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2020 GOLDEN SUN MOTH MONITORING REPORT

Yarralumla Equestrian Park

FINAL

March 2021

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Yarralumla Equestrian Park

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Prepared by
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on behalf of
Suburban Land Agency

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Report 21034/R01
Date: March 2021

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Document Status

Rev No.	Reviewer		Approved for Issue	
	Name	Date	Name	Date
1	David Moore	23 March 2021	David Moore	28 March 2021

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1.0 Introduction

Umwelt Environmental Pty Ltd has monitored the condition of golden sun moth habitat and natural temperate grassland at Yarralumla Equestrian Park (**Figure 1.1**) on behalf of the ACT Government Suburban Land Agency to meet annual reporting requirements for the the site.

The OMP (RJPL 2014a) details the requirement for ongoing monitoring of EPBC Act listed endangered Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory, and the EPBC Act listed critically endangered golden sun moth (*Synemon plana*, GSM) populations at the Yarralumla Equestrian Park (YEP) offset area. Subsequent to the approval, the listing of endangered Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory has been revised under the EPBC Act, and areas within the ACT formerly within this community are now classified as the EPBC Act listed critically endangered Natural Temperate Grassland of the South- Eastern Highlands (Australian Government 2016). In this report, the former endangered ecological community and the revised critically endangered ecological community are collectively referred to as natural temperate grassland (NTG) except where a specific reference to the listed ecological community is required. The 2018 monitoring triggered a review of the original Offset Management Plan (RJPL 2014a), and an updated OMP is currently in preparation (Umwelt, in prep).

This report presents the results of monitoring surveys undertaken in November 2020 through to February 2021 in the YEP offset area. The results are briefly examined in relation to existing site information and the baseline year (i.e. year 0), year 1, year 2, year 3, year 4, year 5 and year 6 monitoring data collected during spring and summer from 2013 to 2018 (RJPL 2014b; RJPL 2015; SMEC 2016; SMEC 2017; SMEC 2018; Umwelt 2019; Umwelt 2020). The implications of results are considered in relation to the performance targets identified in the OMP (Umwelt, in prep.).

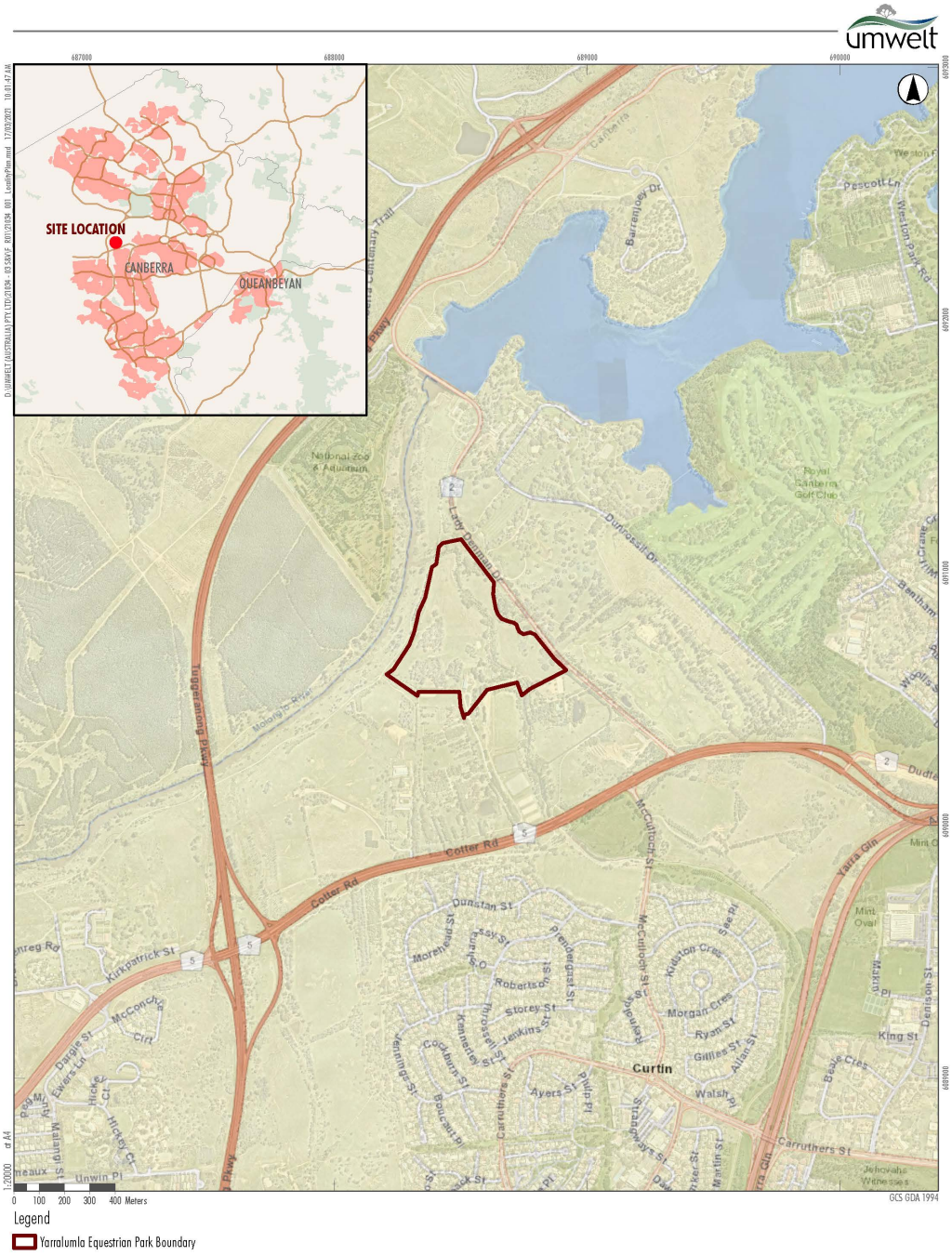


FIGURE 1.1

Locality Plan

Figure 1.1 **Locality Plan**

2.0 Methods

2.1 Regional GSM Information

The start of the GSM flying season was confirmed using known reference sites in the ACT and based on information from other consultants in the ACT, and Conservation Planning and Research, ACT Government (CPR). ACT researchers and consultants shared information regarding the timing and location of GSM sightings, particularly the start of the flying season, via email on a weekly basis during the GSM flying season. At least one of the reference sites is within 1km of the survey area.

2.2 Survey Area

The survey area comprised the YEP offset area defined in the original OMP (RJPL 2014a) (**Figure 2.1**). Corrected locations for vegetation quadrats and point-count assessment reported in the year 0 baseline assessment report (RJPL 2014b) were used.

Figure 2.1 Yarralumba Equestrian Park Offset Area and Survey Details

2.3 Revised Vegetation and GSM Habitat Mapping

Mapping of vegetation and potential GSM habitat areas presented in the OMP (RJPL 2014a) and the year 0 (i.e. 2013), year 1 (i.e. 2014), year 2 (i.e. 2015), year 3 (i.e. 2016), year 4 (i.e. 2017) and year 5 (i.e. 2018) monitoring reports (RJPL 2014b; SMEC 2016; SMEC 2017; SMEC 2018; Umwelt 2019; Umwelt 2020) was reviewed by conducting a meandering traverse throughout the site, with close inspection of native pasture and NTG areas. The distribution of native grassland and GSM habitat, the distribution of exotic perennial tussock grasses was updated in accordance with the OMP in preparation (Umwelt, in prep.).

2.4 Native Pasture and Natural Temperate Grassland Monitoring

Native pasture and natural temperate grassland monitoring was conducted in accordance with the Vegetation Monitoring Statement of Requirements (Umwelt, in prep. Appendix B).Floristic Diversity.

- 12 floristic diversity plots completed for both a 20 m x 20 m plot and a 4 m x 4 m plot nested within the larger plot:
    - 4 m x 4 m plot with floristic values scores calculated in accordance with Rehwinkel (2007) to enable comparison with monitoring data collected between 2013 and 2019
    - 20 m x 20 m plot with floristic value scores calculated in accordance with Rehwinkel (2015) to enable consideration against condition thresholds for the natural temperate grassland CEEC (Commonwealth of Australia 2016) and comparison with monitoring data collected since 2018 collected using the ACT Government Offsets Monitoring – Floristic Surveys Survey 123 App.

As specified in the OMP (RJPL 2014a), a modified version of Rehwinkel (2007) was used to quantitatively determine relative floristic value scores for native pasture and NTG within each quadrat (Appendices C and D of the OMP (RJPL 2014a)), consistent with ACT Government guidelines for assessing NTG (ACT Government 2010a). To ensure consistency and allow comparison with previous years, quadrats were assessed using the floristic value scores based on both Rehwinkel (2007) and Rehwinkel (2015).

NTG condition was reviewed against the criteria for the revised NTG community listing (Australian Government 2016). Threshold values for determining the classification of NTG were determined from the listing criteria (Australian Government 2016). Floristic value scores referenced in these thresholds relate to the updated method of Rehwinkel (2015) measured at 20 x 20 metre plots and are not comparable to those for long-term monitoring of the 4 x 4 metre plots (Rehwinkel 2007).

To meet criteria for classification as NTG, the patch must be >0.1 hectares (e.g. 20 m x 50 m), within the defined region and altitude, and apparently naturally treeless or sparsely treed, and it must meet criterion A or B:

- Criterion A: contains a foliage cover of more than 50% Themeda triandra (Kangaroo Grass) or Poa labillardierei (River Tussock) – or Carex bichenoviana (Plains Sedge) if the patch is an ephemeral wetland
- Criterion B: contains a greater percentage cover of native plants (including annual and perennial species but not cryptogams) than of perennial exotic species (including weeds), AND in favourable sampling times (generally spring and early summer, and in non-drought affected seasons) it has:
    - at least 8 non-grass native species, or
    - at least 2 indicator species, or

- a floristic value score of at least 5

or at other sampling times it has:

- at least 4 non-grass native species, or
- at least 1 indicator species, or
- a floristic value score of at least 3.

Thresholds for favourable sampling times were applied.

Due to the absence of a minimum size criteria for the former EPBC Act listed endangered Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory used to assess the site during the original assessment, the minimum size restriction was not considered as part of the thresholds when monitoring the extent of NTG at this site. The application of this threshold would result in artificial changes in the extent of NTG present.

2.4.1 Grassland Structure

Groundcover structure transects were completed for assessing grassland structure, weed cover and abundance of golden sun moth feed species, collected using the ACT Government Understorey Structure – Step Point App.

Twelve transects were sampled to assess the dominant component of groundcover at such locations. The transects were commenced within the 4 m x 4 m quadrats or adjacent to the quadrats. Groundcover was sampled at 50 points along each transect which measured 25 metres in length. At each point the presence of the 13 attributes was recorded at each of the 50 sampling points, namely cryptogams, bare earth, rock, litter, Chilean needle grass, serrated tussock, annual exotic grass, perennial exotic grass, exotic broadleaf, wallaby grass, *Austrostipa sp*., perennial native grass and other to determine the relative extent of each component along each transect.

2.4.2 Groundcover Biomass Assessment

In addition to the assessment of species richness, assessment of biomass was included during the 2020 monitoring, as the species is known to actively avoid dense swaths of grasses, showing a preference for relatively open areas with reduced biomass (DEWHA 2009, p. 5)

Within each 20m x 20m plot within the grassland areas, ten locations were randomly selected within each plot and then biomass levels assessed using the following method:

- A 1 m x 1 m quadrat was marked out within the wider plot
- 18 golf balls were then dropped onto the grass surface from a 1.3 m height into the quadrat
- Each ball was scored as follows:
  - >90% of the ball is visible: score 1
  - 33 – 90% of the ball is visible: score 0.5
  - <33% of the ball is visible: score 0.

Photographs were taken as a reference for the score.

The average scores for the plot were then calculated to provide an estimate of vegetation cover level (Biomass), with less visibility of the balls being indicative of higher biomass:

- low (15-18)
- medium (6-14)
- high (0-5).

The scores and biomass categorisatins for each plot are provided in the results section.

Note: This approach to biomass assessment has now been superceded by calculation of thatch densisty collected as

2.5 GSM Flying Surveys

Flying GSM surveys were conducted according to the protocol outlined in the OMP in preparation (Umwelt, in prep.), with additions to improve consistency with the ACT Government protocols for monitoring GSM in offset sites (2010b) GSM (**Figure 2.1**).

Two sampling methods were undertaken to survey GSM during 2020, being:

- Rotational counts at 12 established locations for comparsion with surveys conducted from 2013-2018 (RJPL 2014a).
- Timed transects across 15 established 100 m transect locations for consistency with ACT Government Offset monitoring protocols for GSM.

As specified in the OMP (RJPL 2014a), rotational point counts were conducted at the monitoring quadrats located throughout the YEP offset area according to the following protocol:

- Locate each of the quadrats used for the vegetation and habitat assessments using GPS
- While standing in the middle of each quadrat, count all GSM observed in and beyond the quadrat to approximately 20 m while rotating through 360º
- Record GSM numbers on the Flying GSM survey data sheet (RJPL 2014a Appendix G)
- Wait 30 seconds
- Repeat Steps 2-4, nine more times
- Average the GSM count at each site and enter the result on the flying GSM survey data sheet (RJPL 2014a Appendix G).

Fifteen 100 m fixed transect surveys were conducted covering the main areas of habitat at YEP. The timed transect surveys were added to the survey program at YEP in 2018 to improve consistency with standard ACT Government GSM survey programs to allow standardised between-site analysis in flying moth numbers. The following protocol was followed:

- Follow the pre-defined 100 m transects
- Note the time and weather conditions when starting to walk each transect
- Count all GSM observed while walking slowly and steadily along transects

- Note the end time of each transect survey
- Record data as per the ACT Government GSM Survey Protocol
- Calculate the number of GSM observed per minute.

On-site weather data was recorded during all flying GSM field surveys. Incidental GSM observations were also recorded during other site visits and between surveys.

Female golden sun moths and pupa cases were recorded separately from the timed surveys. The records were identified as incidental observations.

2.6 GSM Habitat Monitoring

As specified in the OMP (RJPL 2014a), a qualitative GSM habitat assessment was undertaken using a meandering traverse throughout the site, covering both exotic and native grass dominated areas. The distribution of native grassland and other GSM habitat (such as Chilean needlegrass) and the distribution of exotic perennial tussock grasses was updated in accordance with the OMP in preparation (Umwelt, in prep.).

2.7 Meteorological Data

Meteorological data for Canberra Airport from 1 January 2013 to 31 December 2020 was obtained from the Bureau of Meteorology.

3.0 Results

3.1 Regional GSM Information

Golden sun moth surveys commenced during the known local flight season, based on informal consultation with local specialists (including ACT and New South Wales Government ecologists and consultants). The start of the 2020 flying season was confirmed at numerous sites in mid November 2020 following observations of flying individuals at Cookanella, Jerrabombera East, Jerrabomberra West, North Curtin Horse Paddocks and YEP during the week starting 15 November 2020. The peak flying period was in late November and early December, but ended early due to cool and windy conditions in mid-to-late December, with low numbers of moths recorded after the second week of December.

3.2 Vegetation Mapping

Vegetation mapping, step-point transects, and GSM habitat mapping were conducted from December 2020 to February2021. **Figure** 3.1 shows the distribution of vegetation communities mapped at YEP in 2020/21. This mapping was undertaken in summer 2020/21, whereas in previous years the mapping had been conducted in spring. This was primarily due to the wet, cold spring that did not provide suitable survey conditions. During Summaries of the areas of each vegetation community are shown in **Table 3.1**.

Table 3.1 2020 summary of vegetation and land use mapping

Vegetation type / land use	2021 (ha)
Natural temperate grassland	0.6
Native pasture	1.0
Mixed native and exotic pasture	4.5
Exotic pasture	7.6
(Non-grassland areas (e.g. buildings, riparian margins, woodland))	7.9
Total Project Area	**21.6**[1]

Note: A recalculation of the total project area was undertaken and has resulted in an increase in the total size, however, this would not have a substantial effect on the results.

Where continuous with areas of natural temperate grassland, areas of native pasture are likely to meet criteria for the Commonwealth listing of natural temperate grassland.

3.3 Weed Mapping

The distribution of significant weeds at YEP is shown in **Figure 3.2,** and the calculated extent of weed infestations is summarised in **Table 3.2**. The areas of weed extent have been summarised in the total area, even where there is overlap in the extent as these will require different treatment regimes for control. As a result the total area represents that total area that will require some form of treatment to eliminate weeds on the site.

Chilean needle grass (*Nassella neesiana*) and African lovegrass (*Eragrostis curvula*) occur in a range of patch sizes throughout YEP, and forms a dominant swath in some areas, effectively crowding out more desirable species. Patches of serrated tussock (*Nassella trichotoma*), St John's Wort (*Hypericum* perforatum) and Caltrop (*Tribulus terrestris*) also occur at several locations across YEP, and are often interspersed through degraded sections of the site. Weed contractors also noted encroachment of purple pigeon grass (*Setaria incrassata*) in the northern end of the site.

Caltrop was not recorded in previous surveys, and may have been imported on contaminated stock feed or from the manure of horses visiting the site. Control of weeds focusing on African lovegrass and Chilean needlegrass commenced during spring and summer 2020/21 and specific control for caltrop commenced in February 2021 (CoreEnviro, 2021). Incidental observation of weed distribution noted that weed spraying has been effective in reducing the overall extent of weeds on the site. Patches of large tussocks, particularly African lovegrass, were substantially reduced, however field observations noted that there were numerous young plants emerging this year an areas previously sprayed, likely due to patches of bare ground and the favourable germination conditions.

Table 3.2 2020 summary of significant weeds at YEP

Vegetation type / land use	2019 (ha)	2020/21 (ha)
Chilean Needlegrass dominant	3.2	1.5
African Lovegrass Dominant	3.0	1.4
Serrated Tussock –		Isolated scattered plants areas
St John's Wort		Scattered small patches, ~0.2
Caltrop other areas		1.0
Total Weed affected area	**6.2**	**3.9**

Note: There are some weed areas that are interspersed through the larger dominant patches, however these will require separate treatment regimes, and have been reported as a separate area calculation.

