Using plant functional traits to predict ecosystem vulnerability to changing fire regimes

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Project Objectives

Australia lacks a coherent approach for synthesizing plant functional traits to predict the response of ecosystems to changing fire regimes. Large plant community datasets already exist for major ecosystems in Australia, from rainforests to deserts. This working group aimed to attribute species into fire persistence groups, with the objective of predicting the persistence (bud resprouting type) of the species comprising a community in relation to resource gradients and fire regimes using a new scheme, the Buds-Protection-Resource scheme (BPR) (Clarke *et al*. 2013). Our analyses focussed on creating predictive models with accompanying levels of confidence. Our working group added value to the work of a previous ACEAS working group (Murphy *et al*. 2011; Bowman *et al*. 2013; Murphy *et al*. 2013) by linking their predicted changes in fire regimes to biodiversity effects. Our analyses incorporate an understanding of plant fire resilience traits and the role of the persistence niche into the whole of continent approach developed previously.

Methods

We collated records from 6031 plots of fire resprouting (resprouting R+, or killed, R-) and post-fire seedling recruitment (post-fire seeding S+, or not, S-) for 3,421 woody taxa (species and subspecies, forms and variants) from all the major ecosystems in Australia that account for ~84% of Australia's land cover. These ecosystems were rainforest (tropical, warm temperate and cool temperate), eucalypt forest (wet and dry sclerophyll), savanna (tropical and temperate), eucalypt shrubland (mallee), Acacia shrubland (brigalow, gidgee and mulga), heath (tropical and temperate), 'tussock' grassland (C_4 tropical and subtropical), and 'hummock' spinifex grassland. Plots ranged in size from 25m² for heath to 1000m² for savanna and forest. Only native 'woody' taxa, including those 'herbaceous' taxa with woody underground structures, were included in the analyses. A digital vegetation map of Australia (National Vegetation Information System, 2012), showing the estimated distribution of major vegetation types at the time of European colonisation, was reclassified to indicate the eight ecosystems (listed in Tables 3 and 5) for which resprouter and seeder proportions were estimated. Maps were created of the proportional representation of resprouting and seeding types, and resprouting types (basal, epicormic, underground, apical) in each ecosystem by assigning a numeric value representing the proportion of the relevant class (resprouter, seeder, basal, epicormic, underground, apical) to the mapped ecosystem classes.

To evaluate the extent to which the prevalence of fire response traits (R+ and S+) were correlated with environmental and ecological variables (vegetation type, climate, soil, fire activity), we calculated the mean proportion of R+ and S+ for 100 × 100 km cells across Australia (resulting in 123 attributed cells). For each cell we derived estimates of:

- mean annual rainfall,
- interannual rainfall variability ([90th percentile - 10th percentile]/50th percentile),
- soil phosphorus,
- coefficient of variation of annual burnt area within a 50 km radius,
- typical fire type (i.e. crown vs. surface), and
- vegetation flammability (i.e. pyrophobic vs. pyrogenic).

We used multiple linear regression within an information-theoretic modelling framework to identify important correlates of mean proportion of R+ and S+.

Major Findings

- Resprouting after fire is ubiquitous across Australian ecosystems (Figure 1).
- The level of the resprouting response is strongly linked with landscape productivity at a continental scale and is correlated with fire frequency at local scales.
- The level of the seeding (event driven recruitment) response is associated with crown fire and fire intensity.
- Savanna had the highest proportion of resprouting woody taxa and eucalypt shrubland (mallee had the fewest (Table 1).
- The mallee ecosystem had the highest number of fire-cued seeder taxa (Table 2).
- Shrubs had the highest proportion of post-fire resprouting taxa (51.6%) while parasitic, needle-leaved trees and tropical deciduous trees had the lowest (< 1%).
- Apical resprouting occurred in just 1.7% of the flora whereas many more taxa were capable of basal resprouting (42.9%) and epicormic resprouting (13.07%).
- Resprouting from underground structures (2.7%) was rare.
- Basal resprouting was most common in rainforest (70.7%) although few of these taxa are fire stimulated seeders.
- Epicormic resprouting was most common in the savanna (51.9% of taxa) where there were moderate proportions of fire-cued seeder taxa (55.3%) that were mostly shrubs.
- As mallee and heath ecosystems had much lower levels of resprouting taxa, these systems may be particularly susceptible to any increase in fire frequency.
- Most other ecosystems, particularly tropical savannas, appear to be predisposed through the resprouting response of their component species, towards coping with increased fire frequency in the future.

