Bush regeneration - measuring success

Robin A. Buchanan, Ryde TAFE, 250 Blaxland Road, Ryde, NSW 2112, Australia.

Summary

Control methods for many environmental weeds in Sydney are well established. Methods for monitoring the progress of bush regeneration are now required. As many urban bushland areas are degraded, reference sites with a known vegetation history are needed to establish objectives for the reconstruction of desirable native plant communities. Measurements of structural characteristics: species richness, foliage cover, density, frequency, biomass production and flowering pattern are suitable for monitoring the progress of bush regeneration. An analysis of the function of vegetation, at species and family level, is also needed to set specific regeneration objectives and to achieve prescribed standards. Functional analysis may include factors such as nitrogen fixation, flammability, nectar production and provision of nesting material for specific animal species.

Revegetation aims should consider the sustainability of vegetation communities, their resistance to weed invasion and level of nutrient retention. Specific goals, such as the number of nitrogen-fixing shrubs per unit area at a fixed time interval after weed control, should also be specified. If these goals are not reached, then alternative actions need to be considered.

Introduction

Chemical and mechanical control methods for many environmental weeds in Sydney are well established (National Trust of Australia (NSW) 1991). What is now needed is a concerted effort to ameliorate the factors contributing to environmental weed invasion, and the establishment of methods to measure not just weed control, but the success of bush regeneration. Specific goals need to be developed for each regeneration site. Macdonald *et al.* (1990) list specific vegetation restoration goals as part of the first step of restoration planning and provide criteria for the identification of successful regeneration.

In the last two to three years, bush regenerators in Sydney have focused on regenerating specific species and communities rather than accepting all native species as valuable. At Sheldon Forest, in northern Sydney, bush regenerators face four main problems which typify problems of bush regeneration elsewhere.

1. Lack of reference areas

Where ecosystems have been so greatly disrupted that no undisturbed areas remain, the lack of suitable reference areas is a constraint to restoration planning (Allen 1991). Only tiny remnants of the original vegetation type found at Sheldon Forest, the blue gum high forest, exist today (Benson and Howell 1990). All remnants are surrounded by suburbia, have been invaded by weeds and have an extremely low fire frequency. Most early accounts describe large trees, which were subsequently logged or cleared, and only give a general description of the under-storey vegetation. Present-day botanists have to guess at the species composition of an understorey described as 'very high grass and much thorny growth' (Thorne 1979).

2. Low fire frequency

The recollections of local residents indicates that a large section of Sheldon Forest has not been burnt for at least 40 years. The Sydney region can normally expect a fire every 5 – 12 years (Walker 1981). This unusually low fire frequency at Sheldon Forest has aided the invasion of mesic plant species into the understorey.

3. The invasion of mesic understory species

The native shrub to small tree sweet pittosporum (*Pittosporum undulatum* Vent.) is the main invader at Sheldon Forest. In areas of low fire frequency it has formed a closed canopy at a height of 3 – 5 m. Sweet pittosporum is indigenous to Sheldon Forest, but densities at the current level have not been previously recorded. Smaller shrubs and grasses have vanished or are now uncommon in parts of Sheldon Forest as a result of invasion by sweet pittosporum. Three environmental weeds: camphor laurel (*Cinna-momum camphora* (L.) Nees), large-leaved privet (*Ligustrum lucidum* Ait.) and small-leaved privet (*Ligustrum sinense* Lour.) also appear to have been favoured by the low fire frequency and the dense cover created by *P. undulatum*. These broad-leaved mesic shrubs and trees have added to the closed canopy and contributed to the reduction of species diversity and understorey biomass.

4. A changed ecosystem

Unless Sheldon Forest is meticulously managed it will be unable to carry fires of sufficient frequency and intensity to enable *Eucalyptus* spp., *Acacia* spp. and other hard-seeded native species to germinate.

