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The Short Term Effects of Brush Harvesting on the Kwongan Vegetation at Eneabba, Western Australia

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A. J. M. HOPKINS

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Department of Fisheries and Wildlife

108 Adelaide Terrace

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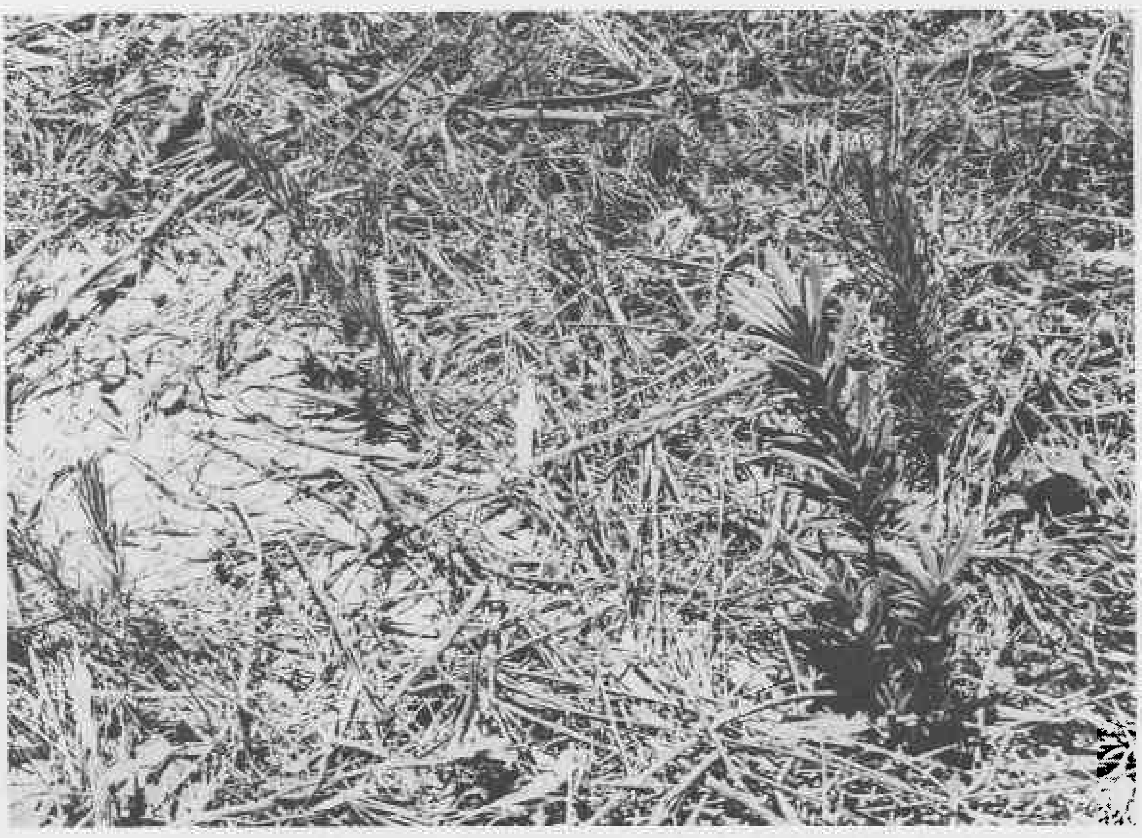

FRONTISPIECE. Seedling regeneration in a brushmatted area of the Allied Eneabba 78D topsoil, mulch and seeding trial.

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THE SHORT TERM EFFECTS OF BRUSH HARVESTING ON THE KWONGAN VEGETATION AT ENEABBA, WESTERN AUSTRALIA

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ABSTRACT

Areas of the kwongan vegetation south of Eneabba are currently being harvested to provide brush for rehabilitation after mining. Because of the botanical importance of the Eneabba kwongan, a study of the effects of the harvesting was initiated. Three areas with different harvest histories were sampled using quadrats paired across cut/uncut boundaries. Floristic and structural differences between quadrats and between areas were assessed. The store of seed in uncut vegetation was measured.

There was a loss of species as a result of harvesting, at least in the short-term. Many species regenerated by resprouting from buds in damaged stems or in below-ground organs. Seedlings were also prominent in some harvested quadrats. A suite of species considered to be most sensitive to cutting was identified. Those species which only regenerated from seed were included in this suite. Harvests in late Summer - early Autumn appeared best for regeneration. The impact of harvesting was increased by low cutting: this practice is probably desirable only when topsoil is to be removed soon afterwards. The store of seed of species with delayed dehiscence was low. This seed store makes an important contribution to the value of the brush for rehabilitation. Some further studies are recommended.

