Willogoleche Wind Farm

Lomandra Grassland Monitoring Report 2020

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GLOSSARY AND ABBREVIATION OF TERMS

%	Percent / Percentage
±	Standard deviation
2	squared
3	Cubed
Annual (plant)	A plant that completes its entire life cycle, from seed germination to flower and the production of seed, within a single growing season (which can be 12 months or less). All roots, stems and leaves of the plant die annually.
Assessment Site	monitoring transect and immediate (50 metre) surrounding area combined
BCMM NAYP	*Bushland Condition Monitoring Manual: Northern Agricultural and Yorke Peninsula*
Biennial (plant)	A plant that requires two years to complete its life cycle.
BOM	Bureau of Meteorology
cm	Centimetre
COEMP	Construction and Operational Environmental Management Plan
Condition Class A	The highest quality representation of Iron-grass Natural Temperate Grassland
Condition Class B	Iron-grass Natural Temperate Grassland of high quality with less native species diversity than Condition Class A.
Condition Class C	Iron-grass Natural Temperate Grassland that is typically significantly degraded, but amenable to rehabilitation.
COVID-19	Corona virus disease of 2019
DAWE	Department of Agriculture, Water and the Environment (Commonwealth)
Declared plant	A weed that is regulated under the *Natural Resources Management Act 2004* due to its threat to primary industry, the natural environment and public safety.
DEW	Department for Environment and Water (South Australian)
EBS	Environmental and Biodiversity Services, *trading as* EBS Ecology
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ha	Hectare(s)
Iron-grass NTG	Iron-grass Natural Temperate Grassland of South Australia
km	kilometre(s)
LGM	Lomandra Grassland Monitoring
LSA Act	*Landscape South Australia Act 2019*

m	metre(s)
m^2	square metre(s)
mm	millimetres
NPW Act	National Parks and Wildlife Act 1972
OEMP	Operational Environmental Management Plan
PCQM	Point-centred Quarter Method
Perennial (plant)	A plant that persists for many growing seasons.
PIRSA	Primary Industries and Regions South Australia
PPH	Plants per hectare
Project	the Willogoleche Wind Farm
SA	South Australia
sp.	species
spp.	species (plural)
ssp.	subspecies
TEC	Threatened Ecological Community
Weed	A plant species which does not naturally occur in an area.
WTG	Wind Turbine Generator
WWF	Willogoleche Wind Farm

EXECUTIVE SUMMARY

Background

The Willogoleche Wind Farm (WWF) Project area contains seven patches (six Category B and one Category C) of Iron-grass Natural Temperate Grassland (Iron-grass NTG), which is a Threatened Ecological Community (TEC) protected by the *Environment Protection and Biodiversity Protection Act 1999* (EPBC Act). As part of the WWF approval conditions under the EPBC Act, the *Willogoleche Wind Farm Operational Environmental Management Plan* (OEMP) was developed to recognise possible threats to the quality and coverage of the Iron-grass NTG caused by WWF, and to outline management actions to minimise these threats. An annual monitoring program was established as a requirement of the OEMP to evaluate the effectiveness of management activities and provide early indication of changes to the health of the seven patches of Iron-grass NTG occurring within WWF.

Baseline monitoring of seven Iron-grass NTG sites was undertaken prior to the construction phase in spring 2017, with further monitoring undertaken annually in 2018 (during construction), and 2019 (post-construction/operational). This report outlines the methodology used for data collection, presents the results of the 2020 Lomandra Grassland Monitoring (LGM), and provides a comparison with previous assessments. It also provides a statement on the overall status of the seven patches of Iron-grass NTG, together with recommendations to ensure the management requirements of the OEMP are fulfilled, and compliance with the conditions associated with the EPBC Act approval is achieved. As per the OEMP the objectives of the 2020 Iron-grass NTG monitoring are to:

- Identify potential impacts to the Iron-grass NTG TEC by determining the state of the Iron-grass NTG and identifying emerging trends compared with previous baseline and monitoring results;
- Monitor and audit to detect attributable impacts;
- If required, establish management actions to avoid, minimise and/or mitigate the impacts; and,
- Implement contingency responses and corrective actions if required.

Methodology

A field survey involving the Point Centre Quarter Method (PCQM) at seven 50 metre (m) transects across the WWF as well as a 50 m x 50 m (0.25ha) ramble survey to identify species diversity and rare flora was undertaken, in line with methods undertaken since 2017. Two of the established sites (5 and 7) were subject to reduced survey effort in 2020, due to a sudden COVID-19 lockdown in South Australia, requiring EBS Ecology staff to return to Adelaide immediately. As this is only the third survey post-baseline Assessment in 2017, and some methodology has changed and/or new methodology added, it is too early to undertake any meaningful statistical analysis. However, descriptive data and any observations of changes or constants between 2017 and 2020 are provided in this report. Statistical analysis may be conducted in future years to ascertain if any changes to Iron-grass NTG health are occurring at the seven sites over the period of the monitoring program.

Summary of results

- The five sites surveyed in 2020 were assessed to be of EPBC Condition Class B

- All sites were within the 'healthy' benchmark range based on Bushland Assessment Monitoring Manual Northern Agricultural and Yorke Peninsula (NAYP BAMM) Community 3.2 indicators such as species diversity and lifeform, percent cover, cryptogam cover and bare ground cover.
- There were no apparent signs of erosion or sedimentation problems, and bare-ground cover (%) had decreased since 2019, while cryptogamic crust cover had increased, both desirable trends.
- Weeds: (refer to *EBS 2020a Weed Report* [in preparation] for more detail)
    - A total of 20 different weed species were recorded at WWF in 2020, compared to 17 in 2019 and 11 in 2017. Two new weed species were recorded in the 2020 Weed Assessment – *Arctotheca calendula* (Capeweed) and *Bromus rubens* (Red Brome).
    - The total average weed coverage across five Assessment Sites increased from 9.5% in 2019 to 31.52% in 2020, largely attributable to seasonal conditions.
    - The *Weed Abundance and Threat Score* (NAYP BAMM) for each Assessment Site ranged from 20 to 28, with five sites maintaining a **moderate** rating as in 2019, and two sites being decreased to a **poor** rating.

Discussion

Following prolonged drought conditions, 2020 had above average rainfall, and so it is likely that many of the changes observed are attributable to seasonal variation rather than from impacts of the operation of the WWF. The condition of the seven Iron-grass NTG sites remain stable, and are currently not being negatively impacted by operation of WWF. Weed encroachment remains the most significant threat to the health of the seven Iron-grass NTG sites.

Recommendations

- Consider minor changes and additions to the methods used in the LGM program including:
    - Assess presence/absence of selected native species including *Lomandra spp.* in 1 x 1 m^2 quadrats;
    - Calibrate accuracy of PPH by counting all tussocks in quadrats; and
    - Define list of species to record in PCQM
- Engage landholders to undertake best practice weed control (grazing, slashing, spraying, physical removal) at WWF.
- Ensure any management actions (including weed management chemical/ physical/ grazing) undertaken by ENGIE and/or landholders are communicated and documented to enable long term annual monitoring observations to be correlated with land management.
- Continue low-level sheep grazing in winter months, as outlined in the OEMP, to ensure inter-tussock spaces are kept open for the recruitment of broad-leaved herbs.

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1 INTRODUCTION

The Willogoleche Wind Farm (WWF; the Project) is located approximately six kilometres (km) west of the township of Hallett in the Mid North of South Australia (SA) (Figure 1). With 32 wind turbine generators (WTGs) the WWF has a generation capacity of 119 Megawatts, giving it the capability of powering 80 000 homes across SA (ENGIE 2019). Willogoleche Power commenced the operation and maintenance phase on 12 November 2019. The WWF is expected to be operational for approximately 25 years, until around 2044.

The WWF contains seven patches (six Category B and one Category C) of Iron-grass Natural Temperate Grassland of South Australia (Iron-grass NTG), which is a Threatened Ecological Community (TEC) protected by the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Figure 1). Under the EPBC Act, actions that have, or are likely to have, a significant impact on a matter of national environmental significance require approval from the Australian Government Department of Agriculture, Water and the Environment (DAWE). EPBC Act Approval, subject to conditions, for the WWF was received on 28 January 2014 (EPBC 2011/5850).

Potential threats to Iron-grass NTG that could be directly attributable to the WWF include weed invasion, altered hydrology, erosion and accumulative dust, as well as clearance of native vegetation. Other threats that are not a direct impact from the wind farm include inappropriate grazing regimes, dry climatic conditions, litter accumulation, and grazing by native herbivores. Threats may lead to a loss in patchiness, increasing dominant species (e.g. native grasses) and loss of more vulnerable and herbaceous species within Iron-grass NTG.

1.1 Background

In the early stages of the Project, EBS Ecology was engaged to perform baseline assessments of the WWF site for Development Approval, and identified the WWF area as likely to contain Iron-grass NTG, an ecological community listed in 2007 as Critically Endangered under the EPBC Act 1999, following advice from the Threatened Species Scientific Committee (TSSC) that the community met Criterion 1 (decline in geographic area), Criterion 2 (small geographic distribution) and Criterion 4 (reduction in community integrity) (Beeton 2007).

EBS Ecology was subsequently contracted to undertake an assessment of several patches of Iron-grass NTG identified within the project area, to determine if their condition satisfied the criteria for listing as a Threatened Ecological Community (TEC) protected under the EPBC Act as set out in the 'E*PBC Act Policy Statement 3.7. Peppermint Box (Eucalyptus odorata) Grassy Woodland of South Australia and Iron-grass Natural Temperate Grassland of South Australia*' (DEWR 2007).

The assessment identified six sites within the project area which met criteria for listing as 'Condition Class B', and one that met 'Condition Class C' (EBS 2010c) (Figure 1), where each condition class defines and describes the conservation value of an area of Iron-grass NTG based on factors such as native species diversity and the size of the area. Condition Class A represents the highest quality of the community, whereas Condition Class B is also of high quality but shows less species diversity. Condition Class C does not meet criteria for listing under the EPBC Act, but represents an area which is considered intact enough to be amenable to rehabilitation.

Since commencement of the project, and in line with the OEMP review schedule, there have been several revisions of the original *Construction and Operation Environmental Management Plan* (COEMP), coinciding with changes to the phase of the project (ie. construction to operation). A review has recently been undertaken (EBS Ecology 2020 *in review*) one year post commencement of operational phase. This review notes that as the site is no longer subject to construction activities, the likelihood and risk of impact is significantly less than during construction works, however risks to the Iron-Grass NTG TEC remain, such as:

- Introduction of new weeds and/or increase in weed occurrence;
- Soil erosion and sedimentation;
- Increase in feral animals; and
- Fire

The OEMP outlines indicators for monitoring of the Iron-grass NTG TEC using metrics such as:

- Grassland health (ie. % dead material, regeneration)
- Dominant species cover and abundance
- Vegetation composition (ie. plant species diversity)
- Seedling recruitment and regeneration
- Soil surface condition (ie. bare ground, cryptogamic crust)

Subsequently, this report presents the findings of the 2020 Lomandra Grassland Monitoring survey, presenting results and discussion on the indicators described above, providing comparisons with data collected in since 2017 and providing recommendations for ongoing management of the seven patches of Iron-grass NTG at WWF.

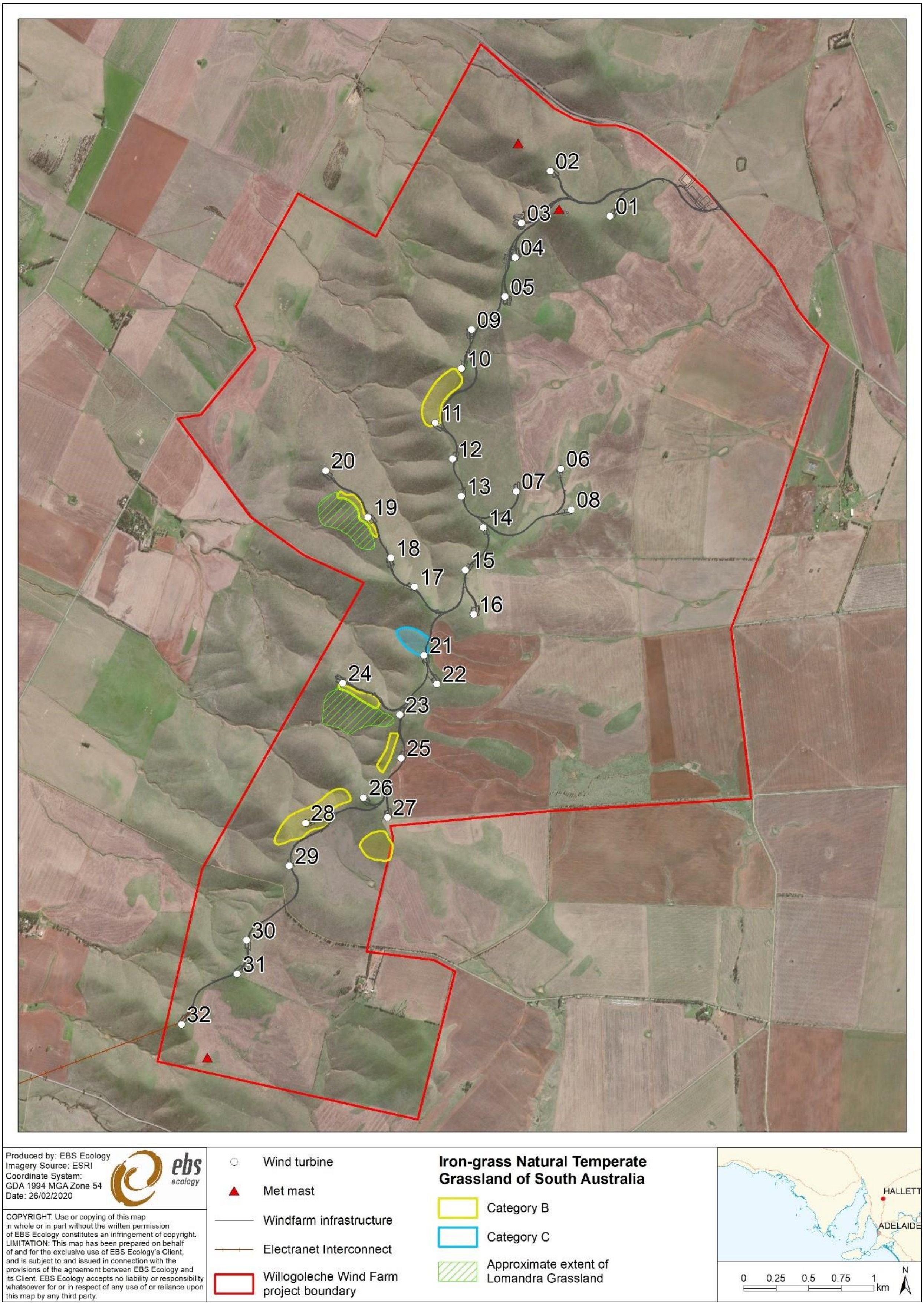

Figure 1. Willogoleche Wind Farm layout plan, including the seven patches of Iron-grass NTG which are monitored annually.

1.2 Objectives

The overall aim of the Iron-grass NTG monitoring program is to determine if construction and/or operation of the WWF has had, or is having any impacts on the health of the seven patches of Iron-grass NTG TEC, and to continually evaluate and review the monitoring approach to achieve this outcome.

As such, this report:

- Outlines the methodology used in the 2020 Iron-grass NTG monitoring program
- Presents monitoring results for the 2020 Iron-grass NTG monitoring assessment;
- Compares 2020 results with the 2017 (baseline) and subsequent (2019, 2019) data;
- Presents a conclusion on whether construction and/or operation of the WWF impacts on Iron-grass NTG;
- Provides further recommendations on the methodology; and
- Provides recommendations to ensure the requirements of the OEMP are fulfilled, and compliance with the conditions associated with the EPBC Act approval is achieved.

1.3 Climate

Climate in the Mid North region wither the WWF is located, consists of mild winters and hot summers, with rain occurring predominantly in the winter months (NY NRM 2018).

1.3.1 Rainfall

Rainfall data has been obtained from the Bureau of Meteorology (BOM) Hallett (Lorraine) weather station (# 21024) which is located approximately 7 km west-south-west of the southern extent of the WWF. Monthly rainfall data for the period of November 2016 (approximately one year prior to the initial Weed Assessment in November 2017) to the date end September 2020, is presented in (Figure 2). In 2010, the year the initial EPBC survey was conducted, the rainfall data is incomplete, but shows higher than average rainfall in most months, and is included for reference to gain an understanding of the conditions at the time of the survey (Figure 3).

Average rainfall at the Hallett (Lorraine) weather station is 462.7 millimetres (mm). The last year of equal to or above average rainfall in the region was 2016, with particularly dry years experienced in 2018 and 2019, recording 23.45% and 34.8% less rainfall than average, respectively. By contrast, 2020 has thus far experienced considerably above average rainfall (17.85% January to October 2020), particularly in April, August, September and October.

