68
	Tea Tree Thicket	0.12	0.12	0.10	0.12	0.12	-	-	-
	Total	13.22	12.33	13.22	14.44	12.29	11.09	11.03	9.72
5	Banksia Thicket	6.59	6.50	8.08	9.48	8.32	7.71	7.58	6.21
	Sedgeland Heath	5.07	4.83	4.52	3.62	3.06	2.50	2.68	1.93
	Tea Tree Thicket	1.47	1.63	1.07	1.09	0.73	0.61	0.57	0.50
	Total	13.13	12.95	13.67	14.19	12.11	10.81	10.83	8.64

Swamp	Sub-community	Area (ha)							
		2014	2016	2017	2018	2019	2020	2021	2022
23	Banksia Thicket	5.34	5.14	5.57	5.29	5.04	4.69	4.68	2.80
	Tea Tree Thicket	0.54	0.60	0.54	0.56	0.59	0.42	0.42	0.47
	Total	5.87	5.74	6.11	5.85	5.62	5.11	5.10	3.27

Annex 2 Statistical analysis – Upland Swamps

Task 1A - Analysis of total flora species richness at swamps within the Dendrobium region

Data collected up to and including 2022

Joanne M. Potts

15 March, 2023

Project History and Version Control

Date	Amendments	Person
27 Feb 2023	Received data from Luke Stone (Niche).	JP
13 Mar 2022	Received revised data from Luke Stone (Niche).	JP
15 Mar 2022	Draft report submitted to Luke Stone (Niche).	JP

Table of Contents

1 Data Summary

On 13 March 2023, The Analytical Edge (hereafter, TAE) received a revised data set from Luke Stone (Niche) via e-mail. It contained data collected during flora swamp monitoring within the Dendrobium region up to and including 2022 (*'a7290_2022_FloristicData_rev_02_20230313.xlsx'*, 16.7 MB).

Notes:

(1) Many species names and complexes had been revised since the previous analysis.

(2) As per previous years, all data relating to swamp S1 were omitted from the analysis.

(3) Different to previous years, S15A(1) is now considered an impact swamp (i.e., all previous years of 'control' data are now classified pre 'impact').

(4) A new 'control' swamp has been added (S131).

(5) 14 records were classified as 'QUADRAT DEAD' and were excluded from the analysis.

Disclaimer: This data file is assumed to be error-free. Any further errors detected by Niche may invalidate the results and conclusions made in this report and will require the analysis to be re-run under the proviso of new contract agreements.

2 Methods

This report follows the structure of TAE (2022). That is, the mean total species richness (TSR) was calculated from data pooled from 2 consecutive years at impact swamps was contrasted against the mean TSR of all control swamp data from prior to the impact. Similarly, we compared TSR for impact and control swamps calculated from pooled data for 3-year, 4-year, and where applicable, 5-year periods. All control swamps were used for each impact swamp (Table 1).

Where applicable, a before-after control-impact (BACI) style analysis was completed, whereby differences in group means before impact between the control and impact swamps, and after impact, were tested to explore whether they were different from 0. If there was only a single year of before-impact monitoring (i.e., swamps S1A and S23), a control-impact analysis was completed, whereby differences in group means after impact at the control and impact swamps was tested to explore whether they were different from 0.

Conducting multiple testing such as this can lead to erroneous interpretation of results; through statistical chance alone, 5% of tests may be concluded significant, and this chance is elevated when multiple tests are conducted. Methods exist for multiple correction (e.g., Holm 1979) but this will decrease the power to detect a difference, if one exists. TAE has previously proposed alternative methods to analyse these data (e.g., using a broken-stick approach), and this will be explored in Task 2 (to be undertaken).

All analyses were conducted in R (v. 4.1.2, R Core Team 2021).

Table 1: The region of each impact swamp and their paired control swamps.

Region	Impact Swamps	Paired control swamps
3A	S15A(1)	S86, S87, S88, S22, S33, S131
3A	S15A(2)	S86, S87, S88, S22, S33, S131
3A	S15B	S86, S87, S88, S22, S33, S131
3B	S11	S86, S87, S88, S22, S33, S131
3B	S13	S86, S87, S88, S22, S33, S131
3B	S14	S86, S87, S88, S22, S33, S131
3B	S1A	S86, S87, S88, S22, S33, S131
3B	S1B	S86, S87, S88, S22, S33, S131
3B	S5	S86, S87, S88, S22, S33, S131
3B	S23	S86, S87, S88, S22, S33, S131

3 Results - Swamp S15A(1)

Monitoring at swamp S15A(1) began in 2005, and this swamp was impacted in 2022. The boxplot of TSR data (Figure 1) shows that prior to impact, the TSR at control sites was more variable (with a wider minimum and maximum TSR observation) and typically lower than TSR at the impact swamp.

For each year of monitoring prior to and post-impact, we calculated the difference in mean TSR between the control and impact swamps. Within-year comparisons (Figure 2) show that TSR remains lower at swamp S15A(2) compared with the control swamps.

Since this swamp has only one year of monitoring post impact, no statistical analyses were undertaken for this swamp.

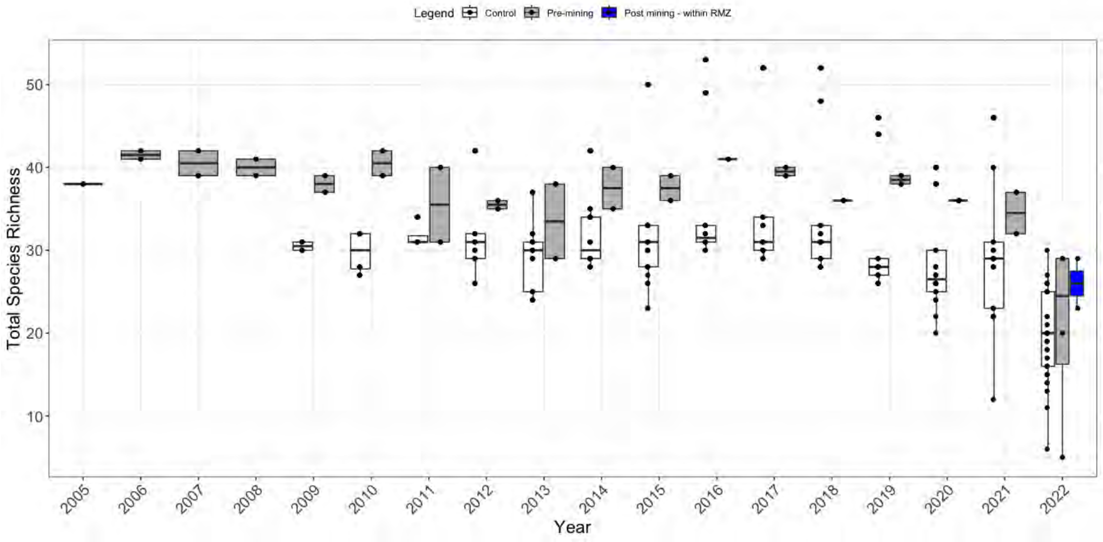


Figure 1: Boxplot of the total species richness for each transect at impact swamp S15A(1), contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

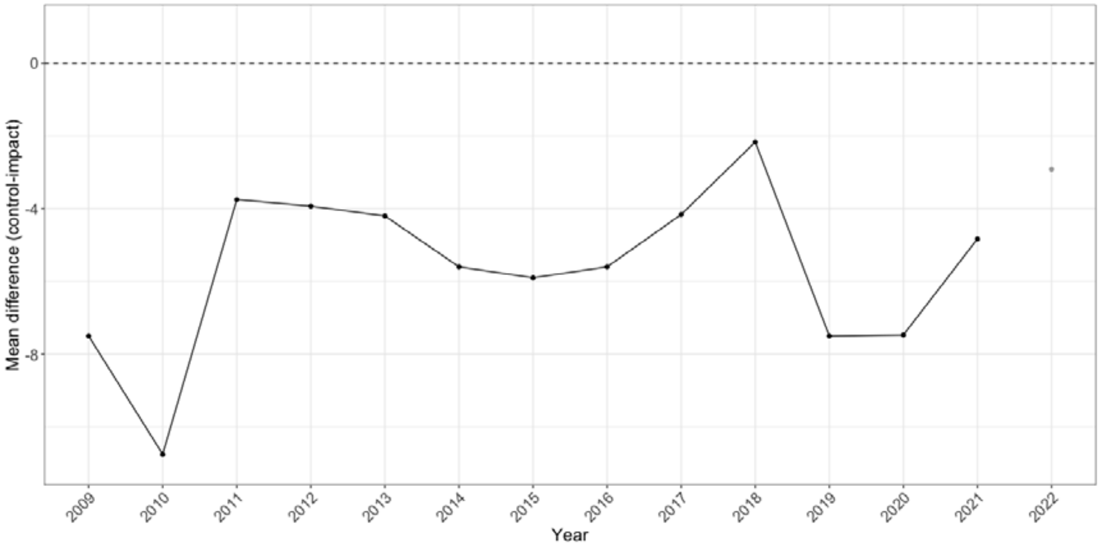


Figure 2: Difference between means for the control swamps and the impact swamp, shaded as black (pre-impact) and light grey (post-impact). Horizontal line at 0 is highlighted.

4 Results - Swamp S15A(2)

Monitoring at swamp S15A(2) began in 2009, and this swamp was impacted in 2013. The boxplot of TSR data (Figure 3) shows that prior to impact, the TSR at control sites was more variable (with a wider minimum and maximum TSR observation) and typically lower than TSR at the impact swamp. Since 2017, TSR at this impact swamp appears to have declined to lower levels than those recorded before impact.

For each year of monitoring prior to and post-impact, we calculated the difference in mean TSR between the control and impact swamps. Within-year comparisons (Figure 4) show that TSR remains higher at swamp S15A(2) compared with the control swamps (i.e., the difference of the means is always negative), and this is trending towards 0, and indeed became positive in the 2022 monitoring (i.e., TSR at swamp S15A(2) is declining to become more similar to, and now less diverse, than the control swamps over time).

A statistically significant difference in 2-yearly comparisons was found in 2018 and 2019 (Table 5). A statistically significant difference in 3-yearly comparisons was found between 2018 and 2019 (Table 6) and 4-yearly comparisons from 2016 (Table 7).

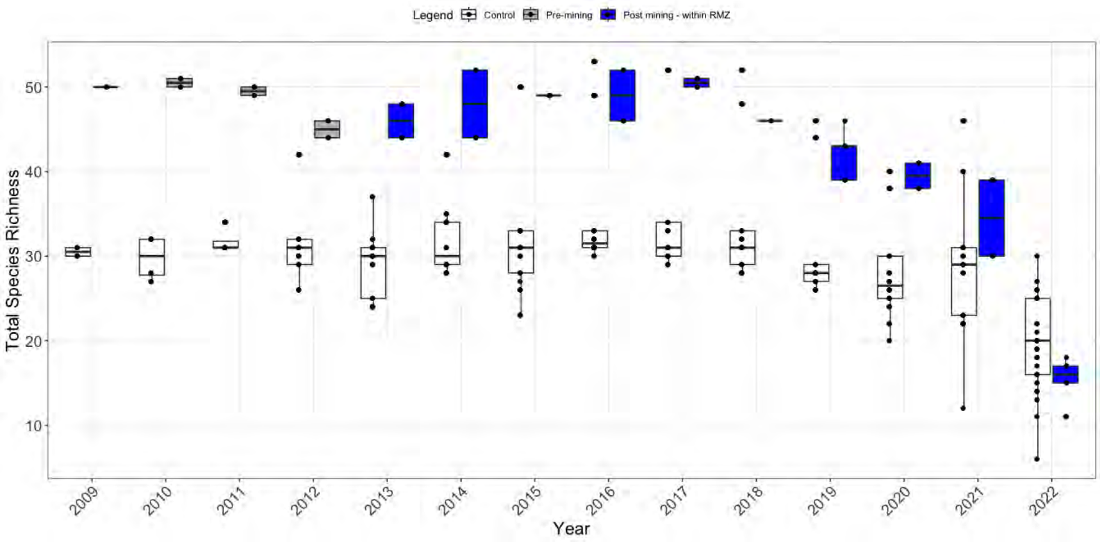


Figure 3: Boxplot of the total species richness for each transect at impact swamp S15A(2), contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

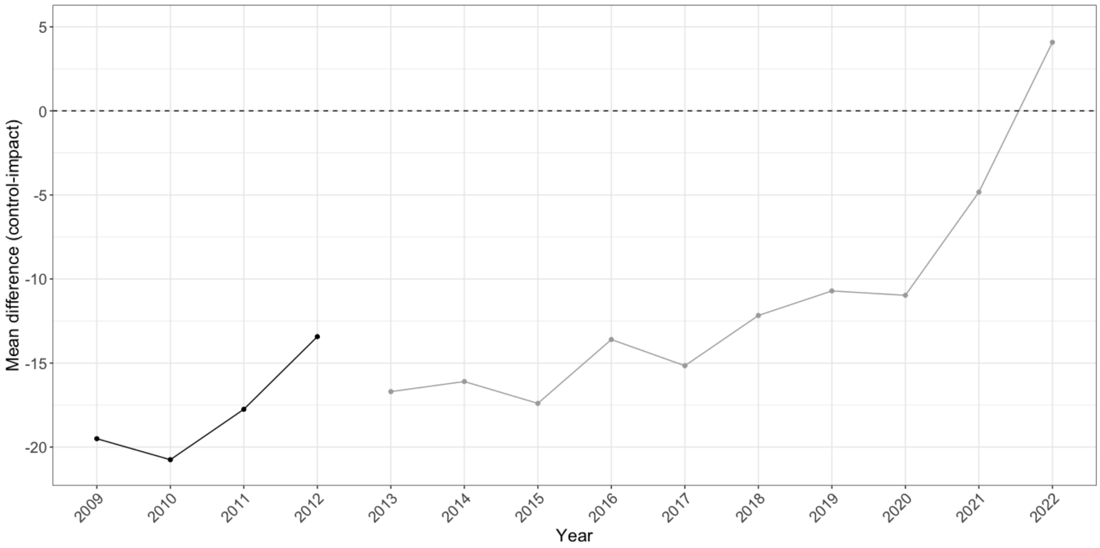


Figure 4: Difference between means for the control swamps and the impact swamp, shaded as black (pre-impact) and light grey (post-impact). Horizontal line at 0 is highlighted.

Table 5: Assessment of two-consecutive-year periods for swamp S152(A).

Comparison	Test statistic	D.f.	P-value
2013–2014	0.90	3.20	0.432
2014–2015	0.64	3.77	0.558
2015–2016	0.95	2.50	0.425
2016–2017	1.95	3.93	0.124
2017–2018	1.92	3.20	0.146
2018–2019	3.65	3.88	0.023
2019–2020	4.37	3.04	0.022
2020–2021	2.88	1.58	0.134
2021–2022	3.69	1.27	0.126

Table 6: Assessment of three-consecutive-year periods for swamp S152(A).

Comparison	Test statistic	D.f.	P-value
2013–2015	0.68	3.33	0.538
2014–2016	1.11	4.89	0.320
2015–2017	1.27	4.88	0.261
2016–2018	2.32	4.44	0.075
2017–2019	2.51	5.00	0.054
2018–2020	3.96	3.46	0.022
2019–2021	3.52	4.22	0.022
2020–2022	3.00	2.54	0.071

Table 7: Assessment of four-consecutive-year periods for swamp S152(A).

Comparison	Test statistic	D.f.	P-value
2013–2016	1.06	4.50	0.343
2014–2017	1.28	4.41	0.263
2015–2018	1.68	5.37	0.150
2016–2019	2.66	4.90	0.046
2017–2020	2.96	5.09	0.031
2018–2021	3.57	6.00	0.012
2019–2022	3.16	4.18	0.032

5 Results - Swamp S15B

Monitoring at swamp S15B began in 2003, and this swamp was impacted in 2010. The boxplot of TSR data (Figure 5) shows that throughout the monitoring period, the TSR at control sites was more variable (with a wider minimum and maximum TSR observation) than at the impact swamp. Since impact, TSR at this swamp appears to have declined to lower levels than before impact.

For each year of monitoring prior to and post-impact, we calculated the difference in mean TSR between the control and impact swamps. Within-year comparisons (Figure 6) show that TSR prior to impact was initially higher at swamp S15B compared with the control swamps (i.e., the difference of the means was negative), and since impact, this became positive (i.e., TSR at swamp S15B became lower than the control swamps over time).

Two-yearly comparisons were statistically significant in 2018 (Table 8). Three-yearly comparisons were statistically significant in 2010 (Table 9) and four-yearly comparisons were statistically significant in 2010 and 2012 (Table 10).

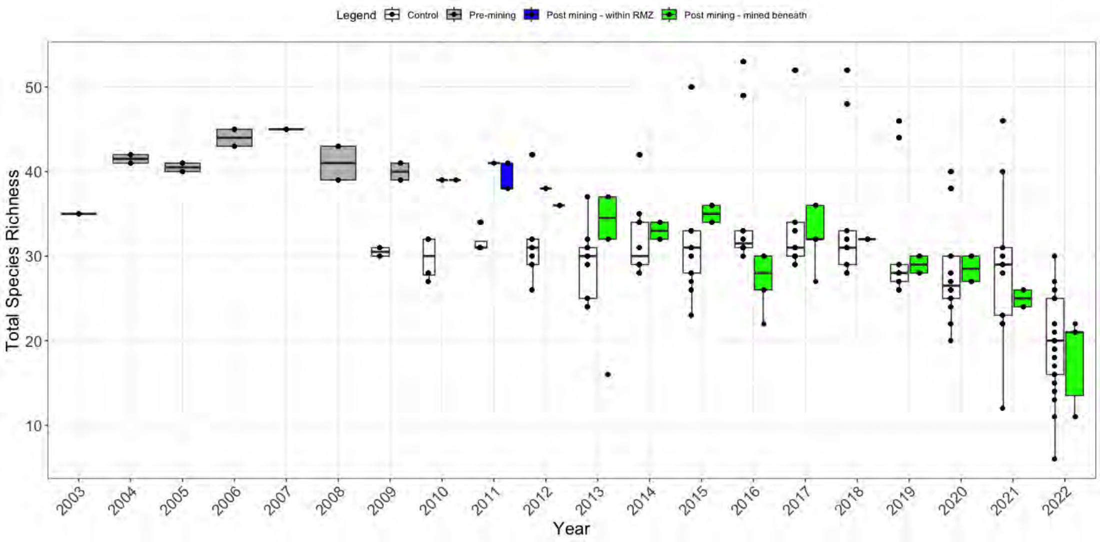


Figure 5: Boxplot of the total species richness for each transect at impact swamp S15B, contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

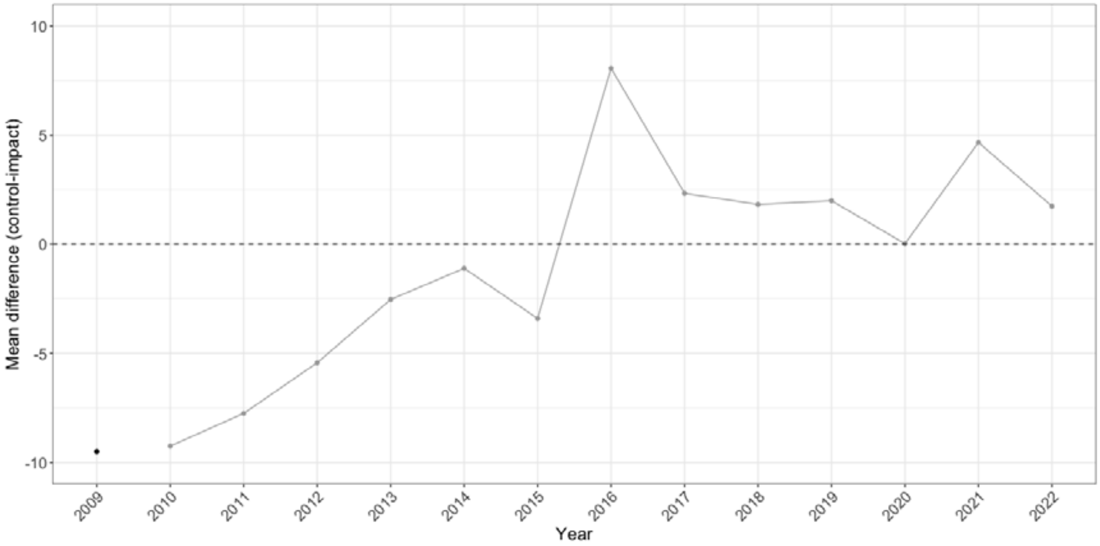


Figure 6: Difference between means for the control swamps and the impact swamp, shaded as black (pre-impact) and light grey (post-impact). Horizontal line at 0 is highlighted.

Table 8: Assessment of two-consecutive-year periods for swamp S15B.

Comparison	Test statistic	D.f.	P-value
2010–2011	-11.33	1	0.056
2011–2012	-5.68	1	0.111
2012–2013	-2.74	1	0.222
2013–2014	-2.54	1	0.239
2014–2015	-1.96	1	0.301
2015–2016	0.41	1	0.754
2016–2017	1.82	1	0.320
2017–2018	8.18	1	0.077
2018–2019	22.53	1	0.028
2019–2020	1.03	1	0.490
2020–2021	1.01	1	0.496
2021–2022	2.20	1	0.272

Table 9: Assessment of three-consecutive-year periods for swamp S15B.

Comparison	Test statistic	D.f.	P-value
2010–2012	-6.73	2	0.021
2011–2013	-3.47	2	0.074
2012–2014	-2.37	2	0.141
2013–2015	-3.50	2	0.073
2014–2016	0.34	2	0.766
2015–2017	0.71	2	0.553
2016–2018	2.04	2	0.178
2017–2019	13.72	2	0.005
2018–2020	2.04	2	0.178
2019–2021	1.66	2	0.239
2020–2022	1.59	2	0.253

Table 10: Assessment of four-consecutive-year periods for swamp S15B.

Comparison	Test statistic	D.f.	P-value
2010–2013	-4.26	3	0.024
2011–2014	-2.83	3	0.066
2012–2015	-3.44	3	0.041
2013–2016	0.10	3	0.928
2014–2017	0.59	3	0.595
2015–2018	0.94	3	0.415
2016–2019	2.36	3	0.099
2017–2020	2.99	3	0.058
2018–2021	2.23	3	0.112
2019–2022	2.20	3	0.115

6 Results - Swamp S11

Monitoring at swamp S11 began in 2003, and this swamp was impacted in 2016. The boxplot of TSR data (Figure 7) shows that throughout the monitoring period, the TSR at control sites was more variable (with a wider minimum and maximum TSR observation) than TSR at the impact swamp. Immediately after impact (2016) TSR rose to the highest observations ever recorded at this swamp) and have since declined to levels never recorded before impact.

For each year of monitoring prior to and post-impact, we calculated the difference in mean TSR between the control and impact swamps. Within-year comparisons (Figure 8) show that TSR prior to, and post impact, was similar between swamp S11 and the control swamps (i.e., the mean difference hovers around 0), however in the previous two years of monitoring, TSR is much lower at the impact swamp than the controls.

No 2-or 4-yearly comparisons were found to be statistically significant at this swamp (Table 11 and Table 13, respectively). One 3-yearly comparison was found to be statistically significant in 2020 (Table 12), and a 5-yearly comparison was found to be significant in 2018 (Table 14).

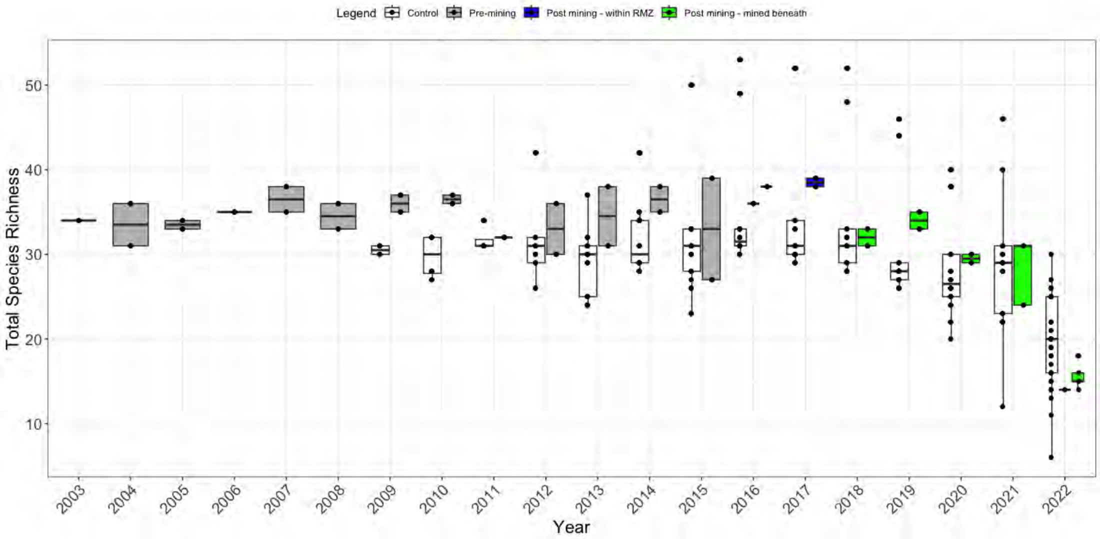


Figure 7: Boxplot of the total species richness for each transect at impact swamp S11, contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

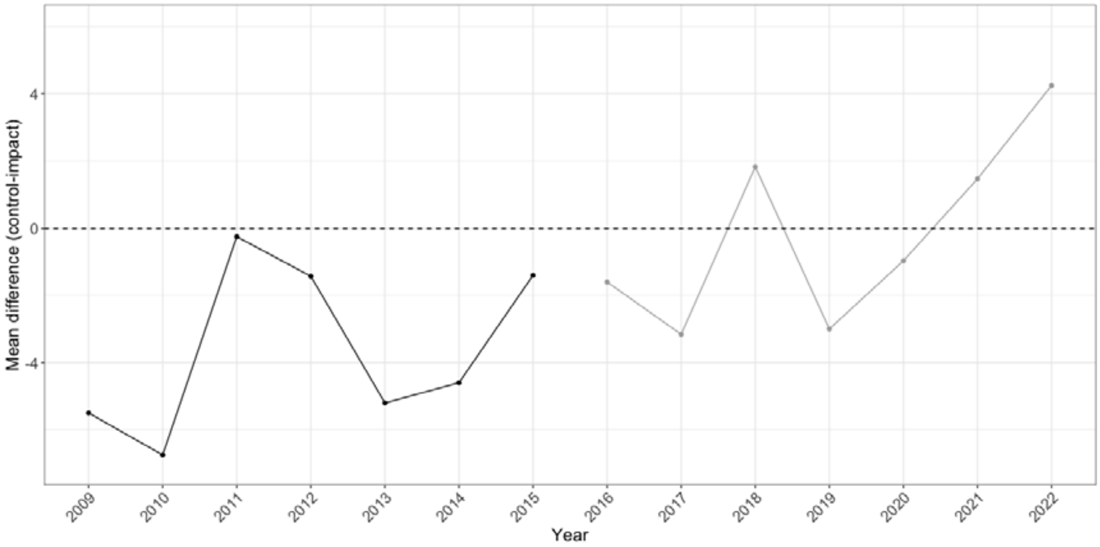


Figure 8: Difference between means for the control swamps and the impact swamp, shaded as black (pre-impact) and light grey (post-impact). Horizontal line at 0 is highlighted.

Table 11: Assessment of two-consecutive-year periods for swamp S11.

Comparison	Test statistic	D.f.	P-value
2016–2017	0.98	4.51	0.375
2017–2018	1.10	1.31	0.435
2018–2019	1.16	1.33	0.414
2019–2020	1.15	3.12	0.329
2020–2021	2.48	2.43	0.109
2021–2022	3.83	2.08	0.058

Table 12: Assessment of three-consecutive-year periods for swamp S11.

Comparison	Test statistic	D.f.	P-value
2016–2018	1.49	3.79	0.214
2017–2019	1.13	3.44	0.329
2018–2020	1.70	3.98	0.165
2019–2021	1.72	4.32	0.155
2020–2022	2.90	3.71	0.048

Table 13: Assessment of four-consecutive-year periods for swamp S11.

Comparison	Test statistic	D.f.	P-value
2016–2019	1.41	6.84	0.203
2017–2020	1.51	6.81	0.176
2018–2021	2.32	6.99	0.054
2019–2022	2.20	5.26	0.076

Table 14: Assessment of five-consecutive-year periods for swamp S11.

Comparison	Test statistic	D.f.	P-value
2016–2020	1.69	9.77	0.123
2017–2021	1.98	9.09	0.078
2018–2022	2.75	8.17	0.025

7 Results - Swamp S13

Monitoring at swamp S13 began in 2013, and this swamp was impacted in 2017. The boxplot of TSR data (Figure 9) shows that throughout the monitoring period, the TSR at control sites was more variable (with a wider minimum and maximum TSR observation) than TSR at the impact swamp. Prior to impact, TSR at this swamp was typically higher than the control swamps, and post-impact there has been a decline in TSR at swamp S13 that was greater than the decline in TSR at the control swamps within the same time period.

For each year of monitoring prior to and post-impact, we calculated the difference in mean TSR between the control and impact swamps. Within-year comparisons (Figure 10) show that prior to impact, aTSR was higher at the impact swamp; and post impact, it remained higher until 2022 (i.e., the mean difference increased to above 1 and then reduced back to pre-impact levels below 0 this year).

A two-year comparison was statistically significant up to, and including, 2019 (Table 15). All 3-, 4- and 5-yearly comparisons were statistically significant (Table 16, Table 17 and Table 18, respectively).

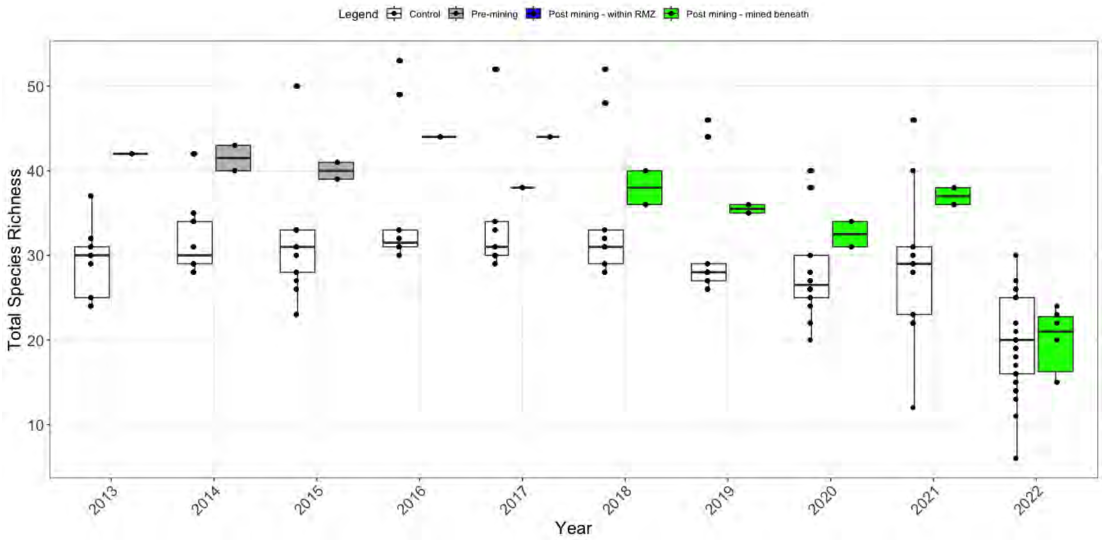


Figure 9: Boxplot of the total species richness for each transect at impact swamp S13, contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

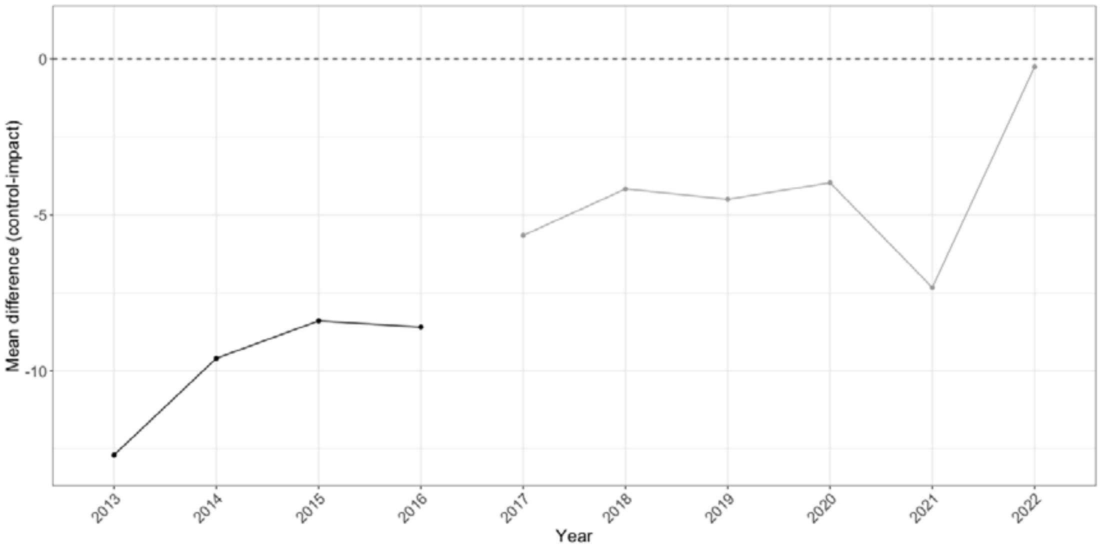


Figure 10: Difference between means for the control swamps and the impact swamp, shaded as black (pre-impact) and light grey (post-impact). Horizontal line at 0 is highlighted.

Table 15: Assessment of two-consecutive-year periods for swamp S13.

Comparison	Test statistic	D.f.	P-value
2017–2018	3.95	3.76	0.019
2018–2019	5.45	3.16	0.011
2019–2020	5.44	3.39	0.009
2020–2021	2.14	1.75	0.184
2021–2022	1.64	1.16	0.322

Table 16: Assessment of three-consecutive-year periods for swamp S13.

Comparison	Test statistic	D.f.	P-value
2017–2019	4.63	4.11	0.009
2018–2020	5.58	3.14	0.010
2019–2021	3.16	4.70	0.027
2020–2022	2.63	2.95	0.080

Table 17: Assessment of four-consecutive-year periods for swamp S13.

Comparison	Test statistic	D.f.	P-value
2017–2020	4.94	3.85	0.009
2018–2021	3.81	5.70	0.010
2019–2022	3.30	5.30	0.020

Table 18: Assessment of five-consecutive-year periods for swamp S13.

Comparison	Test statistic	D.f.	P-value
2017–2021	4.01	5.22	0.009
2018–2022	3.85	7.00	0.006

8 Results - Swamp S14

Monitoring at swamp S14 began in 2017, and this swamp was impacted in the same year. The boxplot of TSR data (Figure 11) shows that throughout the short monitoring period, the TSR at control swamps was more variable (with a wider minimum and maximum TSR observation) than at the impact swamp. This impact swamp has similar TSR than the control swamps, excluding 2022, when TSR at the impact swamp was lower than ever previously recorded at this swamp.

Since monitoring of this swamp began in the same year that the site was impacted, we only had two years of pre-mining TSR data (2017 and 2018) to compare with control site data. Data for transects that were undermined were also only available for two years: 2019 and 2020. Within-year comparisons (Figure 12) show that TSR at the impact swamp is consistently lower than the control swamps and has been a relatively consistent difference over the (short) monitoring period.

No 2-, 3-, or 4-yearly comparisons were found to be statistically significant at this swamp (Table 19, Table 20 and Table 21, respectively). As more data are collected, we recommended that effects are tested only post-impact, as the before-impact monitoring period for this swamp is short.

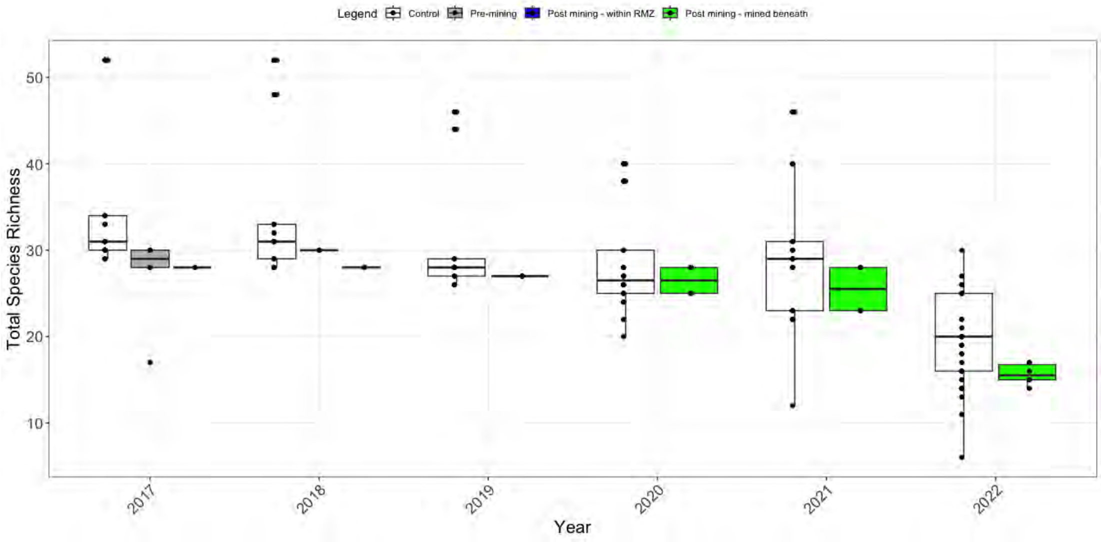


Figure 11: Boxplot of the total species richness for each transect at impact swamp S14, contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

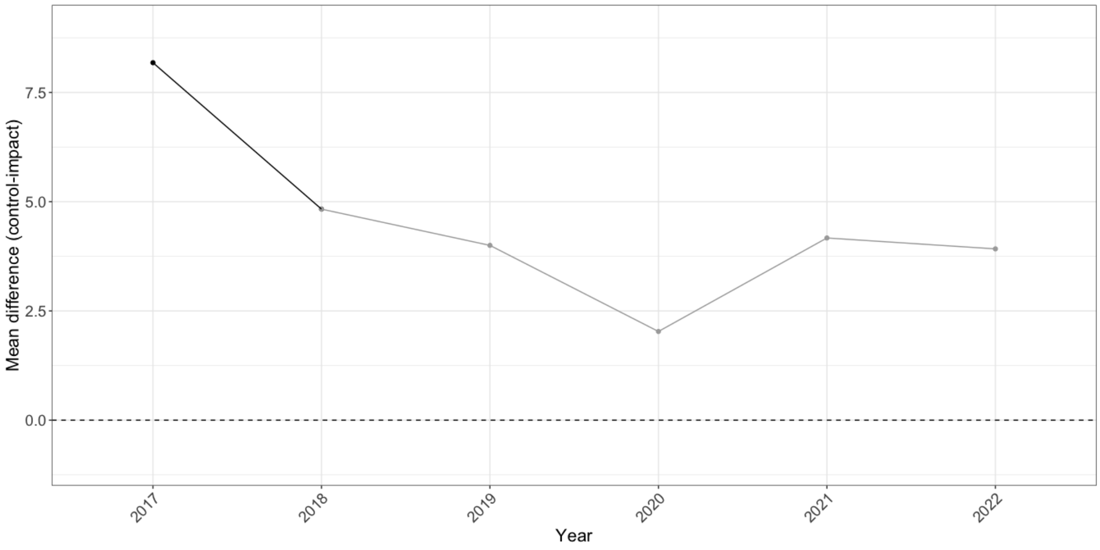


Figure 10: Difference between means for the control swamps and the impact swamp, shaded as black (pre-impact) and light grey (post-impact). Horizontal line at 0 is highlighted.

Table 19: Assessment of two-consecutive-year periods for swamp S14.

Comparison	Test statistic	D.f.	P-value
2018–2019	-1.29	2.50	0.305
2019–2020	-1.80	1.62	0.243
2020–2021	-1.71	1.70	0.250
2021–2022	-1.46	1.01	0.379

Table 20: Assessment of three-consecutive-year periods for swamp S14.

Comparison	Test statistic	D.f.	P-value
2018–2020	-1.67	3.69	0.176
2019–2021	-1.72	1.35	0.285
2020–2022	-1.73	1.33	0.283

Table 21: Assessment of four-consecutive-year periods for swamp S14.

Comparison	Test statistic	D.f.	P-value
2018–2021	-1.73	3.16	0.178
2019–2022	-1.70	1.19	0.308

9 Results - Swamp S1A

Monitoring at swamp S1A began in 2012, and this swamp was impacted in 2013. The boxplot of TSR data (Figure 13) shows that prior to impact, the TSR at the impact swamp was slightly higher than at the control swamps. Overall, TSR at the control swamps was variable (with a wider minimum and maximum TSR observation) and relatively stable across the monitoring period. In 2014, immediately after impact, TSR at the impact swamp rose, but it has declined progressively ever since.

For each year of monitoring prior to and post-impact, we calculated the difference in mean TSR between the control and impact swamps. Within-year comparisons (Figure 14) show that TSR remains higher at swamp S1A compared with the control swamps (i.e., the difference of the means is always negative), and this is trending towards 0 (i.e., TSR at swamp S1A is declining to become more similar to the control swamps over time).

Two-yearly comparisons were found to be statistically significant in 2014, 2015 and 2017 (Table 22). Three- and 4-yearly comparisons were found to be statistically significant every year, excluding the most recent monitoring period (Table 23 and Table 24). Five-yearly comparisons were also significantly different every year (Table 25).

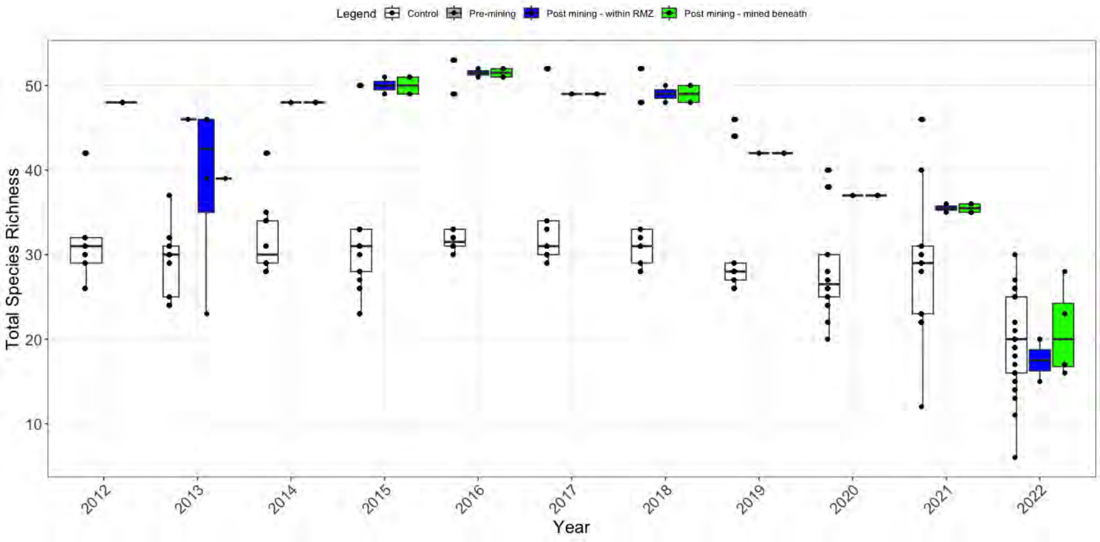


Figure 13: Boxplot of the total species richness for each transect at impact swamp S1A, contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

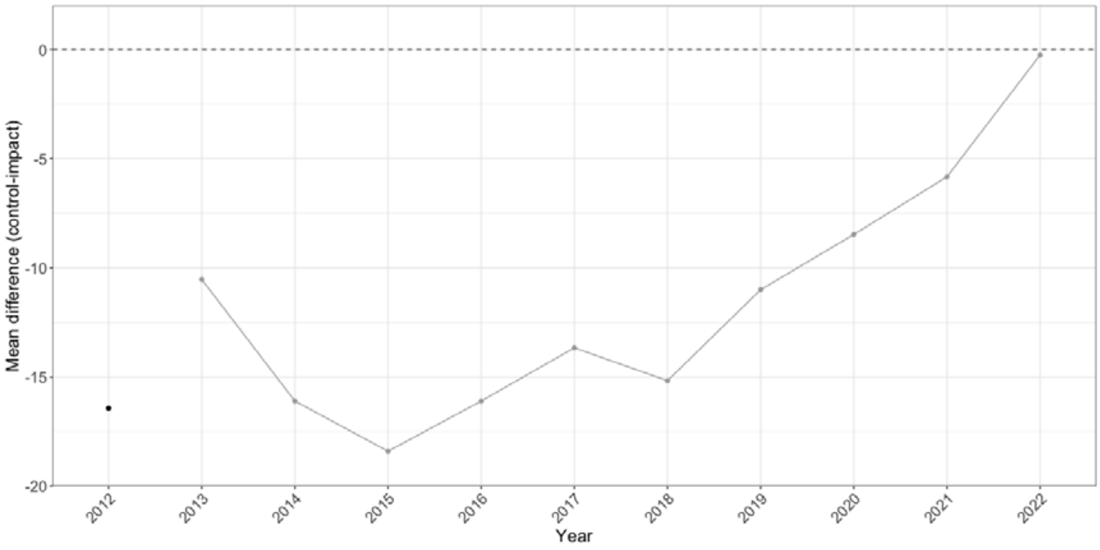


Figure 14: Difference between means for the control swamps and the impact swamp. Pre-impact data is shown as a single point since only one year's data was available. Post-impact data is shown as a grey line. Horizontal line at 0 is highlighted.

Table 22: Assessment of two-consecutive-year periods for swamp S1A. N.B. comparison for 2019-2020 unidentifiable.

Comparison	Test statistic	D.f.	P-value
2013–2014	-4.78	1	0.131
2014–2015	-15.00	1	0.042
2015–2016	-15.00	1	0.042
2016–2017	-12.20	1	0.052
2017–2018	-19.09	1	0.033
2018–2019	-6.28	1	0.101
2020–2021	-5.42	1	0.116
2021–2022	-1.09	1	0.473

Table 23: Assessment of three-consecutive-year periods for swamp S1A.

Comparison	Test statistic	D.f.	P-value
2013–2015	-6.42	2	0.023
2014–2016	-22.00	2	0.002
2015–2017	-11.73	2	0.007
2016–2018	-21.07	2	0.002
2017–2019	-10.89	2	0.008
2018–2020	-5.91	2	0.027
2019–2021	-5.65	2	0.030
2020–2022	-2.00	2	0.183

Table 24: Assessment of four-consecutive-year periods for swamp S1A.

Comparison	Test statistic	D.f.	P-value
2013–2016	-9.13	3	0.003
2014–2017	-16.60	3	0.000
2015–2018	-15.95	3	0.001
2016–2019	-12.55	3	0.001
2017–2020	-8.17	3	0.004
2018–2021	-5.09	3	0.015
2019–2022	-2.77	3	0.069

Table 25: Assessment of five-consecutive-year periods for swamp S1A.

Comparison	Test statistic	D.f.	P-value
2013–2017	-11.19	4	0.000
2014–2018	-20.61	4	0.000
2015–2019	-12.04	4	0.000
2016–2020	-9.20	4	0.001
2017–2021	-6.39	4	0.003
2018–2022	-3.25	4	0.031

10 Results - Swamp S1B

Monitoring at swamp S1B began in 2005, and this swamp was impacted in 2013. Please note, this impact swamp was not monitored in 2010 and 2011. The boxplot of TSR data (Figure 15) shows that prior to impact, the TSR at control sites was more variable (with a wider minimum and maximum TSR observation), and often had a lower mean than TSR at the impact swamps. Since 2016, TSR at this swamp appears to have declined to lower levels than before impact.

For each year of monitoring prior to and post-impact, we calculated the difference in mean TSR between the control and impact swamps. Within-year comparisons (Figure 16) show that TSR was higher at swamp S1B compared with the control swamps (i.e., the difference of the means is always negative), but this is trending towards 0 (i.e., TSR at swamp S1B is declining to become more similar to the control swamps over time).

Two-yearly comparisons were found to be statistically significant in between 2018 and 2020 (Table 26). Three- and 4-yearly comparisons were significantly different from 2017 onwards (Table 27 and Table 28, respectively), and five-yearly comparisons were significant from 2016 (Table 29).