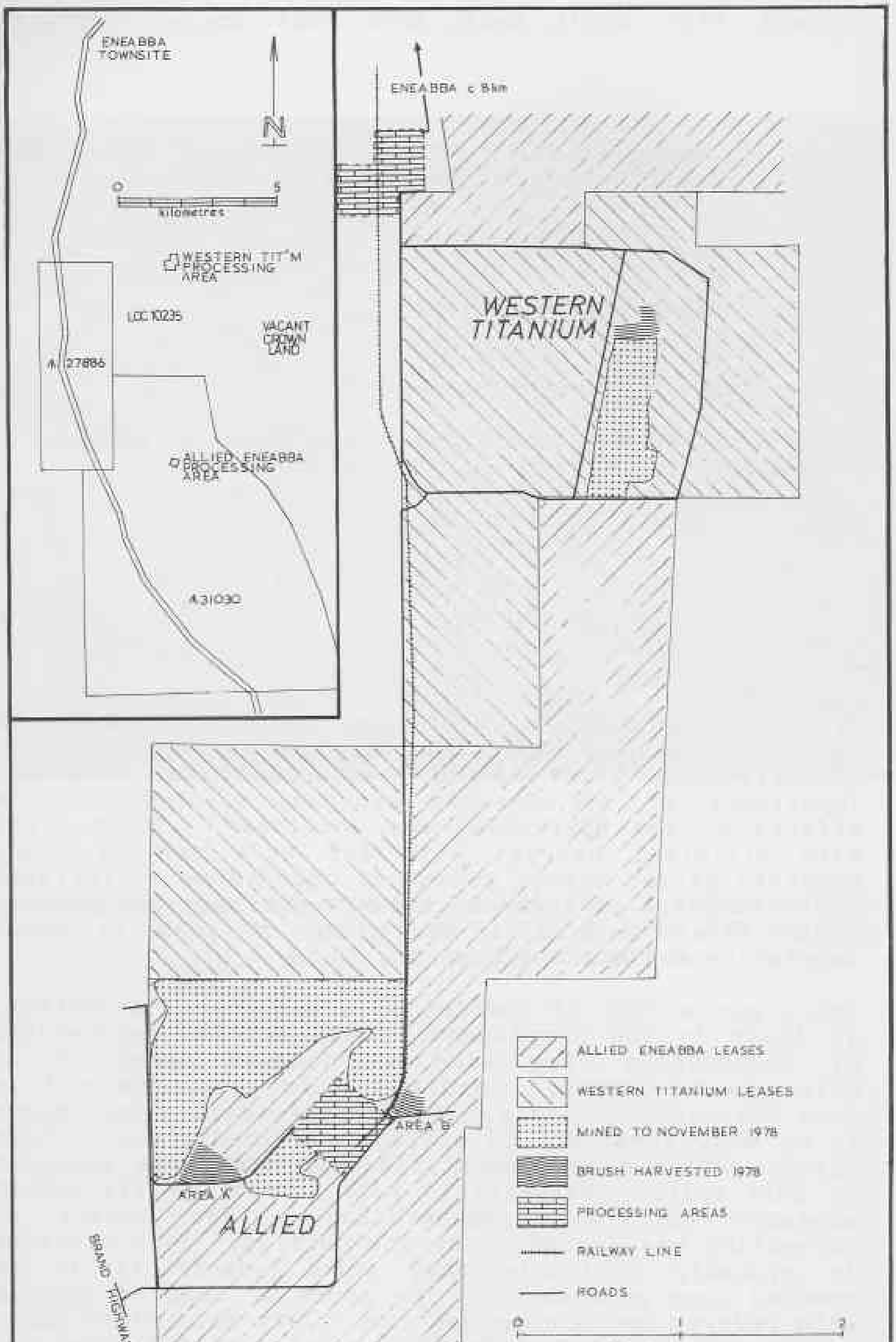

FIGURE 1 *BRUSH HARVESTING LOCATION MAP*

I INTRODUCTION

Within the extensive area of kwongan (sclerophyllous shrubland or sandplain vegetation, Beard 1976) south of Eneabba, a total of about 2 000 ha is to be mined or otherwise disturbed during the operations of heavy mineral sand mining companies. Small, additional areas will also be cleared by State and local government authorities for the extraction of gravel. Two companies are presently mining in this area: Allied Eneabba Ltd., and Associated Minerals Consolidated (formerly Western Titanium Ltd.). The extent of their operations is shown on Figure 1. A third company, Westralian Sands Ltd. (formerly Ilmenite Pty. Ltd.), has mining claims covering the area to the west of the Allied Eneabba and Western Titanium leases.

The mining tenements encompass portions of the two Nature Reserves south of Eneabba (C31030 and C27886), and portions of two blocks of vacant Crown land: Victoria Location 10235 and an unnumbered location to the east (Figure 1).

Under the terms of the relevant Agreement Acts, (Mineral Sands (Allied Eneabba) Agreement Act 1975, Mineral Sands (Western Titanium) Agreement Act 1975) the Companies are required to undertake rehabilitation of mined and disturbed areas. The objective of the rehabilitation programmes of the two companies presently operating is the achievement of a stable cover of native vegetation.

One rehabilitation technique which has been used extensively on the east coast of Australia involves the use of harvested vegetation as a supply of brushmatting* to stabilise the soil and as a source of propagules of native species (e.g. Brooks 1976, Newey & Lewis 1976, Specht 1975). The technique has been little used at Eneabba to date but is likely to be more widely used in future.

A major problem with the use of brush at Eneabba is that, under present operating conditions, the ratio of area harvested for brush to that brushmatted is approximately 3:1 (R. Snook, pers. comm. 1978). For the Companies to proceed with this technique, they will have to either recut areas several times (e.g. every 4-5 years) or to harvest brush from extensive areas outside the mining path. Any choice between these alternatives should be made in the light of knowledge of the impact of brush harvesting on the native vegetation.

The study reported here involves an assessment of the short-term impacts of the current, mechanised brush

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*The term brushmatting is used here to describe harvested vegetation laid on the soil surface and to distinguish this from a treatment where the vegetation is turned into the topsoil at the time of topsoil collection (mulching).

harvesting practice on the native vegetation. Effects of cutting and patterns of regeneration were examined in relation to species biology and for three regimes of harvesting.

II STUDY SITES

At the time of the field work for this study (26.10.78 - 2.11.78) three areas ahead of the mining paths totalling ca. 7 ha had been harvested for brush. All three areas were studied. Details of the harvesting regimes are shown in Table 1; locations of study sites are shown in Figure 1.

All three study sites were located within areas already described in detail by Lamont (1976), Hnatiuk & Hopkins (in press) and Hopkins & Hnatiuk (1981). The land surface slopes gently with a westerly aspect from lateritic hills east of the mining tenements to aeolean dunes adjacent to the railway line. The soils were predominantly grey sands overlying mottled, deep, yellow sandy-clay and with lateritic gravel variously disposed throughout the profile.

The vegetation at the study sites was low closed- to low open-heath with occasional emergent Banksia attenuata, Grevillea eriostachya, Xanthorrhoea reflexa and Xylomelum angustifolium. Larger dense clumps of Banksia candolleana, B. grossa and mallee eucalypts E. tetragona and E. macrocarpa were also conspicuous. Sites have been classified according to both schemes described by Hopkins & Hnatiuk (1981) as detailed in Table 1.

The area experiences a Mediterranean-type climate (Thermo-mediterranean accentuated, UNESCO FAO 1963) and has an annual rainfall of about 550 mm (Bureau of Meteorology 1968, 1975).

The brush was harvested using a Grasslands 600 Forage Harvester towed by a small rubber tyred tractor. This harvester had flail type cutters arranged in three rows and attached by chains along a horizontal, rotating tube. The brush was cut and flung upwards into a cage above and behind the cutters as the harvester was drawn through the vegetation (Plate 1). The cutting height was adjustable.

This type of harvester was primarily designed for use on agricultural crops and proved to be insufficiently robust to cut heavier woody vegetation. Consequently, lenses of uncut vegetation were left around the larger woody species such as Eucalyptus macrocarpa, E. tetragona, Xanthorrhoea reflexa and Xylomelum angustifolium. Some of these lenses were utilised in this study as examples of precut vegetation.

TABLE 1. Details of study sites. Locations of study sites are shown in Figure 1. Other details of cutting practices were supplied by company personnel. Vegetation at each site was classified according to the physiognomic units and floristic groups of Hopkins & Hnatiuk (1981).

Site Name	Western Ti	Allied B	Allied A
Cutting Supervisor	R. Snook	M. Forrest	R. Black
Time of cutting	August 1978	February 1978	May/June 1978
Average Height of cut (cm)	14	19	23
Months from cutting to observations	2	9	4-5
No. of Pairs of Quadrats	5	4	4
Vegetation Type:			
Floristic Group	3 transitional to 3a	3	3 transitional to 2
Physiognmomic Unit	Heath 1	Heath 1 transitional to Heath 2	Heath 2

III METHODS

At each study site, a number of paired quadrats were established as listed in Table 1. Each pair consisted of one quadrat in an area of cut vegetation and one quadrat in an adjacent, similar area of uncut vegetation. Where lenses of uncut vegetation existed within a cut area, as described above, pairs of quadrats could be established well within the study site. Other pairs of quadrats were established close to the margins of cut areas. Pairs of quadrats were distributed widely at each site to encompass geographic variation in the vegetation. A total of 13 pairs of quadrats were studied.

A quadrat size of 4m x 4m square was chosen to provide data suitable for incorporation in the vegetation classification scheme used by Hopkins & Hnatiuk (1981) and Hnatiuk & Hopkins (in press). Within each quadrat each species present was noted and assigned a cover-abundance value using the Braun-Blanquet scores given in Mueller-Dombois & Ellenberg (1974, p.62).

At each of the uncut quadrats additional information gathered included average height and habit of each species; presence and abundance of seeds, fruits, flowers or evidence of recent flowering; percent bare ground; and counts of seedlings and dead plants.

