Endangered ecological communities and landscape conservation in NSW: successes and failures in the Sydney Basin

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ABSTRACT

We examine the nature and extent of listings of endangered ecological communities (EECs) under the *NSW Threatened Species Conservation Act 1995* (*TSC Act*), including the role of endangered ecological communities in conservation from the landscape to species level. We ask how well the implementation of the *TSC Act* is working for ecological communities in relation to the key ecological issues of habitat loss and fragmentation, conservation of remnants, and conservation of ecological processes and disturbance regimes. To do this we use examples of endangered ecological communities from the Sydney Basin.

Some 60 endangered ecological communities have been listed under the *TSC Act* since its inception and the rate of listing is likely to continue for some time yet. Most listings have been in coastal NSW, in particular in the Sydney Basin, with only a few in western NSW. This essentially reflects our current knowledge of vegetation associations in NSW and the fact that the majority of nominations have come from people who live in Sydney. In the Sydney Basin, for both the Duffys Forest EEC and the 12 EECs making up the Cumberland Plain, there has been extensive mapping of remnants and this has significantly increased both the awareness and acceptance of conservation issues relating to these communities. However, continued habitat loss and fragmentation of remnants is undermining their long-term viability. Any attempt to balance losses with reconstruction of ecological communities is not likely to contribute to their maintenance due to the time lags in reconstruction and importantly, our current lack of understanding of how to achieve restoration of complex ecological communities.

Greater success is occurring in ameliorating threats to remnants of EECs, in particular weed control and minimising disturbance, especially through support from local councils and volunteer groups. However, both the number of remnants and their proximity to urban areas will influence the ability to ameliorate threats in remnants due to resource constraints. The recognition that persistence of these EECs is also dependent upon allowing appropriate disturbance regimes is occurring in relation to fire management, with implementation success based on the degree of understanding of how fire affects flora and fauna. This consideration will need to be extended to maintenance of species interactions, ecological processes and other disturbance regimes if viable endangered ecological communities are to be maintained.

Based on this experience in the Sydney Basin, we would argue that the listing of threatened ecological communities in other parts of NSW is a useful conservation mechanism to raise awareness of conservation issues. Implementing recovery and the ongoing viability of such communities will be more dependent on developing an understanding of the processes that affect species persistence and interactions within communities and engaging support for conservation from local human communities.

Key words: clearing, fragmentation, disturbance regimes, threats, management, research

Introduction

The concept of recognising patterns in associations of species across the landscape has a long history, especially for vegetation-based associations. Such associations are often referred to as ecological communities. In NSW, the introduction of the *NSW Threatened Species Conservation Act* (*1995*) allowed for the protection of ecological communities that were considered to be endangered. This has been amended by the *NSW Threatened Species Amendment Act 2002*, which potentially allows for the listing of vulnerable ecological communities, although they are excluded from the licensing provisions of this Act. At the national level the *Endangered Species Protection Act 1992* (now replaced by the *Environmental Protection and Biodiversity Conservation Act 1999*) also allowed for identification and protection of endangered ecological communities. Other Australian states have also adopted threatened species legislation that includes the capacity to list ecological communities, e.g. Victoria and Tasmania.

In NSW, the *TSC Act* has several objectives, with the primary objective relating to biodiversity being 'To conserve biological diversity and promote ecologically sustainable development'. Most threatened species legislation is

Pp 94 - 101 in *Threatened species legislation: is it just an Act?* 2004, edited by Pat Hutchings, Daniel Lunney and Chris Dickman. Royal Zoological Society of New South Wales, Mosman, NSW, Australia.

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focussed on listing of species and hence conservation at the species and within species (genetic) level of biodiversity. The listing and conservation of ecological communities allows for conservation at broader scales across the landscape including genetic, species and ecosystem diversity. Within threatened species legislation, only ecological communities and key threatening processes address conservation of biodiversity at a scale broader than the species scale. Other mechanisms that could address habitat conservation at this scale are not available in threatened species legislation. Endangered ecological communities have a number of roles in the conservation of:

i) ecological process, species interactions and ecological disturbance regimes;

ii) rare patterns in the landscape (e.g. mound springs);

iii) common patterns in the landscape that have been heavily impacted;

iv) common and rare species; and

v) variation in patterns of biota across the landscape.