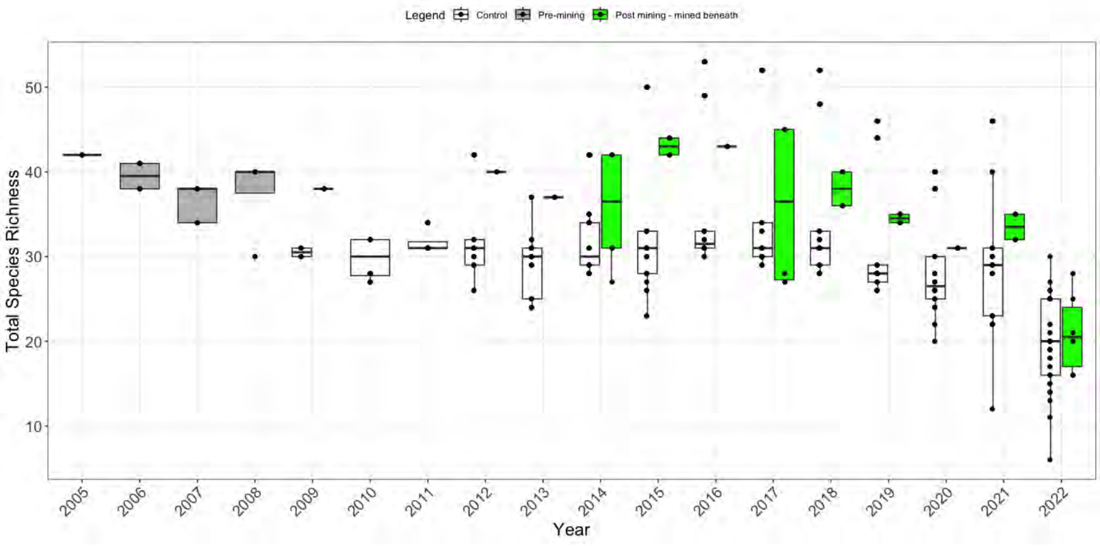


Figure 15: Boxplot of the total species richness for each transect at impact swamp S1B, contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

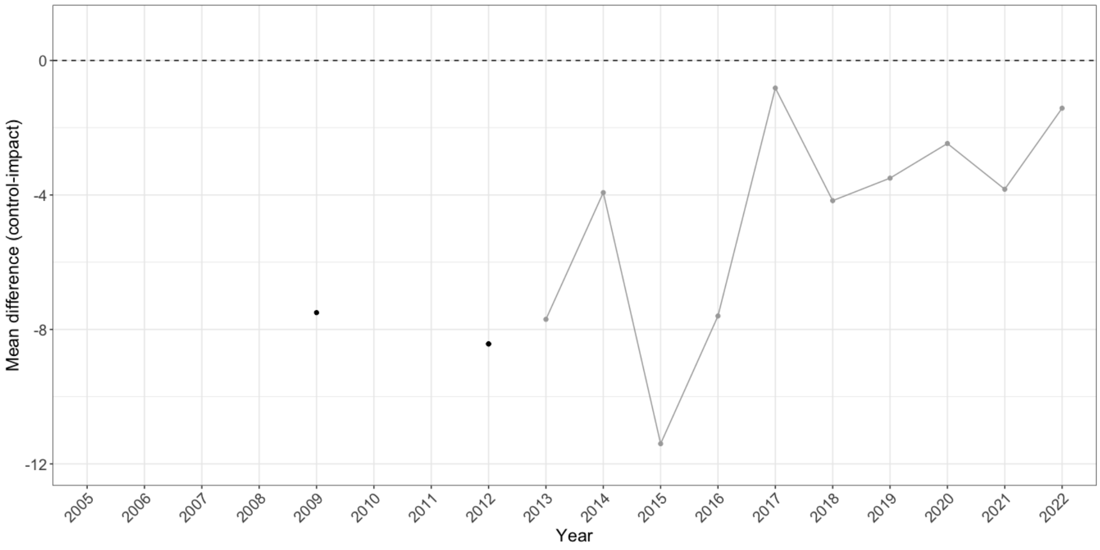


Figure 16: Difference between means for the control swamps and the impact swamp, shaded as black (pre-impact) and light grey (post-impact). Horizontal line at 0 is highlighted.

Table 26: Assessment of two-consecutive-year periods for swamp S1B.

Comparison	Test statistic	D.f.	P-value
2013–2014	1.11	1.12	0.452
2014–2015	0.08	1.03	0.949
2015–2016	-0.78	1.12	0.565
2016–2017	1.10	1.04	0.465
2017–2018	3.15	1.15	0.169
2018–2019	7.21	1.82	0.024
2019–2020	7.18	1.98	0.019
2020–2021	5.84	1.77	0.037
2021–2022	4.13	1.29	0.107

Table 27: Assessment of three-consecutive-year periods for swamp S1B.

Comparison	Test statistic	D.f.	P-value
2013–2015	0.13	2.18	0.907
2014–2016	0.15	2.18	0.896
2015–2017	0.43	2.09	0.705
2016–2018	1.87	2.22	0.189
2017–2019	4.57	2.68	0.025
2018–2020	6.76	2.77	0.008
2019–2021	7.58	2.42	0.010
2020–2022	6.43	2.99	0.008

Table 28: Assessment of four-consecutive-year periods for swamp S1B.

Comparison	Test statistic	D.f.	P-value
2013–2016	0.19	3.49	0.858
2014–2017	0.87	3.24	0.445
2015–2018	0.85	3.24	0.454
2016–2019	2.68	3.57	0.062
2017–2020	6.04	3.97	0.004
2018–2021	7.55	2.33	0.011
2019–2022	7.20	3.46	0.003

Table 29: Assessment of five-consecutive-year periods for swamp S1B.

Comparison	Test statistic	D.f.	P-value
2013–2017	0.90	4.47	0.415
2014–2018	1.28	4.47	0.264
2015–2019	1.31	4.46	0.254
2016–2020	3.50	4.91	0.018
2017–2021	6.56	4.23	0.002
2018–2022	7.14	3.51	0.003

11 Results - Swamp S5

Monitoring at swamp S5 began in 2012, and this swamp was impacted in 2013 (at a single transect). The boxplot of TSR data (Figure 17) shows that prior to impact, the TSR at control sites was more variable (with a wider minimum and maximum TSR observation), and TSR was often higher, than at the impact swamp. Since impact, TSR at this swamp appears to be lower (and more variable) than before impact.

For each year of monitoring prior to and post-impact, we calculated the difference in mean TSR between the control and impact swamps. Within-year comparisons (Figure 18) show that TSR remains lower at swamp S5 compared with the control swamps (i.e., the difference of the means is always positive), but this is trending towards 0 (i.e., TSR at swamp S5 is increasing to become more similar to the control swamps over time), however remained stable in the recent monitoring results.

Two-yearly comparisons were found to be statisticially significant in 2016, 2017 and 2019 (Table 30). All 3-yearly comparisons were significant excluding 2020 (Table 31). All 4- and 5-yearly comparisons were significant (Table 32 and Table 38).

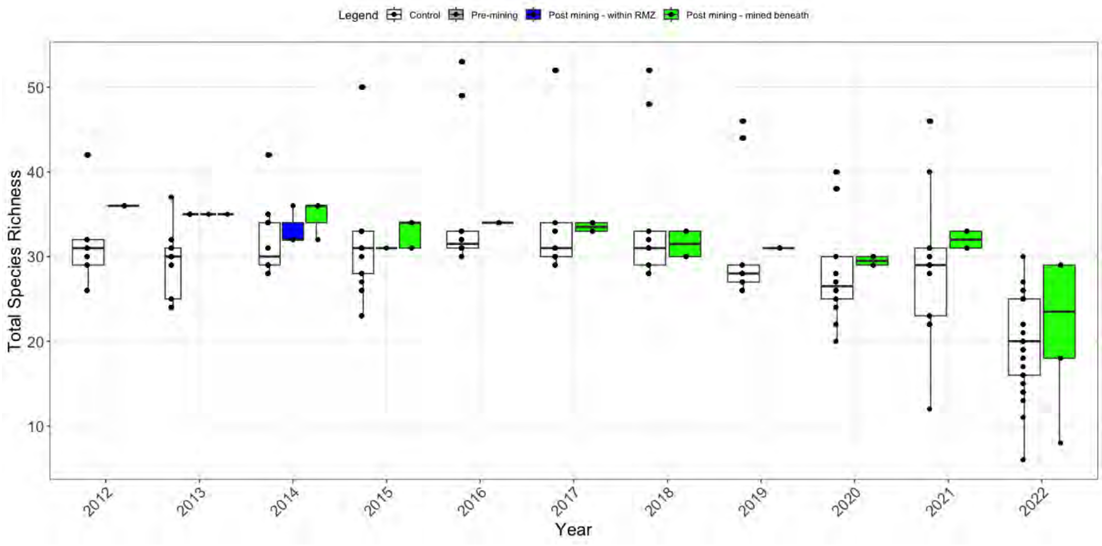


Figure 17: Boxplot of the total species richness for each transect at impact swamp S1B, contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

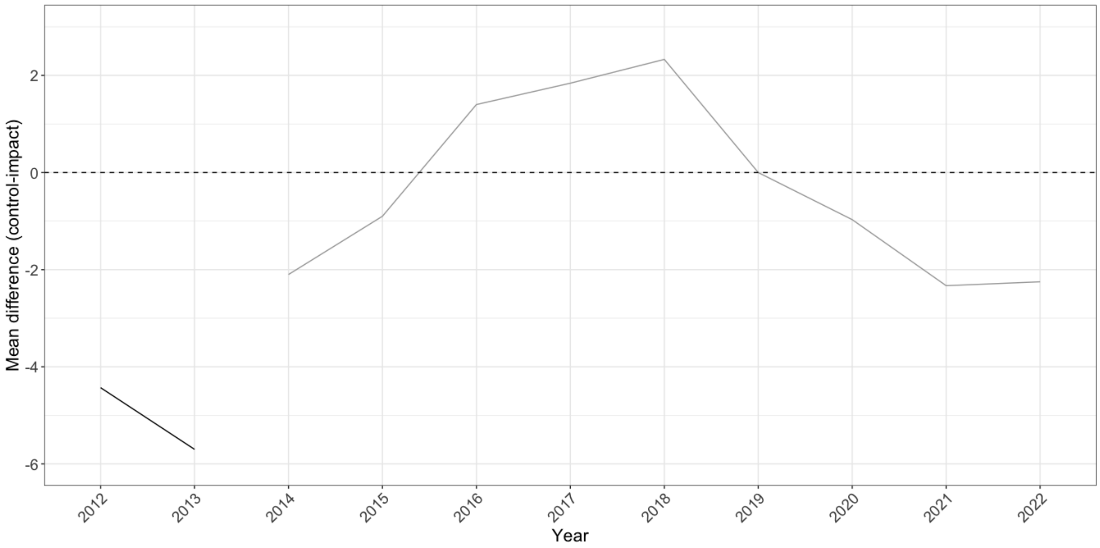


Figure 18: Difference between means for the control swamps and the impact swamp, shaded as black (pre-impact) and light grey (post-impact). Horizontal line at 0 is highlighted.

Table 30: Assessment of two-consecutive-year periods for swamp S5.

Comparison	Test statistic	D.f.	P-value
2014–2015	4.08	1.99	0.055
2015–2016	4.05	1.56	0.083
2016–2017	9.95	1.24	0.039
2017–2018	10.51	1.29	0.033
2018–2019	4.70	1.55	0.068
2019–2020	5.73	1.87	0.034
2020–2021	3.67	1.99	0.067
2021–2022	4.36	1.01	0.142

Table 31: Assessment of three-consecutive-year periods for swamp S5.

Comparison	Test statistic	D.f.	P-value
2014–2016	3.75	2.96	0.034
2015–2017	5.51	2.99	0.012
2016–2018	10.04	1.37	0.030
2017–2019	6.78	2.84	0.008
2018–2020	4.73	2.98	0.018
2019–2021	4.28	2.77	0.028
2020–2022	4.16	1.97	0.055

Table 32: Assessment of four-consecutive-year periods for swamp S5.

Comparison	Test statistic	D.f.	P-value
2014–2017	4.53	3.91	0.011
2015–2018	6.52	3.35	0.005
2016–2019	7.98	2.33	0.010
2017–2020	5.86	3.56	0.006
2018–2021	4.12	3.96	0.015
2019–2022	4.35	2.62	0.029

Table 33: Assessment of five-consecutive-year periods for swamp S5.

Comparison	Test statistic	D.f.	P-value
2014–2018	5.23	4.35	0.005
2015–2019	6.86	2.99	0.006
2016–2020	6.79	3.06	0.006
2017–2021	4.88	4.39	0.006
2018–2022	4.14	4.36	0.012

12 Results - Swamp S23

Monitoring at swamp S23 began in 2017, and this swamp was impacted in 2018. The boxplot of TSR data (Figure 19) shows that prior to impact, the TSR at impact swamp was much lower than the control swamps. Overall, TSR at the control swamps was variable (with a wider minimum and maximum TSR observation) and relatively stable across the monitoring period.

For each year of monitoring prior to and post-impact, we calculated the difference in mean TSR between the control and impact swamps. Within-year comparisons (Figure 20) show that TSR remains lower at swamp S23 compared with the control swamps (i.e., the difference of the means is always positive) and this difference has remained stable over the monitoring period.

No 2-, 3- and 4-yearly comparisons were found to be statistically different (Table 34, Table 35 and Table 36, respectively).

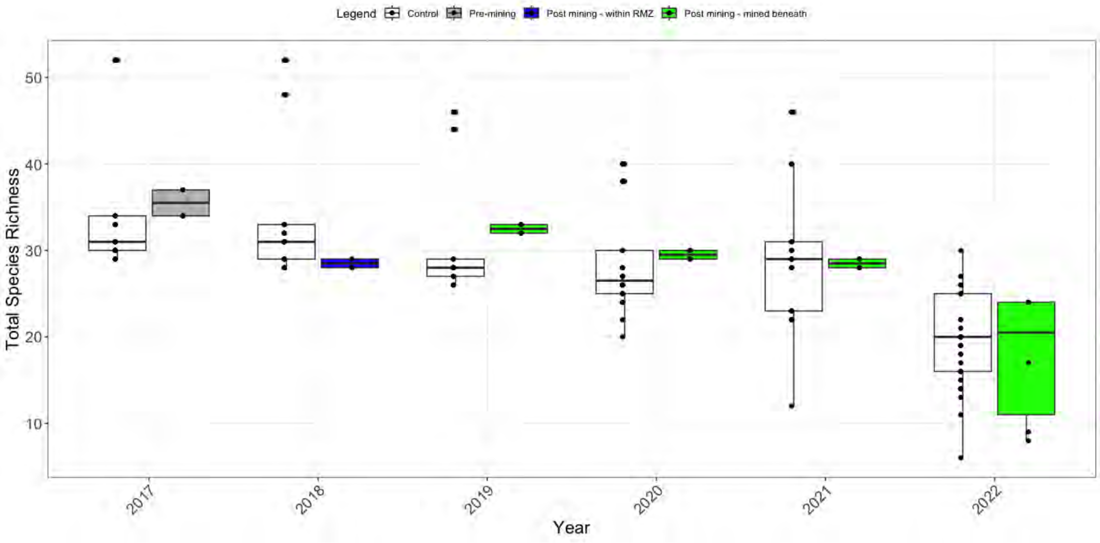


Figure 19: Boxplot of the total species richness for each transect at impact swamp S1B, contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

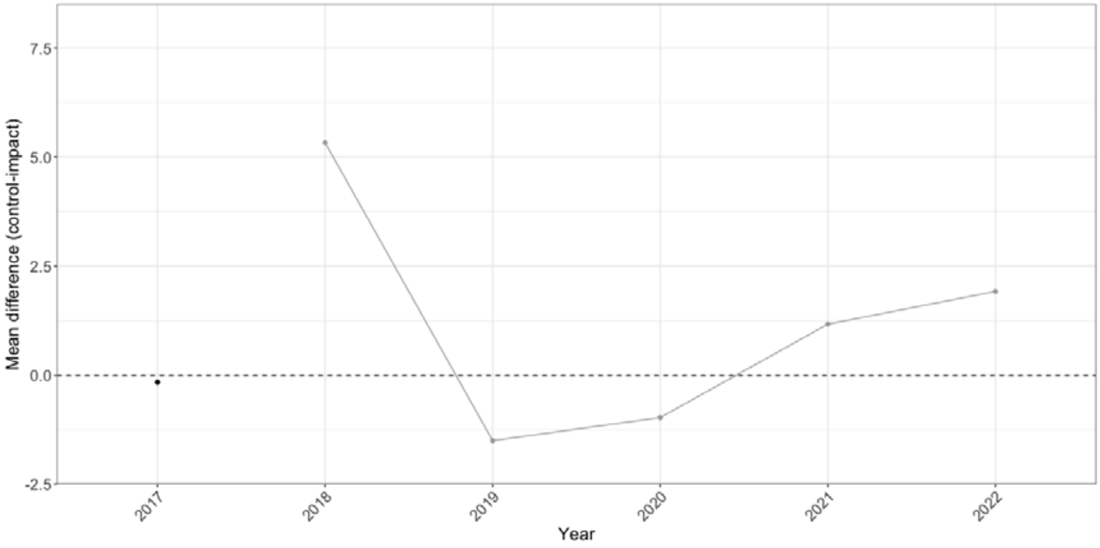


Figure 20: Difference between means for the control swamps and the impact swamp. Pre-impact data is shown as a single point since only one year's data was available. Post-impact data is shown as a light grey line. Horizontal line at 0 is highlighted.

Table 34: Assessment of two-consecutive-year periods for swamp S23.

Comparison	Test statistic	D.f.	P-value
2018–2019	0.56	1	0.675
2019–2020	-4.66	1	0.135
2020–2021	0.09	1	0.941
2021–2022	4.12	1	0.152

Table 35: Assessment of three-consecutive-year periods for swamp S23.

Comparison	Test statistic	D.f.	P-value
2018–2020	0.43	2	0.706
2019–2021	-0.53	2	0.649
2020–2022	0.82	2	0.500

Table 36: Assessment of four-consecutive-year periods for swamp S23.

Comparison	Test statistic	D.f.	P-value
2018–2021	3.62	3.77	0.025
2019–2022	5.02	3.70	0.009

13 References

Holm, S. (1979). A simple sequentially rejective multiple test procedure. Scandinavian Journal of Statistics 6, 65–70.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL *https://www.R-project.org/*.

Analytical Edge (2021). *Analysis of flora species composition at impact swamps within the Dendrobium region, Data collected up to, and including, 2020*. Unpublished report submitted to Niche.

THE ANALYTICAL EDGE
STATISTICAL CONSULTING

Task 1B - Analysis of flora species composition at impact swamps within the Dendrobium region

Data collected up to and including 2022

Joanne M. Potts

15 March 2023

Project History and Version Control

Date	Amendments	Person
27 Feb 2023	Received data from Luke Stone (Niche).	JP
13 Mar 2022	Received revised data from Luke Stone (Niche).	JP
15 Mar 2022	Draft report submitted to Luke Stone (Niche).	JP

Table of Contents

1 Data Summary

On 13 March 2023, The Analytical Edge (hereafter, TAE) received a revised data set from Luke Stone (Niche) via e-mail. It contained data collected during flora swamp monitoring within the Dendrobium region up to and including 2022 (*‘a7290_2022_FloristicData_rev_02_20230313.xlsx’*, 16.7 MB).

Notes:

(1) Many species names and complexes had been revised since the previous analysis.

(2) As per previous years, all data relating to swamp S1 were omitted from the analysis.

(3) Different to previous years, S15A(1) is now considered an impact swamp (i.e., all previous years of ‘control’ data are now classified pre ‘impact’).

(4) A new ‘control’ swamp has been added (S131).

(5) 14 records were classified as ‘QUADRAT DEAD’ and were excluded from the analysis.

Disclaimer: This data file is assumed to be error-free. Any further errors detected by Niche may invalidate the results and conclusions made in this report and will require the analysis to be re-run under the proviso of new contract agreements.

2 Methods

Flora data were used to determine species assemblages – or community composition – at each transect, within each swamp during each survey (i.e., simply a species list of all unique species detected each visit). These multivariate data have been traditionally analysed within a distance-based framework, using methods like principal components analysis or non-metric multidimensional scaling. However, amongst other problems, these methods cannot offer a formal framework in which to test the hypothesis that treatment-effects influence species assemblages (Warton et al., 2012; Wang et al., 2012).

Instead, we can use model-based approaches when dealing with complex, multivariate data such as species assemblages. Here, multivariate presence-absence models were fitted using the 'manyglm' function in the 'mvabund' package (v.4.2.1, Wang, 2022) in program R (v. 4.1.2, R Core Team 2021). These models fit multiple presence-absence models to each detected species, correcting for the correlation between species (thus violating an assumption of standard GLMs) using generalized estimating equations (GEEs). Analysis of variance (ANOVA) was used to formally test the significance of explanatory variables (i.e., 'Mining Status'). Separate models were fitted to data collected at each swamp. If 'Mining Status' was found to be significant, univariate tests were completed to determine which species were driving the change in flora community composition.

2.1 Assessment of impact

Following reporting in 2021, a complete analysis was undertaken of the entire historical data. This is similar to the second round of reports submitted to Niche in 2021 and previously for Biosis. That is, data were subset in to two-consecutive year periods and analysed within a multivariate framework to determine if species composition differed between the two-year period after impact, compared to species composition prior to impact. For example, if a swamp was impacted in 2013, species composition in 2013 and 2014 at the impact swamp was compared to the species composition prior to the impact. This was then repeated for 2014-2015, 2015-2016, 2017-2018, 2018-2019, 2019-2020 and 2020-2021. Three- and four-yearly comparisons were also undertaken, and for swamps in Area 3B, five-yearly comparisons were investigated.

In this approach, not all data are assessed in a single model, and therefore power is lost as data are omitted from the analysis. For example, a small change may never be statistically significant when comparing the data between two consecutive years, but might be significant at a different timescale, such as over the entire survey. TAE has previously expressed potentially better methods to analyse these data (e.g., using a broken-stick approach), and this will be explored in Task 2 (to be undertaken).

For each swamp, the years it was monitored is given in Table 1.

Table 1: For each swamp, the years it was monitored are given as a 1. Bold columns are impact swamps.

Year	**S11**	**S13**	S131	**S14**	S15A(1)	**S15A(2)**	**S15B**	**S1A**	**S1B**	S22	**S23**	S33	**S5**	S86	S87	S88
2003	**1**	**0**	0	**0**	0	**0**	**1**	**0**	**0**	0	**0**	0	**0**	0	0	0
2004	**1**	**0**	0	**0**	0	**0**	**1**	**0**	**0**	0	**0**	0	**0**	0	0	0
2005	**1**	**0**	0	**0**	1	**0**	**1**	**0**	**1**	0	**0**	0	**0**	0	0	0
2006	**1**	**0**	0	**0**	1	**0**	**1**	**0**	**1**	0	**0**	0	**0**	0	0	0
2007	**1**	**0**	0	**0**	1	**0**	**1**	**0**	**1**	0	**0**	0	**0**	0	0	0
2008	**1**	**0**	0	**0**	1	**0**	**1**	**0**	**1**	0	**0**	0	**0**	0	0	0
2009	**1**	**0**	0	**0**	1	**1**	**1**	**0**	**1**	1	**0**	1	**0**	0	0	0
2010	**1**	**0**	0	**0**	1	**1**	**1**	**0**	**0**	1	**0**	1	**0**	0	0	0
2011	**1**	**0**	0	**0**	1	**1**	**1**	**0**	**0**	1	**0**	1	**0**	0	0	0
2012	**1**	**0**	0	**0**	1	**1**	**1**	**1**	**1**	1	**0**	1	**1**	1	1	1
2013	**1**	**1**	0	**0**	1	**1**	**1**	**1**	**1**	1	**0**	1	**1**	1	1	1
2014	**1**	**1**	0	**0**	1	**1**	**1**	**1**	**1**	1	**0**	1	**1**	1	1	1
2015	**1**	**1**	0	**0**	1	**1**	**1**	**1**	**1**	1	**0**	1	**1**	1	1	1
2016	**1**	**1**	0	**0**	1	**1**	**1**	**1**	**1**	1	**0**	1	**1**	1	1	1
2017	**1**	**1**	0	**1**	1	**1**	**1**	**1**	**1**	1	**1**	1	**1**	1	1	1
2018	**1**	**1**	0	**1**	1	**1**	**1**	**1**	**1**	1	**1**	1	**1**	1	1	1
2019	**1**	**1**	0	**1**	1	**1**	**1**	**1**	**1**	1	**1**	1	**1**	1	1	1
2020	**1**	**1**	0	**1**	1	**1**	**1**	**1**	**1**	1	**1**	1	**1**	1	1	1
2021	**1**	**1**	0	**1**	1	**1**	**1**	**1**	**1**	1	**1**	1	**1**	1	1	1
2022	**1**	**1**	1	**1**	1	**1**	**1**	**1**	**1**	1	**1**	1	**1**	1	1	1

3 Results - Swamp S15A(2)

Monitoring of S15A(2) commenced in 2009, and mining within the RMZ commenced in 2013. A total of 67 unique species were detected, of which 7% were detected only once.

Differences in two-yearly comparisons were first statistically significant from 2019 (Table 2), meaning that by 2019, species composition at this swamp was significantly different to species composition observed prior to impact. Differences in three-yearly comparisons were first statistically significant from 2018 (Table 4) and differences in four-yearly comparisons were first statistically significant from 2017 (Table 6). Species that were consistently found to be more common prior to impact for each 2-, 3-, and 4-yearly comparison are given in Table 3, Table 5 and Table 7.

Table 2: Species composition at swamp S15A(2) based on data pooled for 2-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022
prepostMining	0.719	0.626	0.536	0.434	0.134	0.034	0.034	0.013	0.001
PercDev	0.497	0.545	0.52	0.417	0.357	0.346	0.392	0.395	0.373
Species 1	*Leptospermum.juniperinum*	*Lepidosperma.filiforme.urophorum.complex*	*Thysanotus.juncifolius*	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	*Baeckea.imbricata*	*Boronia.parviflora*	*Boronia.parviflora*	*Baeckea.imbricata*	*Baeckea.imbricata*
Species 2	*Drosera.spatulata*	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	*Leptospermum.lanigerum*	*Leptocarpus.tenax*	*Baeckea.imbricata*	*Baeckea.imbricata*	*Boronia.parviflora*	*Boronia.parviflora*
Species 3	*Pteridium.esculentum*	*Leptospermum.lanigerum*	*Leptospermum.lanigerum*	*Baeckea.imbricata*	*Schoenus.brevifolius..lepidosperma.sp.complex*	*Bauera.microphylla..rubioides.sp.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Bauera.microphylla..rubioides.sp.complex*	*Bauera.microphylla..rubioides.sp.complex*
Species 4	*Lepyrodia.muelleri.scariosa.complex*	*Leptospermum.juniperinum*	*Caesia.parviflora.var..parviflora*	*Caesia.parviflora.var..parviflora*	*Empodisma.minus*	*Gonocarpus.sp_.complex*	*Bauera.microphylla..rubioides.sp.complex*	*Leptospermum.polygalifolium.trinervium.complex*	*Baeckea.linifolia*
Species 5	*Lepidosperma.filiforme.urophorum.complex*	*Lepidosperma.neesii.Philothrix.deusta.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Platysace.linearifolia*	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	*Leptospermum.juniperinum*	*Gonocarpus.sp_.complex*	*Baloskion.gracile*	*Lepyrodia.muelleri.scariosa.complex*

Table 3: Whether the five most influential species for each two-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2018-2019	*Boronia.parviflora*	Yes
2018-2019	*Baeckea.imbricata*	Yes
2018-2019	*Bauera.microphylla..rubioides.sp.complex*	Yes
2018-2019	*Gonocarpus.sp_.complex*	Yes
2018-2019	*Leptospermum.juniperinum*	Yes
2019-2020	*Boronia.parviflora*	Yes
2019-2020	*Baeckea.imbricata*	Yes
2019-2020	*Lepidosperma.filiforme.urophorum.complex*	No
2019-2020	*Bauera.microphylla..rubioides.sp.complex*	Yes
2019-2020	*Gonocarpus.sp_.complex*	Yes
2020-2021	*Baeckea.imbricata*	Yes
2020-2021	*Boronia.parviflora*	Yes
2020-2021	*Bauera.microphylla..rubioides.sp.complex*	Yes
2020-2021	*Leptospermum.polygalifolium.trinervium.complex*	Yes
2020-2021	*Baloskion.gracile*	Yes
2021-2022	*Baeckea.imbricata*	Yes
2021-2022	*Boronia.parviflora*	Yes
2021-2022	*Bauera.microphylla..rubioides.sp.complex*	Yes
2021-2022	*Baeckea.linifolia*	Yes
2021-2022	*Lepyrodia.muelleri.scariosa.complex*	Yes

Table 4: Species composition at swamp S15A(2) based on data pooled for 3-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021	2020-2022
prepostMining	0.675	0.423	0.384	0.15	0.069	0.007	0.01	0.002
PercDev	0.462	0.512	0.462	0.348	0.356	0.377	0.408	0.389
Species 1	*Leptospermum.juniperinum*	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	*Baeckea.imbricata*	*Baeckea.imbricata*	*Boronia.parviflora*	*Boronia.parviflora*	*Baeckea.imbricata*
Species 2	*Lepidosperma.filiforme.urophorum.complex*	*Leptospermum.lanigerum*	*Leptospermum.lanigerum*	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	*Boronia.parviflora*	*Baeckea.imbricata*	*Baeckea.imbricata*	*Boronia.parviflora*
Species 3	*Drosera.spatulata*	*Leptospermum.juniperinum*	*Lepidosperma.filiforme.urophorum.complex*	*Leptospermum.lanigerum*	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	*Bauera.microphylla..rubioides.sp.complex*	*Bauera.microphylla..rubioides.sp.complex*	*Bauera.microphylla..rubioides.sp.complex*
Species 4	*Lepyrodia.muelleri.scariosa.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Caesia.parviflora.var..parviflora*	*Lepyrodia.muelleri.scariosa.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Gonocarpus.sp_.complex*	*Baloskion.gracile*	*Lepyrodia.muelleri.scariosa.complex*
Species 5	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	*Thysanotus.juncifolius*	*Lepidosperma.neesii.Philothrix.deusta.complex*	*Caesia.parviflora.var..parviflora*	*Bauera.microphylla..rubioides.sp.complex*	*Leptospermum.juniperinum*	*Hibbertia.riparia.species.complex*	*Baloskion.gracile*

Table 5: Whether the five most influential species for each two-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2018-2020	*Boronia.parviflora*	Yes
2018-2020	*Baeckea.imbricata*	Yes
2018-2020	*Bauera.microphylla..rubioides.sp.complex*	Yes
2018-2020	*Gonocarpus.sp_.complex*	Yes
2018-2020	*Leptospermum.juniperinum*	Yes
2019-2021	*Boronia.parviflora*	Yes
2019-2021	*Baeckea.imbricata*	Yes
2019-2021	*Bauera.microphylla..rubioides.sp.complex*	Yes
2019-2021	*Baloskion.gracile*	Yes
2019-2021	*Hibbertia.riparia.species.complex*	Yes
2020-2022	*Baeckea.imbricata*	Yes
2020-2022	*Boronia.parviflora*	Yes
2020-2022	*Bauera.microphylla..rubioides.sp.complex*	Yes
2020-2022	*Lepyrodia.muelleri.scariosa.complex*	Yes
2020-2022	*Baloskion.gracile*	Yes

Table 6: Species composition at swamp S15A(2) based on data pooled for 4-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2013-2016	2014-2017	2015-2018	2016-2019	2017-2020	2018-2021	2019-2022
prepostMining	0.547	0.338	0.199	0.086	0.023	0.002	0.003
PercDev	0.471	0.494	0.383	0.362	0.375	0.398	0.403
Species 1	*Leptospermum.juniperinum*	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	*Baeckea.imbricata*	*Baeckea.imbricata*	*Boronia.parviflora*	*Boronia.parviflora*
Species 2	*Drosera.spatulata*	*Leptospermum.lanigerum*	*Leptospermum.lanigerum*	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	*Boronia.parviflora*	*Baeckea.imbricata*	*Baeckea.imbricata*
Species 3	*Lepidosperma.filiforme.urophorum.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Baeckea.imbricata*	*Leptospermum.juniperinum*	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	*Bauera.microphylla..rubioides.sp.complex*	*Bauera.microphylla..rubioides.sp.complex*
Species 4	*Thysanotus.juncifolius*	*Drosera.spatulata*	*Leptocarpus.tenax*	*Boronia.parviflora*	*Lepidosperma.filiforme.urophorum.complex*	*Baloskion.gracile*	*Baloskion.gracile*
Species 5	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	*Lepidosperma.neesii.Philothrix.deusta.complex*	*Caesia.parviflora.var..parviflora*	*Platysace.linearifolia*	*Bauera.microphylla..rubioides.sp.complex*	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	*Hibbertia.riparia.species.complex*

Table 7: Whether the five most influential species for each four-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2017-2020	*Baeckea.imbricata*	Yes
2017-2020	*Boronia.parviflora*	Yes
2017-2020	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	Yes
2017-2020	*Lepidosperma.filiforme.urophorum.complex*	No
2017-2020	*Bauera.microphylla..rubioides.sp.complex*	Yes
2018-2021	*Boronia.parviflora*	Yes
2018-2021	*Baeckea.imbricata*	Yes
2018-2021	*Bauera.microphylla..rubioides.sp.complex*	Yes
2018-2021	*Baloskion.gracile*	Yes
2018-2021	*Gompholobium.glabratum..grandiflorum.Sp_.complex*	Yes
2019-2022	*Boronia.parviflora*	Yes
2019-2022	*Baeckea.imbricata*	Yes
2019-2022	*Bauera.microphylla..rubioides.sp.complex*	Yes
2019-2022	*Baloskion.gracile*	Yes
2019-2022	*Hibbertia.riparia.species.complex*	Yes

4 Results - Swamp S15B

Monitoring of S15B commenced in 2003, and mining within the RMZ commenced in 2010. A total of 69 unique species were detected, of which 20% were detected only once.

Differences in two-yearly comparisons have been statistically significant since 2012 (Table 8). Differences in three-yearly and four-yearly comparisons have been statistically significant since 2010 (i.e., the year that the impact occurred, Table 10 and Table 12, respectively).

Species that were consistently found to be more common prior to impact for each 2-, 3-, and 4-yearly comparison are given in Table 9, Table 11 and Table 13.

Table 8A: Species composition at swamp S15B based on data pooled for 2-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
prepostMining	0.137	0.066	0.032	0.005	0.004	0.003
PercDev	0.481	0.463	0.44	0.438	0.437	0.465
Species 1	*Cassytha.glabella..pubescens.sp.complex*	*Cassytha.glabella..pubescens.sp.complex*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*
Species 2	*Gonocarpus.sp_.complex*	*Epacris.obtusifolia*	*Lepyrodia.anarthria*	*Platysace.linearifolia*	*Sprengelia.incarnata*	*Xanthosia.dissecta.pilosa..tridentata.species.complex*
Species 3	*Drosera.binata*	*Bossiaea.heterophylla*	*Platysace.linearifolia*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	*Sprengelia.incarnata*
Species 4	*Bossiaea.heterophylla*	*Gonocarpus.sp_.complex*	*Cassytha.glabella..pubescens.sp.complex*	*Bossiaea.heterophylla*	*Banksia.robur*	*Banksia.robur*
Species 5	*Tetrarrhena.turfosa..Hemarthria.uncinata.complex*	*Blandfordia.Burchardia.Caladenia.Haemodorum.Microtis.Thelymitra.species.complex*	*Bossiaea.heterophylla*	*Pultenaea.divaricata*	*Platysace.linearifolia*	*Platysace.linearifolia*

Table 8B: Species composition at swamp S15B based on data pooled for 2-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022
prepostMining	0.001	0.001	0.001	0.001	0.001	0.001
PercDev	0.409	0.361	0.392	0.376	0.334	0.326
Species 1	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	*Gonocarpus.sp_.complex*	*Epacris.obtusifolia*	*Epacris.obtusifolia*	*Pultenaea.divaricata*
Species 2	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Epacris.obtusifolia*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Epacris.obtusifolia*
Species 3	*Platysace.linearifolia*	*Platysace.linearifolia*	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	*Pultenaea.divaricata*	*Sphaerolobium.Stackhousia.species.complex*
Species 4	*Epacris.obtusifolia*	*Epacris.obtusifolia*	*Platysace.linearifolia*	*Platysace.linearifolia*	*Sprengelia.incarnata*	*Acacia.terminalis*
Species 5	*Banksia.robur*	*Banksia.robur*	*Acacia.terminalis*	*Acacia.terminalis*	*Platysace.linearifolia*	*Cassytha.glabella..pubescens.sp.complex*

Table 9: Whether the five most influential species for each two-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2012-2013	*Gonocarpus.sp_.complex*	Yes
2012-2013	*Lepyrodia.anarthria*	Yes
2012-2013	*Platysace.linearifolia*	Yes
2012-2013	*Cassytha.glabella..pubescens.sp.complex*	Yes
2012-2013	*Bossiaea.heterophylla*	Yes
2013-2014	*Gonocarpus.sp_.complex*	Yes
2013-2014	*Platysace.linearifolia*	Yes
2013-2014	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2013-2014	*Bossiaea.heterophylla*	Yes
2013-2014	*Pultenaea.divaricata*	Yes
2014-2015	*Gonocarpus.sp_.complex*	Yes
2014-2015	*Sprengelia.incarnata*	Yes
2014-2015	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	Yes
2014-2015	*Banksia.robur*	Yes
2014-2015	*Platysace.linearifolia*	Yes
2015-2016	*Gonocarpus.sp_.complex*	Yes
2015-2016	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	Yes
2015-2016	*Sprengelia.incarnata*	Yes
2015-2016	*Banksia.robur*	Yes
2015-2016	*Platysace.linearifolia*	Yes
2016-2017	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	Yes
2016-2017	*Gonocarpus.sp_.complex*	Yes
2016-2017	*Platysace.linearifolia*	Yes
2016-2017	*Epacris.obtusifolia*	Yes
2016-2017	*Banksia.robur*	Yes
2017-2018	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	Yes
2017-2018	*Gonocarpus.sp_.complex*	Yes
2017-2018	*Platysace.linearifolia*	Yes

Year	Species Name	More common before
2017-2018	*Epacris.obtusifolia*	Yes
2017-2018	*Banksia.robur*	Yes
2018-2019	*Gonocarpus.sp_.complex*	Yes
2018-2019	*Epacris.obtusifolia*	Yes
2018-2019	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	Yes
2018-2019	*Platysace.linearifolia*	Yes
2018-2019	*Acacia.terminalis*	Yes
2019-2020	*Epacris.obtusifolia*	Yes
2019-2020	*Gonocarpus.sp_.complex*	Yes
2019-2020	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	Yes
2019-2020	*Platysace.linearifolia*	Yes
2019-2020	*Acacia.terminalis*	Yes
2020-2021	*Epacris.obtusifolia*	Yes
2020-2021	*Gonocarpus.sp_.complex*	Yes
2020-2021	*Pultenaea.divaricata*	Yes
2020-2021	*Sprengelia.incarnata*	Yes
2020-2021	*Platysace.linearifolia*	Yes
2021-2022	*Pultenaea.divaricata*	Yes
2021-2022	*Epacris.obtusifolia*	Yes
2021-2022	*Sphaerolobium.Stackhousia.species.complex*	Yes
2021-2022	*Acacia.terminalis*	Yes
2021-2022	*Cassytha.glabella..pubescens.sp.complex*	Yes

Table 10A: Species composition at swamp S15B based on data pooled for 3-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2010-2012	2011-2013	2012-2014	2013-2015	2014-2016
prepostMining	0.044	0.017	0.002	0.002	0.001
PercDev	0.499	0.445	0.416	0.424	0.473
Species 1	*Cassytha.glabella..pubescens.sp.complex*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*
Species 2	*Gonocarpus.sp_.complex*	*Cassytha.glabella..pubescens.sp.complex*	*Platysace.linearifolia*	*Platysace.linearifolia*	*Sprengelia.incarnata*
Species 3	*Epacris.obtusifolia*	*Bossiaea.heterophylla*	*Bossiaea.heterophylla*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Xanthosia.dissecta.pilosa..tridentata.species.complex*
Species 4	*Bossiaea.heterophylla*	*Epacris.obtusifolia*	*Cassytha.glabella..pubescens.sp.complex*	*Sprengelia.incarnata*	*Platysace.linearifolia*
Species 5	*Baumea.articulata..rubiginosa..teretifolia.sp..chorizandra.cymbaria..sphaerocephalum.species.complex*	*Lepyrodia.anarthria*	*Epacris.obtusifolia*	*Banksia.robur*	*Banksia.robur*

Table 10B: Species composition at swamp S15B based on data pooled for 3-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021	2020-2022
prepostMining	0.001	0.001	0.001	0.001	0.001	0.001

	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021	2020-2022
PercDev	0.427	0.399	0.393	0.395	0.357	0.307
Species 1	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	*Epacris.obtusifolia*	*Gonocarpus.sp_.complex*	*Epacris.obtusifolia*	*Pultenaea.divaricata*
Species 2	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	*Epacris.obtusifolia*	*Gonocarpus.sp_.complex*	*Epacris.obtusifolia*
Species 3	*Sprengelia.incarnata*	*Platysace.linearifolia*	*Gonocarpus.sp_.complex*	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	*Platysace.linearifolia*	*Sprengelia.incarnata*
Species 4	*Platysace.linearifolia*	*Epacris.obtusifolia*	*Platysace.linearifolia*	*Platysace.linearifolia*	*Pultenaea.divaricata*	*Platysace.linearifolia*
Species 5	*Banksia.robur*	*Sprengelia.incarnata*	*Banksia.robur*	*Sprengelia.incarnata*	*Acacia.terminalis*	*Sphaerolobium.Stackhousia.species.complex*

Table 11: Whether the five most influential species for each three-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2010-2012	*Cassytha.glabella..pubescens.sp.complex*	Yes
2010-2012	*Gonocarpus.sp_.complex*	Yes
2010-2012	*Epacris.obtusifolia*	Yes
2010-2012	*Bossiaea.heterophylla*	Yes
2010-2012	*Baumea.articulata..rubiginosa..teretifolia.sp..chorizandra.cymbaria.. sphaerocephalum.species.complex*	Yes
2011-2013	*Gonocarpus.sp_.complex*	Yes
2011-2013	*Cassytha.glabella..pubescens.sp.complex*	Yes
2011-2013	*Bossiaea.heterophylla*	Yes
2011-2013	*Epacris.obtusifolia*	Yes
2011-2013	*Lepyrodia.anarthria*	Yes
2012-2014	*Gonocarpus.sp_.complex*	Yes
2012-2014	*Platysace.linearifolia*	Yes
2012-2014	*Bossiaea.heterophylla*	Yes
2012-2014	*Cassytha.glabella..pubescens.sp.complex*	Yes
2012-2014	*Epacris.obtusifolia*	Yes
2013-2015	*Gonocarpus.sp_.complex*	Yes
2013-2015	*Platysace.linearifolia*	Yes
2013-2015	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2013-2015	*Sprengelia.incarnata*	Yes
2013-2015	*Banksia.robur*	Yes
2014-2016	*Gonocarpus.sp_.complex*	Yes
2014-2016	*Sprengelia.incarnata*	Yes
2014-2016	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	Yes
2014-2016	*Platysace.linearifolia*	Yes
2014-2016	*Banksia.robur*	Yes
2015-2017	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	Yes
2015-2017	*Gonocarpus.sp_.complex*	Yes
2015-2017	*Sprengelia.incarnata*	Yes

Year	Species Name	More common before
2015-2017	*Platysace.linearifolia*	Yes
2015-2017	*Banksia.robur*	Yes
2016-2018	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	Yes
2016-2018	*Gonocarpus.sp_.complex*	Yes
2016-2018	*Platysace.linearifolia*	Yes
2016-2018	*Epacris.obtusifolia*	Yes
2016-2018	*Sprengelia.incarnata*	Yes
2017-2019	*Epacris.obtusifolia*	Yes
2017-2019	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	Yes
2017-2019	*Gonocarpus.sp_.complex*	Yes
2017-2019	*Platysace.linearifolia*	Yes
2017-2019	*Banksia.robur*	Yes
2018-2020	*Gonocarpus.sp_.complex*	Yes
2018-2020	*Epacris.obtusifolia*	Yes
2018-2020	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	Yes
2018-2020	*Platysace.linearifolia*	Yes
2018-2020	*Sprengelia.incarnata*	Yes
2019-2021	*Epacris.obtusifolia*	Yes
2019-2021	*Gonocarpus.sp_.complex*	Yes
2019-2021	*Platysace.linearifolia*	Yes
2019-2021	*Pultenaea.divaricata*	Yes
2019-2021	*Acacia.terminalis*	Yes
2020-2022	*Pultenaea.divaricata*	Yes
2020-2022	*Epacris.obtusifolia*	Yes
2020-2022	*Sprengelia.incarnata*	Yes
2020-2022	*Platysace.linearifolia*	Yes
2020-2022	*Sphaerolobium.Stackhousia.species.complex*	Yes

Table 12: Species composition at swamp S15B based on data pooled for 4-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2010-2013	2011-2014	2012-2015	2013-2016	2014-2017	2015-2018	2016-2019	2017-2020	2018-2021	2019-2022
prepostMining	0.01	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
PercDev	0.479	0.428	0.402	0.452	0.444	0.415	0.416	0.388	0.362	0.315
Species 1	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Epacris.obtusifolia*	*Epacris.obtusifolia*	*Epacris.obtusifolia*
Species 2	*Cassytha.glabella..pubescens.sp.complex*	*Cassytha.glabella..pubescens.sp.complex*	*Platysace.linearifolia*	*Platysace.linearifolia*	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Pultenaea.divaricata*
Species 3	*Bossiaea.heterophylla*	*Bossiaea.heterophylla*	*Bossiaea.heterophylla*	*Sprengelia.incarnata*	*Sprengelia.incarnata*	*Sprengelia.incarnata*	*Epacris.obtusifolia*	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	*Platysace.linearifolia*	*Platysace.linearifolia*
Species 4	*Platysace.linearifolia*	*Platysace.linearifolia*	*Cassytha.glabella..pubescens.sp.complex*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Platysace.linearifolia*	*Platysace.linearifolia*	*Platysace.linearifolia*	*Platysace.linearifolia*	*Sprengelia.incarnata*	*Acacia.terminalis*
Species 5	*Epacris.obtusifolia*	*Epacris.obtusifolia*	*Banksia.robur*	*Banksia.robur*	*Banksia.robur*	*Banksia.robur*	*Sprengelia.incarnata*	*Sprengelia.incarnata*	*Pultenaea.divaricata*	*Gonocarpus.sp_.complex*

Table 13: Whether the five most influential species for each four-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2010-2013	*Gonocarpus.sp_.complex*	Yes
2010-2013	*Cassytha.glabella..pubescens.sp.complex*	Yes
2010-2013	*Bossiaea.heterophylla*	Yes
2010-2013	*Platysace.linearifolia*	Yes
2010-2013	*Epacris.obtusifolia*	Yes
2011-2014	*Gonocarpus.sp_.complex*	Yes
2011-2014	*Cassytha.glabella..pubescens.sp.complex*	Yes
2011-2014	*Bossiaea.heterophylla*	Yes
2011-2014	*Platysace.linearifolia*	Yes
2011-2014	*Epacris.obtusifolia*	Yes
2012-2015	*Gonocarpus.sp_.complex*	Yes
2012-2015	*Platysace.linearifolia*	Yes
2012-2015	*Bossiaea.heterophylla*	Yes
2012-2015	*Cassytha.glabella..pubescens.sp.complex*	Yes
2012-2015	*Banksia.robur*	Yes
2013-2016	*Gonocarpus.sp_.complex*	Yes
2013-2016	*Platysace.linearifolia*	Yes
2013-2016	*Sprengelia.incarnata*	Yes
2013-2016	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2013-2016	*Banksia.robur*	Yes
2014-2017	*Gonocarpus.sp_.complex*	Yes
2014-2017	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	Yes
2014-2017	*Sprengelia.incarnata*	Yes
2014-2017	*Platysace.linearifolia*	Yes
2014-2017	*Banksia.robur*	Yes
2015-2018	*Gonocarpus.sp_.complex*	Yes
2015-2018	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	Yes
2015-2018	*Sprengelia.incarnata*	Yes

Year	Species Name	More common before
2015-2018	*Platysace.linearifolia*	Yes
2015-2018	*Banksia.robur*	Yes
2016-2019	*Gonocarpus.sp_.complex*	Yes
2016-2019	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	Yes
2016-2019	*Epacris.obtusifolia*	Yes
2016-2019	*Platysace.linearifolia*	Yes
2016-2019	*Sprengelia.incarnata*	Yes
2017-2020	*Epacris.obtusifolia*	Yes
2017-2020	*Gonocarpus.sp_.complex*	Yes
2017-2020	*Xanthosia.dissecta.pilosa..tridentata.species.complex*	Yes
2017-2020	*Platysace.linearifolia*	Yes
2017-2020	*Sprengelia.incarnata*	Yes
2018-2021	*Epacris.obtusifolia*	Yes
2018-2021	*Gonocarpus.sp_.complex*	Yes
2018-2021	*Platysace.linearifolia*	Yes
2018-2021	*Sprengelia.incarnata*	Yes
2018-2021	*Pultenaea.divaricata*	Yes
2019-2022	*Epacris.obtusifolia*	Yes
2019-2022	*Pultenaea.divaricata*	Yes
2019-2022	*Platysace.linearifolia*	Yes
2019-2022	*Acacia.terminalis*	Yes
2019-2022	*Gonocarpus.sp_.complex*	Yes

5 Results - Swamp S11

Monitoring of S11 commenced in 2003, and mining within the RMZ commenced in 2016. A total of 61 unique species were detected, of which 8% were detected only once.

Differences in two-yearly comparisons have been statistically significant since 2017 (Table 14). Differences in three-yearly and four-yearly comparisons have been statistically significant since 2016 (i.e., the year that the impact occurred, Table 16 and Table 18, respectively). A five-yearly comparison was statistically significant from 2016 (Table 20).

Species that were consistently found to be more common prior to impact for each 2-, 3-, 4-, and 5-yearly are given in Table 15, Table 17, Table 19 and Table 21.

