



Mattiske Consulting Pty Ltd

MATTISKE CONSULTING PTY LTD
(ACN 063 507 175) (ABN 39 063 507 175)
PO Box 437
KALAMUNDA WA 6076
AUSTRALIA
Tel: +61 08 9257 1625
Email: libby@mattiske.com.au

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Review of Rehabilitation Performance Against Completion Criteria Introduction

Mattiske Consulting Pty Ltd has been commissioned by South32 Worsley Alumina Pty Ltd (Worsley) to complete a summary report of the last 3 years of rehabilitation monitoring against the current draft Completion Criteria (as submitted to the Department of Biodiversity Conservation and Attractions (DBCA)). The draft completion criteria have undergone a third-party review by Stantec (2021) to assess their conformance with the WA Biodiversity Science Institute (WABSI) Completion Criteria Framework, as endorsed by the WA Department of Mines, Industry Regulation and Safety (DMIRS) (Young et al., 2019). The review made several recommended changes which were incorporated into the draft completion criteria prior to submission. Worsley subsequently requested that the annual rehabilitation monitoring program conducted by Mattiske Consulting Pty Ltd be adjusted to specifically address the requirements of the draft completion criteria. Prior to the assessment of the draft completion criteria against the WABSI Framework, Worsley also commissioned a separate independent review by Astron (2017) to undertake a review of the rehabilitation monitoring program implemented at Worsley. This assessment suggested several changes to the monitoring regime which were implemented as a result of the review.

Mattiske Consulting Pty Ltd has to date completed annual monitoring of 1, 5, 10, 20 and 30 year old rehabilitation over three annual monitoring periods to assess the flora and vegetation in rehabilitation against the draft Completion Criteria. This has included rehabilitation from the following years: 1990-1992 (age 30 years), 2000-2002 (age 20 years), 2010-2012 (age 10 years), 2015-2017 (age 5 years) and 2019-2021 (age 1 year). The full results from these monitoring efforts are presented in Mattiske (2023), Mattiske (2022) and Mattiske (2021).

Methods

A review of the 2021-2023 rehabilitation monitoring programs was completed to summarise the conformance to Worsley's draft completion criteria for all rehabilitation included within the survey program to date (15 rehabilitation years). Data was extracted and compiled into tables. These tables present the complete set of flora and vegetation completion criteria associated with the relevant Era (Historical, Established and Current) and age group for each year of rehabilitation monitored. The table includes a simple PASS/FAIL for each completion criteria metric. Rehabilitation of a given year was assigned a PASS where the mean recorded values for the criteria met the applicable completion criteria. Where the mean did not meet the applicable completion criteria a FAIL was assigned. Recommended rehabilitation maintenance activities have been included in the discussion for any rehabilitation year assigned the category of FAIL under any criteria.

The flora and vegetation completion criteria assessed under the annual spring rehabilitation monitoring program are presented in Tables 1a and 1b below.

Table 1a: Summary of the flora and vegetation rehabilitation draft completion criteria (excluding 15 month monitoring)