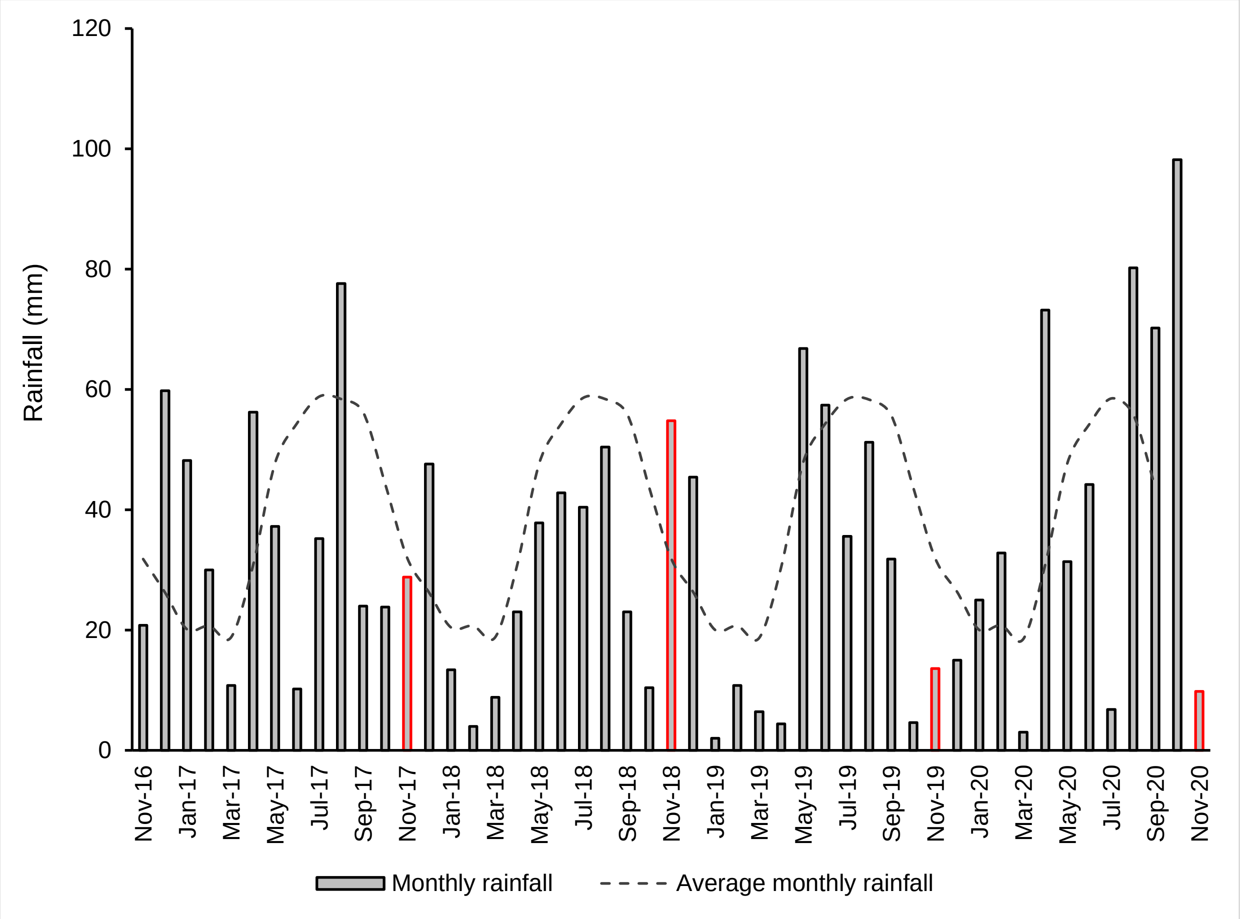

Figure 2. Monthly rainfall data from November 2016 to October 2020, red indicating survey months. Source: Hallett (Lorraine) Bureau of Meteorology (BOM) weather station #21024 (BOM 2020)

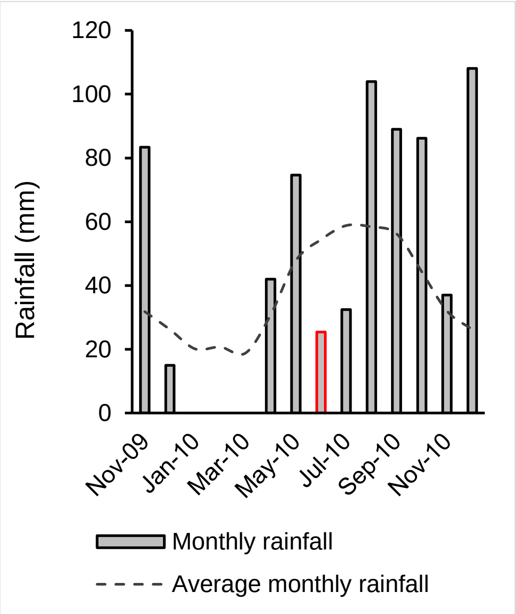

Figure 3. Monthly rainfall data from November 2009 to December 2010, red indicating month of EPBC survey. Source: Hallett (Lorraine) Bureau of Meteorology (BOM) weather station #21024 (BOM 2020)

2 METHODOLOGY

2.1 Survey Timing

Field survey for the 2020 Weed Assessment was undertaken on 16-18 November 2020 by EBS Ecology staff Emma Eichler (Senior Ecologist) and Jessica Skewes (Senior Ecologist). The survey was terminated early due to an outbreak of COVID-19, compelling field staff to return to Adelaide immediately.

2.2 Assessment Sites

Five of the seven monitoring transects established within each of the seven patches of Iron-grass NTG in 2017, were revisited for the 2020 Monitoring. In 2017 a 50 m long monitoring transect was established within each of the seven Iron-grass NTG sites (Table 1 and Map 1-7 in Appendix 1). In 2018 the monitoring area was expanded to include a 'ramble' search area of 0.25 hectares (50x50m) around each transect, and therefore the monitoring transect and immediate surrounding area combined is referred to as an 'Assessment Site'. Refer to Table 1 below and Figure 10 to 16 in Appendix 1 for the location of each assessment site which contains a monitoring transect.

Table 1. Assessment Site location details and EPBC Category of the Iron-grass NTG (as assessed in 2010).

Assessment and Transect Site	Location Details	EPBC Category	*50x50m quadrat direction from transect	Comment
1	Approximately 80 m south-west of WTG 27	Category B	South	
2	Approximately 30 m north-east of WTG 28	Category B	South	
3	Approximately 80 m west of WTG 25	Category B	South	
4	Approximately 20 m south of WTG 24	Category B	South	
5	Approximately 50 m north of WTG 21 (but adjacent access track)	Category C	North	Not surveyed in 2020
6	Approximately 10 m west of WTG 19	Category B	South east	
7	Approximately 180 m south-west of WTG 10 (but 20m west of access track)	Category B	South	Not surveyed in 2020

*Direction from transect from which the EPBC assessment was undertaken

2.3 Point-centred Quarter Method (PCQM)

In 2020, the PCQM methodology used in previous assessments was repeated. PCQM involves surveying ten (10) sample points along a 50 m transect, assessing perennial plant parameters at five metre intervals (starting at zero metres). Each sample point is further divided into four quarters by placing a range pole perpendicular to the transect line, then the distance from the sample point to the nearest native perennial plant in each of the four quarters is measured and recorded (Figure 3), resulting in assessment of 40 perennial plants per transect (Tongway & Hindley 2004). The PCQM is used instead of other methods, for example tussock counts in 1x1 m^2 quadrats, due to the number of small grasses (ie *Rytidosperma spp.*) making counts very time consuming.

At each sample point along the transect, the four distance measures are averaged to represent the distance (*d)* at each sample point, and then these distances are averaged to calculate the average distance of all sample points on a transect.

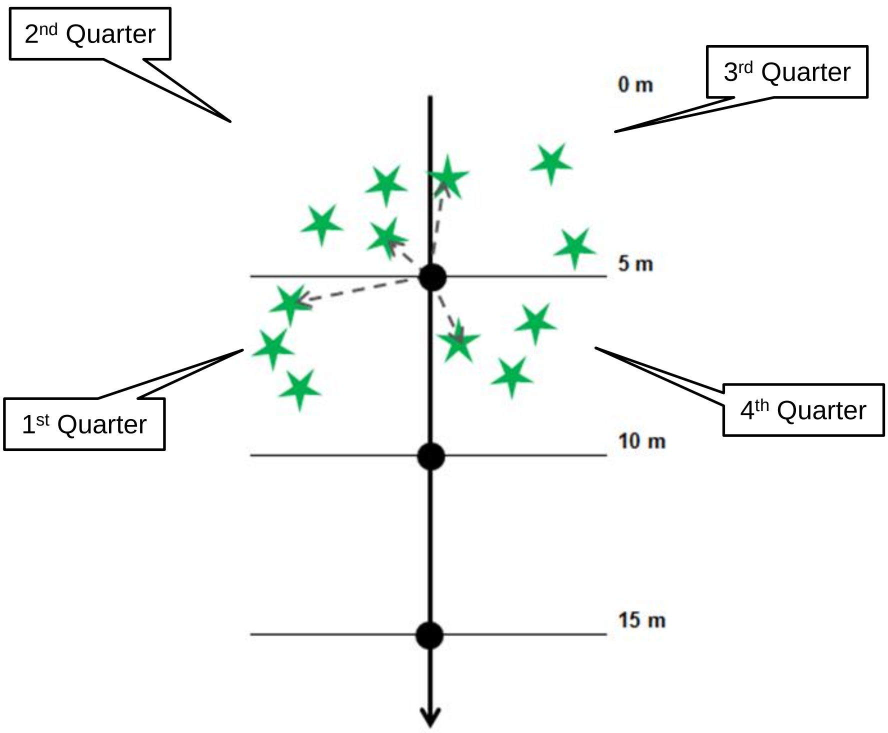

Figure 4. The Point-centred Quarter Method involves collecting data on the closest native perennial plant (indicated by a green star) in four quarters at each sample point (image adjusted from Tongway and Hindley, 2005)

In addition to the species, the canopy width (in cm), plant height (in cm) and basal width (in cm) of each of the 40 perennial plants is recorded (Tongway & Hindley 2005). Previously, the PCQM data has been used to calculate percentage cover and volume of perennial plants in metres cubed (m^3), however, given that canopy width is highly variable dependent on seasonal conditions and is sensitive to grazing, it is considered that trends may be more evident and meaningful if basal area (m^2) is used, which also provides an indication of land function, and influences the relative importance of a species within an ecosystem. Table 2 provides a summary of data collected as part of the PCQM in 2020 for the WWF and how the data was then analysed. The purpose of data collection, the desired data trends to indicate grassland health, potential data limitations and a recommendation for future monitoring is also provided in Table 2 (on the following page).

From the data collected the following indices can be derived:

1. The density of plants per unit area for each species;
2. Basal cover per unit area (m^2/ha)
3. Importance value of each species

Table 2. Data collected as part of the PCQM in 2020, analysis approaches, purpose of data collection, desired data trends and usefulness of the data

Parameter	*Data collected	Analysis	Purpose	Desired trend	Undesirable trend	Comment	Recommendation
Cover (m^2)	Basal width	PCQM	Determine basal cover (m^2) of perennial plants.	Stable or slight increase.	Significant increase or decrease.	Based on several years of monitoring, it was deemed that PCQM had some limitations. Therefore in 2019, the method was supplemented with additional data collection methods. In 2020 these PCQM measures were reviewed again to determine a more appropriate and indicative method moving forwards.	Continue to monitor using PCQM. However, supplement with collecting total percentage native cover data (as undertaken in 2019). Eg. measure using % native cover in 1m x 1m quadrats. In 2020 basal width was used to calculate cover (m^2) to provide information on maturity of perennial plants, and the actual ground cover, rather than projected canopy cover which is highly variable depending on seasonal conditions and/or grazing.
Volume (m^3)	Canopy width breadth, height and canopy density (%)	PCQM	Determine volume of vegetation in metres cubed (m^3).	Ideally stable or increase, but data is not meaningful.	Ideally stable or increase.		Excluded in 2020 due to highly variable and inconsequential results. Recommend to **stop** collecting.
Density (PPH)	Distance from PCQM centre point	PCQM	Determine the number of perennial plants per hectare.	Stable or slight increase.	Significant increase or decrease.		Continue to monitor using PCQM. However, consider supplementing with counts of total number of grass tussocks in 1m x 1m quadrat at each PCQM point to calibrate. Consider selecting the four most dominant or important indicator species to measure (ie *Lomandra, Aristida, Austrostipa spp., Rytidosperma spp.*)
% dead material	Percentage of green material on tussocks (canopy density)	Average % dead material	Determine tussock dieback, a useful indicator in grassland health.	Stable or decreasing	Increasing	Potentially useful indicator of plant health.	**Continue** to measure percentage dead material of 40 plants per transect.

Canopy size of tussock (in cm)	Canopy width	Average canopy width	Aims to changes on the canopy size of tussocks (will detect grazing pressure and seasonal conditions).	Stable or increasing size	Decreasing	Potentially useful indicator of plant size.	**Stop** measuring canopy size, as it is more indicative of seasonal conditions. Height is deemed a more robust and suitable indicator of grazing pressure.
Height of plant (in cm)	Height of plant	Average height	Aims to detect changes in height – useful for determining grazing pressure.	Stable or increasing height	Decreasing	Valuable to collect data on plant size trends.	**Continue** to measure plant height of 40 plants per transect (from ground to tip of leaves, not seed/flower head)

2.4 EPBC Condition Ramble Survey

In addition to the PCQM sampling outlined above, a ramble walk was undertaken across a 0.25 ha (50 x 50 m) quadrat in the immediate area of the Assessment Site, to record any native species present and their estimated cover. The data from this search can then be used to determine the condition class of Iron-grass NTG patches as outlined in the *EPBC Act Policy Statement 3.7. Peppermint Box (Eucalyptus odorata) Grassy Woodland of South Australia and Iron-grass Natural Temperate Grassland of South Australia'*. (DEWR 2007) (Table 3. EPBC Iron-grass TEC condition score parameters (DEWR 2007).), and if they have remained stable or otherwise since the baseline assessment was undertaken in 2017.

Table 3. EPBC Iron-grass TEC condition score parameters (DEWR 2007).

Condition class	Minimum size	Diversity of native species[1]	No. broad-leaved herbaceous species[1] in addition to identified disturbance resistant species[2]	No. perennial grass species[1]	Tussock count[3]
Listed ecological community					
A	0.1ha	>30	+10	>5	1/m
B	0.25ha	>15	+3	>4	1/m
Degraded patches amenable to rehabilitation					
C		>5	No minimum	>1	No minimum

*[1] as measured in a 50 x 50 m quadrat; [2] disturbance resistant species: *Ptilotus spathulatus, Sida corrugate, Oxalis perennans, Convolvulus erubescens, Euphorbia drummondii,* and *Marieana enchylaenoides;* and, [3] as measured along a 50m transect.

2.5 Grassland Health Indicators

Following on from the methods introduced in 2019, the 2020 survey measured the following five grassland health indicator attributes in each of the 10 quadrats indicated in Figure 5. Schematic of a 50m long transect with 10 1m^2 quadrats, surveyed at 5m intervals (not to scale)Figure 5 at each site, to further inform trends in grassland condition and health:

- percentage (%) cryptogams;
- % litter (including alive and dead exotic plants);
- % bare ground;
- % total native cover; and
- % rock.

An overview of the purpose of the data collected, the desirable result trends and comments / recommendations for future monitoring are provided in Table 4.

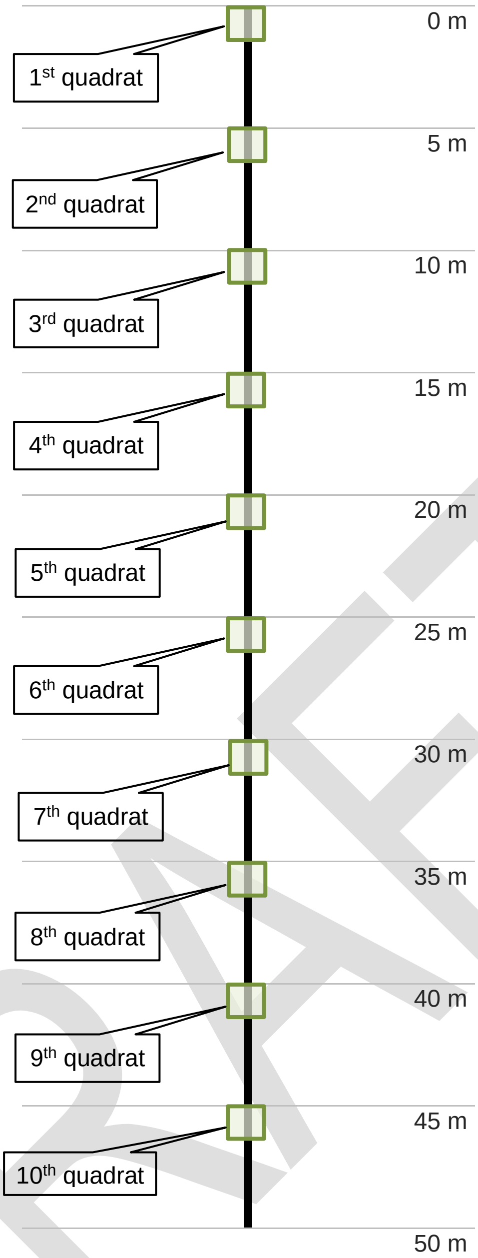

Figure 5. Schematic of a 50m long transect with 10 1m^2 quadrats, surveyed at 5m intervals (not to scale)

Table 4. Grassland health indicators measured in 2020

Attribute	Purpose	Desired trend	Undesirable trend	Comment/ recommendation
% cryptogams	Presence of cryptogams indicates, soil health and nutrient cycling.	Increasing/ benchmark	Decreasing The unofficial benchmark values for cryptogams (with moss and lichen cover) is comprising up to 50% for Grasslands in the Northern Lofty botanical region (Pedler, Croft & Milne, 2007).	Continue to monitor.
% litter including exotic annual grass (the majority of litter)	Will monitor percentage of the site covered in dead annual grass material which indicates a high % of weeds, some loss of patchiness and may inhibit germination of native species.	Decreasing	Increasing (generally indicates increased weeds in the grassland system). The unofficial benchmark values for % litter for Grasslands in the Northern Lofty botanical region is approximately <25%.	Continue to monitor.