Table 14: Species composition at swamp S11 based on data pooled for 2-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021.2022
prepostMining	0.251	0.016	0.011	0.003	0.001	0.001
PercDev	0.35	0.334	0.462	0.494	0.606	0.57
Species 1	*Lindsaea.linearis*	*Lindsaea.linearis*	*Gonocarpus.sp_.complex*	*Almaleea.paludosa*	*Almaleea.paludosa*	*Epacris.obtusifolia*
Species 2	*Empodisma.minus*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Almaleea.paludosa*	*Gonocarpus.sp_.complex*	*Epacris.obtusifolia*	*Almaleea.paludosa*
Species 3	*Dillwynia.floribunda.retorta.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Sphaerolobium.Stackhousia.species.complex*	*Sphaerolobium.Stackhousia.species.complex*	*Boronia.parviflora*	*Gonocarpus.sp_.complex*
Species 4	*Acacia.rubida*	*Gonocarpus.sp_.complex*	*Schizaea.bifida*	*Schizaea.bifida*	*Sphaerolobium.Stackhousia.species.complex*	*Boronia.parviflora*
Species 5	*Lepidosperma.filiforme.urophorum.complex*	*Boronia.parviflora*	*Goodenia.dimorpha..stelligera..bellidifolia.sp.complex*	*Goodenia.dimorpha..stelligera..bellidifolia.sp.complex*	*Gonocarpus.sp_.complex*	*Sphaerolobium.Stackhousia.species.complex*

Table 15: Whether the five most influential species for each two-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2017-2018	*Lindsaea.linearis*	No
2017-2018	*Grevillea.patulifolia.sericea.speciosa.complex*	Yes
2017-2018	*Lepidosperma.filiforme.urophorum.complex*	No
2017-2018	*Gonocarpus.sp_.complex*	Yes
2017-2018	*Boronia.parviflora*	Yes
2018-2019	*Gonocarpus.sp_.complex*	Yes
2018-2019	*Almaleea.paludosa*	Yes
2018-2019	*Sphaerolobium.Stackhousia.species.complex*	Yes
2018-2019	*Schizaea.bifida*	Yes
2018-2019	*Goodenia.dimorpha..stelligera..bellidifolia.sp.complex*	Yes
2019-2020	*Almaleea.paludosa*	Yes
2019-2020	*Gonocarpus.sp_.complex*	Yes
2019-2020	*Sphaerolobium.Stackhousia.species.complex*	Yes
2019-2020	*Schizaea.bifida*	Yes
2019-2020	*Goodenia.dimorpha..stelligera..bellidifolia.sp.complex*	Yes
2020-2021	*Almaleea.paludosa*	Yes
2020-2021	*Epacris.obtusifolia*	Yes
2020-2021	*Boronia.parviflora*	Yes
2020-2021	*Sphaerolobium.Stackhousia.species.complex*	Yes
2020-2021	*Gonocarpus.sp_.complex*	Yes
2021-2022	*Epacris.obtusifolia*	Yes
2021-2022	*Almaleea.paludosa*	Yes
2021-2022	*Gonocarpus.sp_.complex*	Yes
2021-2022	*Boronia.parviflora*	Yes
2021-2022	*Sphaerolobium.Stackhousia.species.complex*	Yes

Table 16: Species composition at swamp S11 based on data pooled for 3-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2016-2018	2017-2019	2018-2020	2019-2021	2020-2022
prepostMining	0.011	0.007	0.001	0.001	0.001
PercDev	0.392	0.359	0.505	0.516	0.558
Species 1	*Grevillea.oleoides*	*Grevillea.oleoides*	*Almaleea.paludosa*	*Almaleea.paludosa*	*Almaleea.paludosa*
Species 2	*Lindsaea.linearis*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Epacris.obtusifolia*
Species 3	*Lepidosperma.filiforme.urophorum.complex*	*Lindsaea.linearis*	*Sphaerolobium.Stackhousia.species.complex*	*Sphaerolobium.Stackhousia.species.complex*	*Gonocarpus.sp_.complex*
Species 4	*Almaleea.paludosa*	*Almaleea.paludosa*	*Schizaea.bifida*	*Epacris.obtusifolia*	*Boronia.parviflora*
Species 5	*Empodisma.minus*	*Sphaerolobium.Stackhousia.species.complex*	*Goodenia.dimorpha..stelligera..bellidifolia.sp.complex*	*Boronia.parviflora*	*Sphaerolobium.Stackhousia.species.complex*

Table 17: Whether the five most influential species for each three-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2016-2018	*Grevillea.oleoides*	No
2016-2018	*Lindsaea.linearis*	No
2016-2018	*Lepidosperma.filiforme.urophorum.complex*	No
2016-2018	*Almaleea.paludosa*	Yes
2016-2018	*Empodisma.minus*	No
2017-2019	*Grevillea.oleoides*	No
2017-2019	*Gonocarpus.sp_.complex*	Yes
2017-2019	*Lindsaea.linearis*	No
2017-2019	*Almaleea.paludosa*	Yes
2017-2019	*Sphaerolobium.Stackhousia.species.complex*	Yes
2018-2020	*Almaleea.paludosa*	Yes
2018-2020	*Gonocarpus.sp_.complex*	Yes
2018-2020	*Sphaerolobium.Stackhousia.species.complex*	Yes
2018-2020	*Schizaea.bifida*	Yes
2018-2020	*Goodenia.dimorpha..stelligera..bellidifolia.sp.complex*	Yes
2019-2021	*Almaleea.paludosa*	Yes
2019-2021	*Gonocarpus.sp_.complex*	Yes
2019-2021	*Sphaerolobium.Stackhousia.species.complex*	Yes
2019-2021	*Epacris.obtusifolia*	Yes
2019-2021	*Boronia.parviflora*	Yes
2020-2022	*Almaleea.paludosa*	Yes
2020-2022	*Epacris.obtusifolia*	Yes
2020-2022	*Gonocarpus.sp_.complex*	Yes
2020-2022	*Boronia.parviflora*	Yes
2020-2022	*Sphaerolobium.Stackhousia.species.complex*	Yes

Table 18: Species composition at swamp S11 based on data pooled for 4-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2016-2019	2017-2020	2018-2021	2019-2022
prepostMining	0.004	0.001	0.001	0.001
PercDev	0.362	0.389	0.487	0.536
Species 1	*Grevillea.oleoides*	*Almaleea.paludosa*	*Almaleea.paludosa*	*Almaleea.paludosa*
Species 2	*Lindsaea.linearis*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Epacris.obtusifolia*
Species 3	*Almaleea.paludosa*	*Sphaerolobium.Stackhousia.species.complex*	*Sphaerolobium.Stackhousia.species.complex*	*Gonocarpus.sp_.complex*
Species 4	*Gonocarpus.sp_.complex*	*Grevillea.oleoides*	*Schizaea.bifida*	*Sphaerolobium.Stackhousia.species.complex*
Species 5	*Goodenia.dimorpha..stelligera..bellidifolia.sp.complex*	*Lindsaea.linearis*	*Boronia.parviflora*	*Boronia.parviflora*

Table 7: Whether the five most influential species for each four-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2016-2019	*Grevillea.oleoides*	No
2016-2019	*Lindsaea.linearis*	No
2016-2019	*Almaleea.paludosa*	Yes
2016-2019	*Gonocarpus.sp_.complex*	Yes
2016-2019	*Goodenia.dimorpha..stelligera..bellidifolia.sp.complex*	Yes
2017-2020	*Almaleea.paludosa*	Yes
2017-2020	*Gonocarpus.sp_.complex*	Yes
2017-2020	*Sphaerolobium.Stackhousia.species.complex*	Yes
2017-2020	*Grevillea.oleoides*	No
2017-2020	*Lindsaea.linearis*	No
2018-2021	*Almaleea.paludosa*	Yes
2018-2021	*Gonocarpus.sp_.complex*	Yes
2018-2021	*Sphaerolobium.Stackhousia.species.complex*	Yes
2018-2021	*Schizaea.bifida*	Yes
2018-2021	*Boronia.parviflora*	Yes
2019-2022	*Almaleea.paludosa*	Yes
2019-2022	*Epacris.obtusifolia*	Yes
2019-2022	*Gonocarpus.sp_.complex*	Yes
2019-2022	*Sphaerolobium.Stackhousia.species.complex*	Yes
2019-2022	*Boronia.parviflora*	Yes

Table 20: Species composition at swamp S11 based on data pooled for 5-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2016-2020	2017-2021	2018-2022
prepostMining	0.001	0.001	0.001
PercDev	0.388	0.418	0.516
Species 1	*Almaleea.paludosa*	*Almaleea.paludosa*	*Almaleea.paludosa*
Species 2	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*	*Gonocarpus.sp_.complex*
Species 3	*Sphaerolobium.Stackhousia.species.complex*	*Sphaerolobium.Stackhousia.species.complex*	*Sphaerolobium.Stackhousia.species.complex*
Species 4	*Lindsaea.linearis*	*Boronia.parviflora*	*Epacris.obtusifolia*
Species 5	*Grevillea.oleoides*	*Grevillea.oleoides*	*Schizaea.bifida*

Table 21: Whether the five most influential species for each five-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2016-2019	*Almaleea.paludosa*	Yes
2016-2019	*Gonocarpus.sp_.complex*	Yes
2016-2019	*Sphaerolobium.Stackhousia.species.complex*	Yes
2016-2019	*Lindsaea.linearis*	No
2016-2019	*Grevillea.oleoides*	No
2017-2020	*Almaleea.paludosa*	Yes
2017-2020	*Gonocarpus.sp_.complex*	Yes
2017-2020	*Sphaerolobium.Stackhousia.species.complex*	Yes
2017-2020	*Boronia.parviflora*	Yes
2017-2020	*Grevillea.oleoides*	No
2018-2021	*Almaleea.paludosa*	Yes
2018-2021	*Gonocarpus.sp_.complex*	Yes
2018-2021	*Sphaerolobium.Stackhousia.species.complex*	Yes
2018-2021	*Epacris.obtusifolia*	Yes
2018-2021	*Schizaea.bifida*	Yes
2019-2022	*Almaleea.paludosa*	Yes
2019-2022	*Epacris.obtusifolia*	Yes
2019-2022	*Gonocarpus.sp_.complex*	Yes
2019-2022	*Sphaerolobium.Stackhousia.species.complex*	Yes
2019-2022	*Boronia.parviflora*	Yes

6 Results - Swamp S13

Monitoring of S13 commenced in 2013, and mining within the RMZ commenced in 2017. A total of 68 unique species were detected, of which 19% were detected only once.

Differences in two-yearly comparisons was statistically significant from 2019 (Table 22). Differences in three-yearly comparisons were first statistically significant in 2019 (Table 24) and the four-yearly comparison was found to be statistically significant from 2018 (Table 26).

Species that were consistently found to be more common prior to impact for each 2-, 3-, and 4-yearly comparison are given in Table 23 and Table 25.

Table 22: Species composition at swamp S13 based on data pooled for 2-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2017-2018	2018-2019	2019-2020	2020-2021	2021.2022
prepostMining	0.57	0.169	0.042	0.035	0.018
PercDev	0.534	0.476	0.367	0.334	0.396
Species 1	*Dillwynia.floribunda.retorta.complex*	*Dillwynia.floribunda.retorta.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Dillwynia.floribunda.retorta.complex*
Species 2	*Dampiera.stricta*	*Lepidosperma.filiforme.urophorum.complex*	*Dampiera.stricta*	*Dampiera.stricta*	*Petrophile.Isopogon.complex*
Species 3	*Grevillea.oleoides*	*Almaleea.paludosa*	*Dillwynia.floribunda.retorta.complex*	*Tetraria.capillaris*	*Tetraria.capillaris*
Species 4	*Grevillea.patulifolia.sericea.speciosa.complex*	*Dampiera.stricta*	*Sphaerolobium.Stackhousia.species.complex*	*Dillwynia.floribunda.retorta.complex*	*Petrophile.isopogon.complex*
Species 5	*Lepyrodia.anarthria*	*Lepyrodia.anarthria*	*Acacia.rubida*	*Almaleea.paludosa*	*Lepyrodia.anarthria*

Table 23: Whether the five most influential species for each two-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2019-2020	*Lepidosperma.filiforme.urophorum.complex*	Yes
2019-2020	*Dampiera.stricta*	Yes
2019-2020	*Dillwynia.floribunda.retorta.complex*	Yes
2019-2020	*Sphaerolobium.Stackhousia.species.complex*	Yes
2019-2020	*Acacia.rubida*	Yes
2020-2021	*Lepidosperma.filiforme.urophorum.complex*	Yes
2020-2021	*Dampiera.stricta*	Yes
2020-2021	*Tetraria.capillaris*	Yes
2020-2021	*Dillwynia.floribunda.retorta.complex*	Yes
2020-2021	*Almaleea.paludosa*	Yes
2021-2022	*Dillwynia.floribunda.retorta.complex*	Yes
2021-2022	*Petrophile.Isopogon.complex*	No
2021-2022	*Tetraria.capillaris*	Yes
2021-2022	*Petrophile.isopogon.complex*	Yes
2021-2022	*Lepyrodia.anarthria*	No

Table 24: Species composition at swamp S13 based on data pooled for 3-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2017-2019	2018-2020	2019-2021	2020-2022
prepostMining	0.251	0.056	0.037	0.008
PercDev	0.501	0.384	0.407	0.302
Species 1	*Dillwynia.floribunda.retorta.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Dillwynia.floribunda.retorta.complex*
Species 2	*Dampiera.stricta*	*Dillwynia.floribunda.retorta.complex*	*Dillwynia.floribunda.retorta.complex*	*Petrophile.Isopogon.complex*
Species 3	*Lepidosperma.filiforme.urophorum.complex*	*Dampiera.stricta*	*Dampiera.stricta*	*Tetraria.capillaris*
Species 4	*Epacris.obtusifolia*	*Almaleea.paludosa*	*Almaleea.paludosa*	*Dampiera.stricta*
Species 5	*Lepyrodia.anarthria*	*Sphaerolobium.Stackhousia.species.complex*	*Sphaerolobium.Stackhousia.species.complex*	*Banksia.marginata*

Table 25: Whether the five most influential species for each three-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2019-2021	*Lepidosperma.filiforme.urophorum.complex*	Yes
2019-2021	*Dillwynia.floribunda.retorta.complex*	Yes
2019-2021	*Dampiera.stricta*	Yes
2019-2021	*Almaleea.paludosa*	Yes
2019-2021	*Sphaerolobium.Stackhousia.species.complex*	Yes
2020-2022	*Dillwynia.floribunda.retorta.complex*	Yes
2020-2022	*Petrophile.Isopogon.complex*	No
2020-2022	*Tetraria.capillaris*	Yes
2020-2022	*Dampiera.stricta*	Yes
2020-2022	*Banksia.marginata*	Yes

Table 26: Species composition at swamp S13 based on data pooled for 4-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2017-2020	2018-2021	2019-2022
prepostMining	0.107	0.041	0.008
PercDev	0.384	0.425	0.335
Species 1	*Dampiera.stricta*	*Lepidosperma.filiforme.urophorum.complex*	*Dillwynia.floribunda.retorta.complex*
Species 2	*Dillwynia.floribunda.retorta.complex*	*Dillwynia.floribunda.retorta.complex*	*Lepidosperma.filiforme.urophorum.complex*
Species 3	*Lepidosperma.filiforme.urophorum.complex*	*Almaleea.paludosa*	*Almaleea.paludosa*
Species 4	*Epacris.obtusifolia*	*Dampiera.stricta*	*Dampiera.stricta*
Species 5	*Banksia.marginata*	*Epacris.obtusifolia*	*Sphaerolobium.Stackhousia.species.complex*

Table 7: Whether the five most influential species for each four-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2018-2021	*Lepidosperma.filiforme.urophorum.complex*	Yes
2018-2021	*Dillwynia.floribunda.retorta.complex*	Yes
2018-2021	*Almaleea.paludosa*	Yes
2018-2021	*Dampiera.stricta*	Yes
2018-2021	*Epacris.obtusifolia*	Yes
2019-2022	*Dillwynia.floribunda.retorta.complex*	Yes
2019-2022	*Lepidosperma.filiforme.urophorum.complex*	Yes
2019-2022	*Almaleea.paludosa*	Yes
2019-2022	*Dampiera.stricta*	Yes
2019-2022	*Sphaerolobium.Stackhousia.species.complex*	Yes

7 Results - Swamp S14

Monitoring of S14 commenced in 2017, and mining within the RMZ commenced in 2018. A total of 42 unique species were detected, of which 12% were detected only once.

Two-yearly comparison was found to be significant from 2020 (Table 27). A three-yearly comparison was significant in 2020 (Table 29). at this swamp was statistically significant.

Table 27: Species composition at swamp S14 based on data pooled for 2-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2018-2019	2019-2020	2020-2021	2021.2022
prepostMining	0.41	0.249	0.045	0.048
PercDev	0.625	0.489	0.537	0.495
Species 1	*Lepyrodia.anarthria*	*Lepyrodia.muelleri.scariosa.complex*	*Lepyrodia. muelleri.scariosa.complex*	*Lepyrodia. muelleri.scariosa.complex*
Species 2	*Leptomeria.acida*	*Leptomeria.acida*	*Epacris.obtusifolia*	*Epacris.obtusifolia*
Species 3	*Drosera.binata*	*Lepyrodia.anarthria*	*Symphionema.paludosum*	*Cassytha.glabella..pubescens.sp.complex*
Species 4	*Cassytha.glabella..pubescens.sp. complex*	*Bauera.microphylla..rubioides.sp.complex*	*Leptomeria. acida*	*Symphionema.paludosum*
Species 5	*Bauera.microphylla..rubioides.sp.complex*	*Monotaxis.linifolia*	*Lepyrodia.anarthria*	*Lepyrodia.anarthria*

Table 28: Whether the five most influential species for each two-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2020-2021	*Lepyrodia.muelleri.scariosa.complex*	Yes
2020-2021	*Epacris.obtusifolia*	Yes
2020-2021	*Symphionema.paludosum*	Yes
2020-2021	*Leptomeria.acida*	Yes
2020-2021	*Lepyrodia.anarthria*	Yes
2021-2022	*Lepyrodia.muelleri.scariosa.complex*	Yes
2021-2022	*Epacris.obtusifolia*	Yes
2021-2022	*Cassytha.glabella..pubescens.sp.complex*	Yes
2021-2022	*Symphionema.paludosum*	Yes
2021-2022	*Lepyrodia.anarthria*	Yes

Table 29: Species composition at swamp S14 based on data pooled for 3-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2018-2020	2019-2021	2020-2022
prepostMining	0.173	0.123	0.028
PercDev	0.496	0.518	0.515
Species 1	*Leptomeria.acida*	*Lepyrodia.muelleri.scariosa.complex*	*Lepyrodia.muelleri.scariosa.complex*
Species 2	*Lepyrodia.anarthria*	*Leptomeria.acida*	*Epacris.obtusifolia*
Species 3	*Lepyrodia.muelleri.scariosa.complex*	*Lepyrodia.anarthria*	*Symphionema.paludosum*
Species 4	*Symphionema.paludosum*	*Epacris.obtusifolia*	*Lepyrodia.anarthria*
Species 5	*Drosera.binata*	*Bauera.microphylla..rubioides.sp.complex*	*Cassytha.glabella..pubescens.sp.complex*

Table 30: Whether the five most influential species for each three-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2020-2022	*Lepyrodia.muelleri.scariosa.complex*	Yes
2020-2022	*Epacris.obtusifolia*	Yes
2020-2022	*Symphionema.paludosum*	Yes
2020-2022	*Lepyrodia.anarthria*	Yes
2020-2022	*Cassytha.glabella..pubescens.sp.complex*	Yes

Table 31: Species composition at swamp S14 based on data pooled for 4-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2018-2021	2019-2022	2020.2023
prepostMining	0.081	0.078	0.035
PercDev	0.506	0.465	0.515
Species 1	*Leptomeria.acida*	*Lepyrodia.muelleri.scariosa.complex*	*Lepyrodia.muelleri.scariosa.complex*
Species 2	*Lepyrodia.anarthria*	*Lepyrodia.anarthria*	*Epacris.obtusifolia*
Species 3	*Lepyrodia.muelleri.scariosa.complex*	*Epacris.obtusifolia*	*Symphionema.paludosum*
Species 4	*Symphionema.paludosum*	*Cassytha.glabella..pubescens.sp.complex*	*Lepyrodia.anarthria*
Species 5	*Bauera.microphylla..rubioides.sp.complex*	*Symphionema.paludosum*	*Cassytha.glabella..pubescens.sp.complex*

Table 32: Whether the five most influential species for each four-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2020-2023	*Lepyrodia.muelleri.scariosa.complex*	Yes
2020-2023	*Epacris.obtusifolia*	Yes
2020-2023	*Symphionema.paludosum*	Yes
2020-2023	*Lepyrodia.anarthria*	Yes
2020-2023	*Cassytha.glabella..pubescens.sp.complex*	Yes

8 Results - Swamp S1A

Monitoring of S1A commenced in 2012, and mining within the RMZ commenced in 2013. A total of 69 unique species were detected, of which 9% were detected only once.

No 2-, 3-, 4-, or 5-yearly comparisons were statistically significant at this swamp (Table 33, Table 34, Table 35 and Table 36, respectively).

Table 33: Species composition at swamp S1A based on data pooled for 2-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021.2022
prepostMining	0.763	0.916	0.847	0.739	0.597	0.614	0.253	0.095	0.062
PercDev	0.483	0.538	0.504	0.447	0.409	0.407	0.338	0.298	0.284
Species 1	*Monotaxis.linifolia*	*Lepidosperma.filiforme.urophorum.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Boronia.parviflora*	*Boronia.parviflora*	*Boronia.parviflora*	*Gymnoschoenus.sphaerocephalus*	*Gymnoschoenus.sphaerocephalus*	*Epacris.obtusifolia*
Species 2	*Lepidosperma.filiforme.urophorum.complex*	*Hakea.teretifolia..sericea.sp.complex*	*Boronia.parviflora*	*Lepidosperma.filiforme.urophorum.complex*	*Drosera.binata*	*Drosera.binata*	*Boronia.parviflora*	*Epacris.obtusifolia*	*Dampiera.stricta*
Species 3	*Billardiera.scandens.var..scandens*	*Lepyrodia.muelleri.scariosa.complex*	*Lepyrodia.muelleri.scariosa.complex*	*Grevillea.sphacelata*	*Symphionema.paludosum*	*Lepyrodia.muelleri.scariosa.complex*	*Lepyrodia.muelleri.scariosa.complex*	*Dampiera.stricta*	*Sphaerolobium.Stackhousia.species.complex*
Species 4	*Leptomeria.acida*	*Monotaxis.linifolia*	*Hakea.teretifolia..sericea.sp.complex*	*Drosera.binata*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Symphionema.paludosum*	*Epacris.obtusifolia*	*Boronia.parviflora*	*Boronia.parviflora*
Species 5	*Hakea.teretifolia..sericea.sp.complex*	*Dillwynia.floribunda.retorta.complex*	*Persoonia.levis*	*Persoonia.levis*	*Grevillea.sphacelata*	*Grevillea.sphacelata*	*Dampiera.stricta*	*Sphaerolobium.Stackhousia.species.complex*	*Gymnoschoenus.sphaerocephalus*

Table 34: Species composition at swamp S1A based on data pooled for 3-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021	2020-2022
prepostMining	0.809	0.863	0.802	0.739	0.72	0.576	0.449	0.303
PercDev	0.446	0.518	0.457	0.444	0.434	0.382	0.437	0.415
Species 1	*Lepidosperma.filiforme.urophorum.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Boronia.parviflora*	*Boronia.parviflora*	*Boronia.parviflora*	*Epacris.obtusifolia*	*Dampiera.stricta*
Species 2	*Hakea.teretifolia..sericea.sp.complex*	*Hakea.teretifolia..sericea.sp.complex*	*Boronia.parviflora*	*Drosera.binata*	*Drosera.binata*	*Drosera.binata*	*Dampiera.stricta*	*Sphaerolobium.Stackhousia.species.complex*
Species 3	*Monotaxis.linifolia*	*Lepyrodia.muelleri.scariosa.complex*	*Lepyrodia.muelleri.scariosa.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Lepyrodia.muelleri.scariosa.complex*	*Lepyrodia.muelleri.scariosa.complex*	*Boronia.parviflora*	*Gymnoschoenus.sphaerocephalus*
Species 4	*Lepyrodia.muelleri.scariosa.complex*	*Boronia.parviflora*	*Hakea.teretifolia..sericea.sp.complex*	*Sphaerolobium.Stackhousia.species.complex*	*Sphaerolobium.Stackhousia.species.complex*	*Sphaerolobium.Stackhousia.species.complex*	*Lepyrodia.muelleri.scariosa.complex*	*Boronia.parviflora*
Species 5	*Leptomeria.acida*	*Monotaxis.linifolia*	*Persoonia.levis*	*Persoonia.levis*	*Hakea.teretifolia..sericea.sp.complex*	*Bauera.microphylla..rubioides.sp.complex*	*Sphaerolobium.Stackhousia.species.complex*	*Lepyrodia.muelleri.scariosa.complex*

Table 35: Species composition at swamp S1A based on data pooled for 4-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2013-2016	2014-2017	2015-2018	2016-2019	2017-2020	2018-2021	2019-2022
prepostMining	0.783	0.828	0.784	0.773	0.752	0.48	0.462
PercDev	0.46	0.48	0.409	0.434	0.4	0.357	0.399
Species 1	*Lepidosperma.filiforme.urophorum.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Boronia.parviflora*	*Boronia.parviflora*	*Boronia.parviflora*	*Boronia.parviflora*	*Boronia.parviflora*
Species 2	*Monotaxis.linifolia*	*Hakea.teretifolia..sericea.sp.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Drosera.binata*	*Drosera.binata*	*Gymnoschoenus.sphaerocephalus*	*Dampiera.stricta*
Species 3	*Hakea.teretifolia..sericea.sp.complex*	*Boronia.parviflora*	*Lepyrodia.muelleri.scariosa.complex*	*Lepyrodia.muelleri.scariosa.complex*	*Lepyrodia.muelleri.scariosa.complex*	*Epacris.obtusifolia*	*Sphaerolobium.Stackhousia.species.complex*
Species 4	*Lepyrodia.muelleri.scariosa.complex*	*Monotaxis.linifolia*	*Hakea.teretifolia..sericea.sp.complex*	*Sphaerolobium.Stackhousia.species.complex*	*Sphaerolobium.Stackhousia.species.complex*	*Lepyrodia.muelleri.scariosa.complex*	*Lepyrodia.muelleri.scariosa.complex*
Species 5	*Persoonia.levis*	*Lepyrodia.muelleri.scariosa.complex*	*Grevillea.sphacelata*	*Lepidosperma.filiforme.urophorum.complex*	*Epacris.obtusifolia*	*Sphaerolobium.Stackhousia.species.complex*	*Bauera.microphylla..rubioides.sp.complex*

Table 36: Species composition at swamp S1A based on data pooled for 5-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2013-2017	2014-2018	2015-2019	2016-2020	2017-2021	2018-2022
prepostMining	0.726	0.79	0.799	0.772	0.694	0.368
PercDev	0.447	0.43	0.407	0.402	0.362	0.345
Species 1	*Lepidosperma.filiforme.urophorum.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Boronia.parviflora*	*Boronia.parviflora*	*Boronia.parviflora*	*Boronia.parviflora*
Species 2	*Hakea.teretifolia..sericea.sp.complex*	*Boronia.parviflora*	*Lepyrodia.muelleri.scariosa.complex*	*Drosera.binata*	*Lepyrodia.muelleri.scariosa.complex*	*Epacris.obtusifolia*
Species 3	*Monotaxis.linifolia*	*Hakea.teretifolia..sericea.sp.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Lepyrodia.muelleri.scariosa.complex*	*Sphaerolobium.Stackhousia.species.complex*	*Sphaerolobium.Stackhousia.species.complex*
Species 4	*Boronia.parviflora*	*Lepyrodia.muelleri.scariosa.complex*	*Grevillea.sphacelata*	*Sphaerolobium.Stackhousia.species.complex*	*Epacris.obtusifolia*	*Gymnoschoenus.sphaerocephalus*
Species 5	*Lepyrodia.muelleri.scariosa.complex*	*Monotaxis.linifolia*	*Hakea.teretifolia..sericea.sp.complex*	*Epacris.obtusifolia*	*Drosera.binata*	*Dampiera.stricta*

9 Results - Swamp S1B

Monitoring of S1B commenced in 2005, and mining within the RMZ commenced in 2013. A total of 74 unique species were detected, of which 16% were detected only once.

Differences in two-yearly comparisons were first significant from 2014 (Table 37). Differences in 3-yearly, 4-yearly and 5-yearly comparisons were statistically significant from 2013 (i.e., when the impact first occurred, Table 39, Table 41, and Table 43, respectively).

Species that were consistently found to be more common prior to impact for each 2-, 3-, 4- and 5-yearly comparison are given in Table 38, Table 40, Table 42 and Table 44.

Table 37: Species composition at swamp S1B based on data pooled for 2-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021.2022
prepostMining	0.081	0.03	0.007	0.004	0.003	0.002	0.001	0.001	0.001
PercDev	0.458	0.562	0.482	0.421	0.454	0.389	0.392	0.274	0.333
Species 1	*Sprengelia.incarnata*	*Lepidosperma.filiforme.urophorum.complex*	*Caesia.parviflora.var..parviflora*	*Tetraria.capillaris*	*Grevillea.oleoides*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Lepidosperma.limicola*	*Sphaerolobium.Stackhousia.species.complex*
Species 2	*Tetraria.capillaris*	*Caesia.parviflora.var..parviflora*	*Lepidosperma.filiforme.urophorum.complex*	*Caesia.parviflora.var..parviflora*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Almaleea.paludosa*	*Caesia.parviflora.var..parviflora*	*Lepidosperma.limicola*
Species 3	*Banksia.oblongifolia*	*Banksia.paludosa*	*Tetraria.capillaris*	*Lepidosperma.filiforme.urophorum.complex*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Lepidosperma.limicola*	*Lepidosperma.limicola*	*Epacris.obtusifolia*	*Grevillea.patulifolia.sericea.speciosa.complex*
Species 4	*Lepidosperma.filiforme.urophorum.complex*	*Tetraria.capillaris*	*Banksia.paludosa*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Tetraria.capillaris*	*Grevillea.oleoides*	*Epacris.obtusifolia*	*Almaleea.paludosa*	*Epacris.obtusifolia*
Species 5	*Goodenia.hederacea..heterophylla.Sp_.complex*	*Banksia.oblongifolia*	*Banksia.oblongifolia*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Banksia.paludosa*	*Epacris.obtusifolia*	*Boronia.parviflora*	*Grevillea.oleoides*	*Almaleea.paludosa*

Table 38: Whether the five most influential species for each two-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2014-2015	*Lepidosperma.filiforme.urophorum.complex*	No
2014-2015	*Caesia.parviflora.var..parviflora*	No
2014-2015	*Banksia.paludosa*	Yes
2014-2015	*Tetraria.capillaris*	No
2014-2015	*Banksia.oblongifolia*	No
2015-2016	*Caesia.parviflora.var..parviflora*	No
2015-2016	*Lepidosperma.filiforme.urophorum.complex*	No
2015-2016	*Tetraria.capillaris*	No
2015-2016	*Banksia.paludosa*	Yes
2015-2016	*Banksia.oblongifolia*	No
2016-2017	*Tetraria.capillaris*	No
2016-2017	*Caesia.parviflora.var..parviflora*	No
2016-2017	*Lepidosperma.filiforme.urophorum.complex*	No
2016-2017	*Grevillea.patulifolia.sericea.speciosa.complex*	Yes
2016-2017	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2017-2018	*Grevillea.oleoides*	No
2017-2018	*Grevillea.patulifolia.sericea.speciosa.complex*	Yes
2017-2018	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2017-2018	*Tetraria.capillaris*	No
2017-2018	*Banksia.paludosa*	Yes
2018-2019	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2018-2019	*Grevillea.patulifolia.sericea.speciosa.complex*	Yes
2018-2019	*Lepidosperma.limicola*	Yes
2018-2019	*Grevillea.oleoides*	No
2018-2019	*Epacris.obtusifolia*	Yes
2019-2020	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2019-2020	*Almaleea.paludosa*	Yes
2019-2020	*Lepidosperma.limicola*	Yes

Year	Species Name	More common before
2019-2020	*Epacris.obtusifolia*	Yes
2019-2020	*Boronia.parviflora*	Yes
2020-2021	*Lepidosperma.limicola*	Yes
2020-2021	*Caesia.parviflora.var..parviflora*	No
2020-2021	*Epacris.obtusifolia*	Yes
2020-2021	*Almaleea.paludosa*	Yes
2020-2021	*Grevillea.oleoides*	No
2021-2022	*Sphaerolobium.Stackhousia.species.complex*	Yes
2021-2022	*Lepidosperma.limicola*	Yes
2021-2022	*Grevillea.patulifolia.sericea.speciosa.complex*	Yes
2021-2022	*Epacris.obtusifolia*	Yes
2021-2022	*Almaleea.paludosa*	Yes

Table 39: Species composition at swamp S1B based on data pooled for 3-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021	2020-2022
prepostMining	0.014	0.006	0.001	0.002	0.001	0.001	0.001	0.001
PercDev	0.466	0.51	0.446	0.412	0.37	0.357	0.313	0.311
Species 1	*Lepidosperma.filiforme.urophorum.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Lepidosperma.limicola*	*Almaleea.paludosa*
Species 2	*Caesia.parviflora.var..parviflora*	*Caesia.parviflora.var..parviflora*	*Caesia.parviflora.var..parviflora*	*Tetraria.capillaris*	*Grevillea.oleoides*	*Lepidosperma.limicola*	*Epacris.obtusifolia*	*Lepidosperma.limicola*
Species 3	*Sprengelia.incarnata*	*Tetraria.capillaris*	*Tetraria.capillaris*	*Grevillea.oleoides*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Epacris.obtusifolia*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Epacris.obtusifolia*
Species 4	*Banksia.oblongifolia*	*Banksia.paludosa*	*Banksia.paludosa*	*Caesia.parviflora.var..parviflora*	*Lepidosperma.limicola*	*Almaleea.paludosa*	*Almaleea.paludosa*	*Sphaerolobium.Stackhousia.species.complex*
Species 5	*Tetraria.capillaris*	*Banksia.oblongifolia*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Epacris.obtusifolia*	*Boronia.parviflora*	*Caesia.parviflora.var..parviflora*	*Xyris.species.complex*

Table 40: Whether the five most influential species for each three-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2013-2015	*Lepidosperma.filiforme.urophorum.complex*	No
2013-2015	*Caesia.parviflora.var..parviflora*	No
2013-2015	*Sprengelia.incarnata*	Yes
2013-2015	*Banksia.oblongifolia*	No
2013-2015	*Tetraria.capillaris*	No
2014-2016	*Lepidosperma.filiforme.urophorum.complex*	No
2014-2016	*Caesia.parviflora.var..parviflora*	No
2014-2016	*Tetraria.capillaris*	No
2014-2016	*Banksia.paludosa*	Yes
2014-2016	*Banksia.oblongifolia*	No
2015-2017	*Lepidosperma.filiforme.urophorum.complex*	No
2015-2017	*Caesia.parviflora.var..parviflora*	No
2015-2017	*Tetraria.capillaris*	No
2015-2017	*Banksia.paludosa*	Yes
2015-2017	*Grevillea.patulifolia.sericea.speciosa.complex*	Yes
2016-2018	*Grevillea.patulifolia.sericea.speciosa.complex*	Yes
2016-2018	*Tetraria.capillaris*	No
2016-2018	*Grevillea.oleoides*	No
2016-2018	*Caesia.parviflora.var..parviflora*	No
2016-2018	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2017-2019	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2017-2019	*Grevillea.oleoides*	No
2017-2019	*Grevillea.patulifolia.sericea.speciosa.complex*	Yes
2017-2019	*Lepidosperma.limicola*	Yes
2017-2019	*Epacris.obtusifolia*	Yes
2018-2020	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2018-2020	*Lepidosperma.limicola*	Yes
2018-2020	*Epacris.obtusifolia*	Yes

Year	Species Name	More common before
2018-2020	*Almaleea.paludosa*	Yes
2018-2020	*Boronia.parviflora*	Yes
2019-2021	*Lepidosperma.limicola*	Yes
2019-2021	*Epacris.obtusifolia*	Yes
2019-2021	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2019-2021	*Almaleea.paludosa*	Yes
2019-2021	*Caesia.parviflora.var..parviflora*	No
2020-2022	*Almaleea.paludosa*	Yes
2020-2022	*Lepidosperma.limicola*	Yes
2020-2022	*Epacris.obtusifolia*	Yes
2020-2022	*Sphaerolobium.Stackhousia.species.complex*	Yes
2020-2022	*Xyris.species.complex*	No

Table 41: Species composition at swamp S1B based on data pooled for 4-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2013-2016	2014-2017	2015-2018	2016-2019	2017-2020	2018-2021	2019-2022
prepostMining	0.005	0.002	0.001	0.001	0.001	0.001	0.001
PercDev	0.455	0.473	0.404	0.346	0.347	0.326	0.329
Species 1	*Caesia.parviflora.var..parviflora*	*Lepidosperma.filiforme.urophorum.complex*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Lepidosperma.limicola*	*Epacris.obtusifolia*
Species 2	*Lepidosperma.filiforme.urophorum.complex*	*Caesia.parviflora.var..parviflora*	*Caesia.parviflora.var..parviflora*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Lepidosperma.limicola*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Lepidosperma.limicola*
Species 3	*Tetraria.capillaris*	*Tetraria.capillaris*	*Lepidosperma.filiforme.urophorum.complex*	*Banksia.paludosa*	*Epacris.obtusifolia*	*Epacris.obtusifolia*	*Almaleea.paludosa*
Species 4	*Sprengelia.incarnata*	*Banksia.paludosa*	*Tetraria.capillaris*	*Caesia.parviflora.var..parviflora*	*Almaleea.paludosa*	*Grevillea.oleoides*	*Sphaerolobium.Stackhousia.species.complex*
Species 5	*Goodenia.hederacea..heterophylla.Sp_.complex*	*Banksia.oblongifolia*	*Banksia.paludosa*	*Tetraria.capillaris*	*Banksia.paludosa*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Banksia.paludosa*

Table 42: Whether the five most influential species for each four-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2013-2016	*Caesia.parviflora.var..parviflora*	No
2013-2016	*Lepidosperma.filiforme.urophorum.complex*	No
2013-2016	*Tetraria.capillaris*	No
2013-2016	*Sprengelia.incarnata*	Yes
2013-2016	*Goodenia.hedercacea..heterophylla.Sp_.complex*	Yes
2014-2017	*Lepidosperma.filiforme.urophorum.complex*	No
2014-2017	*Caesia.parviflora.var..parviflora*	No
2014-2017	*Tetraria.capillaris*	No
2014-2017	*Banksia.paludosa*	Yes
2014-2017	*Banksia.oblongifolia*	No
2015-2018	*Grevillea.patulifolia.sericea.speciosa.complex*	Yes
2015-2018	*Caesia.parviflora.var..parviflora*	No
2015-2018	*Lepidosperma.filiforme.urophorum.complex*	No
2015-2018	*Tetraria.capillaris*	No
2015-2018	*Banksia.paludosa*	Yes
2016-2019	*Grevillea.patulifolia.sericea.speciosa.complex*	Yes
2016-2019	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2016-2019	*Banksia.paludosa*	Yes
2016-2019	*Caesia.parviflora.var..parviflora*	No
2016-2019	*Tetraria.capillaris*	No
2017-2020	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2017-2020	*Lepidosperma.limicola*	Yes
2017-2020	*Epacris.obtusifolia*	Yes
2017-2020	*Almaleea.paludosa*	Yes
2017-2020	*Banksia.paludosa*	Yes
2018-2021	*Lepidosperma.limicola*	Yes
2018-2021	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2018-2021	*Epacris.obtusifolia*	Yes

Year	Species Name	More common before
2018-2021	*Grevillea.oleoides*	No
2018-2021	*Grevillea.patulifolia.sericea.speciosa.complex*	Yes
2019-2022	*Epacris.obtusifolia*	Yes
2019-2022	*Lepidosperma.limicola*	Yes
2019-2022	*Almaleea.paludosa*	Yes
2019-2022	*Sphaerolobium.Stackhousia.species.complex*	Yes
2019-2022	*Banksia.paludosa*	Yes

Table 43: Species composition at swamp S1B based on data pooled for 5-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2013-2017	2014-2018	2015-2019	2016-2020	2017-2021	2018-2022
prepostMining	0.003	0.001	0.001	0.001	0.001	0.001
PercDev	0.442	0.416	0.349	0.331	0.335	0.321
Species 1	*Lepidosperma.filiforme.urophorum.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Caesia.parviflora.var..parviflora*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Lepidosperma.limicola*
Species 2	*Caesia.parviflora.var..parviflora*	*Caesia.parviflora.var..parviflora*	*Banksia.paludosa*	*Caesia.parviflora.var..parviflora*	*Lepidosperma.limicola*	*Epacris.obtusifolia*
Species 3	*Tetraria.capillaris*	*Banksia.paludosa*	*Mitrasacme.polymorpha.pilosa.species.complex*	*Banksia.paludosa*	*Epacris.obtusifolia*	*Almaleea.paludosa*
Species 4	*Sprengelia.incarnata*	*Tetraria.capillaris*	*Lepidosperma.filiforme.urophorum.complex*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Sphaerolobium.Stackhousia.species.complex*
Species 5	*Banksia.paludosa*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Tetraria.capillaris*	*Lepidosperma.limicola*	*Grevillea.oleoides*	*Grevillea.patulifolia.sericea.speciosa.complex*

Table 44: Whether the five most influential species for each five-yearly comparison of species composition were more or less common prior to the impact.

Year	Species Name	More common before
2013-2017	*Lepidosperma.filiforme.urophorum.complex*	No
2013-2017	*Caesia.parviflora.var..parviflora*	No
2013-2017	*Tetraria.capillaris*	No
2013-2017	*Sprengelia.incarnata*	Yes
2013-2017	*Banksia.paludosa*	Yes
2014-2018	*Lepidosperma.filiforme.urophorum.complex*	No
2014-2018	*Caesia.parviflora.var..parviflora*	No
2014-2018	*Banksia.paludosa*	Yes
2014-2018	*Tetraria.capillaris*	No
2014-2018	*Grevillea.patulifolia.sericea.speciosa.complex*	Yes
2015-2019	*Caesia.parviflora.var..parviflora*	No
2015-2019	*Banksia.paludosa*	Yes
2015-2019	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2015-2019	*Lepidosperma.filiforme.urophorum.complex*	No
2015-2019	*Tetraria.capillaris*	No
2016-2020	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2016-2020	*Caesia.parviflora.var..parviflora*	No
2016-2020	*Banksia.paludosa*	Yes
2016-2020	*Grevillea.patulifolia.sericea.speciosa.complex*	Yes
2016-2020	*Lepidosperma.limicola*	Yes
2017-2021	*Mitrasacme.polymorpha.pilosa.species.complex*	Yes
2017-2021	*Lepidosperma.limicola*	Yes
2017-2021	*Epacris.obtusifolia*	Yes
2017-2021	*Grevillea.patulifolia.sericea.speciosa.complex*	Yes
2017-2021	*Grevillea.oleoides*	No
2018-2022	*Lepidosperma.limicola*	Yes
2018-2022	*Epacris.obtusifolia*	Yes
2018-2022	*Almaleea.paludosa*	Yes
2018-2022	*Sphaerolobium.Stackhousia.species.complex*	Yes

Year	Species Name	More common before
2018-2022	*Grevillea.patulifolia.sericea.speciosa.complex*	Yes

10 Results - Swamp S5

Monitoring of S5 commenced in 2012, and mining within the RMZ commenced in 2013. A total of 49 unique species were detected, of which 12% were detected only once.

No 2-, 3-, 4- or 5-yearly comparisons were found to be statistically significant at this swamp (Table 45, Table 46, Table 47 and Table 48 respectively).

Table 45: Species composition at swamp S5 based on data pooled for 2-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021.2022
prepostMining	0.454	0.954	0.87	0.767	0.62	0.827	0.644	0.687	0.594
PercDev	0.597	0.602	0.685	0.722	0.706	0.637	0.571	0.566	0.536
Species 1	*Grevillea.oleoides*	*Acacia.rubida*	*Acacia.rubida*	*Banksia.robur*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Cassytha.glabella..pubescens.sp.complex*	*Cassytha.glabella..pubescens.sp.complex*	*Leptospermum.juniperinum*	*Grevillea.patulifolia.sericea.speciosa.complex*
Species 2	*Grevillea.patulifolia.sericea.speciosa.complex*	*Grevillea.sphacelata*	*Epacris.obtusifolia*	*Lepidosperma.filiforme.urophorum.complex*	*Banksia.robur*	*Acacia.rubida*	*Acacia.rubida*	*Cassytha.glabella..pubescens.sp.complex*	*Banksia.robur*
Species 3	*Grevillea.sphacelata*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Acacia.rubida*	*Cassytha.glabella..pubescens.sp.complex*	*Banksia.robur*	*Drosera.spatulata*	*Acacia.rubida*	*Leptospermum.juniperinum*
Species 4	*Lepidosperma.filiforme.urophorum.complex*	*Grevillea.oleoides*	*Banksia.robur*	*Epacris.obtusifolia*	*Acacia.rubida*	*Baumea.articulata..rubiginosa..teretifolia.sp..chorizandra.cymbaria..sphaerocephalum.species.complex*	*Goodenia.dimorpha..stelligera..bellidifolia.sp.complex*	*Epacris.obtusifolia*	*Cassytha.glabella..pubescens.sp.complex*
Species 5	*Baeckea.diosmifolia*	*Lepidosperma.filiforme.urophorum.complex*	*Drosera.binata*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Epacris.obtusifolia*	*Caesia.parviflora.var..parviflora*	*Grevillea.oleoides*	*Caesia.parviflora.var..parviflora*	*Acacia.rubida*

Table 46: Species composition at swamp S5 based on data pooled for 3-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021	2020-2022
prepostMining	0.583	0.948	0.95	0.811	0.871	0.886	0.918	0.95
PercDev	0.534	0.595	0.728	0.761	0.676	0.555	0.56	0.647
Species 1	*Grevillea.oleoides*	*Lepidosperma.filiforme.urophorum.complex*	*Banksia.robur*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Banksia.robur*	*Banksia.robur*	*Banksia.robur*	*Banksia.robur*
Species 2	*Grevillea.sphacelata*	*Grevillea.sphacelata*	*Lepidosperma.filiforme.urophorum.complex*	*Banksia.robur*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Caesia.parviflora.var..parviflora*	*Caesia.parviflora.var..parviflora*	*Almaleea.paludosa*
Species 3	*Grevillea.patulifolia.sericea.speciosa.complex*	*Grevillea.oleoides*	*Caesia.parviflora.var..parviflora*	*Lepidosperma.filiforme.urophorum.complex*	*Caesia.parviflora.var..parviflora*	*Goodenia.dimorpha..stelligera..bellidifolia.sp.complex*	*Leptospermum.juniperinum*	*Caesia.parviflora.var..parviflora*
Species 4	*Banksia.robur*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Caesia.parviflora.var..parviflora*	*Epacris.obtusifolia*	*Epacris.obtusifolia*	*Epacris.obtusifolia*	*Grevillea.patulifolia.sericea.speciosa.complex*
Species 5	*Acacia.rubida*	*Banksia.robur*	*Drosera.binata*	*Drosera.binata*	*Lepidosperma.filiforme.urophorum.complex*	*Baumea.articulata..rubiginosa..teretifolia.sp..chorizandra.cymbaria..sphaerocephalum.species.complex*	*Drosera.spatulata*	*Xyris.species.complex*

Table 47: Species composition at swamp S5 based on data pooled for 4-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2013-2016	2014-2017	2015-2018	2016-2019	2017-2020	2018-2021	2019-2022
prepostMining	0.565	0.927	0.92	0.851	0.9	0.915	0.909
PercDev	0.632	0.625	0.708	0.648	0.589	0.581	0.596
Species 1	*Grevillea.oleoides*	*Lepidosperma.filiforme.urophorum.complex*	*Banksia.robur*	*Banksia.robur*	*Banksia.robur*	*Banksia.robur*	*Banksia.robur*
Species 2	*Lepidosperma.filiforme.urophorum.complex*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Epacris.obtusifolia*	*Caesia.parviflora.var..parviflora*	*Caesia.parviflora.var..parviflora*	*Leptospermum.juniperinum*
Species 3	*Grevillea.sphacelata*	*Banksia.robur*	*Lepidosperma.filiforme.urophorum.complex*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Epacris.obtusifolia*	*Epacris.obtusifolia*	*Epacris.obtusifolia*
Species 4	*Grevillea.patulifolia.sericea.speciosa.complex*	*Grevillea.sphacelata*	*Caesia.parviflora.var..parviflora*	*Lepidosperma.filiforme.urophorum.complex*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Leptospermum.juniperinum*	*Caesia.parviflora.var..parviflora*
Species 5	*Acacia.rubida*	*Caesia.parviflora.var..parviflora*	*Drosera.binata*	*Caesia.parviflora.var..parviflora*	*Baumea.articulata..rubiginosa..teretifolia.sp..chorizandra.cymbaria..sphaerocephalum.species.complex*	*Baumea.articulata..rubiginosa..teretifolia.sp..chorizandra.cymbaria..sphaerocephalum.species.complex*	*Almaleea.paludosa*

Table 48: Species composition at swamp S5 based on data pooled for 5-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2013-2017	2014-2018	2015-2019	2016-2020	2017-2021	2018-2022
prepostMining	0.58	0.906	0.891	0.865	0.91	0.912
PercDev	0.574	0.631	0.642	0.596	0.625	0.602
Species 1	*Grevillea.patulifolia.sericea.speciosa.complex*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Banksia.robur*	*Banksia.robur*	*Banksia.robur*	*Banksia.robur*
Species 2	*Lepidosperma.filiforme.urophorum.complex*	*Banksia.robur*	*Epacris.obtusifolia*	*Epacris.obtusifolia*	*Caesia.parviflora.var..parviflora*	*Epacris.obtusifolia*
Species 3	*Grevillea.oleoides*	*Lepidosperma.filiforme.urophorum.complex*	*Caesia.parviflora.var..parviflora*	*Caesia.parviflora.var..parviflora*	*Epacris.obtusifolia*	*Caesia.parviflora.var..parviflora*
Species 4	*Acacia.rubida*	*Epacris.obtusifolia*	*Lepidosperma.filiforme.urophorum.complex*	*Cassytha.glabella..pubescens.sp.complex*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Leptospermum.juniperinum*
Species 5	*Caesia.parviflora.var..parviflora*	*Caesia.parviflora.var..parviflora*	*Grevillea.patulifolia.sericea.speciosa.complex*	*Lepidosperma.filiforme.urophorum.complex*	*Baumea.articulata..rubiginosa..teretifolia.sp..chorizandra.cymbaria..sphaerocephalum.species.complex*	*Grevillea.patulifolia.sericea.speciosa.complex*

11 Results - Swamp S23

Monitoring of S23 commenced in 2017, and mining within the RMZ commenced in 2018. A total of 49 unique species were detected, of which 18% were detected only once.

No 2-, or 3-yearly comparisons were found to be statistically significant at this swamp (Table 49 and Table 50, respectively).

Table 49: Species composition at swamp S23 based on data pooled for 2-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2018-2019	2019-2020	2020-2021	X2021.2022
prepostMining	0.731	0.541	0.395	0.341
PercDev	0.617	0.627	0.54	0.462
Species 1	*Acacia.rubida*	*Acacia.rubida*	*Acacia.rubida*	*Xyris.species.complex*
Species 2	*Schoenus.brevifolius..lepidosperma.sp.complex*	*Lomandra.cylindrica.filiformis.micrantha.sp.complex*	*Lomandra.cylindrica.filiformis.micrantha.sp.complex*	*Acacia.rubida*
Species 3	*Baeckea.linifolia*	*Baeckea.imbricata*	*Lepidosperma.filiforme.urophorum.complex*	*Lomandra.cylindrica.filiformis.micrantha.sp.complex*
Species 4	*Pteridium.esculentum*	*Pteridium.esculentum*	*Baeckea.imbricata*	*Caesia.parviflora.var..parviflora*
Species 5	*Lomandra.cylindrica.filiformis.micrantha.sp.complex*	*Baeckea.linifolia*	*Pteridium.esculentum*	*Baeckea.imbricata*

Table 50: Species composition at swamp S23 based on data pooled for 3-year periods. The p-value for PrePostMining and the percentage of deviance explained by the 5 most influential species are shown.

