The birds and the bees and the Banksia mating trees: measuring the success of Banksia woodland restoration using genetic and ecological markers *

A RITCHIE †, S KRAUSS, P NEVILL, E A SINCLAIR & K DIXON

School of Plant Biology, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia and Science Directorate, Botanic Garden and Parks Authority, Kings Park and Botanic Garden, Fraser Avenue, West Perth, WA 6005, Australia.

† *Corresponding author* ✉ *Alison.Ritchie@bgpa.wa.gov.au*

The major threatening processes to natural ecosystems globally are anthropogenic, through changes in land use and degradation. A key strategy to address these damaging processes is to implement ecological restoration programs. Ecological restoration involves the repair or creation of biological communities, ideally representative of the composition, diversity and functionality of the pre-disturbance habitat. The international community recently committed to a new target to restore 15% of degraded ecosystems worldwide by 2020 (Convention on Biological Diversity 2010). The rapid growth of the restoration industry is evident, and is currently estimated to be a $2 trillion industry worldwide. To date, most endeavours have focused on restoring vegetation and habitat structure. Consequently, restoration success has been measured against achievements in the structural properties of ecosystems. Although pollination is a critical ecosystem service, it is yet to be fully investigated or taken into account in evaluations of restoration success (Ritchie & Krauss 2012). Ultimately the fate of restored plant populations depends on restoring or preserving their mutualistic pollinator relationship.

This study is based in the southwest of Western Australia, one of the most biologically diverse yet highly fragmented and disturbed landscapes worldwide. Only 30% of the *Banksia* woodlands on the Swan Coastal Plain remain and the decline has been most marked in the last 20 years. Southwest Western Australia has the highest proportion of bird-pollinated native plants and pollinator diversity in the world (Phillips *et al.* 2010) and their importance for outcrossing and production of genetically robust outbred seed is well known. Predicting and managing the effects of human-induced habitat disturbance is particularly challenging for organisms that rely on interactions with other species for services such as pollination and dispersal (Menz *et al.* 2011), and there is increasing evidence that human disturbance negatively impacts plant–pollinator interactions. The implications of these interactions for restoration success are yet to be fully investigated.

The main objective of this research is to conduct a genetic and ecological assessment of restoration success, by assessing population levels of genetic diversity, structure, mating patterns, connectivity and delivery and diversity of pollinator services in two keystone *Banksia* woodland species. In order to evaluate how well we are achieving ecological restoration, we will examine how seed sourcing impacts the genetic diversity of a restored population, if the products of mating among individuals reflect that of undisturbed ecosystems, and how might these interactions affect the long-term viability and functionality of restored populations. These parameters will be assessed and compared within restored populations and their offspring to those adjacent natural, fragmented and undisturbed natural populations.

Both *Banksia* species (*Banksia attenuata* and *Banksia menziesii*) are preferentially outcrossing and obligately outcrossing with mixed generalist pollination systems, being pollinated by nectar-feeding birds (predominantly honeyeaters in the family Meliphagidae), native bees, wasps and introduced honey bees (*Apis mellifera*). It is vital that the plant–pollinator interactions are restored and with their pollination systems, they are most likely to be impacted by changes in pollinator visitation and movement.

Specific aims of the research are: (i) identification of genetic diversity structure and mating system parameters of *B. attenuata* and *B. menziesii* using microsatellites markers, in restored, natural fragmented and natural unfragmented (control) populations; (ii) assessment of the diversity and abundance of pollinators in restored and natural populations; (iii) characterisation of pollen dispersal for *B. attenuata* and *B. menziesii*, assessing the delivery of pollinator services within and between restored and natural populations through genetic paternity assignment and pollinator observations; and (iv) assessment of the importance of adjacent natural fragments for the ecological restoration success of *Banksia* woodlands.

Genetic methods will be employed to estimate levels of outcrossing, determine paternity and mating systems by assessing the genetic structure of seeds developed from open-pollination. Determining paternity will allow detection of pollen movements and therefore the distances pollinators travelled. However, it is difficult to identify pollinators using molecular data alone therefore pollinator mutualisms will be examined through observing pollinators and their movements in the field.

Patterns of pollen flow and the delivery of pollinator services are directly related to pollinator behaviour, species and relative abundance. Therefore, the relative

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abundance and foraging behaviour of pollinators will be assessed and compared between populations using floral observations (four replicates/population/season) and Malaise tents (six replicates/population/season, collecting flying invertebrates) over three years. As the presence of invertebrate pollinator species may not reflect pollinator efficiency, insect-collected pollen from Hymenoptera will also be examined.

Few studies have evaluated restoration success. This study is one of the first to assess the restoration of functionality. It will provide a solid genetic basis for future restoration and conservation work to better understand the driving mechanisms behind mating systems, pollinator mutualisms, and how these are affected by anthropogenic disruption.

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