In 1989, Ku-ring-gai Municipal Council carried out an experimental burn in a small section (6300 m^2) of the forest. Despite burning immediately before the official fire season to ensure the hottest fire possible (Kevin Whale, personal communication), the fire intensity was low and patchy and was insufficient to kill more than 50% of the *P. undulatum*. Soil temperatures also appear to have been insufficient to initiate abundant germination of hard-seeded species. The densest growth of *Acacia* seedlings was present in a ring around a 2 m high bonfire of dried *P. undulatum* branches.

Monitoring revegetation programs

If the characteristics of reference plant communities are to be adopted as management goals, then simple and periodic measurements to record the progress of vegetation reconstruction need to be taken.

Classic methods of plant ecology measure: production, nutrient budgets and population biology, and describe the structure and floristic composition of vegetation (Moore and Chapman 1986). Many of the methods used to measure variables within these broad categories utilise quadrats or transects in sampling procedures (Lincoln and Boxshall 1987). The number of replicates and the layout of sampling points needs to be carefully planned, especially if statistical analyses are to be carried out. Quadrats and transects can be permanently or temporarily marked (Moore and Chapman 1986). Measurements can be divided into those that record structural or functional characteristics.

Structural and floristic characteristics are commonly used in restoration projects (Harrington 1990, Bonnicksen 1990, Buckner 1990) and those used include: species richness, species density, species biomass, yearly biomass production, foliage cover, species phenology, life form, life-form density, frequency and family composition.

The functional characteristics of species can be considered in a number of ways. *Banksia ericifolia* L.f. and *P. undulatum* can grow in the same community and have a similar height and spread. If left unburnt for 30 – 40 years, *B. ericifolia* can be replaced by *P. undulatum* causing changes to fire frequency and intensity, nutrient cycling and habitat availability (Table 1). Regenerating a *B. ericifolia* dominated understorey after invasion by *P. undulatum* may be difficult as fire, which is required to kill *P. undulatum* and to trigger seed fall and germination of *B. ericifolia*, cannot be sustained.

Many parts of northern Sydney are dominated by the smooth-barked gum (*Eucalyptus haemastoma* Sm.). Other eucalypt species such as *E. piperita* Sm. (short fibrous bark), *E. gummifera* (Gaertn.) Hochr. (corky bark) and various species of stringybark co-occur with *E. haema-stoma* but only as scattered individuals. Rough-barked *Eucalyptus* spp. provide habitat for insects, and hence insectivorous birds, which is not available on smooth-barked gums. Stringybarks also provide nesting material for many birds, and the ringtail possum (*Pseudocheirus perigrinus* Boddaert). Bush regenerators need to ensure that rough-barked *Eucalyptus* spp. are maintained in *E. haemastoma* forests.

Species of Fabaceae (wattles and peas) are nitrogen fixers. Consequently, *Acacia longifolia* (Andrews) Willd. var. *longifolia* is commonly replanted on regeneration sites. Its nitrogen fixing function is quite different to the structurally similar weeds it may be replacing, such as *L. sinense* or *P. undulatum*. Increases in soil nitrogen may increase the susceptability of these sites to weed invasion.

The function of grasses should also be considered in revegetation programs. The experimental fire at Sheldon Forest induced abundant grass regrowth, but the majority was *Oplismenus* sp., a mat-forming species. Tufted grasses such as *Themeda triandra* Forssk. were less common. The inter-tussock spaces of tufted grasses provide niches for herbs and shrubs to establish, while mat-formers tend to blanket the ground reducing the availability of establishment sites.

Measurable functional characteristics of restored communities, including soil functions such as nitrogen fixation, decomposition rates and rate of organic matter accumulation have been developed for wetlands and prairies in America (Zedler *et a1*. 1990, Harrington 1990). The ability of prairies to carry fires has received considerable emphasis. Generally, by the third year of growth, restored prairies should be able to carry a fire and recover quickly. This requires at least one fire carrier per square metre (Harrington 1990). Similar specifications are required for Australian plant communities.

