APPLYING RECENT ADVANCES IN VITAL ATTRIBUTES ANALYSIS TO MANAGEMENT OF FIRE FOR BIODIVERSITY CONSERVATION

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Abstract
Fire affects most Australian ecosystems, yet the majority of past research on the impacts of fire on fauna has focused strongly on change following a single fire, without considering either the sequence of fires of which it forms a part, or the attributes of the fire event itself.

Seminal work by Malcolm Gill in the 1970s and 1980s made a clear case for the importance of considering fire as a recurrent event in the landscape, and provided a conceptual framework – the fire regime – with which to do this. In the subsequent twenty-five years, research on plant ecology in relation to fire has markedly changed direction, with the majority of studies now considering fire regimes, often in the context of spatial patterns, and widely using functional types (groupings of species that respond to disturbance in a similar way) to predict the impacts of particular fire regimes.

We reviewed the literature on fauna published over the last ten years to determine whether the research and publications reflect a similar paradigm-shift. In particular, we assessed the potential to develop functional types for fauna, based on recent advances in plant ecology, as such an approach could greatly improve our ability to generalise and predict the responses of fauna to fire, and resolve many apparent contradictions in the current literature. We found that although more than half of the 251 papers found in the search considered fire regimes many did so in a way that indicated only a limited understanding of the concept. A substantial number of papers showed no awareness of fire regimes. A very small proportion of the literature (16 papers, 6% of those retrieved) applied or discussed functional groups, or considered the utility of defining collections of species that respond in a similar way to fire. Of those that did, more than half applied the ant functional response groups developed by Greenslade and Andersen. We use the Hastings River Mouse (*Pseudomys oralis*) and Ground Parrot (*Pezoporus wallicus*) as examples of possible future functional response group approaches.

Introduction
The ecological impact of any given fire depends not only on the attributes of that particular fire (i.e. its intensity, season, extent and type) but also on the historical context in which it occurs, that is the history of fires that have preceded it, e.g. is it the last in a series of regular fires over a short period or the first in the area in 50 years (Gill 1975, 1981, Whelan 1995). There is now a large body of evidence that what happens (ecologically) following any given fire "event" – a single fire – is a product of the combination of *all* these factors.

This conceptual framework resolved many apparent contradictions and lack of patterns in the response of plants and animals to fire. For example, a single low-intensity intentional burn may cause no mortality or obvious impact on the animals or plants living at a site, but the cumulative impact of fifty or a hundred years of frequent low-intensity intentional burns can completely change the structure and floristic composition of the vegetation, and in turn change the faunal composition in an area (Tasker 2002). Studying the response of the plants and animals to a single low-intensity fire would lead to the conclusion of little or no impact, looking at the cumulative impacts of such fires over time would lead to the opposite conclusion. Most recent vegetation studies on the impacts of fire place their results in the context of fire regimes.

Another key recent advance in fire ecology originating from work on plants is the concept of functional groups. These are groups of species that respond in a similar way to a disturbance, such as fire. The best known are Gill's (1975, 1981) "sprouter"/"non-sprouter [seeder]" dichotomy, and the "vital attributes" scheme of Noble & Slatyer (1980) and Noble and Gitay (1996). This scheme summarises the key attributes that allow species to establish and persist at a site following a disturbance. Particular combinations of the attributes constitute functional types, that is suites of species that respond to fire regimes in particular ways.