	2018-2020	2019-2021	2020-2022
prepostMining	0.754	0.494	0.334
PercDev	0.62	0.637	0.499
Species 1	*Acacia.rubida*	*Lomandra.cylindrica.filiformis.micrantha.sp.complex*	*Lomandra.cylindrica.filiformis.micrantha.sp.complex*
Species 2	*Pteridium.esculentum*	*Baeckea.imbricata*	*Baeckea.imbricata*
Species 3	*Baeckea.linifolia*	*Acacia.rubida*	*Acacia.rubida*
Species 4	*Lomandra.cylindrica.filiformis.micrantha.sp.complex*	*Pteridium.esculentum*	*Xyris.species.complex*
Species 5	*Baeckea.imbricata*	*Baeckea.linifolia*	*Pteridium.esculentum*

12 Discussion

- This analysis tested whether species composition at impact swamps prior to impact was significantly different to a select set of years post-impact. The selected set of years post-impact varied depending on the time period being assessed: 2-, 3-, and 4-yearly subsets of the data between impact and final year of monitoring (2022), were investigated and for swamps in Area 3B, five-yearly comparisons were also investigated where applicable. This differs from the TSR analysis, whereby differences in species richness were tested against a set of control swamps. Therefore, some swamps may have statistically significant differences when assessing species composition (before and after impact), but not be found to be statistically significant impacts in the TSR analysis (before-after control-impact).

- Swamp S15A(1) is now an impact swamp, however has only 1 year of data and was not analysed using this method.

- Some swamps have short pre-impact monitoring periods. E.g., swamp S14, S1A, S5 and S23. As per last reporting period, no yearly comparisons at these four swamps were found to be statistically significant for species composition (exc. S14 in 2020). In future, further analysis should be undertaken that omit pre-impact data and investigate yearly-trends post-impact.

- TSR changes and species composition were both found to be significant at: S15A(2), S15B, S11, S13, S14, S1B.

- TSR change was significant at S1A and S5, however species composition change was not detected.

- TSR changes and species composition were not detected at S23.

13 References

R Core Team (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria.

Wang, Y., Naumann, U., Eddelbuettel, D., Wilshire, J. and D. Warton (2022). *mvabund: Statistical Methods for Analysing Multivariate Abundance Data*. R package version 4.2.1.

Warton, D. I., S. T. Wright, and Y. Wang (2012). Distance-based multivariate analyses confound location and dispersion effects. *Methods in Ecology and Evolution*, 3(1): 89-101

Task 2A - Breakpoint analysis of total flora species richness at swamps within the Dendrobium region

Data collected up to and including 2022

20 March 2023

Project History and Version Control

Date	Amendments	Person
27 Feb 2023	Received data from Luke Stone (Niche).	JP
13 Mar 2022	Received revised data from Luke Stone (Niche).	JP
20 Mar 2022	Draft report submitted to Luke Stone (Niche).	JP

Table of Contents

1 Data Summary

On 13 March 2023, The Analytical Edge (hereafter, TAE) received a revised data set from Luke Stone (Niche) via e-mail. It contained data collected during flora swamp monitoring within the Dendrobium region up to and including 2022 (*'a7290_2022_FloristicData_rev_02_20230313.xlsx'*, 16.7 MB).

Notes:

(1) Many species names and complexes had been revised since the previous analysis.

(2) As per previous years, all data relating to swamp S1 were omitted from the analysis.

(3) Different to previous years, S15A(1) is now considered an impact swamp (i.e., all previous years of 'control' data are now classified pre 'impact'). This swamp was not analysed using the break point analysis, due to limited data.

(4) A new 'control' swamp has been added (S131).

(5) 14 records were classified as 'QUADRAT DEAD' and were excluded from the analysis.

Disclaimer: This data file is assumed to be error-free. Any further errors detected by Niche may invalidate the results and conclusions made in this report and will require the analysis to be re-run under the proviso of new contract agreements.

2 Methods

To date, analysis of total species richness data has been undertaken in a series of 2-, 3-, and 4- yearly comparisons. Conducting multiple testing such as this can lead to erroneous interpretation of results; through statistical chance alone, 5% of tests may be concluded significant, and this chance is elevated when multiple tests are conducted. Methods exist for multiple correction (e.g., Holm 1979) but this will decrease the power to detect a difference, if one exists. In addition, this approach doesn't identify any significant break points that might exist in the data.

TAE has previously proposed alternative methods to analyse these data (e.g., using a broken-stick approach), and last year was the first attempt to analyse these data using such an approach (TAE, 2022). This report follows the same format as last year, i.e., a linear model was fit to the TSR data at each impact swamp. Then estimates of breakpoints were explored (i.e., 1, 2 or 3 break points) and selected based on AIC model selection. All analyses were conducted in R (v. 4.1.2, R Core Team 2021).

3 Results - Swamp S15A(2)

Monitoring at swamp S15A(2) began in 2009, and this swamp was impacted in 2013. The boxplot of TSR data (Figure 1) shows that prior to impact, the TSR was high and remained high for approximately 5 years after impact. Since 2017, TSR at this swamp appears to have declined to lower levels than those recorded before impact.

The best model had 1 break point (Table 1) and was plotted against the underlying data and fitted linear regression model (Figure 2). Estimates of the break point analysis slope parameters are given in Table 2. The second slope was found to be significantly different to 0, i.e., prior to the break point, no linear trend was found to be significant, however after the break point, there was a significant linear decline in TSR at this swamp.

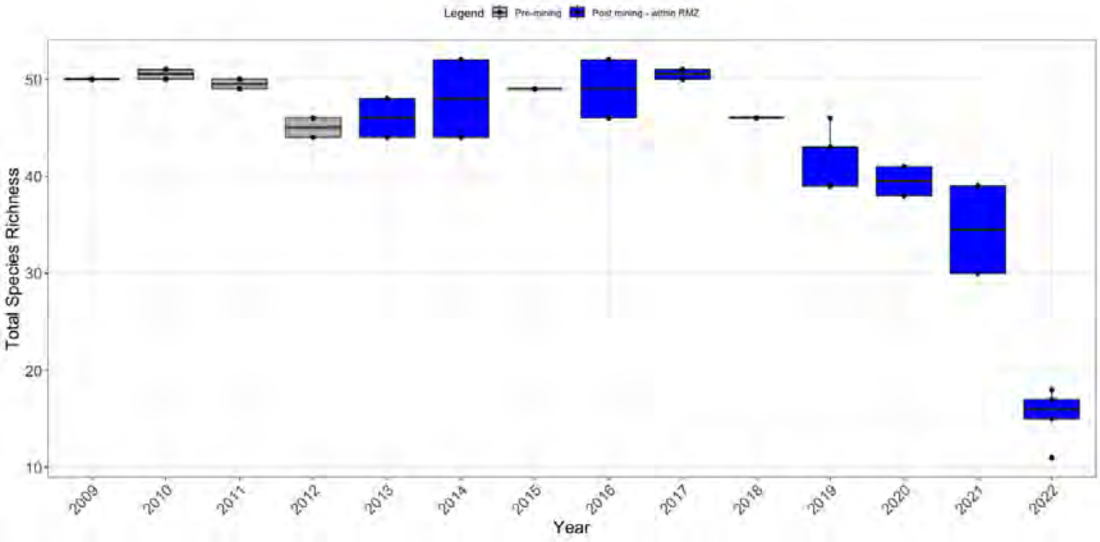


Figure 1: Boxplot of the total species richness for each transect at impact swamp S15A(2), contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

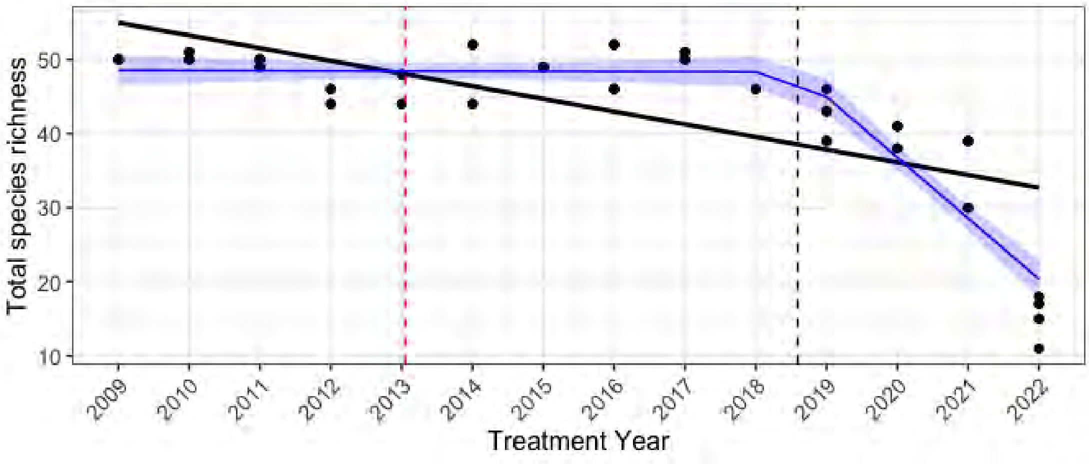


Figure 2: Best break point analysis model (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Break points indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 1: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Best model	1	0.853	434.66	0.00
Linear model	0	0.499	526.15	91.49

Table 2: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
segment1	-0.02	0.2	-0.42	0.37
segment2	-8.18	0.7	-9.54	-6.81

4 Results - Swamp S15B

Monitoring at swamp S15B began in 2003, and this swamp was impacted in 2010. The boxplot of TSR data (Figure 3) shows that throughout the monitoring period, the TSR prior to impact was higher than post-impact. Since impact, TSR at this swamp has declined to lower levels than before impact.

The best model (see Table 3) had 1 break point and was plotted against the underlying data and fitted linear regression model (Figure 4). Estimates of the break point analysis slope parameters are given in Table 4. Both slopes were found to be significantly different to 0, i.e., prior to the break point, there was a significant positive linear trend, and after the break point, there was a significant negative trend in TSR at this impact swamp.

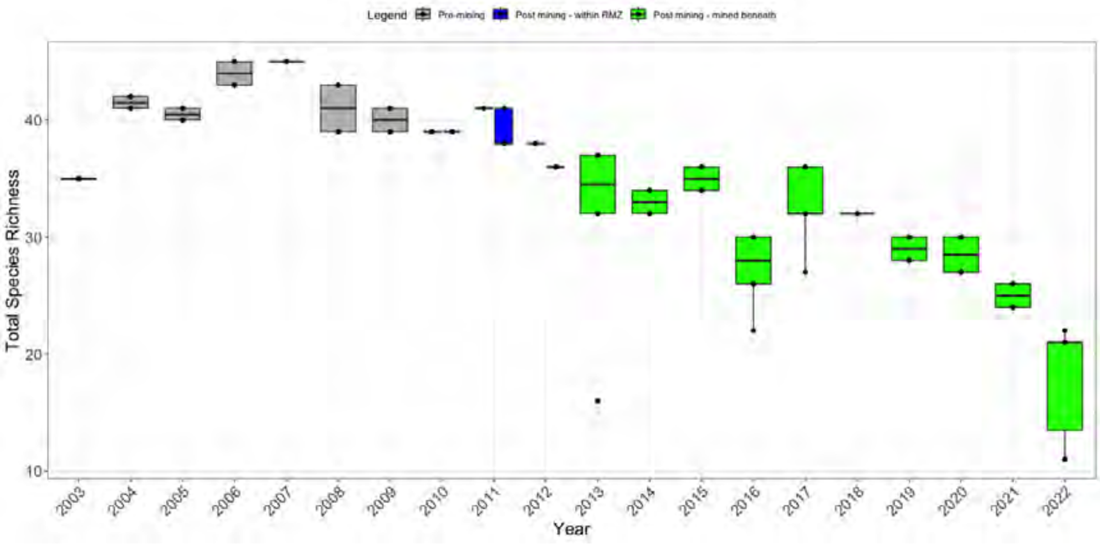


Figure 3: Boxplot of the total species richness for each transect at impact swamp S15B, contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

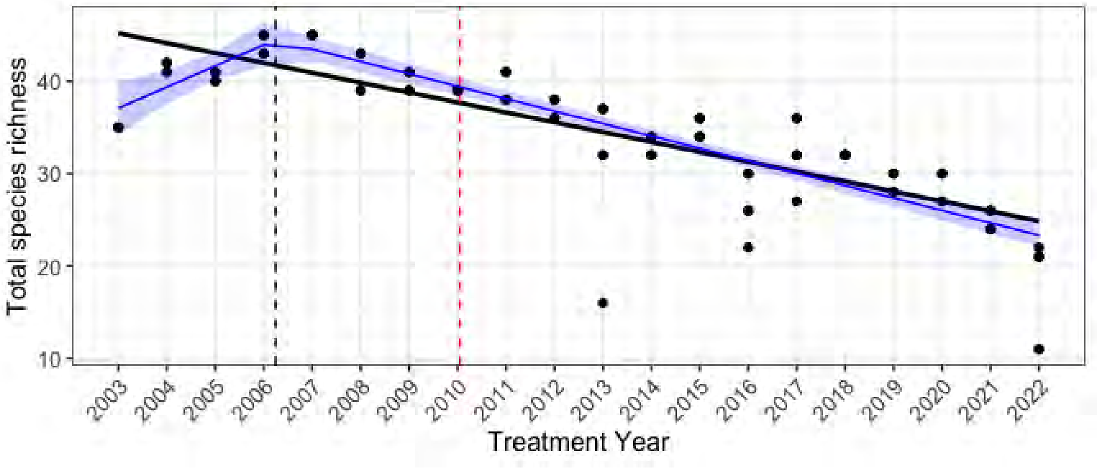


Figure 4: Best break point analysis model (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Break points indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 3: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Best model	1	0.781	632.36	0.00
Linear model	0	0.692	668.50	36.14

Table 4: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
segment1	2.29	0.73	0.86	3.72
segment2	-3.63	0.73	-5.07	-2.20

5 Results - Swamp S11

Monitoring at swamp S11 began in 2003, and this swamp was impacted in 2016. The boxplot of TSR data (Figure 5) shows that throughout the monitoring period, the TSR at this swamp prior to impact was variable. In the years since impact (2016) TSR has steadily declined to levels not recorded before the impact (i.e., 2015).

The best model had 1 break point (Table 5) and was plotted against the underlying data and fitted linear regression model (Figure 6). Estimates of the break point analysis slope parameters are given in Table 6. The second slope was found to be significantly different from 0, i.e., prior to the break point, no linear trend was found to be significant, however after the break point, there was a significant linear decline in TSR.

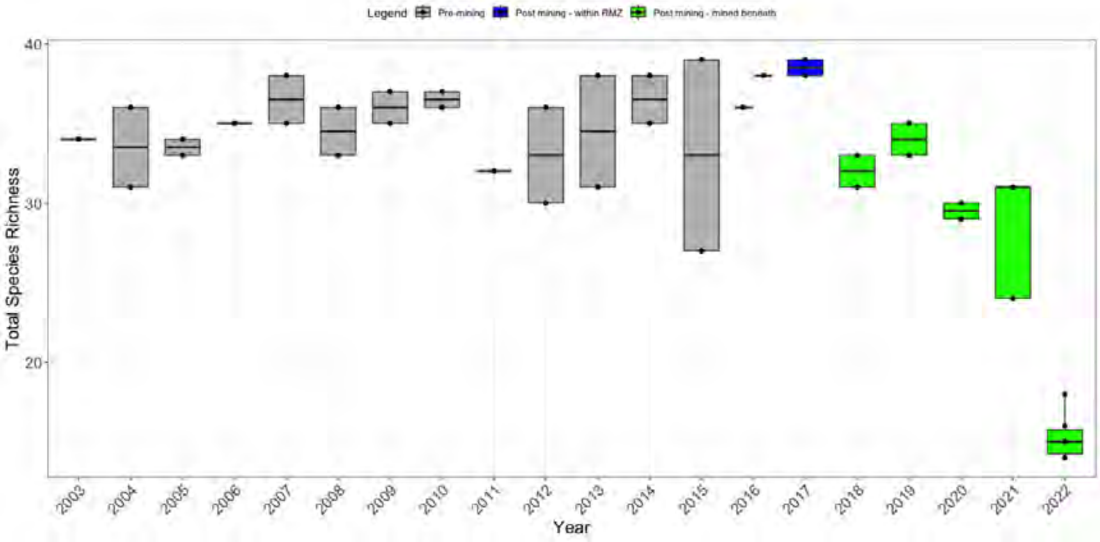


Figure 5: Boxplot of the total species richness for each transect at impact swamp S11, contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

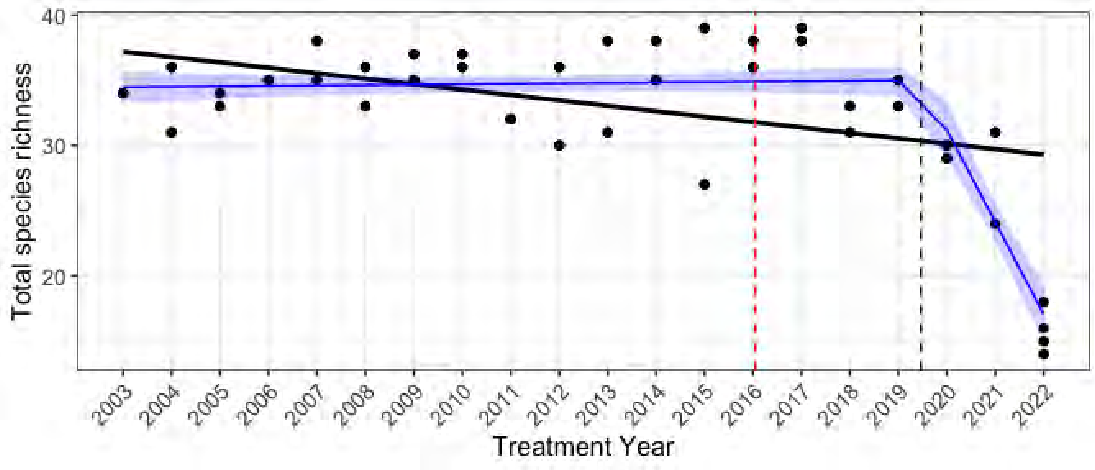


Figure 6: Best break point analysis model (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Break points indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 5: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Best model	1	0.698	585.42	0.00
Linear model	0	0.196	694.89	109.47

Table 6: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
segment1	0.03	0.06	-0.09	0.15
segment2	-7.12	0.85	-8.78	-5.45

6 Results - Swamp S13

Monitoring at swamp S13 began in 2013, and this swamp was impacted in 2017. The boxplot of TSR data (Figure 7) shows that throughout the monitoring period, the TSR prior to impact was high and relatively stable. After impact, TSR at this swamp has declined to levels not observed prior to impact.

The best model (see Table 7) was the linear model (i.e., no breakpoints were found to be significant). Estimates of the break point analysis slope parameters are given in Table 8. No breakpoints were found to be significant, and the linear model was found to have a significant linear decline in TSR over the monitoring period.

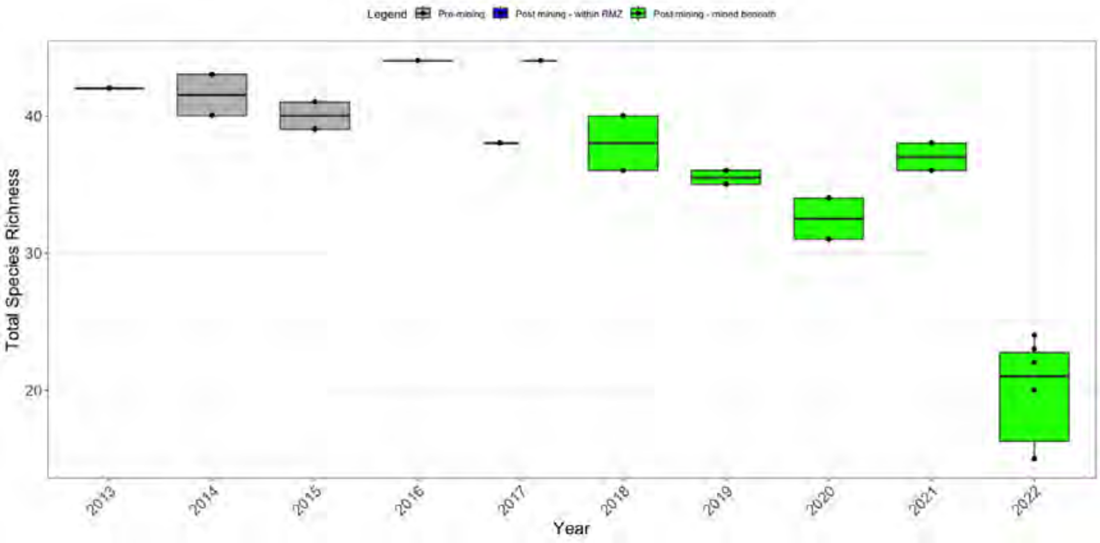


Figure 7: Boxplot of the total species richness for each transect at impact swamp S13, contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

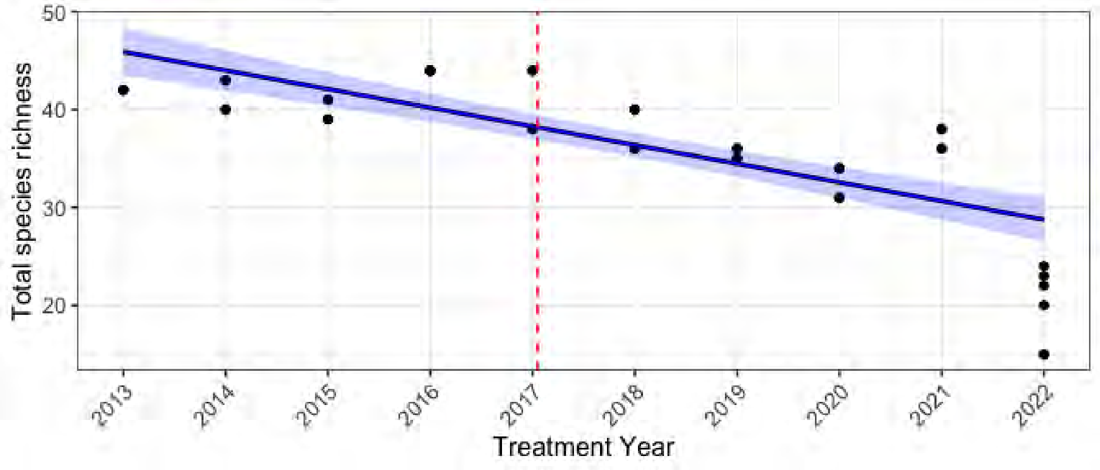


Figure 8: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 7: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.571	340.44	0

Table 8: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	-1.91	0.22	-2.34	-1.47

7 Results - Swamp S14

Monitoring at swamp S14 began in 2017, and this swamp was impacted in the same year. The boxplot of TSR data (Figure 9) shows that throughout the short monitoring period, the TSR prior to impact was variable. Post impact, TSR has declined to levels not observed prior to impact.

The best model had 1 break point (Table 9) and was plotted against the underlying data and fitted linear regression model (Figure 10). Estimates of the break point analysis slope parameters are given in Table 10. The second slope was found to be significantly different to 0, i.e., prior to the break point, no linear trend was found to be significant, however after the break point, there was a significant linear decline in TSR at this swamp.

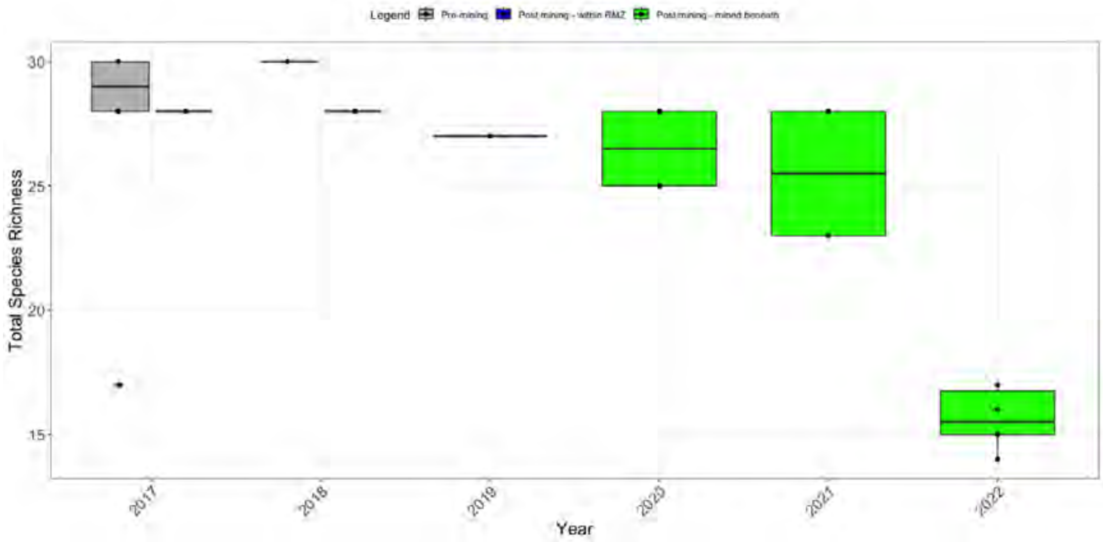


Figure 9: Boxplot of the total species richness for each transect at impact swamp S14, contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

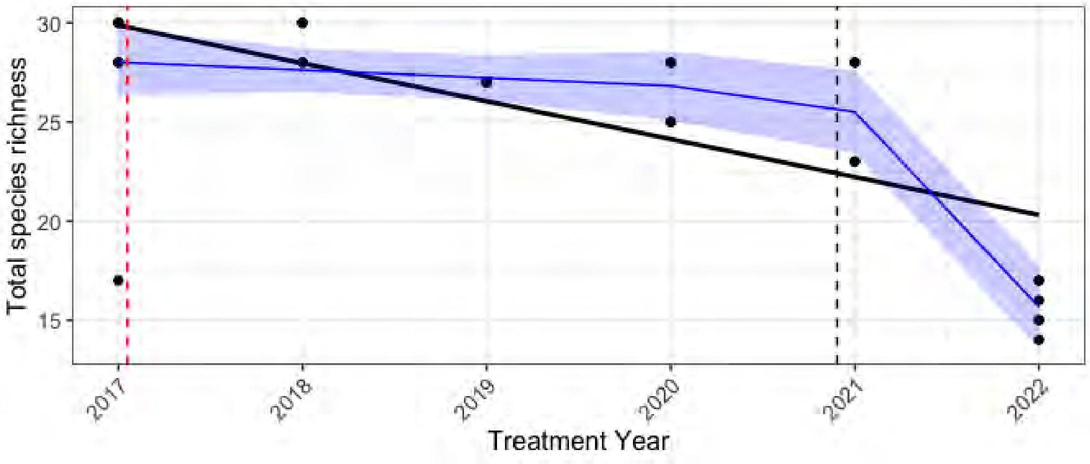


Figure 10: Best break point analysis model (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Break points indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 9: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Best model	1	0.763	179.22	0.0
Linear model	0	0.459	205.82	26.6

Table 10: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
segment1	-0.40	0.44	-1.27	0.47
segment2	-9.43	1.52	-12.42	-6.45

8 Results - Swamp S1A

Monitoring at swamp S1A began in 2012, and this swamp was impacted in 2013. The boxplot of TSR data (Figure 11) shows that prior to impact, the TSR at the impact swamp was variable, and since impact, TSR has declined to levels not observed prior to impact.

The best model had one break point (Table 11) and was plotted against the underlying data and fitted linear regression model (Figure 12). Estimates of the break point analysis slope parameters are given in Table 12. Both slopes were found to be differently different from 0, i.e., prior to the break point were was a significant positive increase in TSR, and after the break point, there was a significant negative decline in TSR.

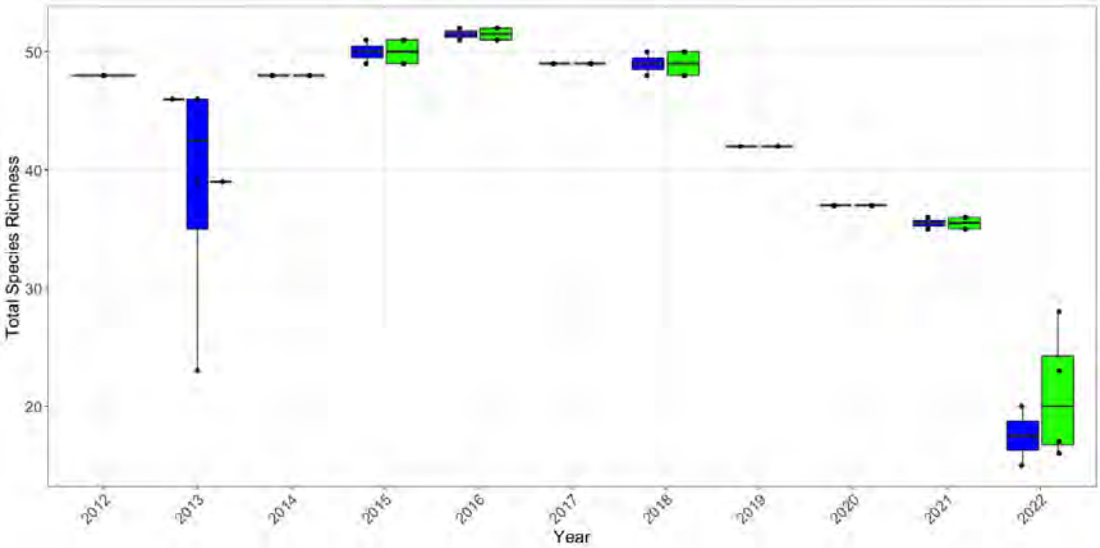


Figure 11: Boxplot of the total species richness for each transect at impact swamp S1A, contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

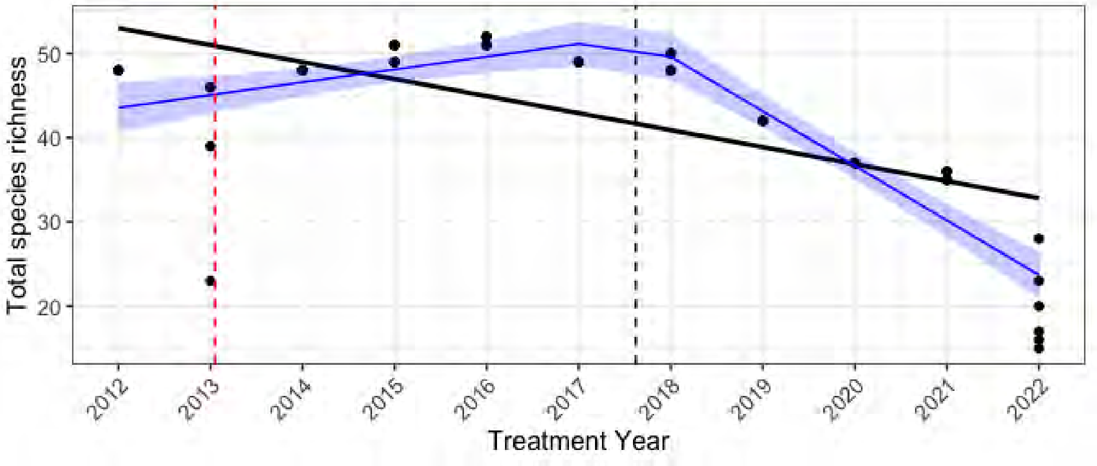


Figure 12: Best break point analysis model (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Break points indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 11: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Best model	1	0.806	369.70	0.00
Linear model	0	0.413	435.47	65.77

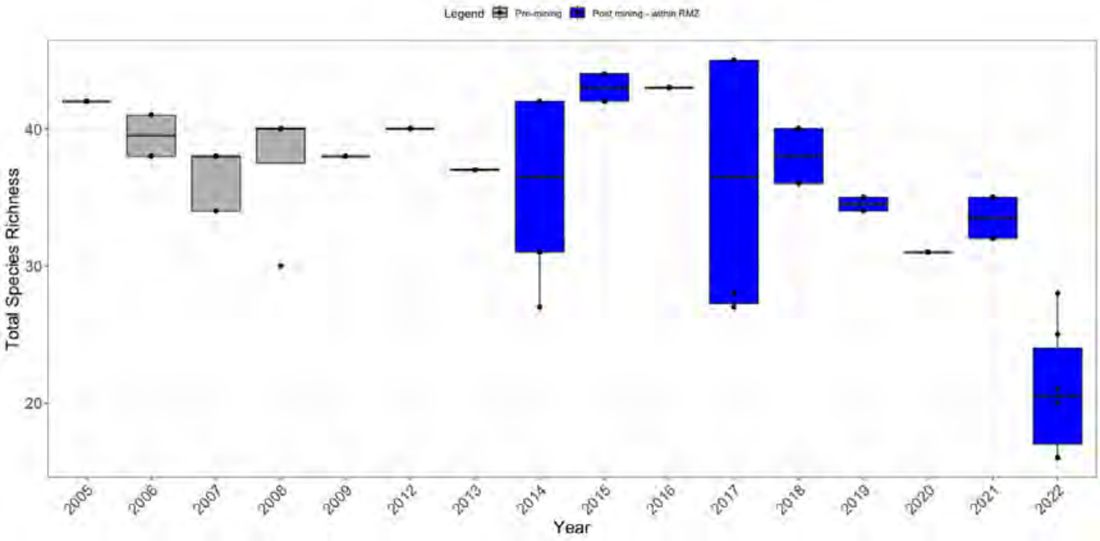
Table 12: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
segment1	1.52	0.47	0.59	2.44
segment2	-8.00	0.73	-9.44	-6.56

9 Results - Swamp S1B

Monitoring at swamp S1B began in 2005, and this swamp was impacted in 2013. Please note, this impact swamp was not monitored in 2010 and 2011. The boxplot of TSR data (Figure 13) shows that since impact, TSR has become more variable, and declined to lower levels than before impact.

The best model had one break point (Table 13) and was plotted against the underlying data and fitted linear regression model (Figure 14). Estimates of the break point analysis slope parameters are given in Table 14. The second slope was found to be significantly different to 0, i.e., prior to the break point, no linear trend was found to be significant, however after the break point, there was a significant linear decline in TSR at this swamp.



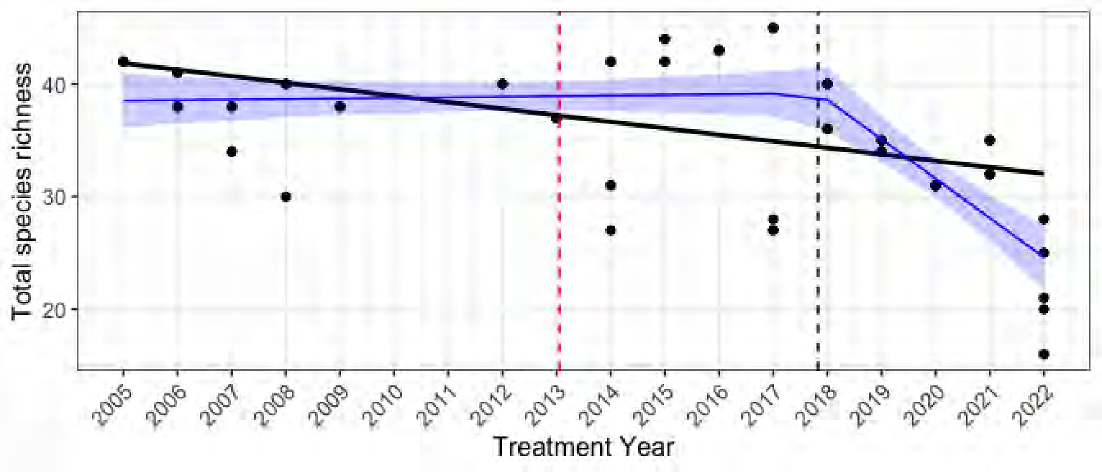


Figure 14: Best break point analysis model (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Break points indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 13: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Best model	1	0.518	497.68	0.00
Linear model	0	0.226	533.44	35.76

Table 14: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
segment1	0.05	0.15	-0.24	0.35
segment2	-3.55	0.60	-4.73	-2.37

10 Results - Swamp S5

Monitoring at swamp S5 began in 2012, and this swamp was impacted in 2013 (at a single transect). The boxplot of TSR data (Figure 15) suggests there has been a stead decline in TSR at this swamp, and the most recent monitoring period had an observed TSR at the lowest levels since monitoring began.

The best model (see Table 15) was the linear model (i.e., had 0 break points) and was plotted against the underlying data and fitted linear regression model (Figure 16). Estimates of the break point analysis slope parameters are given in Table 16. No breakpoints were found to be significant, and the linear model was found to have a significant linear decline in TSR over the monitoring period.

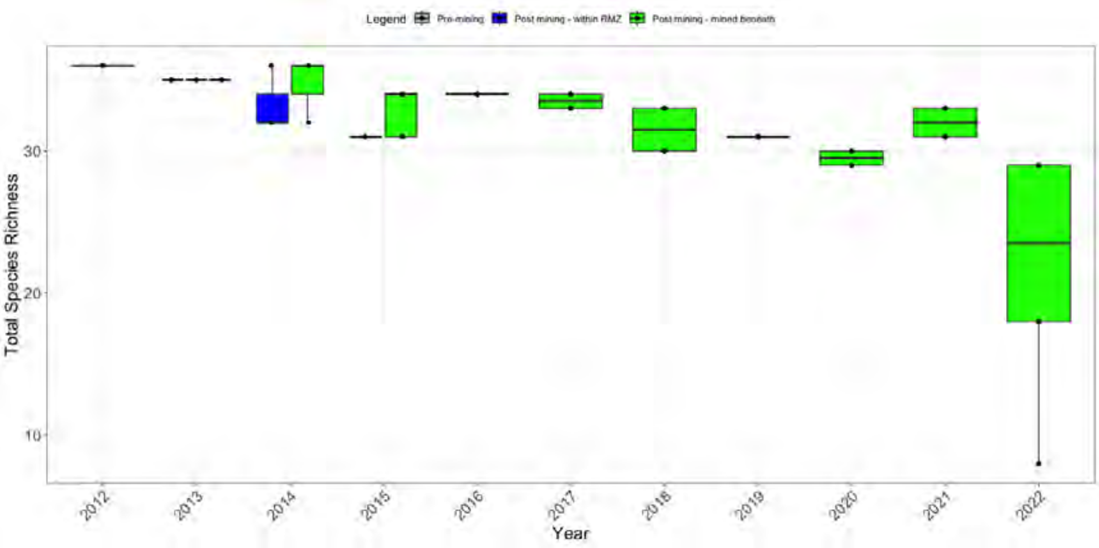


Figure 15: Boxplot of the total species richness for each transect at impact swamp S15, contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

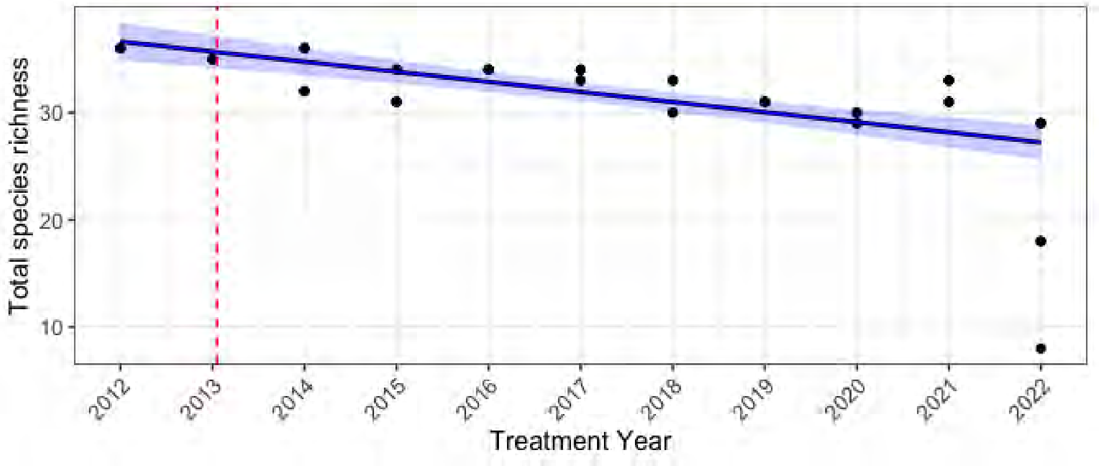


Figure 16: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data.

Table 15: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.408	340.47	0

Table 16: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	-0.94	0.14	-1.22	-0.66

11 Results - Swamp S23

Monitoring at swamp S23 began in 2017, and this swamp was impacted in 2018. The boxplot of TSR data (Figure 17) suggests that TSR at this swamp has steadily declined over the monitoring period. A break point analysis was not conducted last year due to limited data. This year, no break points were estimated due to convergence issues.

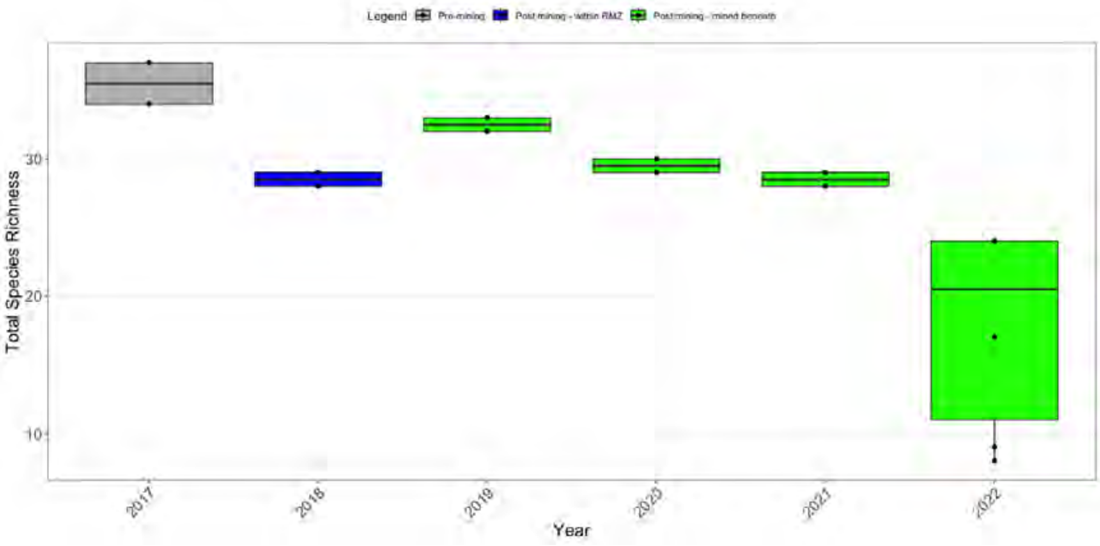


Figure 17: Boxplot of the total species richness for each transect at impact swamp S23, contrasted against all control swamps. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

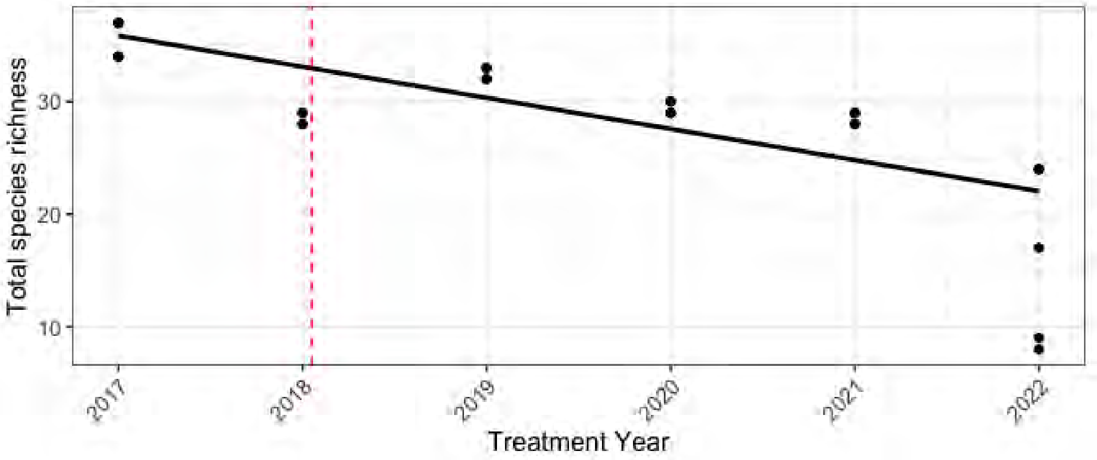


Figure 18: No break points could be estimated due to convergence issues, so the linear model is shown (black line) plotted against data.

12 References

Holm, S. (1979). A simple sequentially rejective multiple test procedure. Scandinavian Journal of Statistics 6, 65–70.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL *https://www.R-project.org/*.

Analytical Edge (2021). *Analysis of flora species composition at impact swamps within the Dendrobium region, Data collected up to, and including, 2020*. Unpublished report submitted to Niche.

THE ANALYTICAL EDGE
STATISTICAL CONSULTING

Task 2B - break point analysis of priority species richness at swamps within the Dendrobium region

Data collected up to and including 2022

20 March 2023

Project History and Version Control

Date	Amendments	Person
27 Feb 2023	Received data from Luke Stone (Niche).	JP
13 Mar 2022	Received revised data from Luke Stone (Niche).	JP
20 Mar 2022	Draft report submitted to Luke Stone (Niche).	JP

Table of Contents

1 Data Summary

On 13 March 2023, The Analytical Edge (hereafter, TAE) received a revised data set from Luke Stone (Niche) via e-mail. It contained data collected during flora swamp monitoring within the Dendrobium region up to and including 2022 (*'a7290_2022_FloristicData_rev_02_20230313.xlsx'*, 16.7 MB).

Notes:

(1) Many species names and complexes had been revised since the previous analysis.

(2) As per previous years, all data relating to swamp S1 were omitted from the analysis.

(3) Different to previous years, S15A(1) is now considered an impact swamp (i.e., all previous years of 'control' data are now classified pre 'impact'). This swamp was not analysed using the break point analysis, due to limited data.

(4) A new 'control' swamp has been added (S131).

(5) 14 records were classified as 'QUADRAT DEAD' and were excluded from the analysis.

Disclaimer: This data file is assumed to be error-free. Any further errors detected by Niche may invalidate the results and conclusions made in this report and will require the analysis to be re-run under the proviso of new contract agreements.

2 Methods

To date, analysis of total species richness data has been undertaken in a series of 2-, 3-, and 4- yearly comparisons. Conducting multiple testing such as this can lead to erroneous interpretation of results; through statistical chance alone, 5% of tests may be concluded significant, and this chance is elevated when multiple tests are conducted. Methods exist for multiple correction (e.g., Holm 1979) but this will decrease the power to detect a difference, if one exists. In addition, this approach doesn't identify any significant break points that might exist in the data.

TAE has previously proposed alternative methods to analyse these data (e.g., using a broken-stick approach), and last year was the first attempt to analyse these data using such an approach (TAE, 2022). This report follows the same format as last year, i.e., a linear model was fit to the number of detection events of select species (as identifiedi by Niche) at each impact swamp. Then estimates of break points were explored (i.e., 1, 2 or 3 break points) and selected based on AIC model selection. All analyses were conducted in R (v. 4.1.2, R Core Team 2021).

3 Results - Swamp S15A(2)

3.1 Baeckea imbricata

Baeckea imbricata was identified by Niche as a species of interest. Figure 1 shows the number of times *Baeckea imbricata* was detected at each transect within swamp S15A(2), slowly trending to 0 detection events by 2020. The break point analysis did not detect any significant break points since the linear model had the lowest AIC (Table 1). There was a statistically significant decline in the number of detection events of this species since monitoring began (Figure 2). The model with 0 break points (i.e., the linear model) and was plotted against the underlying data for comparison (Figure 2).