Year of Establishment	Criteria	Minimum Requirement	Updated DRAFT KPI
Pre 1993	Sustainable Overstorey	≥ 400 mature trees/ha (in range or 500-700 trees/ha)	Average tree density within a pit • 600 tree stems/ha
	Timber Production	≥ 400 mature <i>Eucalyptus</i> species ¹ and <i>Corymbia calophylla</i> trees/ha	
	Mean legumes/m ²	N/A	Average legume density within a pit • 1 native legume plant/m
	Mean non-legumes/m ²	N/A	Average understorey density within a pit • 1 native non-legume plant/m ²
	Mean all plants/m ²	N/A	Average native, plant density across monitoring plots • 3 plants/m ² (excluding tree species)
	Introduced Species	Average introduced species foliage cover <2%	No declared weeds. Average weed density within a pit: • < 5 plants /m ²
Post 1993	Sustainable Overstorey	≥ 200 mature trees/ha (excludes <i>Allocasuarina huegeliana</i> and <i>Banksia grandis</i>)	≥ 200 mature trees/ha (excludes <i>Allocasuarina huegeliana</i> and <i>Banksia grandis</i>) for ≥10 years rehabilitation area
	Timber Production	≥ 200 mature <i>Eucalyptus</i> species and <i>Corymbia calophylla</i> trees/ha	<p>≥ 200 mature <i>Eucalyptus marginata</i> and <i>Corymbia calophylla</i> trees/ha for ≥2 years and <10 years rehabilitation areas</p> <p>≥ 200 mature <i>Eucalyptus marginata</i> and <i>Corymbia calophylla</i> trees/ha for ≥10 years rehabilitation areas</p> <p>≥ 200 mature <i>Eucalyptus marginata</i> and <i>Corymbia calophylla</i> trees/ha for ≥12 years rehabilitation areas</p>
	Sustainable Understorey	≥ 35% of alive native, annual/perennial, understorey species (excluding trees) foliage cover per quadra	<p>≥ 40% of alive native, annual/perennial, understorey species (excluding trees) foliage cover per quadrat for ≥2 years and <10 years rehabilitation areas</p> <p>≥ 35% of alive native, annual/perennial, understorey species (excluding trees) foliage cover per quadrat for ≥10 years rehabilitation areas</p>
		N/A	≥ 40% of alive native species per plot (80m ²) for ≥2 years and <10 years rehabilitation areas
	Introduced Species	<p>Average annual/perennial introduced species foliage cover <2%</p> <p>Declared weeds will not be present</p> <p>Weeds are not at sufficient numbers to limit growth of native species</p>	<p>No declared weeds for >10 years rehabilitation areas</p> <p>Average weed foliage cover of introduced species within a pit - <2 plants/m² for >10 years rehabilitation areas</p>

Table 1b: Summary of the flora and vegetation rehabilitation draft completion criteria for 15 month monitoring (≤2 Years)

Year of Establishment	Criteria	Minimum Requirement	Updated DRAFT KPI
Private Property	Mean Trees (all species)	500-700 mature trees/ha	Average tree density within a pit • 600 tree stems/ha
	Mean legumes/m ²	N/A	Average legume density within a pit • 1 native legume plant/m
	Mean non-legumes/m ²	N/A	Average understorey density within a pit • 1 native non-legume plant/m ²
	Mean all plants/m ²	N/A	Average native, plant density across monitoring plots • 3 plants/m ² (excluding tree species)

3 Results

As discussed in Section 2, the results from the review of rehabilitation performance against flora and vegetation completion criteria have been presented by Era. The draft Completion Criteria (Worsley, 2022) details three different eras:

- Current Era (post 2017),
- Established (post 1993 – 2017) and
- Historical (pre 1993).

The eras and their related criteria were designed based upon an assessment of historical working arrangements, rehabilitation monitoring results, research and development, rehabilitation prescriptions, stakeholder expectations and legislative requirements and recognise the evolution and emergence of restoration ecological principles (Worsley, 2022). In some instances, criteria vary within the Era based on the age of the rehabilitation.

The results of the review are presented for Historical Era (Table 2), Established Era (Tables 3a-3c) and Current Era (Table 4a-4b) below. A summary of the Pass/Fail status for all applicable completion criteria for all rehabilitation years is also provided as Table 5.

As indicated, overall the results reflected the achievement of the draft completion criteria with only a few exceptions. Only one criteria related to understorey failed; however indicated it was very close to meeting the criteria for native foliage cover in the 5 year old rehabilitation areas (see Table 3c). The other failures reflected the high number of tree seedlings in the 15 month monitoring which may either decrease over time or may lead to the requirement for some management in coming years.

Table 2: Historical Era (Pre 1993) – Performance against Completion Criteria

Rehab Year	Age at Monitoring	Total rehab (ha)	Survey Effort	Overstorey: Alive trees (Eucalyptus) (trees/ha)				Weed species foliar cover (%)			
				Criteria	Recorded Range	Mean	Pass/Fail	Criteria	Recorded Range	Mean	Pass/Fail
1990	30 years	42.5	6 tree plots and 5 understorey transects	>400	236-732	460	Pass	<2%	0.00-0.17	0.03	Pass
1991	30 years	49.6	6 tree and 6 understorey transects	>400	416-612	493.3	Pass	<2%	0.00-0.001	<0.001	Pass
1992	30 years	74.96	6 tree and 6 understorey transects	>400	720-1388	927.3	Pass	<2%	0.00-0.21	0.05	Pass

Table 3a: Established Era (1993-2017) – Performance against Completion Criteria (Age ≥10 years)