Table 1. Comparison of the biology and function of *Banksia ericifolia* and *Pittosporum undulatum*

B. ericifolia	*P. undulatum*
Killed by moderately intense fire.	Killed by moderately intense fire (Gleadow and Ashton 1981).
Burns readily.	Burns with difficulty.
Seed released after fire.	Seed released annually.
Seedlings establish best in bare mineral soil with little to no shade.	Seedlings establish in deep leaf litter with moderate shade (Gleadow 1982).
Dense proteoid roots in the leaf litter and top few centimeters of soil helps prevent erosion.	Open root system, not concentrated in upper soil (Gleadow and Ashton, 1981). Erosion under dense stands common.
Leaf litter of fine twiggy material helps prevent erosion.	Leaf litter mainly leaves which are easily washed downslope.
Flowers in autumn/early winter.	Flowers in spring. Attracts few insects and birds.
Abundant nectar attracts insectivorous. and nectar-feeding birds.	Some berry-eating birds attracted in winter.
Fine branches provide nesting sites and shelter for small animals.	Large nest builders such as ring-tail possum most common.

Fauna and micro-organisms

There is a strong temptation for ecologists to assume that the establishment of the vegetation is what comes first and that the animal component will follow naturally, or can be put in almost as an after thought. What is becoming clear is that plant communities are what animal communities make them (Harper 1987).

Animal-pollinated plants should be sufficiently abundant to attract pollin-ators and should be present in a habitat which provides shelter for the pollinator, so that adequate fertilisation of flowers occurs. The habitat should provide breeding sites and be large enough to provide suitable territories for pollinators. A lone *B. ericifolia* growing outside an office building in inner Sydney may fail to attract bird or mammal pollinators (Turner 1982, Paton and Turner 1985) as other requirements may not be present.

Ants are important in most Australian ecosystems and are functionally important at all tropic levels (Andersen 1990). They can disperse seed up to 75 m from the parent plant (Beattie 1982) and often place seed in sites favourable for subsequent germination and establishment. Ants aerate and mix the soil, provide drainage channels, incorporate organic matter deep into the soil and create a low level of long-term disturbance (Kline and Howell 1987). Old or poorly attended ant mounds provide sites for seedling establishment (personal observation). Disturbance by ants may be important for seedling establishment in ecosystems subject to less disturbance by fire and animal diggings than that which occurred prior to European settlement. Bush regenerators have observed that bare soil caused by bandicoot diggings aids seedling establishment during inter-fire periods. Bandicoots are now absent from much of northern Sydney and inter-fire seedling establishment may be reduced. Plants which only regenerate from seed and which depend on bare ground for seedling establishment may be at risk of extinction in areas without bandicoot disturbance and with long inter-fire periods.

The objectives of regeneration

A properly regenerated plant community should have four main attributes (Ewel 1987, St. John 1990):

1. *Sustainability*. The restored community must be capable of self perpetuation. However, this may not be possible in small bushland reserves. In Sheldon Forest, maximum diversity and sustainability is likely to be attained with moderate fires at intervals of 8 – 15 years. Moderate fires at two year intervals would disadvantage fire sensitive species which reach sexual maturity after two years. If the Sheldon Forest becomes incapable of carrying a moderate fire, then the regenerator should consider the desired community unsustainable. Vigorous fire suppression or the replanting of appropriate species may then be necessary.
2. *Low invasibility*. Weed invasions can be symptomatic of incomplete use of resources. Species richness increases stability and resilience to disturbance (the ability to recover from disturbance) as it ensures that native species are available to colonise disturbed areas.
3. *Productivity*. Net ecosystem productivity is a useful measure of community performance because it integrates many processes, including photosynthesis and respiration. Regenerators should aim to achieve maximum productivity in native plant communities.
4. *Nutrient retention*. Conservation of nutrients is greater in natural than disturbed communities. Regenerators should aim for maximum utilisation of nutrients within plant communities.

