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Eastern Suburbs Banksia Scrub: Rescuing an endangered ecological community

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On-ground works prove an important mechanism for gaining knowledge about this near-extinct ecological community, providing new insights into ways to manage and restore it.

Key words: *aeolian sands, bush regeneration, ecological resilience, fragmentation, soil seed banks.*

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Figure 1. Eastern Suburbs Banksia Scrub at North Head. Photographs taken from the top of the former Nicoh Firing Range facing south-west towards the city. The range had previously been mechanically cleared for army firing practice (Photo P. Jensen, Sydney Harbour Federation Trust).

Introduction

Eastern Suburbs Banksia Scrub (ESBS) is a scrub and heath vegetation community confined to deep, wind-formed sand deposits in the coastal suburbs of Sydney (Fig. 1 and Box 1). The community was first described in 1990 (Benson & Howell 1990, 1994) and is now listed at the State and National levels as Endangered. It is estimated to have once covered approximately 5300 ha at the time of European settlement in 1788, but is now highly fragmented and reduced to <145 ha on about 24 sites (Fig. 2), a loss of more than 97% (DEC 2006). The larger remnants in the La Perouse area (in the south of the community's range) and in the Manly area (in the north of its range) represent more intact examples of ESBS, with many of the smaller, more fragmented remnants exhibiting higher levels of degradation.

In September 1999, an ESBS recovery team was established, made up of representatives from state agencies, local government and other agencies with management responsibility for ESBS sites. The major task of this group was to guide the then NSW Department of Environment and

Box 1. Eastern Suburbs Banksia Scrub

Eastern Suburbs Banksia Scrub (ESBS) is largely a sclerophyllous heath or scrub community on nutrient-poor aeolian (wind formed) dune sand in the Sydney Basin, NSW, Australia (NSW Scientific Committee 2002). Depending on site topography and hydrology, some remnants may contain small patches of woodland, low forest or limited wetter areas. Common species include Heath-leaved Banksia (*Banksia ericifolia*), Old Man Banksia (*B. serrata*), Pink Wax Flower (*Eriostemon australasius*), Variable Sword Sedge (*Lepidosperma laterale*), Coast Teatree (*Leptospermum laevigatum*), Tree Broom-heath (*Monotoca elliptica*) and Grass Tree (*Xanthorrhoea resinifera*). Being a predominantly fire-adapted, shrub-dominated community, it is highly dynamic, characterized by periodic ecological disturbance and subsequent regeneration from resprouting and germination from the soil seed bank to maintain floristic and structural diversity (Gill 1981; Bradstock *et al*. 1995; DECC 2009).

Figure 2. The location and distribution of Eastern Suburbs Banksia Scrub (ESBS) in the Sydney Basing Bioregion. (a) Sydney within Australia. (b) Map of the predicted pre-1750 distribution of ESBS and the distribution of remnants in 2004 (Reproduced based on DEC 2004 with permission).

Box 1. (Continued)

Eastern Suburbs Banksia Scrub was the first ecological community to be listed as endangered under the NSW *Threatened Species Conservation Act 1995* (TSC Act) with the (amended) ESBS Final Determination made in 2002. ESBS has since also been listed as an endangered ecological community (EEC) under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The ESBS Final Determination (NSW Scientific Committee 2002) provides a description of the community, which represents its legal definition, and contains a list of species likely to be characteristic of ESBS (Table 1). While such a list can provide at least some information on the degree to which floristics coincide with the community, the NSW Scientific Committee makes it clear that 'The total flora species list for the community may be larger… with many species present only in one or two sites or in very small quantity. In any particular site, not all of the assemblage listed above may be present. At any one time some species may only be present as seeds in the soil seed bank with no above ground individuals present' (NSW Scientific Committee 2002).

The main past pressure on the community has been clearing for urban development. Continuing urban pressures include clearing, altered nutrient status, hydrological regimes and fire regimes; weed invasion, mowing, slashing and the inappropriate use of herbicide; dumping of rubbish; some grazing and trampling by horses and rabbits; unrestricted access by pedestrians and vehicles; infection by *Phytophthora cinnamomi*, inappropriate plantings in and around remnants; and seed and wildflower collection. The recently introduced fungal pathogen, Myrtle Rust (*Uredo rangelii*), which infects species from the Myrtaceae family, may be a threat to this community in future if it becomes widespread throughout Sydney.

The Recovery Plan (DEC 2004), at the time required by both the EPBC and TSC Acts, outlines actions required to be undertaken by (and with the agreement of) land managers to meet their responsibilities for protecting and restoring the community. These actions include (but are not limited to) protection from further clearing, implementation of feral animal control programmes, determining and applying appropriate fire management practices, reducing off-site impacts (particularly storm-water run-off), implementing access management and weed control and preventing rubbish dumping. Active restoration is recommended in the form of systematic and skilled application of bush regeneration techniques, guided by site-specific management plans.

Table 1. Species (63) that were cited as characteristic of ESBS at the time of the EEC's Final Determination (NSW Scientific Committee 2002). As predicted in the Determination, other species may also be recognized as occurring in the community

Acacia longifolia	*Darwinia fascicularis*	*Leptospermum trinervium*
Acacia suaveolens	*Darwinia leptantha*	*Lepyrodia scariosa*
Acacia terminalis	*Dianella revoluta*	*Leucopogon ericoides*
Acacia ulicifolia	*Dichelachne crinita*	*Lomandra longifolia*
Actinotus helianthi	*Dillwynia retorta*	*Melaleuca nodosa*
Actinotus minor	*Epacris longiflora*	*Melaleuca squamea*
Allocasuarina distyla	*Epacris microphylla*	*Monotoca elliptica*
Astroloma pinifolium	*Epacris obtusifolia*	*Monotoca scoparia*
Baeckea imbricata	*Eragrostis brownii*	*Persoonia lanceolata*
Banksia aemula	*Eriostemon australasius*	*Philotheca salsolifolia*
Banksia ericifolia	*Eucalyptus gummifera*	*Pimelea linifolia*
Banksia integrifolia	*Gonocarpus teucrioides*	*Pomax umbellata*
Banksia serrata	*Haemodorum planifolium*	*Pteridium esculentum*
Bauera rubioides	*Hakea teretifolia*	*Restio fastigiata*
Billardiera scandens	*Hardenbergia violacea*	*Ricinocarpos pinifolius*
Boronia parviflora	*Hibbertia fasciculata*	*Styphelia viridis*
Bossiaea heterophylla	*Hypolaena fastigiata*	*Woollsia pungens*
Bossiaea scolopendria	*Kunzea ambigua*	*Xanthorrhoea resinifera*
Brachyloma daphnoides	*Lambertia formosa*	*Xanthosia pilosa*
Caustis pentandra	*Lepidosperma laterale*	
Conospermum taxifolium	*Leptocarpus tenax*	
Cyathochaeta diandra	*Leptospermum laevigatum*	