Key papers or products

- Maps of the current resprouting and seeding responses of all Australian pyromes (*sensu* Archibald *et al*. 2013).
- Predictive models of ecosystem resilience to future fires.

- Clarke, P.J., Lawes, M.J., Murphy, B.M., Russell-Smith, J., Nano, C.E.M., Bradstock, R., Enright, N.J., Fontaine, J.B.,Gosper, C.R., Radford, I., Midgley, J.J. & Gunton, R.M. (submitted) Post-fire recovery traits of woody plants in Australian ecosystems: A continental synthesis for predicting the effects of changing fire regimes.
- Clarke, P.J., Lawes, M.J., Murphy, B.M. & ... (in prep) Post-fire recovery traits of woody plants in Australia: Predicting the effects of changing fire regimes and productivity. To be decided.
- Harrison, S.P., Kelley, D.I., Wang, H., Herbert, A., Li, G., Bradstock, R., Fontaine, J.B., Enright, N.J., Murphy, B.P., Pekin, B., Penman, T., Russell-Smith, J. & Wittkuhn, R. (submitted) Patterns in the abundance of fire-response resprouting in Australia based on plot-level measurements.

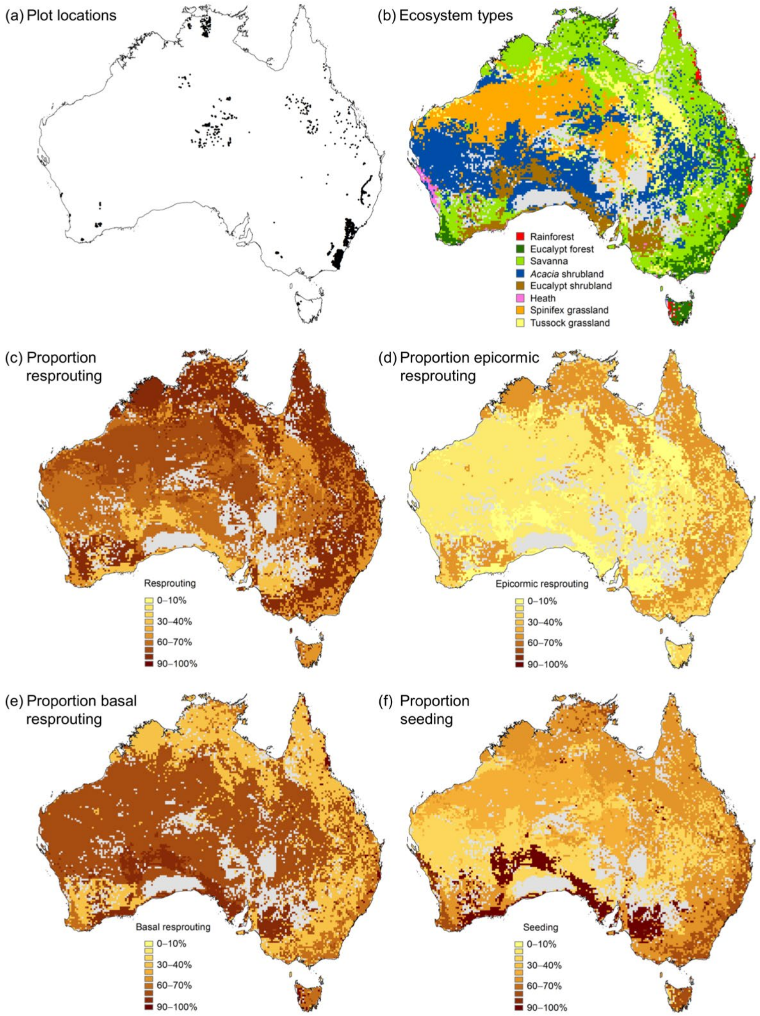

Table 1. Number of resprouting taxa (%) and types of resprouting among ecosystems

