A national register for the fire responses of plant species

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Abstract

Gill, A. Malcolm[1] & Bradstock, R.A.[2] ([1] CSIRO Division of Plant Industry, GPO Box 1600, Canberra, ACT, Australia 2601; [2] NSW National Parks and Wildlife Service, PO Box 1967, Hurstville, NSW, Australia 2220) 1992. *A national register for the fire responses of plant species.* Cunninghamia *2(4): 653–660.* Currently, approximately 1 500 vascular plant species have been classified in relation to their fire responses and included in a national fire response register. In a cooperative scheme to which new contributors are welcome, data are being assembled in order to assist in the development of practical scientifically-based monitoring systems for fire-prone plant species. Other uses of the data are to discover species which show ecotypic variation; or, show varying responses depending on the nature of the fires or environments to which they are exposed. The data collated also may be used to help explain ecosystem dynamics through models (e.g. Noble & Slatyer 1980). Fire-response categories are based on the schemes of Noble & Slatyer (1980) and Gill (1981 *a* & *b*). Further data being collated are for life form, conservation status and longevity.

Introduction

Knowledge of the responses of plant species to fires is of intrinsic interest but the information can be used also in the development of practical, soundly-based monitoring systems for fire effects in state forests, national parks and nature reserves. In a pilot system developed for Nadgee Nature Reserve, Gill & Nicholls (1989) used response data for species collected by observers not just at Nadgee but also at other sites, sometimes in other States. This paper reports the initiation and development of a fire response register to facilitate the accumulation and transfer of knowledge across Australia as a means towards the establishment of scientifically based, but practical, monitoring systems for vascular plant species in state forests, parks and reserves. An urgent priority for the fire management of native landscapes today is for effective monitoring systems; with their development and implementation, resource managers will be able to demonstrate their success in the management of plant-species biodiversity.

The aims of this paper are:

(i) to describe the nature of the data being collected and collated;

(ii) to provide the rationale for the adoption of categories of data chosen;

(iii) to examine some of the difficulties involved in classifying certain species and, thereby, encourage study of their autecology;

(iv) to advise scientists and naturalists of the establishment of the register and invite contributions to it.

The register

The register categorises the responses of species to fires but does not provide the basis for the prediction of *population* behaviour in relation to fire regimes (combinations of frequencies, intensities and times of occurrences of fires) in a detailed quantitative way. Nonetheless, the sort of classification described here may flag extreme responses of species to particular fire regimes, such as extinction due to the occurrence of a fire before the onset of flowering in a fire-sensitive species.

Nomenclature for the register follows that of the recent National Checklist of Australian vascular plant species compiled by Hnatiuk (1990). Before entry into the register, species names are standardised according to the national checklist.

Data recorded in the register are:

(i) species (from checklist) - family, genus, species;

(ii) life form - tree, shrub, non-geophytic herb or graminoid, geophyte, epiphyte (including mistletoes);

(iii) fire-response - fire-response category and observer's name;

(iv) longevity - annual, biennial, perennial;

(v) origin - native, exotic;

(vi) other available data, e.g. response at a particular life-cycle stage (seedling, immature, adult, senescent - an additional line entry), primary juvenile period in years after fire for particular areas (local data only as subject to local variation) and special-case fire-regime vulnerability. Whether the species is rare or threatened (Briggs and Leigh 1988) would be identified from current lists.

Which classification of species responses?

There are many species classifications for species in fire-prone environments. They may be divided into three groups: (i) mechanistic; (ii) consequential; (iii) strategic.

'Mechanistic' classifications attempt to group species which have similar means of resistance and recovery in the face of fire. An example of this is the classification of Gill (1975) which distinguishes, among other things, plants that owe their immediate resistance to the thermal properties of a layer of bark or to those of a stem with dispersed vasculature.

'Consequential' classifications are unconcerned with mechanism; the end result is all that matters. An example of this is the scheme devised by Noble and Slatyer (1980) which concerns itself with, among other things, whether or not plants survive a fire rather than how that occurs.

