

# Plant size and resprouting ability: trading tolerance and avoidance of damage?

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## Summary

**1** Resprouting has been much studied in mature plants and seedlings, but with little attention to how resprouting ability may change with ontogeny in cross-species datasets. Because damage exposure and avoidance through large size may differ between growth forms, size-stage, growth form and disturbance type may interact.

**2** A Bayesian mixed-effects model was used to analyse a wide-ranging literature dataset of resprouting responses following clipping or burning. There were distinct ontogenetic patterns of resprouting ability between growth forms. In ground-dwelling plants, seedling resprouting ability was high and was maintained as plants grew. In trees, survivorship increased with size-stage. However, for disturbances resulting in stem-kill, resprouting ability of trees declined with increasing size.

**3** The finding of distinct ontogenetic patterns of sprouting ability between growth forms demonstrates how species trade-off damage avoidance with resprouting ability to achieve persistence, and provides an example of the life-history trade-off of avoidance and tolerance of damage.

**4** Large random effects associated with between-species variation indicated that although such ontogenetic patterns can be detected, each growth form contains species employing diverse strategies. Bayesian modelling enables flexible and powerful analyses of literature datasets, to reveal diverse strategies often obscured by classical analyses exploring only main effects.

*Key-words:* Bayesian statistics, damage avoidance, damage tolerance, disturbance response, ecological strategies, growth form, plant functional types, research synthesis, sprouting, vegetation dynamics

*Journal of Ecology* (2006) **94**, 1027–1034

doi: 10.1111/j.1365-2745.2006.01154.x

## Introduction

Disturbance and the possibility of damage are ubiquitous aspects of the life of plants. Damage can in many cases be avoided, often referred to as resistance in the herbivory literature (van der Meijden *et al.* 1988; Mauricio *et al.* 1997). Resprouting is a key strategy for plants faced with unavoidable disturbances causing the loss of most above-ground biomass. As a species trait, resprouting is part of a complex demographic trade-off and potentially can vary with disturbance type and intensity, and environmental productivity, among other factors (Bellingham & Sparrow 2000; Bond & Midgley 2001, 2003; Del Tredici 2001; Vesk & Westoby 2004b). In the spirit of simplicity, Bond & Midgley (2001, 2003)

suggested focusing on the resprouting capacity of mature plants for the contribution to persistence, as resprouting by seedlings can be considered to be part of the regeneration niche (Grubb 1977). The questions that arise are whether the resprouting abilities of seedling and mature stages are generally related across species, and if this is the case, how? Here, I address these questions drawing on the published literature on resprouting following clipping or burning.

Hodgkinson (1998) suggested that within-species resprouting ability could be adequately described by three stages (based on shrubs of semi-arid eastern Australia): (1) established seedling stage (height ~5 cm); (2) the stage of first acquiring maximum resprouting ability (25–60 cm); and (3) at the onset of maturity. Bond & van Wilgen (1996) identified four curve types for survivorship of fire through ontogeny: (1) early increase of survivorship, thereafter maintained; (2) a

linear increase; (3) an initial increase followed by a decline; and (4) perpetual low survivorship. However, survivorship is a function of avoidance of mortality risks by size and defence (Jackson *et al.* 1999), as well as resprouting ability. If plants can avoid stem-kill (loss of above-ground biomass, also known as top-kill) then there is no need for resprouting ability (Hoffmann & Solbrig 2003).

For some species, such as semi-arid shrubs, resprouting ability appears to track survivorship, which increases with size (Hodgkinson 1998). Yet although fire survivorship of many trees species in savannas and temperate forests increases with size, resprouting ability actually declines (Bond & van Wilgen 1996; Jackson *et al.* 1999; Bond & Midgley 2001; Del Tredici 2001). This has also been found for *Calluna vulgaris* in Scottish heaths (Kayll & Gimingham 1965), shrubs of *Erica* from California and South Africa (Keeley 1986; Ojeda 1998) and Australian Epacridaceae (Bell & Pate 1996).