In this paper, we briefly examine the nature and extent of listings of endangered ecological communities in NSW since the inception of the *TSC Act*. We then use two examples from the Sydney Basin (Duffys Forest and the suite of communities occurring on the Cumberland Plain) to examine the role that the *TSC Act* has played in the conservation of these communities. We specifically target the successes and failures of these listings in relation to: habitat loss and fragmentation; degradation of remnants, and maintenance of disturbance regimes that impact on species' life histories.

Listings of Endangered Ecological Communities (EECs) in NSW

In NSW, an independent Scientific Committee, established under the *TSC Act*, has been responsible for additions, changes or deletions to the existing schedules. The criteria for listing for EECs in the *TSC Amendment Act* are:

"An ecological community is eligible to be listed as an endangered ecological community if, in the opinion of the Scientific Committee:

(a) it is likely to become extinct in nature in New South Wales unless the circumstances and factors threatening its survival cease to operate, or

(b) it might already be extinct."

Hence, evidence of threat and/or decline is required for listing.

The definition of an ecological community is given in the *TSC Act* as 'an assemblage of species occupying a particular area' combining concepts of both species association and area of habitat, although ignoring ecological processes. Endangered ecological communities are listed on Schedule 1, Part 3 of the *TSC Act*. At the time the Act began in January 1996, no endangered or vulnerable communities were listed. Since that time, the Scientific Committee has listed some 60 EECs, up until October 2003. No vulnerable ecological communities have been listed, as this component of the amended *TSC Act* has not come into force. Fifty seven of the listed EECs have been largely based on plant floristic data (although some may specifically include other taxonomic groups in their definitions), one on wading birds, one on Hygrocybeae fungi and one on lichens. The rate of listings of EECs in NSW has risen to 8-15 per year from 1998 to 2002 (Fig. 1) after some 5 listings in the first 2 years of operation of the *TSC Act*. Independent of what taxonomic group the listings are based on, all taxa (including all life stages, such as seeds in a soil seed bank) within the EEC are considered to be a part of the community and are given some protection. Unlike native vertebrates (excluding fish), invertebrates, vascular and non vascular plants and fungi in NSW have no legislative protection unless they either occur within the National Parks and Wildlife Reserve system, or are listed as a threatened species or they occur within a listed EEC. A small number of vascular plants are also listed as protected if they are subject to harvesting or commercial utilisation. The distribution of the listed communities across NSW (Fig. 2) shows a strong bias towards the Sydney Basin and coastal NSW in general. The listings may also occur at different spatial scales (Fig. 2), partially in response to the scale of variation in floristic patterns, but also in relation to the scale of available data on ecological communities. In essence, both the preponderance of listings based on vegetation data and the concentrations of listings in the Sydney Basin, reflect the greater knowledge base and detailed vegetation survey effort in these areas, as well as the prevalence of nominations from people within Sydney. Also, given the large urban population in Sydney, there has been, and continues to be, significant loss of habitat in this area and hence, a high and continuing level of threat to existing ecological communities. There are some listings from arid and semi-arid NSW, including both EECs that were always very rare in the landscape and have been severely degraded (mound springs) and those that were once widespread, but have been heavily cleared and degraded (e.g. White Box Yellow Box Blakely's Red Gum Woodland).