At each of the cut quadrats, the height of the cut was estimated; these results are included in Table 1. Notes were also made on regeneration and mortality of species and an estimate of percent bare ground. Additional records were made of species observed within the harvested areas but outside the quadrats, their reproductive status and any regeneration.

Plant specimens were collected at each site and later determined and cross checked at the Western Australian Herbarium (PERTH). A set of voucher specimens from this study is lodged at the Herbarium while a field set of voucher seedling specimens is lodged at the Western Australian Wildlife Research Centre. All nomenclature is consistent with that in Appendix IV of Hopkins & Hnatiuk (1981).

The data were assessed in terms of effects on the plant community and on individual species. Community features examined included numbers of species in quadrats and within each study area by treatment, the numbers of species in each cover-abundance class by treatment and by study area, and amounts of bare ground. The effects of cutting on individual species were assessed by presence or absence in treatments, mortality, their relative frequency and cover-abundance and regeneration strategies. Comparisons of effects of the three different harvesting regimes were limited to measures on the community and of seedling regeneration.

IV RESULTS

A. Effects on Community

A summary of the numbers of species occurring in each quadrat, each quadrat pair and at each study site, is presented in Table 2. A mean of 53.8 species were recorded for each 4m x 4m quadrat. The data for species richness separated by treatment (Table 2) show that the uncut quadrats, on average, contained 7.3 species more than the cut quadrats and this difference is significant ($t = 2.76$, $df = 12$, $0.01 < p < 0.05$).

A total of 148 species were encountered during the study

TABLE 2. NUMBERS OF SPECIES RECORDED IN EACH QUADRAT AND AT EACH STUDY SITE

SITE	QUADRAT PAIR	NO. OF SPECIES IN QUADRAT UNCUT	NO. OF SPECIES IN QUADRAT CUT	NO. OF SPECIES IN COMMON	NO. OF SPECIES UNCUT ONLY	NO. OF SPECIES CUT ONLY	TOTAL NO. OF SPECIES
WESTERN TI	1	70	50				
	2	54	53				
	3	53	49				
	4	68	54				
	5	76	45				
(mean)		(64.2)	(50.2)				
SITE TOTAL		105	93	83	22	10	115
ALLIED B	6	51	56				
	7	37	38				
	8	46	43				
	9	59	53				
(mean)		(48.3)	(47.5)				
SITE TOTAL		85	83	64	21	19	104
ALLIED A	10	59	56				
	11	59	52				
	12	59	51				
	13	56	52				
(mean)		(58.3)	(52.8)				
		100	94	84	16	11	111
STUDY MEAN		57.5	50.2				
		(53.8)					
STUDY TOTAL		139	126	118	21	9	148

TABLE 3. AVERAGE NUMBER OF SPECIES PER COVER-ABUNDANCE CLASS PER QUADRAT, CUT VERSUS UNCUT TREATMENTS, TOGETHER WITH AVERAGE PERCENT BARE GROUND RECORDINGS FOR EACH STUDY SITE.

Cover-abundance values are: + = solitary with significant cover, 1 = few individuals with significant cover, 2 = scattered individuals with cover 1-5%, and 3 = any number of individuals with cover 5-25%.

	STUDY SITE						OVERALL (Unweighted)	
	WESTERN T.		ALLIED B		ALLIED B			
Cover-abundance value	Uncut	Cut	Uncut	Cut	Uncut	Cut	Uncut	Cut
3	3	0.4	2.5	0.5	3	0.0	2.8	0.3
2	37.8	22.8	30.3	25.0	34.2	28.7	34.4	26.3
1	13.6	16.6	8.0	15.2	12.8	14.0	11.6	15.4
+	9.8	10.4	7.5	6.8	8.2	10.0	8.6	9.2
Average % bare ground	11	51	16	33	13	34	13	40

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with 139 and 126 species being present in the uncut and cut quadrats respectively. Thirty species (21% of the total) were encountered only in quadrats of one of the treatment types. Significantly more species occurred only in the uncut quadrats (21 vs. 9, $\chi^2 = 4.8$, df = 1, $0.01 < p < 0.05$).

Table 3 shows the average number of species for each cover-abundance class by treatment for each study site. Overall the average number of species with cover-abundance values of 2 or 3 was significantly greater in the uncut quadrats than in the cut quadrats (37.2 and 25.6 respectively, t = 5.89, df = 12, $p < 0.001$). Number of species with low cover (cover abundance values of + or 1) in cut and uncut quadrats were not significantly different.

Data on average percentage bare ground are included in Table 3 to provide some measure of the impact of the vegetation removal and the subsequent regeneration on the overall plant cover.

B. Effects on Individual Species

(1) Presence/Absence.

Table 4 lists the 30 species which were found exclusively in the cut or uncut quadrats together with their frequency of occurrence, annotations on life form (Raunkiaer 1934) and mode of regeneration. Seven of the species which occurred only in uncut quadrats were observed (elsewhere) to regenerate after cutting by resprouting. These were all taller shrubs (phanerophytes, meristems > 25 cm above ground). Six of the remaining phanerophytes had an erect habit with a single thin stem at the base. Six species were geophytes, hemicryptophytes or chamaephytes.

(2) Mortality

It was only possible to observe mortality of individuals with apparently intact root systems. No observations could be recorded for individuals which had been completely removed by the harvester. Also, individuals of species with very slender stems may have been overlooked.

A total of 80 individual plants comprising 27 perennial plant species plus two indeterminate taxa were noted to have died in the 26 quadrats. (Table 5). Forty individuals (19 species) were observed to be dead in the uncut quadrats, and 40 (20 species) were recorded for the cut quadrats. It was difficult to assign a cause of death for most of individuals observed, whether normal mortality (senescence), an effect of the recent drought (Hnatiuk & Hopkins 1980) or an effect of the cutting. Some individuals of three species (Adenanthos drummondii, Hakea cinerea, and Petrophile media), were considered to have been killed by the harvesting.

TABLE 4. LIST OF SPECIES RECORDED ONLY IN QUADRATS OF ONE TREATMENT TYPE

Life Forms according to Raunkiaer (1934) are indicated as P - phanerophyte, shrub with buds > 25 cm above-ground; C - chamaephyte, sub-shrub with buds < 25 cm above-ground; and G - geophytes and hemicryptophytes - plants with buds at or below ground surface. Phanerophytes marked with an asterisk have a woody erect habit with a single stem at ground level.