The probability of stem-kill by disturbance such as browsing or low-intensity fire is reduced in larger plants (Burrows 1985; Hoffmann & Solbrig 2003), in the sense both of larger individuals of a given species and of species with potentially large mature size. This has at least two components. First, bark thickness, and thus cambial insulation, increase with stem diameter (Gill & Ashton 1968; Vines 1968; Ryan & Reinhardt 1988; Uhl & Kauffman 1990). Second, greater height means that buds can be elevated beyond the reach of browsing herbivores, or lethal heating from low-intensity fire (Gill 1981; Morrison & Renwick 2000). The potential size of the plant can thus influence avoidance as, for instance, ground plants have limited opportunity to avoid fire or severe herbivory through size. Yet, given a disturbance that results in stem-kill, resprouting ability may actually decline as plants become larger (Burrows 1985). It is important to note that for some long-return disturbances, such as crown fires or catastrophic windthrow, size may not increase damage avoidance (Peterson & Pickett 1991; Peterson & Rebertus 1997).

Thus, we may expect that the potential size of the plant, the ontogenetic stage and the definition of disturbance intensity all interact to influence damage avoidance, survivorship and the need for resprouting. In this paper, I use a literature dataset to investigate the distribution of resprouting ability between species after clipping and burning in different ontogenetic stages. Specifically, I assess whether there is evidence for interaction between these factors, and how the ontogenetic pattern of resprouting ability and survival may differ among growth forms (as a proxy for potential size). Phylogenetic analyses are not reported here (however, see Vesik & Westoby 2004b) because previous studies have demonstrated that resprouting is a phylogenetically widespread and labile trait across broad phylogenetic trees (Vesik & Westoby 2004b) and within particular clades (Schwilk & Ackerly 2001; Bond & Midgley 2003).

## Methods

### DATA

A database of resprouting responses of plants after clipping or fire was assembled (Vesik & Westoby 2004b). Briefly, studies reporting quantitative data on resprouting were located using the bibliographic database BIOSIS (1973–2001) and reference lists of other papers. Species may occur more than once in a study if different size stages were studied or different treatments were applied. Species may also occur in multiple studies. Where species occurred more than once for a given combination of disturbance and size class, samples were summed for analysis. Studies may report more than one disturbance class. The main analysis reported here concerns 892 records of sprouting responses (as  $n$ , the number of plants, and  $r$ , the number resprouting) unevenly distributed across 561 species from 72 studies, three disturbance classes, and late seedling and juvenile/mature stages (Table 1). The species and stages were

**Table 1** Species representation of size-structured resprouting responses among disturbance classes and vegetation types according to Walter (1984) in the main analysis. Seedlings are late stage, juv/mat is aggregated class of juvenile and mature plants; see text for details

Vegetation type	Disturbance class						Total
	General fire		Stem kill fire		Base clip		
	seedling	juv/mat	seedling	juv/mat	seedling	juv/mat	
Glasshouse	40		33		54	15	142
1. Evergreen rain forest		18		20		20	58
2. Semi-evergreen and deciduous forest	26	75	11	53			165
2a. Dry woodland, savannas, grasslands		30	5	60		53	148
4. Sclerophyll woodlands, winter rain	1	59	3	42		11	116
5. Moist warm temperate woodland	13	80	16	54	16	9	188
6. Deciduous forest				29		3	32
7. Temperate steppe				7	1	3	11
7a. Semi-desert, desert with cold winter	1	18		8	1	4	32
Total	81	280	68	273	72	118	892

unevenly distributed among vegetation types, with a majority of responses coming from various woodlands. Resprouting ability varies across vegetation types (Vesk & Westoby 2004b). This potentially may have biased the analyses, but sample sizes were insufficient to analyse the vegetation types separately, and thus I do not consider vegetation type further.

Records were broadly categorized by size- or age-stage and disturbance class. Size-stages were distinguished based on authors' descriptions, stem diameter, height and age, life history and reproductive status. I recognized three broad stages: (1) early seedlings, < 3 months; (2) late seedlings, 6–18 months or shrubs < 10 cm tall or < 5 mm in basal diameter, or trees < 1.3 m tall; and (3) juvenile or mature plants. In no case was small size used to infer young age, although the reverse may apply, young plants could not be classified as mature. Ground plants (e.g. forbs, grasses and subshrubs) were considered to be mature when > 1 year old. I do not report variation between sizes of established plants because of small sample sizes.