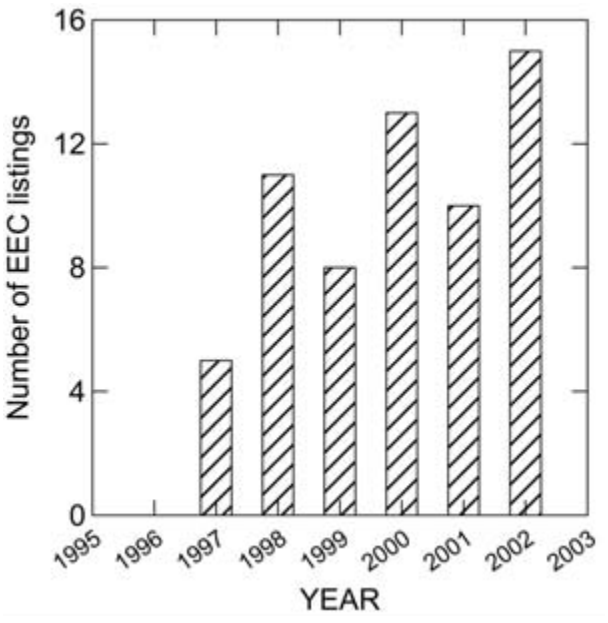

Figure 1. Annual frequency of listings of Endangered Ecological Communities by the NSW Scientific Committee under the *TSC Act*.

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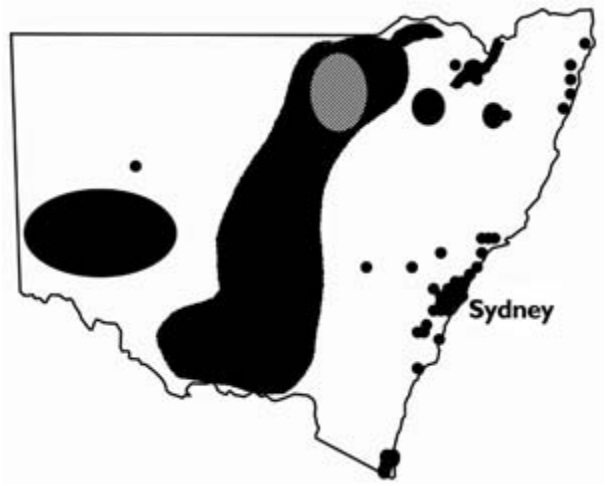

Figure 2. Approximate distribution of listed endangered ecological communities on Schedule 1, Part 3 of the NSW *TSC Act*. Large shaded or cross hatched areas represent boundaries of the distribution of a listed EEC. Remnants of the EEC may be very patchy and limited in occurrence across this distribution.

Key Issues for Conservation of Ecological Communities

Several factors currently influence the conservation of endangered ecological communities. Their listing highlights the degree of past habitat loss and continuing threats to these communities, but there is also a lack of quantitative data (and hence nominations) for ecological communities over much of NSW. We suggest that the factors that need urgent attention for managing listed EECs as viable entities are:

i) cessation of further loss and fragmentation of habitat. Clearing of vegetation has been the primary cause of decline for both species and ecological communities. The significance of this threat is recognised in its listing as a Key Threatening Process in NSW (NSW Scientific Committee 2001). Continued clearing of remnants of listed EECs will reduce their distribution and extent, their connectivity and the viability of the community. It will also increase edge effects and result in further degradation of remaining remnants.

ii) reversing degradation of habitat. Many remnants of existing EECs are small with large edges. They are prone to a range of human-caused disturbances and alterations such as roads, tracks, urban runoff and nutrification. This is frequently associated with invasion by a range of exotic species of plants and animals detrimental to the survival of native species in the remnants. In order to maintain existing remnants into the long term these threats must be mitigated.

iii) maintaining species life history processes and interactions. Species that make up ecological communities are not static through space and time. Progression of species through their life cycles and the maintenance of the ecological interactions between species is necessary for long-term viability. Disturbance regimes such as fire play a key role, and in many ecological communities they have been a key driving force in maintenance of species over evolutionary time scales. Consequently, to maintain EECs, even in degraded and fragmented landscapes, some attempt must be made to implement disturbance regimes that are appropriate for the whole suite of species within the community.