Attribute	Purpose	Desired trend	Undesirable trend	Comment/ recommendation
% bare ground (meaning exposed dirt free of litter, moss, plants (dead or alive), rock or cryptogams)	Will monitor soil disturbance and potential for soil loss or erosion. Can increase due to dry conditions, increased livestock or weed invasion.	Decreasing/ benchmark (native species often germinate in bare ground so some may be desirable).	Increasing. The unofficial benchmark values for % bare ground in Grasslands in the Northern Lofty botanical region is approximately <5% (Pedler, Croft & Milne, 2007).	Continue to monitor.
% total native cover (all perennial and annual species)	Will determine trends in the total native cover and determine if site becomes overgrown or experiences significant losses of vegetation.	Stable or slight increase	Significant increase (loss of patchiness) or significant decrease.	Continue to monitor.
% rock	Data collected to obtain full picture of structural attributes. Rock cover does not need to be collected in future years.	Stable	Stable	Monitor every 5 years.

2.6 Opportunistic Observations

In addition to the PCQM, quadrat and ramble surveys, any plant species of interest that were observed opportunistically when travelling on the access tracks between assessment sites, or within the vicinity of a site but not within the survey boundary, were also recorded.

2.7 Statistical Analysis

Within each of the seven Iron-grass NTG Sites, PCQM data was used to calculate the following five parameters:

- density (plants/ha) - perennial plants per hectare (PPH);
- ground cover (m^2/ha) (basal width)
- Plant height; based on averages of plants measured; and
- % dead material; based on averages of plants assessed.

The data is analysed using the methods described by K. Mitchell (2015) in addition to using standard averages to determine trends. Percentage cover data collected including litter, bare ground, cryptogams and rock were calculated across the site and WWF based on average values using Microsoft Excel. As the LGM program commenced in 2017, and new methods were added in 2019, it is too early in the program to undertake any meaningful statistical analysis. Descriptive data and any observations of changes or constants between 2017 and 2020 are reported in Section 3 (Results) and 4 (Discussion). Statistical analysis will be conducted in future years when there is enough data to ascertain if any changes within the seven patches of Iron-grass NTG are occurring over the period of the monitoring program and if they are related to WWF operational practices or seasonal variation.

2.8 Limitations

In the 2020 LGM only five sites were able to be completely surveyed due to a sudden COVID-19 state-wide lockdown, forcing EBS ecologists to leave the site before finishing. Subsequently the dataset is limited to five sites, however trends can be extrapolated from the five sites that were surveyed, as conditions were equivalent across the WWF.

The PCQM is most commonly used in woodland ecosystems, where trees and shrubs remain relatively stable over time, and as such, the same individuals are measured repeatedly. In grassland environments, perennial plants are subject to considerable seasonal variation, with grass regeneration likely to strongly influence the composition and density estimates, which may not be reflective of a healthy or otherwise ecosystem, but rather of a fluctuating one. The PCQM can be influenced by aggregated (clumped) species, and estimates of PPH could vary significantly if the transect is not placed in the same location each year, or if seasonal variation resulted is a proliferation of regenerating species. For example *Lomandra multiflora ssp. dura* was not recorded at Site 2 using the PCQM at all in 2017, but in subsequent years was detected at a density of 3062 to 3815 PPH. This does not suggest that it wasn't present at the Site in 2017, but rather than the methods failed to detect it, either by the placement of the transect, or various seasonal factors.

Similarly grassland ecosystems are highly variable according to seasonal conditions and therefore visual estimates of cover, which can already be subjective due to observer experience, can cause variation and error in the data which may not necessarily be caused by the effects of WWF or management. Measures that should remain relatively stable over time (such as rock cover), can be used as indicators of this kind of observer variation, and cover of more permanent and or slow growing features, such as cryptogamic crust and *Lomandra spp.* could be used with more confidence in the long term.

Weed invasion and abundance is not recorded in the current report as part of the Lomandra Grassland Monitoring except through the presence of exotic litter. However, weed data was collected during the grassland monitoring with results presented in the *Willogoleche Wind Farm Weed Assessment November 2020* (EBS Ecology 2020b – in review). Weeds are potentially the most likely threat to the WWF Iron-grass NTG as a direct result of the WWF construction and operation.

3 RESULTS

3.1 Iron-grass NTG Monitoring results 2020

The results of the 2020 PCQM monitoring are summarised in Table 5 and Table 6, and explained and discussed in relation to previous years in further detail in the relevant sections below.

Some results reported in previous years have been eliminated from the 2020 data due to irrelevance and inconsistencies in measuring/data usefulness.

Table 5. Summary of 2020 Iron-grass NTG monitoring results from PCQM data

Site	Perennial plants per hectare (PPH)	Spacing of perennial plants (cm)	Average Basal area per plant (cm^2)	Basal coverage (m^2/ha)	% dead material	Rare flora (# of species)	Species diversity
1	148, 500	25.95	72.23	1072.73	9.25	NA	5
2	152, 588	25.60	140.84	2149.09	4.63	3	6
3	333, 642	17.31	139.32	4648.23	16.6	3	3
4	246, 292	20.15	31.54	776.86	7.05	3	8
5	NA	NA	NA	NA	NA	2	NA
6	243, 264	20.27	56.96	1385.68	8	2	5
7	NA	NA	NA	NA	-	NA	NA
Mean	224, 857	21.86 cm	88.18	1982.79	9.11	2.6	5.4

Table 6. Summary of perennial plant species and their density (estimated number of plants per hectare) at each site, calculated from PCQM data

Scientific Name	Common Name	1	2	3	4	6	Mean no. per hectare
Aristida behriana	Brush-wire Grass	29700	26703	141798	43101	0	37378
Atriplex semibaccata	Berry Saltbush	0	0	0	18472	0	2243
Austrostipa spp.	Spear-grass	40837	0	0	36944	12163	35882
Enneapogon nigricans	Purpletop Grass	0	3815	0	6157	0	6728
Lomandra multiflora ssp. dura	Hard Mat-rush	3712	3815	16682	12315	18245	6728
Rytidosperma spp.	Wallaby Grass	70537	91553	175162	116989	194611	109142
Scleraenthus pungens	Prickly Knawel	0	19073	0	6157	0	4485
Vittadinia cuneata	Fuzzweed	0	7629	0	0	6082	2243
Vittadinia gracilis	Woolly New Holland Daisy	3712	0	0	6157	12163	2990

3.2 PCQM

3.2.1 Spacing of perennial plants

Spacing of perennial plants can be used to determine the density of plants on a site, and can be an indicator of changes in tussock density which may relate to seasonal conditions or long term changes at a site. The smaller the spacing of perennial plants from the centre point, the higher the density of perennial plants, and so a downward trend would indicate an increase in perennial plant density.

The average perennial plant distance from centre point was 21.9 centimetres (cm) ± 3.8 (standard deviation) in 2020, lower than all previous years, likely due to good seasonal conditions increasing the density of PPH (Figure 6). Additionally, the standard deviation from the mean was much lower in 2020 than in all other years, inferring that density of perennial plants was consistent across sites. The seven LGM sites are showing a slight downward trend in plant spacing, indicating a higher density of perennial plants.

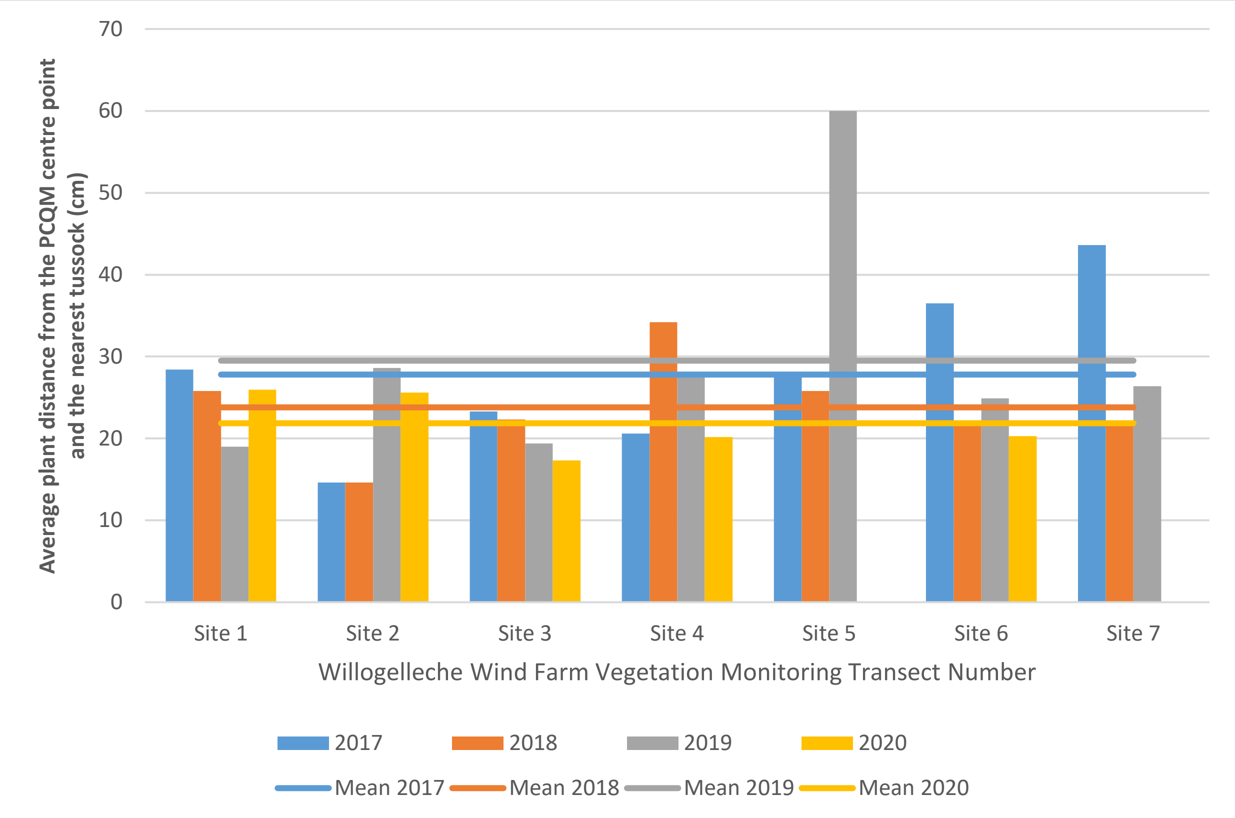

Figure 6. Average plant distance from the PCQM centre point and the nearest tussock (cm) at the Iron-grass NTG TEC monitoring sites recorded during spring 2017-2020 field surveys. The solid lines represent the overall mean values for each year.

3.2.2 Perennial plants per hectare (PPH)

Absolute density of perennial plants is defined as the number of plants per unit area. The distances measured using the PCQM method are used to calculate density without having to count every perennial plant in an area. The estimate works by calculating the mean distance from the centre-point (sum of the nearest point-to-perennial distances in the quarters surveyed, divided by the number of quarters), for each site, and for all sites combined in any given year.

Using this calculation, density per metre squared (m^2) is calculated using the formula *1/mean density*^{2}. This number can then be extrapolated to calculate the average number of perennial plants per hectare by multiplying the result by 10000 (as there are 10000m^2 in a hectare).

In 2020 the mean perennial plant density was 224,857 plants per hectare (PPH) ± 76,951 an increase of 56,831 PPH since 2019 (Figure 7). The mean PPH was significantly higher than in previous years, influenced strongly by Site 3 which recorded a 333,642 PPH. The increase in PPH is consistent with the tighter spacing of perennial plants observed in 2020.

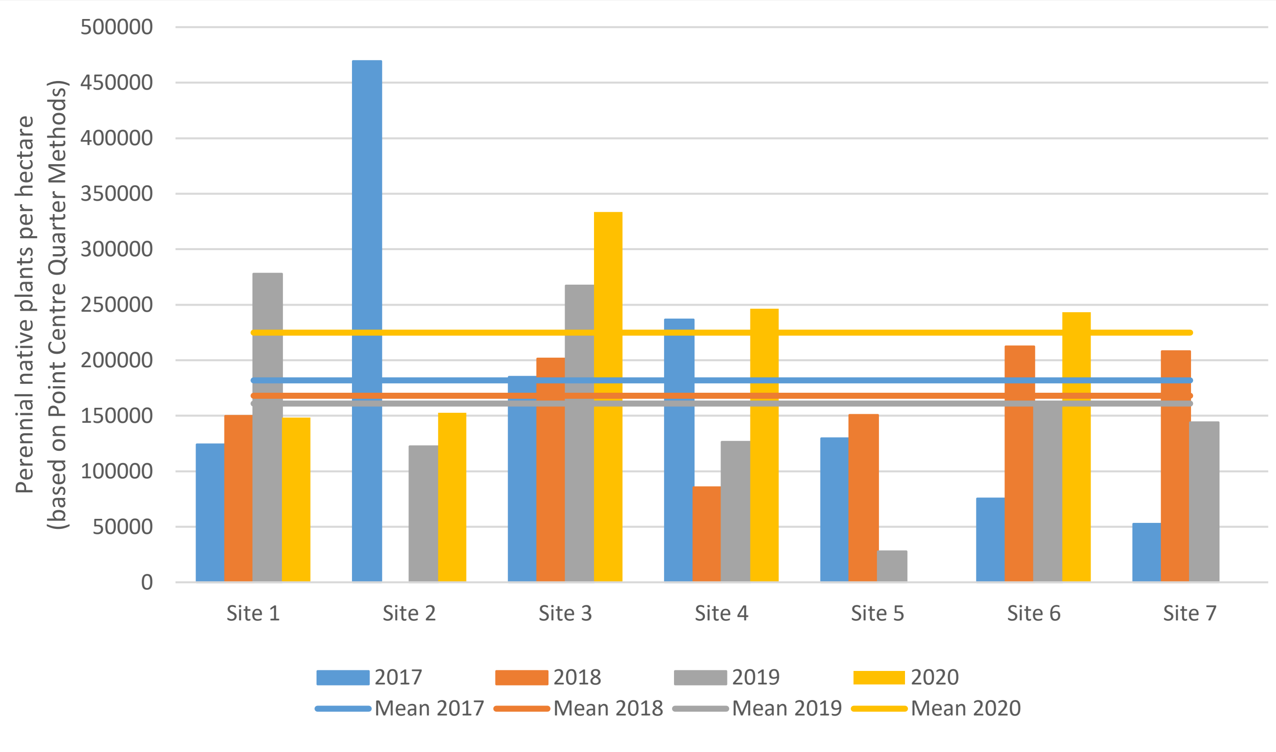

Figure 7. Perennial plant density (PPH) at the Iron-grass NTG TEC monitoring sites recorded during the spring 2017-2020 field surveys. The solid lines represent the overall mean values for each year.

3.2.3 Plant Cover

In previous years plant cover has been reported as percent canopy/foliar cover. Going forwards, this measure will no longer be reported due to its sensitivity to seasonal and grazing effects. Instead, basal cover will be reported, as it is regarded as a more stable measure of cover than canopy, particularly for perennial grasses, as the tussock bases persist even in drought conditions (DPIRD, 2020).

3.2.4 Basal cover

Basal cover or basal area is determined by considering the cross-sectional area of plants near the ground, where the diameter at ground level of a perennial plant (such as a grass tussock) is measured and then converted to calculate an approximate area (m^2) or 'footprint' of the individual plant. It can be sensitive to factors such as stage of growth, but can also be used as an indicator of grassland maturity and regeneration. It is hoped that over the life of the project, basal area can be used to track variation due to seasonal conditions, as well as to detect changes in the dominance of perennial plants over time. In order to increase the sample size at each site, it is recommended that the four most prevalent or important grasses be selected going forwards, to increase sample size and to track their relative importance.

In 2020, Site 3 had significantly higher basal coverage than all other sites, with 46.5% perennial plant basal coverage per hectare. The site with the least coverage was Site 4, with only 7.8% basal cover per hectare (mean 20.1%)

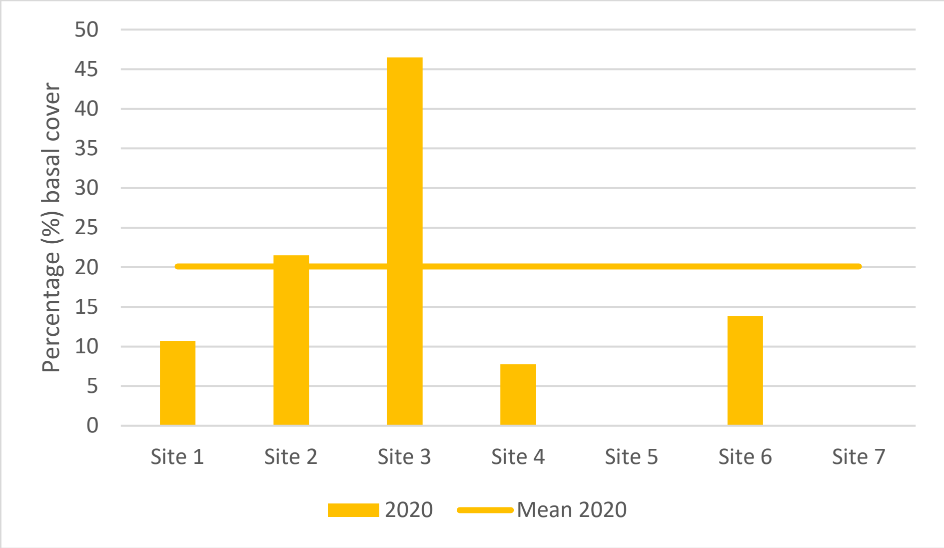

Figure 8. Percent (%) basal cover of perennial plants per hectare (10 000 m^2) for each site surveyed in 2020

3.2.5 Plant height

In the 2017 LGM report, heavy grazing of all perennial plants was observed across WWF. The average perennial plant height in 2020 was 10cm ± 2.8, 20% higher than the four year average of 7.9cm (Figure 9). All previous years of survey have had average or lower than average rainfall, which when combined with grazing, causes a doubled effect of reduced fodder leading to increased completion, resulting in higher grazing pressure. High rainfall in 2020 resulted in abundant feed available for both native and farmed herbivores.