'Strategic' classifications are those which imply behavioural action and tend to be evolutionary in perspective: examples are the classifications of Rowe (1983) and Frost (1984). These distinguish species which are 'evaders', 'resisters', 'endurers', etc. (see also Naveh 1975).

The three approaches outlined above are, in fact, not completely distinct; there are many intermediates and, indeed, the different systems often use similar criteria in arriving at their classifications. Perhaps the mechanistic approach is the most distinct at present. The most comprehensive classification is that of Noble and Slatyer (1980) which includes not just the way a species survives a disturbance, but also its ability to become established and the timing of important events during its life history. No one scheme completely satisfies all users (and uses), nor, perhaps, all circumstances and all levels of knowledge of species' properties.

'Adaptive traits', 'vital attributes' and 'species characteristics'

The most enduring criterion for species response to fires is whether persistence through the event is by seed ('seeders'), or by vegetative means ('sprouters') (e.g. Jarrett & Petrie 1929). Given exposure to the same level of leaf damage (explicit in the classification of Gill (1981*a*) as 100% leaf scorch, but rare elsewhere), most species seem to fall quite readily into one or other of these categories. Even without explicit attention to the level of damage, many species may be readily classified. Beadle (1940), for example, listed the percentage survivals of plants belonging to 13 shrub species without specifying any level of damage: 11 species recorded either 100% death or nil death while the other two were within 12% of these extremes. However, there are species which do have intermediate responses which cannot be attributed to extrinsic factors: Hodgkinson and Griffin (1982) noted that, among the 13 shrub species they observed, mortalities of populations of 10 species were mostly within the range 0–30% or 70–100% while the remaining three species had intermediate mortalities. As a general rule, if mortality within the population with 100% leaf scorch is greater than 70%, then the species would be a 'seeder' species; if mortality is less than 30%, it would be a 'resprouter' species. If there is any doubt into which category a species should be placed, because of intermediate behaviour, the species is better put into both categories with annotation (with a two-line entry into the register).

One expected outcome of the register is to find species which have different responses in different places. In some cases such finds may lead to the discovery of new species such as the *Hakea* species studied by Lee (1984). In other cases, such as hummock grass *Triodia irritans* found in semi-arid NSW and Victoria, resprouting has been observed near Mt Hope, NSW, and in Wyperfeld National Park in northwestern Victoria, but complete mortality has been observed to be a consequence of fire elsewhere (Bradstock 1989). A forest example is *Acacia dealbata* which in mesic forest areas is a 'seeder' but elsewhere is a 'resprouter'(Ashton 1981).

Naveh (1975), in Israel, distinguished three categories of species, viz. 'facultative root resprouters'(termed 'resprouters' here), 'obligatory seed regenerators' (termed 'seeders' here) and 'obligatory root resprouters'. The last of these categories was for species which did not reproduce from seed after fire but did do so vegetatively (i.e. a subsection of 'resprouters'). We do not know whether or not 'obligatory root resprouters' fail to regenerate from seed because there is none available at the appropriate time or because seed present is not stimulated to germinate. The simplest hypothesis is that there is no seed available. If so, knowing that a species falls into this category has particular value in predicting species response to a rare extreme drought (or bulldozing, for example) which may kill the vegetative population. However, classifying a species into this category is difficult because it implies that the reproductive behaviour of the species through time is well known: species with episodic regeneration may seem to be bereft of a seed supply most of the time but may depend on a rare reproductive event for the long-term replenishment of the population.