Success and Failures in Conserving Duffys Forest and Cumberland Plain Endangered Ecological Communities

We evaluate how well the listing of EECs has contributed to their conservation by considering the three key ecological factors listed above. We acknowledge that the implementation of existing listings on the *TSC Act* (as opposed to the listing process) also incorporates both social and economic considerations in making decisions that impact on the conservation of species and EECs. However, we believe that ultimately it is the ecological conservation outcomes that are critical in determining whether or not the *TSC Act* has been successful, irrespective of whether the social and economic consequences are palatable.

Location and descriptions of Duffys Forest EEC and EECs on Cumberland Plain

The Duffys Forest EEC (Smith and Smith 2000, NSW Scientific Committee 2002) is confined to a small area on the urban/bushland interface in northern Sydney. This community was always rare in the landscape and restricted to laterite rich soil on ridges and upper slopes (Benson and Howell 1994). It has been estimated that some 1450 ha existed prior to European settlement (Smith and Smith 2000). Today it exists in less than 50 small fragmented remnants comprising some 15% of the original area (Smith and Smith 2000). Most of the remnants are small (<10ha), have large edges and are internally fragmented by roads or other clearings. Just under half of the known remnants are contained within Ku-ring-gai Chase and Garigal National Parks. A full description of the floristics of Duffys Forest EEC can be found in Smith and Smith (2000).

The Cumberland Plain, located in western Sydney and stretching from Thirlmere in the south to Sackville in the north and to the edge of the Blue Mountains, contains 12 listed EECs (Tozer 2003) (Table 1). An estimated 13% of the vegetation that existed prior to European settlement remains today (Tozer 2003). There is a very large number of remnants and as the original area of

Table 1. Endangered ecological communities listed under *NSW TSC Act* occurring on the Cumberland Plain. Remnant areas derived from Tozer (2003).

Endangered Ecological Community	Approx. remnant area (ha)
Elderslie Banksia Scrub Forest	<1
Agnes Banks Woodland	98
Blue Gum High Forest	168
Western Sydney Dry Rainforest	338
Moist Shale Woodland	604
Castlereagh Swamp Woodland	616
Cooks River/Castlereagh Ironbark Forest	1,012
Sydney Turpentine Ironbark Forest	1,183
Shale/Gravel Transition Forest	1,721
Sydney Coastal River-Flat Forest	5,415
Shale/Sandstone Transition Forest	9,960
Cumberland Plain Woodland	11,054

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vegetation was large (274,000ha), the area of remnants of EECs on the Cumberland Plain overall is much greater than for Duffys Forest (31,500 v 240 ha). The remnants vary in size, with most (97%) less than 80 ha and around half (51%) <3 ha (Tozer 2003). Some of the listed EECs on the Cumberland Plain are also very small, with few remnants, e.g. Agnes Banks Woodland, Elderslie Banksia Scrub, Blue Gum High Forest (see Table 1). The EECs with the most remnant habitat and number of remnants are Cumberland Plain Woodland and Shale/sandstone Transition Forest (Tozer 2003, Table 1). A full description of the floristics of EECs on the Cumberland Plain can be found in Tozer (2003), except for the Elderslie Banksia Scrub Forest, which is briefly described in NSW Scientific Committee (1999).

Loss and fragmentation of habitat

To achieve conservation of remnants of EECs across the landscape, and across the spatial and temporal ecological variation within each community, there should be no further loss of habitat or fragmentation of ecological communities once they are listed as endangered. Listing as endangered is a reflection of the high risk of extinction of EECs. Any further loss will compromise the viability of listed communities. Consequently, the major determinate of the success of the *TSC Act* for EECs should be a measure of the degree and rate of loss pre- versus post-listing.