Specifications and standards

Regeneration standards serve two purposes. These are: to define responsibilities of the planner, client and contractor during a specified time period; and to define the successful end product and how it can be evaluated (Harrington 1990). Considerable thought needs to be given by bush regenerators to three questions proposed by Harrington (1990).

1. What ecological measures indicate success of vegetation restoration pro-

grams?
2. What are the threshold acceptance and rejection values?
3. At what stage is it appropriate to apply standards?

Some easily measured characteristics, such as a pre-determined species richness to be achieved by a specified date, can be too ambitious or misleading. Panetta and Groves (1990) argue that if species with the appropriate characteristics, such as resprouters or obligate seeders, are selected when regenerating a site then resilience of the restored community may be achieved, even when species richness is only a fraction of that originally present .

Specifications and standards of success will vary enormously between communities and can be stated as a range or as specific figures. Theoretical examples from four ecosystems are given to help regenerators devise their own standards (the figures given are hypothetical only).

Standards for Sheldon Forest could read:

1. Six years after the prescribed fire of October 1989, by natural regeneration alone, there will be:
   a) nitrogen-fixing shrubs at a density of 0.25 m^{-2}
   b) mat-forming grasses with a cover of less than 30%
   c) tuft-forming grasses with a density of 0.25 m^{-2}
   d) herbaceous and twining plants with a species richness of 10 m^{-2} and foliage cover of approximately 25%
   e) mesic-leaved shrubs with a density of less than 0.01 m^{-2} and with a foliage cover of less than 1%
   f) sufficient fuel to carry a fire of at least 700ºC at the soil surface in early spring.
2. If the above does not occur naturally within six years, the site will be:
   a) burnt at a moderate to high intensity to induce the germination of nitrogen fixing shrubs, or
   b) planted with 'local' nitrogen fixing shrubs to increase the density to 0.25 m^{-2}
   c) planted or seeded with 'local' tuft-forming grasses, herbaceous and twining plants to achieve the appropriate six year cover and species richness.
3. The system will henceforth maintain the ability to burn at moderate to high intensity every 10 years.
4. After 20 years, *Eucalyptus* seedlings will have a density of 0.1 m^{-2}.
5. At no stage shall the cover of mesic-leaved species exceed 10%.

Specifications for a heathy woodland dominated by *E. haemastoma* but invaded by *P. undulatum* and *L. sinense* could read: Eight years after weed control there will be:

1. At least 10 rough-barked eucalypts per hectare. Of these, at least three will be stringy-barks.
2. Thrity percent cover by the members of the Proteaceae.
3. Seventy percent of flower production in the Proteaceae during late autumn-early winter, 10% in spring, 10% in summer, 10% in early autumn.
4. Nitrogen fixing plants at a density of two species per square metre.
5. Epacridaceae with a cover of 3 – 10% m^{-2}.
6. Rutaceae with a density of 0.005 plants m^{-2}.
7. Less than 0.0l% cover of all mesic species in any layer.
8. Fuel present at the rate of 750-1500 g m^{-2}.

A specification for a coastal dune may be much simpler with an emphasis on vegetative cover:

Five years after the control of *Chrysanthemoides monilifera* (L). Norlindh, the dune will have 80% cover from two perennial native shrubs and one perennial native grass.

Despite the complexities of rainforest regeneration simple early standards can be set. For example, at the end of the second year of weed control there will be a closed canopy at 1 – 3 m of nursery trees, whether introduced or native. Standards for older rainforests may need to be more complex.

Reference areas with a known history of disturbance are needed to set realistic revegetation goals. Structural and functional characteristics would also alter with time in reference communities. A detailed knowledge of the successional sequence in reference areas and that of the regenerated area is needed.