The average plant height at Site 1 was significantly higher than at all other sites (14.6cm average), likely due to the higher representation of grasses such as *Austrostipa* (Spear-grass), which is classified as a 'Tall Grass' in the NAYP BAMM (Pedler et al 2007). Three of the four dominant grasses were between 30% and 48% taller than their four year average. *Lomandra multiflora ssp. dura* was 6% shorter than the four year average (Figure 10).

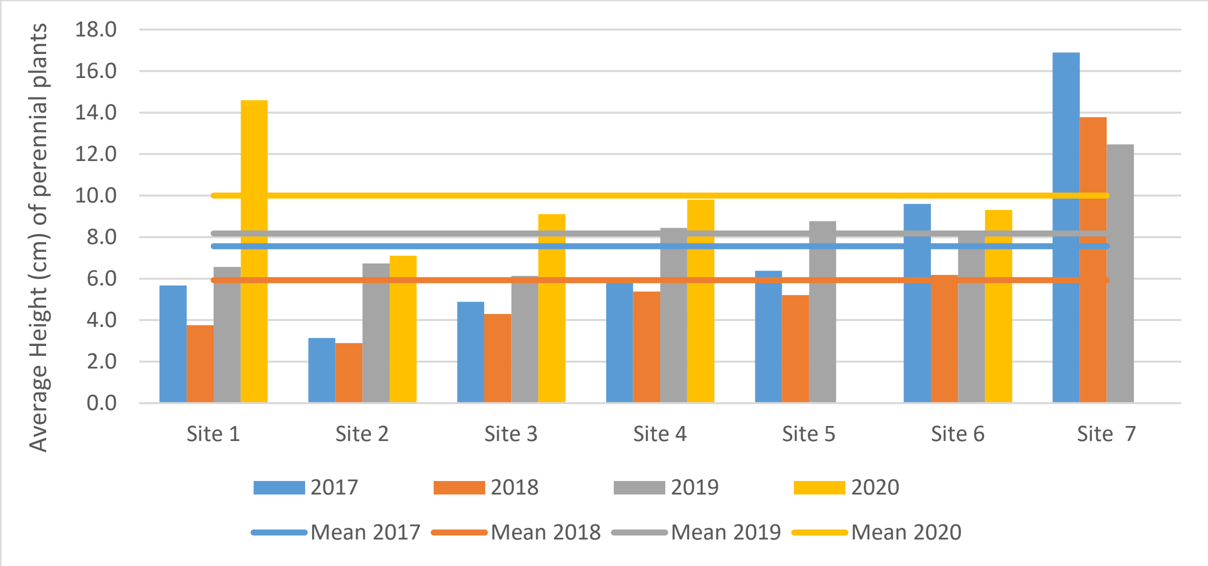

Figure 9. Average perennial plant height (cm) at the Iron-grass NTG TEC monitoring sites recorded on survey over four years from 2017 to 2020. The solid lines represent the mean values for each year.

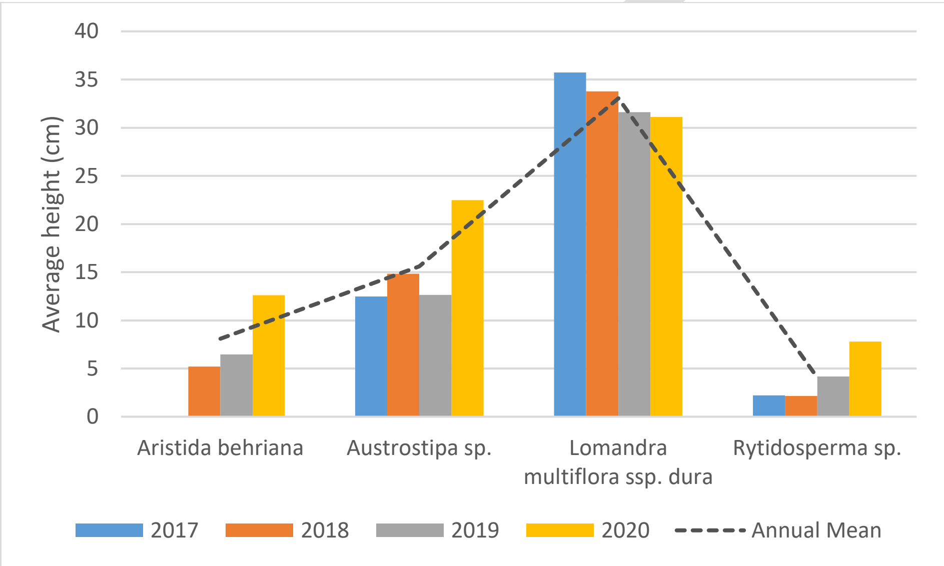

Figure 10. Average height (cm) of the four most dominant perennial grasses from 2017 to 2020

3.2.6 Percentage dead plant material

Percentage dead material is an indicator of plant health, but can vary widely depending on factors such as seasonal conditions, time of year, and grazing pressure. A stable or downward trend is desirable over a long-term dataset, however from year to year, it is likely to be highly variable.

In 2020 the percentage of dead plant material estimated per tussock measured was significantly lower than in all other years, with an average of 9.11 % across all sites, consistent with good seasonal conditions in the months leading up to the survey (Figure 11). This was constant across all sites, with a standard deviation (±) of 4.5 compared to 7.7 to 11.3 in previous years.

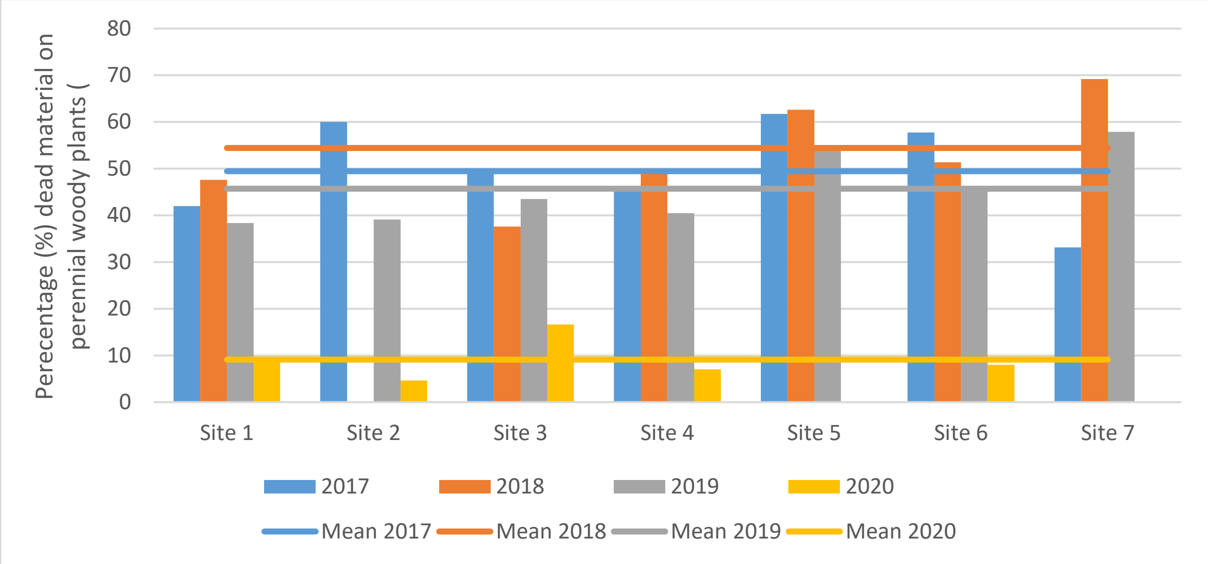

Figure 11. Percentage (%) dead material observed per perennial plant measured during PCQM survey

3.2.7 Species composition

The most frequently recorded perennial plant species, which was present at all sites was *Rytidosperma spp.* (Wallaby Grass), which accounted for 57.5% of all perennial plants recorded on the PCQM survey across all sites, or 10.9 per square metre (m^2). *Aristida behriana* (Brush-wire Grass) was recorded at four of the five surveyed sites and accounted for 19.5% of perennial plants and 3.7/m^2, while *Austrostipa spp.* (Spear-grass) was recorded at three sites and accounted for 9.5% of all perennial plants recorded and 3.6/m^2.

Lomandra multiflora ssp.dura (Hard Mat-rush), was detected at all surveyed sites and accounted for 3.2% of perennial plants and 0.7/m^2. Density of *L. multiflora ssp. dura* was highest at Site 6 with an estimated average of 18,245 tussocks per hectare, and lowest at Site 1 with 3712 tussocks per hectare.

Data from the PCQM can be used to calculate an 'importance value', which provides an indication of distribution of species across the site. The measure weighs up factors of relative density (percentage of sample points species identified at), relative cover (basal area as a percentage of all species recorded at the site) and relative frequency (a measure of distribution along the transect). The relative importance value can have a maximum of 100 which would represent for example, a single species found at every sample point.

Relative importance is shown for the four most dominant species found across sites, *Rytidosperma spp*. (Wallaby Grass), *Austrostipa spp.* (Spear-grass), *Aristida behriana* (Brush-wire Grass) and *Lomandra multiflora ssp dura* (Hard Mat-rush). *Rytidosperma spp*. scored highly and consistently across all sites, with an average score of 39.8 ± 8.4, but was most dominant at Site 6 (54.61). *Lomandra multiflora ssp. dura* had an average score of 12.2 ± 9.0, but was much more dominant at Site 6 with a score of 27.4. *Aristida behriana* and *Austrostipa spp*. were much more variable across the sites (Figure 12). Figures 9 to 13 demonstrate the role that each of the relative measures plays in regards to the final relative importance score. In 2020 measures were taken for perennial grasses as well as herbaceous species such as *Vittadinia spp.,* some chenopods and other small woody perennials. In future, it is recommended that measurements be restricted to the four perennial grass species listed previously, to increase the robustness of the data, and other common perennial species be surveyed for presence/absence in the 1 x 1 m^2 quadrats to produce a frequency score.

In a dry year you might expect to have a higher average basal width, but lower density due to greater distance from the centre point to the nearest plant. Whereas in good seasons, you might expect the opposite, due to a denser coverage of emergent grasses. Plants such as *Lomandra sp*, which are long lived and slow-growing, should remain relatively stable in basal width, but may be variable in their relative frequency, appearing less in good years due to the presence of numerous other grasses filling in the space close to the PCQM point. Iron-grass is a long lived tussock with deep roots which hold soils together, also acting as a seed trap and providing protection from heavy grazing due to their unpalatability (NRMDB 2019). It is recommended that a frequency score for *Lomandra spp.* presence/absence be added to the 1 x 1 m^2 quadrat sampling method in future years to gain a better understanding of its distribution across each site and provide an accuracy comparison for the PCQM.

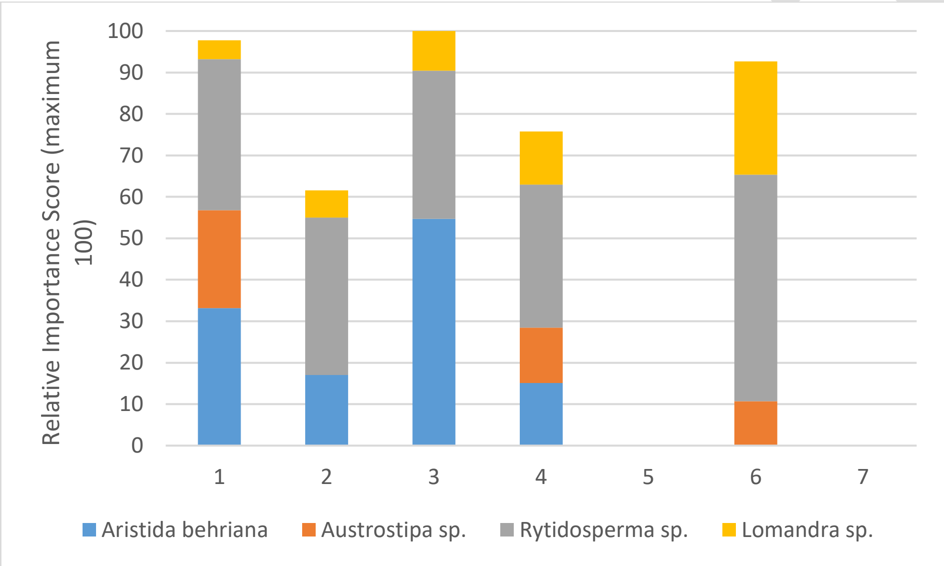

Figure 12. Relative Importance measure of the four most common perennial species across all sites

Site 1

Five species were recorded at Site 1, with the *Rytidosperma spp.* scoring the highest relative importance (36.4). Including only the four perennial grass species listed above, Site 1 had an average tussock density of 14.5 per square metre, and 10.73% basal coverage per hectare.

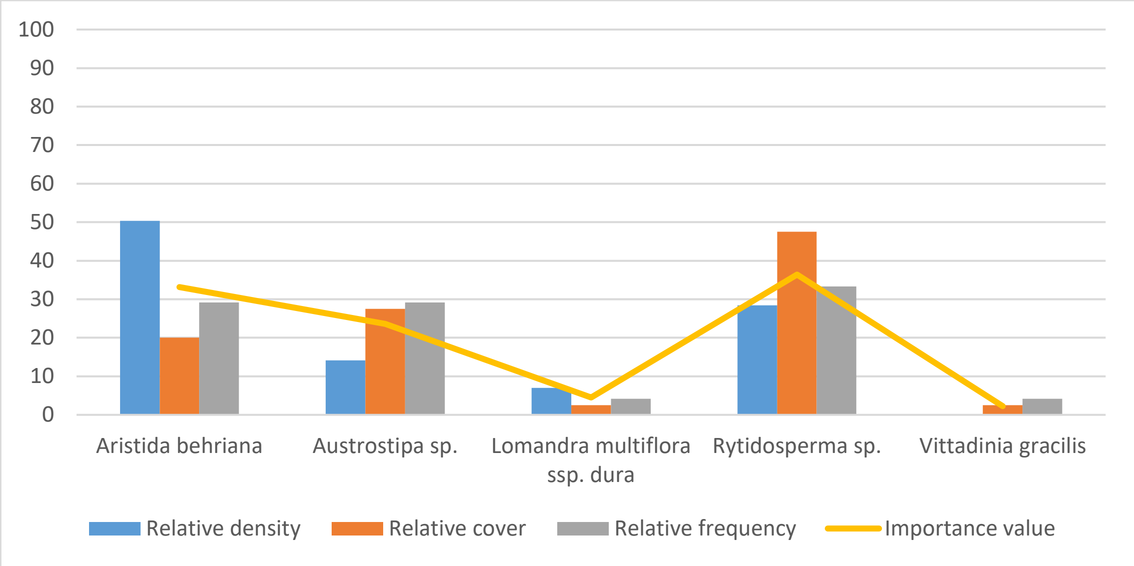

Figure 13. Relative density, cover and frequency of perennial plants recorded using PCQM at Site 1

Site 2

Five species were identified at Site 2, with *Rytidosperma spp.* scoring the highest importance value (37.94). *Scleranthus pungens* (Prickly Knawel) had the highest relative cover (69.85%) due to its low, spreading growth-form, however it was only present at 12.5% of sample points compared to *Rytidosperma spp*. which was present at 60% of sample points. Site 2 had 21.49% basal cover, and was noted to be in good condition, with a diversity of herbaceous species and other lifeforms in the inter-tussock spaces.

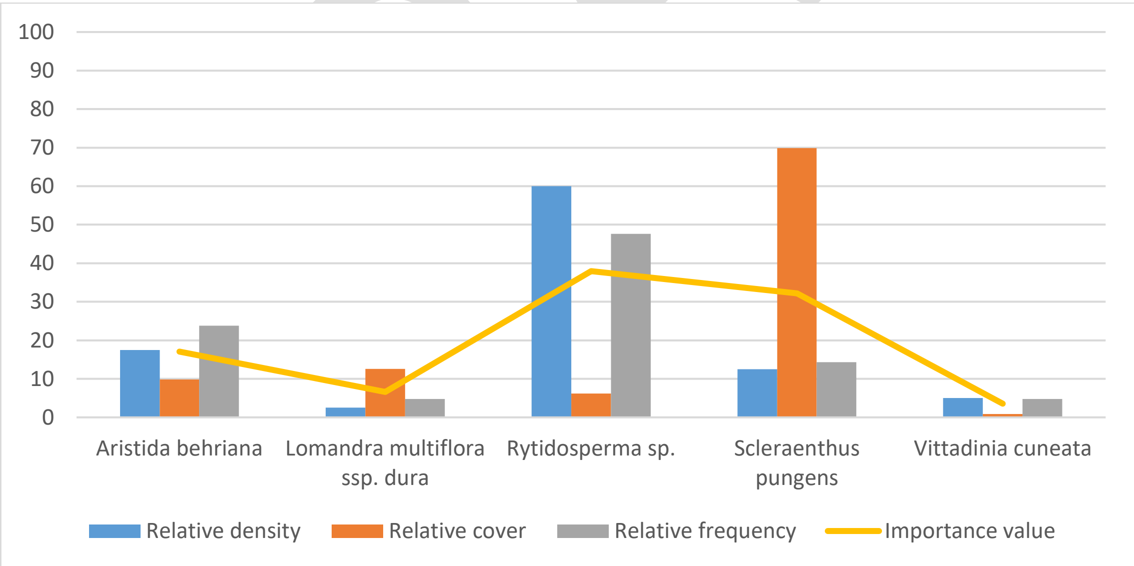

Figure 14. Relative density, cover and frequency of perennial plants recorded using PCQM at Site 2

Site 3

Three species were recorded at Site 3, with *Aristida behriana* (Brush Wire-grass) having the highest relative importance value (54.73) (Figure 15). Though *Rytidosperma spp.* scored almost equally in relative density and relative frequency, it had a much lower relative cover due to the presence of numerous young plants with small basal widths (average 4.04cm). The basal cover was 46.5%, with low tussock, *Aristida behriana* contributing 76.7% of the coverage, with a large average basal width of 17cm. The Site was noted to be in fair condition, with abundant weeds, but otherwise good persistence of herbaceous species such as *Whalenbergia spp.* (Bluebells), *Ptilotus erubescens* (Hairy-tails, SA Rare) and *Arthropodium spp.* (Lily), and regeneration of *Rytidosperma spp.* and *Vittadinia spp.*(Daisy).