Conservation (DEC) in the preparation and implementation of the ESBS Endangered Ecological Community Recovery Plan, approved in 2004 (DEC 2004). The Recovery Plan identifies the actions needed to secure the long-term viability of the community and the parties who will carry out these actions.

Consistent with the recommendations of that plan, the NSW Department of Environment and Climate Change (DECC) and the Sydney Metropolitan Catchment Management Authority jointly prepared a publication entitled *Best practice guidelines: Eastern Suburbs Banksia Scrub* (DECC 2009). Much of the guidelines' recommended techniques were developed from experiences already gained from restoration efforts at ESBS sites.

Works at one site in particular – (Lot 23) York Road in Centennial Parklands – provided important insights for the preparation of the DECC (2009) guidelines. Restoration works were funded as a consent condition of an adjacent development and primarily involved management actions to foster regeneration from the soil seed bank prior to assessing whether planting or direct seeding was also required. This approach was selected because of the likelihood that a soil seed bank may exist for at least some ESBS species (Lesak 2000; Urban Bushland Management 2002) and because the opportunity of funding over a period of 5 years allowed a degree of experimentation.

This paper documents the knowledge gained from the restoration work at the York Road site and draws insights from restoration and management works that have been undertaken at 22 other sites of which the authors have direct experience. The degree to which management at these sites is meeting the objectives of the Recovery Plan is discussed, and comments are made on potential ways for managers to optimize the recovery of this endangered community.

York Road Bondi Junction (Lot 23) – A Case Study

The York Road site was previously part of a larger site excised from Centennial Park during the First World War for the development of a hospital (Conybeare Morrison and Partners 2002). The site was later used by Moriah College and the Department of Community Services. The 1.07 ha patch of land (Lot 23) was returned to Centennial Parklands in 1998 when Moriah College wished to expand into the adjacent lands (DECC 2009). Approval for the lease and the college's development over part of Lot 23 was given on condition that the remainder was rehabilitated and the highly degraded remnant of ESBS present be restored. The cost of conservation and restoration measures was met by Moriah College. The requirements included fencing and storm-water mitigation, as well as complementary rehabilitation and some faunal habitat compensation on the site. The Centennial Park and Moore Park Trust now manage the York Road site.

Condition prior to treatment

Aerial photographs of the York Road site from the 1930s to the 1960s show that the bushland retained in the grounds experienced cycles of high disturbance followed by vegetation re-establishment. By 2002, the site was dominated by large specimens of Radiata Pine (*Pinus radiata*) and, to a lesser extent, the locally native shrub Coast Teatree (IPCS 2004, 2005).

Centennial Park and Moore Park Trust commissioned a vegetation management plan (Urban Bushland Management 2002), which stated that while there was a core area of bushland, the site formed a mosaic where patches of weeds were interspersed with bushland (Fig. 3), including areas dominated by Coast Teatree, providing a thick litter layer. The site contained 31 native vascular plant species, with some only represented by a few individual plants, and regeneration of heath species was minimal. Some 65% of all species recorded on the site were exotic or nonlocal natives, and serious degradation was evident on edges where materials, including incinerator waste, soil and building materials and garden waste, had been dumped over many decades.

The highly heterogeneous site was mapped, with management units identified and ranked in terms of their presumed potential for ESBS regeneration, based on above-ground indicators including residual native species and intact soil profile. As above-ground natives were rare in much of the site, the initial assumption was that the site would require woody weed removal followed by planting. Prior to the plan being finalized, however, a project manager, employed by the Centennial Park and Moore Park Trust, recommended an adaptive management approach based on treatments including the removal of weed and light soil disturbance, to trigger natural regeneration from the soil seed bank and natural expansion of the existing vegetation. After considerable discussion about the potential for natural regeneration, the management team agreed to at least a 5-year trial of such treatments prior to any reintroductions being carried out. As the natural regeneration capacity of the site was unknown, the trial treatments required intensive monitoring and close interaction between the project manager and on-ground ecological restoration practitioners.

Monitoring

Urban Bushland Management (2002) sampled quadrats for floristic assessment prior to works commencing, covering the entire site. As the approximate locations of the quadrats were known, these were re-established as permanent quadrats after works had commenced, allowing the use of the data collected prior to treatment, and additional quadrats were established. This resulted in the entire site being divided into 34 permanent, numbered quadrats. Twenty-one of these quadrats each had an approximate size of 20×20 m, and only these quadrats have been used to report the change in average species richness per quadrat on site. All quadrats were surveyed every 6 months (2004, 2005) and annually (2006, 2007), with data recorded on plant species presence/absence, number of stems of native species (individually counted only if <10) and maturity class [i.e. whether a stem had reached reproductive age (IPCS 2005)]. A photograph was also taken of each quadrat from the north-east corner.

The objective of the monitoring was to gain detailed information on how all parts of the site responded over time to the restoration programme as a whole. That is, the range of treatments was applied systematically, progressing across the site over a period of years. This did not allow an

Figure 3. Typical condition of vegetation on York Road (Lot 23) prior to work. (a) Weed-dominated understorey with deep mulch layer under large Pines, (b) Small patches of Eastern Suburbs Banksia Scrub (ESBS) heath species persisting under Pines and Coast Teatree.

experimental comparison of the effects of various treatments, with the exception of some fire piles and soil disturbance trials where *post hoc* comparisons with adjacent areas could be made. Although no untreated areas were retained as controls, some potential for comparison of treated and untreated sites existed early in the programme as the staged nature of the treatments meant that some areas remained untreated for a number of years.