Functional group analysis is now commonly applied in studies of plant responses to different disturbance regimes (e.g. McIntyre & Lavorel 2001). However, there is currently only rudimentary consideration of functional response groups for fauna, other than the ant functional groups developed by Andersen (1990, 1995). We believe that development of functional response classifications for other faunal groups are urgently needed in order to allow fire management and fire science to advance. Firstly, in order to be able to include invertebrates in considerations of appropriate fire regimes, there is probably no feasible alternative: there are far too many species to consider them individually, and most invertebrate families (particularly for insects) are simply too diverse and heterogeneous to use taxonomic groups as a surrogate. Secondly, whichever animals are being considered, there are too many co-occurring species in any particular area to successfully manage for species in isolation. Different species have different requirements, and except in rare cases where there is an obvious high-profile, charismatic or keystone species for which we make a subjective decision to use single-species fire management, we have to manage for suites of species. The only way to sensibly do this, is by grouping them into assemblages that respond to particular fire regimes in a similar way. Quite apart from these reasons, fauna surveys and manipulated fire experiments on fauna are extremely labour-intensive and often limited in their general applicability. We can't wait until we know the fire requirements of individual species.

Materials and Methods

We searched the published literature for the period 1995 to 2006 using the following databases and search engines: Annual Reviews, Biosis/Biological Abstracts, CSIRO, Science Direct, Web of Science, and supplemented this with targeted searches for book chapters and books as well as special issues of some less widely available journals that were devoted to fauna and fire. We used the following search terms: (fire* OR bushfire* OR burn* OR wildfire* OR forest-fire* OR backburn* OR back-burn* OR pyric) AND (animal* OR fauna* OR bird* OR mammal* OR reptile* OR frog* OR amphibian* OR avifauna* OR herpetofauna* OR insect* OR invertebrate* OR spider* OR beetle* OR ant* OR coleoptera*) AND (Austral*).

Each paper was reviewed. A paper was retained if (i) fire and fauna was the primary subject of the paper, (ii) fire was mentioned in the methods or results, or (iii) fire was substantially addressed in the discussion. Review, discussion or summary papers were retained if they presented new material, new evidence or a new interpretation of existing material, but excluded if all material they included was present in other widely available primary papers. Papers retrieved by the search that were not primarily on fauna but substantially discussed the importance of the topic covered for fauna (e.g. Crowley & Garnett 1999) were also retained. Papers that only mentioned fire in passing (i.e. in just a sentence or two), were not retained even if they recognised fire as very important for fauna.

We did not include theses or "grey" literature because these are not widely available and/or have not been subjected to a rigorous peer review process, but acknowledge that there is much information in these sources, often of high quality. We also acknowledge that there is considerable "buried" knowledge, that contained in first-hand experience of fire managers and field personnel.

Papers that were retained in the database were then assessed for whether they considered, mentioned or applied:

1) fire regimes,
2) functional response groups, vital attributes analysis or guilds (i.e. groupings based on common patterns of response to fire that enable simplification, recognition of common patterns or prediction of responses)

Results and Discussion

Fire regimes

The searches resulted in 300+ papers that matched the search terms. Two hundred and fifty-one of these were retained after the content was more thoroughly assessed and regarded as addressing the topic of fire and fauna. Of the retained papers, slightly more than half considered the concept of fire regimes, although many had methods or approaches that were inconsistent with the concept.

It is apparent that the concept of fire regimes is still unclear for many researchers working on fauna. Even where logistical reasons – and there are many – prevent animal ecologists carrying out experiments on fire regimes, any study of the impacts of fire on fauna needs to place the study, or the aspect of fire being considered, in the context of fire regimes. For example, the search revealed that the majority of fauna-fire studies over the past 10 years were on the response of animals to a particular, single fire event. In such studies, the inclusion of a description of the area burnt by the fire, at least a qualitative description of the scorch height (intensity), patchiness and season of burn, availability of topographic refuges or variability, as well as whatever is known of the history of previous fires at the site would add enormously to the interpretive power and general applicability of the results. For example, Whelan *et al* (1996) in a study of the impacts of the 1994 Sydney bushfires on the brown antechinus *Antechinus stuartii*, found that – in contrast to other studies – their numbers did not decline dramatically. This was apparently because of the presence of numerous rock outcrops and fissures that were used as shelter. If the authors had not noted the presence of these outcrops in the paper, the response of antechinus would have appeared both inexplicable and undermining of the usefulness of patterns previously found in other studies.