Disturbance classes were assigned by nature and intensity of damage, as with Vesk & Westoby (2004b), but combining the 'Crown-kill' and 'Other Fire' classes because of low numbers, to yield the following (with typical descriptors): (1) fires resulting in stem-kill (burnt to ground level, burns preceded by clipping or 'extreme' fire); (2) general fires; and (3) clip (plants cut at base, below 20 cm). For early seedlings, clipping was at the cotyledonary node; for late seedlings, clipping was below 5 cm height.

#### ASSESSING PATTERNS OF RESPROUTING ABILITY

Broad patterns of resprouting ability were assessed using histograms. Subsequently, the probability of resprouting was modelled with a Bayesian Generalized Linear Model with binomial error structure (Congdon 2001). A Bayesian approach was used for the flexibility of modelling and estimating parameter distributions (Link *et al.* 2002; Clark 2005). Models were fit using the Bayesian statistical modelling software WINBUGS 1.4.1 (Lunn *et al.* 2000), available from <http://www.mrc-bsu.cam.ac.uk/bugs/>. There were three fixed effects – size, disturbance and growth form. Size included two levels: late seedling and juvenile or mature. Three levels of disturbance were modelled: stem kill due to fire; other, general fires; and base clip. Three growth forms were included: ground plants, shrubs and trees. Unfortunately, insufficient sample numbers prevented the ground plant class being split into further growth-form classes. All three two-way and interactions the single three-way interaction were included. Random effects terms were included for species and the study or paper from which the data were sourced. One would expect that a single species should have similar resprouting responses in multiple trials and that any of the fixed effects would be more accurately characterized within

a species. It might also be expected that the results from a particular paper might be similar because they share a disturbance, location and size categorization. Thus, these terms were included in the full model:

$$\log\left(\frac{p(x)}{1-p(x)}\right) = \alpha_0 + \alpha_g x_g + \alpha_d x_d + \alpha_s x_s + \alpha_{gd} x_g x_d + \alpha_{gs} x_g x_s + \alpha_{ds} x_d x_s + \alpha_{gds} x_g x_d x_s + \beta_{sp} x_{sp} + \beta_p x_p \quad \text{Eqn 1}$$

where  $p$  is the probability of resprouting,  $\alpha$  denotes a fixed effect coefficient,  $\beta$  denotes a random effect coefficient and  $x$  is a predictor variable; subscripts  $g$ ,  $d$  and  $s$  denote growth form, disturbance and size, respectively. The data were modelled as binomially distributed with order (sample size)  $n$  and rate  $r$ . All fixed effect coefficients were modelled as normally distributed, with minimally informative priors (means 0.0, standard deviations 1000). Random effect coefficients were drawn from a normal distribution with mean 0.0 and unknown variances. These random effect variances were modelled as belonging to gamma distributions, with parameters  $r = \mu = 0.001$ , which yields conjugate yet minimally uninformative priors. In an alternative parameterization, the coefficients for the two random effects were modelled as normally distributed with mean 0.0 and standard deviations drawn from a uniform distribution over the interval (0, 100). This parameterization sometimes led to Markov chains with better sampling properties (lower autocorrelation and quicker convergence) but with essentially similar results. Three chains with different initial values (–1, 0, 1) were run simultaneously for each model run. Typically, chains showed evidence of autocorrelation, and thinning of chains, by up to 1 in 40 samples, was used to improve independence of posterior probability estimates. Burn-in phases were in all cases > 1500 iterations, after thinning.

Bayesian 95% credible intervals were calculated from the posterior probability density of monitored parameters, in each case > 10 000 samples, after thinning. Standard Bayesian diagnostics were used to assess convergence, including plots of each of chain traces, chain auto-correlations and the Gelman–Rubin statistic (Spiegelhalter *et al.* 1995; Zuur *et al.* 2002).