SPECIES	FREQUENCY OCCURRENCE	SPECIES OBSERVED RESPROUTING	LIFE FORM
SPECIES IN UNCUT QUADRATS ONLY			
Adenanthos drummondii			P*
Astroloma xerophyllum	1		P*
Banksia attenuata	2	+	P
Boronia ramosa	1	+	C
Calytrix tenuifolia	1	+	P
Comesperma acerosa	2		P*
Conostephium preissii	2	+	P
Conothamnus trinervis	1	+	P
Daviesia juncea	2		C
Drosera paleacea	1		G
Dryandra carlinoides	3		P*
Dryandra kippistiana	1		P*
Eucalyptus macrocarpa	1	+	P
Haemodorum sp. EAG 1564	2		G
Hakea prostrata	1	+	P
Laxmannia omnifertilis	2		G
Lysinema ciliatum	2		P*
Olax benthamiana	1		P*
Prasophyllum sp. indet.	2		G
Schoenus sp. EAG 1318	2		G
Stylidium brunonianum	1		G
SPECIES IN CUT QUADRATS ONLY			
Conosperma calymega	3	+	P*
Hakea sp. EAG 2162	5	+	P
Lachnostachys eriobotrya	1		P
Lepidosperma ? angustatum	1		G
Leptospermum erubescens	3	+	P
Petrophile shuttleworthiana	3	+	P
Pimelea angustifolia	3	+	P*
Thysanotus sparteus	3		G
Verticordia grandis	3	+	P

TABLE 5. SPECIES AND NUMBERS OF PLANTS RECORDED DEAD IN THE 13 QUADRATS OF EACH TREATMENT TYPE

	TREATMENT	
	Uncut	Cut
Adenanthos drummondii		1
Beaufortia bracteosa		1
Beaufortia elegans	5	1
Calothamnus torulosus	1	
Conospermum triplinervum	2	
Daviesia divaricata	2	1
Daviesia nudiflora	4	1
Dryandra carlinoides	1	1
Dryandra kippistiana	1	
Dryandra nivea		1
Dryandra shuttleworthiana	1	3
Dryandra tridentata	2	2
Eremaea violaceae	6	10
Hakea cinerea		3
Hakea costata	1	
Hakea sp. EAG 2162		1
Isopogon tridens	2	
Leptospermum erubescens		? 2
Melaleuca acerosa	1	1
Melaleuca tricophylla	1	
Petrophile drummondii	3	1
Petrophile macrostachya	4	
Petrophile media		4
Stirlingia latifolia		1
Strangea cynanchicarpa	1	
Thysanotus spiniger	1	
Xanthorrhoea reflexa	1	1
Unknown (2 species)		4
Species dead	19	20
Individuals dead	40	40

Areas where the cutting was very close to the ground, reflecting either a low machine setting or the micro-relief of the ground surface, appeared most severely affected. In some cases the rootstocks had been partially wrenched up, and portions were broken off. This often led to the death of the individual plants. Rootstock damage is promoted by the mounding which these woody structures contribute to micro-topography of the soil surface.

(3) Species Frequency

One hundred and eighteen species occurred in both cut and uncut quadrats. The impact of harvesting on each of these species was considered firstly in terms of any differences in frequency of occurrence between the two treatments.

Frequency data for each species were summed by treatment type over the whole study. Species were ranked in order of percentage relative frequency (% RF) where

$$RF = \frac{\text{Frequency of occurrence in cut quadrats}}{\text{Frequency of occurence in uncut quadrats}} \times 100$$

Further consideration was arbitrarily restricted to species for which departure of the %RF value from 100% was $\geq$ 25%, i.e. species with %RF values in the range 76-124% were not considered further here.

Thirty-nine species had low %RF values (in the range 1-75%) and these are listed alphabetically in Table 6. Two species had high %RF values (> 150%). Species with the lowest %RF values were Cassytha ?micrantha, Leucopogon striatus, Eremaea acutifolia, Casuarina humilis, Dryandra nivea, Hakea costata, Petrophile drummondii, and Astroloma sp. aff. microdonta. Two species, Beaufortia elegans and Petrophile drummondii, were represented in cut quadrats only by seedlings.

(4) Cover - Abundance

The differences in cover-abundance values recorded for the cut versus the uncut quadrats were also used as a measure of the impact of the various harvesting regimes on species found in both quadrat types. Consideration was restricted to those species which, overall, occurred in a total of five or more quadrats and in both quadrats of at least one quadrat pair. Species were then ranked according to the percentage expression, Species Differential Abundance (%SDA)

where

$$\%SDA = \frac{\text{No. of quadrat pairs where cover-abundance in cut} < \text{in uncut}}{\text{Total No. of quadrat pairs in which species occurred.}} \times 100$$

TABLE 6. LIST OF SPECIES WITH PERCENT RELATIVE FREQUENCY (% RF) OUTSIDE THE RANGE 76-124%. (See text for details of the calculation). Figures in brackets are frequencies of mature individuals, where these differ from total frequencies because some quadrats have only seedlings present.

SPECIES	FREQUENCY OF OCCURRENCE	
	Uncut quadrats	Cut quadrats
Species reduced by harvesting		
Astroloma sp. aff. *microdonta*	8	3
Banksia candolleana	2	1
Beaufortia elegans	5	3(0)
Boronia coerulescens	4	2
Cassytha ? *micrantha*	8	1
Cassytha ? *pubescens*	4	2
Casuarina humilis	3	1
Conostylis sp.aff. *crassinervia*	11	7
Dampiera juncea	5	3
Darwinia sanguinea	5	2
Dasypogon bromeliifolius	6	4
Daviesia divaricata	9	6
Daviesia nudiflora	10	5
Diplolaena ferruginea	2	1
Dryandra nivea	9	3
Dryandra tridentata	9	6
Eremaea acutifolia	5	1
Gastrolobium obovatum	7	4
Grevillea shuttleworthiana	6	3
Hakea auriculata	2	1
Hakea costata	6	2
Hemiandra pungens	6	3
Isopogon tridens	12(11)	8(6)
Jacksonia floribunda	10	7
Leptospermum spinescens	4	2
Leucopogon striatus	12	2(1)
Melaleuca tricophylla	8	5
Patersonia juncea	5	3
Petrophile drummondii	3	1(0)
Petrophile media	12(11)	9(8)
Phymatocarpus porphyrocephalus	7	5(4)
Stirlingia latifolia	4	2
Stylidium adpressum	8	5
Stylidium diuroides	4	2
Synaphea polymorpha	2	1
Templetonia biloba	5	3
Thysanotus triandrus	4	2
Xanthorrhoea reflexa	11	8
Xanthosia huegelii	4	2
Species increased by harvesting		
Amphipogon strictus	5	8
Neurachne alopecuroidea	2	4

Twenty-six species had %SDA ≥ 50% (i.e. cover-abundance lower in cut quadrats in at least half the quadrat pairs of occurrence) and these are listed in Table 7.

TABLE 7. LIST OF SPECIES WITH COVER-ABUNDANCE VALUES REDUCED BY HARVESTING.

Definition of the term Percentage Species Differential Abundance (% SDA) is given in the text.

SPECIES	% SDA	NO. of PAIRS OF QUADRATS IN WHICH SPECIES OCCURRED
Amphipogon strictus	50	4
Anigozanthos humilis	50	2
Calothamnus torulosus	100	1
Darwinia neildiana	67	9
Darwinia sanguinea	50	2
Darwinia speciosa	67	6
Dasypogon bromeliifolius	50	2
Dryandra nivea	100	2
Eremaea acutifolia	100	1
Eremaea violacea	64	11
Geleznowia verrucosa	50	8
Hemiandra pungens	100	1
Isopogon tridens	86	7
Jacksonia floribunda	57	7
Lambertia multiflora	100	2
Lasiopetalum drummondii	50	4
Leptospermum spinescens	50	2
Leucopogon striatus	100	1
Leucopogon sp. aff. *conostephioides* (EAG 1543)	50	2
Persoonia sp. aff. *sulcata* (EAG 1249)	50	8
Petrophile media	56	9
Phymatocarpus porphyrocephalus	50	2
Stylidium crossocephalum	50	4
Tricoryne elatior	50	2
Xanthorrhoea reflexa	50	8
Xanthosia heugelii	50	2

(5) Regeneration

It was not possible to determine how each species responded to the cutting treatment as not all species present in the cut quadrats need to have been affected by the cutting treatment. Many of the smaller plants, especially the geophytic species eg. Drosera paleacea, may only have been affected by the cutting when the cutting height was at ground level.

