

# Salvage harvesting fire-damaged wet eucalypt forests in south-eastern Australia: some ecological perspectives

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## Summary

Recent wildfires burned large areas of native forest in south-eastern Australia. Salvage harvesting will inevitably occur in some areas of burned forest to recover timber and pulpwood, but serious consideration should be given to the intensity of salvage harvesting. In order to provide for forest biodiversity, salvage logging operations must retain sufficient numbers of biological legacies such as living and dead trees that remain in fire-damaged stands and landscapes. Such retention is a critical part of sound forest stewardship which considers both ecological and economic issues, and is consistent with the overarching (and agreed) principles of Ecologically Sustainable Forest Management (ESFM). Retaining biological legacies like living trees, large dead hollow trees, large fallen logs and islands of unburned vegetation is critical for maintaining key ecological processes and creating suitable future habitat for a range of elements of forest biodiversity as stand recovery takes place. Planning where to salvage log, which and how many biological legacies to retain, and where and how to burn slash after salvage logging, will influence the structure of forests and the fate of many forest species for the next several centuries.

*Keywords:* forest management; forest ecology; ecosystems; harvesting; salvage felling and logging; fire effects; sclerophyllous forests; *Eucalyptus*; Australia

## Introduction

Wildfires burned substantial areas of forest in south-eastern Australia in 2002 and 2003. Human lives were lost, and there was considerable damage to human-built infrastructure. Following the fires, several inquiries have been set up to examine the possible causes of the fires, canvas future approaches to fire management, and consider an array of other fire and land management policies. In addition to these inquiries, major operations have been begun (starting in March 2003) to salvage timber and pulpwood from some burned areas of wood production forest (e.g. Department of Sustainability and Environment 2003).

Salvage logging is considered important to recover economic values from fire-damaged stands. Salvage operations are often simply intensive forms of traditional silviculture applied to burned areas. However, if conducted without regard to ecological values (including biodiversity conservation), salvage logging can accentuate the negative impacts of wildfires (McIver and Starr 2001).

In this paper we discuss important ecological and biodiversity conservation perspectives that should be considered as part of salvage harvesting operations. These perspectives include accounting for the ecological roles of 'biological legacies' (*sensu* Franklin *et al.* 2000) left in fire-damaged stands and ensuring that significant legacies are retained as part of recovering stands. We also comment on the importance of documenting disturbance effects as part of future research programs to improve the understanding of post-fire stand and forest biodiversity recovery patterns (*sensu* Whelan 1995; Gill *et al.* 1999). Our comments are focused on forests dominated by ash-type eucalypts in south-eastern Australia, such as alpine ash (*Eucalyptus delegatensis*) and mountain ash (*E. regnans*), in which stand-replacing wildfires are one (although not the only) form of natural disturbance (see Lindenmayer and Franklin 1997; McCarthy and Lindenmayer 1998; Mackey *et al.* 2002). Although many of our key points are based on experiences and datasets gathered from ash-type forests in the Central Highlands of Victoria in south-eastern Australia (which were not burned in 2003), they are nevertheless broadly relevant to wet eucalypt forest in the regions recently damaged by fire.

## Natural disturbances and biological legacies

Natural disturbances in forests leave significant features of the original stand in the form of a rich array of biological legacies (Franklin *et al.* 1985; Hansen *et al.* 1991). Biological legacies are defined by Franklin *et al.* (2000) as organisms, organically-derived structures, and organically-produced patterns that survive from the pre-disturbance system. At the stand-level they include large logs (Lindenmayer *et al.* 2002a), intact thickets of understorey vegetation (Mueck *et al.* 1996; Ough 2002), and large living and dead trees (Gibbons and Lindenmayer 2002; Lindenmayer and Franklin 2002). Just as wildfires are uneven in their intensity and impact across forest landscapes (Bradstock *et al.* 2002), they also leave behind landscape-level biological legacies. These include unburned patches of forest (Delong and Kessler 2000; Whelan *et al.* 2002) and stands of forest burned at lower intensities than the surrounds — resulting in spatial variation in the numbers and types of biological legacies (Lindenmayer *et al.* 1999a).

The number, type and spatial arrangement of biological legacies in stands and landscapes are influenced by many factors (Franklin *et al.* 2000), including (among others): the type and intensity of disturbance, the time since the last disturbance (and *its* intensity),

the environment being disturbed (e.g. old growth vs regrowth forest), the topography of the landscape (Lindenmayer *et al.* 1999a), and the recovery strategies of organisms (e.g. resprouters, obligate seeders, etc., in the case of plants as reviewed by Whelan 1995).