A series of models were investigated by removing terms from the full model (eqn 1) and compared using the Deviance Information Criterion (DIC) (Spiegelhalter *et al.* 2002), calculated with WINBUGS. The DIC estimates the information captured by a model of the data penalized for the estimated number of parameters in the model, and is intended as a generalization of Akaike's Information Criterion (AIC) for the purpose of model selection (Spiegelhalter *et al.* 2002). Indeed, in models with negligible prior information, DIC is approximately equivalent to AIC (Spiegelhalter *et al.* 2002). The model with the lowest DIC from a set of models fitted to the same dataset is the model that would be most likely to produce a dataset of the same structure as that observed. The DIC assumes that the

posterior mean is a good estimate of the stochastic parameters. If posterior distributions are highly skewed or multimodal, then the mean is not a good estimate for the parameter and DIC may be inappropriate. Routinely, I checked the posterior distributions for evidence of skew and multimodality. There was no such evidence. The percentage of deviance explained by a fitted model was calculated by first estimating the ‘total deviance’ by the posterior mean of the deviance for a model with only the intercept included. The percentage deviance explained by a particular fitted model was then the total deviance minus the deviance for the fitted model, divided by the total deviance.

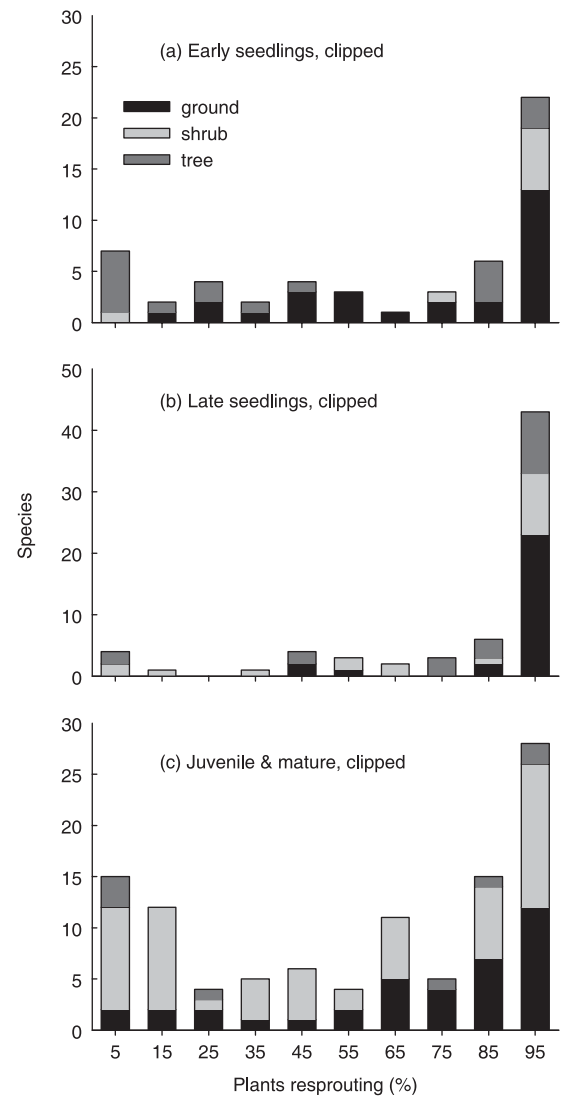
**Results**

**DISTRIBUTION OF RESPROUTING ABILITY AMONG SPECIES IN DIFFERENT STAGES AND DISTURBANCES**

Resprouting was common for species when clipped as early or late seedlings; few species failed to resprout (Fig. 1a,b). Forty-three per cent of species had  $\geq 90\%$  of plants resprout after clipping as early seedlings (Fig. 1a), and 70% of species had  $\geq 90\%$  of plants resprout at late seedling stage (Fig. 1b). Many more species failed to resprout after clipping as juveniles or mature plants, and this pattern was more pronounced for shrubs and less for ground plants (Fig. 1c). By contrast, many species failed to resprout after fires at late seedling stage (Fig. 2a). Thirty-six per cent of species had  $\leq 10\%$  plants resprout after burning. Many species were intermediate in their ability to resprout as late-stage seedlings following fire (26% of 66 species had 30–70% of plants resprout). A greater proportion of large plants resprouted after burning than did late seedlings (Fig. 2a,b). These results indicate that although the ability for seedlings to resprout after clipping (mimicking herbivory) is widespread, far fewer species are able to resprout following fire.