Duffys Forest

One of the key aims of the recovery plan being developed for Duffys Forest is no further loss of remnants. For this community, there has been extensive targeted mapping of remnants (Smith and Smith 2000) as well as pre-listing mapping (Thomas and Benson 1985; Sheringham and Sanders 1993; Benson and Howell 1994). Further, there have been management actions under the *Grevillea caleyi* recovery plan (Scott *et al.* 1995), that cover a number of remnants of Duffys Forest. There has been some limited acquisition of remnants into reserves through the activities of the *Grevillea caleyi* recovery team (NPWS 2001). Some 48% of remnants are in national parks, while the remainder occur on a range of tenures from state and local government to private land (Smith and Smith 2000; NPWS recovery plan for Duffys Forest (in prep.)).

Further losses of remnant habitats are occurring. Such losses vary from the loss of transitional vegetation surrounding Duffys Forest EEC, loss of edges or parts of remnants to the loss of whole remnants. Such losses are mostly associated with continued clearing for housing, as well as infrastructure support such as roads and clearing for fire mitigation. There are currently no complete details on the extent of these losses relative to the amount and type of remnant habitat that remains. An assessment of the current rates of habitat loss is essential, but any further clearing will likely compromise the long-term viability of Duffys Forest EEC.

Cumberland Plain

The aim of the recovery plan being developed for all the EECs on the Cumberland Plain involves a net gain in vegetation cover. The specific goal is to achieve 30% of original landscape with protection and revegetation (NPWS 2002). To do this there has been extensive mapping of remnants and predictions of former habitat (Tozer 2003), combined with an assessment of core habitat areas and areas that may be a useful support for these core habitats. Such mapping has had a number of immediate benefits including: greater certainty in landuse planning decisions; greater acceptance of listed endangered ecological communities on the Cumberland Plain at federal (e.g. Cumberland Plain Woodlands, Shale/sandstone Transition Forest), state and local government levels and among local communities; increased awareness of EEC issues, including threats, ecological processes and disturbance regimes; and increased community awareness. This had led to some significant protection of remnants in conservation reserves. However, significant habitat loss is still occurring outside these reserves. There has been no attempt to assess the current rate of habitat loss, yet such data are important to gain insights into the effectiveness of the *TSC Act* for conservation of EECs on the Cumberland Plain.

Based on the available area of remnant habitat (Tozer 2003), significant areas will need to be revegetated to achieve the 15-30% landscape restoration goal for the remnant EECs on the Cumberland Plain (Fig. 3). Some of the areas identified as remnants in Fig. 3 may only contain intact tree overstorey, while the understorey may have been removed, while others may be cleared in the future (further clearing is not prevented by listing on the *TSC Act*). As well, some areas to be revegetated may have a partially intact understorey, even though the overstorey has been removed or thinned. Consequently, we believe the relative proportions illustrated in Fig. 3 are likely to be a best case scenario. Clearly more survey effort is needed to identify high quality understorey in areas with few or no trees to assist any planning for revegetation as these areas represent significant remnants for the conservation of biodiversity.

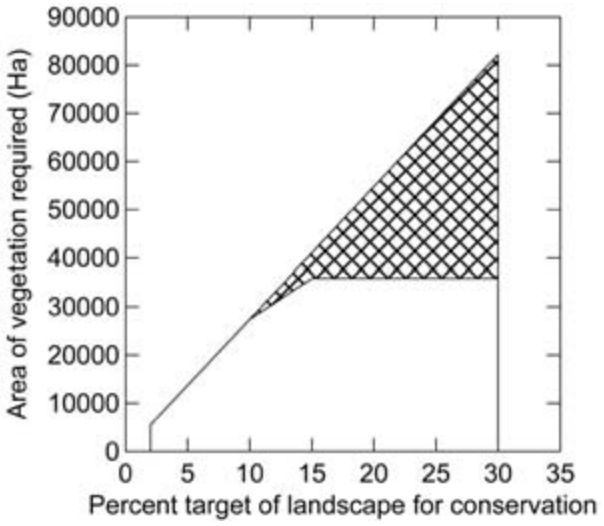

Figure 3. Estimated area of land needed for target restoration of landscape on the Cumberland Plain.

Filled area is essentially cleared and would need revegetation. Open area is remnant vegetation.