Classic ecological methods can be applied to measure characteristics of functional groups of plants for restoration projects. Animals can also be a useful guide to plant community composition. Macdonald (1990) recommends the selection of habitat-specific evaluation species for assessing success of regeneration projects. These are usually species high in the food chain as they are dependant on lower trophic-level species and primary producers. Selection of such species requires a good knowledge of the food web. Andersen (1990) recommends the use of ant communities to evaluate change in Australian ecosystems. He argues that they interact in many ways with other parts of the ecosystem and are functionally important at all trophic levels, they are highly sensitive to environmental variables, they respond rapidly to environmental change and are readily sampled and processed. Perhaps all job specifications could include achieving certain densities of specific ant species within a specified time.

Physical and chemical factors could be incorporated in the measurement of success. Soil erosion and water quality (both dissolved and suspended load) could be legitimate indicators.

Conclusion

Regenerating degraded bushland is no longer simply a matter of weed control or ameliorating the causes of degradation. To ensure that bushland ecosystems continue to function as a specific community with specific habitats, all managers involved with bushland need to have a sound knowledge of ecology.

Managers and consultants involved with regeneration and restoration come from a wide range of backgrounds. Graduates trained in land, resource or park management, landscape architects, horticulturists and sometimes, engineers may find themselves supervising bush regeneration projects. All these mangers need sound ecological training, but more importantly, they need to recognise that bush regeneration requires highly skilled personnel. Regenerators need to be able to develop specifications, carry out work to specifications and perform basic monitoring programs. To date little specific training has been available but it is time educational institutions started training skilled technicians. Financially and politically it is just as important to be able to measure success as it is to achieve it.

Acknowledgements

My thanks to Tein McDonald of Ku-ring-gai Council Sydney for many discussions and references.

References

Allen, E.B. (1991). What are the limits to restoration? *In* 'Program of the third annual Conference Orlando Florida', p. 35 (Society for Ecological Restoration, Madison).

Anderson, A.N. (1990). The use of ant communities to evaluate change in Australian terrestrial ecosystems: A review and a recipe. *In* 'Australian Ecosystems: 200 years of Utilization, Degradation and Reconstruction', eds D.A. Saunders, A.J.M. Hopkins, R.A. How, p. 347-57 (Surrey Beatty & Sons, Sydney).

Beattie, A.J. (1982). Ants and gene dispersal in flowering plants. *In* 'Pollination and Evolution', eds J.A. Armstrong, J.M. Powell and A.J. Richards p. 1-8 (Royal Botanic Gardens, Sydney).

Benson, D. and Howell J. (1990). 'Taken for Granted: The bushland of Sydney and its suburbs', 110 pp. (Kangaroo Press, Sydney).

Bonnicksen, T.M. (1990). Goals and Standards in the restoration of forest communities. *In* 'Restoration '89: The new management challenge. First annual meeting of the Society for Ecological Restoration', eds H.G. Hughes and T.M. Bonnicksen, p. 329 (Society for Ecological Restoration, Madison).

Buckner, D.L. (1990). Use of quantitative performance standards in revegetation of coal mines in the Western U.S. *In* 'Restoration '89: The new management challenge. First Annual meeting of the Society for Ecological Restoration', eds H.G. Huges and T.M. Bonnicksen, pp. 349-56 (Society for Ecological Restoration, Madison).

Ewel, J.J. (1987). Restoration is the ultimate test of ecological theory. *In* 'Restoration ecology. A synthetic approach to ecological research', eds W.R. Jordan III, M.E. Gilpin, J.D. Aber, pp. 31-3 (Cambridge University Press, Melbourne).

Gleadow, R.M. (1982). Invasion by *Pittosporum undulatum* of the Forests of Central Victoria. II Dispersal, Germination and Establishment. *Australian Journal of Botany* 30, 185-98.

Gleadow, R.M. and Ashton, D.H. (1981). Invasion by *Pittosporum undulatum* of the Forests of Central Victoria. I Invasion Patterns and Plant Morphology. *Australian Journal of Botany* 29, 705-20.