Regeneration, where distinguishable from normal seasonal growth, was principally by resprouting from buds associated with swollen stem bases or root stocks (eg. Lambertia multiflora). Other species were resprouting from buds in above-ground shoots (eg. Calytrix superba).

Seedling regeneration at the time of study was relatively un-important, both in terms of biomass contribution and total numbers of species and individuals present. Some seedlings were obviously related to adjacent, mature plants which had apparently died as a result of the drought the previous year.

Seedlings of 29 species were encountered during the study. Of these, 12 species (14 individuals) were observed in the uncut quadrats and 24 species (116 individuals) were in the cut quadrats (Table 8). The species were fairly evenly distributed between those which disperse seed when it is mature and have a seed store in the soil (13 species) and those which exhibit delayed dehiscence or a bradysporous habit (16 species). Seedlings of the first category were most abundant in the cut quadrats. Seedlings of the bradysporous species in the cut quadrats were often associated with loose fruit, apparently dislodged by the cutting.

C. The Cutting Regime

It was not possible to clearly distinguish the contributions to the overall effect of cutting made by the three variables, cutting regime (height and season of cut) and time from cutting to observation, since no two of the three study sites had any feature in common. However, the following observations are pertinent to any such comparison.

At each study site, more species were found in the uncut quadrats than in cut quadrats (Table 2). The differnces between mean values were significant at the Allied A site ($t = 4.73$, $df = 3$, $0.001 < p < 0.01$) but not at the other two sites.

Cut quadrats at the Western Ti site contained more bare ground than those at other sites.

The regeneration at the Allied B site was more advanced than at the other sites. For example, shoots of Banksia

TABLE 8. SEEDLINGS RECORDED IN QUADRATS OF EACH TREATMENT TYPE AT EACH STUDY SITE. Species marked with an asterisk are those which are represented in some cut quadrats only by seedlings. Modes of seed storage are indicated as: B = species with on-plant storage (in bradyspores) and S = species with soil storage.

	Western Ti		Allied B		Allied A		Totals		Seed Storage Mode
	Uncut	Cut	Uncut	Cut	Uncut	Cut	Uncut	Cut	
*Beaufortia elegans**				10				10	B
*Calothamnus sanguineous**				9				9	B
Conospermum triplinervum				1				1	S
*Conostylis teretifolia**				4				4	S
Darwinia neildiana				1				1	S
Daviesia nudiflora	1						1		S
Dryandra kippistiana	3						3		B
Dryandra shuttleworthiana		1			1	1	1	2	B
Dryandra tridentata					1		1		B
Eremaea beaufortioides			1	5			1	5	B
Eremaea violaceae				14				14	B
*Geleznowia verrucosa**				11				11	S
Grevillea shuttleworthiana				1				1	S
*Hakea candolleana**				1				1	B
Hakea costata			1				1		B
Hibbertia crassifolia		1		10		1		12	S
Hibbertia huegelii					1		1		S
Hypocalymma xanthopetalum				1				1	S
*Isopogon tridens**				11	1	1	1	12	B
Jacksonia floribunda				1				1	S
Lambertia multiflora					1	5	1	5	B
*Leucopogon striatus**				2				2	S
Melaleuca acerosa				8		1		9	B
*Petrophile drummondii**	1					5	1	5	B
Petrophile macrostachya	1			1		1	1	2	B
*Petrophile media**			1	2			1	2	B
*Phymatocarpus porphyrocephalus**				1				1	B
Stylidium repens				1				1	S
*Verticordia grandis**				1				1	S
Indeterminate	1		1			1		3	
Species	4	2	3	21	5	7	12	24	
Total seedlings	6	2	3	96	5	15	14	116	
Total seedlings from species with soil stored seed	1	1	0	34	1	1	2	36	
Total seedlings from bradysporous species	5	1	3	62	4	14	12	27	
Average number of seedlings per quadrat	1.2	0.4	0.8	24	1.3	3.8	1.1	8.7	

candolleana at that site were 30-40 cm long whereas those at the Western Ti site were only 5 cm long. Quadrats at Allied B also contained greater numbers of seedlings (species and individuals) than those of other areas.

D. Availability of Seed

The seed bank in the Eneabba kwongan is in two generally definable fractions: seed stored in the soil, mainly contributed by species which liberate seed annually (eg. Geleznowia verrucosa, Hibbertia crassifolia, Verticordia grandis), and seed retained on the adult plant and released later, usually following the death of the supporting branch and often after fire (delayed dehiscence or bradysporous habit as in, for example, Eremaea violaceae, Lambertia multiflora, Melaleuca acerosa, Petrophile drummondii). It is the bradysporous species which will contribute most to the value of the brush material in rehabilitation practice as a source of native plant propagules (see Appendix 1). Some of these species develop their fruits at, or close to the ground surface (geoflorous species) while others support the fruits in, or close to, the canopy at $\geqslant$ 0.5 m above ground surface.

The disposition and abundance of fruits (or aggregations of fruits) were recorded for most bradysporous species encountered in uncut quadrats to provide some estimate of the total reservoir of seed, and the relative importance of the two groups of bradysporous species. The results of this assessment, are presented in Table 9. Data on the regeneration of these bradysporous species after cutting are included in Table 9 to permit assessment of the impact of harvesting on the existing individuals.

V DISCUSSION

The total of 148 species which were encountered during the study was about 21% of species recorded for the two areas surveyed by Lamont (1976) and Hopkins & Hnatiuk (1981). The sampling for this study covered few of the habitats in the area, and was not as exhaustive as the other studies. The observed high numbers of species occurring in each 4 x 4 m quadrat in this study (mean of 53.8) are consistent with results of similar sampling in these habitats (Hopkins & Hnatiuk 1981 and unpublished data). The main heavy mineral deposit underlies a zone of habitat overlap between the lateritic plateau and the deep sands which is extremely rich in plant species (up to 74 species in a 4 x 4 m quadrat, 121 in a reléve of ca. 1 000 m^2). Further, the species richness figures for Eneabba kwongan generally are high relative to those for other parts of south-western Australia and this reflects the considerable phytogeographic importance of this area (George, Hopkins & Marchant 1979, Lamont, Downes & Fox 1977).

TABLE 9. OBSERVATIONS OF FRUIT BEARING HABITS AND REGENERATION STRATEGIES OF BRADYSPOROUS SPECIES IN THE STUDY AREA. Position of fruits are indicated as f = fruits borne high in the canopy at ≥ 0.25 m, g = fruits borne close to ground level N.D. = not determined. Additional data on resprouting from Hnatiuk & Hopkins (1980) and Lamont (1976 Appendix VII) have been included: + = resprouting observed, O = considered not to resprout, ? = resprouting probable.