Rehab Year	Age at Monitoring	Total rehab (ha)	Survey Effort	Overstorey: Alive trees (Jarrah/Marri) (trees/ha)				Weed species foliar cover (%)				Native Plant Foliage Cover (%)			
				Criteria	Recorded Range	Mean	Pass/Fail	Criteria	Recorded Range	Mean	Pass/Fail	Criteria	Recorded Range	Mean	Pass/Fail
2000	20 years	63.4	2 tree plots and 2 understorey plots	>200	125-406	266	Pass	<2%	0.00-0.52	0.11	Pass	>35%	49.11-91.74	75.51	Pass
2001	20 years	85.1	6 tree and 6 understorey plots	>200	225-425	325	Pass	<2%	0.00-0.25	0.04	Pass	>35%	50.58-78.69	61.09	Pass
2002	20 years	153.4	5 tree and 5 understorey plots	>200	175-625	330	Pass	<2%	0.00-0.25	0.04	Pass	>35%	16.67-59.65	45.78	Pass
2010	10 years	126.89	4 tree plots and 4 understorey plots	>200	25-425	238	Pass	<2%	0.00-7.51	1.3	Pass	>35%	57.77-106.1	85.33	Pass
2011	10 years	170.09	6 tree and 6 understorey plots	>200	25-650	283.3	Pass	<2%	0.00-1.18	0.27	Pass	>35%	34.07-61.10	46.92	Pass
2012	10 years	152.96	6 tree and 6 understorey plots	>200	125-925	425	Pass	<2%	0.01-0.83	0.22	Pass	>35%	37.42-49.97	44.48	Pass

Table 3b: Established Era (1993-2017) – Performance against Completion Criteria (Age 2-10 years) – tree and weed metrics

Rehab Year	Age at Monitoring	Total rehab (ha)	Survey Effort	Overstorey: Alive trees (Jarrah/Marri) (trees/ha)				Weed species foliar cover (%)			
				Criteria	Recorded Range	Mean	Pass/Fail	Criteria	Recorded Range	Mean	Pass/Fail
2015	5 years	191.33	6 tree and 6 under-storey plots	>200	0-300	133	Fail	<2%	0.09-5.24	1.16	Pass
2016	5 years	352.1	6 tree and 6 under-storey plots	>200	250-1050	637.5	Pass	<2%	0.00-0.00	0.00	Pass
2017	5 years	202.97	6 tree and 6 under-storey plots	>200	250-1250	604.2	Pass	<2%	0.00-2.14	0.43	Pass

Table 3c: Established Era (1993-2017) – Performance against Completion Criteria (Age 2-10 years) – species richness metrics

Rehab Year	Age at Monitoring	Total rehab (ha)	Survey Effort	Species Richness: Native species per 80m ²				Native Plant Foliage Cover (%)			
				Criteria	Recorded Range	Mean	Pass/Fail	Criteria	Recorded Range	Mean	Pass/Fail
2015	5 years	191.33	6 tree and 6 under-storey plots	>40	39-54	45	Pass	>40%	58.26-86.36	69.21	Pass
2016	5 years	352.1	6 tree and 6 under-storey plots	>40	41-60	46	Pass	>40%	41.47-86.06	61.2	Pass
2017	5 years	202.97	6 tree and 6 under-storey plots	>40	30-58	49.3	Pass	>40%	19.23-59.90	37.15	Fail

Note : 2017 areas were only just below the criteria at 37.15 ± 2.82 (mean & standard error)

Table 4a: Current Era Completion Criteria (2017 on) – Performance against Completion Criteria, tree and weed metrics

Rehab Year	Age at Monitoring	Total rehab (ha)	Survey Effort	Overstorey Establishment: Alive native trees (stems/ha)				Weed species Non-native plants/m ²			
				Criteria	Recorded Range	Mean	Pass/ Fail	Criteria	Recorded Range	Mean	Pass/ Fail
				2019	15 months	212.63	28 plots	500-700	75-2975	1161.6	Fail
2020	15 months	116.33	34 plots	500-700	375-4150	1477.9	Fail	<5	0.01-8.99	1.49	Pass
2021	15 months	231.87	32 plots	500-700	300-3375	1357.8	Fail	<5	0.04-12.23	2.86	Pass

Table 4b: Current Era (2017 on) – Performance against Completion Criteria, understorey metrics