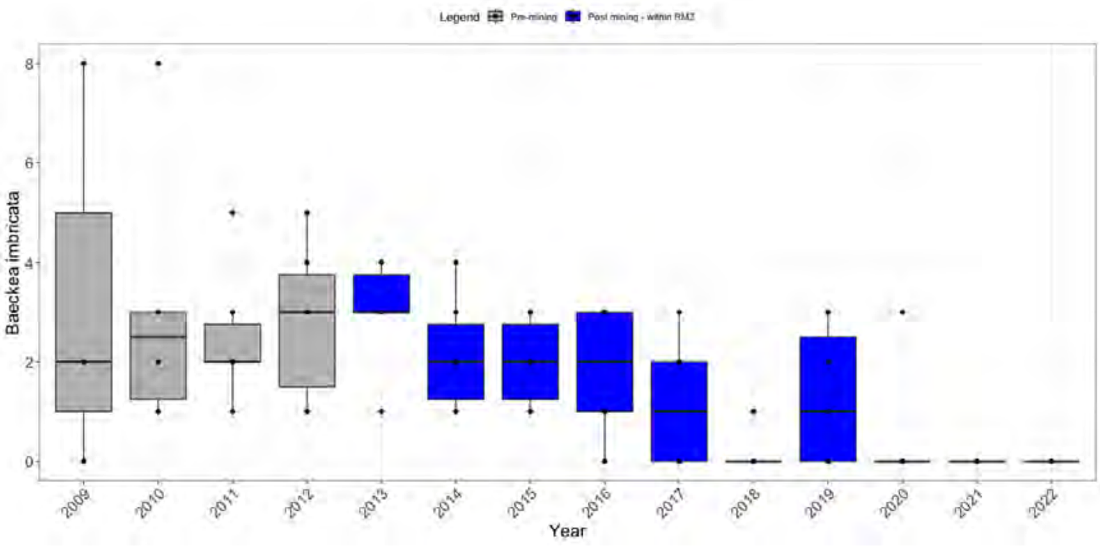


Figure 1: Boxplot of Bakea imbricata for each transect at impact swamp S15A(2). The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

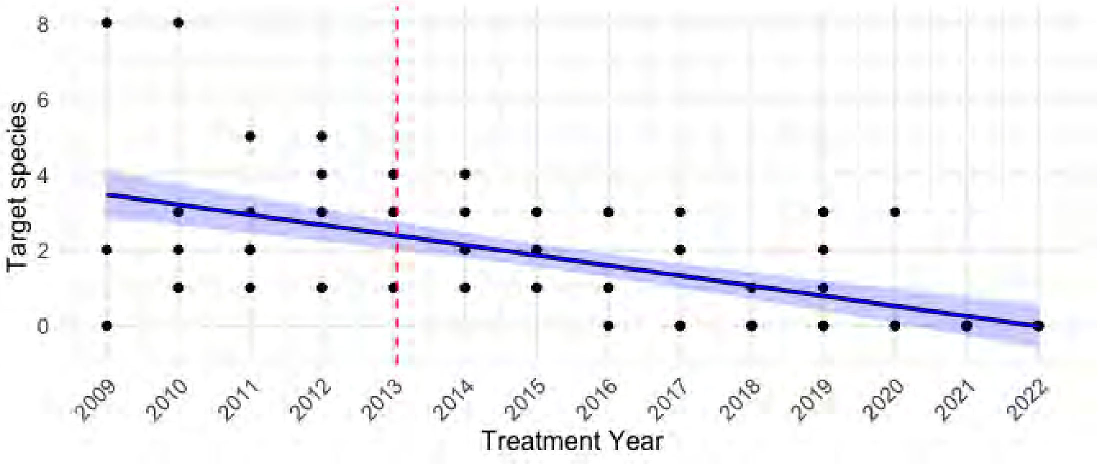


Figure 2: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 1: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.364	288.65	0

Table 2: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	-0.27	0.04	-0.35	-0.19

3.2 Bauera microphylla/ rubioides sp complex

Bauera microphylla/ rubioides sp complex was identified by Niche as a species of interest. Figure 3 shows the number of times *Bauera microphylla/ rubioides sp complex* was detected at each transect within swamp S15A(2), slowly trending to a very low number of detection events by 2021. The best model (see Table 3) had 1 break point and was plotted against the underlying data and fitted linear regression model (Figure 4). Estimates of the break point analysis slope parameters are given in Table 4. Until 2015, there was a positive increase in the number of detection events of this species, after which there has been a statistically significant decline.

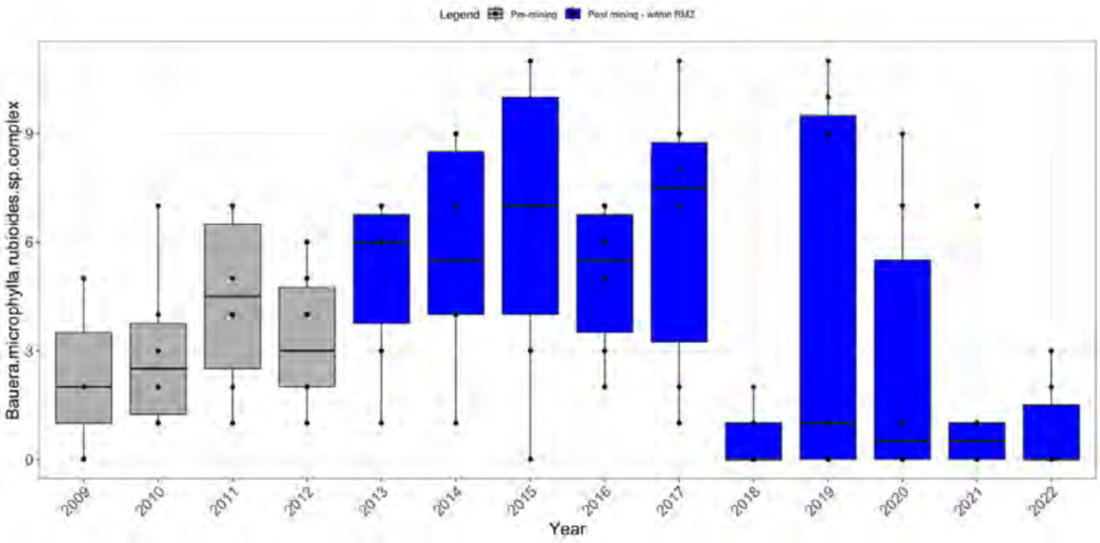


Figure 3: Boxplot of Bauera microphylla rubioides sp complex for each transect at impact swamp S15A(2). The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

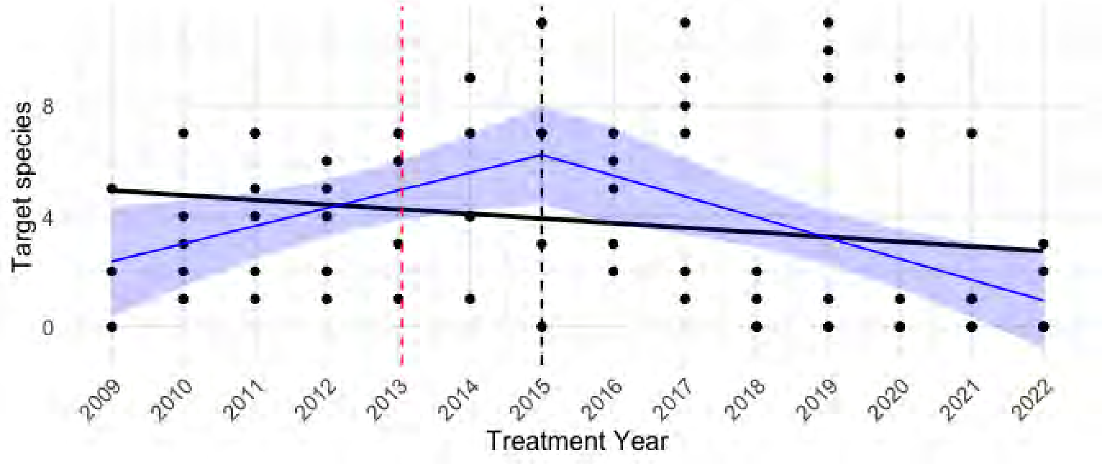


Figure 4: Best break point analysis model (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Break points indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 3: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Best model	1	0.195	421.17	0.0
Linear model	0	0.037	431.67	10.5

Table 4: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
segment1	0.64	0.27	0.12	1.17
segment2	-1.40	0.36	-2.10	-0.69

4 Results - Swamp S15B

4.1 Leptospermum juniperinum

Leptospermum juniperinum was identified by Niche as a species of interest at swamp S15B. The boxplot of *Leptospermum juniperinum* data (Figure 5) shows that throughout the monitoring period, excluding 2003, the number of detection events of this species has steadily declined. The best model (see Table 5) had 0 break points (i.e., the linear model) and was plotted against the underlying data (Figure 6). Estimates of the break point analysis slope parameters are given in Table 6. The linear decline in the number of detection events was statistically significant over the monitoring period.

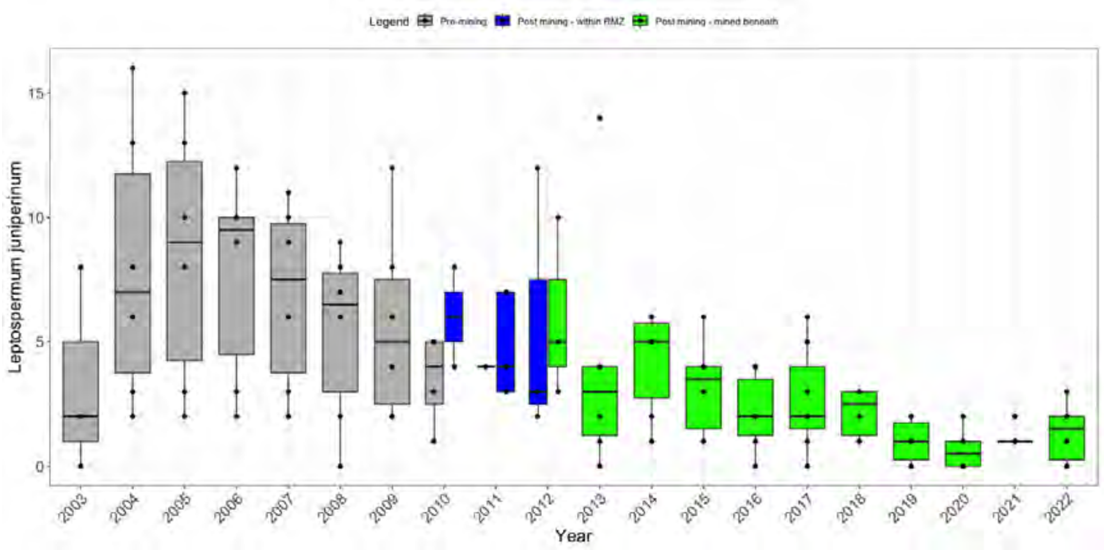


Figure 5: Boxplot of Leptospermum juniperinum for each transect at impact swamp S15B. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

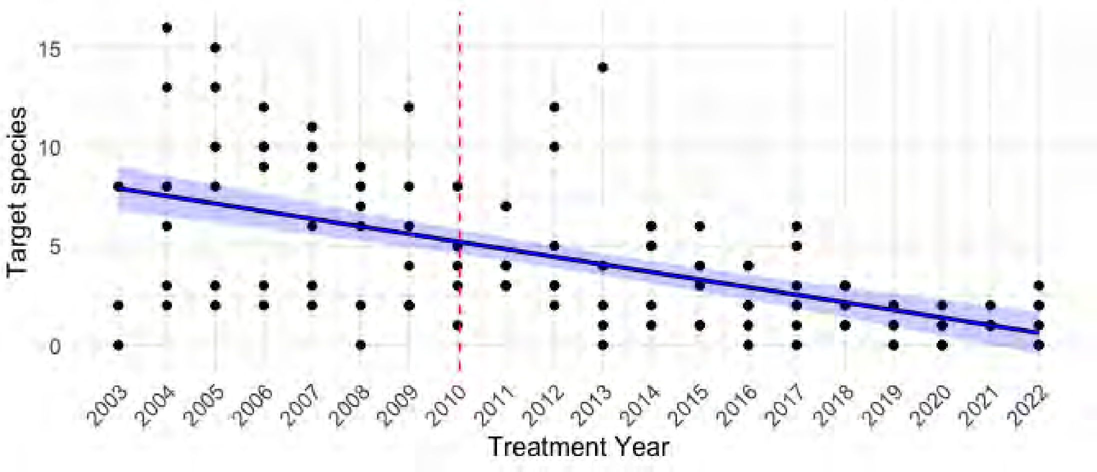


Figure 6: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 5: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.333	604.19	0

Table 6: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	-0.38	0.05	-0.48	-0.28

4.2 Epacris obtusifolia

Epacris obtusifolia was identified by Niche as a species of interest at this swamp. The boxplot of *Epacris obtusifolia* data (Figure 7) shows that throughout the monitoring period, excluding 2003, the number of detection events of this species has steadily declined. The best model (see Table 8) had 0 break points (i.e., the linear model) and was plotted against the underlying data (Figure 8). Estimates of the break point analysis slope parameters are given in Table 8. There was a statistically significant decline in number of detection events across the monitoring period.

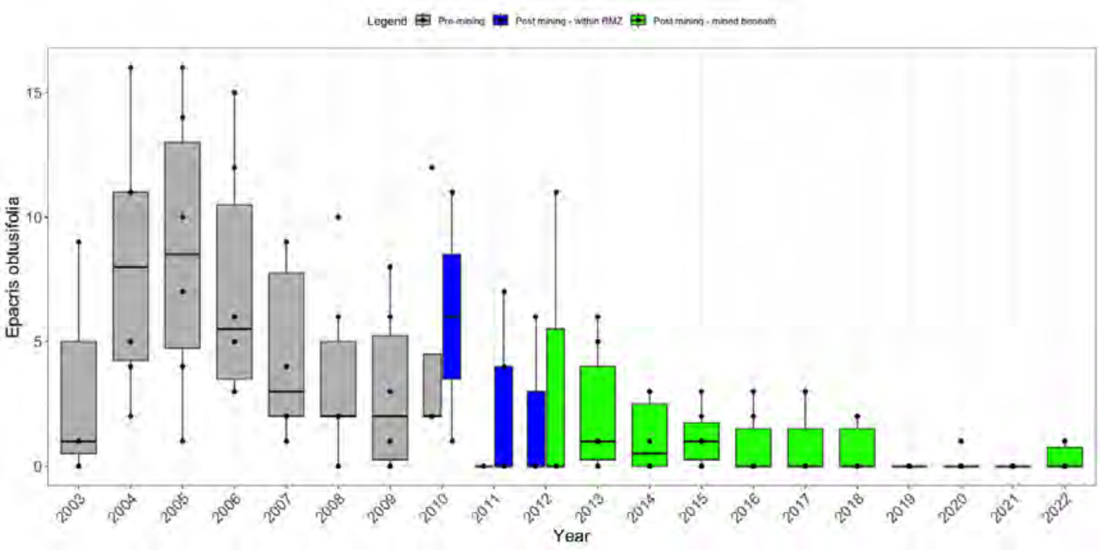


Figure 7: Boxplot of Epacris obtusifolia for each transect at impact swamp S15B. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

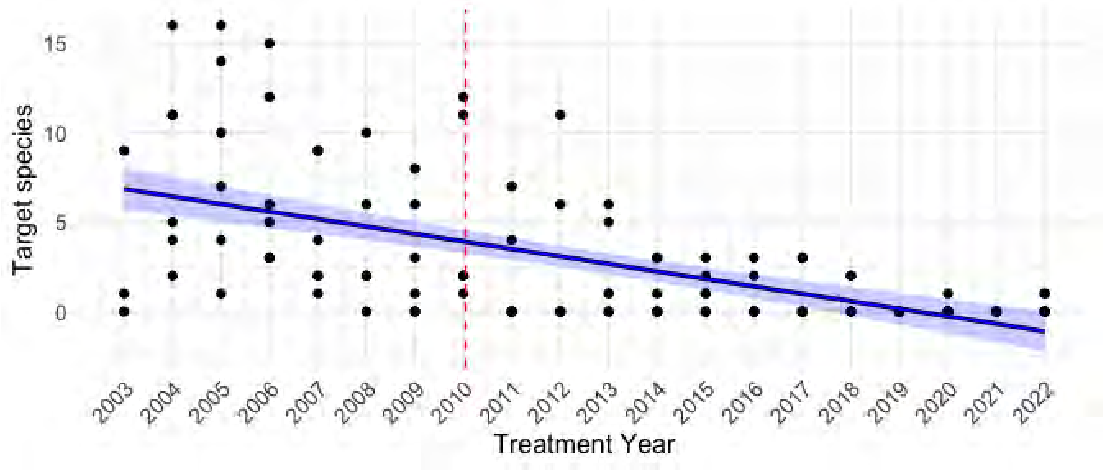


Figure 8: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 7: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.348	617.12	0

Table 8: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	-0.42	0.05	-0.52	-0.31

5 Results - Swamp S11

5.1 Almaleea paludosa

Almaleea paludosa was identified by Niche as a species of interest at this swamp. The boxplot of *Almaleea paludosa* data shows the number of detection events for this species rapidly declining from 2006 to 2012, and by 2020 this species was no longer detected at this swamp (Figure 9). The best model (see Table 9) had 1 break point and was plotted against the underlying data and fitted linear regression model (Figure 10). Estimates of the break point analysis slope parameters are given in Table 10. The period of decline between 2006 and 2012 was found to be significantly significant, which after the number of detection events for this species has been approximately stable.

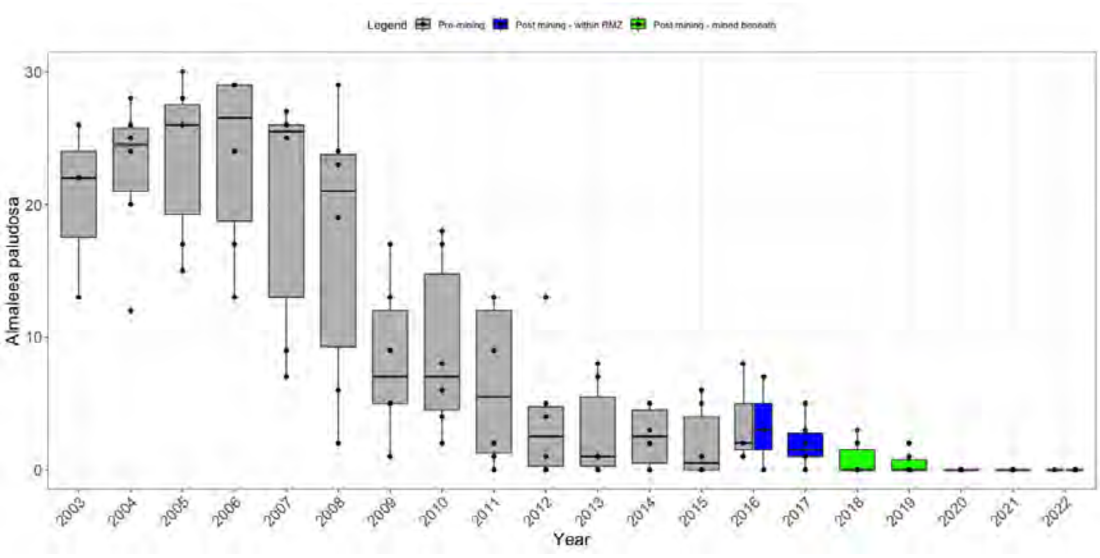


Figure 9: Boxplot of Almaleea paludosa for each transect at impact swamp S11. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

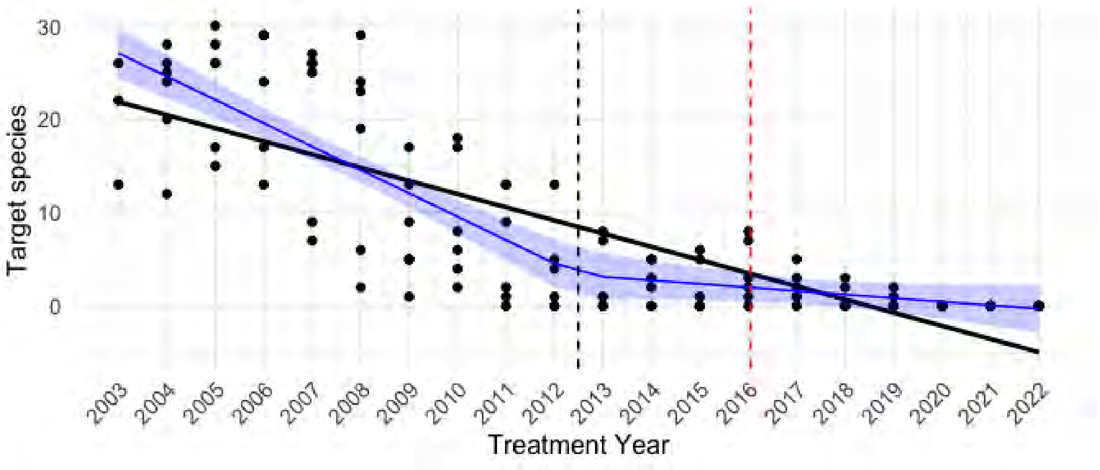


Figure 10: Best break point analysis model (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Break points indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 9: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Best model	1	0.728	720.22	0.00
Linear model	0	0.638	749.36	29.14

Table 10: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
segment1	-2.50	0.25	-3.00	-2.01
segment2	2.12	0.35	1.44	2.80

5.2 Epacris obtusifolia

Epacris obtusifolia was identified by Niche as a species of interest at this swamp. The boxplot of *Epacris obtusifolia* data (Figure 11) shows that throughout the monitoring period the number of detection events of this species has steadily declined and has been 0 since 2021. The best model (see Table 12) had 0 break points (i.e., the linear model) and was plotted against the underlying data (Figure 12). Estimates of the break point analysis slope parameter is given in Table 12. There was a statistically significant decline in number of detection events across the monitoring period.

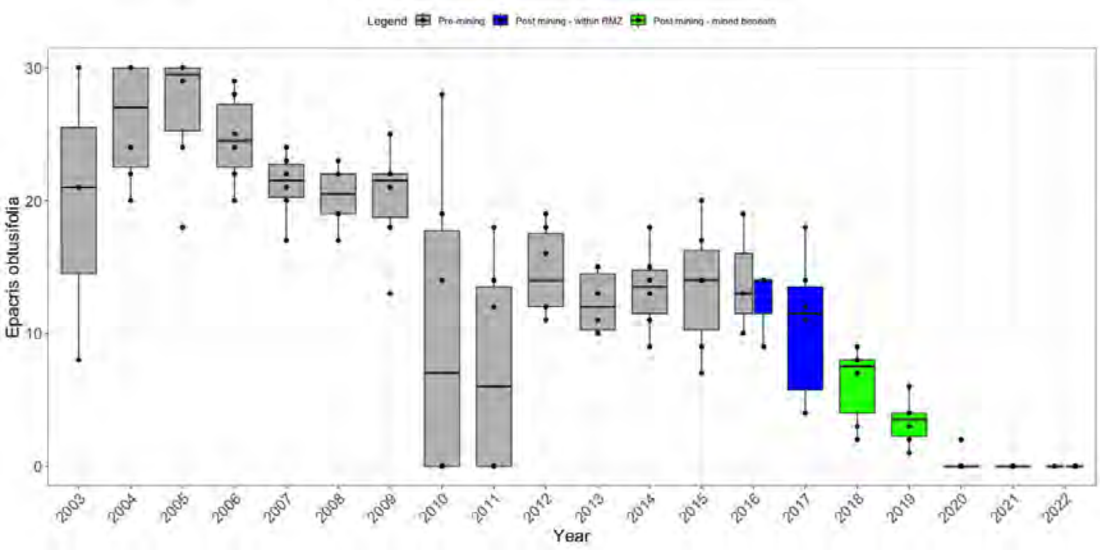


Figure 11: Boxplot of Epacris obtusifolia for each transect at impact swamp S11. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

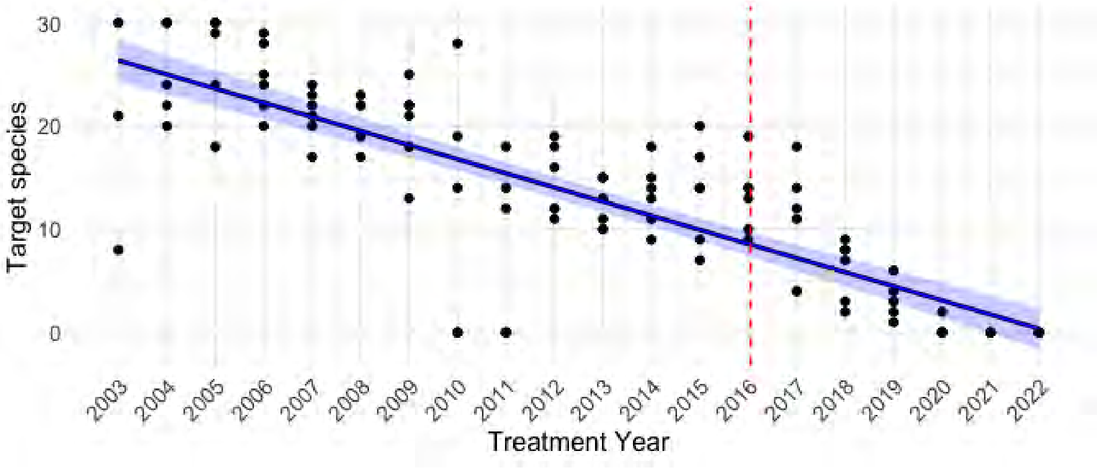


Figure 12: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 11: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.657	732.21	0

Table 12: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	-1.37	0.09	-1.55	-1.19

6 Results - Swamp S13

6.1 Dillwynia floribunda retorta complex

Dillwynia floribunda retorta complex was identified by Niche as a species of interest at this swamp. The boxplot of *Dillwynia floribunda retorta complex* detection events (Figure 13) shows that prior to impact, the number of detection events was quite variable, but since impact the number of detection events has declined. The best model (see Table 13) was the linear model (i.e., no break points, Figure 14). There has been a statistically significant decline in the number of detection events of this species at this swamp since monitoring began.

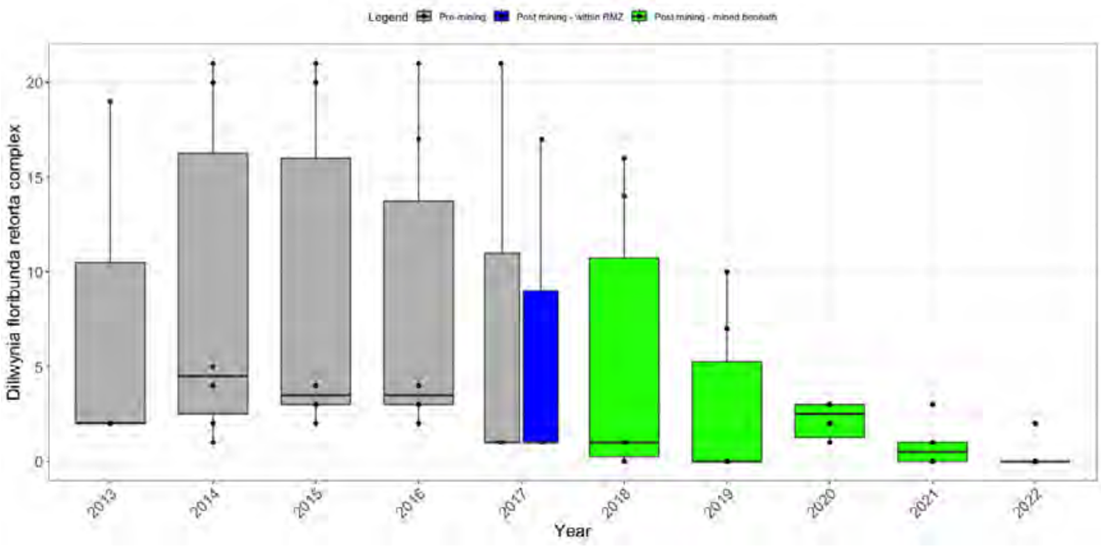


Figure 13: Boxplot of Dillwynia floribunda retorta complex for each transect at impact swamp S13. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

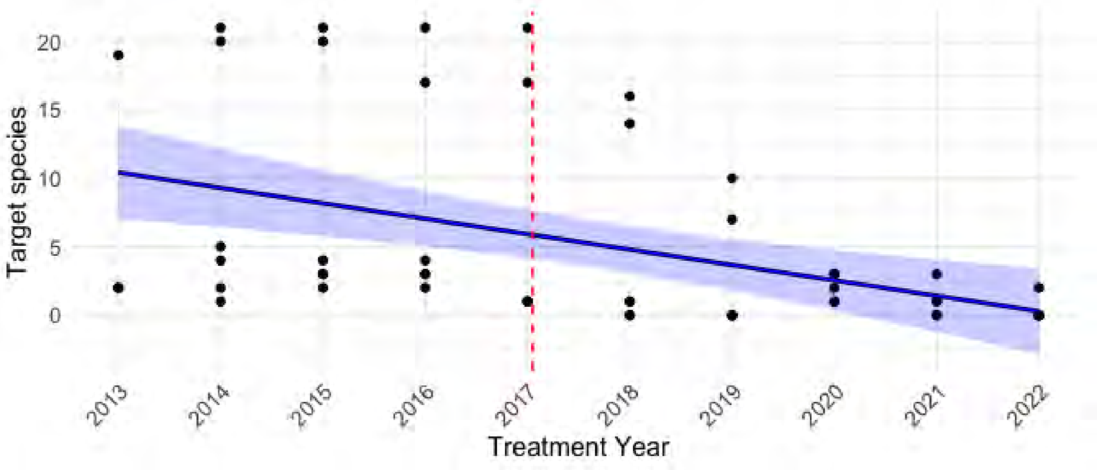


Figure 14: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 13: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.195	377.66	0

Table 14: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	-1.13	0.31	-1.73	-0.52

6.2 Xyris species complex

Xyris species complex was identified by Niche as a species of interest. The boxplot of *Xyris species complex* detection events (Figure 15) shows that throughout the monitoring period, the number of detection events of *Xyris.species.complex* was relatively stable until 2019, after which the number of detection events of this species were much higher. The best model (see Table 15) was the linear model (Figure 16). Estimates of the break point analysis slope parameters are given in Table 16. The increase observed in this species over the course of the monitoring period is statistically significantly.

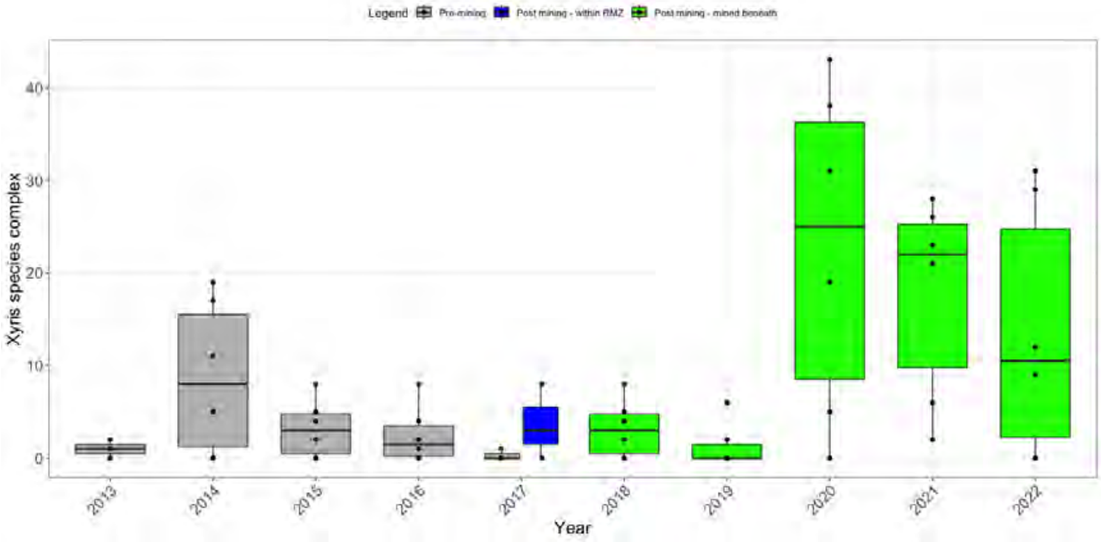


Figure 15: Boxplot of Xyris species complex for each transect at impact swamp S13. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

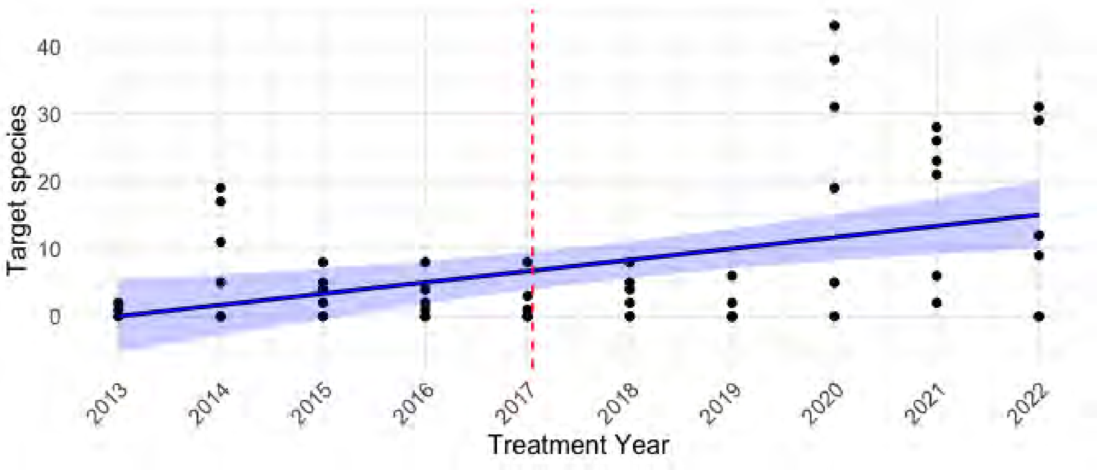


Figure 16: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 15: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.177	429.13	0

Table 16: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	1.67	0.49	0.72	2.62

6.3 Results - Swamp S1B

6.4 Epacris obtusifolia

Epacris obtusifolia was identified by Niche as a species of interest at this swamp. The boxplot of *Epacris obtusifolia* data at swamp S1B (Figure 17) shows that prior to 2016, detection events of the species were relatively common but from 2017 this species has barely been detected. The best model was a linear model (Table 17), which was a significantly linear decline in the number of detection events (Figure 18).

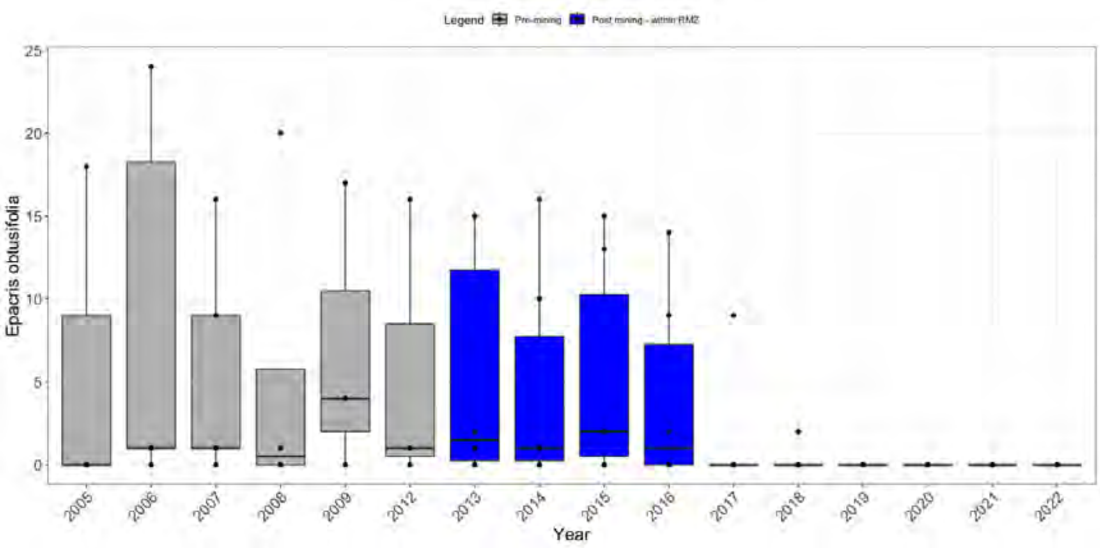


Figure 17: Boxplot of Epacris obtusifolia for each transect at impact swamp S1B. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

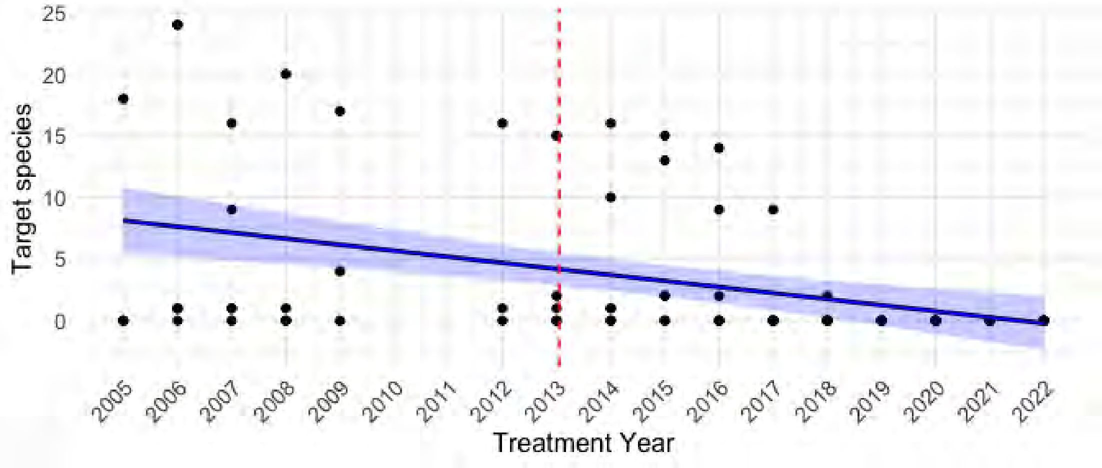


Figure 18: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 17: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.162	540.42	0

Table 18: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	-0.49	0.12	-0.73	-0.25

6.5 Mitrasacme polymorpha/ pilosa species complex

Mitrasacme polymorpha/ pilosa species complex was identified by Niche as a species of interest at this swamp. The boxplot of *Mitrasacme polymorpha/ pilosa species complex* data at swamp S1B (Figure 19) shows that prior to impact, detection events of this species have been variable, however between 2017 and 2020 the number of detection events of this species became very uncommon (mostly 0) but in the past 2 years it has been redetected at this swamp. The best model had a single break point (Table 19, Figure 20). Estimates of the break point analysis slope parameters are given in Table 20. There was initially a period of significant decline, followed by the past two years of a significant increase in detection events of this species at this swamp. The certainty of this break point will become apparent in the coming years of data collection.

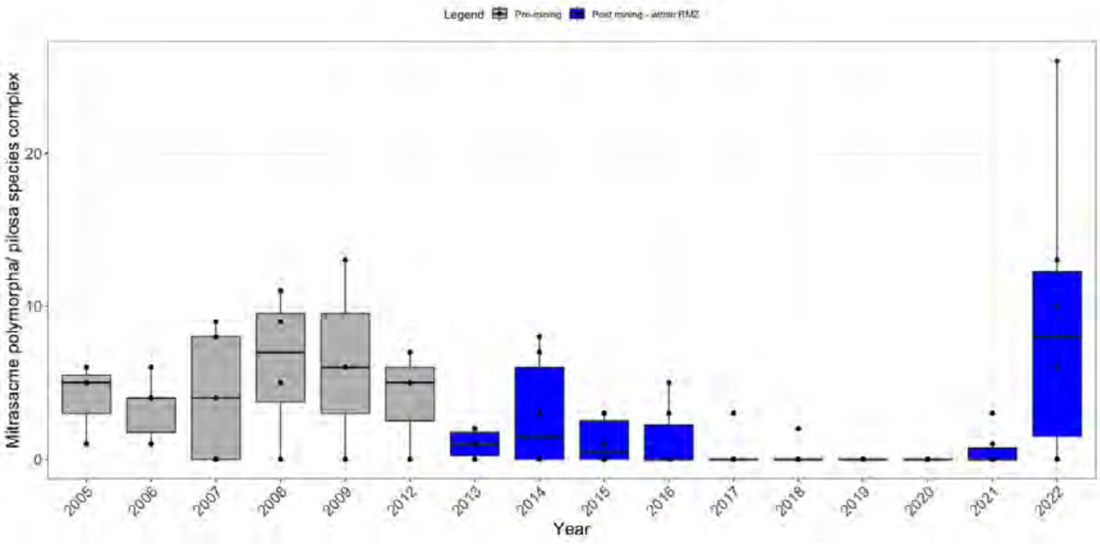


Figure 19: Boxplot of Mitrasacme polymorpha/ pilosa species complex for each transect at impact swamp S1B. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

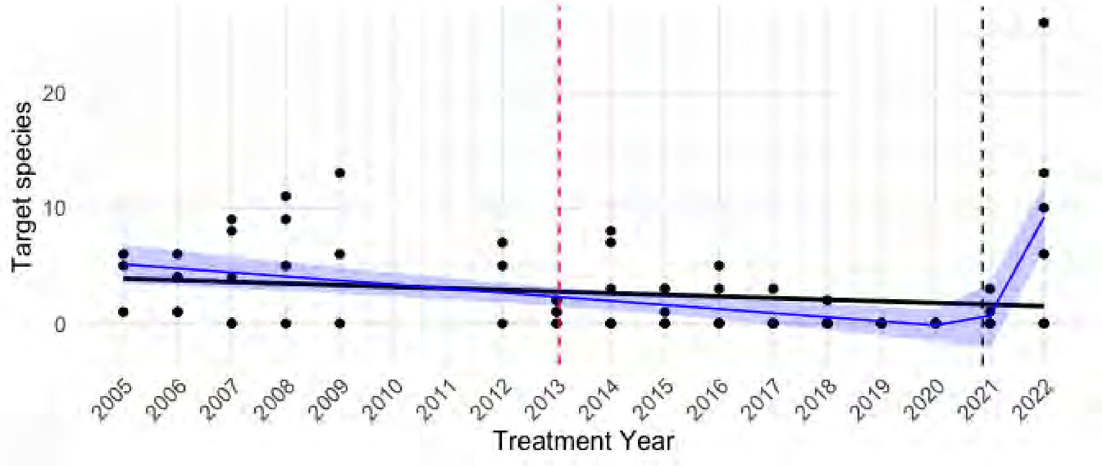


Figure 20: Best break point analysis model (blue line, 95% confidence limits shown by shading) plotted against data. Linear regression shown by black line. Break points indicated by black vertical dashed lines. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 19: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Best model	1	0.340	453.86	0.00
Linear model	0	0.031	482.14	28.28

Table 20: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
segment1	-0.35	0.09	-0.52	-0.18
segment2	8.85	2.01	4.91	12.79

7 Results - Swamp S14

7.1 Epacris obtusifolia

Epacris obtusifolia was identified by Niche as a species of interest at this swamp. The boxplot of *Epacris obtusifolia* data at swamp S14 (Figure 21) shows that prior to 2020 detection events of the species were relatively common but since then this species has not been detected. The best model was a linear model (Table 21), which suggested there was a significantly linear decline in the number of detection events (Figure 22).

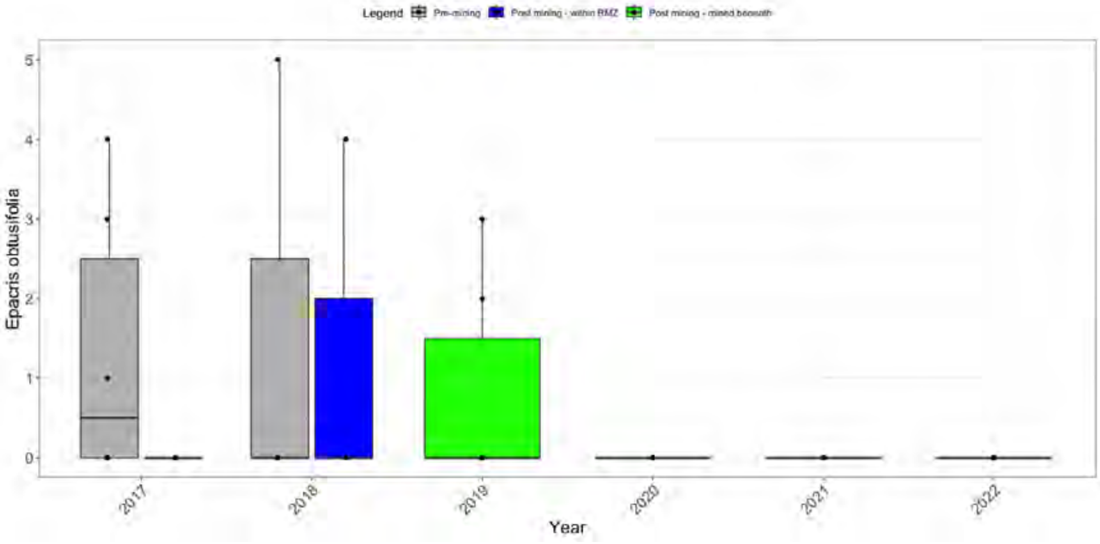


Figure 21: Boxplot of Epacris obtusifolia for each transect at impact swamp S14. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

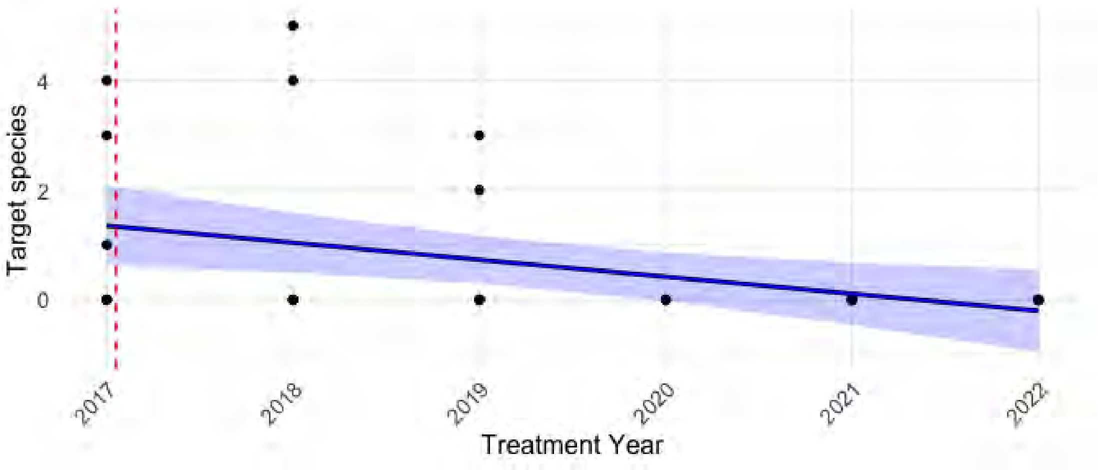


Figure 22: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 21: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.16	126.46	0

Table 22: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	-0.31	0.12	-0.55	-0.08

7.2 Bauera microphylla/ rubioides sp complex

Bauera microphylla/ rubioides sp complex was identified by Niche as a species of interest at this swamp. Figure 23 shows the number of times *Bauera microphylla/ rubioides sp complex* was detected at each transect within swamp S14 was variable. The best model (see Table 23) had 0 break points (i.e., the linear model) and was plotted against the underlying data (Figure 24). Notice there is substantial between transect variation at this swamp. Estimates of the linear model are given in Table 24, that is, no statistically significant decline in the number of detections of this species over the monitoring period was detected.

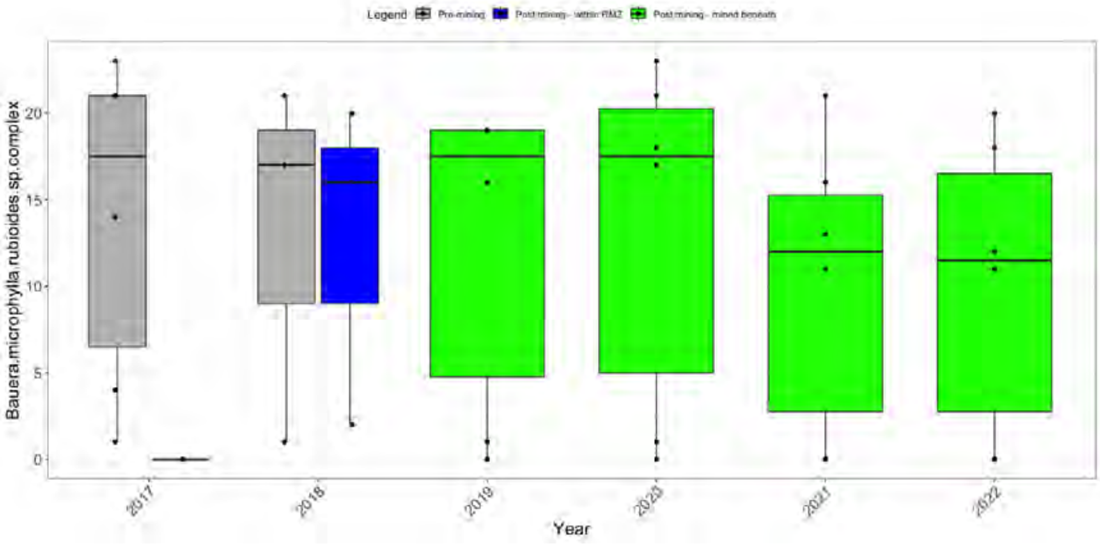


Figure 23: Boxplot of Bauera microphylla/ rubioides sp complex for each transect at impact swamp S14. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

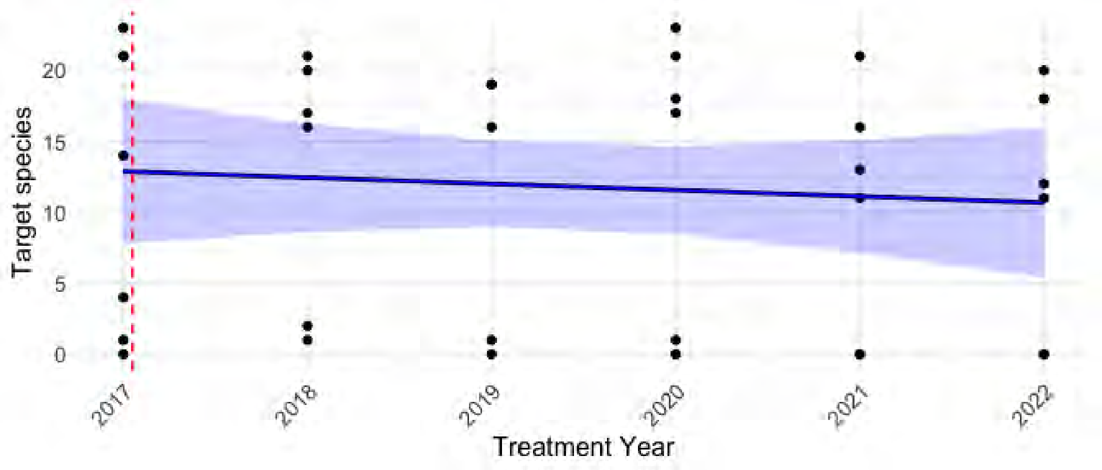


Figure 24: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 23: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.008	270.17	0

Table 24: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	-0.44	0.84	-2.08	1.2

8 Results - Swamp S1A

8.1 Epacris obtusifolia

Epacris obtusifolia was identified by Niche as a species of interest at this swamp. The boxplot of *Epacris obtusifolia* data at swamp S1A (Figure 25) shows that prior to 2019, detection events of the species were in decline, and since 2019 this species has not been detected. The best model was a linear model (Table 25), which suggested there was a significantly linear decline in the number of detection events (Figure 26).