Site sensitivity maps were produced, based on the quadrat data, to identify the locations of species represented by a single specimen and therefore at high risk of localized damage (IPCS 2005).

Restoration activities

A tall, continuous wire fence was erected around the site, and a bush regeneration company was engaged with a detailed guiding brief for the preferred on-ground restoration approach and specific treatments. The first stage of the on-ground restoration works involved the very careful removal of the Radiata Pines by professional arborists under strict controls. This coincided with a fierce storm that felled large numbers of senescent Coast Teatree. On a rolling programme, the whole site, with prioritization of the core areas, was gradually treated to: remove fallen Teatree and weeds; to reduce competitive impacts on natives; and, avoid new weed seed banks building up. This was carried out by skilled bush regenerators (initially twice weekly for 9 months, dropping to weekly, fortnightly and later monthly). Weed removal methods were largely manual, with cut-and-paint herbicide methods used where required but herbicide spray avoided (except in the case of Common Couch, *Cynodon dactylon*) to minimize damage to native plants.

Any standing ESBS vegetation was left intact or pruned, except where accidental disturbance occurred as described above. Further treatments to nonvegetated areas ranged from lower levels of soil disturbance (thick leaf litter removed by manual raking) to higher levels (spade digging and tillage with a mechanical auger) in some small areas. In many parts of the site, a thick crust, which had formed below the litter layer from years of natural debris and dumping, was also removed, while vegetation and topsoil were mechanically disturbed (unplanned) by a bobcat during fence construction (see Box 2).

To provide compensatory fauna habitat, fallen debris from the Coast Teatree was piled to create hides (e.g. for skinks, snails and birds), and a thicket of weeds including Lantana (*Lantana camara*), Morning Glory (*Ipomoea indica*) and other weeds which was already being used as a nesting site for Superb Fairy Wrens (*Malurus cyaneus*) was retained. Access paths were defined to enable works to be carried out while protecting regeneration elsewhere. Some salvaged ESBS plant material from the Moriah College site was excavated and held at Randwick Council Nursery. This was replanted in a prepared, separated section of the site in December 2003 (IPCS 2004, 2005). The Sydney Metropolitan CMA funded trial pile burns, with implementation by DECC. Twenty-two small piles (1 m × 1 m) were burned in 2008 in highly degraded

Box 2. Some results at other sites that contribute to our knowledge of regeneration dynamics of Eastern Suburbs Banksia Scrub (ESBS)

1 **Areas** of lawn at the North Head Sanctuary's former artillery site contain ESBS species pruned by mowing. These areas were identified as potentially having soil seed store of ESBS species. Mowing was discontinued to allow natural regeneration; and Buffalo Grass (*Stenotaphrum secundatum*) and Common Couch (*Cynodon dactylon*) were hand weeded, with some spot spraying. A dramatic increase in species diversity occurred after the cessation of mowing. Prior to treatment, nine species were present in the approximately 0.25 ha area, including only two ESBS species (the dominant shrubs Coast Teatree and Tree Broom-heath). After mowing was discontinued in 2007 and bush regeneration weed control undertaken over a period of 5 years, 37 additional species regenerated on the site. Of these, 18 were listed as characteristic ESBS species in the ESBS Final Determination (see Appendix S2). Coast Teatree, Tree Broom-heath and Kunzea (*Kunzea ambigua*) grew rapidly after the first year and closed the site in again, so these were selectively removed on average once a year, maintaining the diversity of species on the site. Culling was carried out in absence of fire to mimic natural conditions.

2 The national heritage-listed 3rd Quarantine Cemetery on the dunes at North Head Sanctuary was kept clear of woody vegetation for some decades. It was then neglected for a period and naturally regenerated to ESBS. When the Sydney Harbour Federation Trust took over management of this area there was pressure to clear the ESBS, since it conflicted with the built heritage conservation requirements of the site. A compromise position was agreed upon to remove the woody species only. This favoured the sub-shrubs and ground cover species and resulted in the cemetery having a starkly stronger representation of characteristic ESBS species (including *Epacris* sp., *Woollsia pungens*, *Styphelia viridis*, *Restio* spp, and *Lepidosperma*) than the adjacent ESBS area dominated by Coast Teatree with minimal understorey.

3 Small areas at three sites, York Road, the ESBS North Head site and Bunnerong Road each had instances of disturbance by earth moving equipment that resulted in the germination of unexpectedly high numbers of ESBS species. In two small areas where small quantities of three native species were found (*Lomandra longifolia*, *Xanthorrhoea resinifera* and Tree Broom-heath) at Bunnerong Road, for example, dense Bitou Bush (*Chrysanthemoides monilifera* subsp *monilfera*) and some Coral Tree (*Erythrina* × *sykesii*) were cleared in 2006. Some of the clearing was made by volunteers cutting and pulling Bitou Bush, with some cleared with a tractor-mounted tritter (that cuts vegetation at ground level without soil disturbance). In one area, disturbance of the topsoil occurred to a depth of approximately 100 mm as car bodies and partially buried rubbish was pulled from the soil. Regenerating species comprised *Acacia sophorae*, *A. suaveolens*, *Agrostis* sp, *Allocasuarina distylis*, *Bossiaea scl-opendria*, *Dianella sp*, *Digitaria sp*, *Entolasia stricta*, *Eragrostis brownii*, *Hibbertia scandens*, *Lepidosperma laterale*, *Lomandra glauca*, *Lomandra longifolia*, *Microlaena stipoides*, *Monotoca elliptica*, *Pteridium esculentum*, *Omalanthus populifolius*, *Oxalis* sp. and *Wahlenbergia gracilis*. The abundance of each species has increased and the health of the originally occurring plants has improved.

nonvegetated areas only, to trigger regeneration (*sensu* McDonald *et al.* 2002). Fuel for the piles came from the pruning of Sydney Golden Wattle (*Acacia longifolia*) and Coast Teatree. Later in the programme when the regeneration results from the seed bank were largely known, some site-collected seed of Old Man Banksia (*Banksia serrata*), Prickly Moses (*Acacia ulicifolia*) and Sweet-smelling Wattle (*Acacia suaveolens*) were collected and spread in wider areas of the site.