Another limitation in a number of the studies was a lack of replication. It was still surprisingly common for studies to document the response of fauna to a single fire – but attempt to draw conclusions about the impacts of (for example) “low-intensity fires”. Similarly some studies which compared the impacts of high- and low-intensity fires, had just one of example each, in some cases separated by many years or even decades. In such cases, without detailed documentation of the attributes of the fire, the fire history of the sites, and the climatic conditions leading up to and following the fire/s, it is unrealistic to suppose that the results will be generally informative.

Functional response groups

The most striking result is that there have been very few studies on fauna over the past 10 years that have used a functional group approach. Only 16 (6%) of the 251 retained papers considered or applied faunal response groups (Table 1).

Table 1. Papers which considered faunal response groups, fire literature 1995-2006

	Taxa considered	**Grouping used**	**Reference**
1	Ants	Functional groups	Andersen & Clay (1996)
2	Ants	Functional groups	Andrew, Rodgerson & York (2000)
3	Ants	Functional groups	Gunawardene & Majer (2005)
4	Ants	Functional groups	Hoffmann & Andersen (2003)
5	Ants	Functional groups	Hoffmann (2003)
6	Ants	Functional groups	Jackson & Fox (1996)
7	Ants	Functional groups	Vanderwoude, Andersen & House (1997a)
8	Ants	Functional groups	Vanderwoude, Andersen & House (1997b)
9	Soil/tree trunk arthropods	Trophic guilds	Bickel & Tasker (2004)
10	Invertebrates	Trophic/habitat guilds and ant functional groups	York (1999)
11	Birds	Taxonomic/trophic groups	Loyn (1997)
12	Birds	Taxonomic/trophic groups	Loyn (1998)
13	Birds	Foraging guilds	Chapman & Harrington (1997)
14	Vertebrates	Habitat-requirement based	Kavanagh & Stanton (2005)
15	Vertebrates	Discussion of using life-history/habitat groupings	Keith, Williams & Woinarski (2002)
16	Vertebrates	Discussion of potential approaches	Whelan, Rodgerson, Dickman & Sutherland (2002)

A notable exception is the popularity and usefulness of the ant function group classification originally developed by Greenslade (1978) and subsequently refined by Andersen (1990, 1995, 1997): more than half the papers that used a response group approach used this classification for ants.

Of the remaining eight papers, five applied functional groups to analyse data sets from surveys; on soil and tree trunk arthropods (Bickel & Tasker 2004), a broad range of invertebrates (York 1999), birds (Loyn 1997, 1998, Chapman & Harrington 1997), and a broad range of vertebrates (Kavanagh & Stanton 2005). The remaining two papers (Keith et al. 2002, Whelan *et al*. 2002) were discussions of the potential for developing response group approaches, rather than applications to survey results, and gave example species to illustrate contrasting life-history and habitat-requirement attributes that could be used.

While useful response groups for vertebrates and non-ant taxa are still to be resolved, possibilities suggested include the following: (i) for rodents, old endemics versus new endemics (Sutherland & Dickman 1999); (ii) for invertebrates, trophic guilds (Moran & Southwood 1982, Bickel & Tasker 2004, Kitching *et al*. 2005; York 1999); (iii) the use of life history attributes such as reproductive capacity and habitat requirements to group species (Friend 1995, Whelan *et al*. 2002, Keith *et al*. 2002a).

Another method of grouping responses to disturbance used in papers retrieved in the search was is to classify species as "increasers" or "decreasers" (e.g. Wardell-Johnson & Williams 2000). However, while this is useful to describe observed patterns, it is a post-hoc description of observed responses rather than a scheme that has a predictive basis (i.e. containing known or hypothesized responses to disturbance as a result of possessing certain attributes). Thus it is unlikely to be generally transferable amongst events or places, or to allow testing of suspected causative links between traits and outcomes.