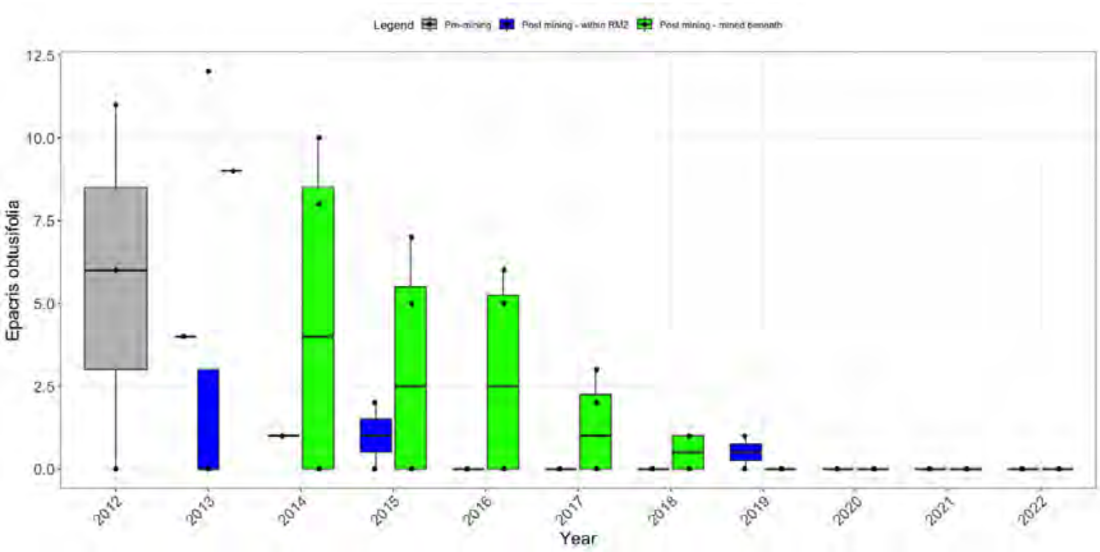


Figure 25: Boxplot of Epacris obtusifolia for each transect at impact swamp S1A. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

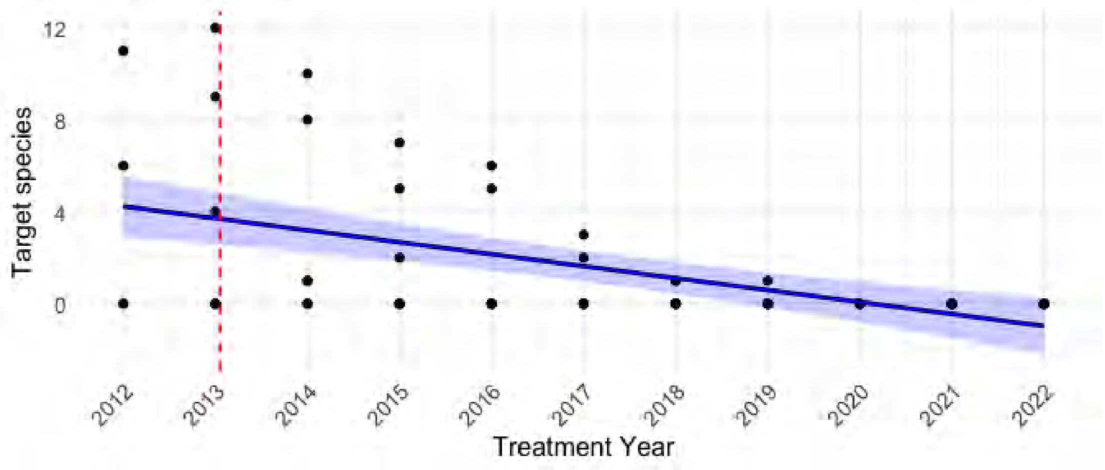


Figure 26: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 25: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.274	304.04	0

Table 26: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	-0.52	0.11	-0.73	-0.31

8.2 Bauera microphylla/ rubioides sp complex

Bauera microphylla/ rubioides sp complex was identified as a species of interest by Niche at swamp S1A. Figure 27 shows the number of times *Bauera microphylla/ rubioides sp complex* was detected at each transect within swamp S14 was variable, however since 2019 has declined (albeit in 2022 was more common again). The best model (see Table 27) had 0 break points (i.e., was linear) and was plotted against the underlying data (Figure 28). Estimates of the linear model are given in Table 28, that is, there was a statistically significant decline in the number of detection events of this species over the monitoring period was detected.

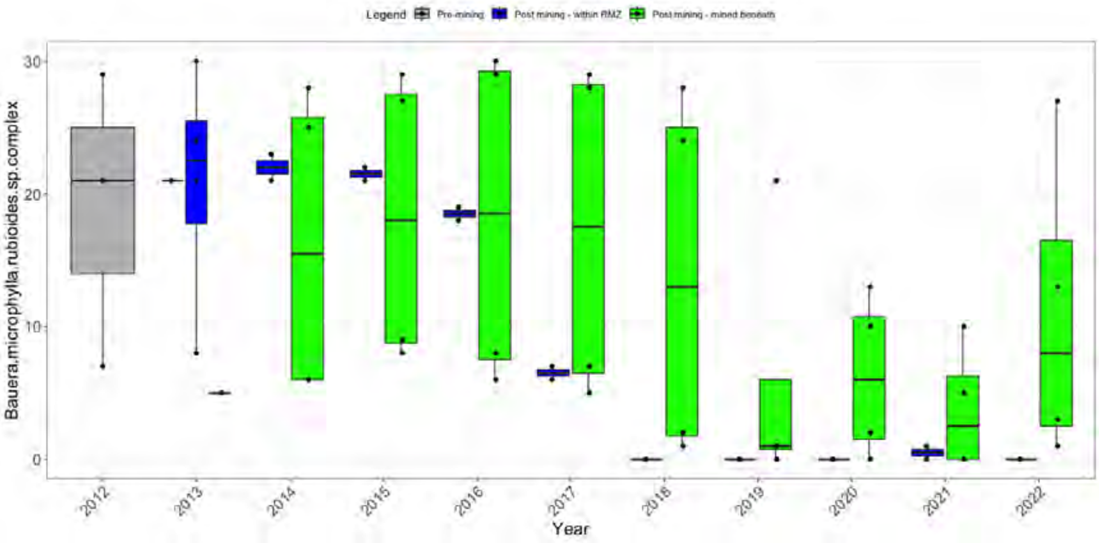


Figure 27: Boxplot of Bauera microphylla/ rubioides sp complex for each transect at impact swamp S1A. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

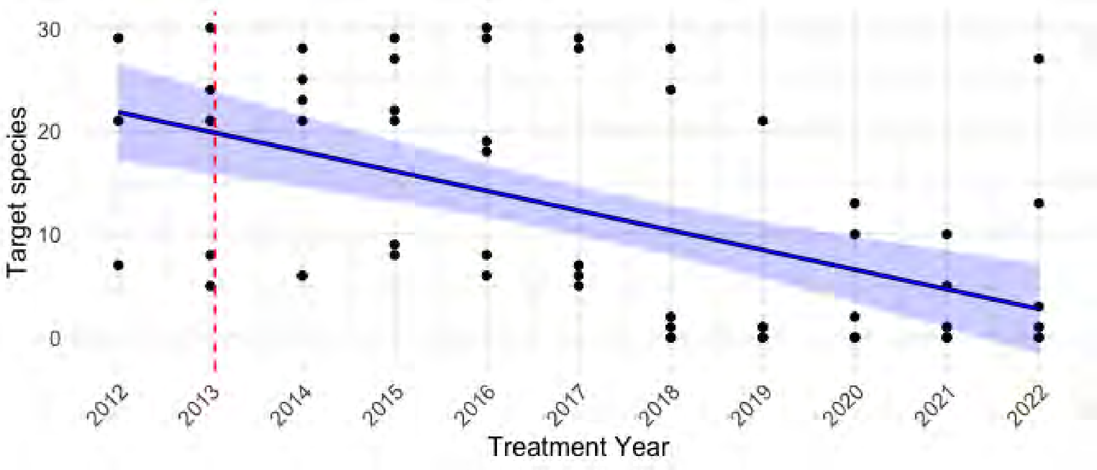


Figure 28: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 27: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.283	464.62	0

Table 28: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	-1.9	0.39	-2.67	-1.14

9 Results - Swamp S23

9.1 Baeckea imbricata

Baeckea imbricata was identified by Niche as a species of interest at swamp S23. Figure 29 shows the number of times *Baeckea imbricata* was detected at each transect within swamp S23; after 2019 this species has not been detected at this swamp. The break point analysis did not detect any significant break points since the linear model had the lowest AIC (Table 29). There was a statistically significant decline in the number of detection events of this species since monitoring began (Figure 30). The model with 0 break points (i.e., the linear model) and was plotted against the underlying data for comparison (Figure 30).

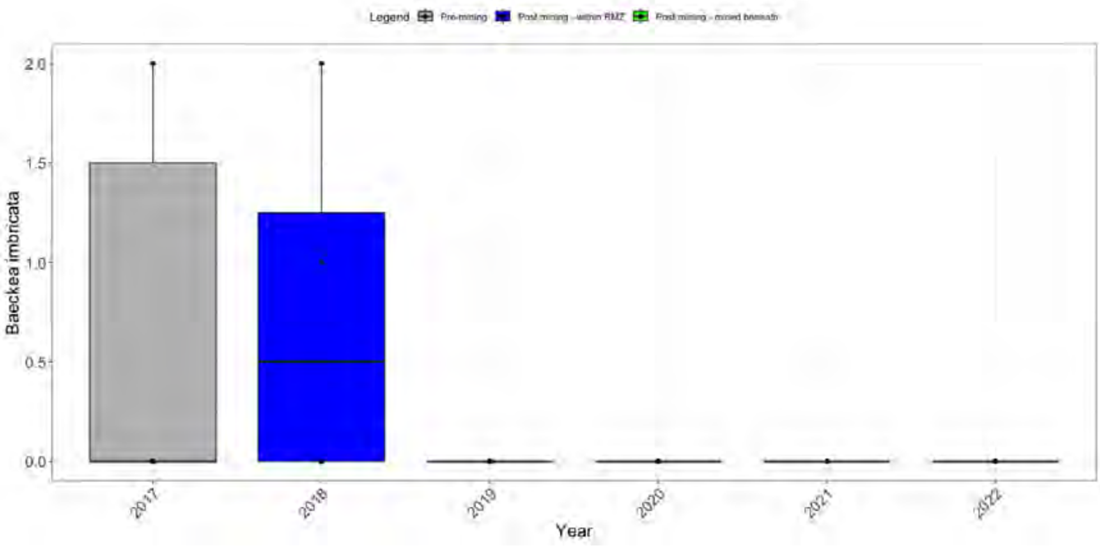


Figure 29: Boxplot of Baeckea imbricata for each transect at impact swamp S23. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

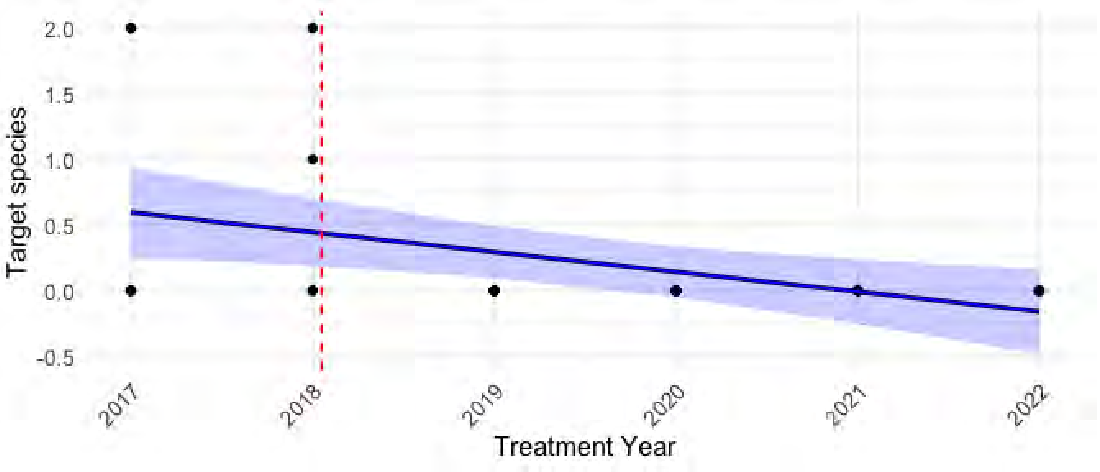


Figure 30: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 29: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.197	58.33	0

Table 30: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	-0.15	0.05	-0.26	-0.05

9.2 Xyris species complex

Xyris species complex was identified by Niche as a species of interest. The boxplot of *Xyris species complex* detection events (Figure 31) shows that throughout the monitoring period, the number of detection events of *Xyris.species.complex* was not detected until 2020, after which the number of detection events of this species was much higher. The best model (see Table 31) was the linear model (Figure 30). Estimates of the break point analysis slope parameters are given in Table 32. The increase observed in this species over the monitoring period is statistically significantly, however should be intrepreted with caution due to seemingly large between-transect variance and highly influential observations occuring in 2021 and 2022.

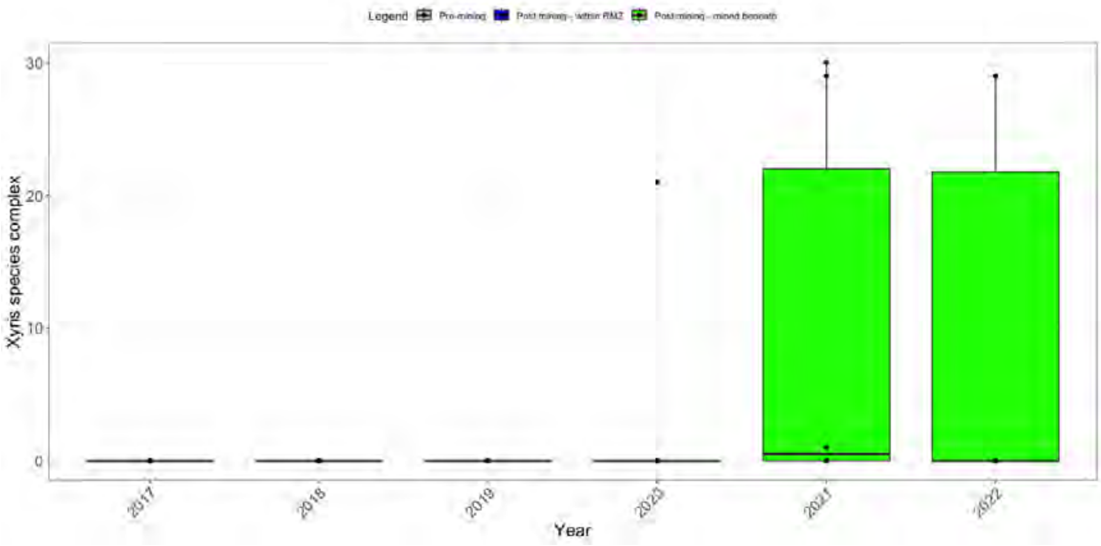


Figure 31: Boxplot of Xyris species complex for each transect at impact swamp S23. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

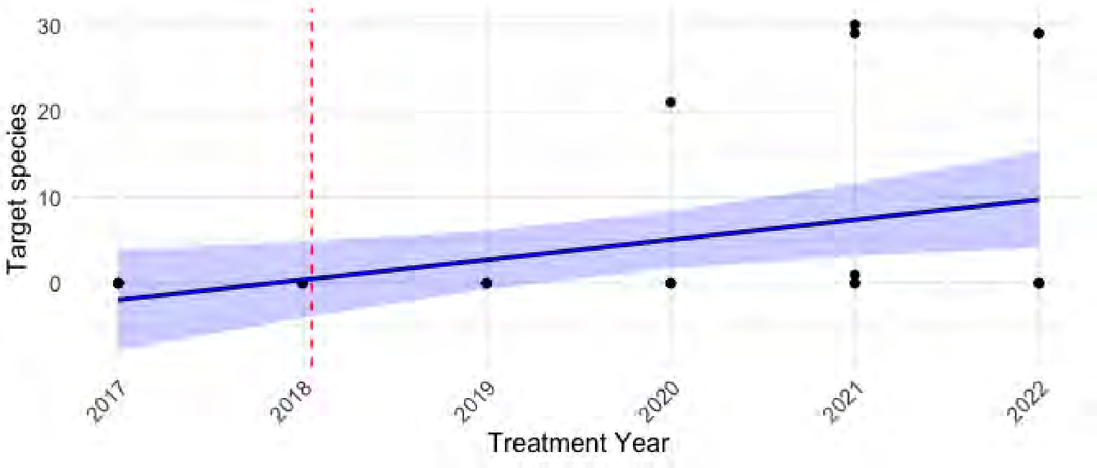


Figure 32: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 31: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.165	251.9	0

Table 32: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	2.33	0.93	0.51	4.14

10 Results - Swamp S5

10.1Bauera microphylla/ rubioides sp complex

Bauera microphylla/ rubioides sp complex was identified by Niche as a species of interest at swamp S5. Figure 33 shows the number of times *Bauera microphylla/ rubioides sp complex* was detected at each transect within swamp S5 has steadily declined over the monitoring period. The break point analysis did not detect any significant break points since the linear model had the lowest AIC (Table 33). There was a statistically significant decrease in the number of detection events of this species since monitoring began (Figure 34), however the between-transect variability is high and this result should be interpreted with a lot of caution.

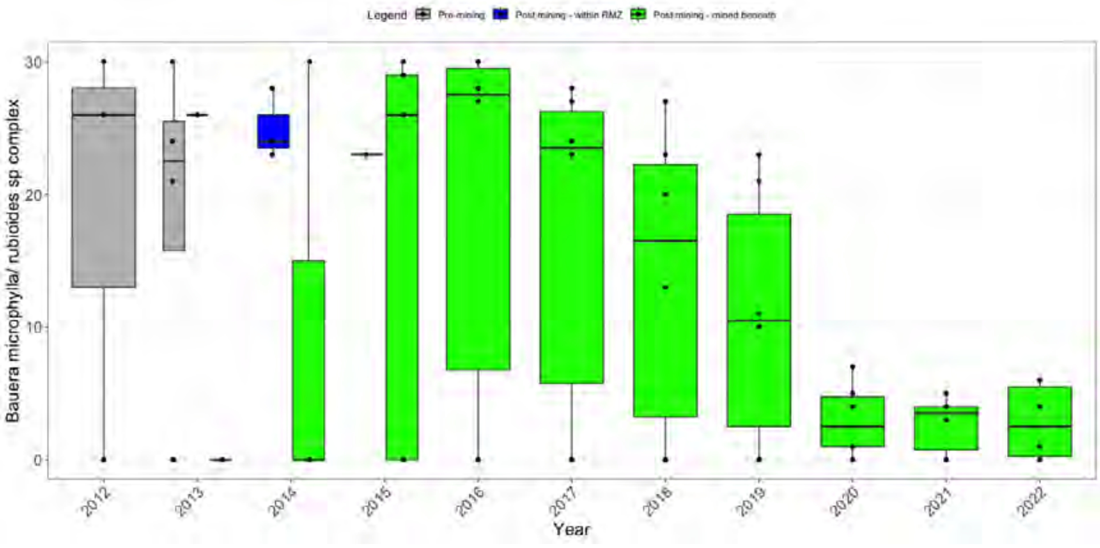


Figure 33: Boxplot of Bauera microphylla/ rubioides sp complex for each transect at impact swamp S15. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

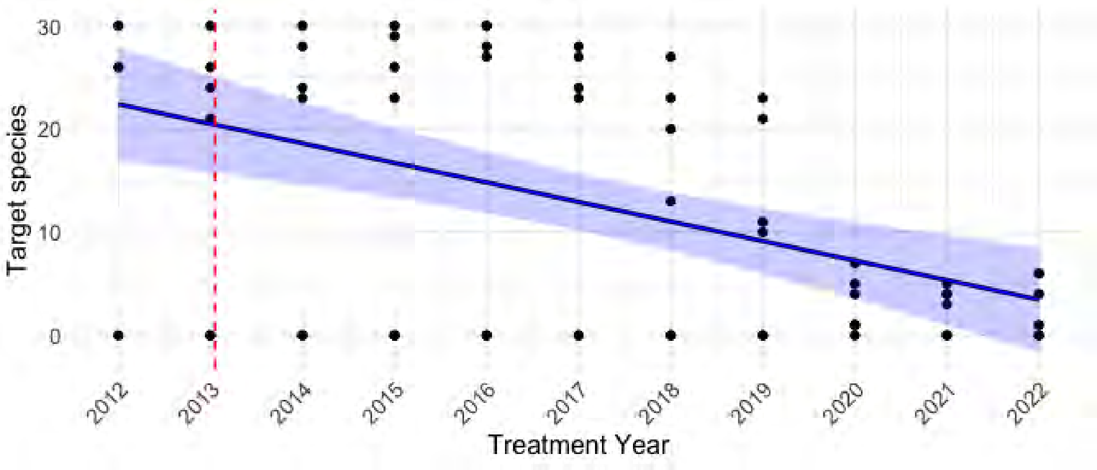


Figure 34: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 33: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.224	483.4	0

Table 34: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	-1.89	0.45	-2.78	-1.01

10.2Xyris species complex

Xyris species complex was identified by Niche as a species of interest. The boxplot of *Xyris species complex* detection events (Figure 35) shows that throughout the monitoring period *Xyris.species.complex* was variable and increasing. The best model (see Table 35) was the linear model (Figure 34, Table 36). The increase observed in this species over the course of the monitoring period is statistically significant.

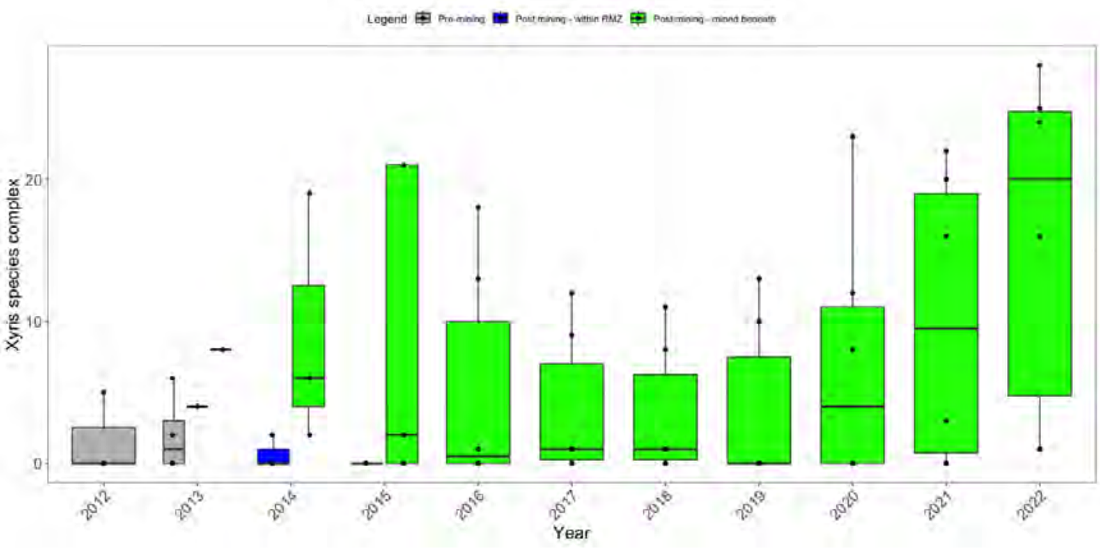


Figure 35: Boxplot of Xyris species complex for each transect at impact swamp S15. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

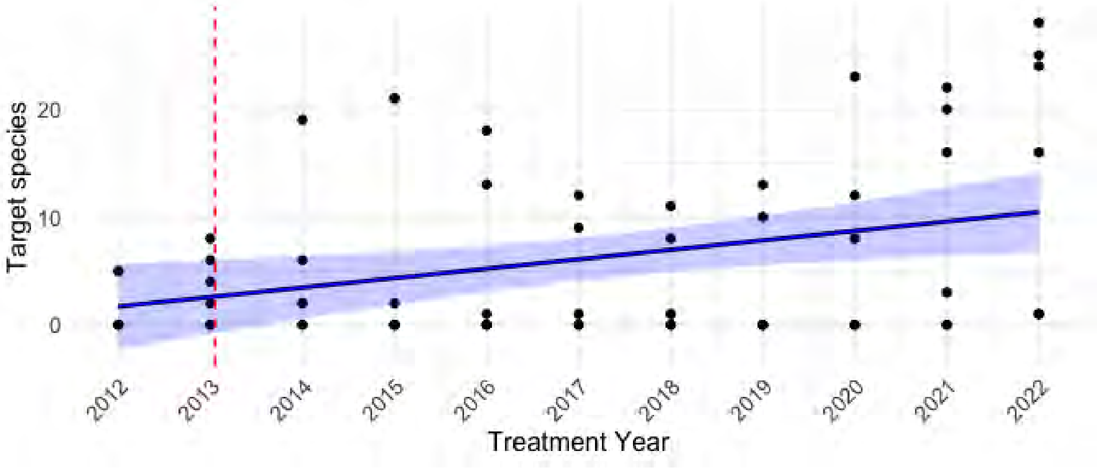


Figure 36: No break points were estimated, so the linear model is shown (blue line, 95% confidence limits shown by shading) plotted against data. Red dashed line indicates impact year (shifted forward 0.05 years).

Table 35: Summary of model fit.

Model	BPs	Rsquared	AIC	dAIC
Linear model	0	0.105	443.19	0

Table 36: Best break point analysis model slope parameters and 95% confidence intervals (CIs).

Slope	Estimate	Standard error	lower CI	upper CI
linear	0.87	0.33	0.23	1.52

11 References

Holm, S. (1979). A simple sequentially rejective multiple test procedure. Scandinavian Journal of Statistics 6, 65–70.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL *https://www.R-project.org/*.

Analytical Edge (2022). *Analysis of flora species composition at impact swamps within the Dendrobium region, Data collected up to, and including, 2021*. Unpublished report submitted to Niche.

Task 3 - Investigation of differences in seasonal monitoring at swamps within the Dendrobium region

Data collected up to and including 2022

Joanne M. Potts

31 March, 2023

Project History and Version Control

Date	Amendments	Person
27 Feb 2023	Received data from Luke Stone (Niche).	JP
13 Mar 2022	Received revised data from Luke Stone (Niche).	JP
31 Mar 2022	Draft report submitted to Luke Stone (Niche).	JP

Table of Contents

1 Data Summary

On 13 March 2023, The Analytical Edge (hereafter, TAE) received a revised data set from Luke Stone (Niche) via e-mail. It contained data collected during flora swamp monitoring within the Dendrobium region up to and including 2022 (‘*a7290_2022_FloristicData_rev_02_20230313.xlsx*’, 16.7 MB).

Notes:

(1) Many species names and complexes had been revised since the previous analysis.

(2) As per previous years, all data relating to swamp S1 were omitted from the analysis.

(3) Different to previous years, S15A(1) is now considered an impact swamp (i.e., all previous years of ‘control’ data are now classified pre ‘impact’).

(4) A new ‘control’ swamp has been added (S131).

(5) 14 records were classified as ‘QUADRAT DEAD’ and were excluded from the analysis.

Disclaimer: This data file is assumed to be error-free. Any further errors detected by Niche may invalidate the results and conclusions made in this report and will require the analysis to be re-run under the proviso of new contract agreements.

2 Methods

The aim of this task was to investigate if any seasonal differences occur at monitored swamps (Table 1, i.e., spring versus autumn monitoring).

First, boxplots of TSR for each year of monitoring, separated by season, were explored for all control and impact swamps. Secondly, the number of unique species detected at each swamp within each season were calculated. Finally, a multivariate abundance model (i.e., see Task 1B) were fitted to all data, specifically testing for season effects. Note, since Swamp 15A(1) has only a single year of post-impact monitoring, the interaction of season and PrePost could not be tested.

All analyses were conducted in R (v. 4.1.2, R Core Team 2021).

Table 1: Monitored swamps classified by whether they are impact or control swamps.

Impact Swamps	Control swamps
S15A(1)	S86
S15A(2)	S87
S15B	S88
S11	S22
S13	S33
S14	S131
S1A	
S1B	
S5	
S23	

3 Results

3.1 Differences in total species richness

Boxplots of total species richness for each control and impact swamp, contrasted by season, are provided in Figure 1 and Figure 2, respectively.

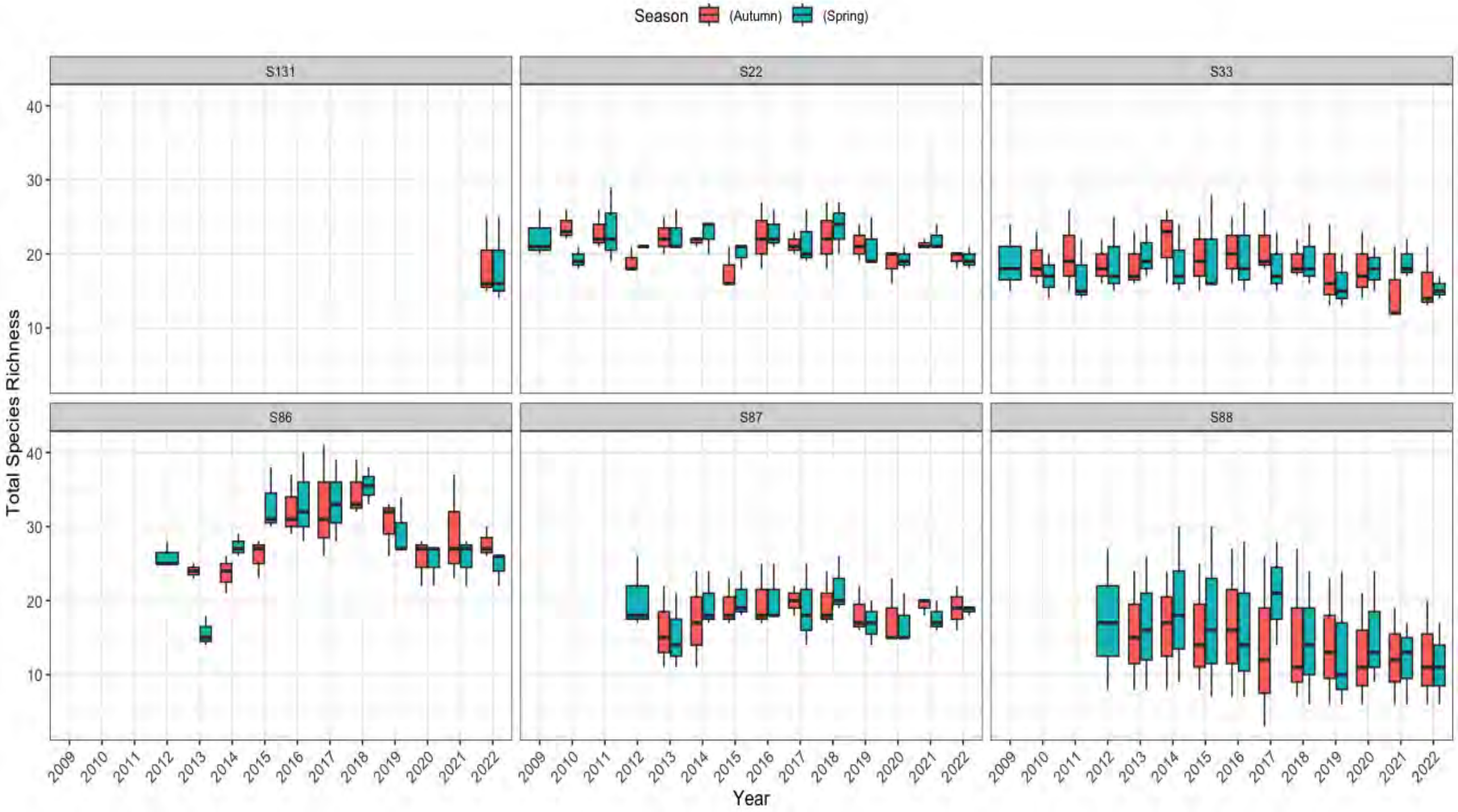


Figure 1: Boxplot of the total species richness for each transect at each control swamp, contrasted by season. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

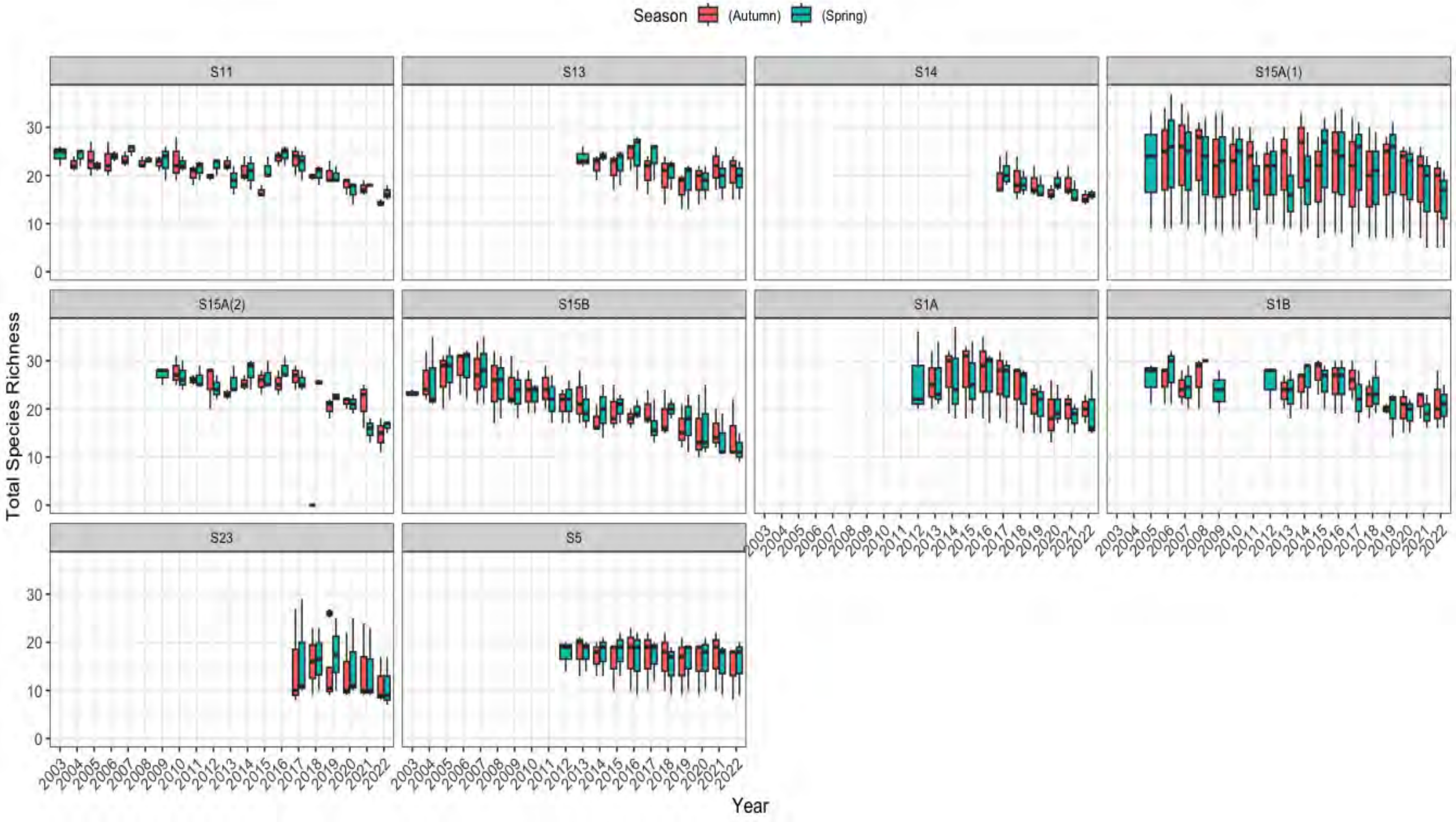


Figure 2: Boxplot of the total species richness for each transect at each impact swamp, contrasted by season. The solid line within the boxes is the median (i.e., the 50th percentile), the margins of the box are the interquartile range (IQR, i.e., the 25th and 75th percentiles), and the whiskers of the boxplot cover 1.5 times the IQR of the data.

3.2 Unique species detected in each season, per swamp

At every swamp, there was a subset of species that were detected in only one of the two seasons visited. Typically, more species are detected in spring and fewer species are detected only in autumn (and not in spring).

3.2.1 S15A(1)

At swamp S15A(1), 52 unique species were detected in autumn, and 53 unique species were detected in spring monitoring. 5 species detected in spring monitoring were *never* detected in autumn, but only 4 species were detected in autumn monitoring and never in spring (Table 2).

Table 2: Unique species detected in only one season at swamp S15A(1).

Species	Autumn	Spring
Baumea acuta	0	12
Brachyloma Monotoca Lissanthe Leucopogon complex	0	8
Lomandra cylindrica/filiformis/micrantha sp complex	0	1
Tetrarrhena juncea	0	17
Xanthorrhoea resinosa/ media sp complex	0	3
Comesperma defoliatum	2	0
Fleshy lily	3	0
Lepidosperma filiforme/urophorum complex	1	0
Thysanotus juncifolius	5	0

3.2.2 S15A(2)

At swamp S15A(2), 64 unique species were detected in autumn, and 65 unique species were detected in spring monitoring. 3 species detected in spring monitoring were *never* detected in autumn, but only 2 species were detected in autumn monitoring and never in spring (Table 3).

Table 3: Unique species detected in only one season at swamp S15A(2).

Species	Autumn	Spring
Epacris paludosa	0	1
Gompholobium minus pinnatum complex	0	1
Leptospermum squarrosum	0	12
Banksia spinulosa var. spinulosa	3	0
Tetrarrhena juncea	1	0

3.2.3 S15B

At swamp S15B, 65 unique species were detected in autumn, and 58 unique species were detected in spring monitoring. 4 species detected in spring monitoring were *never* detected in autumn, yet 11 species were detected in autumn monitoring and never in spring (Table 4).

Table 4: Unique species detected in only one season at swamp S15B.

Species	Autumn	Spring
Acianthus species complex	0	6
Baeckea imbricata	0	2
Genoplesium species complex	0	1
Hakea teretifolia/ sericea sp complex	0	1
Allocasuarina littoralis	1	0
Almaleea paludosa	1	0
Baumea acuta	1	0
Cryptostylis sp_complex	1	0
Goodenia hedercacea/ heterophylla Sp_ complex	1	0
Hakea dactyloides/ salicifolia Sp_ complex	1	0
Lomandra cylindrica/filiformis/micrantha sp complex	1	0
Mirbelia rubiifolia/ speciosa Sp_ Complex	2	0
Petrophile/Isopogon complex	1	0
Pseuderantherum variable/ brunoniella sp complex	1	0
Symphionema paludosum	1	0

3.2.4 S11

At swamp S11, 54 unique species were detected in autumn, and 60 unique species were detected in spring monitoring. 7 species detected in spring monitoring were *never* detected in autumn, but only 1 species was detected in autumn monitoring and never in spring (Table 5).

Table 5: Unique species detected in only one season at swamp S11.

Species	Autumn	Spring
Acacia terminalis	0	2
Lepyrodia cryptica	0	46
Lomandra cylindrica/filiformis/micrantha sp complex	0	2
Lycopodiella lateralis	0	2
Melaleuca thymifolia	0	1
Mitrasacme polymorpha/pilosa species complex	0	3
Utricularia species complex	0	6
Baumea acuta	4	0

3.2.5 S13

At swamp S13, 60 unique species were detected in autumn, and 60 unique species were detected in spring monitoring. 8 species detected in spring monitoring were *never* detected in autumn, but a different set of 8 species were detected in autumn monitoring and never in spring (Table 6).

Table 6: Unique species detected in only one season at swamp S13.

Species	Autumn	Spring
Allocasuarina littoralis	0	1
Callistemon subulatus	0	1
Dianella caerulea complex	0	3
Epacris microphylla	0	1
Mitrasacme polymorpha/12ilosa species complex	0	1
Patersonia species complex	0	1
Pultenaea aristata	0	4
Thysanotus juncifolius	0	7
Brachyloma Monotoca Lissanthe Leucopogon complex	4	0
Callistemon citrinus	1	0
Dianella revoluta var. revoluta	4	0
Gahnia Sp_complex	14	0
Grevillea sphacelata	5	0
Leptospermum lanigerum	5	0
Selaginella uliginosa	1	0
Xanthorrea media	1	0

3.2.6 S14

At swamp S14, 36 unique species were detected in autumn, and 40 unique species were detected in spring monitoring. 6 species detected in spring monitoring were *never* detected in autumn, and 2 species were detected in autumn monitoring and never in spring (Table 7).

Table 7: Unique species detected in only one season at swamp S14.

Species	Autumn	Spring
Acacia rubida	0	9
Banksia spinulosa var. spinulosa	0	1
Baumea acuta	0	29
Epacris paludosa	0	1
Melaleuca thymifolia	0	3
Monotaxis linifolia	0	3
Lepidosperma filiforme/urophorum complex	1	0
Selaginella uliginosa	1	0

3.2.7 S1A

At swamp S1A, 65 unique species were detected in autumn, and 65 unique species were detected in spring monitoring. 4 species detected in spring monitoring were *never* detected in autumn, and 4 species were detected in autumn monitoring and never in spring (Table 8).

Table 8: Unique species detected in only one season at swamp S1A.

Species	Autumn	Spring
Allocasuarina paludosa	0	1
Banksia marginata	0	1
Patersonia species complex	0	3
Tetraria capillaris	0	2
Comesperma defoliatum	1	0
Epacris paludosa	1	0
Hibbertia riparia species complex	4	0
Tetrarrhena juncea	2	0

3.2.8 S1B

At swamp S1B, 68 unique species were detected in autumn, and 64 unique species were detected in spring monitoring. 6 species detected in spring monitoring were *never* detected in autumn, and 10 different species were detected in autumn monitoring and never in spring (Table 9).

Table 9: Unique species detected in only one season at swamp S1B.

Species	Autumn	Spring
Amperea xiphoclada	0	2
Banksia ericifolia	0	1
Drosera binata	0	2
Hakea teretifolia/ sericea sp complex	0	5
Petrophile/Isopogon complex	0	1
Thysanotus juncifolius	0	1
Calytrix tetragona	1	0
Comesperma defoliatum	4	0
Comesperma sphaerocarpum	1	0
Grevillea sphacelata	31	0
Hibbertia riparia species complex	2	0
Lagenifera stipitata	1	0
Leptospermum squarrosum	5	0
Mirbelia rubiifolia/ speciosa Sp_ Complex	3	0
Parsonsia straminea	4	0
Persoonia lanceolata	1	0

3.2.9 S5

At swamp S5, 47 unique species were detected in autumn, and 43 unique species were detected in spring monitoring. 2 species detected in spring monitoring were *never* detected in autumn, and 6 species were detected in autumn monitoring and never in spring (Table 10).

Table 10: Unique species detected in only one season at swamp S5.

Species	Autumn	Spring
Acacia rubida	0	1
Dampiera purpurea	0	9
Comesperma defoliatum	3	0
Cryptandra ericoides	13	0
Cryptostylis sp_complex	1	0
Goodenia hedercacea/ heterophylla Sp_ complex	10	0
Patersonia species complex	1	0
Petrophile/Isopogon complex	1	0

3.2.10 S23

At swamp S23, 41 unique species were detected in autumn, and 48 unique species were detected in spring monitoring. 8 species detected in spring monitoring were *never* detected in autumn and was a single species detected in autumn monitoring and not in spring (Table 11).

Table 11: Unique species detected in only one season at swamp S23.

Species	Autumn	Spring
Baeckea linifolia	0	1
Bossiaea scolopendria	0	1
Leptospermum rotundifolium	0	15
Micrantheum ericoides	0	1
Schizaea bifida	0	1
Stylidium Sp_ complex	0	1
Tetraria capillaris	0	6
Thysanotus juncifolius	0	2
Acacia terminalis	1	0

3.2.11 S86

At swamp S86, 74 unique species were detected in autumn, and 82 unique species were detected in spring monitoring. 15 species detected in spring monitoring were *never* detected in autumn, but only 7 species were detected in autumn monitoring and never in spring (Table 12).

Table 12: Unique species detected in only one season at swamp S86.

Species	Autumn	Spring
Comesperma ericinum f. A	0	1
Conospermum tenuifolium	0	1
Dodonaea camfieldii	0	3
Drosera binata	0	1
Epacris paludosa	0	3
Eurychorda complanata	0	1
Goodenia hedercacea/ heterophylla Sp_ complex	0	5
Hybanthus monopetalus	0	1
Lepidosperma limicola	0	1
Leptomeria acida	0	1
Leptospermum rotundifolium	0	1
Melaleuca linariifolia	0	13
Orchidaceae indeterminate	0	1
Persoonia levis	0	1
Pultenaea divaricata	0	31
Allocasuarina littoralis	1	0
Baeckea imbricata	1	0
Bossiaea heterophylla	1	0
Brachyloma Monotoca Lissanthe Leucopogon complex	1	0
Drosera peltata	30	0
Gymnoschoenus sphaerocephalus	1	0
Persoonia lanceolata	1	0

3.2.12 S87

At swamp S87, 45 unique species were detected in autumn, and 48 unique species were detected in spring monitoring. 8 species detected in spring monitoring were *never* detected in autumn, and5 species were detected in autumn monitoring and never in spring (Table 13).

Table 13: Unique species detected in only one season at swamp S87.

Species	Autumn	Spring
Adiantum aethiopicum	0	37
Baumea acuta	0	1
Calochilus campestris	0	3
Eriochilus cucullatus	0	1
Gonocarpus sp_ complex	0	1
Lachnagrostis filiformis	0	1
Leptospermum polygalifolium/trinervium complex	0	1
Mitrasacme polymorpha/pilosa species complex	0	1
Baeckea imbricata	1	0
Comesperma defoliatum	5	0
Pterostylis parviflora	2	0
Pultenaea aristata	2	0
Tetraria capillaris	1	0

3.2.13 S88

At swamp S88, 38 unique species were detected in autumn, and 41 unique species were detected in spring monitoring. 5 species detected in spring monitoring were *never* detected in autumn, but only 2 species was detected in autumn monitoring and never in spring (Table 14).

Table 14: Unique species detected in only one season at swamp S88.

Species	Autumn	Spring
Blandfordia Burchardia Caladenia Haemodorum Microtis Thelymitra species complex	0	4
Dillwynia floribunda retorta complex	0	1
Drosera peltata	0	3
Drosera spatulata	0	1
Panicum simile	0	4
Lomandra cylindrica/filiformis/micrantha sp complex	1	0
Tetrarrhena juncea	30	0

3.2.14 S22

At swamp S22, 47 unique species were detected in autumn, and 47 unique species were detected in spring monitoring. 4 species detected in spring monitoring were *never* detected in autumn, and a separate 4 species were detected in autumn monitoring and never in spring (Table 15).

Table 15: Unique species detected in only one season at swamp S22.

Species	Autumn	Spring
Dampiera stricta	0	1
Poa Sp_ complex	0	6
Stylidium Sp_ complex	0	1
Utricularia species complex	0	2
Actinotus minor	1	0
Baumea acuta	1	0
Boronia parviflora	10	0
Omphacomeria acerba	1	0

3.2.15 S33

At swamp S33, 49 unique species were detected in autumn, and 43 unique species were detected in spring monitoring. 4 species detected in spring monitoring were *never* detected in autumn, and 10 species were detected in autumn monitoring and never in spring (Table 16).

Table 16: Unique species detected in only one season at swamp S33.

Species	Autumn	Spring
Blandfordia Burchardia Caladenia Haemodorum Microtis Thelymitra species complex	0	1
Gonocarpus sp_ complex	0	1
Persoonia levis	0	3
Pittosporum undulatum	0	1
Actinotus minor	1	0
Baumea acuta	1	0
Comesperma defoliatum	1	0
Conospermum tenuifolium	1	0
Cyclosorus interruptus	1	0
Drosera spatulata	1	0
Epacris paludosa	3	0
Mitrasacme polymorpha/pilosa species complex	3	0
Petrophile/isopogon complex	1	0
Plinthanthesis paradoxa	1	0

3.3 Species composition

As per Task 1B, multivariate generalized linear models were fit to impact-swamp specific data to investigate seasonal differences in species composition. No seasonal differences between swamps were detected for all impact swamps, excluding swamp S14 (see Table 17).

Table 17. The total number of unique species, proportion of species detected only once and the output of the full model for each impact swamp monitored in 2022.

Site	ANOVA test of full model

S15A(1)

```
##             Res.Df Df.diff      Dev Pr(>Dev)
## season         103       1 54.21609    0.435
```

S15A(2)

```
##                 Res.Df Df.diff       Dev Pr(>Dev)
## Pre_post            79       1 145.15090    0.044
## season              78       1  52.57192    0.745
## Pre_post:season     77       1  37.98127    0.810
```

S15B

```
##                 Res.Df Df.diff       Dev Pr(>Dev)
## Pre_post           116       1 487.23839    0.001
## season             115       1  62.52937    0.629
## Pre_post:season    114       1  30.18155    0.901
```

S11

```
##                 Res.Df Df.diff       Dev Pr(>Dev)
## Pre_post           114       1 276.41826    0.001
## season             113       1  35.00562    0.955
## Pre_post:season    112       1  25.44648    0.906
```

S13

```
##                 Res.Df Df.diff       Dev Pr(>Dev)
## Pre_post            55       1 142.94940    0.031
## season              54       1  57.78299    0.669
## Pre_post:season     53       1  18.93012    0.984
```

S14

```
##                 Res.Df Df.diff      Dev Pr(>Dev)
## Pre_post            35       1 73.49588    0.059
## season              34       1 77.48308    0.030
## Pre_post:season     33       1 14.95730    0.774
```

S1A

```
##                 Res.Df Df.diff      Dev Pr(>Dev)
## Pre_post            61       1 53.22775    0.650
## season              60       1 28.17037    0.975
## Pre_post:season     59       1 50.67004    0.381
```

S1B

```
##                 Res.Df Df.diff       Dev Pr(>Dev)
## Pre_post            82       1 308.69799    0.001
## season              81       1  52.28988    0.894
## Pre_post:season     80       1  11.45411    0.999
```

S5

```
##                 Res.Df Df.diff      Dev Pr(>Dev)
## Pre_post            61       1 32.58030    0.628
## season              60       1 32.54193    0.733
## Pre_post:season     59       1 10.61835    0.999
```

S23

```
##                 Res.Df Df.diff      Dev Pr(>Dev)
## Pre_post            32       1 37.76030    0.559
## season              31       1 43.01401    0.515
## Pre_post:season     30       1 13.81843    0.939
```

4 Conclusions

No seasonal differences were detected in total species richness (Section 2) or species composition (Section 4), excluding S14 (see Section 3.2.6). When inspecting individual species, most species were more readily detected in spring compared to autumn. However, the removal of autumn surveying would mean species detected only in autumn could potentially be missed (this ranged between a single species and up to 11 unique species at individual swamps, see Section 3).