What regenerated after the treatments?

As treatments to remove weed and other biomass removal progressed and warm-season rainfall provided suitable germination conditions regeneration occurred. The degree and extent of regeneration from the persistent seed bank, however, exceeded expectations. The total number of native species increased only slightly over the 6 years (2001–2007) from 31 to 35 species, but there was a dramatic increase in abundance and distribution of native species across the site. The average native species richness in the total of 21 quadrats steadily increased from 5 to 14 species, with a maximum per quadrat of 10 in 2001 to 22 in 2004, stabilizing around that point (Fig. 4). Species that regenerated as a result of the initial treatments soon began to colonize the open spaces, with visible increases in density. The increase was particularly evident as a 'halo' effect, moving from the stronger regenerating areas outwards to more bare areas left after the clearing of Radiata Pine, Coast Teatree and the thick litter/debris crust.

As expected, the initial regeneration flush was higher in areas that were mapped (on the basis of residual above-ground vegetation and intact soil profiles) as having higher regeneration potential. What was not expected, however, was that many of the lower-ranked areas also showed a positive response including regeneration of characteristic ESBS species, particularly where the soil was physically disturbed by raking and thick litter removal. For example, Variable

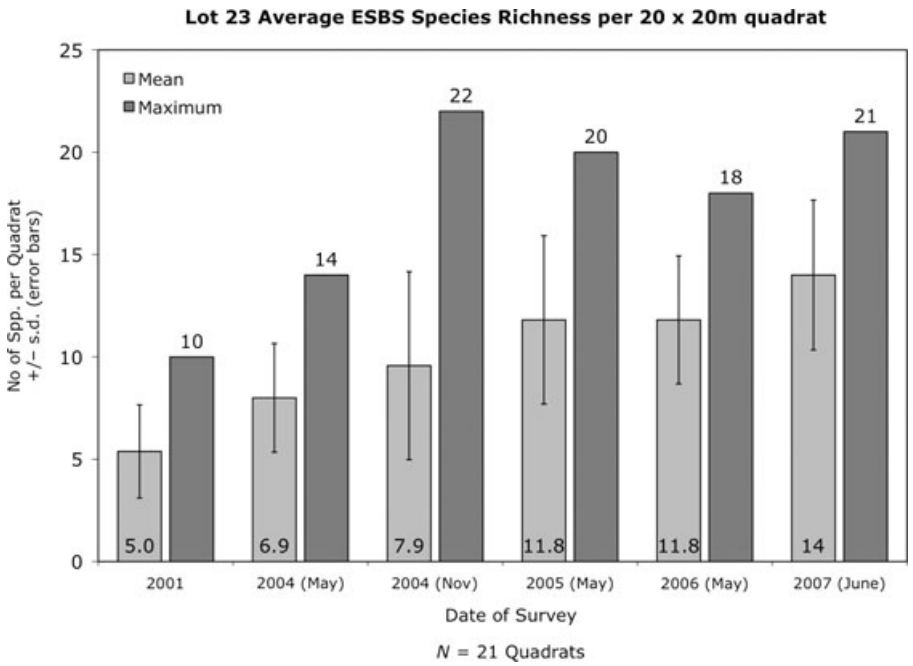

Figure 4. Steady growth in mean species richness per quadrat of Eastern Suburbs Banksia Scrub (ESBS)-characteristic species between 2001 and June 2007 (Note that two readings for 2004 are presented here – and the range of treatments, their gradual application and the patchy condition of the site are all factors that would help to explain the high variance in the results). Data sources: 2001: Urban Bushland Management (D. Thomas); 2004–2005: Ian Perkins Consultancy Services; 2006–2007: Parsons Brinkerhoff.

Bossiaea (*Bossiaea heterophylla*), Pine Heath (*Astroloma pinifolium*) and Tree Broom-Heath regenerated in the lowest ranked Zone 6, where weeds were treated by hand and the ground bared; *Dillwynia glaberrima* germinated in a small 1×1 m area that had been dug with a spade to a depth of 20 cm, and outstanding regeneration of a range of ESBS species occurred in one section of the fence construction area, Management Unit 7, after a bobcat was used to clear vegetation for the construction of the fence line (Fig. 5). Other parts of the fence line that were similarly disturbed did not show similar results.

In the bare areas, regeneration was most evident where small banks of fine leaf litter/organic matter had built up on the bare sand, possibly providing more suitable locations for seed to collect and germinate. However, some areas on the more damaged boundaries did not produce a regeneration of a diversity of species, even with the burning of fire piles. Indeed, there was little difference in the number (species richness) of regenerating ESBS species between soil disturbance and fire piles in the more damaged areas (to which fire was confined).

None of the more sensitive species salvaged from the site survived the initial salvage and storage stage of the process. The only species that survived the translocation process were hardy monocotyledons and Commelina (*Commelina cyanea*) (IPCS 2004, 2005). Some of the boundaries of the site, particularly where the contaminated soil was not removed, remained highly weed dominated (mainly by the grass Ehrharta, *Ehrharta erecta*).

The gradual increase in natives was not substantially affected by the scattering of some native seed (collected from the site) as this did not occur until 2006 and was only carried out to a minor extent. An exception is in the case of Old Man Banksia, where scattering is likely to have been responsible for increasing numbers of this species establishing both near the single parent tree and also at a distance, because *Banksia* spp. do not store seed in the soil.

Did 'characteristic ESBS' species increase on site?

Fifteen ESBS-characteristic species (as listed in the Final Determination) occurred on site prior to works commencing (Urban Bushland Management 2002; I. Perkins, 2012, unpubl. data). To date, a further four have been found, some of which clearly regenerated after the commencement of works (including *Hibbertia fasciculata*). Like all species, these species increased in abundance and distribution across the site. The most abundant species regenerating were the colonizing species such as Sydney Golden Wattle, Sweet-smelling Wattle and Coast Teatree, although amongst the most abundant juveniles were Variable Bossiaea, Prickly Beardheath (*Leucopogon juniperinus*), Pine Heath, Tree Boom-heath and Prickly Moses (Parsons Brinkerhoff 2007). Other species that regenerated are listed in Table 2, and the spread of all characteristic ESBS species across the site, compared to all regenerating species, is illustrated in Fig. 6.