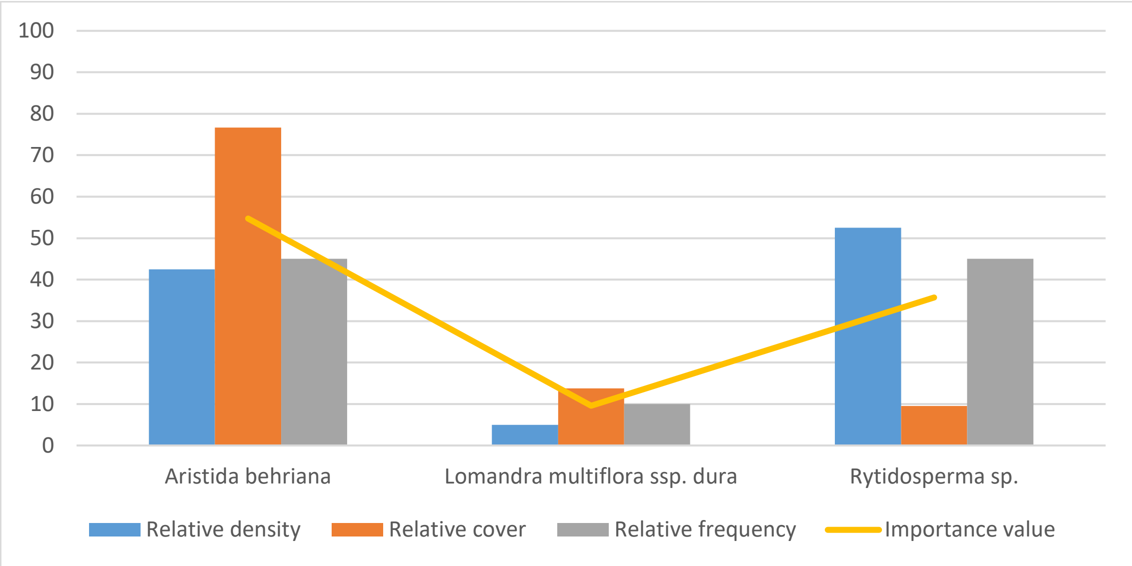

Figure 15. Relative density, cover and frequency of perennial plants recorded using PCQM at Site 3.

Site 4

Site 4 recorded the highest species diversity, with eight perennial species identified in the PCQ survey, with *Rytidosperma spp.* recording the highest relative importance (34.46). Basal cover was low with 7.77%, represented primarily by regenerating *Rytidosperma spp*. with an average basal width of only 3.2 cm. The Site was observed to have a high diversity and good coverage of herbs in the inter-tussock spaces including *Wahlenbergia spp* (Bluebells) and *Asperula conferta* (Common Woodruff).

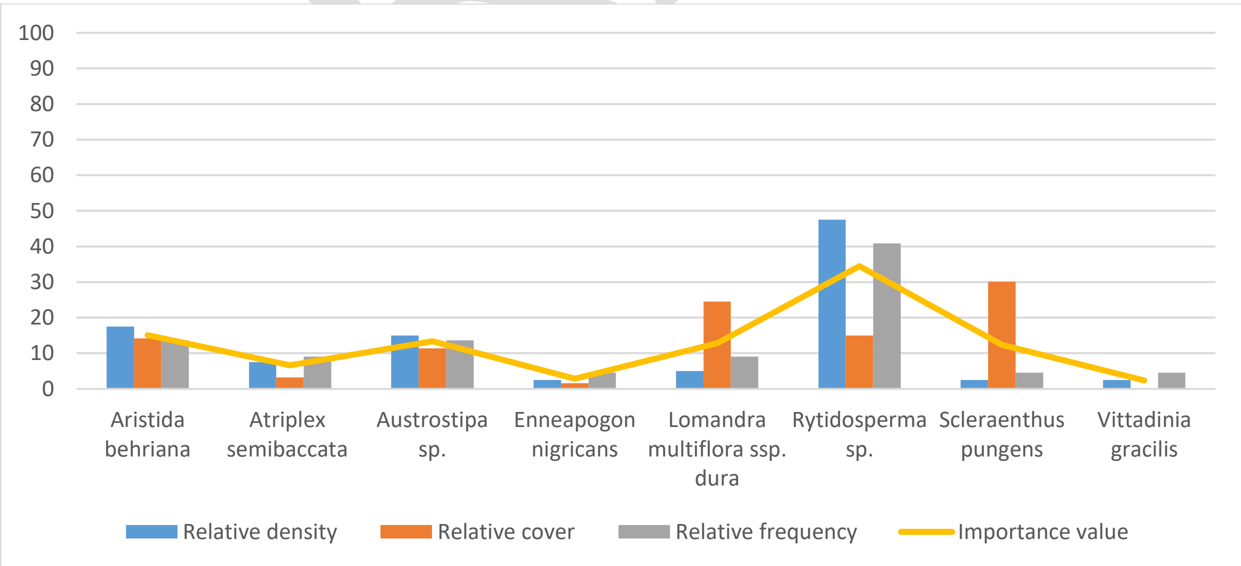

Figure 16. Relative density, cover and frequency of perennial plants recorded using PCQM at Site 4.

Site 5

Not surveyed in 2020. A brief qualitative assessment deemed the Site to be in fair condition, showing reasonable diversity including abundant *Whalenbergia spp.* and some regeneration, but with abundant weeds, in particular *Echium plantagineum* (Salvation Jane), and *Carthamus lanatus* (Saffron Thistle).

Site 6

Five species were recorded at Site 6, with *Rytidosperma spp.* recording the highest relative importance value (54.61) (Figure 16). Basal cover was 13.86%, with vegetation noted to be sparse between *Lomandra spp.* but with an intact cryptogamic crust layer, some regeneration, and the presence of rare species such as *Rumex dumosa* (Wiry Dock).

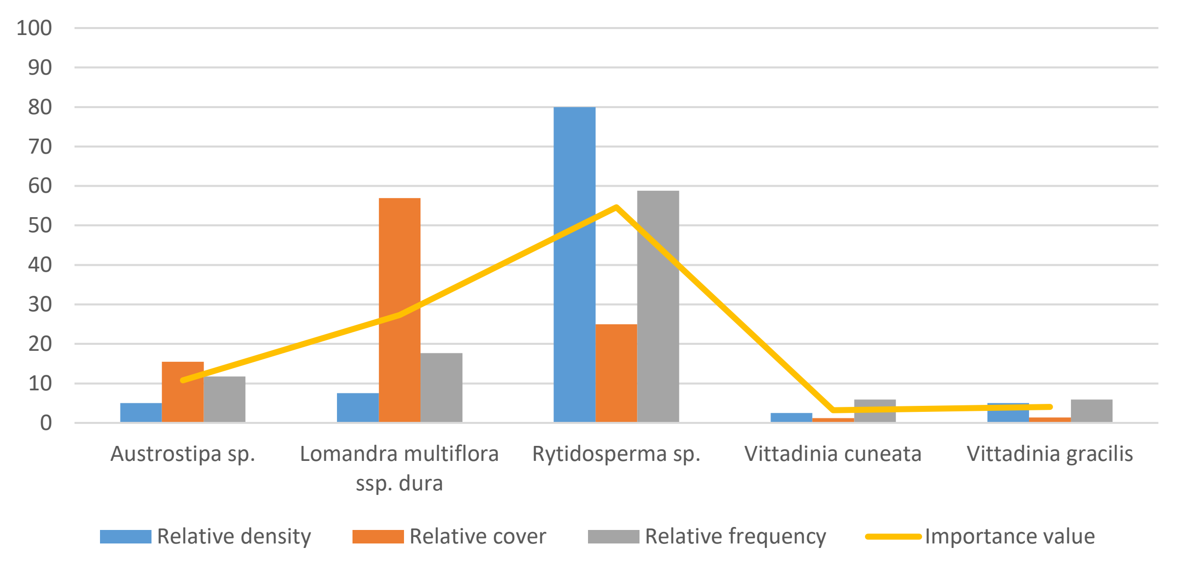

Figure 17. Relative density, cover and frequency of perennial plants recorded using PCQM at Site 6.

Site 7

Not surveyed in 2020. A brief qualitative assessment identified *Austrostipa spp.* as the most abundant native grass, with large *Lomandra multiflora ssp dura* clumps, and few other herbaceous native species present, but with a carpeting of weed *Trifolium angustifolium* (Narrow-leaved Clover).

3.3 EPBC Ramble Survey

Site 1 and Site 7 were not surveyed for native species diversity in 2020 due to COVID-19 forcing early termination of the survey.

A total of 32 native species were observed across the WWF in 2020, a reduction from 41 in 2019, likely due to the supplemental survey effort undertaken in 2019. The five sites assessed were found to be of Condition Class B, including Site 5 which had previously been classified as Condition Class C in the initial assessment (EBS Ecology 2010c). Table 7 summarises the findings at each site in relation to the EPBC Criteria across all years to date, and Table 8 lists the native species and their lifeform for each site.

In 2018, Site 5 and Site 6 were deemed to be in Condition Class C due to extremely dry conditions, however in 2019 and again in 2020 both of these sites matched the EPBC Criteria for Condition Class B.

Table 7. EPBC Criteria by site for each year of the survey since baseline assessment in 2010, EPBC minimum criteria at top of table in red.

Site (Size)	Year	Native species	Non-disturbance resistant herbaceous species	Native Grasses (excluding Lomandra)	Tussocks per m²	Condition
>0.1ha	**-**	**≥30**	**≥10**	**≥5**	**≥1/m²**	**A**
>0.25ha	**-**	**≥15**	**≥3**	**≥4**	**≥1/m²**	**B**
No min.	**-**	**≥5**	**-**	**≥1**	**-**	**C**
Site 1 (>9 ha)	2010	27	12	5		B
	2018	17	5	10		B
	2019	23	10	4		B
	2020	**NA**	**NA**	**NA**	**14.5/m²**	**B***
Site 2 (4.3 ha)	2010	24	13	5		B
	2018	NA	NA	NA		NA
	2019	27	10	5		B
	2020	**25**	**9**	**5**	**12.6/m²**	**B**
Site 3 (1.8 ha)	2010	26	12	4		B
	2018	16	4	5		B
	2019	17	5	3^		C
	2020	**27**	**8**	**7**	**33.4/m²**	**B**
Site 4 (1.8 ha)	2010	22	9	5		B
	2018	17	5	4		B
	2019	21	7	4		B
	2020	**23**	**7**	**5**	**21.6/m²**	**B**
Site 5 (1.8 ha)	2010	13^	4	4		C
	2018	13^	2^	4		C
	2019	22	9	4		B
	2020	**21**	**6**	**4**	**NA**	**B***
Site 6 (2.0 ha)	2010	18	5	4		B
	2018	11^	3	3^		C
	2019	19	6	4		B
	2020	**19**	**4**	**4**	**22.5/m²**	**B**
Site 7 (6.5 ha)	2010	23	8	5		B
	2018	17	4	4		B
	2019	25	11	4		B
	2020	**NA**	**NA**	**NA**	**NA**	**B***

*Condition class estimated without all EPBC criteria values available

^ Value falls short of EPBC Class B listing.

Table 8. Native species recorded at each Lomandra Grassland Monitoring Site in 2020

Lifeform	Scientific Name	Common Name	2	3	4	5	6
Broad-leaf Herb	*Arthropodium strictum*	Common Vanilla Lily		✓		✓	
	Asperela conferta	Common Woodruff	✓	✓	✓	✓	
	Chenopodium desertorum ssp. microphyllum	Small leaved Goosefoot	✓	✓		✓	
	Einadia nutans	Climbing Saltbush	✓				
	*Ptilotus erubescens**	Hairy-tails	✓	✓	✓		
	*Rumex dumosus**	Wiry Dock	✓	✓	✓	✓	✓
	Salsola australis	Rolypoly			✓		

	Unidentified daisy (purple five leaf daisy)	(blank)	✓				
	Vittadinia cuneata var.	Fuzzy New Holland Daisy	✓	✓	✓	✓	✓
	Vittadinia gracilis	Woolly New Holland Daisy	✓	✓	✓		✓
	Wahlenbergia spp.	Native Bluebell	✓	✓	✓	✓	✓
Disturbance Resistant Broad-leaf Herb	*Convolvulus erubescens*	Grassy Bindweed	✓	✓	✓	✓	✓
	Euphorbia drummondii	Caustic Weed		✓			
	Euphorbia drummondii group	Spurge	✓		✓	✓	✓
	Maireana enchylaenoides	Wingless Fissure-plant	✓	✓	✓	✓	✓
	Oxalis perennans	Native Sorrel	✓	✓	✓	✓	✓
	Ptilotus spathulatus	Pussy-tails	✓	✓	✓	✓	✓
	Sida corrugata var.	Corrugated Sida	✓	✓	✓	✓	✓
Grass/Sedge	*Anthosachne scabrus*	Common wheat grass	✓	✓			
	Aristida behriana	Brush Wire-grass	✓	✓	✓	✓	✓
	Austrostipa blackii	Crested Spear-grass		✓			
	Austrostipa spp.	Spear-grass	✓	✓		✓	✓
	Enneapogon nigricans	Black-head Grass	✓	✓	✓	✓	✓
	Juncus sp.	(blank)		✓	✓		
	Lomandra multiflora ssp. dura	Hard Mat-rush	✓	✓	✓	✓	✓
	Rytidosperma spp.	Wallaby-grass	✓	✓	✓	✓	✓
Shrub	*Atriplex semibaccata*	Berry Saltbush		✓	✓	✓	✓
	Bursaria spinosa	Sweet Bursaria			✓		
	*Cryptandra amara ssp. longifolia**	Long-flower Cryptandra	✓	✓	✓	✓	✓
	Eutaxia microphylla	Common Eutaxia	✓	✓	✓	✓	
	Maireana aphylla	Cotton-bush	✓	✓			✓
	Scleranthus pungens	Prickly Knawel	✓	✓	✓	✓	✓

*NPW Act 1972 SA Rare species

3.3.1 Rare Plants

Three SA Rare species, under Schedule 9 of the National Parks and Wildlife Act 1972 (NPW Act), continued to be identified across the WWF LGM sites (Table 9). No new rare species were detected in 2020.

Ptilotus erubescens (Hairy-tails) was detected at three sites in 2020, including two sites at which it had not previously been detected at (Site 2 and Site 4), but was not detected at Sites 1, 5 or 7 where it had previously been detected. As it is a small and inconspicuous plant, especially when not in flower, it is likely that individuals were present on site but simply not detected.

Rumex dumosus (Wiry Dock) was detected at all surveyed sites in 2020, and was observed in both its winter (green), and summer tumbleweed (red, dried) forms (Figure 18).

Figure 18. *Rumex dumosus* (Wiry-dock) in its dried tumbleweed form (left), and winter form (right).

Cryptandra specimens had been observed at several sites previously, but were unable to be identified to species due to heavy grazing and absence of flowers. Based on previous records (EBS Ecology 2010), and location, it is likely that these specimens are a rare species *Cryptandra campanulata* (Long-flowered Cyrptandra) (previously named *Cryptandra amara*). In 2020 specimens were identified at five sites, including two new sites, however they remained in poor condition and were unable to be positively identified to species.

Table 9. Rare flora observed at the WWF within 50x50m ramble quadrats in 2020, and previous years.

Species	Common Name	SA	WWF Site number and number of individuals present in 50m x 50m							
			Year	1	2	3	4	5	6	7
Cryptandra campanulata (?)	Bitter Cryptandra	R (?)	2018	✓					✓	✓
			2019	✓	✓		✓		✓	✓
			2020	-	✓	✓	✓	✓	✓	-
Ptilotus erubescens	Hairy-tails	R	2018			✓				
			2019	✓		✓		✓		✓
			2020	-	✓	✓	✓			-
Rumex dumosus	Wiry Dock	R	2018	✓		✓	✓		✓	✓
			2019	✓	✓	✓	✓	✓	✓	✓
			2020	-	✓	✓	✓	✓	✓	-

3.4 Grassland Health Indicators

Following on from methods introduced in 2019, in 2020 a range of grassland health indicators were collected while undertaking 1 x 1 m^2 quadrats (for the 2020 Weed Assessment) along the established 50m transects at each site. A summary of the percentage cover recorded for each life form is presented in Figure 19, and described in detail for each lifeform below.