SPECIES	Average No. of fruit per plant (No. of plants examined)	Position of fruit	Seedlings in cut quadrats	Resprouting
Casuarinaceae				
Casuarina humilis	6(5)	f		+
Casuarina microstachya	5(2)	g		?
Proteaceae				
Banksia attenuata	5(7)	f		+
Banksia candolleana	1(6)	g		+
Banksia grossa	5(4)	g		+
Banksia incana	N.D.	g		?
Banksia menziesii	2(1)	f		+
Dryandra carlinoides	N.D.	f		O
Dryandra kippistiana	N.D.	f		O
Dryandra nivea	0(2)	g		+
Dryandra shuttleworthiana	1(7)	g	+	+
Dryandra tridentata	4(5)	g		+
Hakea auriculata	0(1)	f		+
Hakea candolleana	4(6)	f		+
Hakea cinerea	12(3)	f		+
Hakea costata	N.D.	f		+
Hakea prostrata	0(1)	f		+
Hakea incrassata	0(3)	f		+
Hakea sp. EAG 2162	N.D.	f		+
Isopogon adenanthoides	N.D.	f		+
Isopogon tridens	11(6)	f	+	+
Lambertia multiflora	15(3)	f	+	+
Petrophile drummondii	2(4)	f	+	O
Petrophile macrostachya	2(6)	f	+	+
Petrophile media	17(4)	f	+	+
Petrophile shuttleworthiana	N.D.	f		+
Strangea synanchicarpa	N.D.	f		?
Xylomelum angustifolium	N.D.	f		+
Myrtaceae				
Beaufortia bracteosa	22(1)	f		O
Beaufortia elegans	N.D.	f	+	O
Calothamnus sanguineus	159(3)	f	+	+
Calothamnus torulosus	10(1)	g		+
Conothamnus trinervis	26(2)	f		+
Eremaea acutifolia	26(1)	f		+
Eremaea beaufortioides	139(4)	f	+	+
Eremaea violaceae	249(2)	f	+	+
Eucalyptus macrocarpa	150(1)	f		+
Eucalyptus tetragona	100(2)	f		+
Leptospermum erubescens	6(1)	f		+
Leptospermum spinescens	0(1)	f		+
Melaleuca acerosa	41(4)	f	+	+
Melaleuca tricophylla	16(4)	f		+
Phymatocarpus porphyrocephalus	5(7)	f	+	+
Cupressaceae				
Actinostrobus acuminatus	13(3)	g		+

Brush harvesting removed most, and occasionally all, above ground biomass of the kwongan vegetation. Regeneration was conspicuous in all areas but most advanced at the oldest site (Allied B). Resprouting from swollen stem bases and rootstock was the most common mode of regeneration, with some resprouting from buds in aerial stems, and regeneration from seeds being important for some species.

Clearly the impact of the harvesting would be reduced with time. However it was not possible, on the basis of this study, to estimate the length of time necessary for complete regeneration of the canopy. Hopkins & Hnatiuk (1981) have estimated that the Eneabba kwongan may take in excess of 15 years to regenerate after fire; post harvest regeneration is unlikely to be any more vigorous because much of the nutrient pool is removed during the harvesting process (see Appendix II in Hopkins & Hnatiuk 1981).

The cutting led to a significant decrease in average numbers of species in the higher cover-abundance categories (Table 3). The changes in numbers in the lower cover-abundance classes were not significant. Three possible interpretations are: that this reflects the actual removal of above-ground biomass during harvesting; that individuals of some species were removed during harvesting; or that taller species were affected more than the smaller species. These factors could be distinguished in an experiment in which the vegetation is sampled both before and after harvesting.

The data on species richness, frequency of occurrence and mortality indicate that the brush harvesting causes mortality in some species. Those species which appeared most severely affected were the non-resprouting, obligate seed-regenerators. Most of these non-resprouting species were single-stemmed at ground level. Some of these species were not found in cut quadrats (Table 4, eg. *Dryandra carlinoides* and *Lysinema ciliatum*), some were found dead in cut quadrats (Table 5, eg. *Adenanthos drummondii*), some occurred infrequently in cut quadrats relative to their occurrence in uncut quadrats (Table 6, eg. *Hakea costata* and *Leucopogon striatus*) and some were represented in cut quadrats only be seedlings, all mature individuals apparently having been killed by the cutting (Table 6, eg. *Beaufortia elegans* and *Petrophile drummondii*). Other species which appeared to decline after harvesting, and with habit characteristics which may have engendered vulnerability, included the parasitic twiner (liana), *Cassytha ? micrantha*, and *Laxmannia omnifertilis*, a slender plant of fine stilted roots. *Dryandra nivea* also seemed severely affected by the cutting but this species does not exhibit features in common with species already listed, being a resprouter with a reptant habit.

The kwongan at Eneabba had experienced two years of aseasonal drought prior to the cutting and this produced noticeable affects in the vegetation (Hnatiuk & Hopkins 1980, E.A. Griffin, unpublished data). Clearly, drought was implicated in many of the deaths reported for the uncut quadrats, and some of the deaths in the cut quadrats could also be attributed to that cause. However, some deaths seemed to result from the cutting practice. These individuals may have been predisposed to die because of the prevailing drought.

There is some similarity between the findings of Hnatiuk & Hopkins (1980) on drought effects and our finding on brush harvesting effects: both studies show a suite of species which are sensitive to disturbance and do not regenerate by resprouting. These include *Beaufortia elegans*, *Dryandra carlinoides*, *Leucopogon striatus*, *Lysinema ciliatum* and *Petrophile drummondii*. Most of these species are also killed by fire (E.A. Griffin, unpublished data).

The seedling numbers reported in the drought study appear higher than numbers normally observed in the kwongan. Survival of these seedlings would be jeopardised by the harvesting, particularly if the cutting height was low. This effect is suggested by the low seedling numbers in cut quadrats at the Western Ti site. Thus, the effects of brush harvesting may be exacerbated by recent or concurrent drought. Alternatively, the defoliation effect of the cutting may assist the survival of mature individuals of some species.

Seed storage in the Eneabba kwongan is both in the soil and suspended in the vegetation in bradyspores. Seed from both types of storage contributed to the seedlings recorded in the study (Table 8). Seedlings of bradysporous species originated mainly from fruits broken off during harvesting, although some seed was contributed by otherwise dead, possibly drought affected, plants. There was some germination of soil-stored seed in the uncut quadrats, but seedlings were more abundant in cut quadrats. The harvesting constitutes a disturbance suitable for promoting germination of some soil-stored seed, but the response is not as marked as, for example, that following fire (cf. Specht 1981, A.J.M. Hopkins unpublished data).

The species for which seedlings were recorded are unlikely to be lost from the area as the result of a single brush harvest. However, they remain vulnerable to further disturbance (eg. fire) until seed reserves have been replenished. In particular, eleven of the species were represented in some cut quadrats only as seedlings; seven of these were bradysporous and thus had little further seed present in harvested areas.

The observations from the three harvested areas are not sufficient to establish conclusively the optimum cutting practice. Certainly the vegetation at Allied B site showed the best recovery. This site was harvested in Summer, at an intermediate height above ground and the time from cutting to observation was longest. The following observations appear pertinent:

a) The vegetation probably takes several weeks to recuperate from the effects of the cutting and to develop new buds. This time may be prolonged where cutting is close to the ground or when soil moisture availability is low. Thus, for example, the vegetation at the Allied A site would have experienced best conditions for recuperation having been cut relatively high above the ground and at the time of first Autumn rains (see Table 1 and Fig. 6 in Hopkins & Hnatiuk 1981).

b) This vegetation type exhibits a phenological pattern where shoot elongation of perennial shrubs occurs predominantly over the months October - December (Specht, Rogers & Hopkins 1981), although this pattern can be affected by disturbance eg. fire, Baird 1977). Optimal regeneration by resprouting could be anticipated when shrubs had fully recuperated prior to the beginning of this growing period. Thus, the vegetation at both the Allied sites would have had similar, near-optimal, amounts of growing time, whereas the vegetation at the Western Ti site may still have been recuperating at the beginning of October.

c) Observations of seedlings of bradysporous species in the Eneabba kwongan over the period 1977-79 suggest that establishment has been most successful when seeds were in the soil by Autumn. This is consistent with horticultural experience with species from this general area (eg. West Australian Wildflower Society 1973). To achieve this with brush harvesting, sufficient time must be allowed for capsules to dry and dehisce. Excessively early harvesting may render the seeds susceptible to predation. This suggests that harvests in the period March-May should provide best regeneration of bradysporous species in harvested areas and in brushmatted rehabilitation areas. As a further consideration, harvesting should be carried out before seedlings naturally germinate to avoid disturbance-induced mortality. In terms of seedling regeneration then, the Allied B site was harvested at a good time and the Western Ti site at a poor time. Seedling counts at the three sites (Table 8) are consistent with this.