Rehab Year	Age at Monitoring	Total rehab (ha)	Survey Effort	Understorey Establishment: native legumes /m ²				Understorey Establishment: native non-legumes per m ²				Understorey Establishment: native plants /m ² (excluding tree species)			
				Criteria	Recorded Range	Mean	Pass / Fail	Criteria	Recorded Range	Mean	Pass / Fail	Criteria	Recorded Range	Mean	Pass / Fail
				2019	15 months	212.63	28 plots	>1	0.12-4.38	1.86	Pass	>1	0.15-10.06	3.16	Pass
2020	15 months	116.33	34 plots	>1	0.43-1.8	1.18	Pass	>1	0.4-3.05	1.52	Pass	>3	2.03-11.53	5.95	Pass
2021	15 months	231.87	32 plots	>1	1.10-6.51	2.7	Pass	>1	1.00-21.5	7.45	Pass	>3	2.65-22.81	10.15	Pass

Table 5a: 5, 10, 20 and 30 year old Rehabilitation Completion Criteria Review Summary

Rehab Year	Overstorey Criteria	Pass/Fail	Native Plant Foliage Cover Criteria	Pass/Fail	Species Richness	Pass/Fail	Weed Criteria	Pass/Fail	Overarching Pass/Fail
1990	>400 trees per ha (Eucalyptus)	PASS	-	-	-	-	Foliar cover <2%	PASS	PASS
1991		PASS	-	-	-	PASS		PASS	
1992		PASS	-	-	-	PASS		PASS	
2000	>200 trees/ha (Jarrah and Marri)	PASS	>35% live foliar cover of native species	PASS	-	-		PASS	PASS
2001		PASS		PASS	-	-		PASS	PASS
2002		PASS		PASS	-	-		PASS	PASS
2010		PASS		PASS	-	-		PASS	PASS
2011		PASS		PASS	-	-		PASS	PASS
2012		PASS	PASS	-	-	PASS		PASS	
2015		FAIL	>40% live foliar cover of native species	PASS	>40 species per 80m ²	PASS		FAIL	
2016		PASS		PASS		PASS	PASS		
2017		PASS		FAIL		PASS	FAIL		

Table 5b: 15 month old Rehabilitation Completion Criteria Review Summary

Rehab Year	Overstorey Criteria	Understorey Establishment Criteria (Native)	Pass/Fail	Species Richness Criteria	Pass/Fail	Weed Criteria	Pass/Fail	Overarching Pass/Fail
2019	500-700 trees per ha	>1 legume per m ²	PASS	3 native plants/m ² (excluding tree species)	PASS	<5 plants/m ²	PASS	FAIL*
			>1 native per m ²					
>1 legume per m ²		PASS	PASS					
		>1 native per m ²			PASS			
2021		>1 legume per m ²	PASS		PASS			
			>1 native per m ²				PASS	

* Tree stems per hectare were above the upper Completion Criteria limit.

4 Discussion

The results obtained through regular monitoring indicate successful outcomes of the rehabilitation against the draft completion criteria in most circumstances. The exception to this statement is the continuing recording of >500-700 stems in 15 month old rehabilitation over the last 3 years of monitoring. The dominance of tree seedlings in the 15 month period tends to be short-lived as some seedlings cannot survive the initial summer months. The latter is evident from the decline in the tree numbers in the older rehabilitation areas. Depending on the seasonal conditions this decline may vary from year to year. If the decline does not occur then some management actions during the first five to ten years may assist with reducing the tree densities to the regional values of well below 700 stems per hectare (Worsley Alumina, 1985). On the few occasions that the criteria may not have been met (e.g. overstorey on 2015 rehabilitation areas) the results are generally related to subtle difference in seasonal conditions that influence establishment and growth. In most instances there has been a tendency to overstock the rehabilitation areas with tree seedlings.

The vast majority of the understorey results for both native and weed species met the draft completion criteria. The presence of introduced species is generally reliant on short lived annual species that decline as the foliage cover of the native species increases. The rehabilitation areas on the native forest areas are generally less weed infested than those areas near agricultural properties where wind tends to encourage the spread of some more aggressive weed species. In terms of understorey species there is always a need to balance the variety of species with the growth of species. On the few occasions that the criteria may not have been met (e.g. species richness in 2017 rehabilitation areas) the results are generally related to subtle difference in seasonal conditions that influence establishment and growth.

In terms of native plant growth the foliage cover results are often more reliable than density results as the density results can be influenced by the fluctuations in short-lived annual natives.

5 References

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Dr Elizabeth (Libby) Mattiske
Mattiske Consulting Pty Ltd