In the specific case of wet eucalypt forests such as those dominated by ash-type eucalypts, there is no doubt that even though stand-replacing fire is a common form of natural disturbance, significant biological legacies remain in the form of large living and dead fire-scarred trees (Lindenmayer *et al.* 1991a), understorey thickets (Mueck *et al.* 1996) and large charred logs (Lindenmayer *et al.* 1999b). Smith and Woodgate (1985), for example, described many levels of damage to trees in mountain ash forest following the 1983 Ash Wednesday fires — only two of which corresponded to dead stems. Other examples of trees surviving wildfires have been documented in central Victoria ash forests (e.g. Ashton 1976; McCarthy and Lindenmayer 1998) as well as ash stands in the East Gippsland region of that State (Chesterfield *et al.* 1991). Mackey *et al.* (2002) showed that for the ash-type forests in the Central Highlands of Victoria, areas of reduced fire intensity (where greater numbers of living trees survived) were typically on steep slopes with low levels of incoming radiation.

### The role of biological legacies and implications for salvage logging

Biological legacies at the stand and landscape levels significantly influence the rate and pathway of recovery of a post-disturbance forest (Franklin *et al.* 2000; Lindenmayer and Franklin 2002). They have many critical ecological roles: (i) surviving, persisting and regenerating after disturbance and being incorporated as part of the recovering stand (e.g. producing multi-aged stands of ash forest (Lindenmayer *et al.* 1999a)); (ii) facilitating survival of other species in disturbed stands (Kavanagh and Turner 1994); (iii) providing habitat for species that eventually recolonise a disturbed site (Lindenmayer *et al.* 1991b); (iv) influencing patterns of recolonisation in disturbed areas (Whelan *et al.* 2002); (v) providing a source of energy and nutrients for other organisms (Amaranthus and Perry 1994); and (vi) modifying or stabilising environmental conditions in a recovering stand (Perry 1994).

Salvage logging can either facilitate or impede ecological recovery processes, depending on how biological legacies are treated. The long-term impacts can be substantial because of the ecological roles of biological legacies, especially in the conservation of forest biodiversity (see Saab and Dudley 1998; McIver and Starr 2001 for examples in a North American context). Salvage harvesting can be done with relatively limited impact on future habitat values for some species if sufficient biological legacies are retained. As an example, large living and dead trees and large fallen logs add considerable structural complexity to recovering stands, by acting as critical habitat elements for many forest-dependent taxa (Gibbons and Lindenmayer 2002; Lindenmayer *et al.* 2002a). Where salvage harvesting approximates clearfelling practice, it will remove most or all of the large living and dead structures left by wildfires, which would otherwise become important habitat components for many species. For example, in the alpine and mountain ash forests of the Central Highlands of Victoria, salvage harvesting continued for almost two decades after the 1939 wildfires (Noble 1977) and was one of the major factors

contributing to the paucity of hollow-bearing trees for an array of cavity-dependent vertebrates (>40 species) throughout large parts of the region (Lindenmayer *et al.* 1997).

The ecology of the endangered Leadbeater's possum (*Gymnobelideus leadbeateri*) illustrates the importance of retaining biological legacies. The distribution of this species includes young ( $\geq 20$ -year-old) ash forests developing following fire but where biological legacies (in the form of large living and/or dead hollow trees) remain. Habitat suitability for the species is a function of (among other things) four inter-related factors: (i) the age of the forest when it was burned — old or multi-aged forest is typically more likely to contain trees with existing or developing hollows than young forest (Gibbons and Lindenmayer 2002); (ii) the time elapsed since the last disturbance and hence for regrowth of the eucalypt overstorey and understorey; (iii) the number and types of biological legacies remaining after disturbance and which are incorporated in the recovering stand; and (iv) the intensity of salvage logging following natural disturbance. Recent monitoring studies (Lindenmayer *et al.* 2002b) have shown that the species occurs in some parts of the Powelltown State Forest which were salvage logged after the 1983 wildfires — but where significant numbers of living and dead trees with hollows were left. Many species in addition to Leadbeater's possum (including the mountain brushtail possum (*Trichosurus cunninghamii*) and the greater glider (*Petauroides volans*)) could be used to illustrate the key inter-relationships between disturbance, biological legacies, salvage logging, and habitat suitability.

Thus, where forest managers aim to maintain populations of key elements of biodiversity, salvage logging prescriptions must provide for the retention of sufficient numbers of biological legacies at the time of harvesting.