Noble & Slatyer (1980) and Gill (1981*a*) subdivided the seed regenerators into three identical groups, viz. those that depend on external sources of seed for their representation in the burned area, those that depend on seed stored in the soil for regeneration, and those that depend on canopy-stored seed. The diaspores of species in these three groups show particular morphologies and means of responses to fires, such as hard seededness (many leguminous species - Auld & O'Connell 1991), succulent fruits assisting dispersal (e.g. mistletoes), and containment in large woody fruits (e.g. *Hakea* species). It is tempting to subdivide those species that disperse seed back into an area after fire according to the nature of the diaspore (winged seed, succulent fruit, spore) but the numbers of species involved are small and, therefore, subdivision may be unwarranted. Noble & Slatyer (1980) also had another group which may be seen as a subgroup of those that depend on seed for regeneration; this 'sub-group' was for species that had no available seed storage while the plant was in the juvenile stage (only), a useful subgroup for species such as the annual *Sorghum* species of the Northern Territory which can be eliminated locally by deliberate application of fire in the wet season (Stocker & Sturtz 1966).

We draw attention to a class of species with canopy-stored seed which seems to have been little discussed morphologically. Previously, the canopy-store category has been thought of as containing only species with woody fruits which protected the seed from fire during its passage. However, there are certain *Acacia* species which, when their pods split and reflex, expose seeds which remain on the canopies for considerable periods (O'Dowd & Gill 1986). This seed is likely to be vulnerable to fire. Some of these *Acacia* species, at least, would be expected to have seed stored in the soil as well, and would be best characterised on this basis rather than on canopy storage if the host plants are fire sensitive. An extreme case of this seems to be *Acacia cyclops*, a shrub of coastal areas of Western Australia and South Australia. *A. cyclops* shows storage of seed on canopies for long periods (O'Dowd & Gill 1986) but few seeds stored in the soil, apparently because seeds in soil are destroyed by hemipteran predators (Gill & Neser 1984). In Australia, it would be classified best, on the basis of present knowledge, as a 'seeder' reliant on external seed sources for its re-establishment. In South Africa where it is introduced, however, it would be characterised best as a 'seeder' species with soil-stored seed; there, it stores considerable quantities of seed in soil (see Gill & Neser 1984). These classifications for *A. cyclops* assume that any seed present on the bush at the times of fires would be destroyed or killed. Canopy seed storage also occurs in *Gahnia melanocarpa*, a robust, stemmed sedge, which displays persistent small seeds on thin threads dangling from the parent inflorescence; in this case, however, *Gahnia* is a species which usually survives fire and regrows from terminal buds - a 'resprouter'.

Among the vegetatively regenerating species, Gill (1981*a*) distinguished four categories viz. those regenerating from basal buds, root suckers, epicormic shoots (from aerial stems), or from large aerial apical buds unaffected by the fire. Regeneration from basal buds was distinguished from regeneration by root suckers because the latter have the potential for population growth after a fire event but the former do not. Mature plants regenerating from aerial sources comprised the last two categories of vegetatively regenerating plants: these were distinguished because the mechanisms of response are so different. Species which regenerate from epicormic shoots are trees or tall shrubs which may replenish their leaf populations quickly after fire and thereby shade their competitors. Species which regenerate from large apical buds, like many Xanthorrhoeaceae, may also have a fire-induced flowering response (Gill 1981*b*).

The fire-response categories distinguished for the purposes of the register may be determined from the key in Table 1. Note that while all categories in the table apply to woody plants, not all apply to herbaceous plants. In particular, there will be no entries for herbaceous plants in categories 1 and 6.

Table 1. Key for the classification of species according to their fire responses (after Gill 1981*a*).

Mature plants just subject to 100% leaf scorch from fire die (category 8 if no further data available):

* Propagules present after fire's passage are in the form of viable canopy-stored seed .... **Category 1**
* Propagules present after fire's passage are in the form of soil-stored seed .... **Category 2**
* No propagules remain on the site after fire .... **Category 3**

Mature plants just subject to 100% canopy scorch survive (category 9 if no further data available):

* Resprout from root suckers or rhizomes .... **Category 4**
* Resprout from basal stem buds such as those in lignotubers .... **Category 5**
* Resprout from epicormic shoots .... **Category 6**
* Regrowth from unharmed, usually terminal, aerial buds .... **Category 7**

Additional data

The idea of the 'additional data' is that more detailed information than the species response only can be incorporated into the system. For example, if it is observed that a species at a particular life stage has a response that is different from that expected from the mature-plant response, then an extra entry can be made by repeating the species' name in the register (with life stage bracketed after it) and noting the response at that stage. A similar multiple entry can be made if there is a geographic variation in response (with geographic location bracketed) or a seasonal variation (with season bracketed).