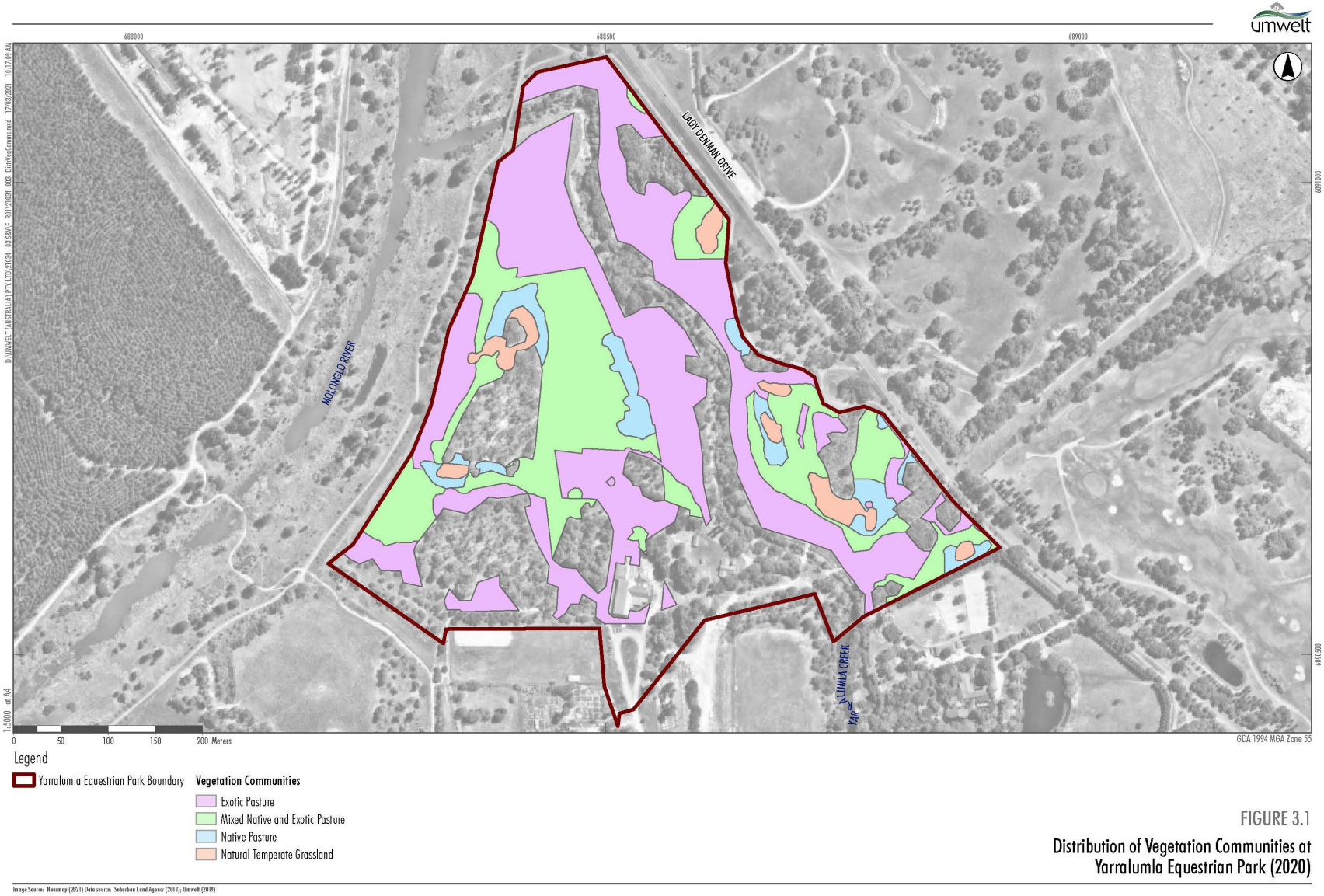


Figure 3.1 Distribution of Vegetation Communities at Yarralumla Equestrian Park (2020)

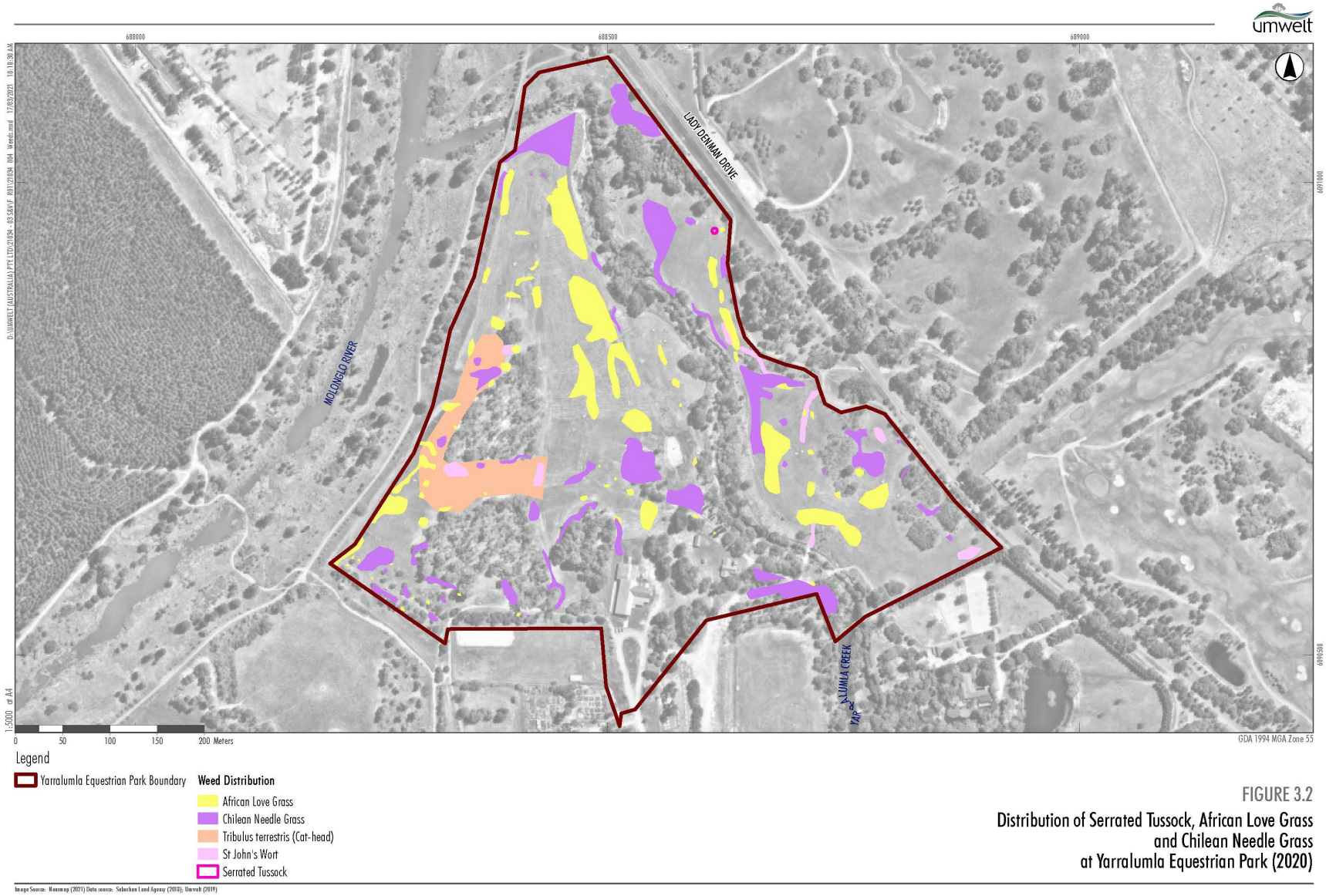


FIGURE 3.2
Distribution of Serrated Tussock, African Love Grass and Chilean Needle Grass at Yarralumla Equestrian Park (2020)

Figure 3.2 Distribution of serrated tussock, African lovegrass and Chilean needle grass at Yarralumla Equestrian Park (2020)

3.4 GSM Habitat Mapping

GSM habitat extent within YEP was surveyed during December 2020 and extended into February 2021. The survey results are summarised in **Table 3.3** and shown in **Figure 3.3**. Low to moderate quality GSM habitat persists across the majority of the grassland present at YEP, with no areas of high quality habitat detected during the field surveys.

Table 3.3 2020 summary of GSM habitat areas

GSM habitat area	2021 (ha)
Low quality	5.5
Low-quality habitat dominated by Chilean needle grass	1.9
Moderate quality	1.3
High quality	0
Total	**8.7**

3.5 Native Pasture and Natural Temperate Grassland Monitoring

Grassland monitoring was conducted over two days on 3-5 February 2021, following a period of dry weather. Monitoring was completed late due to the high germination of annuals in spring 2020 which inhibited survey. Incidental observation notes indicated that the condition of native grasslands was improved relative to 2019, with forbs and native grasses appearing more dominant than in previous surveys. The condition of natural temperate grassland patches was qualitatively assessed as improved.

Plant species, along with Braun-Blanquet abundance scores were recorded for both for a 4 x 4 m quadrat for comparison with previous monitoring results and for a 20 x 20 m quadrat for application of listing condition thresholds for natural temperate grassland and consistency with other sites (**Table 3.4)**. Floristic value scores for the 4 x 4 metre plot are calculated using Rehwinkel 2007, In 2017-2020, floristic value scores were also calculated according to Rehwinkel 2015 to facilitate consideration against criteria for inclusion in the revised NTG listing (**Table 3.4**). Floristic data is presented in **Appendix A** and understorey transect data are presented in **Appendix B**. Understorey structure transects were recorded with multiple hits per point, rather than dominant recorded at each point. Consequently, proportions have been calculated based on the total number of records on the transect, including multiple hits.

Error! Reference source not found. provides a summary of the key indicator metrics identified by ACT Government relevant to natural temperate grassland for each identified vegetation zone against condition metrics for natural temperate grassland. These metrics are comparable with other ACT Government Environmental Offsets Monitoring completed by the ACT Government.

Assessment of the site against the updated criteria for the critically endangered community listings for the 20 m^2 quadrats are shown in **Table 3.5**. Seven quadrats were determined to meet condition thresholds for inclusion in the listed critically endangered ecological community, while five quadrats, 1, 4, 5, 9 and 11 did not meet criteria (**Figure** 3.1). All quadrats that do not meet criteria are located in areas mapped as exotic (quadrat 5), mixed native and exotic pasture (quadrats 1 and 9) and native pasture (quadrats 4 and 11). It was noted that quadrat 11, when completed as a 20 x 20 m quadrat spans the boundary of native pasture and mixed native and exotic pasture due to the small scale of this patch. The quadrat completed in mapped native pasture around quadrat 6 met criteria for classification as natural temperate grassland, and further consideration of the extent of vegetation meeting criteria is warranted in the next survey.

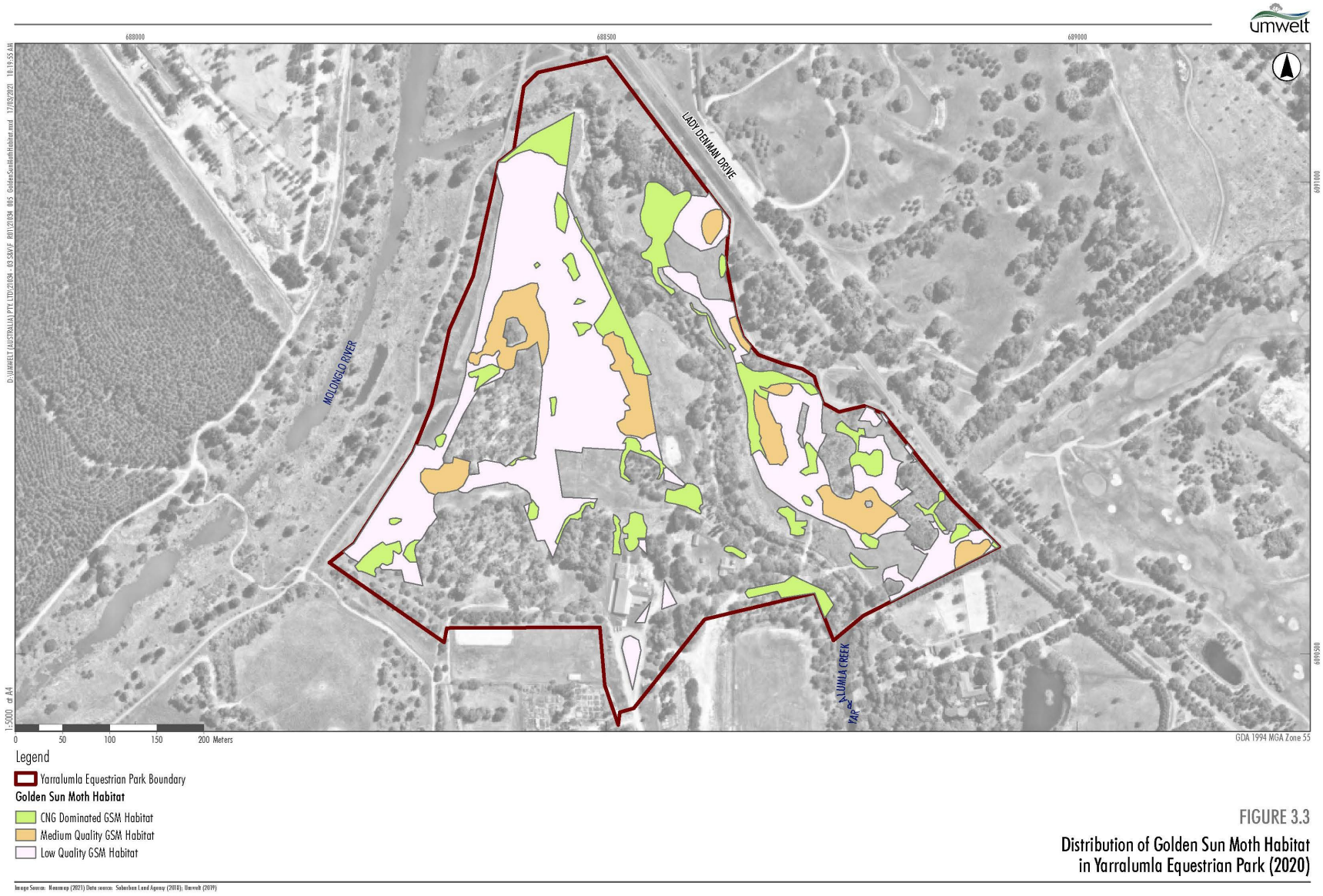


Figure 3.3 Distribution of Golden Sun Moth habitat in Yarralumla Equestrian Park (2020)

Table 3.4 2020/21 vegetation survey results

Quadrat	Number of native species 4x4m plot	Number of exotic species 4x4m plot	Number of significant weeds 4x4m plot	Floristic value score (Rehwinkel 2007) (4x4m plot)	Floristic value score (Rehwinkel 2015) (20x20m plot)	Biomass average score (golf ball method)	Biomass Category
1	5	10	1	0	2.6	11.65	Moderate
2	12	10	2	1	14.1	11.6	Moderate
3	11	3	1	1	15.3	15.1	Low
4	6	5	0	1	16.9	13.8	Moderate
5	7	11	2	1	6.4	6.7	Moderate
6	13	8	2	2	11.9	6.6	Moderate
7	7	6	2	1	9.9	11.6	Moderate
8	13	7	2	4	18.5	9.15	Moderate
9	4	9	2	0	3.7	6.5	Moderate
10	11	7	2	4	20.7	12.95	Moderate
11	8	13	2	1	13.2	9.75	Moderate
12	9	8	1	1	16.7	10.8	Moderate

Table 3.5 Summarised assessment against Commonwealth criteria for the EPBC Act-listed natural temperate grassland critically endangered ecological community based on floristic data and site characteristics for the 20 m² quadrats

Quadrat (Threshold)	Mapped Condition	Number of non-grass native species (8)	Number of indicator species (2)	Floristic value score (5)	Proportion perennial cover made up of native grass (50)	Meets natural temperate grassland criteria (Australian Governmen t 2016)
1	Mixed pasture	4	0	2.6	18	No
2	Natural temperate grassland	9	5	14.1	100	Yes
3	Natural temperate grassland	10	4	15.3	86	Yes
4	Native pasture	10	5	16.9	22	No
5	Exotic pasture	5	1	6.4	47	No
6	Native pasture	7	3	11.9	80	Yes
7	Natural temperate grassland	4	2	9.9	73	Yes
8	Natural temperate grassland	10	6	18.5	92	Yes
9	Mixed pasture	3	0	3.7	12	No
10	Natural temperate grassland	10	7	20.7	96	Yes
11	Mixed pature	9	4	13.2	38	No
12	Natural temperate grassland	8	6	16.7	100	Yes

3.6 Weed Density Monitoring

Chilean needle grass was observed on five monitoring transects and African lovegrass was observed in eleven transects. No serrated tussock was observed on the transects, however this is present in the wider area of the site and could potentially re-occupy areas should weed control be discontinued. Chilean needle grass was most prevalent at quadrat five and nine whilst African lovegrass was most prevalent at transects six and eleven (**Figure 3.3**). The density of key weed species is at each plot is shown in **Table 3.6.** This metric will provide comparable densities of key threats over time.

Table 3.6 Weed metrics at plots in January 2021.

