Australian Journal of Botany 65(2), 109–119 © CSIRO 2017 http://dx.doi.org/10.1071/BT16104\_AC

## **Supplementary material**

## Rainfall and grazing: not the only barriers to arid-zone conifer recruitment

Heidi C. Zimmer<sup>A,B,D</sup>, Singarayer K. Florentine<sup>A</sup>, Rita Enke<sup>C</sup> and Martin Westbrooke<sup>A</sup>

<sup>A</sup>Centre for Environmental Management, Faculty of Science and Technology, Federation University Australia, PO Box 663, Vic. 3350, Australia.

<sup>B</sup>Present address: NSW Office of Environment and Heritage, PO Box 1967, Hurstville, NSW 1481, Australia.

<sup>C</sup>Office of Environment and Heritage, NSW National Parks and Wildlife Service, PO Box 318, Buronga, NSW 2739, Australia.

<sup>D</sup>Corresponding author. Email: heidi.zimmer@gmail.com



**Figure S1.** PCA of spring 2015 groundcover at 2000-2008 exclosures. Garnpang sites are black points, Mungo sites are white points. Treatments are in text: rabbit exclusion

(Rabbit), large herbivore exclusion (Lge hvore), rabbit and large herbivore exclusion (All) and control.

**Table S1.** Loadings for each ground cover variable by principal component, resulting from PCA of ground cover at 2000-2008 exclosures (see also Figure S1). Key variables in bold.

Groundcover	PC1	PC2	PC3	PC4
Grass	-0.02	-0.57	0.01	0.18
Wood	0.04	-0.42	-0.12	0.61
Litter	0.45	-0.22	0.21	-0.43
Forb	-0.50	-0.12	0.22	0.18
Sub-shrub	-0.55	-0.09	-0.14	-0.12
Cryptogam	-0.30	-0.09	-0.40	-0.45
Shrub	0.38	-0.03	-0.33	0.18
Bare ground				
(ant hole)	0.11	0.07	-0.61	0.04
Tree	0.01	0.25	0.45	0.15
Bare ground	-0.05	0.59	-0.17	0.34

X	Parameter estimates (significant parameters)	<i>P</i> -values	Marginal, conditional R <sup>2</sup>	Model no	AIC					
(a) Plot	(a) Plot scale models of count of 2015 recruitment in the 2000-2008 exclosures.									
Treatment + litter	Rabbit = 2.02, $All = 3.02,$ $LarHerbi = 1.49,$ $Litter = -2.02$	Treat (Rabbit=<0.001, All=<0.001, LarHerbi=0.007),	0.12, 0.95	1	82.3					
Treatment + forb	Rabbit = 1.30	Treat (Rabbit = $<0.001$ )	0.09, 0.93	2	89.1					
Treatment	Rabbit = 1.09, All = 0.94	Treat (Rabbit =<0.001, All = <0.001)	0.05, 0.93	3	89.1					
Treat+ basal area	Rabbit = 1.13, All = 1.01	Treat (Rabbit =<0.001, All = <0.001)	0.06, 0.93	4	89.5					
Treatment +bare ground	Rabbit = 1.47,	Treat (Rabbit =0.01)	0.06, 0.93	5	90.6					
Treatment + bare ground+ basal area	Rabbit = $1.48$ , All = $1.71$	Treat (Rabbit =0.004, All = 0.079)	0.07, 0.93	6	90.9					
Treatment + ground cover summary (PC1)	Rabbit = 1.02, All = 1.16	Treat (Rabbit =<0.001, All=0.04)	0.05, 0.94	7	91.0					
Treatment + sub shrub	Rabbit = 1.08, All = 0.95	Treat (Rabbit =<0.001, All = <0.001)	0.05,0.94	8	91.1					
Treatment + ground cover summary PC1+ basal area	Rabbit = 1.09, All = 1.13	Treat (Rabbit =<0.001, All=0.02)	0.05, 0.94	9	91.4					
(b) Plot-scale	models of recruitment	counts in 2008,2011,2	013 and 2015 in	the 2000-20	008					
Treat + year + rain (1 site)	Rabbit = $1.14$ , All = $1.08$ , Year = $0.60$ , Rain = $0.66$	Treat (Rabbit = <0.001, All=<0.001) Year = <0.001 Rain = <0.001	0.10, 0.91	1	276.5					
Treat+Rain (year site)	Rabbit = 1.14, All = 1.08,	Treat (Rabbit=<0.001, All = <0.001),	n.a.	2	282.6					
Treat + year (1 site)	Rabbit = 1.14, All = $1.08$ ,	Treat (Rabbit = <0.001,	0.07, 0.91	3	289.7					

**Table S2.** Recruitment model comparison. Treatment names are abbreviated: rabbit exclusion (Rabbit), large herbivore exclusion (Larherbi), large herbivore and rabbit exclusion (All).