Implications for management at other sites

The overall appearance of the York Road site changed dramatically over a period of 5 years from a dark, overshaded and weedy site to an open shrubby character as a result of the consistent programme of treatments designed to remove weeds and trigger regeneration. Weed infestations were generally confined to small sections, including areas left untreated to provide fauna habitat.

Restoration practitioners at the time assumed that the removal of competition and mimicking of natural disturbances would help kick start successional recovery at York Road, as had occurred elsewhere (Pallin 2000; McDonald *et al.* 2002). This has been borne out by observations of progress at the site, but to a much

Box 3. Greening the greens

Five golf courses in eastern Sydney contain substantial areas of ESBS. Some clubs are progressing well with restoration and management programs (See Appendix S1). New South Wales Golf Club and Bonnie Doon Golf Club, for example that have active management programs and have had good success in restoring ESBS.

Bonnie Doon Golf Course has a number of high quality remnants, some of which have been under bush regeneration treatment for many years, along with a range of other management and restoration initiatives (See Appendix SI). An accidental fire in 2007 produced very favourable germination of ESBS species and reinvigorated existing stands of vegetation. Bush regeneration is now being carried out by staff and volunteers, including Club members, which has generated interest and cultural change within the Club (Fig. 7).

NSW Golf Course at La Perouse has 12.96 ha of high quality, diverse ESBS remnants, with linkages to Botany Bay National Park, which has 10 ha of ESBS. A wildfire in 1998 improved the condition of some of the remnants so the Club adopted fire as an ecological and management tool. An ongoing fire strategy has been in place since 2006, with the Club working in collaboration with the Office of Environment and Heritage (OEH) and Botany Bay National Park. In addition, contract bush regeneration works have been ongoing without interruption for about 7 years. Works include pre- and post-fire weeding and address issues including excessive wattle germination after a fire. This has resulted in diverse stands of ESBS and a more appealing golf course.

The experiences of these golf courses show that it is possible to improve the condition of ESBS whilst allowing for a workable golf course. This can provide a positive experience for golfers and potentially a financial return to the club.

In 2011, the OEH ran a workshop to show other golf clubs that this was possible. The workshop was hosted by New South Wales Golf Club and brought together interested parties to showcase best-practice management of this community, discuss the specific management needs of golf courses, and establish ongoing collaborative working relationships. Club managers also had an opportunity to air concerns and exchange information about ESBS management, resulting in an increase in interest and a sense that there is a community working together and gaining support and assistance. Randwick City Council offered free bush regeneration training to provide practical knowledge and assistance in preparation of grant applications, which had golf club board members and Bushcare volunteers in attendance.

The Sydney Metropolitan Catchment Management Authority has since gained a Biodiversity Fund grant to work with a network of stakeholders within the golf industry, state and local government, universities and ecological consultants. Further workshops are planned for owners/managers of golf courses with federally listed EECs. Some on-ground activities on golf courses (including at Bonny Doon and The Lakes) will also be funded.

Figure 7. Bush regeneration at Bonnie Doon Golf Course being carried out by staff and volunteers, including Club members (Photo. Gary Dempsey).

Figure 5. Regeneration of Eastern Suburbs Banksia Scrub (ESBS) species in Management Unit 7 following disturbance by a bobcat (180 degree view from within Lot 23 to north-east.) (a) April 2003 following vegetation clearing and soil disturbance for fence construction, (b) High levels of native regeneration in May 2004.

Table 2. The 21 species (listed in the Final Determination as characteristically ESBS) that occurred at the York Road site prior to 2005. Most existed prior to works but all expanded their range by 2005. (Updated from Parsons Brinkerhoff 2007)

Acacia longifolia	*Bossiaea scolopendria*	*Kunzea ambigua*
Acacia suaveolens	*Brachyloma daphnoides*	*Leptospermum laevigatum*
Acacia ulicifolia	*Dianella revoluta*	*Leucopogon ericoides*
Astroloma pinifolium	*Dichelachne crinita*	*Lomandra longifolia*
Banksia integrifolia	*Dillwynia retorta*	*Monotoca elliptica*
Banksia serrata	*Eragrostis brownii*	*Persoonia lanceolata*
Bossiaea heterophylla	*Hibbertia fasciculata*	*Xanthosia pilosa*

ESBS, Eastern Suburbs Banksia Scrub.

higher degree than was predicted. That is, in all management units, the removal of weed or heavy shade was sufficient to trigger germination of a range of species in most of the treated quadrats. This was less evident in lower-condition quadrats, although germination still occurred in these without the addition of seeds.

Regeneration after the creation of bare soil conditions, followed by rainfall, conforms to what would be expected of heath communities that are adapted to regenerate after being exposed to conditions created by wind and periodic fire (Gill 1981; Bradstock *et al.* 1995; Hill & French 2004). The heath shrubs and subshrubs that regenerated were mainly soil seed-storing species rather than the whole suite of species, however, that might be expected to occur in fresh topsoils (Tozer *et al.* 2011). Although some regeneration of two *Banksia* species did occur (Table 2), it is possible that the site may have previously contained resprouting species that did not survive the long period of degradation (McDonald 1996, 2000).

We also found that the removal of the thick leaf litter layer and debris crust was important in that it revealed a more natural sandy soil and removed weedy and nutrient-rich topsoils. Where weeds were problematic, it was highly beneficial to invest in the removal of this topsoil. In other areas, however, the key appeared to be allowing time for regeneration and the consistent removal of weed species before they created new seed banks. This was reinforced when a crisis of funding meant that general horticultural staff replaced skilled regeneration contractors, and the standard of treatment was not kept up. The increase in weed infestations during this horticultural maintenance period resulted in a bush regeneration team being re-engaged on site.

Arguably, the major lesson, however, is that, prior to this work, residual above-ground vegetation of at least some sort was used as a predictor of regeneration potential (Urban Bushland Management 2002), whereas after works at York Bunnerong Road it became clear that the absence of above-ground indicators did not necessarily mean absence of a buried seed bank, that is, there was a higher than predicted regeneration response of species in areas initially assessed as 'nonbushland'.