The approach outlined by Friend (1995), Keith *et al* (2002a) and Whelan *et al*. (2002) appears to offer promise. It classifies animal species using a combination of microhabitat association, ability to avoid the direct impacts of fire, breadth of habitat and diet, susceptibility to competition and predation, dispersal ability and reproductive rate. All of these factors are likely to be important predictors of responses to particular fires or fire regimes. Applying the scheme to well-studied species, such as the ground parrot *Pezoporus wallicus*, gave a predicted response to wildfire that matched the observed patterns reasonably well. However, the major problem with such an approach is that it is necessary to a considerable amount about the species it is to be applied to. For many species, particularly those that are rare or uncommon (and often are those that are more vulnerable to inappropriate fire regimes) there is only limited knowledge of their ability to avoid fire, their diet, dispersal ability, reproductive rate, and so on.

Another promising direction that requires less autecological knowledge of the animal species to be managed is to apply recent advances in the development of upper and lower fire-frequency thresholds defined on the basis of particular plant communities (e.g. Bradstock & Kenny 2003) and use this as the basis to manage fauna dependent on certain habitat attributes or floristic composition. For example, the Hastings River mouse *Pseudomys oralis* is a rare Australian rodent found in the eucalypt forests of south-eastern Queensland and north-eastern New South Wales. It is closely associated with mesic forests with a floristically rich understorey – typically with a substantial grass and/or sedge component. Research by Tasker (2002, 2003) found that the understorey attributes with which the mouse is closely associated are created and maintained by (moderately) frequent burning associated with forest cattle grazing practices. Too frequent burning, i.e. annual-biennial, reduced ground cover and logs below what appeared to be a minimum cover threshold, but burning every 2-5 years created ideal conditions. A suite of other mammal species seem to require similar vegetation attributes in the forests of the region, such as the rufous bettong *Aepyprymnus rufescens* and the common dunnart *Sminthopsis murina,* and thoughtful groupings of species with similar requirements may prove a useful tool for managers to reduce some of the complexity in applying appropriate fire regimes. Although the causative links between the fire regimes and presence of the mouse require further investigation, combining our knowledge of what habitat attributes the Hastings River mouse is associated with, and our knowledge of the upper and lower burning frequencies likely to maintain particular vegetation communities (Bradstock & Kenny 2003), provide a powerful tool for fire management for fauna. Of course such an approach needs to be accompanied by monitoring of animal numbers, and preferably experimental testing of the suggested upper and lower thresholds, to assess whether they are indeed appropriate. Upper and lower thresholds for particular vegetation types are already being widely applied in fire management plans for various national parks in NSW and in the Bush Fire Environmental Assessment Code Guidelines for Hazard Reduction Burning, so extending these to fauna would be a logical next step.

Finally, fire management for large numbers of species will require resolution of conflicting requirements among them (Keith *et al*. 2002b). In any given area there will be species that require, for example, more or less frequent fire. This can be achieved by having temporal variability in fire regimes (i.e. occasional short intervals close to the lower threshold of species requiring longer intervals), and by spatial variability.

Conclusions

We conclude that the concept of the fire regime has had a reasonable uptake in fauna-fire studies, but both understanding and application still lag considerably behind plant-fire studies. In its most basic form, application of the fire regime concept to fauna-fire studies does not require significantly more work, though much more useful information for both understanding and management will result. We strongly urge that all fire studies record relevant information about the attributes of the fire/s, and as much as possible can be gleaned about the fire history of the site. Ideally, fire-fauna studies should incorporate a reasonable understanding of fire regimes and their impacts on vegetation into their design.

There has been little progress on developing functional groups for fauna over the last ten years, other than for ants. Efforts to identify and develop functional response group classifications for animals are urgently needed. This approach offers the best hope of significant improvement of fire management for fauna in the future.

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