	Year $= 0.5$	All=<0.001), Year = <0.001							
Treat (year site)	Rabbit = 1.14, Year = 1.08	Treat (Rabbit=<0.001, All = <0.001)	n.a.	4	298.0				
(c) Plot-scale mod	(c) Plot-scale models of recruitment presence or absence in the 2014 exclosures. All models have a								
Traatmont	1000000000000000000000000000000000000		0.08.0.00	1	1/3				
Treatment	A11 - 844.0	<0.01	0.98, 0.99	1	14.3				
	AII = 044.0, L ar Harbi = 844.0								
	Lame 101 - 644.0.								
Basal area	18 41	0.13	0.04 0.99	2	21.5				
Dubui urcu	10.11	0.15	0.01, 0.99	2	21.5				
Ground cover	2.66	0.1	0.81, 0.82	3	19.6				
summary (PC2)			,						
Ground cover	9.02	0.08	0.05, 0.99	4	20.4				
summary (PC1)									
Bare ground	2.24	0.19	0.22, 0.41	5	24.4				



**Figure S2.** Principal components analysis of ground cover at 2014 exclosures in spring 2015. Treatments are rabbit and large herbivore exclusion (all excluded; black), large

herbivore exclusion (grey) and control (white). Points represent individual treatments at each site, with site codes in text.

**Table S3.** Loadings for each ground cover variable by principal component, resulting from PCA of ground cover at 2014 exclosures (see also Figure S2). Key variables in bold.

Ground cover	PC1	PC2	PC3	PC4
Litter	0.07	-0.50	0.46	-0.35
Cryptogam	-0.41	-0.39	-0.17	0.30
Shrub	-0.52	-0.01	-0.21	-0.42
Tree	-0.25	0.00	0.67	0.54
Forb	0.53	0.04	-0.16	0.36
Grass	0.25	0.32	0.42	-0.43
Wood	-0.35	0.40	0.22	0.02
Bare	-0.16	0.58	-0.10	0.09

Table S4. Summary information for recruitment l	hotspots.
---	-----------

Site	Location	Recruitment year	SPEI (recruitment year, year before recruitment, two years before recruitment)	Fenced post- recruitment?	Triodia scariosa present?	Blowout <sup>1</sup>	Minimum height of recruitment (m)	Range in DBH (cm)	DBH (cm) of nearest large, old tree (source tree)
Site A	33.8 S, 142.1 E	~1995	0.07, 1.21, 1.96	Yes (rabbits + large herbivores)	Present	Yes	0.74	1-11	69 (also 81 - dead)
Site Z	33.7 <b>S</b> , 143.0 E	~1988/1989 <sup>4</sup>	1.54, 0.50, 0.80, 0.30	Yes (rabbits)	Absent (but present nearby)	Somewhat	0.03	3.0 - 27.2	216 <sup>2</sup>
Site S1	33.3 S, 141.6 E	~1983/1984	1.28, -0.58, -0.98, -1.64	Yes (large herbivores)	Absent (but present nearby)	Yes	>1.35	13-61	87
Site S3	33.3 S, 141.6 E	~2011	2.15, 0.226, -0.70	No	Absent	Yes	0.11	None	130
Site T1	33.7 S, 142.9 E	~1991	-0.45, 0.07, 1.47	Yes (rabbits + large herbivores)	Present	Yes	>1.35	8.9-45.2	62.5
Site T3	33.6 S, 142.9 E	~2005	-0.58, -0.76, -1.17	No	Present	Yes	>1.35	1.9-21.5	99 <sup>3</sup>
Site T4	33.6 S, 143.0 E	~2005, 2015	-0.75, -0.93, -2.33 (and as for T3)	Yes (rabbits + large herbivores)	Present	Yes	0.17	8.6 - 22.7	86

<sup>1</sup>Concave depression >5 m in diameter, on the crest or slope of a dune, characterised by loose sand/disturbance
<sup>2</sup>Fused with a *Schinus* sp. which may influencing size measurement, next closest large *C. glaucophylla* was 136 cm DBH.
<sup>3</sup> There was also a large tree 227 cm DBH nearby.
<sup>4</sup> Small recruits were fenced then; recruitment occurred in the years before.

	Total BA (m <sup>2</sup> )*	DBHmax (cm)	DBH mean (SD) (cm)	Stem count
2000-2008 exclosures				
Garnpang00	268.69	58.8	35.6 (13.8)	22.0
Garnpang08	277.08	45.7	26.6 (10.4)	42.0
Mungo00	275.68	78.0	19.3 (21.3)	45.0
Mungo08	512.28	69.0	27.0 (12.3)	65.0
2004 exclosures				
В	390.13	60	29.2 (15.2)	46
B2	594.88	70	31.8 (15.3)	61
С	1375.36	63	17.9 (10.4)	410
C2	852.79	92	39.4 (22.5)	53
GS**	1152.61	37	17.9 (8.2)	379
L	912.60	63	25.7 (11.6)	146
М	1370.32	70	18.5 (10.6)	386
W	1088.10	73	27.7 (11.0)	156

**Table S5.** Characteristics of mature *Callitris glaucophylla* in 2000-2008 and 2014

 exclosures. The exclosures with the highest recruitment in each group are in bold.

\*Total BA for 2000-2008 exclosures is across al exclosure area 0.5 ha. Total BA for 2014 exclosures is across al exclosure area 1.5 ha. \*\* Data for GN was not available; the nearest site for comparison is GS.