Harper, J.L. (1987). The heuristic value of ecological restoration. *In* 'Restoration ecology. A synthetic approach to ecological research', eds W.R. Jordan III, M.E. Gilpin, J.D. Aber, pp. 35-45 (Cambridge University Press, Melbourne).

Harrington, J.A. (1990). Developing standards for planning and evaluating tallgrass prairie restoration. *In* 'Restoration '89: The new management challenge. First annual meeting of the Society for Ecological Restoration', eds H.G. Huges and T.M. Bonnicksen, pp. 319-28 (Society for Ecological Restoration, Madison).

Kline, V.M. and Howell, E.A. (1987). Prairies. *In* 'Restoration ecology. A synthetic approach to ecological research', eds W.R. Jordon III, M.E. Gilpin, J.D. Aber, pp. 75-83 (Cambridge University Press, Melbourne).

Lincoln, R.J. and Boxshall, G.A. (1987). 'The Cambridge Illustrated Dictionary of National History'. 413 pp. (Cambridge University Press, Melbourne).

Macdonald, K.B. (1990). Top-down planning: an integrated approach to restoration goals, criteria for success, and monitoring in coastal wetlands. *In* 'Restoration '89: The new management challenge. First annual meeting of the Society for Ecological Restoration', eds H.G. Huges and T.M. Bonnicksen pp. 365-75 (Society for Ecological Restoration, Madison).

Macdonald, K.B., Wier, H.A., Vanderwier, J.M. and Evans M.U. (1990). Riparian restoration planning in southern California - What's missing? *In* 'Restoration '89: The new management challenge. First annual meting of the Society for Ecological Restoration' eds H.G. Huges and T.M. Bonnicksen pp. 152-61 (Society for Ecological Restoration, Madison).

Moore, P.D. and Chapman S.B. (1986). 'Methods in plant ecology'. 589 pp. (Blackwell Scientific Publications, Melbourne).

National Trust of Australia (NSW) (1991). 'Bush Regenerator Handbook'. 32 pp. (National Trust of Australia (NSW), Sydney).

Panetta, F.D. and Groves, R.H. (1990). Weed management and revegetation programmes. *In* 'Australian Ecosystems: 200 years of Utilization Degradation and Reconstruction', eds D.A. Saunders, A.J.M. Hopkins, R.A. How, pp. 537-43 (Surrey Beatty & Sons, Sydney).

Paton, D.C. and Turner, V. (1985). Pollination of *Banksia ericifolia* Smith: Birds, Mammals and Insects as Pollen Vectors. *Australian Journal of Botany* 33, 271-86.

St. John, T.V. (1990). Practical application of Ewel's Criteria for successful restoration. *In* 'Restoration '89: The new management challenge. First annual meeting of the Society for Ecological Restoration', eds H.G. Huges and T.M. Bonnicksen p. 376 (Society for Ecological Restoration, Madison).

Thorne, L.G. (1979). 'A history of the North Shore, Sydney, from 1788 to today'. 222 pp. (Angus and Robertson, Sydney).

Turner, V. (1982). Marsupials as pollinators in Australia. *In* 'Pollination and Evolution', eds J.A. Armstrong, J.M. Powell and A.J. Richards. pp. 55-66 (Royal Botanic Gardens, Sydney).

Walker, J. (1981). Fuel dynamics in Australian vegetation. *In* 'Fire and the Australian Biota', eds A.M. Gill, R.H. Groves and I.R. Noble, pp. 101-27 (Australian Academy of Science, Canberra).

Zedler, J.B., Langis, R., Cantilli, J., Zalejko, M. and Rutherford, S. (1990). Assessing the functioning of constructed salt marshes. *In* 'Restoration '89: The new management challenge. First annual meeting of the Society for Ecological Restoration', eds H.G. Huges and T.M. Bonnicksen pp. 311-18 (Society for Ecological Restoration, Madison).