Quadrat	Weed Value Score	Weed density – Chilean Needlegrass – (plants per ha)	Weed density – African Lovegrass – (plants per ha)	Weed density – St John's Wort – (plants per ha)
1	9.4	0	28	14
2	17.8	0	5650	541
3	20.7	994	241	139
4	15.5	0	233	0
5	35.2	118	9549	161
6	26.8	0	9549	737
7	16.5	9549	568	26
8	15.4	0	9549	1061
9	22.2	0	3304	1135
10	24.1	139	9549	994
11	22.5	0	5650	1973
12	24	0	233	1218

3.7 GSM Flying Surveys

Two transect surveys and two rotational count surveys were conducted between 11:00 and 14:00 on warm days with light winds **(Table 3.7)**. All GSM survey records are presented in **Appendix C**. As previously noted, the climatic conditions during spring and early summer 2020 did not provide ideal survey conditions, with a restricted number of suitable survey days. Conseqeuntly, surveys were completed in conditions that were cooler than ideal, and, in the case of the final survey, with higher cloud cover. Flying moth surveys were undertaken during the peak period of GSM activity in the ACT and are consequently valid representations of GSM activity levels at the YEP offset site. Flying moth numbers were typically lower than average at sites throughout the ACT.

Table 3.7 Weather conditions during GSM flying moth surveys

Component	Date	Temp (ºC)	Last rainfall (mm)	Wind speed (km/h)	Cloud cover (%)
Transect Survey 1	17 November 2020	20-22	4.2 (13 Nov)	<10	<10
Transect Survey 2/ Rotational Survey 1	2 December 2020	21-23	3.4 (29 Nov)	<10	<30
Rotational Survey 2	15 December 2020	21-25	0.8 (13 Dec) 12.0 (6 Dec)	<10	>90

GSM were recorded at 13 of the 15 transects with the highest numbers occurring at transect 2C (**Table 3.7**) (). The highest numbers of GSM were recorded at points 4, 6 and 8 whilst the lowest numbers were observed at points 7, 10 and 11.

Table 3.7 Summary of transect survey results (2020)

Transect	Survey 1 Total GSM	Survey 2 Total GSM	Total GSM	Average GSM
1A	0	4	4	2
1B	0	4	4	2
2A	0	2	2	1
2B	4	1	5	2.5
2C	8	1	9	4.5
2D	0	2	2	1
3A	0	1	1	0.5
3B	0	3	3	1.5
3C	1	0	1	0.5
3D	0	1	1	0.5
4A	0	0	0	0
4B	0	0	0	0
4C	0	3	3	1.5
4D	1	2	3	1.5
5A	0	3	3	1.5

Table 3.8 Summary of rotational survey results (2020)

Point	Survey 1 Average	Survey 1 Max	Survey 2 Average	Survey 2 Max	Combined Average	Combined Max
1	2.1	5	2.7	5	2.4	5
2	1.6	3	2.3	6	2.0	6
3	4.2	7	0.1	1	2.2	7
4	2	8	6.8	10	4.4	10
5	0.5	1	1.3	3	1.0	3
6	1.8	3	14.9	20	8.4	20
7	0	0	0	0	0	0
8	3.9	9	7	11	5.5	11
9	0	0	1.3	3	0.7	3
10	0.3	1	2.7	5	1.5	5
11	0.4	1	0.7	2	0.6	2
12	0.4	2	2.2	4	1.3	4

3.8 Incidental Observations

Female GSM and pupa cases were recorded as incidental observations and locations are shown in **Figure 3.5.** One female was recorded on 2 December 2020. No pupa cases were recorded in 2020 (cf. 20 in 2019, 39 in 2018, and zero in 2017). A total of 76 male GSM were recorded incidentally on 2 and 15 December 2020, but are not mapped.

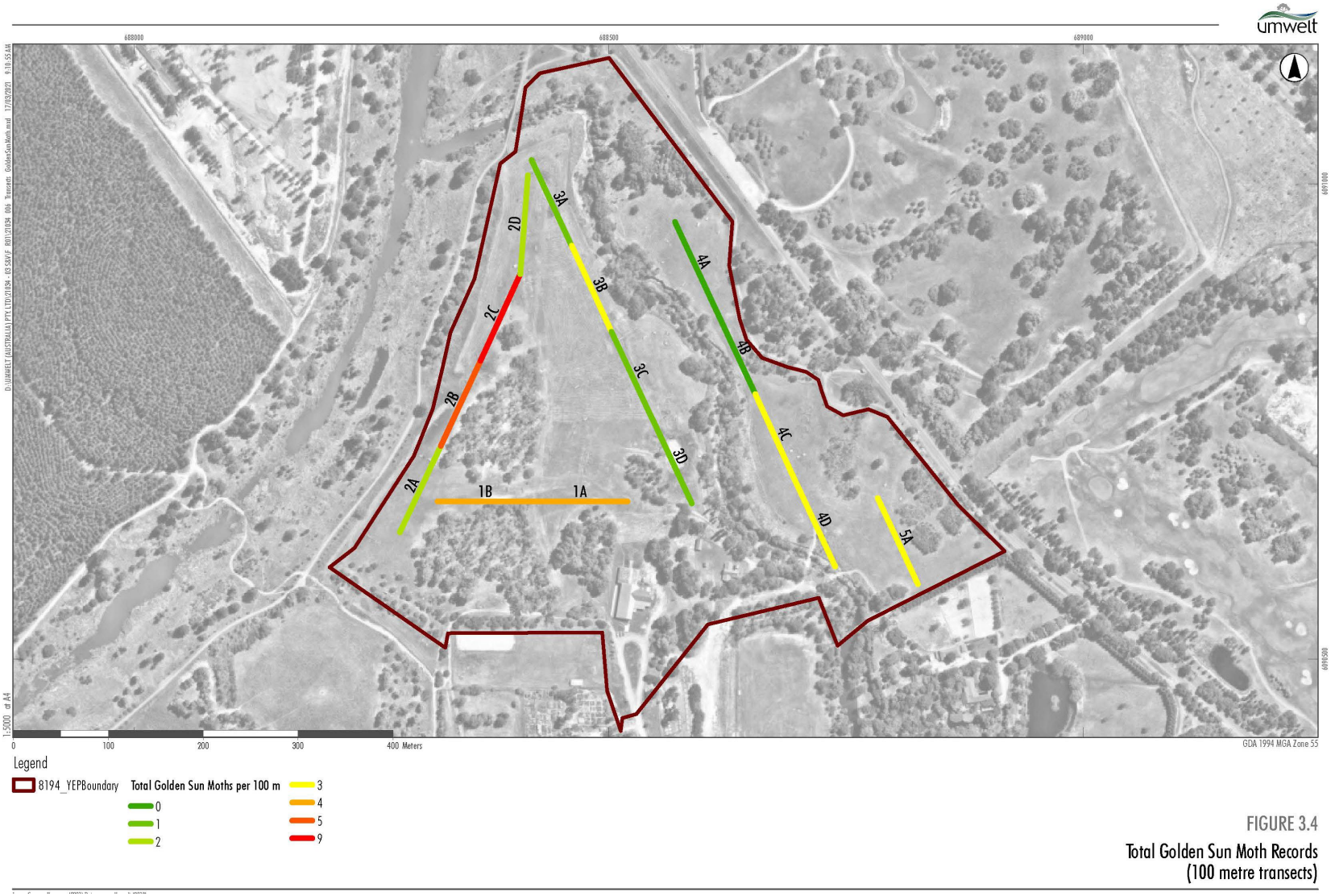


Figure 3.4 Total Golden Sun Moth records (100 metre transects)

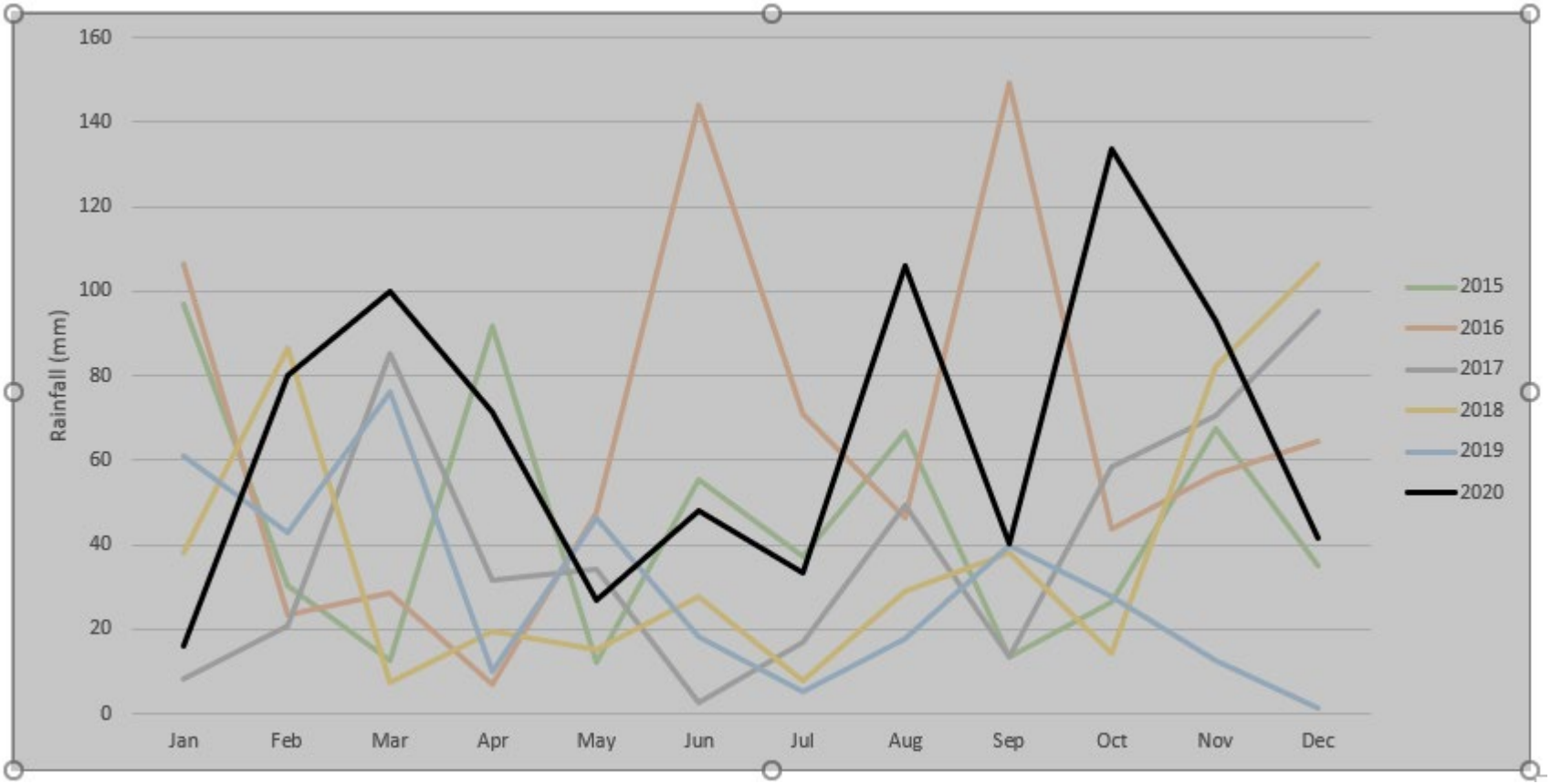
Figure 3.5 Distribution of Golden Sun Moth records (rotational point surveys) at Yarralumla Equestrian Park (2020)

3.9 Meteorological Data

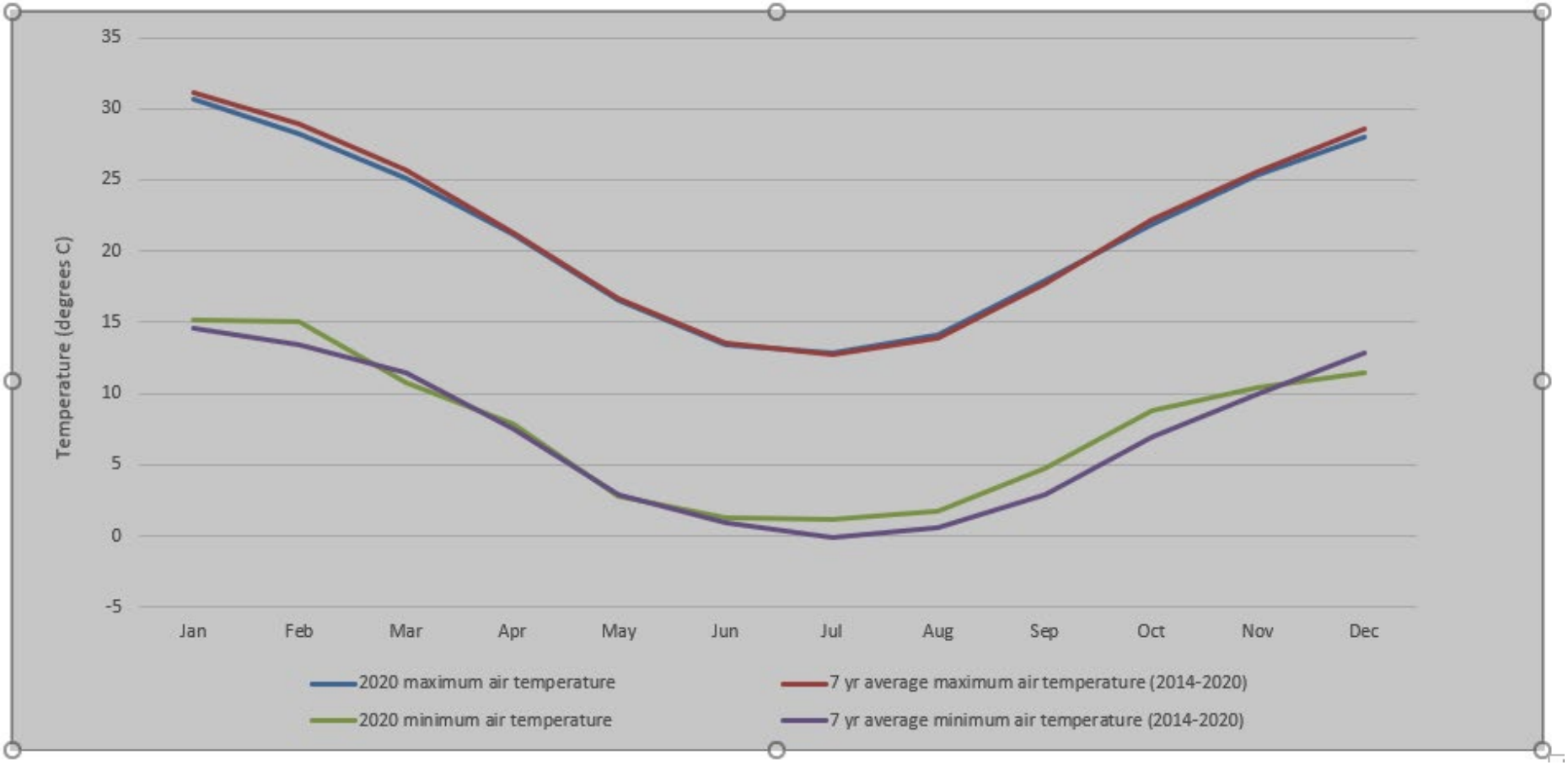
Where applicable, survey data is interpreted with reference to summarised meteorological data for the season. Monthly rainfall and average daily maximum and minimum air temperatures (2015-2020) are presented in **Graph 3.1** and **Graph 3.2** respectively.

Total rainfall during the months leading up to the GSM 2020 flying season (i.e. June to October: 361.4 mm) was greater than the 10-year average (i.e. 219 mm) and far higher than during the same period in 2018 and 2019 (i.e. 117.0 mm and 108.4 mm respectively). Rainfall during the 2020 flying season (i.e. November / December: 134.4 mm) was close to the the 10-year average (i.e. 123 mm) though far higher than during the same period in 2019 (i.e. 13.8 mm).

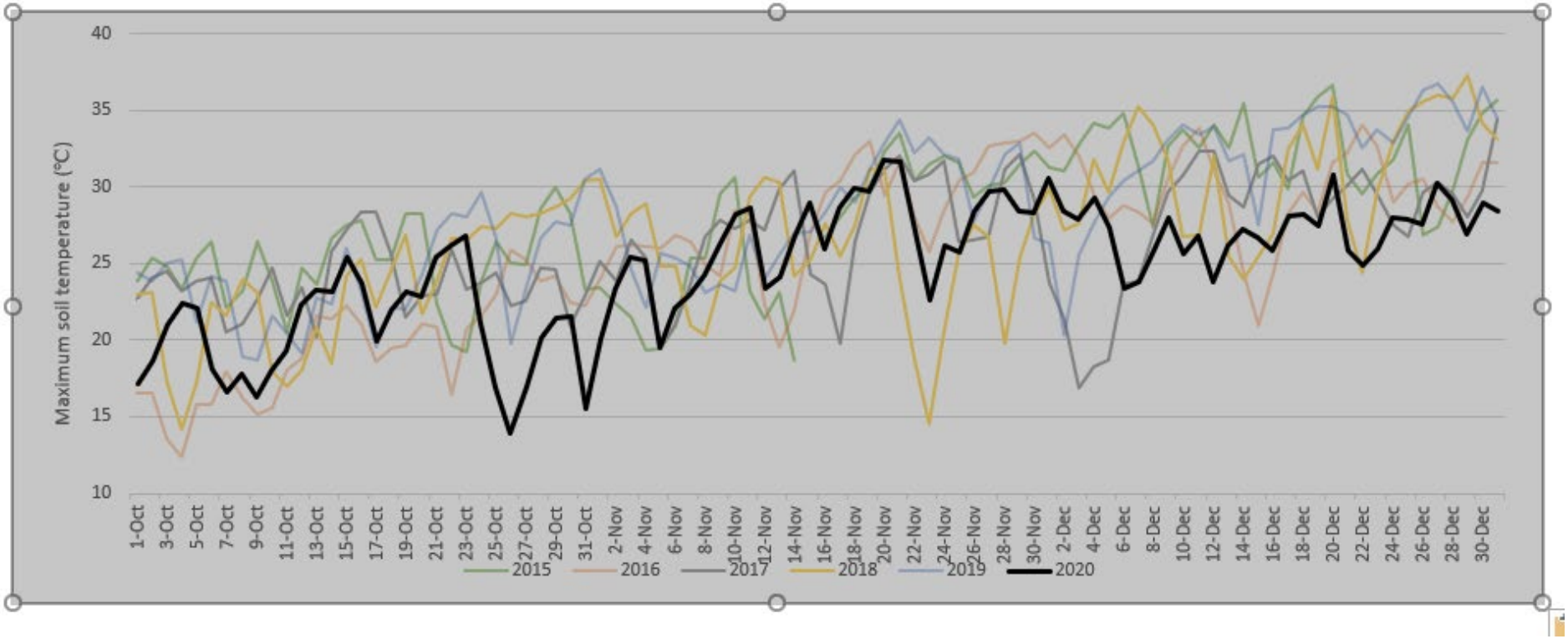
Monthly average daily maximum soil temperatures recorded at 10 cm depth for 2015- 2020 is presented in **Graph 3.3**. **Graph 3.4** shows daily maximum soil temperature and **Graph 3.5** shows daily precipitation leading up to and during the past six GSM flying seasons (i.e. October to December). Summarised relevant meteorological data from 2014 to 2020 are presented in **Appendix D.** All meteorological data presented in this report were recorded at the Canberra Airport (i.e. site 070351).