**MODELLING OF RESPROUTING PROBABILITY AS AFFECTED BY GROWTH FORM, DISTURBANCE TYPE AND STAGE**

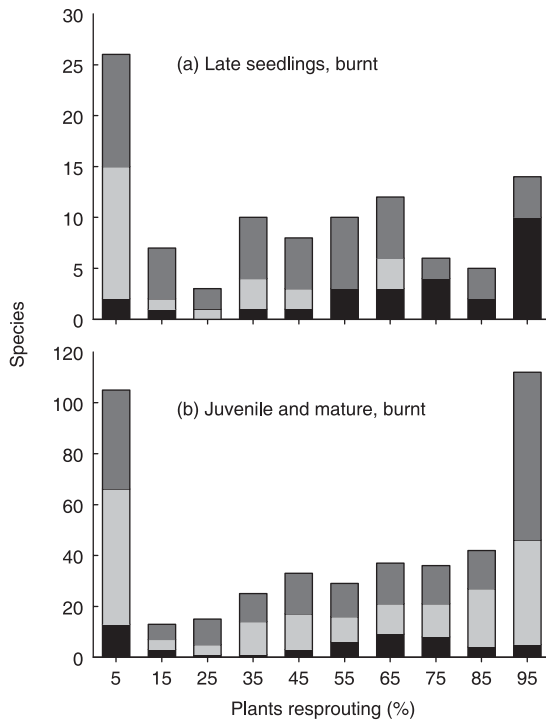
The ‘best’ model, as estimated by the DIC, was the full model, explaining  $\sim 90\%$  of the deviance (Table 2). Thus, predictions from this model were used; parameter estimates are given in Table 3. There was clear evidence that transitions between seedling and later stages were associated with changes in resprouting ability that were dependent upon the growth form and the nature of the disturbance (Fig. 3). Ground plants had generally high resprouting ability (Fig. 3a). Seedlings were no less likely to resprout than juvenile or mature plants, regardless of the disturbance (Fig. 3a). In fact, seedlings of ground plants have marginally higher predicted probabilities of resprouting after general fires and after clipping than juvenile and mature plants (Fig. 3d).



**Fig. 1** Frequency histograms of resprouting proportions for clipped plants: (a) early seedlings,  $n = 54$ ; (b) late seedlings,  $n = 67$ ; (c) juvenile and mature plants,  $n = 104$ . Black shading indicates ground plants, pale shading represents shrubs and dark grey shading represents trees.

**Table 2** Comparison of models for resprouting probability removing various terms from the full model (see eqn 1). DIC is Deviance information Criterion (Spiegelhalter *et al.* 2002),  $\bar{D}$  is the posterior mean of the deviance

DIC	$\bar{D}$	Explained deviance (%)	Terms omitted from full model
4597	4081	90	—
4758	4245	90	$\alpha_{ids}$
4847	4338	89	$\alpha_{ids}\alpha_{id}$
4894	4383	89	$\alpha_{ids}\alpha_{is}$
6232	5737	86	$\beta_p$
6233	5725	86	$\alpha_{ids}\alpha_{is}$
22 830	22 740	45	$\beta_{sp}$
35 125	35 107	15	$\beta_p\beta_{sp}$
35 943	35 929	13	$\alpha_{ids}\beta_p\beta_{sp}$



**Fig. 2** Frequency histograms of resprouting proportions for burnt plants as: (a) late seedlings,  $n = 95$ ; and (b) juvenile and mature plants,  $n = 293$ . Black indicates ground plants, light grey represents shrubs and dark grey represents trees.