5 References

Holm, S. (1979). A simple sequentially rejective multiple test procedure. Scandinavian Journal of Statistics 6, 65–70.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL *https://www.R-project.org/*.

Analytical Edge (2022). *Analysis of flora species composition at impact swamps within the Dendrobium region, Data collected up to, and including, 2020*. Unpublished report submitted to Niche.

Annex 3 Littlejohn’s Tree Frog detection data (2007 – 2022)

Table 55: Littlejohn's Tree Frog detection data

Site	Lifestage	Distance (m)	No. breeding pools	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Control																				
DC8	Adults	432	3								5	6	17	8	8	1	8	8	0	9
DC8	Eggmass	432	3								2	1	0	228	7	49	24	0	0	0
DC8	Tadpoles	432	3								12	20	39	21	50	0	100	4	4	0
SC7(1)	Adults	474	20	21	27	0	0	0	1	7	7	3	7	4	19	2	17	20	5	6
SC7(1)	Eggmass	474	20	0	2	0	0	0	0	0	55	75	45	33	8	0	23	6	57	53
SC7(1)	Tadpoles	474	20	0	10	1	47	5	0	0	25	15	0	264	35	208	125	241	111	0
SC7(2)	Adults	436	9			0	6	7	6	11	6	7	15	18	19	2	2	0	2	13
SC7(2)	Eggmass	436	9			20	0	21	0	4	44	10	93	22	0	0	8	0	1	13
SC7(2)	Tadpoles	436	9			15	47	603	40	70	262	96	80	3	144	21	60	373	191	130
SC7A	Adults	453	22	12	0	0	6	7	29	23	15	4	22	14	19	0	7	5	3	9
SC7A	Eggmass	453	22	0	0	15	0	41	2	0	9	147	167	56	25	4	23	0	44	159
SC7A	Tadpoles	453	22	0	10	75	194	864	145	271	67	275	127	1987	162	32	519	634	525	79
SC8	Adults	315	21		2	1	2	3	0	4	0	3	1	2	1	0	4	9	1	7
SC8	Eggmass	315	21							4	7	1	9	6	0	7	9	0	10	7
SC8	Tadpoles	315	21						100	4	82	211	260	1058	74	2	2	190	6	0
WC10	Adults	346	19					15	5	22	7	30	13	44	9	1	110	27	4	11
WC10	Eggmass	346	19					21	0	2	138	16	95	30	10	2	38	59	120	83
WC10	Tadpoles	346	19					208	30	59	46	42	21	40	63	61	684	488	149	45
WC11	Adults	176	6					1	5	4	2	7	4	3	0	0	2	6	2	5
WC11	Eggmass	176	6					1	4	0	17	0	22	2	38	0	5	2	6	9
WC11	Tadpoles	176	6					128	39	2	80	68	7	356	210	0	841	45	38	0
CR29	Adults	837	15																	2
CR29	Eggmass	837	15																	19

Site	Lifestage	Distance (m)	No. breeding pools	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CR29	Tadpoles	837	15																	7
CR29D	Adults	351	9																	0
CR29D	Eggmass	351	9																	7
CR29D	Tadpoles	351	9																	14
Impact																				
6CDL	Adults	89	8				0	0	1	4	0	0	1	0	0	0	0	1	0	2
6CDL	Eggmass	89	8				0	0	0	9	39	0	13	10	4	0	0	0	2	4
6CDL	Tadpoles	89	8				200	0	38	5	347	180	149	1093	120	43	50	422	765	95
DC1	Adults	642	17								3	1	2	9	2	1	2	6	0	3
DC1	Eggmass	642	17								0	0	7	11	0	0	1	6	10	5
DC1	Tadpoles	642	17								0	0	0	15	4	12	4	108	6	0
DC13	Adults	641	17					8	12	9	2	0	2	5	5	0	0	4	0	4
DC13	Eggmass	641	17					11	0	4	0	0	30	56	8	0	0	17	13	25
DC13	Tadpoles	641	17					23	4	19	0	9	36	1079	27	0	9	46	169	0
LA2	Adults	593	23												3	1	19	7	2	0
LA2	Eggmass	593	23												70	0	16	1	0	0
LA2	Tadpoles	593	23												73	1	353	241	0	0
LA4A	Adults	209	3		1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
LA4A	Eggmass	209	3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LA4A	Tadpoles	209	3		0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0
SC10(1)	Adults	539	15	9	19	0	0	10	0	1	4	16	8	18	15	31	15	25	19	19
SC10(1)	Eggmass	539	15	0	0	0	0	0	0	0	10	6	65	2	7	46	23	4	0	9
SC10(1)	Tadpoles	539	15	7	0	4	0	5	0	3	0	3	0	0	4	142	27	0	0	0
SC10(2)	Adults	950	36	21	19	30	26	23	56	4	30	26	13	20	23	39	9	41	11	33
SC10(2)	Eggmass	950	36	0	0	0	4	9	3	6	1	3	29	101	104	194	66	30	92	599

Site	Lifestage	Distance (m)	No. breeding pools	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
SC10(2)	Tadpoles	950	36	0	0	16	81	16	13	58	77	164	22	963	89	91	862	292	138	81
SC10C	Adults	481	12	9	20	0	11	7	15	1	0	0	4	4	0	5	0	1	0	8
SC10C	Eggmass	481	12	0	0	0	0	3	0	11	0	0	28	1	0	2	0	0	0	3
SC10C	Tadpoles	481	12	0	2	10	17	44	9	20	27	4	0	0	0	0	0	0	0	2
WC15	Adults	478	16						5	2	7	10	10	40	9	7	7	0	1	1
WC15	Eggmass	478	16						1	0	0	0	13	8	38	2	0	0	0	30
WC15	Tadpoles	478	16						0	4	1	1	36	27	46	28	2	200	0	17
WC17	Adults	177	7						5	0	1	0	0	2	3	0	4	0	0	4
WC17	Eggmass	177	7						3	0	2	0	0	0	0	0	0	0	0	3
WC17	Tadpoles	177	7						87	0	1	0	0	0	120	0	2	125	63	1
WC21	Adults	1399	35								2	1	0	13	4	8	9	6	3	4
WC21	Eggmass	1399	35								0	0	4	15	25	13	4	0	2	26
WC21	Tadpoles	1399	35								0	0	148	719	112	38	100	157	95	2
ND1	Adults	742	26						23	0	4	15	7	15	17	24	9	21	2	31
ND1	Eggmass	742	26						0	0	1	0	36	110	0	36	70	15	119	36
ND1	Tadpoles	742	26						15	2	22	1	5	596	105	0	380	1054	69	45
ND2	Adults	123	7					0	0	3	0	0	0	1	0	0	0	20	0	0
ND2	Eggmass	123	7					0	0	0	0	0	0	0	0	0	0	0	0	0
ND2	Tadpoles	123	7					0	0	0	0	0	0	0	0	0	0	87	8	0
NDC	Adults	555	18		3	9	2	2	8	3	3	9	10	10	4	0	13	23	6	2
NDC	Eggmass	555	18		0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0
NDC	Tadpoles	555	18		0	0	0	1	0	8	0	0	11	32	29	403	9	46	19	0

Annex 4 Statistical analysis – Littlejohn's Tree Frog

Dendrobium Area 3A

The results below are the output and raw data from the statistical analysis for Dendrobium Area 3A.

Table 56: ANOVA table of linear models for Adults, Tadpoles, Eggmasses, comparing counts over 2021-2022 between Control and Impact sites.

Life stage	ANOVA	Numerator DF	Denominator DF	F-value	p-value
Adults	(Intercept)	1	9	7.068	**0.026**
	Treatment	2	9	0.608	0.565
	year	1	9	9.82	**0.012**
	Treatment:year	2	9	0.533	0.604
Tadpoles	(Intercept)	1	9	69.975	**<.0001**
	Treatment	2	9	121.302	**<.0001**
	year	1	9	0.638	0.455
	Treatment:year	2	9	92.025	**<.0001**
Eggmass	(Intercept)	1	9	1.662	0.23
	Treatment	2	9	0.227	0.802
	year	1	9	6.776	**0.029**
	Treatment:year	2	9	0.961	0.418

6CDL

Table 57: ANOVA results for 6CDL

6CDL	ANOVA	DF	F-value	p-value
Adults	(Intercept)	1	13.251	**<.0001**
	Mine_status	2	25.001	**<.0001**
Tadpoles	(Intercept)	1	42.157	**<.0001**
	Mine_status	2	11.269	**<.0001**
Eggs	(Intercept)	1	60.673	**<.0001**
	Mine_status	2	1.321	0.268

Table 58: Tukey HSD test for 6CDL

6CDL	Comparison	Estimate	Standard Error	Z-value	p-value
Adults	Pre-CONTROL = 0	-14.6591	2.4471	-5.99	**<.0001**
	RMZ - CONTROL = 0	-13.7403	1.9623	-7.002	**<.0001**
	RMZ - Pre = 0	0.9188	1.5792	0.582	0.823
Tadpoles	Pre-CONTROL = 0	272.86	81.5	3.348	**0.00205**
	RMZ - CONTROL = 0	91.87	27.24	3.373	**0.00173**
	RMZ - Pre = 0	-180.99	85.88	-2.107	0.07771
Eggs	Pre-CONTROL = 0	-14.659	14.541	-1.008	0.548
	RMZ - CONTROL = 0	-5.898	4.433	-1.33	0.353
	RMZ - Pre = 0	8.761	14.959	0.586	0.815

SC10C

Table 59: ANOVA results for SC10C

SC10C	ANOVA	DF	F-value	p-value
Adults	(Intercept)	1	34.901	**<.0001**
	Mine_status	3	22.269	**<.0001**
Tadpoles	(Intercept)	1	26.822	**<.0001**
	Mine_status	3	14.356	**<.0001**
Eggs	(Intercept)	1	10.214	**0.002**
	Mine_status	3	17.651	**<.0001**

Table 60: Tukey HSD test for SC10C

SC10C	Comparison	Estimate	Standard Error	Z-value	p-value
Adults	Pre-CONTROL = 0	-11.6422	1.8256	-6.377	**<.001**
	RMZ - CONTROL = 0	-10.4248	1.991	-5.236	**<.001**
	Mined under - CONTROL = 0	-13.2388	1.8019	-7.347	**<.001**
	RMZ - Pre = 0	1.2174	0.9731	1.251	0.56123
	Mined under - Pre = 0	-1.5966	0.4791	-3.332	**0.00378**
	Mined under - RMZ = 0	-2.814	0.9278	-3.033	**0.01077**
Tadpoles	Pre-CONTROL = 0	-10.5117	2.0952	-5.017	**<.001**
	RMZ - CONTROL = 0	-11.7291	3.0413	-3.857	**<.001**
	Mined under - CONTROL = 0	-12.6399	1.9306	-6.547	**<.001**

SC10C	Comparison	Estimate	Standard Error	Z-value	p-value
	RMZ - Pre = 0	-1.2174	2.6999	-0.451	0.967
	Mined under - Pre = 0	-2.1282	1.3293	-1.601	0.36
	Mined under - RMZ = 0	-0.9108	2.5743	-0.354	0.984
Eggs	Pre-CONTROL = 0	-13.5552	1.8956	-7.151	**<.001**
	RMZ - CONTROL = 0	-13.6856	2.2947	-5.964	**<.001**
	Mined under - CONTROL = 0	-12.7989	1.8344	-6.977	**<.001**
	RMZ - Pre = 0	-0.1304	1.5838	-0.082	1
	Mined under - Pre = 0	0.7563	0.7798	0.97	0.749
	Mined under - RMZ = 0	0.8868	1.5101	0.587	0.93

SC10(1)

Table 61: ANOVA results for SC10(1)

SC10(1)	ANOVA	DF	F-value	p-value
Adults	(Intercept)	1	62.373	**<.0001**
	Mine_status	3	15.145	**0.0001**
Tadpoles	(Intercept)	1	36.612	**<.0001**
	Mine_status	3	8.378	**<.0001**
Eggmass	(Intercept)	1	28.339	**<.0001**
	Mine_status	3	13.575	**<.0001**

Table 62: Tukey HSD test for SC10(1)

SC10(1)	Comparison	Estimate	Standard Error	Z-value	p-value
Adults	Pre-CONTROL = 0	-12.2517	1.8975	-6.457	**<.001**
	RMZ - CONTROL = 0	-13.6856	2.3025	-5.994	**<.001**
	Mined under - CONTROL = 0	-10.7699	1.8353	-5.868	**<.001**
	RMZ - Pre = 0	-1.434	1.5973	-0.898	0.791
	Mined under - Pre = 0	1.4818	0.7865	1.884	0.215
	Mined under - RMZ = 0	2.99158	1.523	1.915	0.202
Tadpoles	Pre-CONTROL = 0	-13.0819	3.2915	-3.974	**<.001**
	RMZ - CONTROL = 0	-13.6856	6.4396	-2.125	0.132
	Mined under - CONTROL = 0	-10.6153	2.58	-4.115	**<.001**
	RMZ - Pre = 0	-0.6038	6.7787	-0.089	1
	Mined under - Pre = 0	2.4666	3.3376	0.739	0.873
	Mined under - RMZ = 0	3.0703	6.4633	0.475	0.962
Eggmass	Pre-CONTROL = 0	1.37E+01	2.232		**<.0001**
	RMZ - CONTROL = 0	-1.39E+01	3.558		**<.0001**
	Mined under - CONTROL = 0	-1.07E+01	2.009		**<.0001**
	RMZ - Pre = 0	1.30E-13	3.372		1
	Mined under - Pre = 0	2.95E+00	1.661		0.270792
	Mined under - RMZ = 0	2.95E+00	3.216		0.785476

SC10(2)

Table 63: ANOVA results for SC10(2)

SC10(2)	**ANOVA**	**DF**	**F-value**	**p-value**
Adults	(Intercept)	1	131.754	**<.0001**
	Mine_status	3	16.152	**<.0001**
Tadpoles	(Intercept)	1	66.293	**<.0001**
	Mine_status	3	1.261	0.288
Eggmass	(Intercept)	1	61.745	**<.0001**
	Mine_status	3	1.684	0.17

Table 64: Tukey HSD test for SC10(2)

SC10(2)	**Comparison**	**Estimate**	**Standard Error**	**Z-value**	**p-value**
Adults	Pre-CONTROL = 0	-11.1537	1.8415	-6.057	**<.001**
	RMZ - CONTROL = 0	-7.7282	2.0627	-3.747	**<.001**
	Mined under - CONTROL = 0	-11.2863	1.8092	-6.238	**<.001**
	RMZ - Pre = 0	3.4255	1.1382	3.01	0.0118
	Mined under - Pre = 0	-0.1325	0.5604	-0.236	0.9947
	Mined under - RMZ = 0	-3.5581	1.0852	-3.279	0.0043
Tadpoles	Pre-CONTROL = 0	-11.281	12.35	-0.913	0.774
	RMZ - CONTROL = 0	-12.303	27.385	0.449	0.965
	Mined under - CONTROL = 0	13.699	8.43	1.625	0.33
	RMZ - Pre = 0	-1.021	29.935	-0.034	1
	Mined under - Pre = 0	24.98	14.739	1.695	0.293
	Mined under - RMZ = 0	26.002	28.542	0.911	0.776
Eggmass	Pre-CONTROL = 0	-13.40905	6.49873	-2.063	0.145
	RMZ - CONTROL = 0	-13.3665	14.08783	-0.949	0.757
	Mined under - CONTROL = 0	-1.91264	4.57481	-0.418	0.972
	RMZ - Pre = 0	0.04255	15.3085	0.003	1
	Mined under - Pre = 0	11.49642	7.53738	1.525	0.39
	Mined under - RMZ = 0	11.45386	14.59608	0.785	0.846

WC17

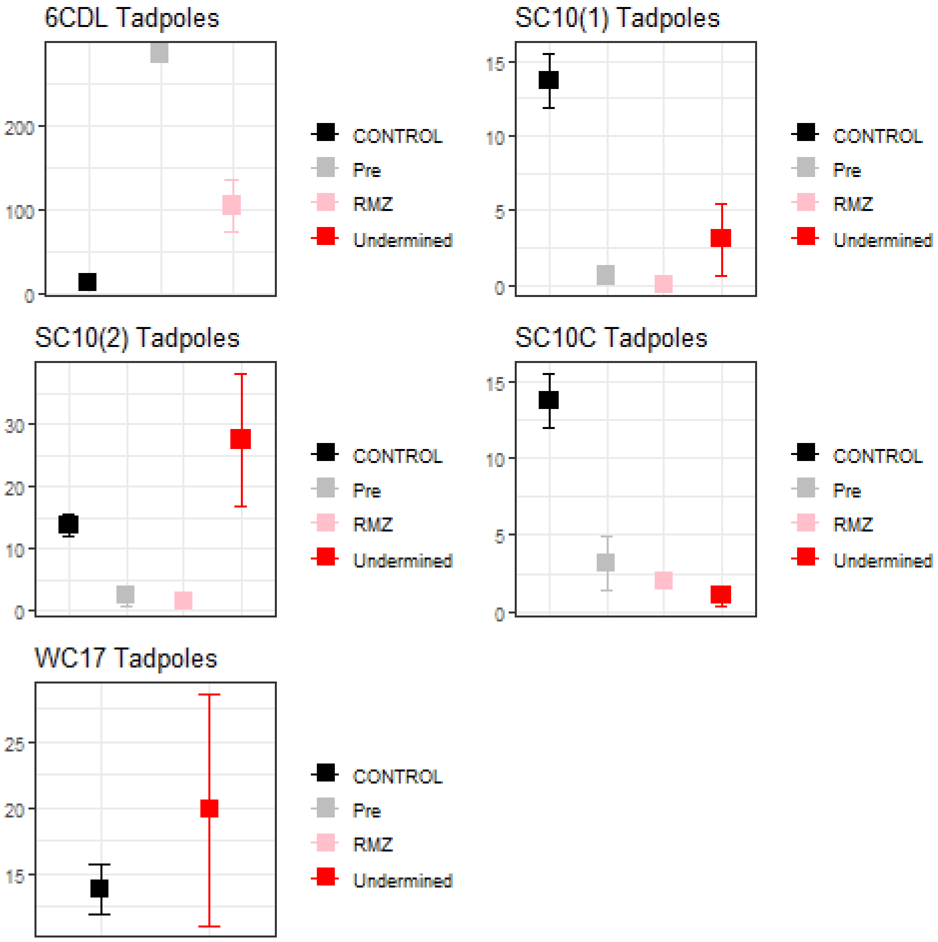
Table 65: ANOVA results for WC17

WC17	**ANOVA**	**DF**	**F-value**	**p-value**
Adults	(Intercept)	1	17.642	**<.0001**
	Mine_status	1	46.212	**<.0001**
Tadpoles	(Intercept)	1	60.155	**<.0001**
	Mine_status	1	0.483	0.488
Eggmass	(Intercept)	1	7.603	**0.006**
	Mine_status	1	51.311	**<.0001**

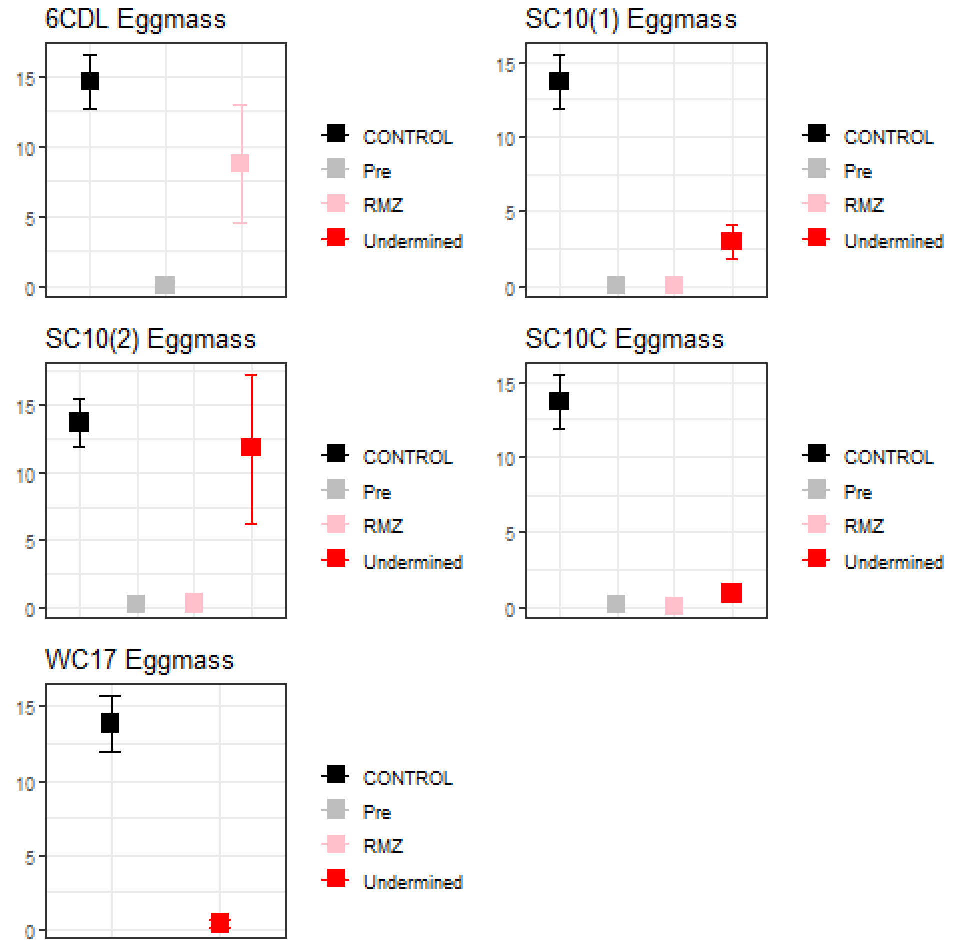
Table 66: Tukey HSD test for WC17

WC17	Comparison	Estimate	Standard Error	Z-value	p-value
Adults	Mined under - CONTROL = 0	-12.873	1.894	-6.798	**<.0001**
Tadpoles	Mined under - CONTROL = 0	5.989	8.617	0.695	0.487
Eggmass	Mined under - CONTROL = 0	-13.441	1.876	-7.163	**<.0001**

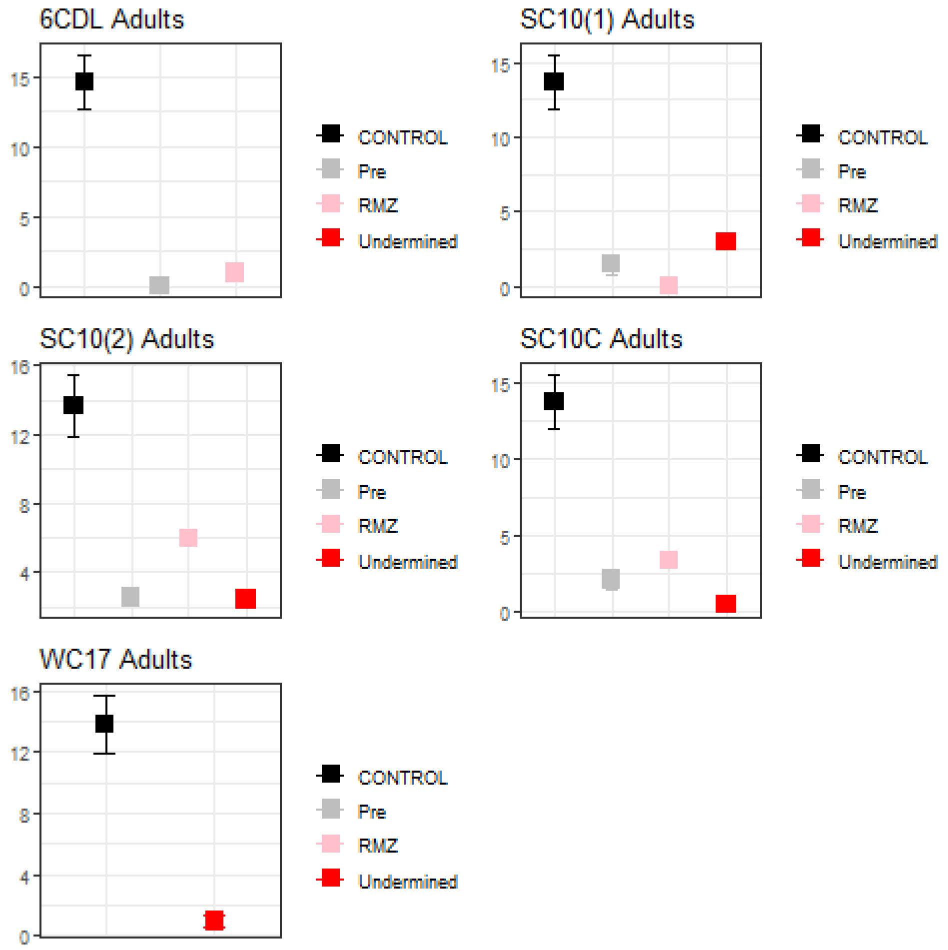
CPUE boxplot comparisons



Graph 64: CPUE for ± 95% confidence for Tadpoles as a function of Mine Status for each Site.



Graph 65: Mean CPUE ± 95% confidence for Eggmass as a function of Mine Status for each Site.



Graph 66: Mean CPUE ± 95% confidence for Adults as a function of Mine Status for each Site.

Dendrobium Area 3B

The results below are the output and raw data from the statistical analysis for Dendrobium Area 3B.

Table 67: ANOVA table of linear models for Adults, Tadpoles, Eggmasses, comparing counts over 2021-2022 between Control and Impact sites

		Numerator DF	Denomiator DF	F-value	p-value
Adults	(Intercept)	1	22	21.699	**<.0001**
	Impact	2	22	11.93	**<.0001**
	Year	1	22	2.811	0.108
	Impact:Year	2	22	2.544	0.101
Tadpoles	(Intercept)	1	22	6920.508	**<.0001**
	Impact	2	22	4.953	0.017
	Year	1	22	6920.301	**<.0001**
	Impact:Year	2	22	2.59	0.098
Eggmasses	(Intercept)	1	22	7.721	**0.011**
	Impact	2	22	4.718	**0.02**
	Year	1	22	0.26	0.615
	Impact:Year	2	22	1.443	0.258

DC(1)

Table 68: ANOVA results for DC(1)

DC(1)	**ANOVA**	**DF**	**F-value**	**p-value**
Adults	(Intercept)	1	15.958	**<.0001**
	Mine_status	2	46.037	**<.0001**
Tadpoles	(Intercept)	1	28.534	**<.0001**
	Mine_status	1	22.878	**<.0001**
Eggmass	(Intercept)	1	13.659	**<.0001**
	Mine_status	2	44.697	**<.0001**

DC13

Table 69: ANOVA results for DC13

DC13	ANOVA	DF	F-value	p-value
Adults	(Intercept)	1	56.647	**<.0001**
	Mine_status	2	43.138	**<.0001**
Tadpoles	(Intercept)	1	27.689	**<.0001**
	Mine_status	2	19.396	**<.0001**
Eggmass	(Intercept)	1	27.689	**<.0001**
	Mine_status	2	19.396	**<.0001**

Table 70: Tukey HSD test for DC13

DC13	Comparison	Estimate	Standard Error	Z-value	p-value
Adults	Pre-CONTROL = 0	-13.3684	1.9895	-6.72	**<.0001**
	Mined under - CONTROL = 0	-14.5988	1.9835	-7.36	**<.0001**
	Mined under - Pre = 0	-1.2304	0.2105	-5.844	**<.0001**
Tadpoles	Pre-CONTROL = 0	-12.033	33.858	-0.355	0.928
	Mined under - CONTROL = 0	6.895	15.259	0.452	0.886
	Mined under - Pre = 0	18.928	37.018	0.511	0.857
Eggmass	Pre-CONTROL = 0	-14.133	2.452	-5.763	**<.0001**
	Mined under - CONTROL = 0	-12.554	2.133	-5.885	**<.0001**
	Mined under - Pre = 0	1.579	1.649	0.958	0.596

LA2

Table 71: ANOVA results for LA2

LA2	ANOVA	DF	F-value	p-value
Adults	(Intercept)	1	9.016	**0.003**
	Mine_status	3	8.627	**<.0001**
Tadpoles	(Intercept)	1	35.003	**0.001**
	Mine_status	3	2.218	0.089
Eggmass	(Intercept)	1	11.221	**0.001**
	Mine_status	3	6.95	**<.0001**

Table 72: Tukey HSD test for LA2

LA2	Comparison	Estimate	Standard Error	Z-value	p-value
Adults	Pre-CONTROL = 0	-13.6997	2.8547	-4.799	**<.001**
	RMZ - CONTROL = 0	-13.4324	2.9106	-4.615	**<.001**
	Mined under - CONTROL = 0	-14.4438	2.8688	-5.035	**<.001**
	RMZ - Pre = 0	0.2674	0.8028	0.333	0.985
	Mined under - Pre = 0	-0.7441	0.6347	-1.172	0.613
	Mined under - RMZ = 0	-1.0115	0.8515	-1.188	0.603
Tadpoles	Pre-CONTROL = 0	2.332	8.005	0.291	0.9906
	RMZ - CONTROL = 0	26.015	13.277	1.959	0.1896
	Mined under - CONTROL = 0	-14.612	9.598	-1.522	0.4038

LA2	Comparison	Estimate	Standard Error	Z-value	p-value
	RMZ - Pre = 0	23.683	14.979	1.581	0.3697
	Mined under - Pre = 0	-16.944	11.842	-1.431	0.4594
	Mined under - RMZ = 0	-40.627	15.888	-2.557	**0.0472**
Eggmass	Pre-CONTROL = 0	-11.1997	3.1891	-3.512	**0.00225**
	RMZ - CONTROL = 0	-14.4438	3.8125	-3.789	**<.001**
	Mined under - CONTROL = 0	-14.6124	3.3558	-4.354	**<.001**
	RMZ - Pre = 0	-3.2441	2.9545	-1.098	0.6846
	Mined under - Pre = 0	-3.4127	2.3357	-1.461	0.45377
	Mined under - RMZ = 0	-0.1686	3.1337	-0.054	0.99994

LA4A

Table 73: ANOVA results for LA4A

LA4A	ANOVA	DF	F-value	p-value
Adults	(Intercept)	1	5.329	**0.022**
	Mine_status	2	30.877	**<.0001**
Tadpoles	(Intercept)	1	4.038	**0.045**
	Mine_status	2	30.563	**<.0001**

Table 74: Tukey HSD test for LA4A

LA4A	Comparison	Estimate	Standard Error	Z-value	p-value
Adults	Pre-CONTROL = 0	-13.76733	-	-	**<.001**
	RMZ - CONTROL = 0	-13.94277	-	-	**<.001**
	RMZ - Pre = 0	-0.17544	-	-	0.124
Tadpoles	Pre-CONTROL = 0	-13.9428	1.8169	-7.674	**<.0001**
	RMZ - CONTROL = 0	-13.6008	1.8181	-7.481	**<.0001**
	RMZ - Pre = 0	0.3419	0.1861	1.837	0.113

WC15

Table 75: ANOVA results for WC15

WC15	ANOVA	DF	F-value	p-value
Adults	(Intercept)	1	22.944	**<0.0001**
	Mine_status	3	12.17	**<.0001**
Tadpoles	(Intercept)	1	54.738	**<.0001**
	Mine_status	3	1.878	0.134
Eggmass	(Intercept)	1	22.944	**<0.0001**
	Mine_status	3	12.17	**<.0001**

Table 76: Tukey HSD test for WC15

WC15	Comparison	Estimate	Standard Error	Z-value	p-value
Adults	Pre-CONTROL = 0	-11.9788	2.128	-5.629	**<.0001**
	RMZ - CONTROL = 0	-13.4073	3.2657	-4.106	**0.000177**
	Mined under - CONTROL = 0	-12.2719	2.3012	-5.333	**<.0001**

WC15	Comparison	Estimate	Standard Error	Z-value	p-value
	RMZ - Pre = 0	-1.4286	2.8603	-0.499	0.957181
	Mined under - Pre = 0	-0.2931	1.677	-0.175	0.998002
	Mined under - RMZ = 0	1.1354	2.9914	0.38	0.980424
Tadpoles	Pre-CONTROL = 0	-10.271	4.449	-2.308	0.0854
	RMZ - CONTROL = 0	-7.755	10.842	-0.715	0.8809
	Mined under - CONTROL = 0	-2.376	5.658	-0.42	0.9725
	RMZ - Pre = 0	2.516	11.416	0.22	0.9958
	Mined under - Pre = 0	7.895	6.693	1.18	0.616
	Mined under - RMZ = 0	5.38	11.94	0.451	0.9663
Eggmass	Pre-CONTROL = 0	-11.9788	2.128	-5.629	**<.0001**
	RMZ - CONTROL = 0	-13.4073	3.2657	-4.106	**0.000177**
	Mined under - CONTROL = 0	-12.2719	2.3012	-5.333	**<.0001**
	RMZ - Pre = 0	-1.4286	2.8603	-0.499	0.957181
	Mined under - Pre = 0	-0.2931	1.677	-0.175	0.998002
	Mined under - RMZ = 0	1.1354	2.9914	0.38	0.980424

WC21

Table 77: ANOVA results for WC21

WC21	ANOVA	DF	F-value	p-value
Adults	(Intercept)	1	19.259	**<.0001**
	Mine_status	1	46.741	**<.0001**
Tadpoles	(Intercept)	1	52.727	**<.0001**
	Mine_status	1	0.973	0.325
Eggmass	(Intercept)	1	13.005	**<.0001**
	Mine_status	1	44.553	**<.0001**

ND1

Table 78: ANOVA results for ND1

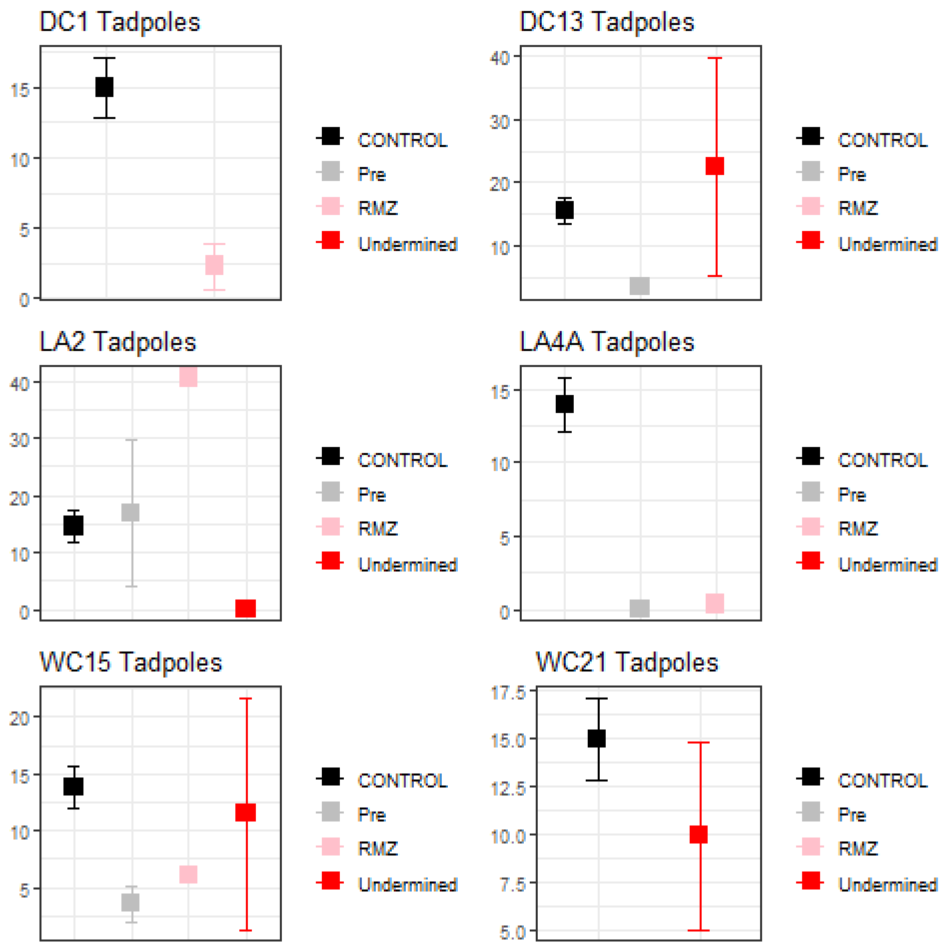
ND1	ANOVA	DF	F-value	p-value
Adults	(Intercept)	1	53.309	**<.0001**
	Mine_status	2	22.302	**<.0001**
Tadpoles	(Intercept)	1	58.404	**<.0001**
	Mine_status	2	0.599	0.55
Eggmass	Intercept	1	50.234	**<.0001**
	Mine Status	2	6.67	**0.001**

Table 79: Tukey HSD test for WC15

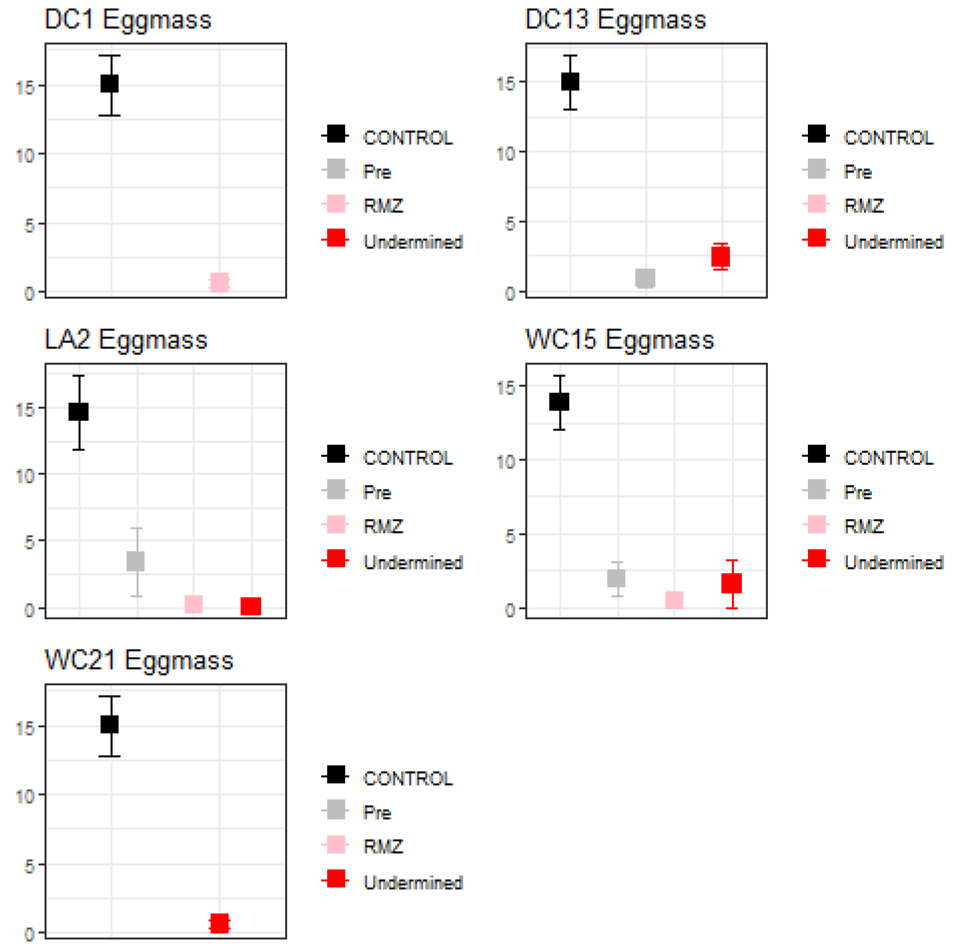
ND1	Comparison	Estimate	Standard Error	Z-value	p-value
Adults	Pre - Control = 0	-12.141	1.896	-6.402	**<.0001**

ND1	Comparison	Estimate	Standard Error	Z-value	p-value
	RMZ - Control = 0	-9.667	2.153	-4.489	**<.0001**
	RMZ - Pre = 0	2.474	1.117	2.214	0.0637
Tadpoles	Pre - Control = 0	13.931	12.928	1.078	0.5
	RMZ - Control = 0	-7.781	42.468	-0.183	0.98
	RMZ - Pre = 0	-21.712	44.313	-0.49	0.866
Eggmass	Pre - Control = 0	-9.05069	2.52481	-3.585	**<.001**
	RMZ - Control = 0	-8.99336	5.93297	-1.516	0.268
	RMZ - Pre = 0	0.05733	5.88137	0.01	1

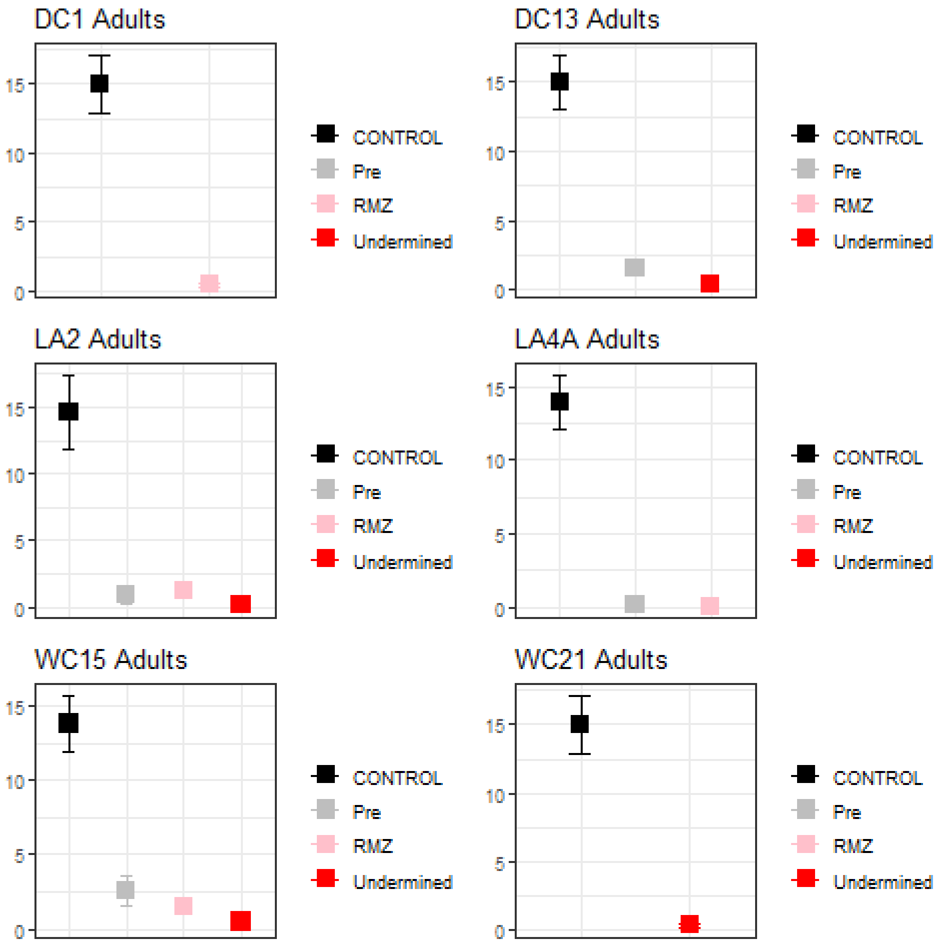
CPUE boxplot comparisons



Graph 67: CPUE for ± 95% confidence for Tadpoles as a function of Mine Status for each Site.



Graph 68: Mean CPUE ± 95% confidence for Eggmass as a function of Mine Status for each Site.



Graph 69: Mean CPUE ± 95% confidence for Adults as a function of Mine Status for each Site.

NDC

Table 80: ANOVA results for NDC

NDC	ANOVA	DF	F-value	p-value
Adults	(Intercept)	1	35.302	**<.0001**
	Mine_status	2	24.549	**<.0001**
Tadpoles	(Intercept)	1	58.816	**<.0001**
	Mine_status	2	1.29	0.277
Eggmass	(Intercept)	1	4.01	**0.046**
	Mine_status	2	29.556	**<.0001**

Table 81: Tukey HSD test for WC15

NDC	Comparison	Estimate	Standard Error	Z-value	p-value
Adults	Pre - Control = 0	-12.656	1.8308	-6.913	**<.0001**
	RMZ - Control = 0	-13.5823	2.0676	-6.569	**<.0001**
	RMZ - Pre = 0	-0.9263	1.0272	-0.902	0.624
Tadpoles	Pre - Control = 0	-7.075	4.939	-1.433	0.298
	RMZ - Control = 0	-13.943	17.885	-0.78	0.695
	RMZ - Pre = 0	-6.867	18.376	-0.374	0.92
Eggmass	Pre - Control = 0	-13.90606	1.8128	-7.671	**<.0001**

NDC	Comparison	Estimate	Standard Error	Z-value	p-value
	RMZ - Control = 0	-13.94277	1.81412	-7.686	**<.0001**
	RMZ - Pre = 0	-0.03671	0.07378	-0.498	0.856

ND2

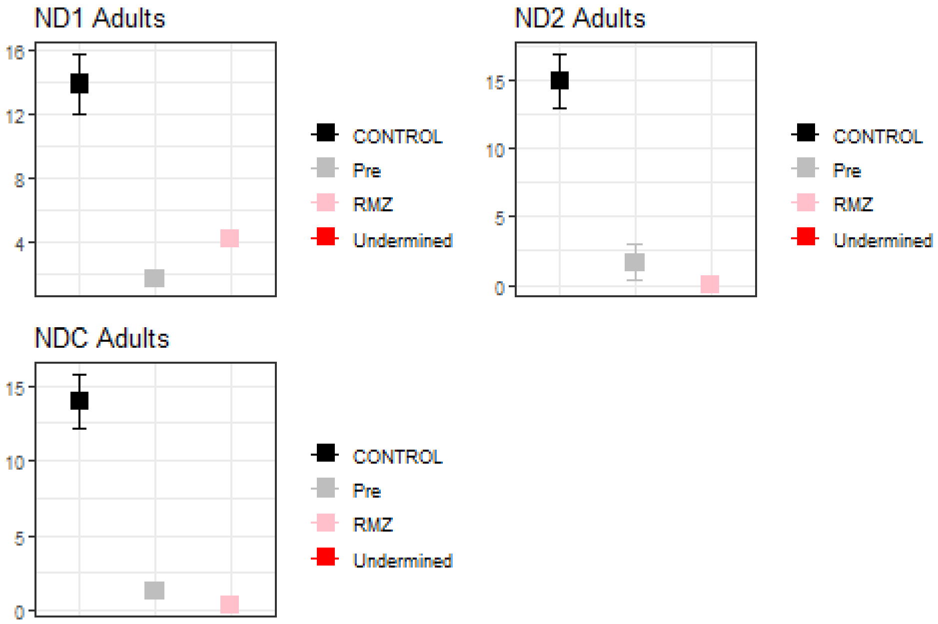
Table 82: ANOVA results for ND2

ND2	ANOVA	DF	F-value	p-value
Adults	(Intercept)	1	24.927	**<.0001**
	Mine_status	2	16.914	**<.0001**
Tadpoles	(Intercept)	1	55.651	**<.0001**
	Mine_status	2	1.369	0.256
Eggmass	(Intercept)	-	-	-
	Mine_status	-	-	-

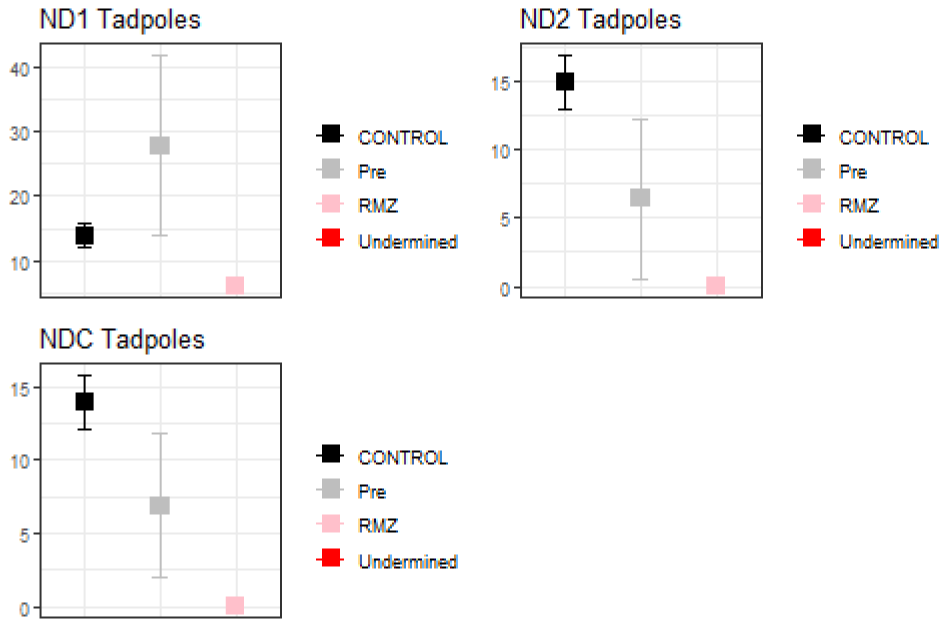
Table 83: Tukey HSD test for ND2

ND2	Comparison	Estimate	Standard Error	Z-value	p-value
Adults	Pre - Control = 0	-13.299	2.339	-5.687	**<.001**
	RMZ - Control = 0	-14.953	4.74	-3.155	**0.00376**
	RMZ - Pre = 0	-1.654	4.482	-0.369	0.92442
Tadpoles	Pre - Control = 0	-8.534	5.766	-1.48	0.277
	RMZ - Control = 0	-14.953	18.861	-0.793	0.688
	RMZ - Pre = 0	-6.419	19.523	-0.329	0.937

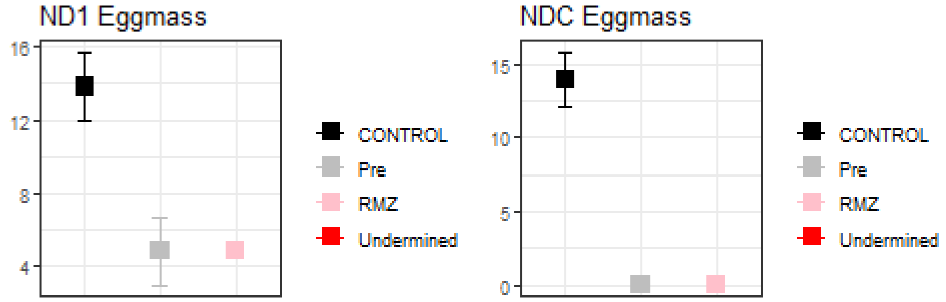
CPUE boxplot comparisons



Graph 70: CPUE for ± 95% confidence for Adults as a function of Mine Status for each Site.