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Although EECs on the Cumberland Plain are often considered collectively for conservation planning and restoration purposes, it must be emphasised that a 15-30% conservation target for the Cumberland Plain will not necessarily ensure adequate conservation of all EECs on the Cumberland Plain. First, the area of remnant bushland varies widely between individual EECs (Table 1) and the conservation of large remnant areas of vegetation may make no impact on the status of individual EECs unless they are specifically targeted. Second, for some EECs, a large proportion of the original habitat may be unavailable for restoration due to urban encroachment, therefore any restoration activities will have no impact for these communities. Third, ecological communities are not homogeneous units, rather they vary in structure and composition throughout their range. For example, Cumberland Plain Woodland encompasses floristic variation significant enough to warrant recognition of separate communities (Tozer 2003). Any conservation or restoration activity must encompass this variation to be effective in the conservation of the EECs. Fourth, the issue of just how much restoration or how many remnants are needed to maintain viable communities (i.e. communities that will persist into the future with the maintenance of species interactions, life cycles and ecological processes that drive species persistence in the community) is also currently unknown. As well the success, in term of restoration of species, species interactions and ecological processes, of revegetation on cleared or degraded habitat will be dependent upon the degree of soil disturbance in the past (Doherty 2000).

We suggest that areas that are currently essentially cleared habitat and are then subject to revegetation are not considered to be part of the listed EECs. The concept of offsets, whereby areas of remnant habitat are cleared and, as a trade off, some 1-20 times the area of cleared habitat are to be 'revegetated' has been suggested in some instances. This concept does not assist the conservation of EECs as remnant habitat is lost. Any 'revegetated' areas should not be considered to add to the area of remnant EECs as:

a) they take no consideration of the considerable time lag needed to potentially regrow communities. This is likely to be in the order of decades if not centuries.

b) based on current knowledge there is little chance of reconstruction of complex communities. Recent work on revegetation in the Cumberland Plain (Wilkins *et al.* 2003) suggests very little success.

Consequently, while it will be worthwhile to plan for potential revegetation, more data on where high quality remnants exist, and research into revegetation techniques are currently needed prior to any implementation of extensive revegetation. Additionally, we need an understanding of how to restore faunal communities within these habitats. Any revegetation should not be traded off against the key importance of retaining all existing remnants.

Maintenance of viability of remnants in the landscape

The viability of existing EEC remnants is frequently compromised by degradation of habitat. This may involve: further loss of habitat; loss of adjacent vegetation or transitional vegetation that may help buffer the EEC from adverse disturbance; invasion by exotic weeds; disturbance to habitat by road and track construction, rubbish dumping; firewood collecting; nutrient enrichment from adjacent urban runoff etc. Hence, control of these adverse impacts is needed to maintain these communities. Restoration of degraded areas may also be required to create large enough remnants that are viable or to reduce adverse effects of weedy incursions into remnants.

Duffys Forest

A program to ameliorate the threats to remnant patches of the EEC currently covers some 30% of the known area of remnant habitat. This is based on work carried out under the implementation of the recovery plan for the endangered plant *Grevillea caleyi* (Scott *et al.* 1995; NPWS 2001). This has involved weed management, disturbance control and development of plans of management for specific sites. Further work for the remainder of the known sites is being planned. The sandstone soils on which this EEC and surrounding vegetation occur appear to be relatively resistant to weed invasion, with invasion governed by physical disturbance, and in particular, nutrient enrichment of sites (Leishman 1990). Thus, the vegetation of even small remnant sites may be viable in the long term if adverse disturbance can be minimised. There is also an interaction between weed invasion and fire, with remnant sites that are long unburnt being susceptible to recruitment of weeds such as small-leaved privet *Ligustrum sinense*, lantana *Lantana camara* and the native *Pittosporum undulatum* (which is not native to the ridgetop sites of this EEC).