The results from the assessment of the seed store reveal that relatively few species had many fruits per plant, with some noteable exceptions in the Myrtaceae. The area has remained unburnt for about 10 years (Hopkins & Hnatiuk 1981). Either accumulation of fruits is slow in the Eneabba kwongan, a process which may have been exacerbated by the recent drought, or this vegetation only carried a small reservoir of seed in bradyspores.

Nine geoflorous species were amongst the 44 bradysporous species for which seed stores were studied. However, seedlings of only one geoflorous species (Dryandra tridentata) were observed in an area rehabilitated with brush whereas a total of 17 bradysporous species were recorded there (Appendix I). Fruits of Banksia spp. in the Banksia sphaerocarpa group have also been observed in nearby brushmatted areas (A.J.M. Hopkins unpubl. observations). These geoflorous species thus appear to be under-represented in rehabilitation areas and this is probably because the low fruits are not readily gathered by the harvesting method studied. Low cutting would increase representation by geoflorous species in the brush material. However, in view of the deleterious effects of low cutting which have already been described, this practice can only be justified in areas where the topsoil is to be removed soon after.

Two aspects of the brushmatting practice warrant discussion. The brush material can serve two major purposes in rehabilitation: stabilizing the tailings areas and providing propagules for regeneration. Yet the merits of brushmatting relative to other techniques to achieve the same results, and the optimal rates of application for each purpose, appear not to have been assessed quantitatively. Some of these questions are addressed in the 78D Topsoil, Mulch and Seeding Trial at Eneabba (see Appendix I). The current rate of application of brush at Eneabba is about 15-20 tonnes ha^{-1} Oven Dry Weight (ie. 2-3 times the average of 7 tonnes ha^{-1} ODW for aerial plant parts in Appendix II, Hopkins & Hnatiuk 1981). It is not known whether this rate was selected for optimum stabilizing effect or optimum regeneration.

The brushmatting acts to stabilise the soil surface by reducing wind speed, reducing erosion, trapping airborne particles and reducing evaporation. It has been used extensively for stabilizing tailings following heavy mineral sands mining in eastern Australia (eg. Barr & McKenzie 1976, Brooks 1976, Newey & Lewis 1976). The ameliorating effects of soil surface roughness on wind speed have been demonstrated in a laboratory situation by Marshall (1971), yet no quantitative field assessment has been reported.

The value of brush material as a source of propagules (mainly seed) at one location at Eneabba is discussed briefly in Appendix I. It has also been mentioned for eastern Australian situations by Brooks (1976) and Specht (1975) where it appears less important than at Eneabba. Other techniques for providing seed of bradysporous species have not been assessed in a comparable way. It has been suggested (R.F. Black, pers. comm. 1980) that current rates of application of brush are too high, the matting being too thick for some seedlings to grow through and promoting some composting.

VI CONCLUSIONS AND RECOMMENDATIONS

In this paper we have investigated aspects of the Eneabba vegetation relevant to its use for rehabilitation. The sclerophyllous shrub vegetation is harvested above the ground, transported, then spread over the areas to be rehabilitated, where it liberates seed of the native plant species and also acts as a soil stabilizing agent. Within the study area, two companies are presently mining for heavy mineral sands and a number of additional areas have been cleared for gravel extraction. Rehabilitation of mined areas using a brushmatting technique commenced in 1978, and it was envisaged that large areas of native vegetation would be required for harvesting in the ensuing years. This study was initiated following these early harvests to provide a basis for assessing the implications of large scale harvesting on the vegetation in this botanically important area.

A total of 148 vascular plant species were encountered in the 26 study quadrats. These quadrats were largely confined to one of three floristic units of vegetation in the study area. Future harvesting will probably affect the units on the lateritic gravels and on the deep sands to a greater extent; there is a need to investigate these further.

The harvesting caused an immediate loss of species as well as a reduction in relative importance of many other species. Some mortality, which could be directly attributed to the cutting was observed. The vegetation was regenerating principally by resprouting from above and below ground tissues. Seedling regeneration was important for some species. Seedlings occurred in uncut areas but they were more abundant in cut areas and comprised bradysporous species as well as species with seed stored in the soil.

A suite of species considered to be most sensitive to brush harvesting was identified. These could be grouped generally by habit and regeneration strategy and included a number of non-resprouting, obligate seed regenerating species, typically woody perennial shrubs with a single erect stem at ground level. Twiners (lianas) some small perennials with fine stilt roots and some recumbent perennials may also be excessively affected.

The optimum time for harvesting (and for brushmatting) appears to be around March-May. If the area to be harvested is shortly to be mined, then the vegetation should be cut close to the ground surface and the topsoil should be removed and respread soon after. In areas away from the mining path harvesting should be higher (ca. 20 cm above ground surface).

An assessment of the quantity of seed stored in bradyspores showed this to be generally small but probably sufficient for regeneration after most types of nature disturbance. However, the substantial reduction in the seed store as a result of harvesting may have long-term deleterious effects on the vegetation, and special post-harvest management, especially fire protection is essential.

There are effects of the brush harvesting practice which can only be determined by before and after sampling of harvested areas and through a long term study of regeneration. The question of regeneration time (time to preharvest biomass and levels of seed storage) in particular, has not been addressed by this study and this is critical both for future management of the harvested areas and to appraise the potential for reharvesting. Accordingly it is recommended that:

1. **The companies mining heavy mineral sands in the Eneabba area undertake, as a part of their ongoing programmes of research and monitoring, and as a matter of some urgency, a study of the long term effects of brush harvesting on the vegetation in the vicinity of mining areas.**

One problem that has yet to be addressed is the relative priority placed by the mining companies on the two important values of brushmatting in their rehabilitation operations. Further, the efficacy of the brush, at current rates of application, for each purpose needs to be assessed. If the brush material is being utilized in the rehabilitation process solely as a source of propagules, then there are means of achieving similar results without effecting such damage on the vegetation. Seed collection in the brush is principally of bradysporous species; seed of many such species could readily be collected by hand. However, if the brush is to be utilized for soil rehabilitation, then the optimum level of application for this purpose, and the effect of this on regeneration, should be ascertained quantitatively by experiment. This would ensure that the best use is made of the valuable vegetation resources in the area and with minimum impact. It is therefore recommended that:

2. **The companies continue studies to ascertain the value of brush material as a source of propagules and initiate studies to determine the value of brush matting for soil stabilization and optimal levels of application for both purposes.**

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PLATE 1. Grasslands Forage Harvester being used to harvest vegetation from the Western Ti area.