Graph 71: Mean CPUE ± 95% confidence for Tadpoles as a function of Mine Status for each Site.



Graph 72: Mean CPUE ± 95% confidence for Eggmass as a function of Mine Status for each Site.

Annex 5 Photo point monitoring data

The complete photo point monitoring dataset has been provided as separate electronic documents due to the large file sizes, titled:

- Dendrobium3A3B_PhotoLog_20220328 (2009 – 2021)
- 7290_Dendrobium3A3B_PhotoLog_2022 (2022)

Annex 6 Trigger Action Response Plans (IMC 2021)

Table 1.1 – Dendrobium Landscape Key Monitoring Sites

Monitoring Site		Monitoring Type	Monitoring Frequency	Monitoring Parameters
LANDSCAPE FEATURES – TARGETED SITES (Refer to Dendrobium Area 3A SMP Figures 19.2 and 19.3 and Dendrobium Area 3B Figure 18.1 for location of sites)				
AREA 2	**Cliffs** A2-CL1 (above LW4)	The categories of site inspection include: 1. Specific targeted monitoring sites based on potential risk 2. Re-visits to identified impact sites	• Two 6 monthly baseline monitoring campaigns 1 year prior to mining • 6 monthly monitoring during mining and monthly during any substantial subsidence period • Monitoring to continue 6 monthly for 2 years following the completion of mining	Baseline recording includes landform elements from the Australian Soil and Land Survey Field Handbook including: • Slope • Morphological type • Dimensions • Mode of geomorphological activity and geomorphological agent During mining recording includes impacts to landform elements, e.g. • Drainage • Disturbance of site • Erosion • Aggradations • Inundation • Rock Fracturing • Changes in runoff • Changes in vegetation • Rockfalls • Soil cracking • Slumping
	Steep Slopes A2-SL1 and A2-SL2 (above LWs 4 & 5)			
	Watercourses A2-WC13 (above LWs 4 & 5)			
	Swamp A2-SW1 (above LWs 4 & 5)			
	4WD Track A2-FT1 (above LWs 4 & 5)			
	Crinanite Surface Extent A2-CN1 & A2-CN2 (above LWs 3 & 4)			
AREA 3A	**Cliffs** A3-CL1 & A3-CL2 (above LW10) A3-CL3 & A3-CL4 (W end of LW10) A3-CL5 (SW end of LW9)			
	Steep Slopes A3-SL1 (above LW6) A3-SL2 (SE corner of LW6) A3-SL3 (W end of LW7) A3-SL4 & A3-SL5 (above LWs 7 and 8) A3-SL6 (E end of LW8) A3-SL7 (W end of LW9) A3-SL8 (above LW9) A3-SL9 (W end of LW9)			
	Watercourses / Swamps A3-WC1 (above LW7 in Swamp 12) A3-WC2 & A3-WC3 (above LWs 8, 9 and 10 in Swamps 15a and 15b)			
	Fire Trails A3-FR1 (across LWs 6-10) A3-FR2 (above LWs 6 & 7)			

AREA 3B	**Cliffs** DA3-CF19 (E LW13) DA3-CF20 (E LW13) DA3-CF21 (E LW13) DA3-CF22 (E LW13) DA3-CF23 (E LW13) DA3-CF25 (E LW17) DA3-CF26 (E LW17) DA3-CF41 (E LW18) DA3-CF42 (E LW18) DA3-CF43 (E LW 18)	The categories of site inspection include: 1. General inspection of all active subsidence areas 2. Re-visits to identified impact sites	• Baseline monitoring campaign prior to mining • monthly monitoring during any subsidence period • Monitoring to continue 6 monthly for 2 years following the completion of mining	Baseline recording includes landform elements from the Australian Soil and Land Survey Field Handbook including: • Slope • Morphological type • Dimensions • Mode of geomorphological activity and geomorphological agent During mining recording includes impacts to landform elements, e.g. • Drainage • Disturbance of site • Erosion • Aggradations • Inundation • Rock Fracturing • Changes in runoff • Changes in vegetation • Rockfalls • Soil cracking • Slumping
	Watercourses / Swamps *Refer to DA3 Watercourse and Swamp Monitoring TARPs*			
	Fire Trails Fire Road No.6A (across LWs 10-18) Fire Road No.6N (across LW14) Fire Road No.6Q (across LW 15, 16 and 17)			
INSPECTION OF ACTIVE MINING AREA - LANDSCAPE FEATURES, VEGETATION, WATERCOURSES				
AREA 3A	All mapped cliff, steep slopes, watercourse, swamp and fire trail sites in subsidence area *Refer to Dendrobium Area 3A SMP Figure 19.3 for location of sites* General observation of active mining areas	The categories of site inspection include: 1. General inspection of all active subsidence areas 2. Re-visits to identified impact sites	• Weekly monitoring when longwall extraction is within 400m of feature	During mining recording includes impacts to: • Drainage • Disturbance of site • Erosion • Aggradations • Inundation • Rock Fracturing • Changes in runoff • Changes in vegetation • Impacts to fauna/fish • Rockfalls • Soil cracking • Slumping
AREA 3B	All mapped cliff, steep slopes, watercourse, swamp and fire trail sites in subsidence area *Refer to Dendrobium Area 3B SMP Figure 5.3, 15.1 and 18.1 for location of sites* General observation of active mining areas			

TERRESTRIAL FLORA				
AREA 2 **AREA 3A** **AREA 3B**	A number of sites located across and around Areas 2, 3A and 3B *Refer Dendrobium Area 3A SMP Figure 21.1, 21.2 and 21.3 and 3B Figure 20.1*	Observational and quantitative (transect) monitoring to identify stressed or dead vegetation including riparian and upland swamp vegetation not readily explained by natural processes. Causes may include rock/cliff falls or mass movement, gas emissions, changes in ponding and interconnectivity, and iron staining from ferruginous spring releases	• Two baseline monitoring campaigns 1 year prior to mining during autumn and spring • 6 monthly monitoring during mining in autumn and spring each year • 6 monthly monitoring post mining for two years or as otherwise required	• Vegetation communities • Vegetation condition • Changes in vegetation • Tree health • Swamp vegetation • Threatened species • Control sites
TERRESTRIAL FAUNA				
AREA 2 **AREA 3A** **AREA 3B**	A number of sites located across and around Areas 2, 3A and 3B *Refer Dendrobium Area 3A SMP Figure 21.1, 21.2 and 21.3 and 3B Figure 20.1*	Observational and quantitative (population counts) monitoring to identify alteration or loss of fauna habitat, fauna habitat assessed to be degraded without a natural cause readily apparent	• Two baseline monitoring campaigns 1 year prior to mining • 6 monthly monitoring during mining • 6 monthly monitoring post mining for two years or as otherwise required	• Species and habitat characteristics • Targeted surveys and monitoring of known populations of threatened frog species

ABORIGINAL ARCHAEOLOGY (Refer Dendrobium Area 3A SMP Figure 22.1 and Dendrobium Area 3B Figure 21.1 for location of sites)				
AREA 2	• Dendrobium 4	Observational and photographic monitoring in consultation with stakeholders	• Baseline archival recording: prior to longwall mining • First impact assessment recording: Following initial subsidence movement of the site • Sandstone shelter Aboriginal sites will be monitored during mining • Further impact assessment recording: twelve months after undermining or final subsidence movement of the site	• Re-recording of the principal components identified by Sefton (Sefton 2000) • Macro and micro recording using digital photography (Navin Officer 2003) • Detailed elevation plans of shelter walls recording structural and surface features including but not limited to the art itself, graffiti, joints , bedding planes, exfoliation scars, cracks, mineral and micro-organism growth, drip line and water seepage locations
AREA 3A	• Browns Road Site 33 (recording code 52-2-0458) • Browns Road Site 32 (recording code 52-2-1646) • Browns Road Site 20 (recording code 52-2-1647) • Sandy Creek Road 21 (recording code 52-5-0274) • Sandy Creek Road 22 (recording code 52-5-0274) • Sandy Creek Road 25 (recording code 52-5-0277) • Sandy Creek Road 26 (recording code 52-5-0278) • DM13 (New recording) • DM15 (New recording) • DM20 (New recording) • DM23 (New recording)			

AREA 3B	• Donalds Castle Creek Site 1; Cordeaux Catchment Area (recording code 52-2-1562) • Browns Road Site 8 (recording code 52-2-1623) • Browns Road Site 11 (recording code 52-2-1626) • Browns Road Site 12 (recording code 52-2-1627) • Browns Road Site 13 (recording code 52-2-1628) • Upper Avon 35 (recording code 52-2-1771) • Upper Avon 36 (recording code 52-2-1772) • Upper Avon 37 (recording code 52-2-1773) • Upper Avon 38 (recording code 52-2-1774) • Upper Avon 39 (recording code 52-2-1775) • Upper Avon 40 (recording code 52-2-1776) • Upper Avon 41 (recording code 52-2-1777) • DENDROBIUM 1 (recording code 52-2-2208) • DENDROBIUM 2 (recording code 52-2-2209) • SITE 1 – DB1 (recording code 52-2-2229) • DENDROBIUM 6 (recording code 52-2-2246) • DENDROBIUM 7 (recording code 52-2-2248) • DENDROBIUM 8 (recording code 52-2-3088) • DM16 (recording code 52-2-3640) • DM17 (recording code 52-2-3641) • DM21 (recording code 52-2-3645) • DM22 (recording code 52-2-3878)	Observational and photographic monitoring in consultation with stakeholders	• Baseline archival recording: prior to longwall mining • First impact assessment recording: Following initial subsidence movement of the site • Sandstone shelter Aboriginal sites will be monitored during mining • Further impact assessment recording: twelve months after undermining or final subsidence movement of the site	• Re-recording of the principal components identified by Sefton (Sefton 2000) • Macro and micro recording using digital photography (Navin Officer 2003) • Detailed elevation plans of shelter walls recording structural and surface features including but not limited to the art itself, graffiti, joints , bedding planes, exfoliation scars, cracks, mineral and micro-organism growth, drip line and water seepage locations

Table 1.2 – Dendrobium Landscape Impacts, Triggers and Response

Monitoring	Trigger	Action
LANDSCAPE FEATURES		
AREA 2 **Cliffs** A2-CL1 (above LW4) **Steep Slopes** A2-SL1 and A2-SL2 (above LWs 4 & 5) **Watercourses** A2-WC10 and A2-WC11 (above LW3) A2-WC13 & A2-WC16 (above LWs 4 & 5) **Swamp** A2-SW1 (above LWs 4 & 5) **4WD Track** A2-FT1 (above LWs 4 & 5) **Crinanite Surface Extent** A2-CN1 & A2-CN2 (above LWs 3 & 4) **AREA 3A** **Cliffs** All mapped cliff sites in subsidence area (Refer to Dendrobium Area 3A SMP Figures 19.3 for location of sites) **Steep Slopes** All mapped steep slopes in subsidence area *Refer to Dendrobium Area 3A SMP Figures 19.3 for location of sites* **Watercourses/ Swamps** All mapped watercourse and swamps in subsidence area *Refer to Dendrobium Area 3A SMP Figure 19.3* **Fire Trails** All mapped fire trails in subsidence area *Refer to Dendrobium Area 3A SMP Figure 19.3* **AREA 3B** **Cliffs** All mapped cliff sites in subsidence area *Refer to Dendrobium Area 3B SMP Figures 18.1 for location of sites*	***Level 1 **** • Rock fall from a cliff which is left mostly intact (<10% length), resulting in insignificant ground disturbance • Surface movement or rock displacement with negligible soil surface exposed • Crack at the surface, which should not result in any significant erosion or further ground movement • Crack in a fire trail which should not result in erosion or impede access • Crack or fracture up to 100mm width • Crack or fracture up to 10m length • Erosion in a localised area which would be expected to naturally stabilise without CMA and within the period of monitoring	• Continue monitoring program • Report impacts to key stakeholders • Summarise impacts and Report in the End of Panel Report and AEMR
	Level 2 * • Rock fall or overhang collapse at a cliff site, where characteristics of the cliff have changed, and there has been significant ground disturbance • Surface movement or rock displacement that has exposed significant areas of soil • A crack at the surface, which could result in significant erosion or movement at the surface • A crack at the surface with potential risk to safety and/or fauna entrapment • A crack in the fire trail, which could result in significant erosion or impede vehicle access • Crack or fracture between 100 and 300mm width • Crack or fracture between 10 and 50m length • Significant erosion at any location, which is not likely to naturally stabilise within the period of monitoring, or is located in a sensitive area e.g. swamps, creek, lake shore, and may result in increased sediment transport to Cordeaux Dam, or has been previously identified as Level 1, but is not likely to naturally stabilise within the monitoring period	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Provide safety signage and barricades as appropriate • Implement approved repairs to ensure safety and serviceability on fire trails • Implement agreed CMAs as approved *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of impacts i.e. cracking at the surface with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*
	Level 3 * • Major cliff collapse where the characteristics of the cliff change significantly and there is significant ground disturbance that is unlikely to naturally stabilise within the monitoring period	• *Actions as stated for Level 2* • Immediately notify DoPI, DPIM, SCA, resource managers and relevant technical specialists and seek advice on any CMA required • Site visits with stakeholders if required

Table 1.2 – Dendrobium Landscape Impacts, Triggers and Response

Monitoring	Trigger	Action
	• Crack or fracture over 300mm width • Crack or fracture over 50m length • Mass movement of a slope causing large areas of exposed soil with potential for further movement	• Review monitoring program and modify if necessary within 1 month • Implement increased monitoring if required within 2 weeks • Develop site CMA in consultation with key stakeholders within 1 month, (pending stakeholder availability) and seek approvals • Completion of works following approvals • Issue CMA report within 1 month of works completion • Conduct initial follow up monitoring & reporting within 2 months of CMA completion • Review the relevant TARP and Management Plan in consultation with key stakeholders *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of impacts i.e. cracking at the surface with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*
Sandy Creek Waterfall	***Exceeding Prediction*** • Rock fall at Sandy Creek Waterfall or from its overhang • Structural integrity of the waterfall, its overhang and its pool are impacted • More than negligible cracking within 30 m of the waterfall • More than negligible diversion of water from the lip of the waterfall	• Actions as stated for Level 3 • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation
TERRESTRIAL FLORA AND FAUNA		
A number of sites located across and around Areas 2, 3A and 3B *Refer Dendrobium Area 3A SMP Figure 21.1, 21.2 and 21.3 and Dendrobium Area 3B Figure 20.1 for location of sites* General observation of active mining areas	***Level 1 **** • Vegetation impacted by mining (by rockfalls, soil slippage, gas emissions) that is likely to naturally regenerate within the monitoring period	• Continue monitoring program • Report impacts to key stakeholders • Summarise impacts and Report in the End of Panel Report and AEMR
	Level 2 * • Vegetation impacted by mining (by rockfalls, soil slippage, gas emissions) that is unlikely to naturally regenerate within the monitoring period • Statistically significant difference between Before After Control Impact sites as a result of mining	• Actions as stated for Level 1 • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved

Table 1.2 – Dendrobium Landscape Impacts, Triggers and Response

Monitoring	Trigger	Action
	Level 3 * - Vegetation impacted by mining that is not responding to CMAs	- Actions as stated for Level 2 - Immediately notify OEH, DoPI, DPI, SCA, other resource managers and relevant technical specialists and seek advice on any CMA required - Site visits with stakeholders if required - Review monitoring program and modify if necessary within 1 month - Implement increased monitoring if required within 2 weeks - Develop site CMA in consultation with key stakeholders within 1 month, (pending stakeholder availability) and seek approvals - Completion of works following approvals - Issue CMA report within 1 month of works completion - Conduct initial follow up monitoring & reporting within 2 months of CMA completion - Review the relevant TARP and Management Plan in consultation with key stakeholders
ABORIGINAL ARCHAEOLOGY		
Area 2 (1 site): Dendrobium 4 **Area 3A (11 total):** - Browns Road Site 33 (recording code 52-2-0458) - Browns Road Site 32 (recording code 52-2-1646) - Browns Road Site 20 (recording code 52-2-1647) - Sandy Creek Road 21 (recording code 52-5-0273) - Sandy Creek Road 22 (recording code 52-5-0274) - Sandy Creek Road 25 (recording code 52-5-0277) - Sandy Creek Road 26 (recording code 52-5-0278) - DM13 (New Recording) - The site DM15 (New Recording) - The site DM20 (New Recording) - The site DM23 (New Recording)	***Level 1 **** - Change in shelter conditions not attributable to natural weathering or preservation – mineral growth or micro-organism growth (as observed by comparing pre-mining photographs with post-subsidence/mining photographs) - Changes external to the shelter that affect the site context (e.g. ground cracking, boulder slumping, rock and/or tree falls)	- Continue monitoring program - Condition assessment and photographic record - Notify relevant specialists and key stakeholders (e.g. Aboriginal community groups) - Summarise impacts and Report in the End of Panel Report and AEMR
	Level 2 * - Change in shelter conditions not attributable to natural weathering or preservation – change in drip line or seepage, cracking or exfoliation of overhang or shelter, movement or opening of existing planes and joints at panel, block fall within shelter or overhang, shelter or overhang collapse	- Actions as stated for Level 1 - Modify monitoring program if necessary - Consider development of site management plan to mitigate effects in consultation with Registered Aboriginal Groups and the Landowner (SCA)
	Level 3 * - Level 2 impacts at greater frequency than predicted - Level 2 impacts attributable to mining remote from the mining area	- Actions as stated for Level 2 - Immediately notify OEH, DoPI, DPI, SCA, other resource managers and relevant technical specialists and seek advice on any CMA required - Site visits with stakeholders if required - Review monitoring program and modify if necessary within 1 month - Implement increased monitoring if required within 2 weeks - Develop site CMA in consultation with key stakeholders within 1 month, (pending stakeholder availability) and seek approvals - Completion of works following approvals

Area3B (25 total): • Donalds Castle Creek Site 1; Cordeaux Catchment Area (recording code 52-2-1562) • Browns Road Site 8 (recording code 52-2-1623) • Browns Road Site 11 (recording code 52-2-1626) • Browns Road Site 12 (recording code 52-2-1627) • Browns Road Site 13 (recording code 52-2-1628) • Upper Avon 35 (recording code 52-2-1771) • Upper Avon 36 (recording code 52-2-1772) • Upper Avon 37 (recording code 52-2-1773) • Upper Avon 38 (recording code 52-2-1774) • Upper Avon 39 (recording code 52-2-1775) • Upper Avon 40 (recording code 52-2-1776) • Upper Avon 41 (recording code 52-2-1777) • DENDROBIUM 1 (recording code 52-2-2208) • DENDROBIUM 2 (recording code 52-2-2209) • SITE 1 – DB1 (recording code 52-2-2229) • DENDROBIUM 6 (recording code 52-2-2246) • DENDROBIUM 7 (recording code 52-2-2248) • DENDROBIUM 8 (recording code 52-2-3088) • DM16 (recording code 52-2-3640) • DM17 (recording code 52-2-3641) • DM21 (recording code 52-2-3645) • DM22 (recording code 52-2-3878)	🟧	• Issue CMA report within 1 month of works completion • Conduct initial follow up monitoring & reporting within 2 months of CMA completion • Review the relevant TARP and Management Plan in consultation with key stakeholders

* These may be revised in consultation with DoPI and DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data. These TARPs relate to Dendrobium Area 3B and impacts resulting from mining in Areas 1, 2 and 3A were managed under previous TARPs.

Office of Environment and Heritage (OEH)

Department of Planning and Infrastructure (DoPI)

Department of Primary Industries: including Division of Resources and Energy, Office of Water, Fisheries (DPI)

Sydney Catchment Authority (SCA)

Performance Measures	***Potential Impacts***	***Performance Triggers***	***Management Strategies***	***Offsets***	***Other Actions***
Negligible erosion of the surface of the swamp	Gully erosion or similar	*Level 1:* The increase in length of erosion within a swamp (compared to its pre-mining length) is **2%** of the swamp length or area; and/or Erosion in a localised area (not associated with cracking or fracturing) which would be expected to naturally stabilise without CMA and within the period of monitoring. *Level 2*: The increase in length of erosion within a swamp (compared to its pre-mining length) is **3%** of the swamp length or area; and/or Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention; and/or Gully knickpoint forms or an existing gully knickpoint becomes active. *Level 3:* The increase in length of erosion within a swamp (compared to its pre-mining length) is **4%** of the swamp length or area; and/or Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention. *Exceeding Prediction* Mining results in the total length of erosion within a swamp (compared to its pre-mining length) to increase **>5%** of the length or area of the swamp compared to any increase in total erosion length in a reference swamp (ie increase in length or area of erosion in an impact swamp less any increase in length or area in erosion in a reference swamp is **>5%**).	a) upfront mine planning b) erosion monitoring (ie ALS, observation) c) coir logs d) knickpoint control e) water spreading f) weeding g) fire management h) reporting i) investigation and review j) update future predictions	Offset required **immediately**, if no remediation considered practicable. Offset required **2 years** following remediation, if it is ineffective. This period can be extended to **5 years**, with the agreement of the Secretary.	
Minor changes in the size of the swamps **Minor changes** in the ecosystem functionality of the swamps **No significant change** to the composition or distribution of	Swamp vegetation changes: - Swamp size - Species richness, distribution, composition and diversity - Vegetation sub-communities	**Swamp Size** *Level 1:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for two consecutive monitoring periods, greater than observed in the Control Group, and exceeding the standard error (SE) of the Control Group. *Level 2:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for three consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Level 3:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for four consecutive monitoring periods, greater than observed in the Control Group, and	a) upfront mine planning b) vegetation monitoring c) water spreading d) seeding/planting e) weeding f) fauna monitoring g) fire management h) grouting of controlling of controlling	Offset required **immediately**, if no remediation considered practicable. Offset required **5 years** following remediation, if it is ineffective. This period can be extended to **10 years**, with	Monitoring period for swamp size is related to capture of Lidar data at the end of each longwall ~ 1 year Triggers for groundwater decline result in increased intensity and

species within the swamps		exceeding the SE of the Control Group. *Exceeding Prediction:* Mining results in a trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for five consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. **Ecosystem Functionality** *Level 1:* A trending decline in the extent of any individual groundwater dependent community within a swamp for two consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Level 2:* A trending decline in the extent of any groundwater dependent community within a swamp for three consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group.. *Level 3:* A trending decline in the extent of any groundwater dependent community within a swamp for four consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group.. *Exceeding Prediction:* Mining results in a trending decline in the extent of a groundwater dependent community within a swamp for five consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. **Species Composition and Distribution** *Level 1:* A **2%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **two** consecutive years; and/or *Level 2:* A **5%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **three** consecutive years. *Level 3:* An **8%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **four** consecutive years.	rockbars and bedrock base and/or use of other remediation techniques i) reporting j) investigation and review k) update future predictions	the agreement of the Secretary.	frequency of vegetation monitoring

		Exceeding Prediction: Mining results in a **>10%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **five** consecutive years.			
Maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamps	Subsidence impacts (ie cracking) on bedrock base or controlling rockbar	*Level 1:* Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water of **10%** compared to baseline for the pool (in addition to any decrease in reference pools). *Level 2:* Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water of **20%** compared to baseline for the pool (in addition to any decrease in reference pools). *Level 3:* Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water of **20%** compared to baseline for the pool for **>20%** of the time over a period of **1** year (in addition to any decrease in reference pools). *Exceeding Prediction* Structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored, ie pool water level within the swamp after CMAs continues to be **>20%** lower than baseline for **>20%** of the time over a period of **1** year.	a) upfront mine planning b) subsidence monitoring c) surface water monitoring d) groundwater monitoring e) grouting of controlling of controlling rockbars and bedrock base and/or use of other remediation techniques f) CMAs g) reporting h) investigation and review i) update future predictions	Offset required **immediately**, if no remediation considered practicable. Offset required **2 years** following remediation, if it is ineffective. This period can be extended to **5 years**, with the agreement of the Secretary.	
Minor changes in the ecosystem functionality of the swamps	Falls in surface or near-surface groundwater levels in swamps *NB. Not linked specifically to a PM and would not be considered a breach if predictions were exceeded.*	*Level 1:* Groundwater level lower than baseline level at any monitoring site within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at any monitoring site (measured as average mm/day during the recession curve). *Level 2:* Groundwater level lower than baseline level at **50%** of monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at a **50%** of monitoring sites (within 400m of mining) within the swamp.	a) upfront mine planning b) groundwater monitoring c) implementation of swamp research program d) weeding e) fire management f) reporting g) update future predictions		Triggers for groundwater decline result in increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars

		Level 3: Groundwater level lower than baseline level at **>80%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at **>80%** of monitoring sites (within 400 m of mining) within the swamp.			
Minor changes in the ecosystem functionality of the swamps	Falls in soil moisture levels in swamps *NB. Not linked specifically to a PM and would not be considered a breach if predictions were exceeded.*	*Level 1:* Soil moisture level lower than baseline level at **any** monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps). *Level 2:* Soil moisture level lower than baseline level at **50%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps). *Level 3:* Soil moisture level lower than baseline level at **>80%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps).	a) upfront mine planning b) soil moisture monitoring c) water spreading d) weeding e) fire management f) reporting g) update future predictions		Triggers of soil moisture decline result in increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars

Table 1.1 – Dendrobium Area 3 Watercourse Monitoring

Watercourse monitoring within Dendrobium Area 3 will be installed ahead of mining to achieve 2 years baseline data (subject to timing and approval timeframes of any request to install additional monitoring). Monitoring will be conducted throughout the mining period and for at least 2 years following active subsidence. A review of the continuation and potentially extending post mining monitoring will be carried out in consultation with DPIE, WaterNSW and other relevant agencies where required. Where impacts are observed, the monitoring period will be extended and this will be reported in Impact Assessment Reports and End of Panel Reports. For Level 2 and 3 Triggers and for impacts exceeding prediction this review will be conducted in consultation with key agencies. The location of monitoring sites is indicated on Figures 2-1 to 2-57.

MONITORING SITE		SITE TYPE	MONITORING FREQUENCY	PARAMETERS
OBSERVATIONAL-MONITORING				
AREA 3A	Sandy Creek and tributaries (including SC7 and SC10) *Refer to Figure 2-1*	Observation and photo point monitoring: • Sites based on an assessment of risk • Streams and swamps • Pools and rockbars • Previously observed impacts that warrant follow-up inspection	• Monthly 2 years pre- and post-mining, weekly when longwall is within 400 m of monitoring site • Reference sites 6 monthly	Visual signs of impacts to creeks and drainage lines (i.e. cracking, vegetation changes, increased erosion, changes in water colour, soil moisture etc.) determined by comparing baseline photos with photos during the mining period Key water quality parameters in pools analysed to identify any changes resulting from mining Pool water levels to identify any changes resulting from mining
AREA 3B	**Impact Sites:** • Native Dog, Wongawilli and Donalds Castle Creeks, WC21, WC18, WC16, WC15, WC12, WC9, WC8, WC7, WC6, LA5, LA4, LA3, LA2, ND1 and DC13 • Swamps 5, 10, 11, 13, 14, 23, 35a, 35b, 1a, 1b, 8, 3 and 4 *Refer to Figures 2-2 to 2-11 and 2-25 to 2-32* **Reference Sites:** • Wongawilli Creek, Sandy Creek, LC5, WC11, SC9A, SC10A, NDC1, DC10 and D10 • Swamps 2, 7, 15a, 22, 24, 25, 33, 84, 85, 86, 87 and 88 *Refer to Figures 2-12 to 2-25, 2-28 to 2-30 and 2-33 to 2-35*			
WATER QUALITY				

AREA 3A	**Wongawilli Creek** WWU1, WWU4, WC_Pool 46, WWM2, WC_Pool 43b and Wongawilli Creek (FR6) **Sandy Creek** SCk_Rockbar 5 (Sandy Creek adjacent to LW7) *Refer to Figure 2-1*	• Grab sample • Field water quality	• Monthly monitoring pre, during and post mining for two years	Manual Field Testing: • Field pH, Temp, EC, DO and ORP • Lab. analytes (incl. lab check of pH, lab. check of EC, DOC, Na, K, Ca, Mg, Filt. SO4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si)
AREA 3B	**Wongawilli Creek** WWU1 (Wongawilli Creek headwaters) WWU4 (Wongawilli Creek upstream) WC_Pool 51 (Wongawilli Creek downstream of WC7) WC Pool 49 (Wongawilli Creek adjacent to LW15) WC_Pool 46 (Wongawilli Creek adjacent to LW12) WWM2 (Wongawilli Creek adjacent to LW11) WC_Pool 43b (Wongawilli Creek downstream of LW9) Wongawilli Creek (FR6) (Wongawilli Creek downstream) WC21_Pool 5 (Wongawilli Creek tributary downstream of mining) WC21 Pools 30 and 53 (Wongawilli Creek tributaries over mining) WC15_Pool 28 (Wongawilli Creek tributary downstream of mining) WC15_Pool 9 (Wongawilli Creek tributary downstream of mining) WC15_Pool 2 (Wongawilli Creek tributary downstream of mining)WC7_Pool 1(Wongawilli Creek tributary downstream of mining) **Lake Avon** LA4_S1, LA4_S2, LA5_S1, LA5_S2, LA3 Pool 4, LA2 Pool 5 and LA_1 (Lake Avon tributaries downstream of mining) NDC4 (Native Dog Creek downstream of mining) NDC1 (Native Dog Creek upstream of Area 3B) **Donalds Castle Creek** Donalds Castle Creek (FR6) (Donalds Castle Creek lower) DCL3 (Donalds Castle Creek @ Cordeaux River)			

	DC_Pool 22 (Donalds Castle Creek downstream of mining) DC13_Pool 2b (Donalds Castle Creek tributary downstream of mining) **Lake Cordeaux** *LC5_S1 (Reference Site)* *Refer to Figure 2-35*			
WATER FLOW				
Ref Sites	**O'Hares Creek** [NSW govt site] 213200 (O'Hares Creek @ Wedderburn) **Wongawilli Creek** WWU (Wongawilli Creek upstream)	• Some data (for reference sites) is provided by WaterNSW		Other reference sites may be used depending on data availability and quality (e.g. Woronora River 2132101 and Bomaderry Creek 215016)
AREA 3A	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL_A (Wongawilli Creek downstream) **Sandy Creek** SCL2(Sandy Creek at downstream) SC10S1 and SC10CS1 (Sandy Creek tributary) *Refer to Figures 2-35 and 2-36*	• Pressure transducer with data logger.	• Continuous 1-hour logging intervals	Automatic pool water level measurements which are converted to flows by calculation of rating curves using measured creek cross sections/measured flows at the monitoring point. Hydrological changes are assessed by comparing pre- and post-mining observed flows from impact or assessment sites to flow data from similar reference sites (that are not impacted by mining).
AREA 3B	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL_A (Wongawilli Creek downstream) WC21S1 (Wongawilli Creek tributary downstream of mining) WC15S1 (Wongawilli Creek tributary downstream of mining) WC12S1 (Wongawilli Creek tributary downstream of mining) **Donalds Castle Creek** DCU (Donalds Castle Creek @ FR6) DC13S1 (Donalds Castle Creek tributary downstream of mining) DCS2 (Donalds Castle Creek downstream of mining) **Lake Avon** LA4S1 (Lake Avon tributary downstream of mining) LA3S1 (Lake Avon tributary downstream of mining) LA2S1 (Lake Avon tributary downstream of mining)			

	NDTS1 (Lake Avon Tributary downstream of mining) **Lake Cordeaux** LC5S1 (Reference Site) *Refer to Figures 2-35 and 2-36*			
AQUATIC ECOLOGY				
AREA 3A	Sandy Creek Catchment: Sites 8, 9, 10, 11, 12 and 13 *Refer to Figure 2-57*	- Quantitative and observational monitoring	- Two baseline monitoring campaigns prior to mining during autumn and spring - Monitoring during mining in autumn and spring - Monitoring post mining for two years or as otherwise required - Monitoring targets sites as mining progresses through the domain	Macroinvertebrate sampling and assessment using the AUSRIVAS protocol and quantitative sampling using artificial collectors In consideration of Adams Emerald Dragonfly, Giant Dragonfly and Sydney Hawk Dragonfly, individuals of the genus Austrocorduliidae and Gomphomacromiidae, Petalura are identified to species level if possible Fish are sampled by visual observations and dip netting in Area 3A, and sampled using a back-pack electrofisher and baited traps in Area 3B
AREA 3B	**Impact Sites:** Sites 2, 3, 4, X4, X5 and X6 (Wongawilli Creek) Sites X2 and X3 (WC21) Site X1 (Donalds Castle Creek) **Reference Sites:** Site 1 (Wongawilli Creek – until LW15) Site 5 (Wongawilli Creek) Site 14 (Donalds Castle Creek) Site 6 (WC21) Site 7 (Sandy Creek) Sites 15 and 16 (Kentish Creek) *Refer to Figure 2-57*			
TERRESTRIAL FAUNA – THREATENED FROG SPECIES				
AREA 3B	**Impact Sites:** DC13 (Donalds Castle Creek tributary) DC(1) (Donalds Castle Creek) WC15 and 21 (Wongawilli Creek tributaries) LA4A (Lake Avon tributary) ND1 (Native Dog Creek tributary) *Refer to Figures 2-42 to 2-47* **Reference Sites:** WC10 and 11 (Wongawilli Creek tributaries) SC6, SC7-1, SC7-2, SC7A and SC8 (Sandy Creek tributaries) DC8 (Donalds Castle Creek tributary) NDC (Native Dog Creek) *Refer to Figures 2-48 to 2-56*	- Standardised transects in potential breeding habitat for two threatened frog species, Littlejohn's Tree Frog and Giant Burrowing Frog	- Surveys are undertaken in optimal periods over the season (i.e. when frogs are calling and/or active at known sites)	Frog surveys are conducted along creeks with a focus on features susceptible to impacts e.g. breeding pools. Potential breeding habitat for Littlejohn’s Tree Frog and Giant Burrowing Frog will be targeted. Standardised transects have been established to record numbers of individuals recorded at each site from one year to the next. Tadpole counts will also be undertaken as part of the breeding habitat monitoring transects. These transects are surveyed by walking down the creekline and counting all amphibians seen or heard on either side of the line

Table 1.2 – Dendrobium Area 3B Watercourse Impacts, Triggers and Response

OBSERVATIONAL-MONITORING		
Wongawilli Creek, Donalds Castle Creek and WC-WF54 **Relevant Performance Measure(s):** • Wongawilli Creek - minor environmental consequences • Donalds Castle Creek - minor environmental consequences • Waterfall WC-WF54 – negligible environmental consequences	***Level 1*** • Crack or fracture up to 100mm width at its widest point with no observable loss of surface water or erosion • Crack or fracture up to 10m length with no observable loss of surface water or erosion • Erosion in a localised area (not associated with cracking or fracturing) which would be expected to naturally stabilise without CMA and within the period of monitoring • Observable release of strata gas at the surface • Observable increase in iron staining within the mining area • Observation that a pool on a subject Creek is dry • Observation that the subject Creek has ceased to flow	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, DRG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
General observation of streams in active mining areas when longwall is within 400m	***Level 2*** • Observation that a single pool on a subject Creek is dry in consecutive monitoring events • Observation that two or more pools on a subject Creek are dry in a single monitoring event • Observation that the subject Creek has ceased to flow in consecutive monitoring event	• *Actions as stated for Level 1* • Carry out Water Flow Assessment Method D • Review monitoring frequency • Submit letter report to DPIE, DRG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	• Crack or fracture between 100 and 300mm width at its widest point or any fracture which results in observable loss of surface water or erosion • Crack or fracture between 10 and 50m length • Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention • Observable increase in iron staining within the mining area continues to outside the mining area i.e. 400m from the longwall	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, DRG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 • Crack or fracture over 300mm width at its widest point • Crack or fracture over 50m length • Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water • Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, DRG, Water NSW • Implement additional monitoring or increase frequency if required • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, DRG, Water NSW • Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced

	• Gas release results in vegetation dieback, mortality or loss of aquatic habitat • Observable increase in iron staining within the mining area continues more than 600m from the longwall	movements and impacts are complete), including monitoring and reporting on success • Review relevant TARP and Management Plan in consultation with key agencies
	Exceeding Prediction • Structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored i.e. pool water level within the pool after CMAs continues to be lower than baseline period • Gas release results in vegetation dieback that does not revegetate • Gas release results in mortality of threatened species or ongoing loss of aquatic habitat • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at Wongawilli Creek downstream monitoring site Wongawilli Creek (FR6) • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at the Donalds Castle Creek downstream monitoring site Donalds Castle Creek (FR6) • Rock fall at WC-WF54 or its overhang • Impacts on the structural integrity of WC-WF54, its overhang or its pool	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Native Dog Creek, DC13, WC21, WC15, LA2, LA3, LA4, LA5, ND1, WC6, WC7, WC8, WC9, WC12, WC16 and WC18 General observation of streams in active mining areas when longwall is within 400m	***Level 1*** • Crack or fracture up to 100mm width at its widest point with no observable loss of surface water or erosion • Crack or fracture up to 10m length with no observable loss of surface water or erosion • Erosion in a localised area (not associated with cracking or fracturing) which would be expected to naturally stabilise without CMA and within the period of monitoring • Observable release of strata gas at the surface • Observable increase in iron staining within the mining area	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, DRG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR

	Level 2 • Crack or fracture between 100 and 300mm width at its widest point or any fracture which results in observable loss of surface water or erosion • Crack or fracture between 10 and 50m length • Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention • Observable increase in iron staining within the mining area continues to outside the mining area i.e. 400m from the longwall	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, DRG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 • Crack or fracture over 300mm width at its widest point • Crack or fracture over 50m length • Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water • Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention • Gas release results in vegetation dieback, mortality or loss of aquatic habitat • Observable increase in iron staining within the mining area continues more than 600m from the longwall	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, DRG, Water NSW • Implement additional monitoring or increase frequency if required • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, DRG, Water NSW • Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success • Review relevant TARP and Management Plan in consultation with key agencies
WATER QUALITY		
Wongawilli Creek **Relevant Performance Measure(s):** • Wongawilli Creek - minor environmental consequences Wongawilli Creek (FR6) Baseline means: • pH 5.98 • EC 98.8 uS/cm • DO 89.5%	***Level 1*** • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, DRG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Two non-consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, DRG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)

	Level 3 • Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, DRG, Water NSW • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key agencies • Develop site CMA (subject to agency feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so • Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Donalds Castle Creek **Relevant Performance Measure(s):** • Donalds Castle Creek - minor environmental consequences Donalds Castle Creek (FR6) Baseline means: • pH 5.41 • EC 116.0 uS/cm • DO 85.6%	***Level 1*** • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, DRG Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Two non-consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, DRG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, DRG, Water NSW • Implement additional monitoring or increase frequency if required

	• Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• Review relevant TARP and Management Plan in consultation with key agencies • Collect laboratory samples and analyse for: – pH, EC, major cations, major anions, Total Fe, Mn & Al – Filterable suite of metals • Develop site CMA (subject to agency feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so • Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Lake Avon **Relevant Performance Measure(s):** • Lake Avon - negligible reduction in the quality of surface water inflows to Lake Avon Lake Avon tributary (LA4_S1) Baseline means: • pH 5.38 • EC 90.8 uS/cm • DO 89.9%	***Level 1*** • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, DRG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Two non-consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, DRG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, DRG, Water NSW • Implement additional monitoring or increase frequency if required

	- Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	- Review relevant TARP and Management Plan in consultation with key agencies - Collect laboratory samples and analyse for: – pH, EC, major cations, major anions, Total Fe, Mn & Al – Filterable suite of metals - Develop site CMA (subject to agency feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so – Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period - Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction - Mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	- *Actions as stated for Level 3* - Investigate reasons for the exceedance - Update future predictions based on the outcomes of the investigation - Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
POOL WATER LEVEL		
Wongawilli Creek and Donalds Castle Creek **Relevant Performance Measure(s):** - Wongawilli Creek - minor environmental consequences - Donalds Castle Creek - minor environmental consequences	***Level 1*** - Single pool on a subject Creek is observed as dry	- Continue monitoring program - Carry out Water Flow Assessment Method D. - Submit letter report to DPIE, DRG and Water NSW - Report in the End of Panel Report - Summarise actions and monitoring in AEMR
	Level 2 - Single pool on a subject Creek is observed as dry in consecutive monitoring events - Two or more pools on a subject Creek are observed as dry in a single monitoring event	- *Actions as stated for Level 1* - Review monitoring frequency - Submit letter report to DPIE, DRG and Water NSW and seek advice on any CMA required - Implement agreed CMAs as approved (subject to agency feedback)

	Level 3 - Fracturing resulting in diversion of flow such that <10% of the pools have water levels lower than baseline period	- *Actions as stated for Level 2* - Offer site visit with BCD, DPIE, DRG, Water NSW - Implement additional monitoring or increase frequency if required - Review relevant TARP and Management Plan in consultation with key agencies - Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BD, DPIE, DRG, Water NSW - Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction - Fracturing resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period	- *Actions as stated for Level 3* - Investigate reasons for the exceedance - Update future predictions based on the outcomes of the investigation - Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Waterfall WC-WF54 **Relevant Performance Measure(s):** - Waterfall WC-WF54 – negligible environmental consequences	***Exceeding Prediction*** - Fracturing in Wongawilli Creek within 30m of the waterfall which results in observable flow diversion - Fracturing in Wongawilli Creek which results in observable flow diversion from the lip of the waterfall	- *Actions as stated for Level 3* - Investigate reasons for the exceedance - Update future predictions based on the outcomes of the investigation - Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent

Monitoring	Trigger	Action
SURFACE WATER FLOW		
Wongawilli Creek and Donalds Castle Creek **Lake Avon and Cordeaux River** **Relevant Performance Measure(s):**	***Level 1*** - A) Lower flow than expected (additional 10-15% of days where Q% lower than Reference Q%) - B) 5-10% increase in cease-to-flow frequency beyond natural) - C) Reduction in Q50 (10-15% beyond natural)	- Continue monitoring program. - Submit an Impact Report to BCD, DPIE, DRG, WaterNSW. - Report in the End of Panel Report. - Summarise actions and monitoring in AEMR.

• Wongawilli Creek - minor environmental consequences • Donalds Castle Creek - minor environmental consequences • Lake Avon - negligible reduction in the quantity of surface water inflows to Lake Avon[1] • Cordeaux River - negligible reduction in the quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek[2] **Surface water flow Reference sites** (as in Table 1.1)**:** • Wongawilli Creek - WWU (Wongawilli Creek upstream); • O'Hares Creek at Wedderburn (213200); • (other such sites, if necessary, include Woronora River 2132101 and Bomaderry Creek 215016) NB. This section of the TARP contains four Water Flow Assessment Methods, labelled A, B, C and D, which are specified in detail in Watershed HydroGeo (2019). Hydrological changes are assessed by comparing pre- and post-mining observed flows from impact or assessment sites to flow data from the reference sites. *Natural variability ('NV') will be defined as the 'average' change at the selected reference sites. Triggers may occur when the apparent impact at a site (NV + x% change) could be less than maximum observed variability at one of the reference sites.*	***Level 2*** • A) Lower flow than expected (additional 15-20% of days where Q% lower than Reference Q%). • B) 10-20% increase in cease-to-flow frequency (beyond natural) • C) 15-20% reduction in Q50 (beyond natural) • D) Observation that the subject Creek has ceased to flow at spatially consecutive monitoring sites.	• *Actions as stated for Level 1* • Review monitoring frequency. • D) → carry out Water Flow Assessment Method D. • Submit letter report to DPIE, DRG and WaterNSW and seek advice on any CMA required. • Implement agreed CMAs as approved (subject to agency feedback).
	Level 3 • A) Lower flow than expected (additional >20% of days where Q% lower than Reference Q%) • B) >20% increase in cease-to-flow frequency (beyond natural) • C) >20% reduction in Q50 (beyond natural)	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, DRG, WaterNSW. • Implement additional monitoring or increase frequency if required. • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, DRG, WaterNSW. • Completion of works following approvals and at a time agreed between S32, DPIE, DRG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success. • Review relevant TARP and Management Plan in consultation with key agencies.
	Exceeding Prediction Measured surface water flow reduction, based on Assessment Methods C, D, to be compared against predictions made in contemporary groundwater modelling conducted to the satisfaction of the Secretary to assess whether effects that cannot be explained by natural variability "exceed prediction".	• *Actions as stated for Level 3* • Investigate reasons for the exceedance. • Update future predictions based on the outcomes of the investigation. • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent.

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[1] Surface water inflows calculation = [Impacts at gauged catchments (LA1 + LA2 + LA3 + LA4 + LA6+ NDT1 + ND2) + estimated impacts at ungauged but undermined catchments (e.g. LA5)] / [total inflow to LA].

[2] Flow reduction as determined from measured at flow gauging station WWL_A.

Tributaries of Wongawilli Creek and Donalds Castle Creek and other affected watercourses not subject to performance measures **Surface water flow Reference sites** (as in Table 1.1)**:** • Wongawilli Creek - WWU (Wongawilli Creek upstream); • O'Hares Creek and Wedderburn (213200); • (other such sites, if necessary, include Woronora River 2132101 and Bomaderry Creek 215016) NB. This section of the TARP contains four Water Flow Assessment Methods, labelled A, B, C and D, which are specified in detail in Watershed HydroGeo (2019). Hydrological changes are assessed by comparing pre- and post-mining observed flows from impact or assessment sites to flow data from the reference sites. *Natural variability ('NV') will be defined as the 'average' change at the selected reference sites. Triggers may occur when the apparent impact at a site (NV + x% change) could be less than maximum observed variability at one of the reference sites.*	***Level 1*** • A) Lower flow than expected (additional 10-20% of days where Q% lower than Reference Q%) • B) 5-10% increase in cease-to-flow frequency (beyond natural) • C) 10-20% reduction in Q50 (beyond natural)	• Continue monitoring program. • Submit an Impact Report to BCD, DPIE, DRG, WaterNSW. • Report in the End of Panel Report. • Summarise actions and monitoring in AEMR.
	Level 2 • A) Lower flow than expected (additional 20-30% of days where Q% lower than Reference Q%) • B) 10-20% increase in cease-to-flow frequency (beyond natural) • C) 20-30% reduction in Q50 (beyond natural)	• *Actions as stated for Level 1* • Review monitoring frequency. • Submit letter report to DPIE, DRG and WaterNSW and seek advice on any CMA required. • Implement agreed CMAs as approved (subject to agency feedback).
	Level 3 • A) Lower flow than expected (additional >30% of days where Q% lower than Reference Q%) • B) >20% increase in cease-to-flow frequency (beyond natural) • C) >30% reduction in Q50 (beyond natural)	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, DRG, WaterNSW. • Implement additional monitoring or increase frequency if required • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, DRG, WaterNSW. • Completion of works following approvals and at a time agreed between S32, DPIE, DRG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success. • Review relevant TARP and Management Plan in consultation with key agencies.
AQUATIC ECOLOGY		
Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat • Wongawilli Creek catchment – 8 sites • Donalds Castle Creek catchment – 1 site	***Level 1*** • Reduction in aquatic habitat for 1 year	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, DRG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2	• *Actions as stated for Level 1*

Relevant Performance Measure(s): - Wongawilli Creek - minor environmental consequences - Donalds Castle Creek - minor environmental consequences	- Reduction in aquatic habitat for 2 years following the active subsidence period	- Review monitoring frequency - Submit letter report to DPIE, BCD, DRG and Water NSW and seek advice on any CMA required - Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 - Reduction in aquatic habitat for >2 years following the active subsidence period	- *Actions as stated for Level 2* - Offer site visit with BCD, DPIE, DRG, Water NSW - Implement additional monitoring or increase frequency if required - Review relevant TARP and Management Plan in consultation with key agencies - Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, DRG, Water NSW - Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
TERRESTRIAL FAUNA – THREATENED FROG SPECIES		
Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat - Wongawilli Creek catchment – 2 sites - Donalds Castle Creek catchment – 2 sites - Lake Avon tributary – 1 site - Native Dog tributary – 1 site **Relevant Performance Measure(s):** - Wongawilli Creek - minor environmental consequences - Donalds Castle Creek - minor environmental consequences	***Level 1*** - Reduction in habitat for 1 year	- Continue monitoring program - Submit an Impact Report to BCD, DPIE, DRG, Water NSW - Report in the End of Panel Report - Summarise actions and monitoring in AEMR
	Level 2 - Reduction in habitat for 2 years following the active subsidence period	- *Actions as stated for Level 1* - Review monitoring frequency - Submit letter report to DPIE, BCD, DRG and Water NSW and seek advice on any CMA required - Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 - Reduction in habitat for > 2 years following the active subsidence period	- *Actions as stated for Level 2* - Offer site visit with BCD, DPIE, DRG, Water NSW - Implement additional monitoring or increase frequency if required - Review relevant TARP and Management Plan in consultation with key agencies - Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, DRG, Water NSW - Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced

	🟧	movements and impacts are complete), including monitoring and reporting on success

Department of Planning, Industry and Environment (DPIE)

Biodiversity and Conservation Division (BCD) within DPIE

Division of Resources and Geoscience within the Department (DRG) within DPIE

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Central Coast
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Our services

Ecology and biodiversity
Terrestrial
Freshwater
Marine and coastal
Research and monitoring
Wildlife Schools and training

Heritage management
Aboriginal heritage
Historical heritage
Conservation management
Community consultation
Archaeological, built and landscape values

Environmental management and approvals
Impact assessments
Development and activity approvals
Rehabilitation
Stakeholder consultation and facilitation
Project management

Environmental offsetting
Offset strategy and assessment (NSW, QLD, Commonwealth)
Accredited BAM assessors (NSW)
Biodiversity Stewardship Site Agreements (NSW)
Offset site establishment and management
Offset brokerage
Advanced Offset establishment (QLD)