Ecosystem	Resprouting (%)							
	Resprouter	Nonsprouter	Total	Apical	Epicormic	Basal	Underground	Total
Forests/woodlands								
Rainforest (tropical and temperate)	181 (78.0)	51	232	6 (3.3)	10 (5.5)	164 (90.6)	1 (0.5)	181
Eucalypt forest (wet and dry sclerophyll)	690 (59.8)	463	1153	27 (3.9)	166 (24.1)	473 (68.5)	24 (3.5)	690
Savanna (tropical and temperate)	206 (87.7)	29	235	5 (2.4)	122 (59.2)	77 (37.4)	2 (1.0)	206
Shrublands								
Eucalypt shrubland (Mallee)	82 (38.1)	133	215	0 (0)	6 (7.3)	69 (84.1)	7 (8.5)	82
Acacia shrubland (Brigalow, Mulga, Gidgee)	116 (63.0)	68	184	0 (0)	19 (16.4)	87 (75.0)	10 (8.6)	116
Heath (wet and dry heaths)	323 (52.0)	298	621	10 (3.3)	33 (10.9)	242 (79.6)	19 (6.2)	304
Grasslands								
Tussock grasslands (tropical and subtropical)	54 (50.5)	53	107	0 (0)	0 (0)	42 (77.8)	12 (22.2)	54
Spinifex grasslands (Triodia)	95 (71.4)	38	133	1 (1.0)	18 (18.9)	75 (78.9)	1 (1.0)	95
Total	1747 (60.7)	1133	2880	49 (2.8)	374 (21.6)	1229 (71.1)	76 (4.4)	1728

Figure 1. (a) Location of plots for attribution of woody taxa by growth form, resprouting type and seeding type. (b) The distribution of the eight major ecosystems for which prevalence of resprouting and seeding were estimated. (c-e) The proportion of woody taxa that resprout after fire (R+). High levels of resprouting occur in the tropical and temperate savannas where most trees have thick bark and epicormic resprouting. More woody taxa are killed by fire in the mallee and heathland of southern Australia. Remarkably, rainforest taxa are generally not killed by fire but resprout basally. (f) The proportion of woody taxa that have strong fire-cued recruitment after fire (S+). The highest levels of seeding are particularly common in mallee and heath vegetation of southern Australia but can also occur in the tropical zone heathlands. Low levels of post-fire recruitment were prominent in the arid Acacia communities that less rarely burn at high intensity. Grey areas are ecosystems that were not sampled and comprise 16% of Australia's land surface area.

Table 2. Number (%) of 'seeding' (S+) woody taxa present in the ecosystems.

Ecosystem	Seeding (%)		
	Seeder	Nonseeder	Total
Forests/woodlands			
Rainforest (tropical and temperate)	46 (20.4)	179	225
Eucalypt forest (wet and dry sclerophyll)	500 (76.6)	153	653
Savanna (tropical and temperate)	130 (55.3)	105	235
Shrublands			
Eucalypt shrubland (Mallee)	197 (92.9)	15	212
Acacia shrubland (Brigalow, Mulga, Gidgee)	50 (27.5)	132	182
Heath (wet and dry heaths)	528 (88.0)	72	600
Grasslands			
Tussock grasslands (tropical and subtropical)	60 (60.0)	40	100
Spinifex grasslands (Triodia)	57 (43.8)	73	130
Total	1568 (67.1)	769	1337

Participants of the second meeting of the working group (L-R): Catherine Nano, Ross Bradstock, Mike Lawes, Neal Enright, Sandy Harrison, Bill Hoffmann, Richard Gunton, Doug Kelley, Peter Clarke, Brett Murphy and Gareth Hempson.

How will this affect Australian ecosystem science & management?

The syntheses conducted by this working group brought together three key elements for the first time:

(i) Vegetation data custodians from contrasting Australian ecosystems that are vulnerable to fire (arid, alpine, tropical, temperate and Mediterranean-type).

(ii) Integration of these data with a global framework for attributing species response to fire (Buds-Protection-Resources scheme); and

(iii) Using innovative methods to identify and interpret plant fire traits to model the resilience of contrasting ecosystems to fire.

Our assessment of the proximal patterns of resprouting and seeding responses across all major ecosystems provides an empirical basis for better prediction of ecosystem assembly and resilience to changing fire regimes on the Australian continent. Our findings demonstrate that plant fire response traits differ among growth forms and ecosystems because of the historically contingent effects of climate, soils and fire. The ecosystem-specific scenarios identified by this working group permit prediction of the effect of changing fire regimes on plant community assembly on this flammable continent.

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