PLATE 2. Subsequent removal of topsoil to an average depth of 15 cm by an elevating scraper prior to mining. Topsoil so collected is either stockpiled for later use or used immediately for rehabilitation.

PLATE 3. The sequence of premining activities (from the rear):
a) the undisturbed heath vegetation,
b) a brush harvested strip, and
c) the topsoil removed immediately prior to mining.

PLATE 4. Harvested material being unloaded from the Forage Harvester onto an area to be brushmatted.

PLATE 5. Pre-harvest situation at Allied B showing the typical low closed-heath vegetation with an average height of about 60 cm with occasional emergents.

PLATE 6. Post-harvest vegetation in Allied B area in May, 1979, 14 months after harvesting, showing substantial regeneration, mainly through resprouting.

APPENDIX 1

THE EFFECTS OF BRUSH MATERIAL ON REGENERATION OF NATIVE PLANT SPECIES IN A REHABILITATED AREA

Harvested material from the Allied Eneabba Ltd. C2 pit area and the adjacent Allied A brush harvesting study site was utilized by Dr R.F. Black of Allied Eneabba Ltd. for an experiment on the effects of various rehabilitation treatments (78D, Topsoil, Mulch and Seeding Trial). Early results from this experiment are available and these permit some assessment to be made of the value of brush for rehabilitation. It is not the objective of this present publication to report in detail on the 78D Trial. Rather we seek to highlight one aspect of the trial which is relevant to the brush harvesting study.

The following information regarding the 78D, Topsoil, Mulch and Seeding Trial is reproduced from the Allied Eneabba Ltd. Environmental Management Programmes reports (Allied Eneabba 1978, 1979) with permission.

The aims of the trial were to test:

(i) the benefits of varying topsoil configurations,
(ii) the effects of mulch (brushmatting treatments on topsoil stabilization and the regeneration of native plants,
(iii) the relative stabilizing action of a cereal rye crop, and
(iv) the significance of the basic fertilizer treatment alone with respect to the inhibition on stimulation of native plant regeneration.

Vegetation was harvested over a period of about 6 weeks in April-June 1978 according to the cutting regime outlined in Table 1 of the main report. The brush material was transferred immediately to the experimental area where it was unloaded and gradually spread in the desired configuration.

A factorial experiment was laid out over an area of 3.4 ha to test the following combinations of treatments:

New topsoil layered		Brush Matting		Cereal rye & fertilizer
New topsoil mixed	x		x	Fertilizer only
Old topsoil mixed		No Brush Matting		No cereal rye; no fertilizer

Laying out of the experiment was completed by 19 June 1978.

APPENDIX I TABLE 1. SPECIES AND NUMBERS OF INDIVIDUALS RECORDED IN SAMPLE QUADRATS IN THE ALLIED ENEABBA LTD. 78D TOPSOIL, MULCH AND SEEDING TRIAL IN OCTOBER 1979. Data have been summed for the 90 $1m^2$ quadrats in each of the two treatment types listed. Modes of seed storage are also indicated, where b = species with storage on the plant (in bradyspores), s = species with seed stored in the soil, s* = species with soil stored seed but with some delay in dehiscence.

Species	Treatment: Topsoil and brushmatting	Treatment: Topsoil only	Seed Storage Mode
Acacia auronitens	0	1	s*
Anigozanthos humilis	0	2	s
Adenanthos cygnorum	10	0	s
Agrostis avenacea	1	0	s
Astroloma prostratum	11	21	s*
Banksia hookerana	1	0	b
Boronia ramosa	3	0	s
Burtonia conferta	0	3	s
Cassytha sp.	4	17	s*
Casuarina humilis	8	0	b
Conostylis aculeata	2	9	s*
Conostylis aurea	1	1	s*
Conostylis dielsii	0	13	s*
Dryandra tridentata	26	0	b
Dryandra sp.	2	0	b
Darwinia neildiana	1	2	s
Daviesia nudiflora	1	0	s
Daviesia quadrilatera	1	0	s
Eremaea beaufortioides	95	0	b
Eremaea pauciflora	3	0	b
Eremaea violacea	193	0	b
Eucalyptus tetragona	5	0	b
Geleznowia verrucosa	6	0	s
Grevillea shuttleworthiana	1	0	s
Gyrostemon ramulosus	0	1	s*
Hakea auriculata	3	0	b
Hakea incrassata	2	0	b
Hibbertia crassifolia	10	15	s
Hibbertia glomerosa	2	0	s
Hibbertia hypericoides	4	5	s
Isopogon dubius	19	10	b
Jacksonia floribunda	1	3	s
Juncus plebeius	0	2	s*
Lambertia multiflora	55	0	b
Lasiopetalum drummondii	0	1	s
Laxmannia sessilis	3	1	s*
Lepidobolus sp.	1	0	s*
Lepidosperma tenue	0	2	s*
Leptospermum spinescens	20	0	b
Lysinema ciliatum	4	0	s
Melaleuca acerosa	252	0	b
Melaleuca trichophylla	76	0	b
Mesomelaena stygia	4	4	s*
Petrophile macrostachya	3	0	b
Petrophile media	12	0	b
Pymatocarpus porphyrocephalus	11	0	b
Pileanthus filifolius	8	0	s
Restio sphacelatus	2	0	s
Scholtzia capitata	15	0	s*
Stylidium crossocephalum	1	2	s*
Templetonia biloba	0	2	s
Thysanotus multiflorus	5	0	s
Xanthosia hueglii	2	1	s
Unidentified monocots	19	27	
Unidentified dicots	61	10	

Regeneration was monitored in September 1978 and October 1979 using a stratified random sample of 180 $1m^2$ quadrats. Data from the 1979 observations are reproduced below (Table 1). Notations are included to indicate the mode of seed storage for each species. These results are summarised in Table 2.

A total of 55 species were recorded in the study area in 1979. Of these, 46 were found in the brush matted areas and only 24 were found in the topsoil only areas. A further three readily determinable species were recorded in the study area in 1978: *Acanthocarpus preissii*, *Drosera* sp. and *Olax benthamiana*, and of these only the first was recorded for brushmatted areas (J. Elkington, pers. comm. 1979).

The brushmatted areas had twice as many species present as the topsoil-only areas. Table 2 shows that the major difference between these two treatments can be accounted for by the numbers of bradysporous species present in each treatment: all 18 bradysporous species were recorded in the brushmatted areas but only one, *Isopogon dubius*, was noted in topsoil-only areas.

APPENDIX 1. TABLE 2.

Numbers of species of each seed storage mode recorded for each of the two rehabilitation treatments. Unidentified species have not been tallied. Numbers in brackets are species restricted to each particular treatment.

	Treatment		Total
	Topsoil and brushmatting	Topsoil only	
Species with soil-stored seed	26(14)	21(9)	35
Species with delayed dehiscence	18(17)	1(0)	18
TOTAL	44(31)	22(9)	53

The number of species with soil stored seed was slightly greater in the presence of brushmatting than without it, (26 versus 21). The limited data suggest that, at least for *Adenanthos cygnorum*, *Pileanthus filifolius* and *Scholtzia capitata*, the brushmatting provided a more suitable environment for germination and establishment.

The brushmatting is very clearly enriching the flora of the rehabilitation areas with species which may otherwise not be on those sites. For this reason alone, the practice of spreading harvested vegetation is a good one.

References

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