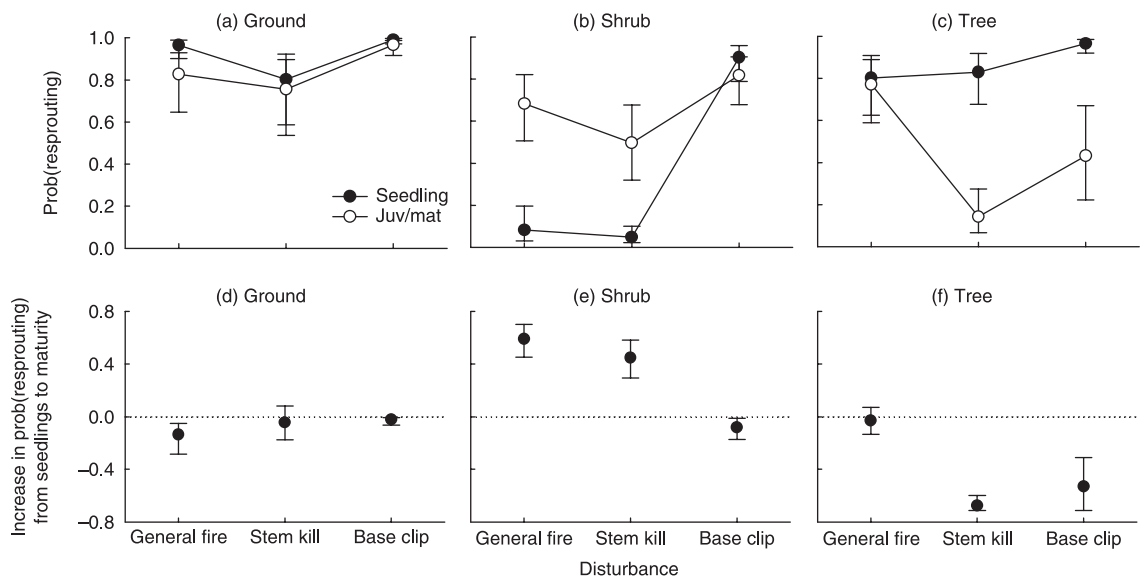
Shrub seedlings, by contrast, had generally poor resprouting ability after stem-killing and general fires, much poorer than juvenile and mature plants (Fig. 3b,e). Shrubs were predicted to have high resprouting ability following clipping regardless of size stage.

Tree seedlings had high resprouting ability regardless of disturbance (Fig. 3c), similar to ground plants.

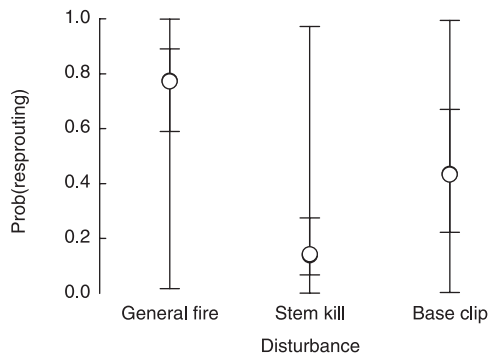
**Table 3** Parameter estimates calculated from posterior distributions from the full mixed-effects model predicting resprouting ability from growth form, disturbance and size of plants. The cell means model used holds the first level of each model term constant, i.e. ground plant, stem-kill and seedling for growth form, disturbance and size stage, respectively. Parameter estimates for other levels are expressed relative to that reference level. Model terms are as in eqn 1, levels for each term are given in square brackets.  $\sigma_p$  and  $\sigma_{sp}$  are standard deviations of the random effects distributions for papers and species, respectively