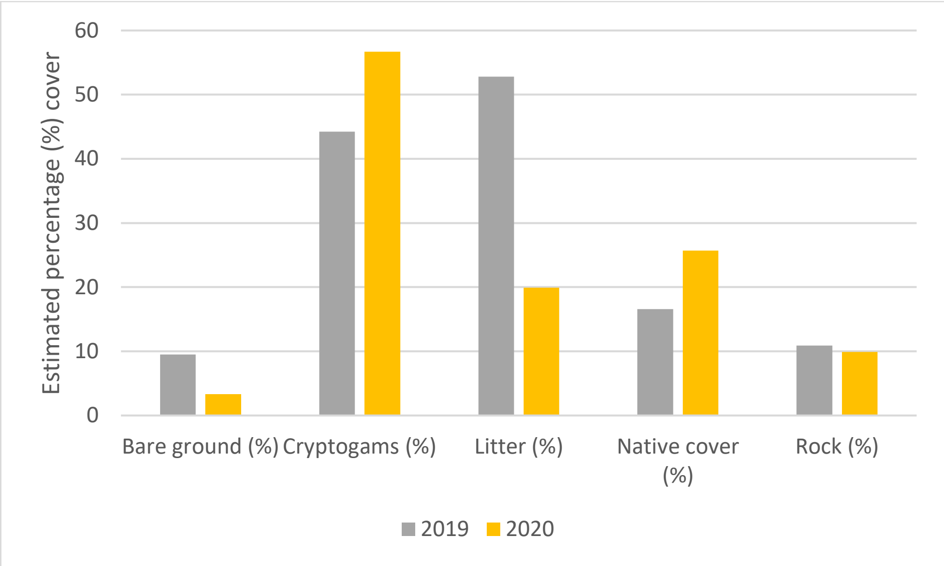

Figure 19. Annual comparison of average (percentage) lifeform cover in 1 x 1 ^{m2} quadrats at assessment sites

3.4.1 Bare Ground, erosion and sedimentation

Bare soil surface refers to soil surface that is not adequately protected by vegetation or litter against accelerated erosion. In grasslands, small bare areas occur naturally in a well-dispersed mosaic with the vegetation, in which cases grasses, litter and cryptogamic crust species such as moss and lichen will provide a degree of protection, binding the soil and protecting it from erosion. In cases where grazing is too heavy this balance may be disturbed, loosening the surface of the soil and exacerbating erosion caused by wind or runoff. At WWF erosion was identified as a possible impact to the Iron-grass NTG, caused by increased wind erosion and potential runoff from bare soils around the WTG hard-stands.

The average percentage of bare ground has significantly decreased from 9.5% in 2019 when it was first surveyed, to 3.34% in 2020 (Figure 20). Site 1 had the highest percentage of bare ground at 8.5%. Given only two years of data, it is too early to identify this as improvement, and is more likely due to an increase in plant cover reducing the amount of bare soil exposed.

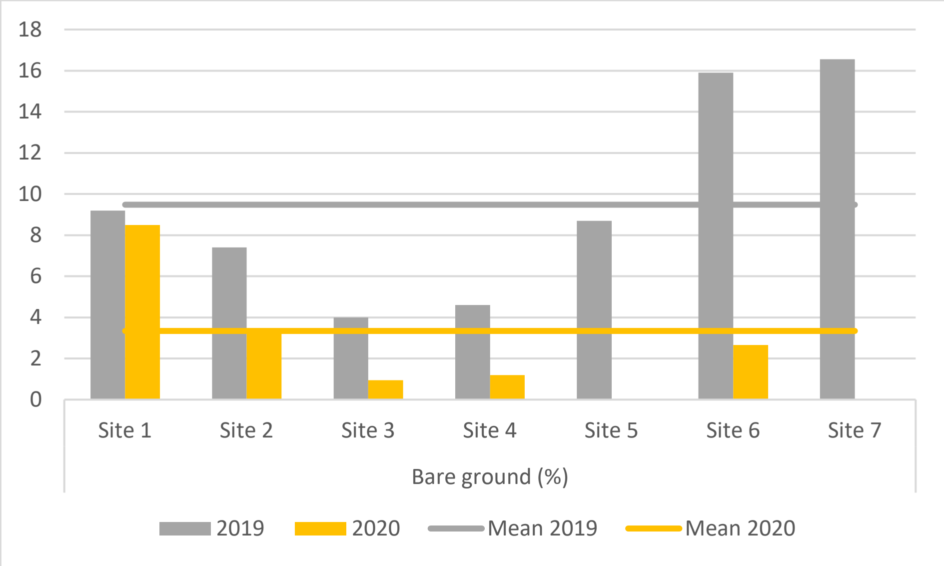

Figure 20. Annual comparison of percent bare ground in 1 x 1 ^{m2} quadrats at assessment sites

3.4.2 Cryptogamic crust

Cyptogamic crust averaged 44.26% in 2019 and 56.7% in 2020, in line with the BAMM NAYP benchmark for this community, signifying a healthy inter-tussock space (Figure 21). A significantly lower cover was recorded at Site 1 (24%), consistent with 2019 (11.3%).

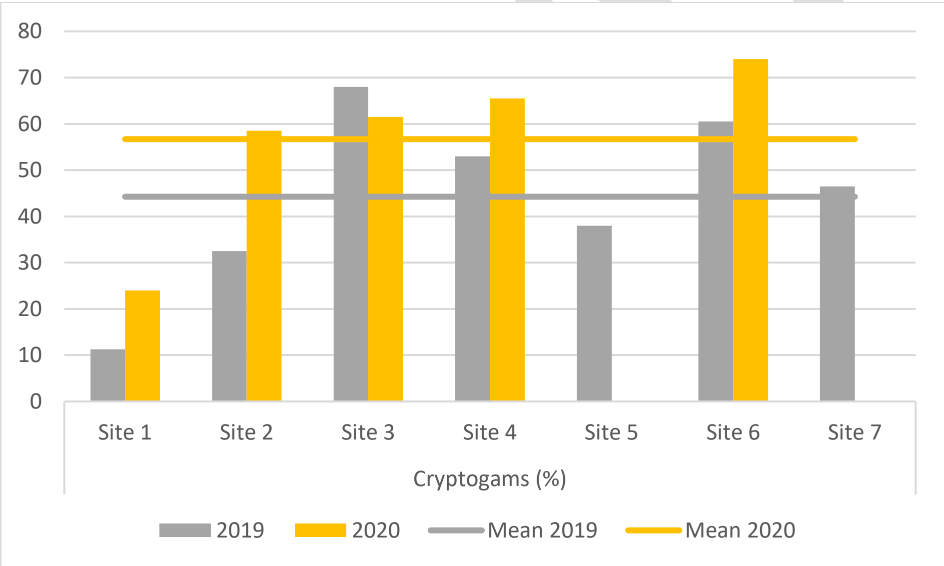

Figure 21. Annual comparison of percent cryptogamic cover (lichen and moss) in 1 x 1 ^{m2} quadrats at assessment sites

3.4.3 Litter (including exotic grasses)

Litter cover decreased between 2019 and 2020 with 52.8% in 2019 compared to 19.2% litter in 2020 (Figure 22). This is likely due to a poor definition and/or understanding of litter in the sense of including live and dead exotic annual vegetation as a measure of predicted coverage on the ground after drying off, which might reduce seedling recruitment. In future it is recommended that this definition be clearly amended to include an estimation of all annual exotic plant material (dead or alive) and dry debris as a measure of residual dry biomass.

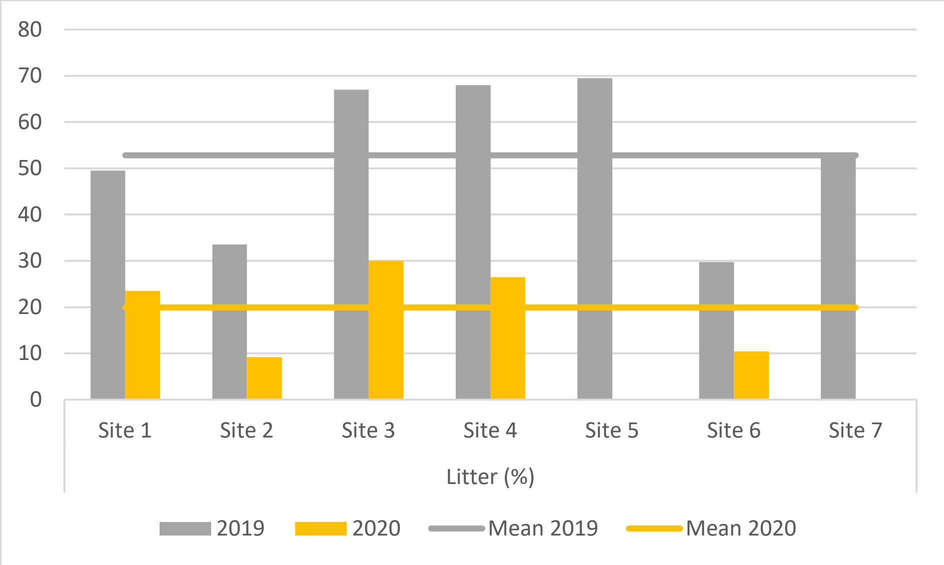

Figure 22. Annual comparison of percent litter cover (including exotic grasses) in 1 x 1 m² quadrats at assessment sites.

3.4.4 Native cover – all species

Percent native cover increased from 16.56% in 2019 to 25.7% in 2020 (Figure 23) consistent with above average rainfall leading to increased native and weedy growth across the region. The largest difference was observed at Site 6 which had 26.5% native cover in 2020 compared to only 10.9% in 2019. Similarly Site 2 had 29% cover in 2020 and only 13.7% cover in 2019.

As a comparison of methods, basal cover from the PCQM method was plotted with estimated native foliage cover in the 1 x 1 m² and showed a close relationship (Figure 24). On average, the projected foliage cover was 27.85% larger than the basal coverage. When excluding the basal width outlier of Site 3, the projected foliage cover was 45.6% higher than the basal coverage, or a canopy: basal width ratio of 1:0.55. A sustained decrease in this proportion overtime might indicate reducing health of native cover caused by impacts such as die-back or heavy grazing, but year to year this proportion may fluctuate based on seasonal conditions.

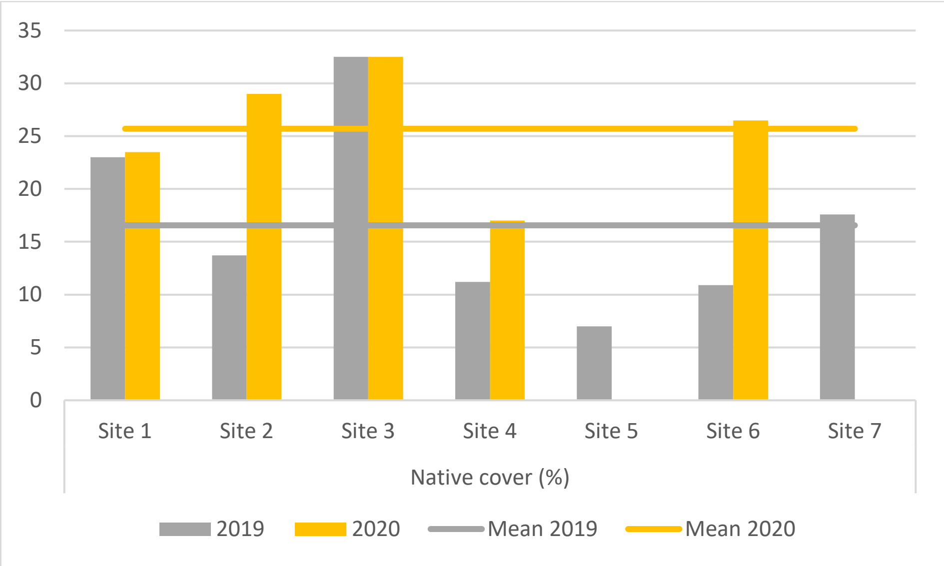

Figure 23. Annual comparison of percent native cover in 1 x 1 m^2 quadrats at assessment sites

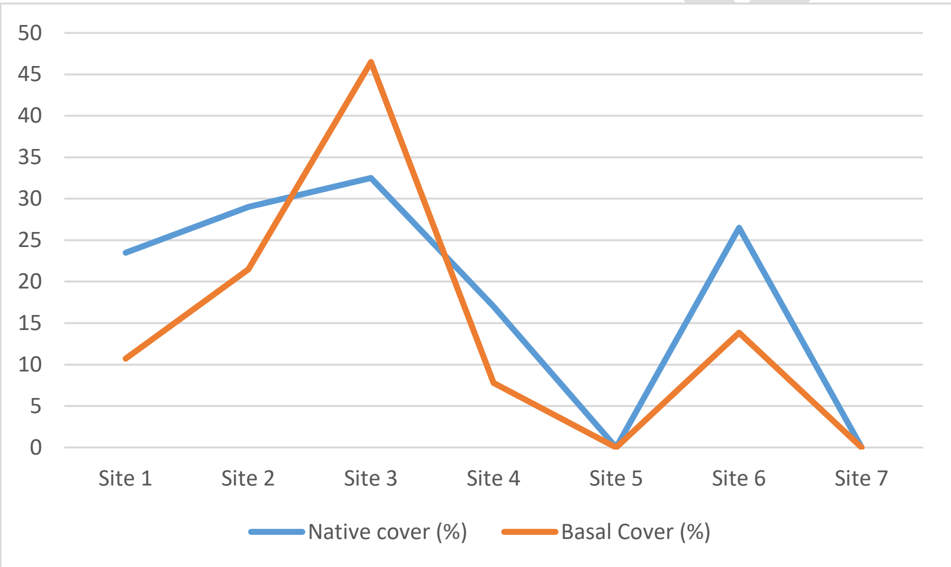

Figure 24. Native cover percentage (1 x 1 m^2 quadrat) compared to percent basal cover (PCQM)

3.4.5 Rock

In 2019, Site 1 was not surveyed for percentage rock cover and so the 2020 survey results provide the baseline. Rock cover is not anticipated to show much change over the life of the windfarm, but is useful as an observer comparison, to indicate if there are inconsistencies with the method. Mean native cover remained similar between years, averaging 10.9% in 2019 and 9.89% in 2020.

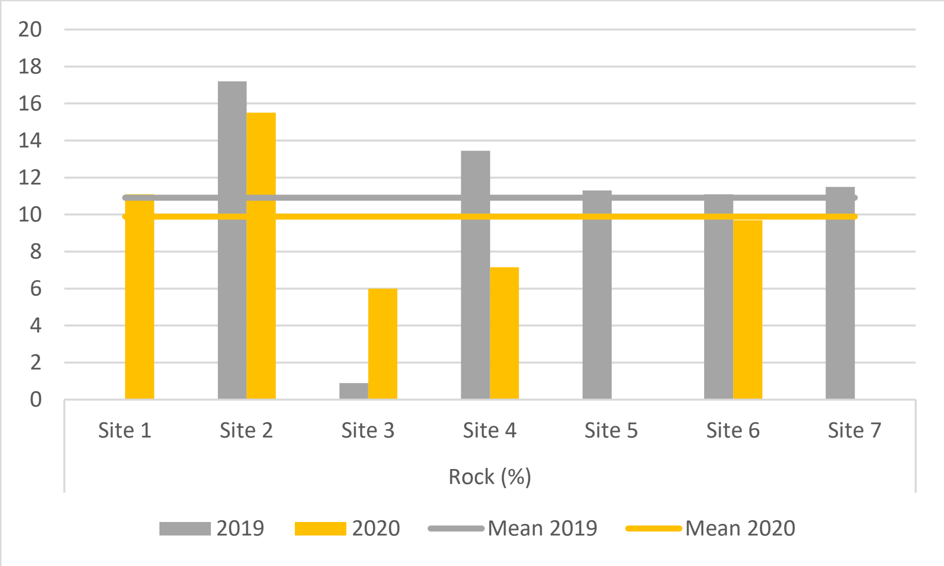

Figure 25. Annual comparison of percent rock cover in 1 x 1 m^2 quadrats at assessment sites

DISCUSSION

Native grasslands are naturally-occurring areas that have few or no trees and few shrubs (<10%), and are dominated by native grass tussocks and a diversity of annual and perennial herbs (DAWE 2008). In South Australia, Iron-grass Natural Temperate Grasslands are unique ecological communities in which Iron-grass (*Lomandra ssp. multiflora spp dura and L. effusa)* forms a characteristic and dominant component of the vegetation, commonly occurring with native perennial grasses and other herbaceous species (Turner 2012).

Iron-grass NTG TEC's fit into the framework of the Northern Agricultural Community 3.2 Grasslands (NAYP BAMM), which provides benchmark scores for various attributes which indicate if an ecosystem is healthy or otherwise (Table 10).

Table 10. Summary of percentage cover of lifeform attributes and relevant indicator scores and condition ratings measured at LGM Sites at WWF, benchmark scores from Northern Agricultural Community 3.2 Grasslands, adapted from NAYP BAMM V3 (Pedler *et al.* 2007)

Lifeform	Percentage (%) cover or score of each attribute seven Iron-grass NTG Assessment Sites							Annual Average		Benchmark
	1	2	3	4	5	6	7	2020	2019	
Bare ground (%)	8.5	3.4	0.95	1.2	-	2.65	-	**3.34**	**9.48**	**~5%**
Cryptograms (%)	24	58.5	61.5	65.5	-	74	-	**56.70**	**44.26**	**up to 50%**
Litter (%)	23.5	9.2	30	26.5	-	10.4	-	**19.92**	**52.81**	**> 25%**
Native cover (%)	23.5	29	32.5	17	-	26.5	-	**25.70**	**16.56**	**NA**
Rock (%)	11.1	15.4	6	7.15	-	9.7	-	**9.89**	**10.91**	**NA**
Grass basal cover per hectare (%) PCQM	10.7	6.28	46.48	5.18	-	13.49		**16.5**	**NA**	**5-15%**
Species diversity EPBC Ramble	-	25	27	23	21	19	-	**23**	**22**	1-3 (Very Poor) 4-7 (Poor) 8-14 (Moderate) 15-20 (Good) 21+ (Excellent)

Species diversity is important because it creates adaptability and resilience within a grassland, where some species are adapted for dry conditions and others for wet, some grow in summer and others in winter, some are short lived and others slow growing. The diversity means that at all times of the year there should be something growing, providing live functioning roots year round to provide a more resilient and erosion resistant ecosystem and reducing problems such as dust storms. A complex root system in turn creates a diverse soil ecosystem, which improves nutrient cycling and water holding capacity (NRMDB, 2019).