Works at Other ESBS Sites

The Recovery Plan identified five objectives to improve the conservation management of ESBS (DEC 2004: 10–12) at 24 ESBS sites known in 2004. It is not the intent of this paper to assess the extent to which land managers are progressing with these five objectives. However, we believe that we can make some useful comments on the extent to which progress is being made with Objective 3 (*To restore, and where practical, connect and enlarge remnants through appropriate management*). Appendix S1 – drawn from our own observations and informal discussions with other ESBS managers – provides some insights into current progress with Objective 3 and notes the threats currently being managed and those not yet being managed.

The Recovery Plan also identified a requirement for each remnant to have a management plan that addresses a range of site management issues (including fire management, weed management, site hydrology, pest management, access, decontamination, protective fencing and interpretive signs) and provided a checklist of whether such actions were underway at the 24 sites. Table 3 provides an update of the original table in the Recovery Plan, adding data we have gleaned from our own experience and contact with site managers and agencies. Although the level of intervention that a land manager may have carried

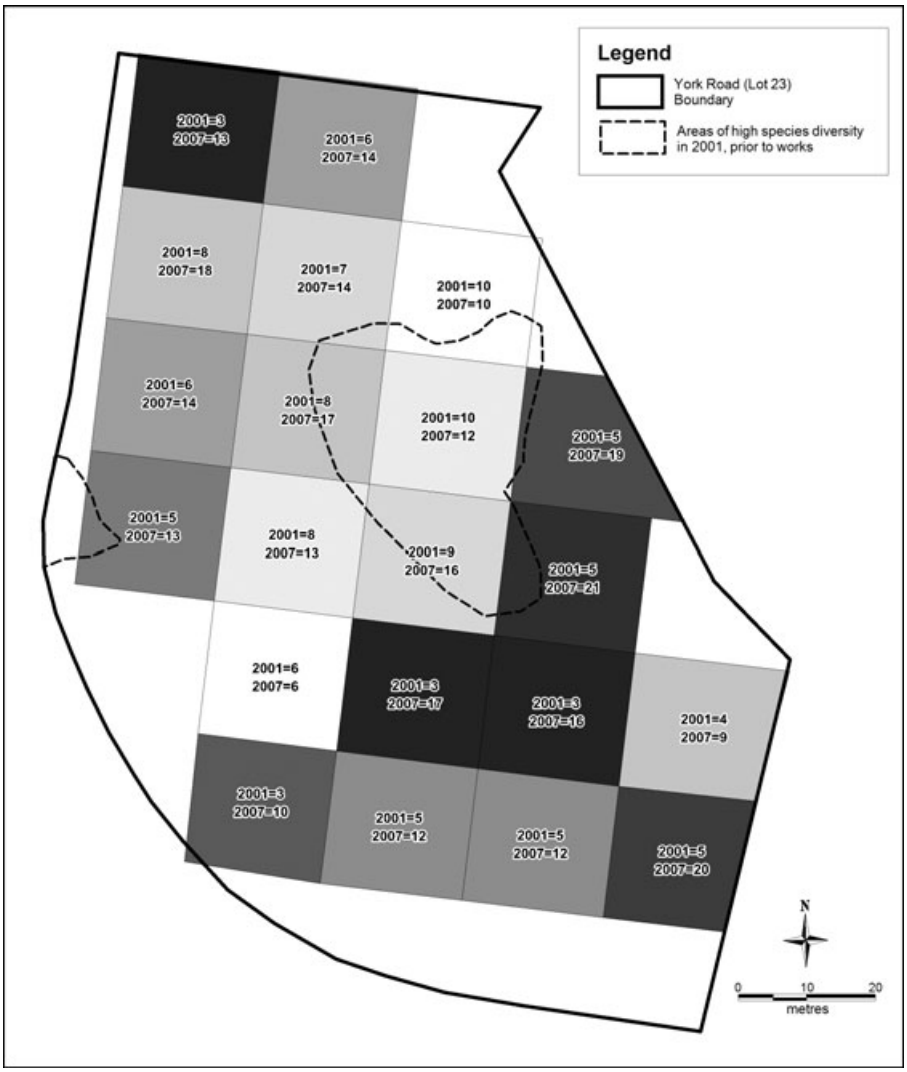

Figure 6. Increase in Eastern Suburbs Banksia Scrub (ESBS)-characteristic species in the approximately 20 × 20 m quadrats, York Road (Lot 23) from 2001 to 2007 (Darker shading denotes higher increase, and lighter shading denotes nil or lower increase). While greater change (denoted by darker shading) occurred in areas that originally did not have as many species to start with, high final species richness was not confined to areas with stronger above-ground vegetation.

out is not indicated in the table, progress is clearly being made at most of the sites.

Variable progress at the 24 sites

Our direct observations over the years (summarized in Appendix S1) suggest that management and adherence to the Recovery Plan and Best Practice Guidelines has been taken up well by some local, State and Commonwealth government agencies, and some other landholders, notably golf clubs. Fifteen of the 24 sites report an improvement in condition of the remnant and a further three report some improvement. Generally speaking, the government agencies recognize their responsibilities under the State and Commonwealth legislation, although there are a couple of exceptions. Active management of ESBS is poorest to nonexistent on private land holdings where the intention is development. Indeed, the extent of ESBS has been reduced due to development or other actions at five sites, and it is currently under threat from development at a number of other sites.

There are several reasons why this variable rate of progress may be the case: less work may have been undertaken at some sites than at others due to varying levels of funding for, and commitment to, works, and/or there is varying capacity and commitment of the land managers to carry out this work. Some sites, however, despite the best available management, show only limited recovery potential, at least using the methods applied to date. Of the remnants under the management of Randwick City Council, for example, parts of the Bunnerong Rd site have been affected by heavy horse and rabbit grazing and most of Randwick Environmental Park's topsoil was excavated and moved around in the mid-20th century. While some ESBS species in these two locations have responded to regeneration techniques in the last 10 years, others remain absent. Whether deeper soil disturbance will provoke regeneration of a more diverse range of species is yet to be tested. This reinforces the need to customize restoration plans for each reserve depending on their land-use history, and building in an experimental component.