	Mean	SD	2.5% CI	97.5% CI
$\alpha_0$	1.421	0.525	0.419	2.464
$\alpha_g$ [shrub]	-4.405	0.468	-5.318	-3.473
$\alpha_g$ [tree]	0.158	0.533	-0.895	1.195
$\alpha_{gd}$ [shrub, clip]	1.94	0.472	1.014	2.87
$\alpha_{gd}$ [shrub, fire]	-1.355	0.486	-2.319	-0.423
$\alpha_{gd}$ [tree, clip]	-1.532	0.414	-2.35	-0.734
$\alpha_{gd}$ [tree, fire]	-2.107	0.379	-2.859	-1.378
$\alpha_{gds}$ [shrub, clip, juv/mat]	-2.677	0.511	-3.693	-1.679
$\alpha_{gds}$ [shrub, fire, juv/mat]	1.701	0.531	0.671	2.749
$\alpha_{gds}$ [tree, clip, juv/mat]	0.806	0.512	-0.194	1.818
$\alpha_{gds}$ [tree, fire, juv/mat]	4.696	0.461	3.799	5.61
$\alpha_{gs}$ [shrub, juv/mat]	3.244	0.385	2.478	3.986
$\alpha_{gs}$ [tree, juv/mat]	-3.11	0.377	-3.862	-2.382
$\alpha_d$ [clip]	3.272	0.366	2.576	4.006
$\alpha_d$ [fire]	1.924	0.313	1.33	2.542
$\alpha_{ds}$ [clip, juv/mat]	-1.023	0.398	-1.818	-0.258
$\alpha_{ds}$ [fire, juv/mat]	-1.49	0.372	-2.221	-0.774
$\alpha_s$ [juvenile/mature]	-0.273	0.356	-0.956	0.447
$\sigma_p$	2.301	0.272	1.824	2.898
$\sigma_{sp}$	2.653	0.117	2.433	2.892

Although the resprouting ability of juvenile and mature trees was similarly high after general fires, the probability of resprouting after fires resulting in stem-kill was low, considerably lower than for seedlings. Similarly, for trees cut at their base, juvenile and mature plants



**Fig. 3** (a–c) Predicted probabilities of resprouting for plants of different size stages from different growth forms and exposed to different disturbances. (d–f) Predicted difference between the probabilities of resprouting for seedling and larger plants. Symbols represent medians and Bayesian 95% credible intervals from a Bayesian logistic regression model.



**Fig. 4** Comparison of 95% credible intervals about predicted mean probabilities of resprouting for juvenile and mature trees. Inner intervals and means are equivalent to Fig. 3(c), and represent parameter uncertainty, i.e. about the location of the mean prediction. Outer intervals incorporate between-species variability, i.e. true variation in resprouting probability for a species chosen at random.

had low resprouting ability. Thus, for disturbances resulting in stem-kill, mature trees had very much lower resprouting ability than tree seedlings (Fig. 3f).

#### PREDICTION AND RANDOM EFFECTS

Removing the species' random effect had a very large effect on the DIC and halved the explained deviance (Table 2). The random effect for study had a much smaller effect alone, but together the two random effects accounted for 85% of the explained deviance. This means that species vary widely in their resprouting ability within a specific combination of growth form, disturbance type and ontogenetic stage. Thus, although clear evidence was found of different mean ontogenetic patterns for combinations of growth form and disturbance type, the variation associated with species was overwhelming. Credible intervals that incorporated the variation between species were far larger than those around mean effects (Fig. 4). Thus, predicting species responses based on these factors (size-stage, growth form, disturbance class) has little specificity.

#### Discussion

This study has shown that plant resprouting ability may change through ontogeny. At least some of the changes can be explained by exposure to, and possibility of avoiding, damage. Yet considerable variation exists between species with similar exposure and avoidance ability. Previous studies have demonstrated an ontogenetic change in resprouting ability, but only in single species or relatively small cross-species datasets (Kayll & Gimingham 1965; Burrows 1985; Keeley 1986; Bell & Pate 1996; Bond & van Wilgen 1996; Hodgkinson 1998; Jackson *et al.* 1999). The current study brings a generalized perspective to this issue.

As seedlings, plants are highly exposed to damage from herbivory and other sources, and thus there is an