In the 2020 LGM survey, four of the sites surveyed (2, 3, 4 and 5) had 21 or more native species within a 50 x 50 m plot, representing what would be a 'good' to 'excellent' condition score given that NAYP scores are based on a 30 x 30 m plot. Site 6 had 19 species, representing a 'moderate' to 'good' score, while Sites 1 and 7 were not surveyed to completion. Interestingly, species diversity remained very similar to the previous year despite considerably different seasonal conditions, but was much higher than in 2018 (average species diversity 15.17), presumably due to increased survey effort introduced in the 2019 survey.

Furthermore, the NAYP BAMM states that a grassland in good condition can have perennial native grass coverage of up to 50%, with tall tussocks accounting for around 5% and low tussocks representing 5-10% cover. Basal cover, calculated from PCQM data, was highly variable across the sites ranging from 7.8% at Site 4 to 46.5% at Site 3, with an average of 20%, but all sites were within the healthy grassland range.

An important feature of these grassland communities is the inter-tussock space between grasses, which in a healthy ecosystem is covered with a cryptogamic crust consisting of moss and lichen, and supports a diversity of herbaceous plants. The structure of these grasslands create an important ecological niche, with the grass tussocks providing filtration of water runoff for erosion control, and the cryptogamic crust holding the surface soil in place and providing seed collection and open feeding grounds for grassland fauna. Cryptogamic crust was observed across all sites at slightly higher average cover (56.7%) than the benchmark community of 50%, indicating a healthy inter-tussock space. Crust had increased since 2019 when it was first surveyed, likely due to higher visibility related to the more favourable conditions.

Broad-leaved herbs and twiners/vines (eg. *Convolvulus spp.* [Bindweed] and *Arthropodium spp.* [Lily]) should occur in the spaces between the grasses and tussocks, but many of these are annual or only seasonally evident, and together may contribute up to 30% cover. While no direct measure of the cover of these lifeforms was recorded at LGM Sites, a diversity of these species were present at all sites, and in high enough numbers to meet Condition Class B for EPBC TEC listing (refer back to Table 8).

Grassland health indicators from the 2020 LGM survey indicate a healthy functioning Iron-grass NTG TEC at all sites, with no observable impact from construction or operation of WWF. The primary threat to the health of the seven patches of Iron-grass NTG at WWF remains as weed invasion, which is reported in detail in the *Willogoleche Wind Farm Weed Assessment* (2020a – in review). In the Northern Agricultural and Yorke Region, and in grasslands across Australia, weed invasion is a widespread issue, with weeds accounting for more than 19% of the plant species present in Iron-grass NTG (Beeton 2007), in line with the average exotic litter cover score of 19.92% recorded in 2020. The future stability of the seven patches of Iron-grass NTG at WWF rely on ongoing weed maintenance along roadside verges and hard-stand areas, to prevent the gradual encroachment of weeds into the grasslands.

4 CONCLUSION AND RECOMMENDATIONS

The seven patches of Iron-grass NTG remain in a stable condition, and are not currently being negatively impacted by the operation of WWF. It is evident that many observed changes between years, such as species diversity, weed and native cover, and plants per hectare are not necessarily indicative of long term trends, but rather, are attributable to seasonal variation. As such, the following recommendations pertain to maintaining the health of the seven patches of Iron-grass NTG at WWF, and improving survey methodology to be able to determine non-seasonal variation.

4.1 Recommendations

4.1.1 Monitoring methodology

Repeat annual monitoring

- Measure distance to nearest plant using PCQM (40 plants);
- Measure metrics of 40 perennial plants including basal width, height, percentage dead material;
- Continue to measure the percentage cover of bare ground, litter, cryptogams and native cover;
- Continue to undertake ramble assessment of species diversity each year
- Continue to search for threatened flora at LGM Sites; and
- Continue to undertake weed assessment

Amendments and recommendations to 2020 methodology for future years

- Define list of species to record in PCQM (ie dominant perennial grasses such as *Rytidosperma spp., Austrostipa spp., Aristida behriana, Lomandra multiflora ssp. dura*);
- Continue to report 'Importance Value' based on the basal width, frequency and dominance of perennial grasses measured using PCQM (in place of plant volume and canopy cover which is deemed more relevant when using PCQM for woodland sites);
- Calibrate accuracy of PCQM PPH metric by counting all tussocks in quadrats at a selection of sites.
- Add an assessment of presence/absence of selected perennial native species including *Lomandra spp.* in 1 x 1 m^2 quadrats to gain a better understanding of density of native species and plant lifeforms (eg. shrubs, tussocks, herbs, vines/twiners, geophytes); and

4.1.2 Other recommendations

- As per the OEMP, continue to conduct an annual Iron-grass NTG TEC monitoring survey annually during the first five years of operation of the wind farm to determine whether operation of the wind farm causes and impacts to the Iron-grass NTG, and consider continuing this assessment on a 3-5 year schedule thereafter;

- Undertake weed management actions as outlined in the WWF Weed Assessment 2020 (EBS 2020b), to ensure that weed spread is detected and addressed swiftly, as this is considered the main threat to Iron-grass NTG attributable to the operation of WWF, in particular;
    - Engage landholders to undertake best practice weed control (grazing, slashing, spraying, physical removal) at WWF.
    - Continue low-level sheep grazing in winter months, as outlined in the OEMP, to ensure inter-tussock spaces are kept open for the recruitment of broad-leaved herbs.
    - Consider addition of several new weed monitoring transects to track the rate of encroachment of weeds from roadsides into the grasslands, to be used as an early trigger warning. Currently weed monitoring at sites tracks mostly seasonal variation and aids in detection of new species, however as weeds are likely to invade from disturbed areas, their encroachment may not be detected until they have already entered the Iron-grass NTG sites. Addition of new sites may enable annual weed monitoring effort at Assessment Sites to be undertaken less frequently.
- Ensure any management actions (including weed management chemical/ physical/ grazing) undertaken by ENGIE and/or landholders are communicated and documented to enable long term annual monitoring observations to be correlated with land management.
- Undertake ongoing evaluation of monitoring techniques to supplement or amend the current methodology and consider a major overall review after five years (2022-2023).

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6 APPENDICES

Appendix 1: Weed Assessment Site location maps.

(Refer to the following pages.)