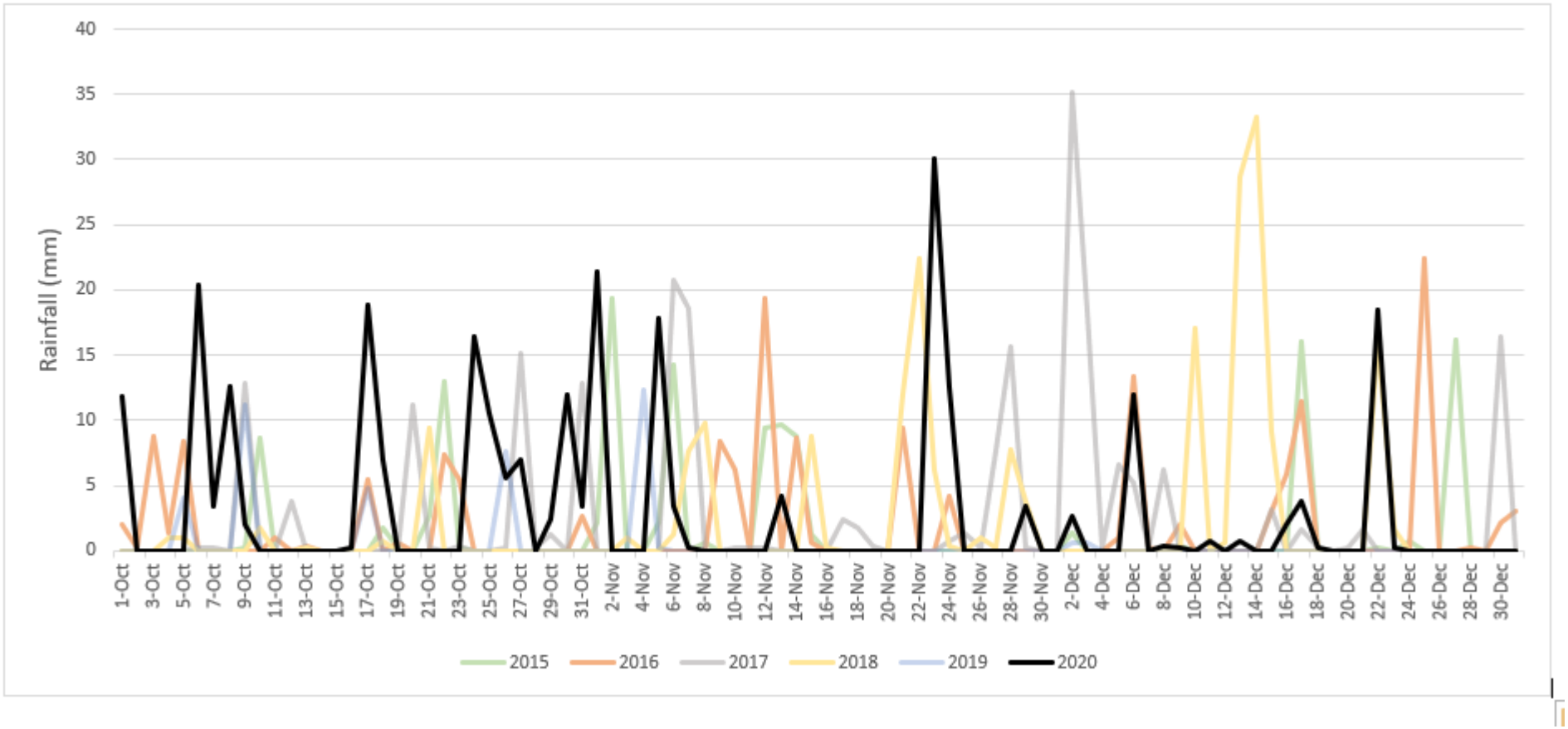
Graph 3.1 Monthly rainfall at Canberra Airport (2015-2020)



Graph 3.2. Monthly average daily maximum and minimum temperature at Canberra Airport (2020 vs 2014-2020 average)



Graph 3.3 Maximum daily soil temperature at Canberra Airport leading up to and during the GSM flying period (1 October – 31 December 2015-2020)



Graph 3.4 Daily rainfall at Canberra Airport leading up to and during the GSM flying period (1 October – 31 December, 2015-2020)

4.0 Discussion and Analysis

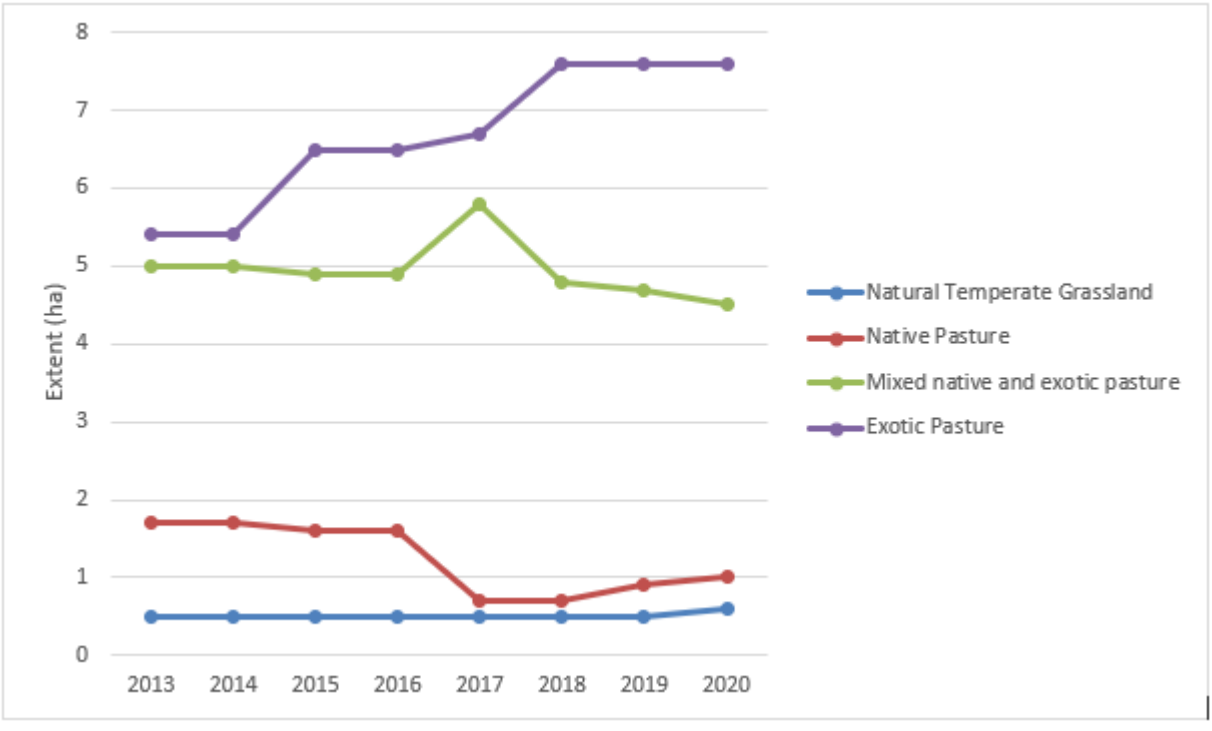
4.1 Native grassland extent and condition

4.1.1 Extent

Changes in the extent of vegetation types and land uses reported in the OMP (RJPL 2014a), and year 0 (RJPL 2014b), year 1, year 2, year 3 and year 4 and year 5 monitoring reports (RJPL 2015; SMEC 2016, SMEC 2017, SMEC 2018, Umwelt 2019) to 2020 are summarised in **Appendix E.** Trends in the extent of NTG and other grassland types within YEP are shown in **Graph 4.1**.

While the extent of NTG has remained stable since 2013, the extent of native dominated pasture has declined substantially (i.e. more than halved) between 2016 and 2017 due to substantial increases in weed invasion. The extent of increased slightly in 2019, and this improvement continued in 2020.

The decline in native pasture areas in recent years has been driven by the invasion of native pasture areas by perennial exotic tussock grasses, particularly African lovegrass, and Chilean needle grass, resulting in the reclassification of substantial areas as mixed native and exotic pasture. The extent of exotic pasture remained stable from 2018 to 2020, after increasing in previous years. The increase in native pasture extent in 2020 was due to areas that were previously a mixed native/exotic pasture improving to either native pasure or native temperate grassland, likely as an early result of weed control.



Graph 4.1 Changes in grassland extent at Yarralumla Equestrian Park (2013-2020)

4.1.2 Condition

Comparison with previous monitoring

Floristic scores (after Rehwinkel 2007) for the 4 x 4 metre plot each survey season are shown in Error! Reference source not found. . Three quadrats, i.e. quadrats 1, 5 and 9 were located within predominantly exotic vegetation, and this was consistent with previous years. A high level of inter-annual variability in floristic value scores is present within each monitoring quadrat which is the result of variable seasonal conditions and survey timing.

In 2020, two quadrats had a floristic value score of four or greater, compared with seven in 2019, two in 2018, two in 2017 and seven in 2016. two quadrats achieved a floristic value score of 0 in 2020 compared with three in 2019, four in 2018, six in 2017, three in 2016, four in 2015, three in 2014 and two in 2013. Floristic value scores were below the the 2013 – 2019 average at 7 quadrats and equal to or higher than average at the remaining 5 quadrats. Exotic species richness was greater than native species richness in7 of the 12 monitoring quadrats. At least one significant weed species was recorded in all of the quadrats, highlighting that wee management remains the primary issue across the site.

The average floristic value score in 2020 was 1.41, which is less than both the long term average, the three year average and the three year baseline, but not the lowest that has been recorded on the site. Six plots had a rolling 3 year average less than the 3 year baseline, three plots had a rolling three year average equal to the 3 year baseline and three plots had a rolling three year average equal to the 3 year baseline. It is noted that during the initial monitoring, 4x4 metre plots in natural temperate grassland and native pasture were placed at the most diverse points in the associated vegetation zone. Subsequently, 4 x 4 metre plots have been located based on GPS coordinates, which may have an error of ±5 metres. Observation of the 20 x 20 metre plots has indicated that sampling of the 4 x 4 metre plots has no longer sampled the most diverse point. Consequently, the reduction in floristic value over time may be in part due to spatial error in sampling at this scale. Consequently, for future monitoring it is recommended that the 4 x 4 metre plot be completed in the most diverse part of the 20 x 20 m plot established centred on the relevant coordinates.

Floristic value scores recorded at YEP show a high level of inter-annual variation. Inter-annual variation in grassland composition and structure (and hence, site floristic scores) at YEP can be strongly influenced by rainfall during the months leading up to each annual vegetation survey. For example, rainfall during winter and spring 2016 was well above average in Canberra (i.e. 511 mm cf. average of 296 mm), which led to favorable conditions for exotic grassland species that following spring/summer (SMEC 2017). Rainfall in Canberra during winter and spring of 2017 (SMEC 2018), 2018 (Umwelt 2019) and 2019 was far lower than average and this may have influenced survival rates for moth larvae hatching in these years due to less food availability and harder ground due to the poorer than average growing conditions at YEP. Moths are believed to spend thee years in the grub phase, meaning that the moths observed flying in 2020 initially hatched in 2017, and have spent most of their development under moderate to severe drought conditions. The high level of inter-annual variation is likely attributable to variation in seasonal conditions. Grassland ranking scores in 2019 were similar to scores recorded in 2018. Declines in vegetation condition at YEP are associated with the invasion of perennial exotic tussock grasses, as outlined in **Section** Error! Reference source not found.**.**

Comparison with listing advice

The number of quadrats which meet natural temperate grassland criteria at YEP is greater when assessed against the 2016 listing criteria rather than the previous listing criteria. A total of ten 20x20m quadrats meet the floristic condition threshold for natural temperate grassland classification criteria, while seven of these are within areas dominated by native perennial species (**Table 3.5**). Consequently, in total, seven plots (2, 3, 6, 7, 8, 10, 12) meet condition criterial for the natural temperate grassland critically endangered

ecological community. This includes one plot, plot 6, surrounding which the vegetation is mapped as native pasture. This indicates that in accordance with the current listing advice, natural temperate grassland is more widely distributed at YEP than was mapped under the previous listing for this community. Furthermore, areas currently not identified as natural temperate grassland retain sufficient floristic condition to be classified as natural temperate grassland in the event that Areas mapped as native pasture that are continuous with adjacent areas meeting criteria for natural temperate grassland, including around

Comparison with benchmarks

Comparison averaged key metrics for each mapped vegetation zone with key benchmarks, consistent with the ACT Government Environmental Offsets Monitoring method, are shown in **Table 4.2**.

Areas identified as natural temperate grassland meet benchmarks for four out of seven non-weed related benchmarks, including those related to Commonwealth condition thresholds. While bare ground cover and thatch cover are less than benchmark, the overall thatch density meets benchmark. Density of Chilean needlegrass, African lovegrass and St Johns wort also exceed the thresholds. As these metrics were not collected in a consistent manner in previous monitoring it is not possible to compare these with previous seasons, however they will be a valuable tool for future monitoring.

Native pasture areas met thresholds for three of the seven non-weed related thresholds, however did not meet the threshold for the proportion of native cover. The failure to meet thresholds for proportion of native cover is not consistent with general observations during mapping, which sought to identify areas with a dominant cover of native species. The proportion of native cover should be reviewed in future monitoring, and the location of understorey structure transects confirmed to be within the correct zone.

Future montoring should continue to monitor thatch cover and bare ground cover to determine if any short term management responses are required. It is, however noted that thatch density met benchmark, and anticipated that bare ground cover may improve following several years of intense weed control. Biomass management at the site is constained by equestrian uses, and potentially by future weed control requirements.

Areas of mixed native and exotic pasture, and exotic pasture, each met three thresholds, however in the majority of these cases these related to thatch cover and thatch density, which are short term rather than long term management indicators.

Table 4.1 Summary of floristic value scores (2013-2020)

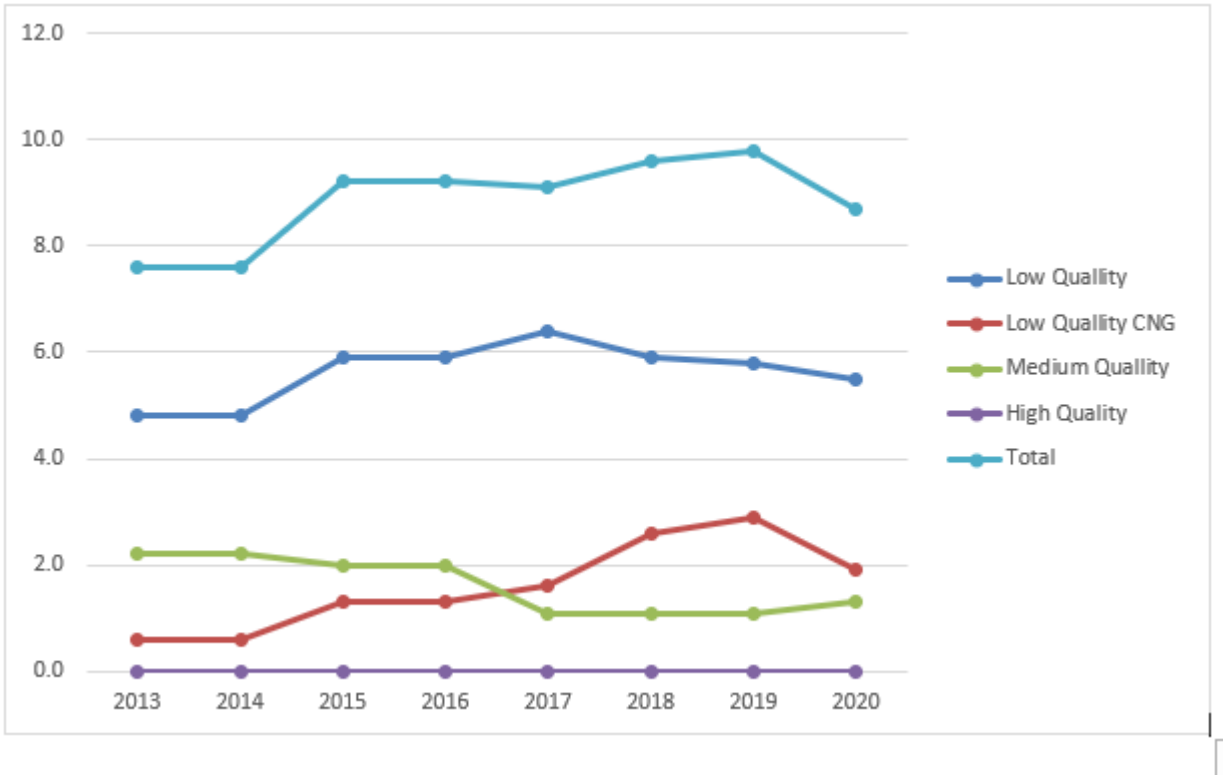
Quadrat	Baseline (Av 2013-15)	Baseline Standard deviation	Floristic value score 2013	Floristic value score 2014	Floristic value score 2015	Floristic value score 2016	Floristic value score 2017	Floristic value score 2018	Floristic value score 2019	Floristic value score 2020	Rolling 3 year average	Rolling 3 year standard deviation
1	0.0	0.0	0	0	0	0	0	0	0	0	**0.0**	0.0
2	4.0	3.5	4	7	1	7	1	1	1	1	**1.0**	0.0
3	4.3	1.5	7	4	2	1	2	1	1	1	**1.0**	0.0
4	1.7	2.1	2	2	1	5	0	0	0	1	**0.3**	0.6
5	0.3	0.6	1	0	0	1	0	0	1	1	**0.7**	0.6
6	2.3	2.6	1	5	1	0	2	3	2	2	**2.3**	0.6
7	2.3	2.6	1	5	1	0	2	3	2	1	**2.0**	1.0
8	1.3	5.9	2	2	0	11	5	3	4	4	**3.7**	0.6
9	0.0	0.0	0	0	0	0	0	0	0	0	**0.0**	0.0
10	2.7	2.3	2	5	1	5	2	4	8	4	**5.3**	2.3
11	3.0	2.1	4	4	1	5	0	1	1	1	**1.0**	0.0
12	3.0	2.1	4	4	1	5	0	1	1	1	**1.0**	0.0
Average	2.1	1.9	2.75	4.25	0.75	3.83	1.42	1.5	2.0	1.41	1.6	0.3

Table 4.2 Monitoring metrics showing reference benchmarks (if available) and values for mean ± standard deviation (number of sites (n)) for each zone, and whether the available benchmark (green tick = met; red cross= not met) has been met (*).^EPBC metrics for vegetation community listing.