imperative for resprouting ability at seedling stages. Seedlings were broadly able to resprout following clipping whereas fewer resprouted after fire, although this pattern was strongest in shrubs. This is consistent with herbivory being a major hazard to seedlings, but for fire to be relatively less important (Leishman *et al.* 2000). Resprouting ability of seedlings (indeed all stages) does vary widely between species (see, for example, Figs, 1, 2 and 4), and will probably be driven by reserves both in cotyledons (Armstrong & Westoby 1993; Harms & Dalling 1997) and post-establishment storage (Klimešová & Klimeš 2003; Walters *et al.* 2005). For ground plants, escape from the reach of terrestrial herbivores and fires is not an option. Thus, resprouting ability throughout the lifetime is at a premium. Trees are able to avoid many disturbances by being large, in particular tall, and by defences (Loehle 1988; Jackson *et al.* 1999). In this case, resprouting ability may be less necessary. Results from disturbances that cannot be avoided, such as when a tree is sawn down or the stem cambium irredeemably burned (as opposed to a blackened trunk), suggest that many species that survive fire by resprouting do so epicormically and that basal resprouting is relatively rare in trees (but see Del Tredici 2001), although this may well differ with site productivity (see below). Broadly, this study suggests that if damage cannot be avoided through growth, resprouting ability should be maintained throughout life. But where growth allows damage to be avoided, then resprouting ability may decline with increased size. The mechanism responsible for declines in sprouting ability is not clear and may include a number of causes. Buds may senesce over time and it is conceivable that buds of different species differ in their longevity (Vesik & Westoby 2004a). Buds may become trapped in bark (Cremer 1972; Fink 1983, 1984). Poor vascular connections between sprouts and roots following resprouting may prevent successful sprouting despite sufficient buds and reserves (Midgley 1996; Del Tredici 2001). Additionally, ongoing respiratory demands of large established root systems following stem kill may prevent buds from successful resprouting if the carbon assimilated through photosynthesis by sprouts is insufficient (Vesik & Westoby 2004a).

This investigation also points to the issue of defining disturbance intensity. Using extrinsic measures of intensity (e.g. Byram's fire intensity or, less well defined, 'crown-fire') as explanatory variables will confound avoidance and resprouting ability. However, intrinsic measures such as leaf scorch or stem-kill are dependent upon species attributes such as size.

Resprouting ability is under selection pressure not only from disturbance regimes but also from site productivity and climate (Specht 1981; Lamont & Markey 1995; Midgley 1996; Iwasa & Kubo 1997; Kruger *et al.* 1997; Ojeda 1998; Bellingham & Sparrow 2000; Clarke *et al.* 2005). Presently, a comprehensive understanding of how resprouting varies along productivity and disturbance gradients is unavailable (Vesik & Westoby

2004b); both increases (Clarke *et al.* 2005) and decreases (Kruger *et al.* 1997) in sprouting ability with increased productivity have been reported. Issues of scope and scale are part of the obstacle, and thus the solution; what part of the disturbance regime spectrum is assessed, and what is the range of site productivity studied? Bellingham & Sparrow (2000) presented a theoretical synthesis by scaling disturbance severity and frequency by site productivity, but an integrated analysis with empirical data has yet to be done.

The use of Bayesian modelling allowed between-species variation to be incorporated into predictions (Clark 2005). The standard credible intervals (analogous to classical confidence intervals) represent uncertainty about the between-species mean. By incorporating the species random effect, which cannot be achieved in a classical analysis, it is possible to appreciate the variation between species within classes and that, in some species, patterns very different from those indicated by the mean can be expected. This demonstrated the low specificity of prediction; this is unsurprising, given that resprouters and non-sprouters are found in most clades, vegetation types and disturbance classes (Figs 1 and 2; Vesik & Westoby 2004b).

Analyses can only be as good as the data on which they are based. There are many limitations in these data, assembled from studies of multiple vegetation types, growth forms and clades; observation error will also be associated with size and disturbance definition. For example, previous work has found that resprouting ability is mixed within growth forms (Bellingham *et al.* 1994; Hodgkinson 1998; Vesik *et al.* 2004), although some growth forms are less variable, e.g. grasses tend to be resprouters and subshrubs from the Chenopodiaceae tend to be non-resprouters (Vesik *et al.* 2004). However, these data do represent the current state of knowledge. The patterns here warrant testing in a more controlled dataset, which may result in predictions with higher specificity; the Bayesian framework enables incorporation of the current results as prior information.

### Acknowledgements

I thank Josh Dorrrough, Dan Falster, Peter Bellingham and two anonymous referees for comments that improved the manuscript.

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Received 23 February 2005

revision accepted 10 May 2006

Handling Editor: Peter Bellingham