At the same time, further losses of habitat at the edges of remnant sites continue to occur. Some guidelines for buffer protection are proposed in the draft recovery plan for this EEC to minimise such losses. There is also some enforced habitat restoration occurring, with topsoil from remnant areas that are to be cleared being used to restore severely degraded nearby areas of former Duffys Forest habitat. The success of such restoration may take decades to judge.

Cumberland Plain

The magnitude of the number of small remnants, and their wide distribution across western Sydney, make amelioration of threats at remnant sites a major challenge. A number of significant protection/management measures are underway. These include remnant site management and threat amelioration by some local councils and volunteer bush regeneration groups. Techniques for regeneration of degraded remnants have been developed and are being implemented (Hawkesbury Nepean Catchment Management Trust 2000).

The richer clay soils on the Cumberland Plain may make remnants less resilient to weed invasion than sandstone-derived plant communities such as Duffys Forest. The key

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weeds of the Cumberland Plain (olives *Olea eurpoea* subsp. *africana* and bridal creeper *Myrsiphyllum asparagoides*) are bird dispersed (Tozer 2003) and appear to have the ability to out-compete natives. Control of these weeds is a priority (Tozer 2003) and will be influenced by the extent of connectivity of the landscape in relation to the avian seed dispersers of these weeds. Hence, great care should be taken in any attempts to 'reconstruct' the landscape and create corridors to ensure such reconstructed areas do not simply serve as a pathway for dispersal of weed seeds. As most local native species have only local seed dispersal, the concepts of linkages and corridors being necessary for remnant viability may not apply to many vascular plants and more active management may be needed to restore species that have been lost. The role of such restored areas or corridors for the movement of vertebrates and invertebrates also requires further study.

Management of species' life histories and interactions via appropriate ecological process/disturbance regimes

Essential for the long-term viability of ecological communities is an appreciation that the species composition will to some extent vary both spatially and temporally. The component species have evolved in response to a number of disturbance regimes that impact on species persistence, species interactions and the movement of individuals through the life cycle of a species. Here we use fire as an example of a key disturbance regime that impacts on a number of EECs. We ask how effective management of the Duffys Forest and the EECs in Cumberland Plain has been in relation to fire.

Duffys Forest

Research on the ecology of the endangered plant *Grevillea caleyi* has informed management in relation to the potential impacts of fire in Duffys Forest. *G. caleyi* is a characteristic species of Duffys Forest and acts as an indicator of the impacts of fire frequency of the community. It is a slow growing species that has low levels of seed production and much of the seed produced is consumed by the native bush rats *Rattus fuscipes* and swamp wallabies *Wallabia bicolor* (Scott *et al*. 1995; Auld and Denham 2001; Regan *et al*. 2003). It is likely to be one of the slowest plant species in the EEC to replenish its seedbank after a fire. Consequently high frequency fire may impact on survival of this and other species in the community (see NSW Scientific Committee 2000; Regan *et al*. 2003; Regan and Auld in press). Other key indicator species, such as fire-sensitive *Persoonia*, appear to have a similar requirement to *G. caleyi*.

If fire is excluded for a long interval (>20-25 years) then a number of key structural components of the understorey of Duffys Forest will be absent or reduced (Auld and Scott unpubl). Long unburnt remnants are also prone to invasion by bird-dispersed weeds such as privet and lantana. Hence, infrequent fire is also likely to be a threat to the community. However, the impact of other components of the fire regime on species persistence within this community is less well understood. Guidelines for fire management for Duffys Forest (Table 2) have been developed (Scott *et al*. 1995; NPWS 2001; NPWS in prep.) as a guide to land managers and fire management authorities. These guidelines have been implemented through Rural Fire Service, NPWS and local councils. However, with the recent implementation of the Rural Fire Service Bushfire Environmental Assessment Code, there may be increased pressure on remnants of Duffys Forest that occur in asset protection or strategic management zones, e.g. including habitat clearing or the application of high fire frequency.