Metric	Benchmark	Natural Temperate Grassland (Plots 2, 3, 7, 8, 10, 12)	*	Native Pasture (Plots 4, 6, 11)	*	Mixed Native and Exotic Pasture (Plots 1, 9)	*	Exotic Pasture (Plot 5)	*
Proportion native cover (<1 m height) (%)^	≥50	65.8±16.8	✓	26.8±22.2	✗	8.1±0.6	✗	18.9	✗
Bare ground cover (%)	10-20	4.9±4.2	✗	6.0±6.5	✗	0	✗	0	✗
Thatch cover (%)	10-20	5.0±7.0	✗	8.2±0.5	✗	19.4±7.3	✓	12	✓
Floristic Value Score (FVS)^	≥5	15.9±3.7	✓	14±2.6	✓	3.15±0.8	✗	6.4	✓
Native plant species richness	>24	16±4	✗	16±2	✗	8.5±0.7	✗	8	✗
Thatch density (thatch cover x thatch depth)	<0.25	0.04±0.09	✓	0.06±0.01	✓	0.2±0.02	✓	0.3	✓
Average grass height (cm)	5-12	7.4±1.1	✓	7.6±1.2	✓	9.4±3.2	✓	12.6	✗0
Density CNG (plants per ha)	<50	1780±3825	✗	0	✓	0	✗	118	✗
Density ALG (plants per ha)	<50	4298±4558	✗	5144±4678	✗	1666±2316	✗	9549	✗
Density ST (plants per ha)	<50	0	✓	0	✓	0	✓	0	✓
Density SJW (plants per ha)	<50	663±504	✗	903±997	✗	574±793	✗	161	✗
Weed Value Score (WVS)	N/A	19.75		21.6		15.8		35.2	

4.2 GSM habitat extent and condition

GSM habitat extent reported in the OMP (RJPL 2014a) and the year 0 (i.e. 2013) (RJPL 2014b), year 1 (RJPL 2015), year 2 (SMEC 2016), year 3 (SMEC 2017), year 4 (SMEC 2018) and year 5 (Umwelt 2019) monitoring reports are summarised in **Appendix E**, along with the current monitoring results**.** Overall, the extent of GSM habitat based on native grassland has increased slightly since 2019, however the extent of Chilean needlegrass areas decreased due to ongoing weed control (**Graph 4.2**). While in the short-term this has reduced potential occupancy, over time this will support the recovery of native habitats for the species. There was a slight downward trend in low quality GSM habitat, and a slight upward trend in medium-quality habitat, but this is still below the 2013 level**.** The slight increase in the extent of medium quality habitat is likely to represent early results from the weed control program.

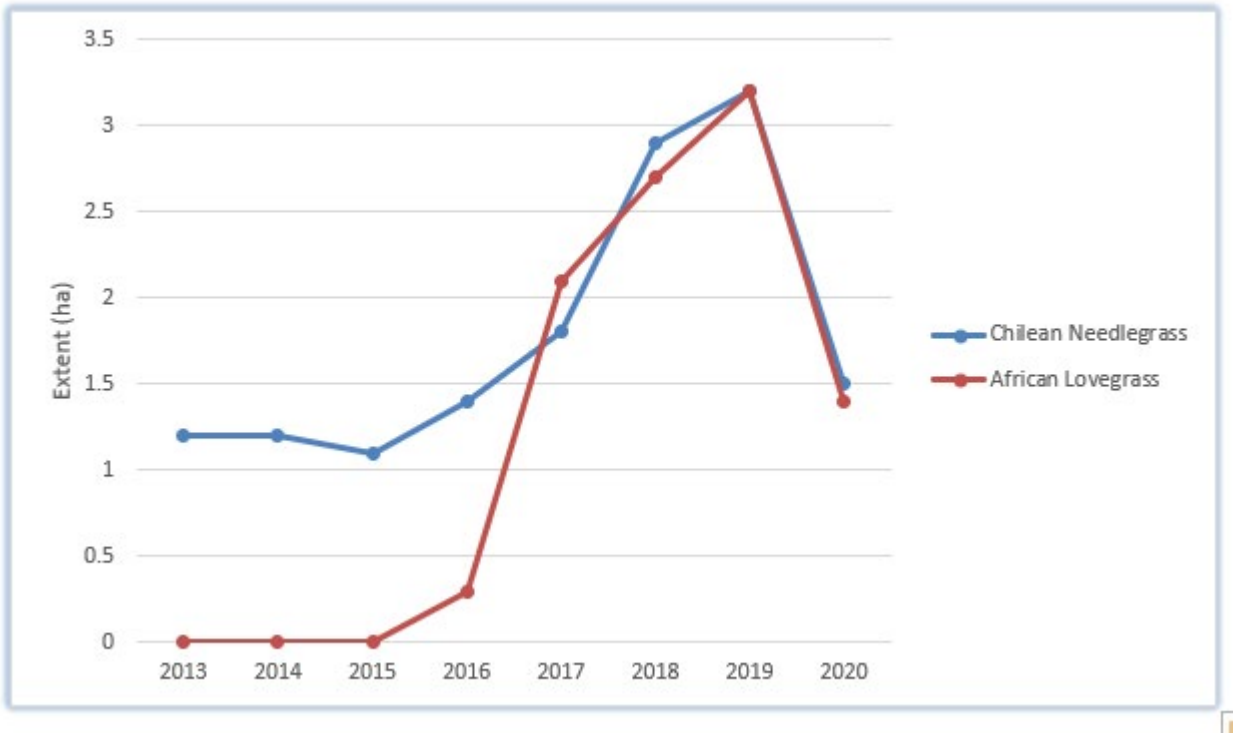


Graph 4.2 Change in the extent of golden sun moth habitat at Yarralumla Equestrian Park (2013-2020)

4.3 Weed distribution and management

The extent of African lovegrass and Chilean needle grass recorded annually at YEP since 2013 is summarised in **Appendix E.** Trends in the extent of Chilean needle grass and African lovegrass since 2013 are shown in **Graph 4.2**. The extent of African lovegrass at YEP first appeared in 2015 and then increased significantly every year until 2019, when control operations commenced. Since the peak in 2019 and November 2020 there has been a significant reduction in extent, with coverage of African Lovegrass more than halving across the site. Large tracts of African lovegrass are still dominant across much of the central and eastern parts of YEP, threatening existing areas of NTG, and it is important that control operations are maintained in the future (**Figure** 3.2). The coverage of Chilean needle grass also reduced by more than 50% between November 2019 and November 2020 from 3.2 to 1.5 hectares. The extent of this weed is now roughly the same as the original monitoring in 2013.

Spraying treatment of serrated tussock, African lovegrass, Chilean needle grass with glyphosate, flupropanate and blue dye respectively was undertaken by Core Enviro Solutions during 22-25 October 2019. St John's Wort, blackberry, and other weeds were treated with fluroxypyr, Wetter 1000, metsulfuron-methyl, and blue dye during November 2019 (CoreEnviro Solutions 2019a, CoreEnviro Solutions 2019b). These treatments continued during 2020 in response to recommendations. There is evidence that weed control is having a positive impact on the condition of native grassland and native pasture.



Graph 4.3 Change in the extent of major weed species at Yarralumla Equestrian Park (2013-2020)

As previously noted in the results, the higher soil moisture appears to have stimulated emergence of weed seeds, which allows for a more effective control of the actively growing young plants and further reductions of weed species in the soil seed bank. This is also likely to have been stimulated by the presence of bare ground following previous weed control. It is important that ongoing weed control is undertaken to ensure removal of new recruitment of tussock grasses, along with other broadleaf weeds, and providing the opportunity for recolonisation by native grasses.

The discovery of caltrop across the site in 2020 matched areas where it was observed that sand had been spread on the site, and chemical control of this weed commenced in February 2021. Spreading of this material is important to reduce the hardness of the ground, which is a safety hazard for horses in the event of falls, and is likely to continue in the medium term. Intensive weed control in this area is recommended to prevent future expansion of caltrop.

The the intensive weed control program at Yarrlaumla equestrian park is having visible positive impacts. However, weed control remains an ongoing issue and the next few years provide an opportunity to recover and improve condition of natural temperate grassland and golden sun moth habitat. Continued engagement with weed control practitioners is required, including integration of a weed control plan in the updated plan of management, is required to ensure that weed control programs are consistent with the maintenance of healthy natural temperate grassland and golden sun moth habitat.

4.4 GSM population monitoring

GSM numbers recorded during the monitoring period (2013-2020), as measured by the rotational point counts, are presented in **Appendix F**. It is noted that, in line with ACT Government Offset Monitoring Protocols and recommendations of the draft updated OMP (Umwelt, in prep), flying moth monitoring was undertaken on two occasions rather than three.

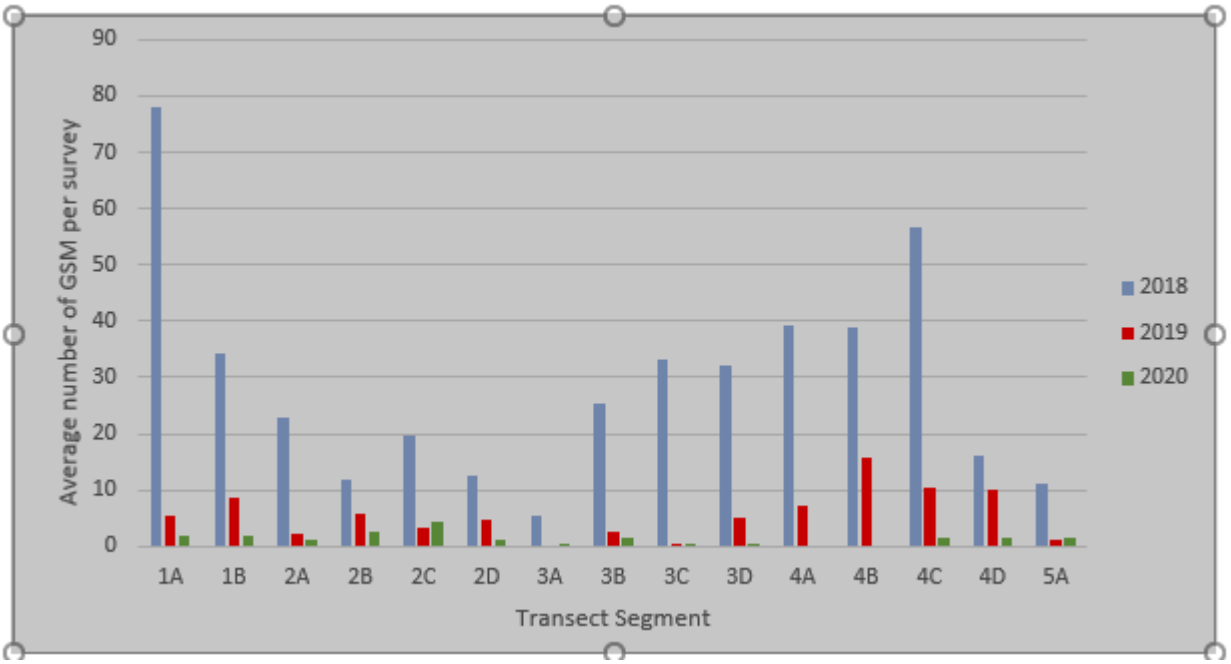
An average of 1.4 moths per transect was recorded in 2020 compared with 5.5 in 2019 and 29.1 in 2018 when record numbers of GSM were recorded at Yarralumla Equestrian Park (**Graph 4.4, Appendix F**Error! Reference source not found.). The number of moths recorded was lower in 2020 than in the previous two years at 11 of the 15 transect segments sampled. The varaiblity in the number of observed moths both between 2018 and 2019 and between the three survey days during 2019 is likely partly due to climatic factors and normal seasonal and daily stochasticity respectively. A combination of these factors may be responsible for the absence of GSM at transect segment 4A and 4B in 2020 despite reasonable numbers being recorded at such locations in previous years. Intersestingly, transect segment 4B supported higher numbers of moths than all other segments in 2019.

GSM were recorded at eleven of twelve rotational point sites during 2020 (**Graph 4.5**). The average number of GSM recorded during the rotational point surveys in 2020 was higher than the 2013-2020 average at sites 5, 6, 8 and 12 and lower than the 2013-2019 average at the remaining 8 sites (**Graph 4.5, Appendix F)**.

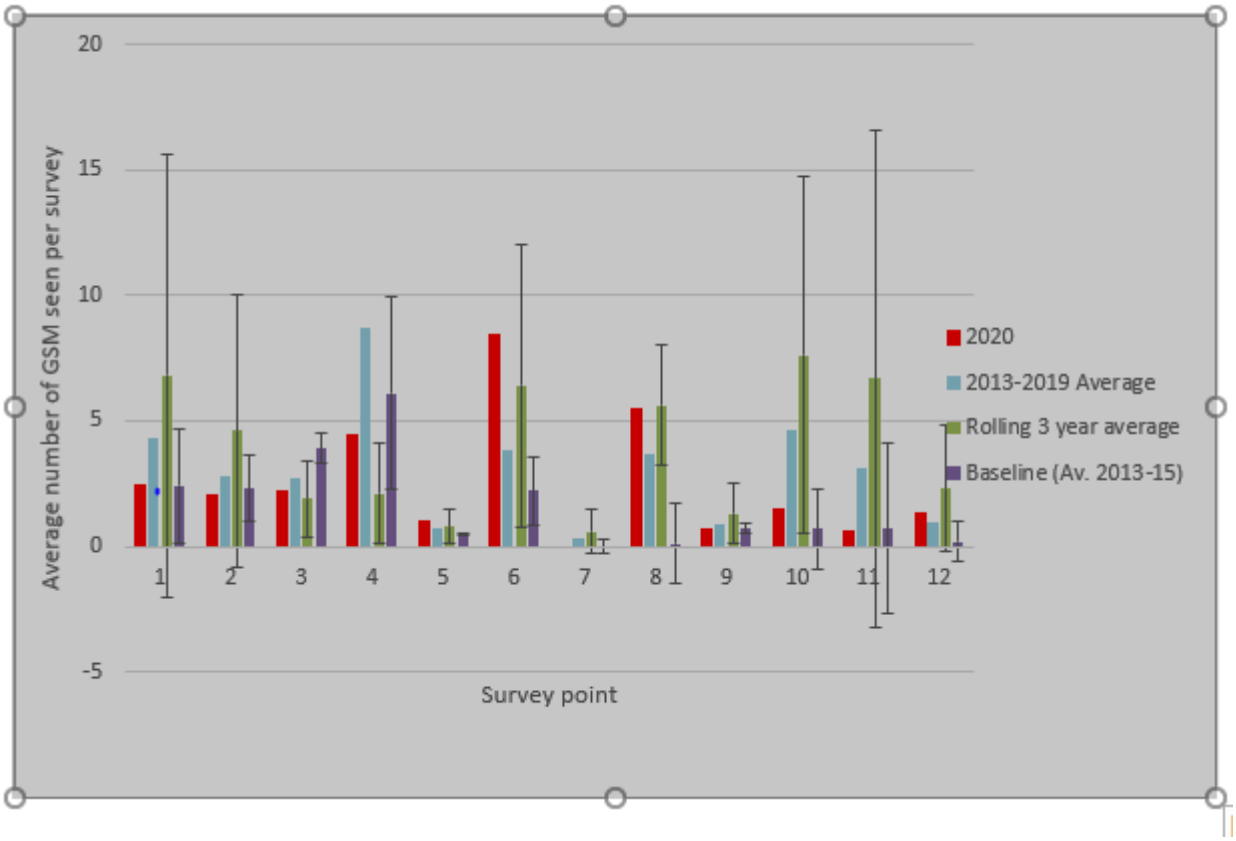
The high inter-annual variability in GSM activity levels at YEP is likely primarily a result of inter-annual climatic and site condition variability, but may also be influenced by the high variability in GSM flying levels between days. Regression analysis indicates a statistically significant correlation between pre-flying season rainfall and GSM flying activity at YEP (SMEC 2018). Similary, soil temperatures are alo likely to be a key driver.