### Congruence between natural disturbance and human disturbance regimes

The concept of biological legacies and their relationships with salvage logging is closely related to another key concept in multiple-use forest management. That is, the level of congruence between natural and human disturbance regimes. Attiwill (1994), Bunnell (1995) and other authors (e.g. see Korpilähti and Kuuluvainen 2002) contend that logging (including salvage logging) will have minimal effects on biodiversity if it is within the bounds of natural disturbance regimes. Similarly, Hunter (1994) hypothesized that the conservation of biodiversity in wood production landscapes requires management to be as consistent as possible with natural ecological processes. The logic of these proposals is that while organisms are best adapted to the disturbance regimes under which they have evolved (Bergeron *et al.* 1999; Hobson and Schieck 1999), they may be susceptible to novel forms of disturbance, disturbances that are more or less frequent and/or more or less intensive than would normally occur, and new combinations of disturbances (Foster *et al.* 1997; Paine *et al.* 1998).

If the importance of congruence between natural and human disturbance is accepted, then the scale, pattern and intensity of logging in managed forests should be broadly similar to the scale, pattern and intensity of natural disturbance regimes (Bunnell and

Kremsater 1990). Unfortunately, there is a relatively low level of congruence between the impacts of wildfires and traditional forms of clearfelling in ash-type eucalypt forest (Lindenmayer and Franklin 1997; Lindenmayer and McCarthy 2002). Other authors have argued that wildfires and clearfelling will set montane ash forests on quite different successional trajectories (Ough 2002).

The lack of broad congruence between human and natural disturbance regimes in montane ash forests has substantial implications for the conduct of salvage logging operations — if ecological values such as biodiversity conservation are an important objective of forest management. For example, removal of most biological legacies left by natural disturbance in subsequent salvage harvesting operations will result in considerable divergence between natural and human disturbance regimes. Important biological legacies will no longer be present and the functional roles they play will be absent, with significant implications for some species and key ecological processes (Franklin *et al.* 2000). An alternative to intensive clearfelling might be, for example, to salvage only a proportion of a given biological legacy after a fire (Lindenmayer and Franklin 2002). The extent of retention would be guided by an understanding of the spatial variation in disturbance regimes (and resulting patterns of biological legacies). For example, in the case of ash-type eucalypt forests, more legacies (e.g. larger numbers of living and dead standing trees) would be retained in forests on flat terrain and stands characterised by low levels of incoming radiation. This is because these are places where multi-aged stands are more likely to occur (Chesterfield *et al.* 1991; Lindenmayer *et al.* 1999a). Multi-aged stands on flat terrain are also places where the diversity of key groups such as arboreal marsupials is likely to be significantly higher than elsewhere (Lindenmayer *et al.* 1991b).

### Variations in natural silvicultural models

Due to the inherent variability in natural disturbance regimes in any given forest ecosystem (and hence the variability in biological legacies that remain after disturbance), no single natural disturbance regime provides a complete model for a silvicultural system. Informed forest management will require knowledge of the existence of multiple disturbance pathways and, in essence, a continuum of variability. Therefore, silvicultural prescriptions, including those for salvage logging, will need to vary in different parts of the landscape (Rülcker *et al.* 1994), as well as within the same stand (Bergeron *et al.* 1999; Chambers *et al.* 1999). This is the ‘don’t do the same thing everywhere approach’ of Bunnell (1999).

From a practical perspective, it is clear that human disturbance can never mimic natural disturbance regimes exactly. For example, wildfires remove only a small fraction of forest biomass (i.e. because of incomplete combustion of trees (Whelan 1995)) in contrast with the large biomass removal in logging (Angelstam 1996). Therefore, an objective should be to quantify differences between natural and human disturbance regimes and, in turn, to find ways of creating human disturbance regimes more similar (rather than identical) to naturally-occurring ones. Indeed, creating an identical replicate of natural disturbance regimes would be impossible and is not the aim of modified silvicultural systems.

### Multiple and potentially cumulative disturbance impacts

As outlined above, natural disturbances have value as an ecological template to guide human disturbance regimes such as timber harvesting and salvage harvesting. Studies of natural disturbances in several forest types have highlighted a need to alter silvicultural practices to create greater congruence between human and natural disturbance (see Delong and Kessler 2000). It is critical, however, that forest and wildlife managers recognise that populations of many species have to cope with both wildfire and logging and their cumulative impacts. The following example illustrates some of the potential pressures on populations inhabiting wood production forests subject to past logging. In dry years (when fires typically occur), populations must contend with (i) drought and high temperatures (which can negatively influence some species (e.g. How *et al.* 1984; Rübssamen *et al.* 1984)), (ii) wildfire (which can further reduce populations (Keith *et al.* 2002)), and (iii) post-fire salvage logging. Although studies of such potentially compounding impacts are difficult and therefore rare, it seems likely that recovery from cumulative effects is likely to be slow. This reinforces the value of areas such as Special Protection Zones within Victorian wood production forests which are quarantined from standard forms of harvesting as well as from salvage logging.