Cumberland Plain

Less is known about the impacts of fire on plants from shale soils on the Cumberland Plain. Hence the development of fire management guidelines is less advanced than for Duffys Forest. However, the planning for EECs on the Cumberland Plain does encourage incorporation of fire management guidelines. The impact of asset protection and strategic management zones on EECs on the Cumberland Plain remains to be assessed. Fire frequency requirements for different vegetation types as part of the Bushfire Environmental Assessment Code will be applied to EECs on the Cumberland Plain until further research informs management.

Table 2. Guidelines for fire management for Duffys Forest EEC. The overall objective is to ensure conservation of all sites by appropriate fire management practices. Guidelines based on Scott *et al.* (1995) and Auld unpubl.

Fire regime component	Suggested guideline
Fire Frequency	1) prevent fire from burning sites which are <8-12 years old;
	2) prevent any site from being burnt by three consecutive fires at <5 year intervals;
	3) allow fire to burn a site if it is >15-20 years old.
Fire Intensity	1) fire intensity effect little known. Some species require significant soil heating effect for germination. Fires of varying intensities recommended.
Fire Season	1) no evidence of seasonal effects: late summer/autumn burns more likely to be favourable for regeneration than winter/spring burns. More research is needed.
Fire size/patchiness	1) if fires are to be implemented specifically for management of a Duffys Forest site, the area to be burnt should be large to reduce the impact of seed predators post-fire, and to reduce the potential for increasing the fire frequency at the site;
	2) if planned fires are required for bush in the vicinity of, but not in a Duffys Forest site, give the site a large buffer zone of surrounding unburnt vegetation. This applies for wildfires as well, if such controls are possible.

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Future Directions

Based on the three key ecological issues described above, we recognise several key future management and research issues. Some of these apply specifically to the Cumberland Plain, but most are applicable to the conservation of all EECs.

Research should be focussed on:

i) understanding of key processes that allow species persistence, e.g. disturbance regimes (e.g. fire on Cumberland plain), pollination, dispersal, predation/ grazing, in relation to remnant size and degree of fragmentation.

ii) understanding how threats acting on the community affect population persistence of component species;

iii) estimating current rates of habitat loss within EECs; and

iv) developing techniques for increasing the effectiveness of restoration programs.

For management, key issues are:

i) development and release of recovery plans to guide management;

ii) on-ground threat mitigation activities;

iii) development of site based plans of management for remnants;

iv) involvement of community groups in conservation activities; and

v) survey of areas with little tree cover for remnants with good understorey (e.g. Cumberland Plain).

As well, there will be issues relating to resource planning and allocation. With the increasing number of listings of endangered ecological communities (Fig. 1), as well as species and key threatening processes, there will not be sufficient available resources for all aspects of management or research that are needed for conservation. Priorities and development of key issues across EECs will be required. At the same time, there will be other ecological communities that are in decline and may be considered common, but declining, near threatened or even vulnerable. Addressing such landscape-scale decline needs to be a priority. One way will be to address key threatening process at the landscape scale (rather than simply in relation to high priority threatened species). We suggest that this will also prevent communities and species from becoming threatened.

Summary

Listing of EECs under the NSW *TSC Act* has lead to significant improvements in awareness and acceptance of conservation needs for protection of these communities across the landscape. For that reason alone, listing has been beneficial for conservation of these communities. Combined with this increased awareness, there is a number of sound on-site management solutions to threats, often based at local government and community levels. This has enhanced the viability of remnants of EECs, although both the size and number of remnants will influence management success as will proximity to urban areas.

In contrast to these successes, there has been continued loss and fragmentation of habitat of listed EECs. This continues to undermine the on-site threat mitigation and habitat restoration activities. In a scenario of continued habitat loss, the long-term viability of remnants remains in doubt and will depend on the resilience of the species making up each community to threats that impact on them. The resilience is likely to vary among species across EECs and hence across the landscape. At present our understanding of the dynamics of ecological communities and the species that comprise them is limited and predictions of the degree of resilience of particular communities remain equally limited. Research and management initiatives should be directed at understanding the role of ecological process, disturbance regimes and species interactions in maintaining species within ecological communities.

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