The tolerance categories of Noble & Slatyer (1980) were considered for inclusion in the register but it was concluded that the level of detail they provide is beyond the broad scope of the purposes here defined. In the future, categories such as these may be worth including as the system moves towards a population level classification.

Further species data are needed if events such as the demise of populations of the annual tropical grass *Sorghum intrans* with a single wet-season fire (Stocker & Sturtz 1966) and the rapid depletion of mallee eucalypts with a series of annual or biennial autumn fires (Noble 1989) are to be predicted. While these events are unknown outside of deliberate human intervention, their occurrences have far reaching consequences.

In the case of annual *Sorghum* (Stocker & Sturtz 1966), the important point is that all propagules present were simultaneously vulnerable to fire at a particular stage of the life cycle. For the mallees, normally resprouters, vulnerability to a particular sequence of events occurred when all plants were at the same stage of regeneration and there was no seed present. Similarly, the 'obligate resprouters' may be seen as having populations which are synchronously vulnerable to particular events. Such circumstances as those described here in this section are considered to be, in general, beyond the resolution of the classification.

Life forms: vascular epiphytes

In our simple classification of life forms, we have included the category of 'vascular epiphytes' (taken broadly to include mistletoes) because of the special survival circumstances to which such plants may occur in relation to fires: they may be at various heights in the canopy of the host and, therefore, have positional protection (although they would have the same species response category as determined from Table 1); and, they may occur on host tissues with varying survival potential during fires. We know of no quantitative information on the fire responses of vascular epiphytes and their hosts.

Local use of the classification

Local use of the data in the register may involve the determination of juvenile periods, plant longevity and the minimum time interval between fires if predictions are to be made of local survivorship of the species given fires of an intensity sufficient to scorch plant canopies. For example, if the species has its entire population in the vegetative state and it is fire sensitive, then the population will become extinct when fire sufficient to scorch all the plant canopies occurs; if the population dies out before fire occurs, then it will become locally extinct also (assuming no seed in the soil in this case); if seed production occurs but is inadequate to completely replace the parent population when fire occurs, then repeated fires at the same interval will eventually cause the population to become extinct. Because of the importance of the fire interval of the most sensitive species, it is important to know the primary juvenile period (Gill 1975) of various species. This period varies from place to place (Benson 1985) but it is possible that the same two species at two different sites may have different juvenile periods but show the same relative chronology in coming to flower at each site.

The interval between fires varies widely from place to place and at the one site. A recent extreme occurred for heathland near Sydney when a small portion of an experimental site, burned a few weeks previously, was again burned when a severe unplanned fire occurred. Examples of two fires within a year are coming to light in the Sydney heathlands, such as in parts of the Royal National Park. Such examples are important because local declines, even extinctions, of vegetatively resprouting species could occur if short intervals between fires are repeated often enough (Bradstock & Myerscough 1988, Bradstock 1990). We know very little about relative sensitivities among resprouters to such events though there are parts of northern Australia that are routinely subject to annual fires.

Conclusions

This scheme is a national scheme but State nodes are envisaged which would collate and distribute State information. Already, people in Victoria, NSW, SA, Qld, WA and the ACT have indicated their willingness to take part in the scheme.

The national register, to date, has been compiled from unpublished sources as well as the literature. There are currently about 1 500 entries; most of the data are for mallee, heath and forest lands.

The State species check lists may be drawn from the master national checklists such that all contributors are working according to the same nomenclature. The system can operate on personal computers.

In the future, species response data to types of 'disturbance' other than fires are envisaged. Such data, fed into monitoring or other managerial systems, should provide managers with tools to assist them further in their management of our native landscapes. Eventually, demographic classes may be used to replace species' classification in designing monitoring systems.

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