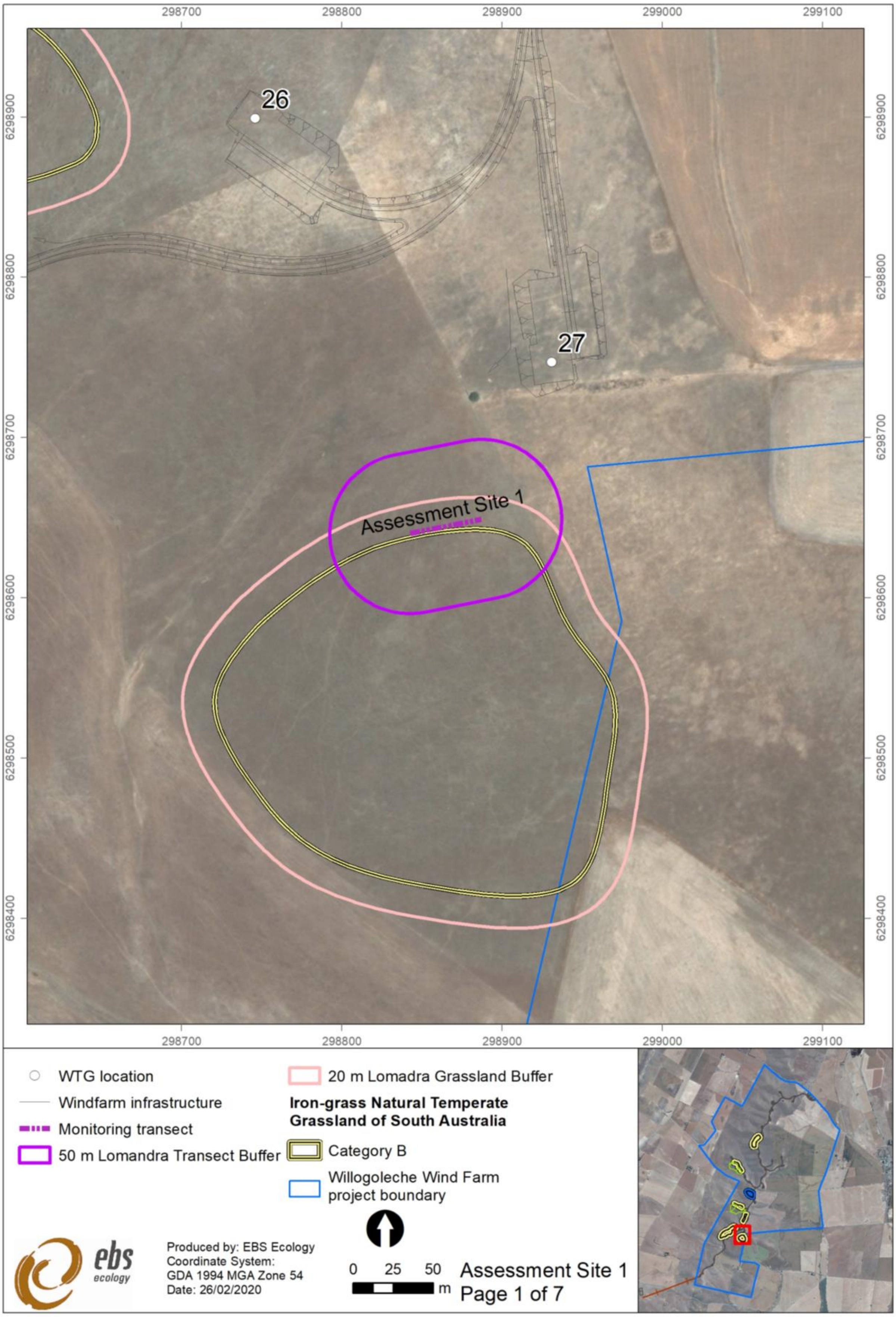

Figure 26. Weed Assessment Site 1

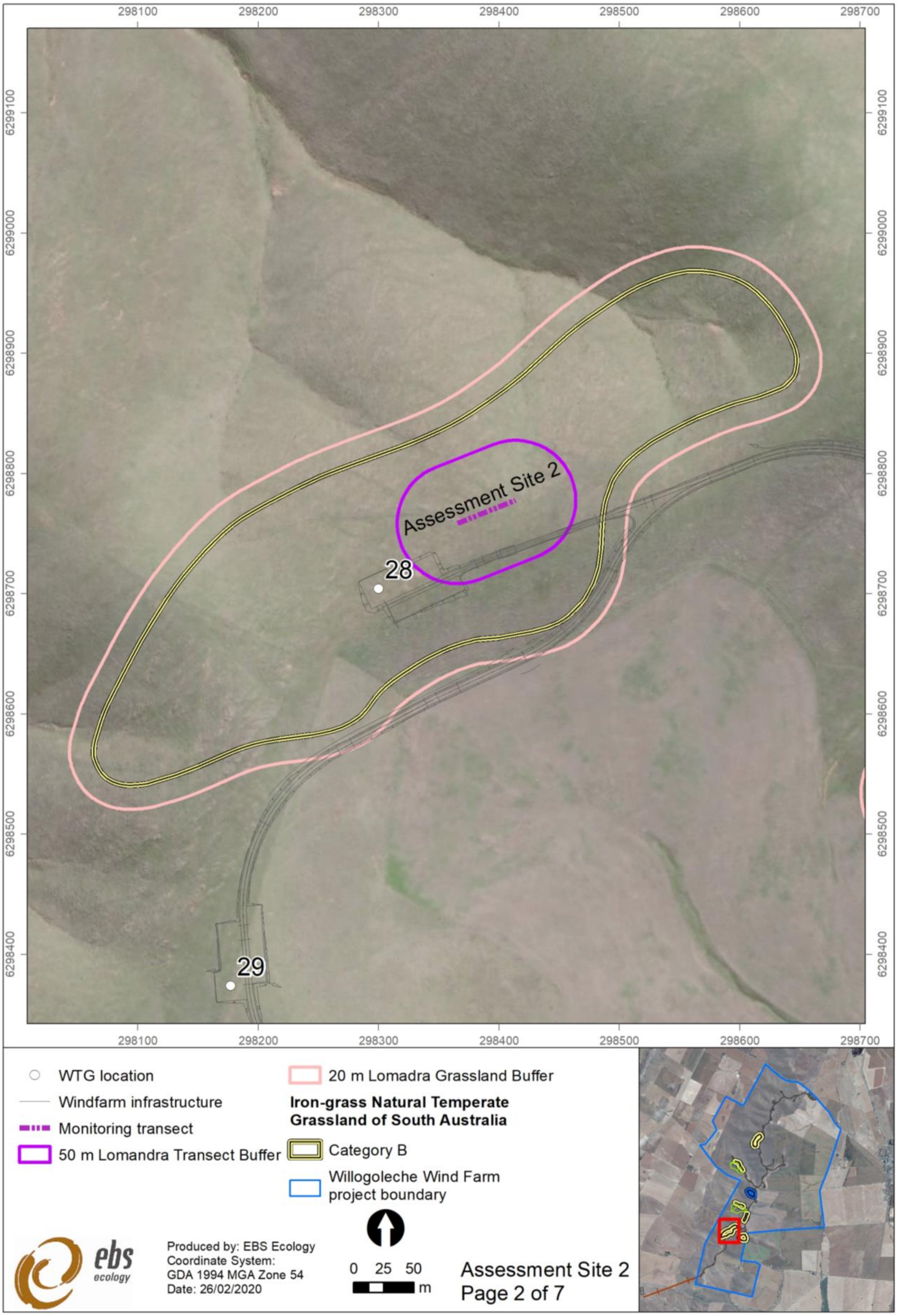

Figure 27. Weed Assessment Site 2

Figure 28. Weed Assessment Site 3

Figure 29. Weed Assessment Site 4

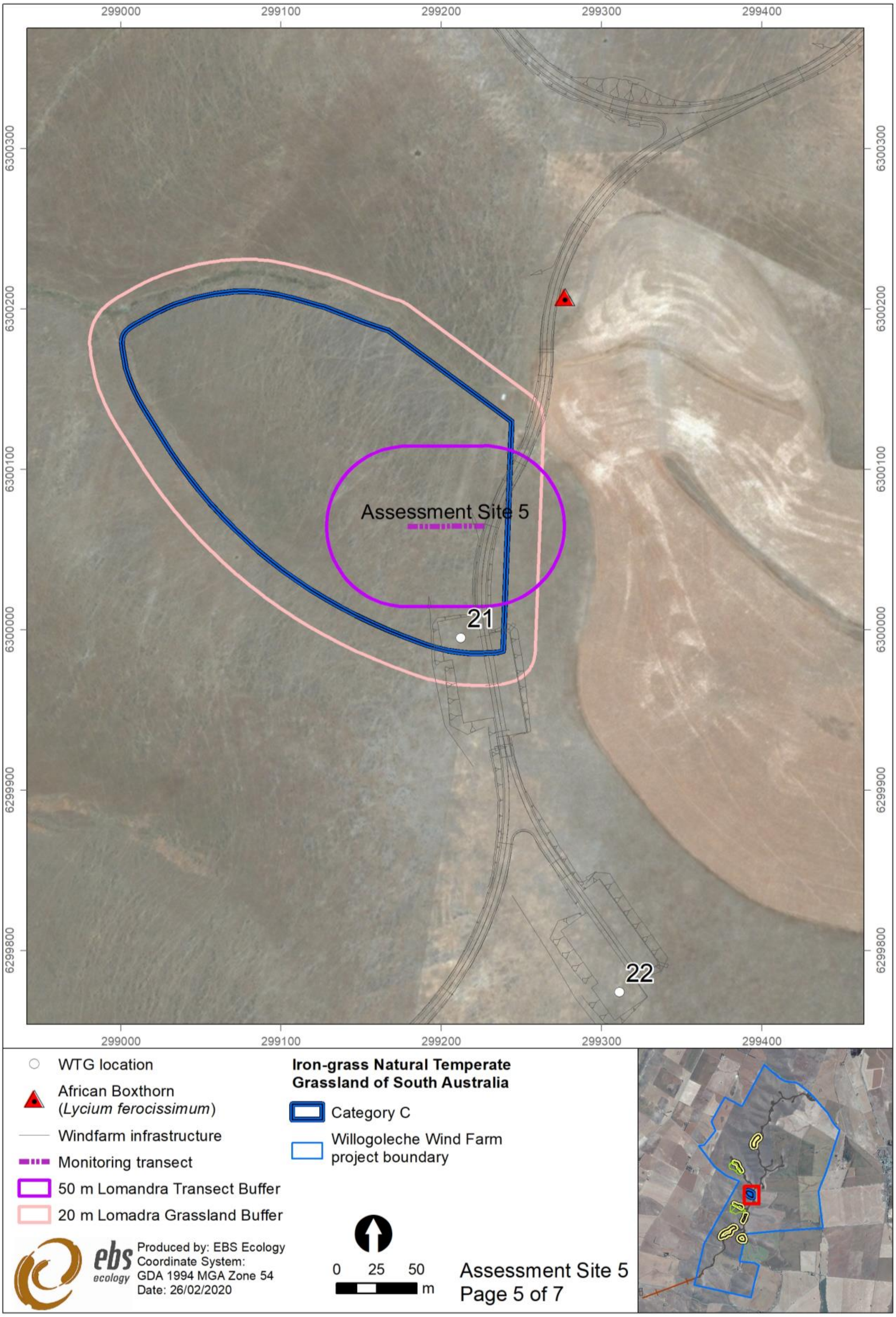

Figure 30. Weed Assessment Site 5

Figure 31. Weed Assessment Site 6

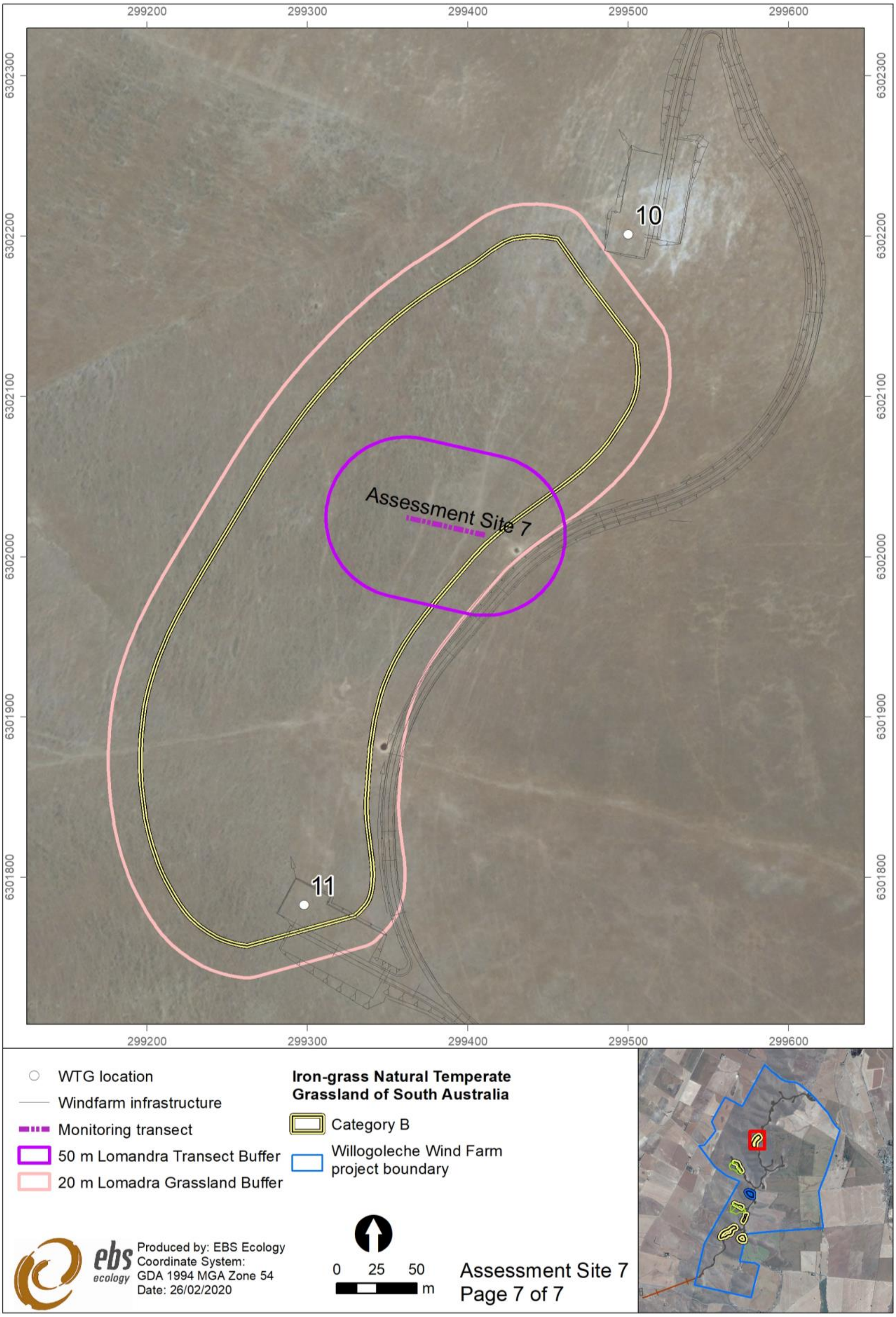

Figure 32. Weed Assessment Site 7.

Appendix 2: Weed Assessment Site Photographs

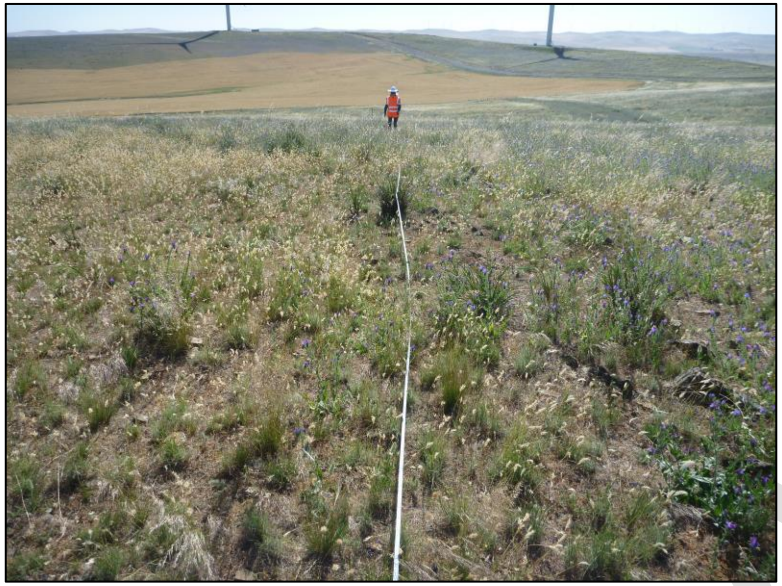

Figure 33. Site 1 2020 (Start, east looking west)

Figure 34. Site 1 2020 (End, west looking east)

Figure 35. Site 1 2019 (Start, east looking west)

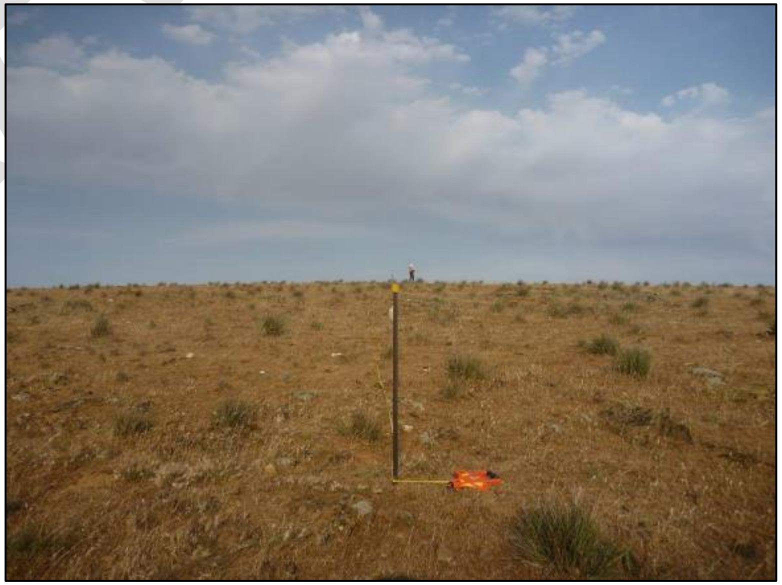

Figure 36. Site 1 2019 (End, west looking east)

Figure 37. Site 2 2020 (Start, east looking west)

Figure 38. Site 2 2020 (End, west looking east)

Figure 39. Site 2 2019 (Start, east looking west)

Figure 40. Site 2 2019 (End, west looking east)

Figure 41. Site 3 2020 (Start, east looking west)

Figure 42. Site 3 2020 (End, west looking east)

Figure 43. Site 3 2019 (Start, east looking west)

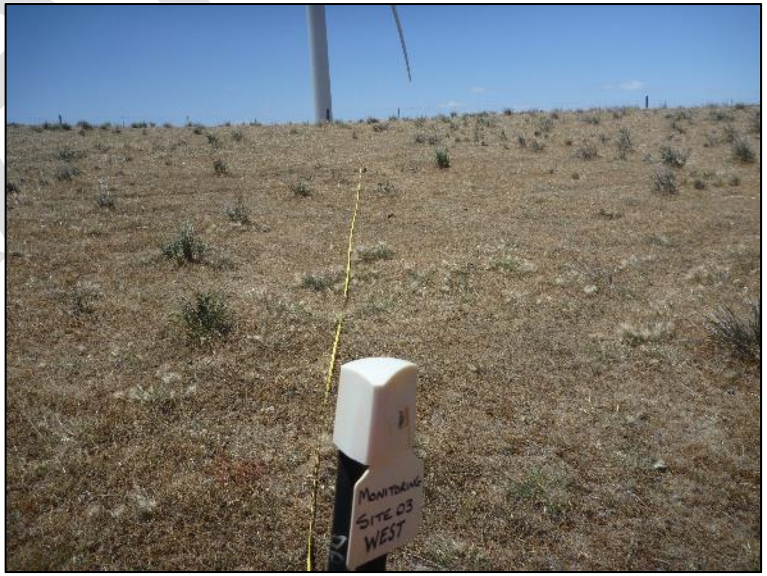

Figure 44. Site 3 2019 (End, west looking east)

Figure 45. Site 4 2020 (Start, east looking west)

Figure 46. Site 4 2020 (End, west looing east)

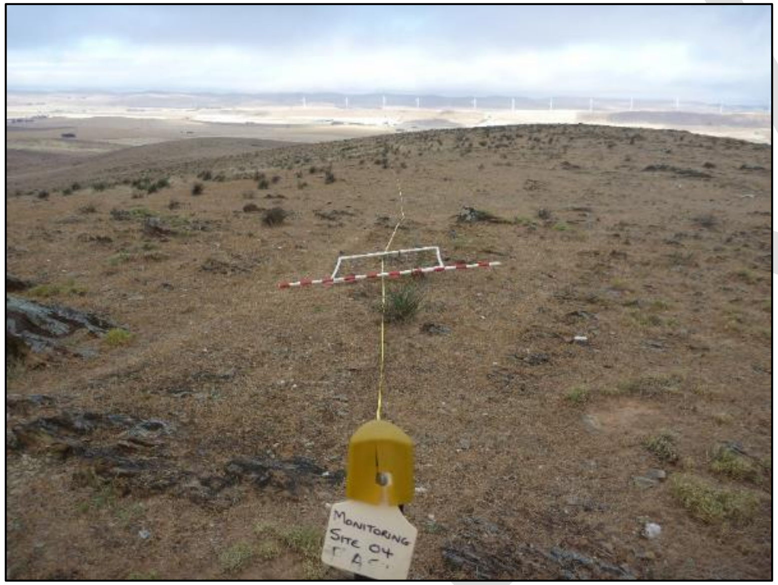

Figure 47. Site 4 2019 (Start, east looking west)

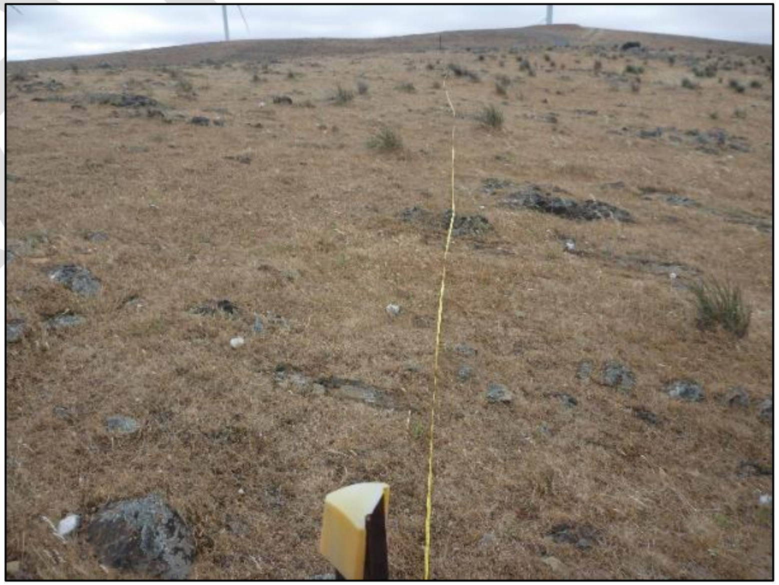

Figure 48. Site 4 2019 (End, west looking east)

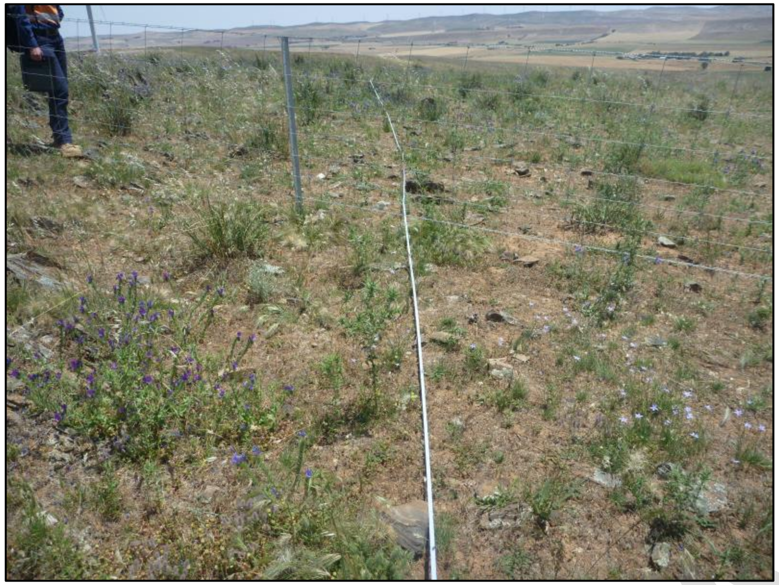

Figure 49. Site 5 2020 (Start, east looking west)

Figure 50. Site 5 2020 (End, west looking east)

Figure 51. Site 5 2019 (Start, east looking west)

Figure 52. Site 5 2019 (End, west looking east)

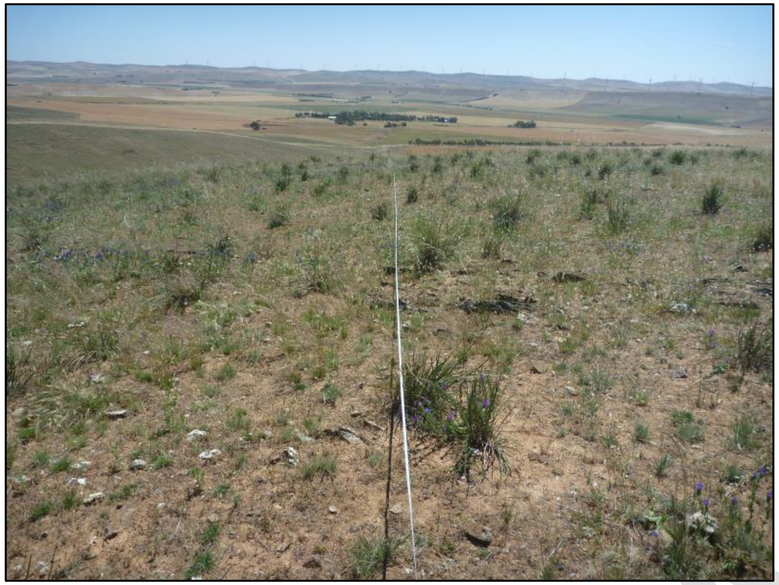

Figure 53. Site 6 2020 (Start, east looking west)

Figure 54. Site 6 2020 (End, west looking east)

Figure 55. Site 6 2019 (Start, east looking west)

Figure 56. Site 6 2019 (End, west looking east)

Figure 57. Site 7 2020 (Start, east looking west)

Figure 58. Site 7 2020 (End, west looking east)

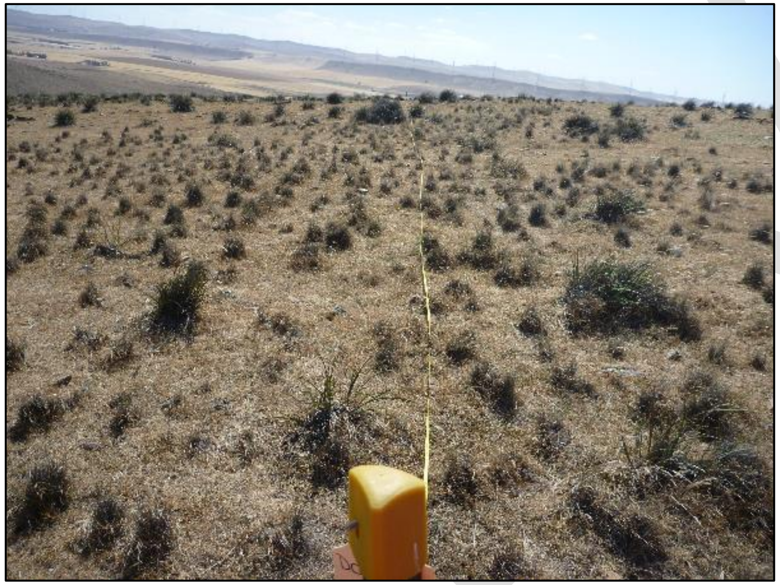

Figure 59. Site 7 2019 (Start, east looking west)

Figure 60. Site 7 2019 (End, west looking east)

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