Lessons Learned

About regeneration potential

It is clear that the ecological restoration efforts described here provide strong collective evidence that the disturbance adaptation of many of the species in ESBS lends a capacity for regeneration from soil seed banks, in some cases even after prolonged absence of optimal disturbance (such as fire). It is equally clear, however, that excessive disturbance and impacts such as horse grazing, dumping or soil pollution can severely deplete the capacity of this seed bank and can also lead to the depletion of resprouting native species over time.

The results at York Road highlight the importance of triggering natural regeneration, and leaving sufficient time for it to occur. Thus, species that

are adapted to the soils and conditions of a site – whether ESBS or any similarly adapted ecosystem – may regenerate naturally, lessening the need for the planting of material sourced from elsewhere. If the site been planted, without opportunity or effort to facilitate regeneration from the soil seed bank, it is very likely that valuable species and genetic material would have been wasted or lost, replaced by species and genetic material already occurring in other remnants. Thankfully, this was known at the time of the development of the Recovery Plan, which recommended that ESBS restoration programmes should utilize the *in situ* resilience of the remnant to the fullest extent practical.

Works experienced or observed by the authors at York Road and a range of other ESBS sites reinforce that sound results require sound site assessment, an understanding of the history of the site, skilled management interventions and commitment over a long period. Different disturbances may need to be carried out to maximize the diversity of the regenerating species. For example, more deeply buried, older seed banks may need greater levels of soil disturbance to bring seed to the surface, particularly in the absence of fire and native animal digging. Disturbance in better areas may result in regeneration of less common ESBS species that are in short supply. Commitment to long-term funding is highly desirable, whatever a site's condition. If this assurance is not available, it is important to work strategically to safeguard the better areas, and reduce the extent of primary weed control to suit the resources available.

About ongoing management issues

Managers have identified a range of detrimental issues that persist with ESBS remnants including the ongoing exclusion of natural disturbances, loss of species and restricted gene pool in some remnants, lack of connectivity, ongoing legal destruction and inadequate links to research.

Exclusion of natural disturbance

Until the 1990s, many ESBS sites remained long unburnt. Fire (along with wind blows and animal diggings) is a natural disturbance type that would have periodically culled dominant species and allowed a broader diversity of species to emerge and reproduce, recharging the soil seed banks (Gill 1981; Tozer & Bradstock 2002). Although long-lived, resprouting native shrubs such as *Banksia* spp and *Xanthhorrhoea resinifera* still characterize the vegetation in some remnants, decades of inappropriate fire regimes have led to a lowering of diversity of soil-storing species. This effect was most evident at the smaller, less intact and isolated remnants (DEC 2004).

Table 3. *In situ* conservation measures being undertaken at ESBS sites. This is adapted from Table 2 of the Recovery Plan (DEC 2004), updated by the authors after consultation with agencies and the active landholders. The nonbold text represents the entries recorded in the original Table 2 of the Recovery Plan (DEC 2004), and the bolded text represents the June 2012 updated entries. Blanks indicate no activity at this date, to the best of our knowledge

Site name & location	Mgt. Plan	Weed mgt.	Fire mgt.	Erosion mgt.	Access mgt.	Protective fencing (or other)
Anzac Parade Malabar	**Yes**	Yes		**Yes**		
Arthur Byrne Reserve, Maroubra	Yes	Yes		Yes	**Yes**	Yes
Australian Golf Club Kensington						Part
Banksmeadow Primary School, Banksmeadow	Yes				**Yes**	Yes
Bonnie Doon Golf Course, Pagewood	Yes	Yes	**Yes**	Yes	**Yes**	
Botany Bay NP, La Perouse	Yes	Yes	Yes	Yes	Yes	
Bunnerong Road, Chifley	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Bunnerong Substation, Matraville	**Yes**	**Yes**		**Yes**	**Yes**	Yes
Centennial Park	Yes	Yes	**Yes**	Yes		Yes
Eastlake Golf Course, Eastlakes	**Yes**	**Yes**				
Jennifer St (ALC Lands), Little Bay						
Jennifer St (Telstra Lands), La Perouse & Little Bay						Yes
Malabar Headland East, Malabar	**Yes**	Yes			**Yes**	**Yes**
Malabar Headland West, Malabar	**Yes**	Yes	Yes		**Yes**	Yes
Maroubra Reservoir, Johnston Parade Maroubra						Yes
North Head, Manly	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Part**
NSW Golf Course, La Perouse	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes
Pioneers Park, Malabar	**Yes**	**Yes**		**Yes**	**Yes**	**Yes**
(Former) Prince Henry Hospital Anzac Parade, Little Bay		**Yes**	**Yes**		**Yes**	**Yes**
Randwick Environment Park, Kingsford	Yes	Yes		**Yes**	**Yes**	Yes
St Michael's Golf Course, Little Bay		Yes				
The Lakes Golf Course, Eastlakes	**Yes**	**Yes**	**Yes**	**Yes**		
Wassell St., Chifley	**Yes**	Yes	**Yes**	Yes	**Yes**	Yes
York Rd, Bondi Junction	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes

ESBS, Eastern Suburbs Banksia Scrub.

Accidental hot fires that occurred in remnants at the NSW Golf Course (1998) and Malabar (1990s) have resulted in strong recovery of ESBS species. This reinforced the value of the use of fire as a regeneration tool for this community. Since then, fire management strategies have been prepared for a number of ESBS remnants, notably Botany Bay National Park and the NSW and Bonnie Doon golf courses. Other sites that are unable to conduct surface burns due to risk to infrastructure replace fire with pruning of vegetation to remove biomass and prevent overshadowing. Indeed, the overwhelming consensus from managers is that all the sites that have been opened up by the removal of weeds or overmature vegetation have experienced natural regeneration from the soil seed bank over time.

In areas depleted of above-ground natives, fire piles and/or raking the soil is increasingly being trialed (such as at Centennial Park) to mimic natural disturbances in an attempt to stimulate germination from long-buried seed banks. These efforts, which are generally only applied in highly degraded sites, have resulted in some recovery but greater success has occurred with higher-magnitude soil disturbances (e.g. from a bobcat) in at least two sites, which suggests that deeply buried seed banks may need to be brought to a higher level in the soil profile to germinate (See Box 2).