GSM were typically recorded at substantially lower numbers throughout the ACT during the 2020 flying season than in either the 2019 or 2018 seasons. However, the rolling three year average is still substantially greater at most locations than the three year baseline Graph 4.5 (**Appendix F**). The lower numbers observed at Yarralumla Equestrian Park reflect the generally poor seasonal conditions for detection of flying GSM and do not represent any indication of population declines at the site. The combined rainfall and soil temperatures are likely to have interacted to have created a short flying season with relatively low emergence.

The combined data from monitoring to date confirms that GSM activity has remained widespread throughout open areas of YEP though there has been high inter-annual variability in observed numbers characterised by large spikes in abundance such as in 2018. Overall, there were low numbers of GSM recorded at YEP in November and December 2020.



Graph 4.4 Average number of GSM recorded during each survey at each transect in 2018, 2019 and 2020



Graph 4.5 Average number of GSM recorded during rotational point counts (2019 vs 2013-2019 average)

5.0 Compliance with the Offset Management Plan

5.1 Survey Requirements

Detailed monitoring has been completed in to meet monitoring requirements. However, a number of changes to monitoring methods were implemented to improve consistency with monitoring of Commonwealth offsets elsewhere in the ACT and also to allow improved quanitiative comparison of results against the baseline.

NTG and GSM monitoring surveys were conducted according to the methods specified in the OMP (RJPL 2014a), with the following amendments:

- '*meandering traverse'* monitoring was not completed, and replaced with sampling of 100 metre transects, as '*meandering traverse'* surveys proved uninformative and difficult to compare between seasons (this is the second year this has been completed).

- In addition to the 4 x 4 m floristic monitoring plots, a 20 x 20 metre montoring plot was completed to meet standards required for ACT Government monitoring and allow assessment against listing criteria for the natural temperate grassland critically endangered ecological community (this is the second year this has been completed)

- A range of additional data collection techniques were trialled to inform the updated OMP (Umwelt in prep), consistent with and comparable with ACT Government Environmental Offsets monitoring for goldens sun moth.

- Quadrats were located at co-ordinates specified in the 2013 monitoring report (RJPL 2014b), which are consistent with Figure 5 of the OMP (RJPL 2014a), rather than at the incorrect co-ordinates reported in Appendix B of the OMP.

- GSM surveys were conducted over two rather than three days, consistent with recommendations in the updated OMP (Umwelt, in prep) and ACT Government Environment Offset monitoring standards.

For the purposes of this report, the baseline conditions for floristic condition and golden sun moth monitoring are assumed to be the average of the first three years of monitoring (2013 to 2015). As some monitoring elements have recently been added, such as monitoring flying moth numbers along 100 m transects and vegetation structure transects, these cannot be compared with the baseline. However these proved more informative information relating to the distribution of golden sun moth activity and the condition of groundcover in comparison with benchmarks for the ACT that can be used in the future to inform short term monitoring responses.

5.2 Reporting Requirements

The OMP (RJPL 2014a) requires that annual monitoring reports:

- provide and assess the monitoring data for the previous twelve months against the previous monitoring results

- conclude whether or not there has been a lack of increase or a decline in GSM population numbers in the YEP due to equestrian activities, taking into account regional population trends and local ecological conditions

- conclude whether or not there has been no improvement or a decline in GSM habitat, and NTG quality and extent in the YEP due to equestrian activities, taking into account local ecological conditions.

The preparation of this report fulfils the reporting requirements for monitoring during the 2020 flying season (year 8), as specified in the OMP (RJPL 2014a).

5.3 Management Response

The recommended management responses outlined in the 2017 Yarralumla Equestrian Park Offset Report have been acted upon with weed spraying being carried out in November 2018, October and November 2019 (SMEC 2018), and a number of occasions during 2020. As noted in the results section above, this has resulted in a reduction of more than 50% for priority weeds across the site, and the current year also had a wetter seedbed, which has stimulated germination of weed seeds, allowing them to be targeted more effectively.

Current management of the offset site is considered to be appropriate, subject to continuation of effective weed control. The weed management response is appropriate, but will need to be maintained on an ungoing basis. A updated OMP is currently in preparation, and has been informed by the current monitoring data to ensure that appropriate and targeted management actions are being undertaken. The updated OMP will include a 5 year weed management plan to guide weed management, and ensure that objectives with respect to maintenance of natural temperate grassland and golden sun moth habitat are remained.

The impacts of such management actions on grassland quality and the extent of African love grass, Chilean needle grass, and Caltrop in particular, must be assessed in future monitoring events. No evidence of degradation of natural temperate grassland or golden sun moth habitat due to weed control practices must be monitored. Based on qualitative observations, it is anticipated that current weed control will result in significant improvements in the proportion of native cover, particularly in areas of native pasture and mixed native and exotic pasture, and there is substantial potential for improvement in response to weed control.

5.4 Impact Thresholds

The OMP (RJPL 2014a) includes a variety of ongoing management actions derived from the approval conditions. Subsequent active management responses are also identified should specified adverse impact response thresholds be met or exceeded. Four impact thresholds triggered in 2018 are outlined in the 2017 Yarralumla Equestrian Park Offset Report (SMEC 2018). Whilst no statistical analyses were conducted following the most recent two rounds of survey, the findings of the current reporting that relate to impact thresholds were consistent with those reported in both the 2017 - 2019 Yarralumla Equestrian Park Offset Reports, namely:

- There has been a very small increase (20%) in the spatial extent of NTG and GSM habitat, which is likely to represent static extent overall given the very small areas on the site. There has also been significant varance in the floristic scores within grassland areas, with these scores within the long-term range for the site.

- There has been no decline in flying moth numbers over at least three consecutive seasons. Though record numbers of GSM were recorded in 2018, the high degree of stochasticity (both inter- and intra-annual) in GSM numbers means that it remains unclear whether this species is undergoing a long-term increase at Yarralumla Equestrian Park. The lower numbers recorded in the current monitoring are most likely due to seasonal weather conditions, as the species is still widespread across the areas where it was recorded at the comencent of monitoring. The current three year rolling average is typically higher than the three year baseline, hence there is no evidence of a decline.

As a result of the findings of the 2017 and 2018 Yarralumla Equestrian Park Offset Report (SMEC 2018, Umwelt 2019), a new OMP is currently being prepared (Umwelt, in prep). The impact thresholds defined above are difficult to implement, and consideration of updated thresholds consistent with ACT Government practices on other Commonwealth Offset sites is recommended as part of this process. Similarly, the appropriateness of monitoring approaches, and their applicability to the thresholds applied should be reviewed. The following recommendations should be considered:

- Adoption of the average of the first three years of monitoring data as the 'baseline' for floristic condition and golden sun moth flying activity

- Adoption of a three year rolling average for comparison against baseline to minimize impact of stochastic variation in seasonal conditions during comparison of results for floristic condition and golden sun moth flying activity.

6.0 Conclusions and Recommendations

6.1 Outcomes

The key results of the 2020 monitoring program are:

- There is no evidence of substantial degradation relative to the baseline. While floristic conditions and golden sun moth numbers were both low relative to early monitoring, these are attributable to seasonal conditions and survey timing in 2020.

- Small improvements in natural temperate grassland extent, native pasture and golden sun moth habitat extent were recorded. While to early to confirm long term improvements, these minor improvements indicate the effectiveness of weed control measures implemented since 2018. These measures are progressively redcing the extent and severity of infestations of invasive tussock grasses across the site, driving improvements.

- Floristic value scores (based on Rehwinkle 2007) for 4 x 4 m plots were close to or slightly below the baseline and average in 2020, with seasonal rainfall, weed invasion and the late timing of surveys the most likely drivers of these scores. In addition, GPS error was noted as likely to be a significant driver in error of 4 x 4 m plots, with sampling typically not being carried out in the most diverse parts of the 20 x 20 m plots. Consequently, an alternative approach to locating the nested 4 x 4 m plots within the 20 x 20 m plots is recommended for future monitoring.

- Completion of floristic assessment and vegetation structure assessment at 20 x 20 metre plots confirms that vegetation within areas identified as natural temperate grassland meets criteria for inclusion in the Commonwealth *Natural Temperate Grassland of the South Eastern Highlands* critically endangered community. One plot located in native pasture also met thresholds to be included in the listed ecological community, and further mapping in this area is recommended in the next monitoring event to assess the extent of higher diversity.

- Qualitative assessment and mapping of weed extent indicates that the extent and cover of invasive exotic tussock grasses has decreased substantially in the past year, likely as a result of improved weed control. One new weed, Caltrop, was detected and weed control for this species commenced following consulation with ACT Government and weed control contractors.

- Moths were recorded in low numbers throughout monitoring points across the site. Below average numbers of flying moths were recorded in 2020, however this was consistent with reduced detection of flying moths elsewhere in ACT, and is likely due to seasonal conditions. To date, there has been no evidence of a decline in the GSM population at YEP despite substantial recent changes in grassland composition across the site.

- Trials of ACT Government app-based monitoring were successful, and it is recommended that the updated OMP incorporate the approach of the ACT Government Environmental Offsets Monitoring Method, but retain 4 x 4 m floristic monitoring plots as a subset of 20 x 20 metre monitoring plots as well as retain rotational point couts for comparison with previous monitoring.

The substantial increase in the distribution of perennial exotic tussock grasses such as African lovegrass and Chilean needle grass during previous years represents a major threat to the extent and condition of native grassland and moderate-quality GSM habitat at YEP, and hence compliance with the offsetting requirement of the Commonwealth approval conditions. The weed control programs are showing significant poisitive impacts on weed abundance, and maintaining this will be critical in the ongoing recovery of grasslands.

6.2 Recommendations

The key recommendations of this are:

- Control of perennial exotic tussock grasses, specifically African lovegrass, Chilean needle grass, and serrated tussock remains a priority at Yarralumla Equestrian Park in order to maintain or improve the extent, integrity, and condition of NTG and GSM habitat at the YEP. Incorporation of a five year weed control plan is required to ensure that weed control requirements are defined and understood.

- Until populations of exotic tussock grasses have stabilised and are demonstrably controlled under a defined plan of management, ongoing monitoring of vegetation condition and GSM habitat is recommended. Following stabilisation of exotic tussock grass populations, there is potential to revisit ongoing monitoring requirements.

- Locating the 4 x 4 m plots using GIS has substantial error, resulting in substantial change in positions between years. As original plots were located in the most diverse vegetation, it is recommended that, for future monitoring, GIS coordinates be used to identify the centre point of 20 x 20 metre floristic plots, and 4 x 4 m plots be located in the most diverse section of the 20 x 20 metre floristic plots. This is likely to result in 2007 floristic value scores more comparable to original baseline monitoring, and more replicable results.

- Additional vegetation structure transects should be completed in areas of '*mixed native and exotic pasture*' and *'native pasture*' to assist in qualitatively distinguishing these vegetation zones where it is ambiguous.

- The OMP review process should also include a review of impact thresholds and monitoring methods to ensure effectiveness and identify opportunities for consistency with application of thresholds and monitoring strategies at other Commonwealth offset sites in the ACT. This process should consider application of benchmarks to determine whether management responses are required.

- It is recommended that the OMP review process consider the adoption of an average of the first three years of monitoring (2013 to 2015) as the baseline data, and that this be compared with a rolling 3 year average of the last three years of monitoring, for GSM population data and floristic condition to assist in the determination of thresholds for management review.

7.0 References

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APPENDIX A

2020 Floristic Plot Survey Results

Scientific Name	Common Name	E/N*	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Native Grasses and Rushes														
Anthosachne scabra	Wheatgrass													1
Austrostipa bigeniculata	tall spear grass		4	6	5	4		4	2	3		3	3	4
Austrostipa scabra	rough speargrass			1	3	3		3		1		2		3
Bothriochloa macra	redleg grass		1	5	4	3		5	5	5	3	4	4	6
Carex sp.	carex sp.													
Chloris truncata	Windmill grass		4	4	3	2		3		4	3	3	3	3
Cymbonotus lawsonianus	Bears ear				1			1					1	1
Cynodon dactylon	Couch		5	4	4	4	4	4						
Eragrostis sp.					1				1					
Microlaena stipoides	Weeping grass									2	3	1		
Panicum effusum	hairy panic			3	3	2		3	3	3	4	4	4	3
Rytidosperma caespitosum	tall wallaby grass								3					
Rytidosperma carphoides	short wallaby grass							3						
Rytidosperma racemosum	Striped wallaby grass		3	4	3	3	3	3	3	3	3			

Scientific Name	Common Name	E/N*	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Rytidosperma sp.	wallaby grass													
Sporobolus creber	Western rat-tail grass									1		2	1	1
Themeda australis	kangaroo grass													
Themeda triandra	Kangaroo grass									1		2	3	
Native forbs														
Acaena ovina	sheep's burr									1		1	3	
Chrysocephalum apiculatum	yellow buttons			4	3	3	3	4	4	4		4	4	5
Crassula sieberiana														
Dysphania pumilio	Small crumbweed		3	3	3	3	3	3			2		3	
Erodium crinitum	blue storkskbill		1		2	1				1		1		
Euchiton involucratus	Star cudweed				1									
Euchiton sphaericus				3	3	2	2	3	1	3		3	3	3
Euchiton sp.	cudweed sp.													
Euphorbia drummondii	Caustic weed						3			2			1	
Glycine tabacina	Variable glycine									2		2		

Scientific Name	Common Name	E/N*	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Goodenia pinnatifida														3
Lomandra bracteata	mat-rush sp.													
Lomandra filiformis subsp. coriacea	mat-rush sp.			2	2	3				2		3		3
Lomandra multiflora	mat-rush sp.					1		3	2	1		1		1
Oxalis perennans	Grassland wood sorrel			3	3	2				3	3	3	3	3
Oxalis sp.			1				4	3	3					
Plantago varia					2	1								
Portulaca oleracea	Pigweed, Purslane		3	3	3	3	3	3					1	
Pseudognaphalium luteoalbum	Jersey cudweed				1		2			1			2	1
Rumex brownii	swamp dock		3				3	3	3	2	3		1	
Tricoryne elatior	Yellow autumn-lily, Yellow rush-lily					2								
Triptilodiscus pygmaeus														
Vittadinia muelleri	Narrow leaf new holland daisy			3										
Wahlenbergia communis	tufted bluebell									2		2	3	3
Wahlenbergia graniticola	Granite bluebell			2										

Scientific Name	Common Name	E/N*	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Wahlenbergia luteola	bluebell sp.			3								2		
Wurmbea dioica	early Nancy													
Exotic grasses														
Aira sp.	hairgrass												1	
Arrhenatherum elatius	False oat grass						3							
Avena fatua	Wild oats			1	3	3		3		1		2		3
Avena sp.	oats								1	2	3	2	2	
Briza minor	shivery grass													
Bromus catharticus	prairie grass		3	3	4	5	4	4					3	
Bromus diandrus	ripgut brome													
Bromus hordeaceus	soft brome		4											
Bromus molliformis	Soft brome			3		2		3			2	3	4	3
Bromus sp.	bromes													
Cyperus eragrostis	Umbrella sedge											10		
Dactylis glomerata	cocksfoot			2	2			3						
Digitaria sp.*											2			
Eragrostis curvula	African lovegrass		1	3	3	3	5	4	5	4	4	5	5	3

Scientific Name	Common Name	E/N*	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Eragrostis pilosa	Soft lovegrass						2				1		3	
Eleusine tristachya			6	3	5	6	4	4	4	3	3	4	3	
Festuca arundinacea	tall fescue													
Festuca pratensis	Meadow fescue						3	2			2	4	3	3
Hordeum sp.	Barley													
Lolium perenne	perennial ryegrass													
Nassella neesiana	Chilean needle grass				3		5	2				4		
Nassella trichotoma	serrated tussock													1
Panicum capillare	Witchgrass		3	3	1		3	3		1	2	1	2	
Paspalum dilatatum	paspalum					2	3	2	5	3	5	3	3	2
Phalaris aquatica	tall phalaris						3				3			3
Poa annua	annual meadow grass		1										2	
Poa bulbosa	bulbous bluegrass													
Setaria parviflora	Marsh bristlegrass					2	2			3	6	3	3	3
Sporobolus africanus	Parramatta grass			1	1	2		1	2	2	2	3		2
Vulpia muralis														

Scientific Name	Common Name	E/N*	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Vulpia sp.	rat's tail fescue						3			3			2	
Exotic forbs														
Alternanthera pungens	Khaki weed		1									1		
Arctotheca calendula	Cape weed													
Cathamus lanatus	saffron thistle													
Centaurium erythraea	Common centaury			2			2			3		3	3	3
Centaurium sp.	centaury sp.													
Cerastium glomeratum	mouse-ear chickweed													
Chenopodium album	Fat hen				2	1		2					1	
Chondrilla juncea	skeleton weed		1	3	2	3	5	3	3	3	3	3	2	2
Conyza bonariensis	Flaxleaf Fleabane			3										
Conyza sp.			1	1	3	2	3	3	3	3	3	3	3	3
Crataegus monogyna	Hawthorn												1	1
Echium vulgare	viper's bugloss													
Echium plantagineum	Patterson's Curse													

Scientific Name	Common Name	E/N*	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Erodium botrys	stork's bill sp.													
Erodium cicutarium	common storksbill													
Erodium sp.													1	
Foeniculum vulgare	Fennel						3	2						
Gamochaeta americana	Cudweed					1		2						
Hirschfeldia incana	hairy mustard			3	3	1	3		2		3	3	3	
Hypericum perforatum	St John's wort		1	3	2		3	3	3	3	3	3	3	
Hypochaeris glabra	flatweed			1	2						2			
Hypochaeris radicata	flatweed			2			3		2	3		3	3	3
Lactuca serriola				3	3		2			2				1
Lepidium africanum					1									
Lycium ferocissimum	African boxthorn													1
Lysimachia arvensis	Scarlet pimpernel, Blue pimpernel				1							3		
Malva parviflora	Small flowered mallow		1											
Malva sp.	mallow													
Marrubium vulgare														
Medicago sp.	medick						3			3		3		