Cumulative effects are also relevant to the numbers and spatial distribution patterns of biological legacies, such as large trees with hollows. Large trees burned in a wildfire can either survive or, if killed, remain standing for many years during which cavity formation can occur (Inions *et al.* 1989). However, such trees may have a very high risk of collapse if subjected to a second high-intensity fire soon after, such as a regeneration burn used to reduce logging slash following post-fire salvage (Lindenmayer *et al.* 1990). Hence, the cumulative effects of natural and human disturbance regimes on biological legacies can be pronounced, with additional cascading impacts on biota that are strongly associated with them (such as cavity-dependent fauna).

### Documenting natural disturbance impacts and salvage logging regimes

An understanding of the effects of major natural disturbances such as wildfires on the types and numbers of biological legacies can help guide ways of managing forest ecosystems recovering after such events. The information also can help account for historical impacts of past human and natural disturbance. In a North American example, Foster *et al.* (1997) found that the effects of the 1938 hurricane on the forests of eastern USA should be re-interpreted as the impacts of extensive and intensive post-disturbance salvage logging operations in which the rich array of biological legacies left behind by the storm was subsequently removed. These salvage harvesting operations (the largest in the history of the USA) had enormous effects on hydrology and many other ecosystem processes. In the mountain ash forests of the Central Highlands of Victoria, some of the impacts on stand structure ascribed to the 1939 wildfires were at least partially related to extensive and intensive post-fire salvage harvesting (Lindenmayer 1996).

A valuable lesson learned from the experiments on simulated hurricane disturbance in north-eastern USA was the usefulness of documenting the extent of natural disturbance regimes and the nature of post-disturbance salvage harvesting operations (Foster *et al.* 1997). Such documentation is important for forest ecosystems where trees can be long-lived and where much of the research is dependent on retrospective studies that substitute space for time (i.e. by comparing stands at different stages since disturbance). Substituting space for time in ecological studies requires caution because results can be confounded by past histories (Pickett 1989) and because records on past histories such as silvicultural treatments are often lacking.

Given that cross-sectional retrospective studies will continue to be a significant part of forest research, there is a need to assess and carefully document both: (i) the characteristics of fire-damaged stands following natural disturbance, such as damage classes — as Smith and Woodgate (1985) did after the 1983 wildfires in Victorian ash forests; and (ii) the nature of salvage harvesting operations, by recording, for example, the type of cutting and the types and numbers of structural features retained. The documentation ensures that managed sites can be used in retrospective studies if the need should arise at some later stage (e.g. with respect to research on the effectiveness of regeneration or biodiversity response).

### Future policies and approaches

It is obvious that substantial areas of native eucalypt forest in south-eastern Australia have been disturbed by wildfire in the past few years. It is not always obvious how best to manage such fire-damaged stands and landscapes. Policies on salvage harvesting need to consider not just wood production and silvicultural objectives but also ecological factors such as the structural complexity of the recovering stands and the potential to create habitat for particular species. On this basis, and assuming that biodiversity conservation is an essential element of ecologically sustainable forest management (Commonwealth of Australia 1992), intensive and extensive clearfelling operations that remove most or all of the biological legacies left after fire are inappropriate. Governments and forest management agencies need to quarantine some areas from salvage harvesting. Policies have been adopted by the Government of Victoria to prevent salvage logging in the Yarra Ranges National Park should a major fire take place (Land Conservation Council 1994). In other cases, such as forests outside the dedicated reserve estate, ecologically appropriate management practices could limit the proportion of a given biological legacy that is salvaged after a fire — such as occurs on Federal Government land in north-western North America (e.g. Forest Ecosystem Management Assessment Team 1993).

### Concluding remarks

If the maintenance of multiple forest values (such as wood production and biodiversity conservation) is an aim of forest management, then any salvage harvesting operations must retain significant numbers of biological legacies. Ecological factors that should guide such salvage operations are: (i) the roles of biological legacies (*sensu* Franklin *et al.* 2000) left following disturbances in influencing post-fire ecosystem recovery; (ii) spatial variability

in disturbance intensity and the associated variation in the numbers and types of biological legacies; (iii) the habitat requirements of particular elements of biodiversity of management concern; and based on the first three points, (iv) the level of congruence (or otherwise) between human disturbance regimes and natural disturbance regimes (Attiwill 1994; Hunter 1994).

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