These results indicate that ESBS communities may initially appear more degraded (or less resilient) than they are. It needs to be noted, however, that highly degraded soil seed banks themselves may have a disproportionate representation of more resilient species and lower numbers of less persistent soil seed–storing species than might have been the case in their healthy states. This could cause some species to dominate disproportionately in the above-ground flora if not managed for a period of some decades. There could be a case to be made, therefore, for favouring the build-up of some less resilient species by culling to reduced more resilient species such as *Acacia* spp. (where this does not affect other species) until the sites return to a more biodiverse state. Long-term studies would be needed to test these assumptions.

Loss of species, reduced gene pool and low connectivity

A case may be made for reintroducing other species likely to have been on a site but which are now absent, particularly shrubs that may have been cleared in the past or species that do not form persistent soil seed banks. It is important to note, however, that the very small size of some fragments limits their capacity to assimilate extra species and higher diversity may not be functionally necessary. The isolation of many sites also raises the question of the potential need for reintroductions from other ESBS remnants to avoid inbreeding depression (Broadhurst *et al.* 2008), although caution needs to be taken to first determine the adequacy of the existing level of gene flow and the diversity across the landscape for the species in question.

Linking some areas may provide increased area and greater habitat connectivity that may in turn assist with genetic function. It must be remembered, however, that ESBS is naturally confined to fairly uncommon and very low-fertility aeolian sands that have naturally formed islands within a matrix of other communities. Appendix S1 and the maps in the Recovery Plan identify that there is only limited potential for expansion and direct linking of ESBS remnants, although potential exists for links with other community types. The highest potential occurs at three complexes: North Head, Malabar and La Perouse. The focus of policy is understandably on conserving, restoring and extending large tracts of intact remnants. However, it is clear that the value of lower-condition lands is increased where these may be situated near other remnants or where they can be connected to form larger areas. They are also important as they provide links or stepping stones for nectarivorous birds that may assist with pollination. Connectivity could potentially be enhanced through appropriate management of the landscape 'matrix' between ESBS remnants.

Planting and direct seeding, however, would be improved if a number of protocols were implemented to maintain the scientific values of sites (such as accurately recording the location of plantings). Indeed, it is important that managers avoid slipping into a 'gardening' mentality, that is, they refrain from planting excessive numbers of species for the size of the site or undertaking excessive levels of culling or planned disturbance to favour more aesthetically pleasing species at the expense of others. Care needs to be taken, therefore, to base decisions about culling on whether the target plants are preventing other species from recharging their seed banks and to base decisions about planting on a sound assessment of whether a small stand is genuinely species deficient, or when they have the appropriate number and type for their patch size. Well-defined biodiversity conservation and management objectives for ESBS, not aesthetics, should form the basis for applying interventions such as culling, planting, seeding and planned disturbance.

Ongoing legal destruction

The cases reported above where development has occurred, destroying ESBS remnants, highlight the fact that listing under the TSC Act, while influential, does not confer absolute protection. This problem is exacerbated by a tendency of people to assume that the Recovery Plan's mapping of ESBS is definitive and that if a site is not mapped it can't be ESBS. What determines whether a site is ESBS or not, however, is the definition of ESBS in the Final Determination (NSW Scientific Committee 2002), not maps.

Similarly, problems arise when such decisions are made on the basis of how many species persist above ground. Indeed, a strong ecological case could be made that because the soil seed bank is part of the community, as listed in the Final Determination (and we know soil seed banks can be triggered to express a wider range of species), a relatively depauperate patch of aeolian sand with an intact seed bank should still be considered ESBS.

Weak links to research

All of the above issues associated with ESBS restoration management warrant further involvement by researchers to provide or improve the evidence supporting the conservation and management of this community. In particular, improvements could readily be made in the value of monitoring data if monitoring were designed with research questions in mind. Formal monitoring is only carried out on a few sites and even on some of those sites, sampling is not undertaken in ways that can gain insights about the responses of sites of different condition to different treatments. Insights into the role of disturbance, genetic diversity, reproduction issues and species–area relationships could all be enhanced by further formal research.

Take-home Messages

For reasons discussed above, our recommendations are that land managers

- Seek to conserve all intact aeolian soils and consider testing these sites for regeneration and reconstruction potential
- Experiment to provide information on more optimal levels of disturbance including fire, deep raking, mechanical disturbance with machines and/or smoke water to optimize the regeneration of characteristic ESBS species from potentially long-buried seed banks wherever they may be. These seed banks are not reliably predicted by above-ground flora or its condition
- Undertake ecologically informed revegetation to achieve habitat extension and improved linkages where suitable conditions exist (and to enhance existing depleted areas that were known to have higher species richness in the past)
- Consider potential ESBS areas on the potential of their soils alone, and include regeneration areas in development consent conditions for areas affected by development applications
- Avoid slipping into a 'gardening' mentality that favours aesthetics over ecological outcomes.
- Actively seek relationships with research and educational institutions to support increased investment in research to provided stronger evidence for ongoing adaptive management.

The achievement of higher than anticipated levels of regeneration at Lot 23, despite its highly degraded state prior to work, highlights the need for us to be cautious in giving up on small, degraded patches of ESBS and other communities. Not all communities will be like ESBS, but until we know which ones do not fit the same model, we should tread cautiously.

In conclusion, we observe that the fragmented nature and small size of many of the sites is unlikely to change and the difficulty of expanding and linking these areas due to competing land uses will persist. Rather than dampening commitment, however, this fact should galvanize us to further our efforts to save what remains of this EEC and others like it.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Degree to which sites under management have progressed in terms of Objective 3 of the ESBS Recovery Plan (i.e. to restore, and where practical, connect and enlarge remnants through appropriate management).

Appendix S2. Species Regeneration in (50 × 50 m) Formerly Mown Lawn Area, North Head Sanctuary, North Head Scenic Drive, Manly Recorded by Peter Jensen Environment Officer Sydney Harbour Federation Trust 2007–2012.

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