Scientific Name	Common Name	E/N*	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Marrubium vulgare	Red flowered mallow						3	2						
Moenchia erecta	erect chickweed													
Oenothera glazioviana	large-flowered evening-primrose													
Oenothera stricta	Evening primrose												2	1
Onopordum acanthium							3							
Paronychia brasiliana	Brazilian whitlow		3	3										
Petrorhagia nanteuilii	proliferous pink			2	2		2		1				3	3
Plantago lanceolata	narrow leaf plantain		4	3	3	2	4	3	4	3	3	3	4	
Polygonum aviculare	Wireweed		3	3	3			3						
Prunus sp.														1
Rosa rubiginosa	Sweet briar, Eglantine													1
Rubus fruticosus	Blackberry							1			3			2
Rumex cripus	hooked dock													
Salvia verbenaca	Vervain, Wild sage			2	2							2		
Sanguisorba minor	Salad burnet, Sheep's burnet				1				2					2

Scientific Name	Common Name	E/N*	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Solanum chenopodioides	Whitetip nightshade						2							
Solanum nigrum	Black-berry nightshade				1									
Sonchus asper	Prickly sowthistle						1							
Sonchus oleraceus	Common sowthistle				1		2							
Sonchus sp.														
Spergularia rubra	red sand-spurrey													
Taraxacum officinale	Dandelion													
Tolpis barbarta	yellow hawkweed													
Tragopogon sp.							3		2				2	
Tribulus terrestris	Caltrop, Cat-head		3	1	1									
Trifolium angustifolium	Narrow-leaved clover									2				1
Trifolium arvense	haresfoot clover			1	2		3						1	3
Trifolium campestre	hop trefoil													
Trifolium glomeratum			2	3	3								3	1
Trifolium sp.	clover													

Scientific Name	Common Name	E/N*	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Trifolium subterraneum	subterranean clover													
Ulmus sp.									3	2	1			
Verbascum thapsus	Great mullein		1		1		3	1	2		2	2	2	
Verbena bonariensis	Purpletop						1	1						

APPENDIX B

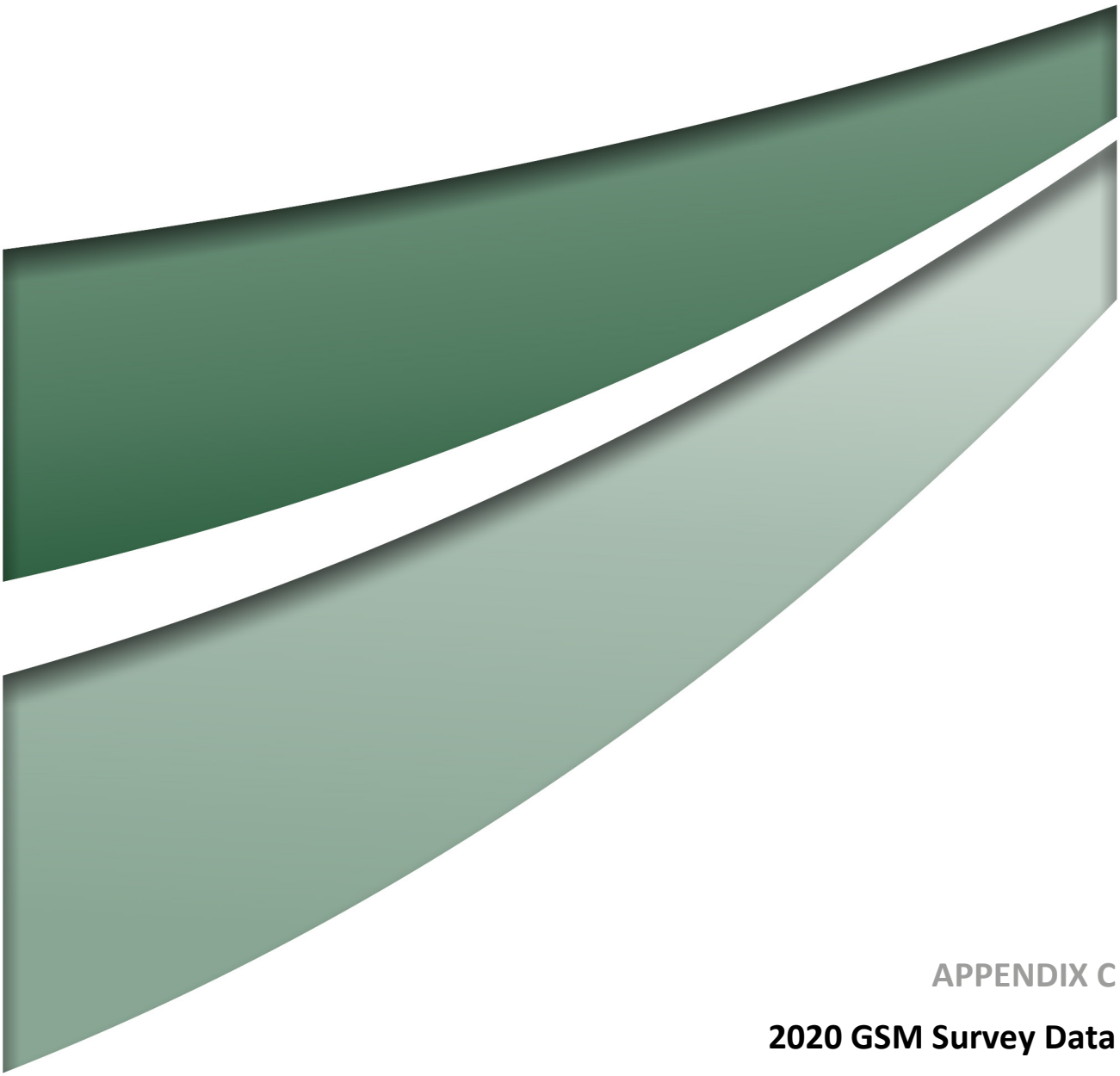
2020 Vegetation Structure (Transect) Survey Results

Understorey structure tansect survey results (1 of 2)

Plot	Condition	C4 Native	C3 Native	Wallaby Grass	Speargrass	Native Other	Other Native Perennial Grass	Cryptogram	Rock Cover	Leaf Litter	Dead Plant
1	Mixed pasture	1	4	0	1	0	0	0	0	0	11
2	Native grassland	28	0	1	19	0	10	0	0	2	3
3	Native grassland	15	0	2	28	0	4	0	0	2	1
4	Native pasture	1	0	0	9	0	1	0	0	0	2
5	Exotic pasture	14	0	0	0	0	0	0	0	0	0
6	Native pasture	26	0	0	4	0	3	0	0	0	0
7	Native grassland	31	0	1	10	0	4	1	0	0	0
8	Native grassland	17	0	0	2	0	5	0	0	0	4
9	Mixed pasture	4	0	0	1	0	0	0	0	0	0
10	Native grassland	25	0	2	7	0	19	0	0	0	2
11	Mixed pasture	9	0	0	0	0	0	0	0	0	7
12	Native grassland	39	0	0	8	0	17	0	0	0	2

Understorey structure tansect survey results (2 of 2)

Plot	Condition	Chilean needle grass	Serrated Tussock	African love grass	Exotic Annual grass	Other Exotic Perennial grass	Exotic forb	Log Wood	Other	Average Thatch Density	Average Grass Height	Bare Ground	Thatch Cover
1	Mixed pasture	0	0	1	28	27	12	0	0	0.7	7.1	0	10
2	Native grassland	0	0	2	2	0	9	0	0	0.25	5.7	2	1
3	Native grassland	1	0	0	9	8	4	0	0	0.6	8.9	9	3
4	Native pasture	0	0	8	46	38	0	0	0	0.6	6.2	9	6
5	Exotic pasture	6	0	13	35	16	10	0	0	2.1	12.6	0	9
6	Native pasture	1	0	16	25	8	0	0	0	0.9	8.5	0	5
7	Native grassland	0	0	2	19	17	2	0	0	0.6	6.9	1	2
8	Native grassland	0	0	6	8	2	8	0	0	1.15	7.3	1	13
9	Mixed pasture	6	0	1	44	37	0	0	0	1.6	11.7	0	16
10	Native grassland	0	0	6	8	2	0	0	0	0.15	7.3	6	2
11	Mixed pasture	1	0	23	38	14	5	0	0	0.75	8.1	1	6
12	Native grassland	0	0	8	8	0	0	0	0	0.15	8.2	3	0



APPENDIX C

2020 GSM Survey Data

Rotational point count

Date	Survey	Quadrat	Turn 1	Turn 2	Turn 3	Turn 4	Turn 5	Turn 6	Turn 7	Turn 8	Turn 9	Turn 10	Total	Average
2/12/2020	1	1	1	2	2	5	1	5	3	2	0	0	21	2.1
2/12/2020	1	2	0	3	3	2	1	1	2	2	2	0	16	1.6
2/12/2020	1	3	4	3	7	2	3	4	4	4	6	5	42	4.2
2/12/2020	1	4	2	0	2	3	1	1	1	1	1	8	20	2.0
2/12/2020	1	5	0	1	1	1	1	1	0	0	0	0	5	0.5
2/12/2020	1	6	2	3	1	2	1	2	1	3	2	1	18	1.8
2/12/2020	1	7	0	0	0	0	0	0	0	0	0	0	0	0
2/12/2020	1	8	3	3	3	5	2	5	3	9	4	2	39	3.9
2/12/2020	1	9	0	0	0	0	0	0	0	0	0	0	0	0
2/12/2020	1	10	0	1	1	1	0	0	0	0	0	0	3	0.3
2/12/2020	1	11	1	1	1	1	0	0	0	0	0	0	4	0.4
2/12/2020	1	12	0	1	0	1	0	2	0	0	0	0	4	0.4
15/12/2020	2	1	3	2	3	0	2	3	3	4	5	2	27	2.7
15/12/2020	2	2	0	2	4	1	0	0	6	2	2	6	23	2.3
15/12/2020	2	3	0	0	0	0	0	0	0	0	1	0	1	0.1
15/12/2020	2	4	5	10	7	4	5	8	10	7	7	5	68	6.8
15/12/2020	2	5	0	2	1	1	3	2	2	0	0	2	13	1.3
15/12/2020	2	6	17	15	14	9	17	20	10	19	13	15	149	14.9
15/12/2020	2	7	0	0	0	0	0	0	0	0	0	0	0	0
15/12/2020	2	8	7	5	6	9	9	11	5	8	3	7	70	7
15/12/2020	2	9	3	3	0	1	3	1	2	0	0	0	13	1.3
15/12/2020	2	10	3	5	3	2	2	5	4	1	0	2	27	2.7
15/12/2020	2	11	1	1	1	1	0	1	0	0	2	0	7	0.7
15/12/2020	2	12	3	4	2	0	3	0	2	4	4	0	22	2.2

Transect survey results

Date	Transect Segment	Time	Count	Cloud Cover	Wind	Temp. (°C)
17/11/2020	1A	12:11	0	Fine	Light (<11 km /h)	22
17/11/2020	1B	12:09	0	Fine	Light (<11 km /h)	22
17/11/2020	2A	12:06	0	Fine	Gentle-moderate(11-28 km /h)	22
17/11/2020	2B	12:04	4	Fine	Light (<11 km /h)	22
17/11/2020	2C	12:01	8	Fine	Light (<11 km /h)	22
17/11/2020	2D	11:58	0	Fine	Light (<11 km /h)	22
17/11/2020	3A	11:52	0	Fine	Light (<11 km /h)	22
17/11/2020	3B	11:50	0	Fine	Light (<11 km /h)	22
17/11/2020	3C	11:49	1	Fine	Light (<11 km /h)	21
17/11/2020	3D	11:47	0	Fine	Light (<11 km /h)	21
17/11/2020	4A	11:23	0	Fine	Light (<11 km /h)	20
17/11/2020	4B	11:28	0	Fine	Light (<11 km /h)	21
17/11/2020	4C	11:31	0	Fine	Light (<11 km /h)	21
17/11/2020	4D	11:33	1	Fine	Light (<11 km /h)	21
17/11/2020	5A	11:37	0	Fine	Light (<11 km /h)	21
2/12/2020	1A	11:27	4	Scattered cloud (<30% cover)	Light (<11 km /h)	21
2/12/2020	1B	11:31	4	Scattered cloud (<30% cover)	Light (<11 km /h)	21
2/12/2020	2A	11:36	2	Scattered cloud (<30% cover)	Light (<11 km /h)	21
2/12/2020	2B	11:39	1	Scattered cloud (<30% cover)	Light (<11 km /h)	21
2/12/2020	2C	11:41	1	Scattered cloud (<30% cover)	Light (<11 km /h)	21
2/12/2020	2D	11:44	2	Scattered cloud (<30% cover)	Light (<11 km /h)	21
2/12/2020	3A	11:48	1	Scattered cloud (<30% cover)	Light (<11 km /h)	21

Date	Transect Segment	Time	Count	Cloud Cover	Wind	Temp. (°C)
2/12/2020	3B	11:51	3	Scattered cloud (<30% cover)	Light (<11 km /h)	21
2/12/2020	3C	11:54	0	Scattered cloud (<30% cover)	Light (<11 km /h)	21
2/12/2020	3D	11:57	1	Scattered cloud (<30% cover)	Light (<11 km /h)	21
2/12/2020	4A	12:23	0	Scattered cloud (<30% cover)	Light (<11 km /h)	22
2/12/2020	4B	12:20	0	Scattered cloud (<30% cover)	Light (<11 km /h)	22
2/12/2020	4C	12:16	3	Scattered cloud (<30% cover)	Light (<11 km /h)	22
2/12/2020	4D	12:13	2	Scattered cloud (<30% cover)	Light (<11 km /h)	22
2/12/2020	5A	12:07	3	Partly cloudy (>30% and <90% cover)	Light (<11 km /h)	22

Incidental GSM Observations

Date	X	Y	Number of GSM	Sex/Pupae Case	Survey Type
2/12/2020	688753	6090645	1	M	Incidental
2/12/2020	688540	6090953	2	M	Incidental
2/12/2020	688505	6090749	6	M	Incidental
2/12/2020	688373	6090689	1	M	Incidental
2/12/2020	688469	6090908	1	M	Incidental
2/12/2020	688494	6090825	4	M	Incidental
2/12/2020	688788	6090643	1	M	Incidental
2/12/2020	688662	6090565	2	M	Incidental
2/12/2020	688663.6	6090563	1	F	Incidental
15/12/2020	688422.4	6090719	1	M	Incidental
15/12/2020	688404.5	6090682	1	M	Incidental
15/12/2020	688397.2	6090693	1	M	Incidental
15/12/2020	688378.8	6090693	2	M	Incidental
15/12/2020	688417	6090889	5	M	Incidental
15/12/2020	688398.4	6090866	2	M	Incidental
15/12/2020	688419.4	6090892	1	M	Incidental
15/12/2020	688422.6	6090913	2	M	Incidental
15/12/2020	688423.9	6090941	4	M	Incidental
15/12/2020	688434.5	6091010	2	M	Incidental
15/12/2020	688423.9	6091023	3	M	Incidental
15/12/2020	688470.9	6090895	3	M	Incidental
15/12/2020	688473.4	6090862	3	M	Incidental
15/12/2020	688480.8	6090851	3	M	Incidental

Date	X	Y	Number of GSM	Sex/Pupae Case	Survey Type
15/12/2020	688444	6090853	4	M	Incidental
15/12/2020	688509.5	6090785	2	M	Incidental
15/12/2020	688755.2	6090644	1	M	Incidental
15/12/2020	688770.1	6090618	2	M	Incidental
15/12/2020	688780.9	6090617	1	M	Incidental
15/12/2020	688863.3	6090625	1	M	Incidental
15/12/2020	688760.9	6090735	1	M	Incidental
15/12/2020	688685.5	6090781	1	M	Incidental
15/12/2020	688659.7	6090795	6	M	Incidental
15/12/2020	688621.2	6090884	4	M	Incidental
15/12/2020	688628.3	6090875	2	M	Incidental

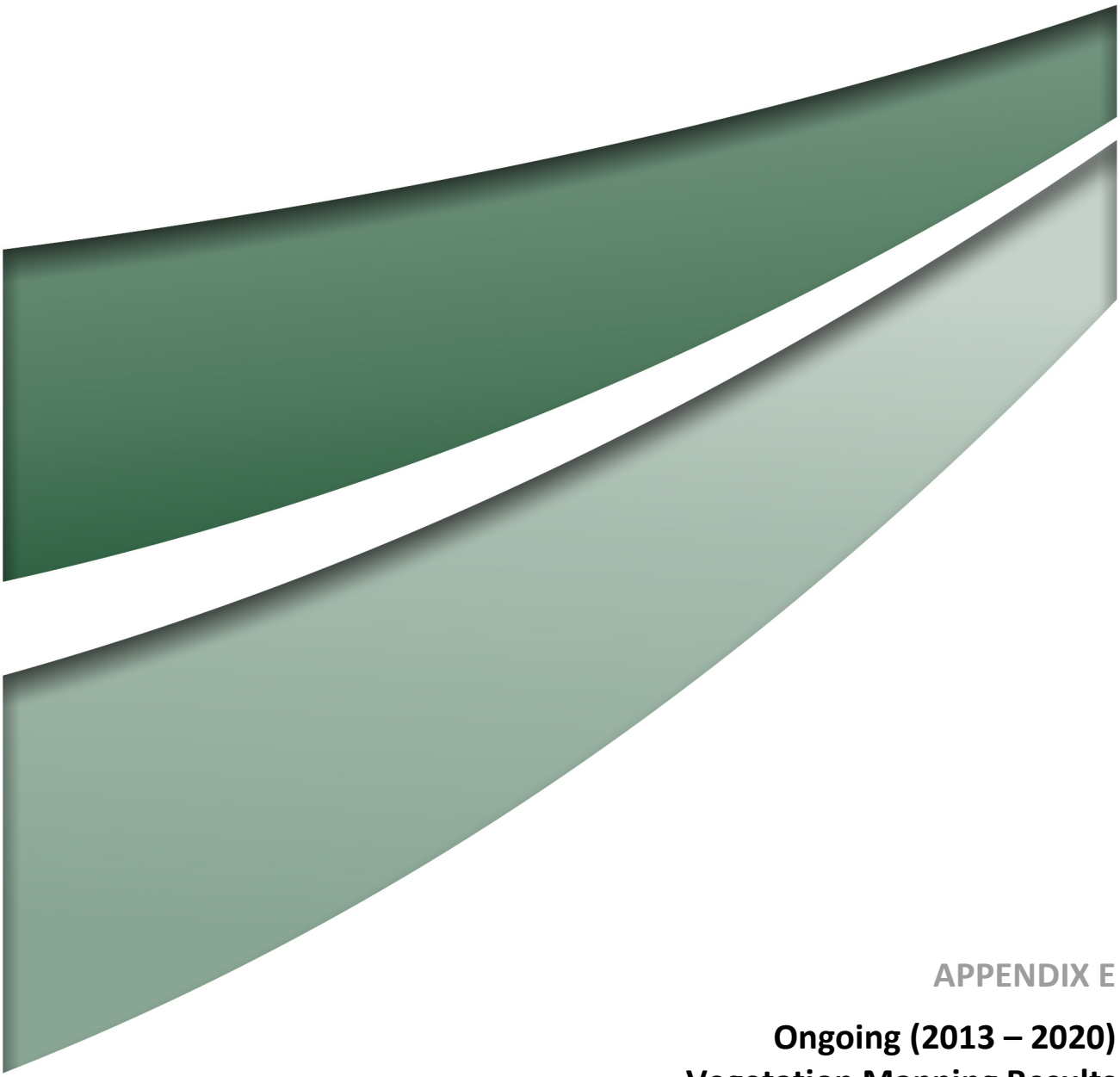
APPENDIX D

Summarised meteorological data (2013-2020)

Year	Month	Average Maximum Daily Air Temperature (◦C)	Average Minimum Daily Air Temperature (◦C)	Monthly Precipitation (mm)	Average Maximum Daily Soil Temperature (°C at 10cm depth)	Average Minimum Daily Soil Temperature (°C at 10cm depth)
2013	January	32.3	13.9	72.6	33.2	23.8
2013	February	27.4	12.8	30	30	21.4
2013	March	25.7	9.6	26.6		
2013	April	22.1	5.5	9.8		
2013	May	17.4	1.3	6.6		
2013	June	13.9	1.6	85.2		
2013	July	13.4	1.7	42.8	10.5	6.2
2013	August	14.8	2.4	27	12.1	6.6
2013	September	19.9	4	91	17.8	10.8
2013	October	21.9	3.8	13.4	21.7	13.3
2013	November	23.8	6.7	105.6	25.3	16.3
2013	December	28.5	11.5	23.2	33.7	23.6
2014	January	31.6	12.1	4.8	35.7	24.8
2014	February	29.4	13.5	83.6	33.2	23.8
2014	March	24.2	12.2	88	25	18.7
2014	April	19.7	7.4	69.2	19.3	13.9
2014	May	17.6	2.7	14.4	14.7	9.5
2014	June	13.2	2.8	57.2	10.7	7.3
2014	July	12.2	0	16.2	9.1	4.9
2014	August	14.3	-0.8	26.8	11.8	5.7
2014	September	17.9	2.7	28.8	16.9	9.5
2014	October	22.5	5.4	53.4	22.5	13.9
2014	November	27.9	10.2	24.2	29.5	19.9
2014	December	27.7	12.7	102	29.5	20.4
2015	January	27.4	13.9	97	29.6	21.4
2015	February	28.1	13.1	30.2	30	21.4
2015	March	26.3	9.1	12.4	27.1	18.6
2015	April	19.4	7.2	91.8	17.7	12.6
2015	May	16.3	2.7	12.2	14	8.8
2015	June	13.8	-0.8	55.2	10.6	5.7
2015	July	11.5	-0.7	37.2	8.6	3.9
2015	August	13.7	1	66.8	10.7	5.3
2015	September	17.4	1.5	13.6	17.3	8.7
2015	October	24.8	8.3	26.6	24.6	16.2
2015	November	25.3	10.9	67.6	26.1	17.9

Year	Month	Average Maximum Daily Air Temperature (◦C)	Average Minimum Daily Air Temperature (◦C)	Monthly Precipitation (mm)	Average Maximum Daily Soil Temperature (°C at 10cm depth)	Average Minimum Daily Soil Temperature (°C at 10cm depth)
2015	December	29.3	11.4	35	32.3	21.9
2016	January	28.5	14	106.4	29	21.5
2016	February	29.3	13.3	23.4	31.5	22.6
2016	March	27.7	12.6	28.4	28.1	20.2
2016	April	23.9	8.3	6.8	22.8	16.3
2016	May	17.4	4.8	47.6	15	9.9
2016	June	13	3	144.2	10.4	6.6
2016	July	12.7	2.2	71	10.2	5.8
2016	August	14.3	1.1	46.2	11.9	5.8
2016	September	15.8	4.8	149.2	14.7	8.7
2016	October	18.5	5.2	43.6	19.5	11
2016	November	24.8	8.6	56.8	28	17.6
2016	December	28.7	13.5	64.6	29.8	21.4
2017	January	32.8	14.9	8.4		
2017	February	30.1	12.9	20.6		
2017	March	25.9	12.8	85.2		
2017	April	19.9	5.5	31.6		
2017	May	16.4	1.6	34.2		
2017	June	13.6	-1.4	2.4		
2017	July	12.9	-2.3	17		
2017	August	13.9	0.5	49.2		
2017	September	18.1	2.7	13.4		
2017	October	23.2	7.1	58.4		
2017	November	24.3	9.6	70.4		
2017	December	27.8	13.9	95.2		
2018	January	31.6	14.4	38	33.4	23.4
2018	February	29	12.8	86.4	31.5	22.0
2018	March	26.3	10.4	7.2	27.7	19.0
2018	April	25	8.7	19.6	23.9	16.6
2018	May	17.5	2.2	15	15.1	8.8
2018	June	13.2	1.8	27.8	10.7	6.1
2018	July	13.3	-1.7	7.8	10.6	4.2
2018	August	13.9	0.8	29	12.2	5.7
2018	September	18	1.8	38.2	17.8	9.1
2018	October	22.8	7.3	14.2	23.5	14.9

Year	Month	Average Maximum Daily Air Temperature (◦C)	Average Minimum Daily Air Temperature (◦C)	Monthly Precipitation (mm)	Average Maximum Daily Soil Temperature (°C at 10cm depth)	Average Minimum Daily Soil Temperature (°C at 10cm depth)
2018	November	24.5	10.5	82.4	25.6	16.8
2018	December	29.3	13.7	106.4	31.1	21.1
2019	January	34.5	17.7	61.2	35.4	25.0
2019	February	29.1	12.9	42.8	32.5	22.3
2019	March	26	12	76.2	26.9	18.9
2019	April	22.6	7.5	10	22.3	14.5
2019	May	16.6	3.3	46.2	14.5	8.5
2019	June	14.1	-0.1	18	11.2	5.2
2019	July	13.7	0.7	5	11.4	5.4
2019	August	14.2	0.1	17.8	13.0	6.0
2019	September	18.8	2.1	40	17.7	9.1
2019	October	23.6	6.2	27.6	24.0	14.0
2019	November	26.8	9.5	12.6	28.3	18.3
2019	December	31.7	13.1	1.2	32.3	22.7
2020	January	31.7	15.2	16.0	32.5	23.4
2020	February	27.7	15.1	80	29.9	21.7
2020	March	23.4	10.8	99.8	25.1	17.7
2020	April	18.9	7.9	71.6	18.2	12.9
2020	May	15.0	2.8	26.8	12.7	8.1
2020	June	13.5	1.3	48.2	10.5	6.2
2020	July	13.2	1.2	33.4	10.4	5.7
2020	August	12.8	1.7	105.8	11.2	5.7
2020	September	17.6	4.7	40.4	17.0	9.9
2020	October	20.3	8.8	133.6	20.6	13.6
2020	November	25.1	10.4	93	26.4	18.3
2020	December	25.4	11.5	41.4	27.3	20.4



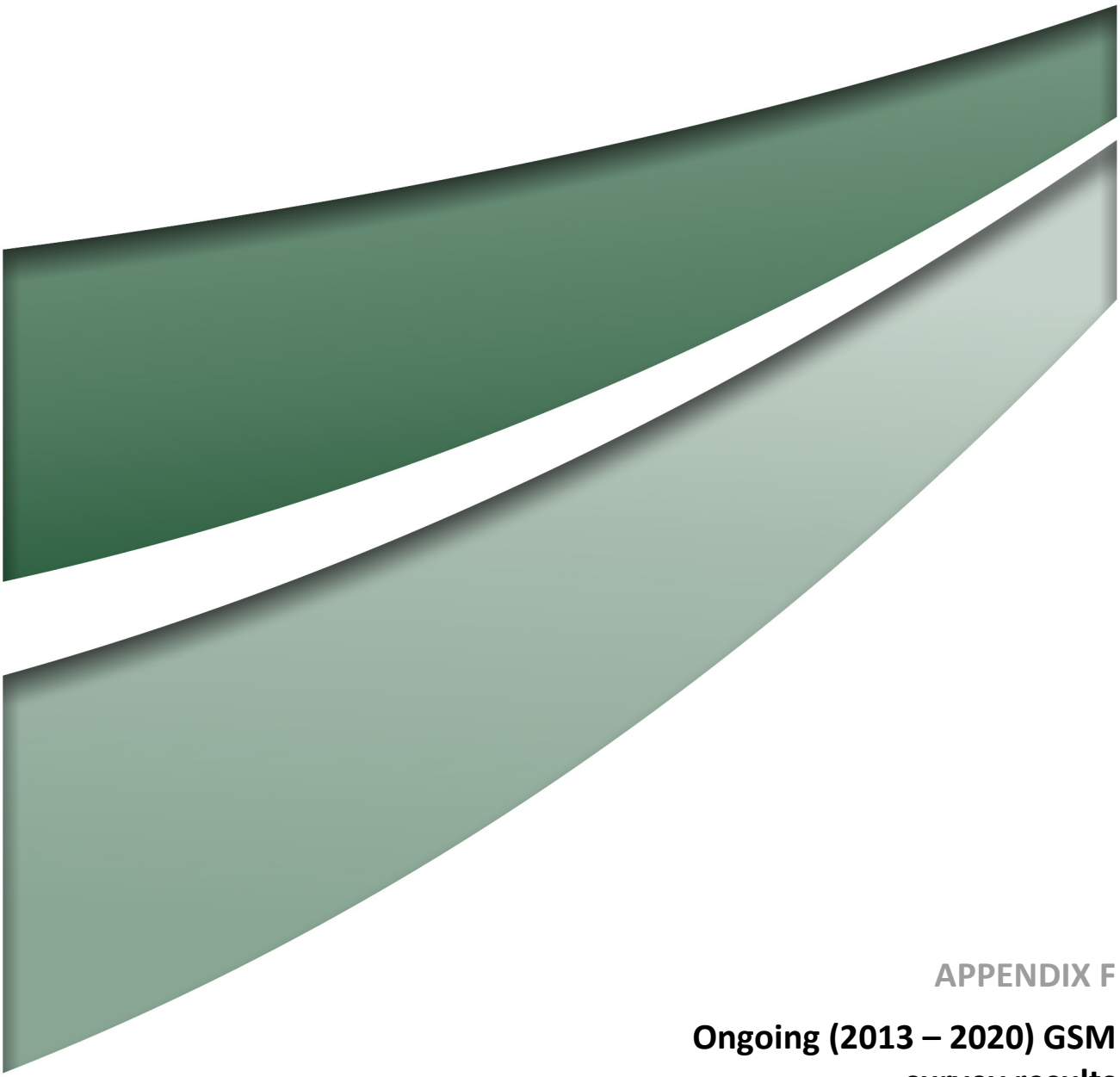
APPENDIX E

Ongoing (2013 – 2020) Vegetation Mapping Results

Appendix F-1: Revised 2020 vegetation compared with 2013 - 2019

Vegetation type / land use	2013 (ha)	2014 (ha)	2015 (ha)	2016 (ha)	2017 (ha)	2018 (ha)	2019 (ha)	2020 (ha)	Change since 2013 (ha) (%)	Change since 2019 (ha) (%)
Natural temperate grassland	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	+0.1 (20%)	+0.1 (20%)
Native pasture	1.7	1.7	1.6	1.6	0.7	0.7	0.9	1.0	-0.7 (-41%)	+0.1 (+11%)
Mixed native and exotic pasture	5.0	5.0	4.9	4.9	5.8	4.8	4.7	4.5	-0.5 (-10%)	-0.2 (-4%)
Exotic pasture	5.4	5.4	6.5	6.5	6.7	7.6	7.6	7.6	+2.2	0 (0%)
(Construction area)	0.8	0.8	0	0	0	0	0	0	-0.8 (-100%)	0 (0%)
(Non-grassland areas (e.g. buildings, riparian margins, woodland))	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.9	-0.1 (-1%)	-0.1 (-1%)
Total Project Area	**21.6**	**21.6**	**21.6**	**21.6**	**21.6**	**21.6**	**21.7**[1]	**21.6**	**0 (0%)**	**0 (0%)**
Chilean needle grass	1.2	1.2	1.1	1.4	1.8	2.9	3.2	1.5	+.3 (+25%)	-1.7 (-53%)
African lovegrass	**0**	0	0	0.3	2.1	2.7	3.2	1.4	+1.4 (N/A)	-1.8 (43%)

1. A recalculation of the total project area was undertaken and has resulted in an increase in the total size, however, this would not have a substantial effect on the results.



APPENDIX F

Ongoing (2013 – 2020) GSM survey results

Appendix F-1: Summary of transect survey results (2018 – 2020)

Transect	Total (2018)	Average (2018)	Total (2019)	Average (2019)	Total (2020)	Average (2020)
1A	234	78.0	16	5.3	4	2
1B	103	34.3	26	8.7	4	2
2A	68	22.7	7	2.3	2	1
2B	36	12.0	17	5.7	5	2.5
2C	59	19.7	10	3.3	9	4.5
2D	38	12.7	14	4.7	2	1
3A	16	5.3	0	0.0	1	0.5
3B	76	25.3	8	2.7	3	1.5
3C	100	33.3	1	0.3	1	0.5
3D	96	32.0	15	5.0	1	0.5
4A	118	39.3	22	7.3	0	0
4B	117	39.0	47	15.7	0	0
4C	170	56.7	31	10.3	3	1.5
4D	48	16.0	30	10.0	3	1.5
5A	33	11.0	4	1.3	3	1.5

Appendix F-3: Average numbers of GSM at rotational survey sites (2013-2020)

Plot	Baseline (Av. 2013-15)	Av. 2013	Av. 2014	Av. 2015	Av. 2016	Av. 2017	Av. 2018	Av. 2019	Av. 2020	Rolling 3 Year Average	Rolling 3 Year Standard Dev (Average)	Combined Av. 12-20
1	**2.4**	2.1	3.4	1.7	2.2	5.0	16.9	1.0	**2.4**	6.8	8.8	4.3
2	**2.3**	2.3	2.3	2.4	0.5	1.2	10.8	1.0	**2.0**	4.6	5.4	2.8
3	**3.9**	3.0	6.3	2.3	3.6	0.7	3.3	0.3	**2.2**	1.9	1.5	2.7
4	**6.1**	3.9	8.9	5.6	43.2	1.5	1.3	0.7	**4.4**	2.1	2.0	8.7
5	**0.5**	0.4	0.6	0.4	1.7	0.0	1.4	0	**1.0**	0.8	0.7	0.7
6	**2.2**	0.8	1.9	3.8	4.4	0.5	10.8	0.1	**8.4**	6.4	5.6	3.8
7	**0.0**	0.1	0.0	0.0	0.0	0.0	1.7	0.2	**0**	0.6	0.9	0.3
8	**0.1**	0.2	0.0	0.0	12.1	0.2	8.1	3.3	**5.5**	5.6	2.4	3.7
9	**0.7**	0.0	0.8	1.3	1.4	0.0	2.6	0.5	**0.7**	1.3	1.2	0.9
10	**0.7**	0.1	0.7	1.2	11.8	0.1	15.4	6.0	**1.5**	7.6	7.1	4.6
11	**0.7**	0.2	0.7	1.1	2.1	0.2	18.1	1.4	**0.6**	6.7	9.9	3.1
12	**0.2**	0.0	0.5	0.0	0.5	0.2	5.2	0.5	**1.3**	2.3	2.5	1.0

Appendix F-4: Average numbers of GSM at rotational survey sites (2013-2020)

Plot	Baseline (Av. 2013-15)	Max.2013	Max. 2014	Max. 2015	Max. 2016	Max. 2017	Max. 2018	Max. 2019	Max. 2020	Rolling 3 Year Average (Max)	Rolling 3 Year Standard Deviation (Max)
1	**7.7**	6	14	3	8	24	65	6	**5**	25.3	34.4
2	**6.3**	7	7	5	2	4	40	5	**6**	17.0	19.9
3	**11.0**	8	20	5	14	3	14	2	**7**	7.7	6.0
4	**16.3**	14	26	9	129	12	9	10	**10**	9.7	0.6
5	**2.7**	5	2	1	7	1	9	0	**3**	4.0	4.6
6	**5.0**	4	5	6	13	3	38	1	**20**	19.7	18.5
7	**0.7**	1	1	0	0	0	9	2	**0**	3.7	4.7
8	**1.0**	3	0	0	51	1	33	15	**11**	19.7	11.7
9	**1.7**	0	2	3	4	1	10	3	**3**	5.3	4.0
10	**2.0**	1	2	3	46	1	63	25	**5**	31.0	29.5
11	**1.3**	2	1	1	7	2	62	10	**2**	24.7	32.6
12	**0.7**	1	1	0	6	2	23	3	**4**	10.0	11.3