Recruitment of *Banksia* spp. in an anthropogenically disturbed mediterranean climate type woodland in Western Australia

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Submitted by

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DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

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s= number of sites.

Chapter 5

ABSTRACT

Introduction *Banksia* woodland is the characteristic mediterranean type vegetation of the sand plains of the Swan Coastal Plain in the Perth region of Western Australia. Once extensive in the past the woodlands are nowadays severely fragmented and threatened by a variety of perturbations including weeds, fire and seed predation. Conservation and management of the woodlands depends very much upon the knowledge of past land use, type of original vegetation, frequency and magnitude of significant disturbances and surrounding land-use.

The results of a long-term study in the Kings Park bushland, comparing vegetation differences between the 1939 and 1999, showed that there have been substantial changes in the composition and structure of the woodland. In term of tree species, the most significant trends have been a decrease in *Banksia spp.*

Aim The research reported in this thesis aims for an understanding of the features and different stages of *Banksia* spp. recruitment in an environment such as the Kings Park bushland urban remnant. The final objective of this study is to assess if recruitment of *Banksia* spp. is affected by the perturbations mentioned above, ultimately influencing bushland conservation.

Materials &Methods The study was conducted both in urban bushland and in suburban areas in the Perth region. Several of the experiments and investigations on some specific stages of recruitment also included other species dominant in the bushland. The stages of recruitment investigated are: seed production and dispersal, seed germination and seedling establishment, seed predation.

Results In the Perth region *B. attenuata* and *B. menziesii* have a small degree of serotiny, the two species release seeds at different times of the year - B. attenuata from Summer to Autumn and B. menziesii from Spring to Summer. In post- fire conditions seed release is more synchronised than for unburned trees but the amount of seed released depends on the timing of the fire. Fires in early Summer lead to mass release of *B. menziesii* seeds and destruction of immature seeds of *B. attenuata*. Later fires destroy *B. menziesii* seed that has been shed on to the soil but synchronises release of *B. attenuata* seed.

Of the investigated locations Kings Park, and Ridge State Forest, have higher level of pre-dispersal seed predation compared to other locations. The post-dispersal surveys and experiment, both in inter-fire and post-fire environment show that in Kings Park in Winter,

approximately 75% of the banksia seeds were consumed. Moreover, *Banksia* seed predation is not related to the density of seeds. Presence of leaf litter, weeds and plant material in the experimental unit reduced predation values. Most of the germination occurred on sandy soil, while presence of weeds and of a thick layer of leaf litter reduced germination numbers for the *Banksia* species. In post-fire conditions seedlings are also associated with "burn residuals" (accumulation of burned litter and ash). Most of the seeds that were sown in the soil and had germinated died.

Conclusion This project confirmed and quantified the decrease of banksia individuals (which until now was only assumed) over time and lack of their recruitment. Seed predation, both before and after seed release greatly affects banksia seed availability in Kings Park. Furthermore unfavourable sites for germination such as a thick layer of leaf litter and weeds are a great obstacle for establishment of large seeded species such as *Banksia*. Other dominant species, such as *Allocasuarina fraseriana*, *Acacia saligna* and *Dryandra sessilis*[1] on the contrary do not seem to reduce their recruitment potential as predation (or removal) is not conspicuous and the various substrata do not reduce the ratio between the number of germinants and seedlings that survive. In order to boost banksia recruitment a number of management actions could be taken. In particular weeds and thick layers of leaf litter must be removed and a sandy soil substratum should be arranged especially in the areas where, even in the presence of banksia trees, the number of seedlings is low. Predation must be reduced, in particular through removal of pests

[1] *Dryandra sessilis* (Knight) is now known as *Banksia sessilis* (Knight) A.R.Mast & K.R.Thiele. See Mast and Thiele (2007). In this thesis, however, will be always used the term *Dryandra sessilis*

GENERAL SUMMARY OF THE DIFFERENT CHAPTERS OF THE THESIS

Banksia woodland is the characteristic vegetation of the sand plains in the Dry Mediterranean Bioclimatic Zone of Western Australia. It is widespread on the Swan Coastal Plain and is remarkably consistent, in terms of physiognomy and species composition. The region is distinguished by mediterranean climate with cool mild winters and hot dry summers.

Banksia woodland is dominated by small trees of about 6-10m among which *Banksia* spp. occur in abundance. *Banksia* woodlands comprise floristically rich and taxonomically diverse plant communities; the canopy comprises the dominants *Banksia attenuata* and *B. menziesii*, while *Allocasuarina fraseriana*, *Eucalyptus calophylla, E. marginata, Nuytsia floribunda* and other *Banksia* spp. occur, though less frequently, while *Banksia ilicifolia* is present in the wetter sites. The well developed evergreen sclerophyllous shrub understorey is dominated by the woody shrub families Myrtaceae, Ericaceae, Proteaceae and Fabaceae. Dominant herbaceous or woody-herbaceous elements are represented by members of the Anthericaceae, Stylidiaceae, Haemodoraceae, Xanthorrhoeaceae, Cyperaceae, Zamiaceae and Dasypogonaceae. These dominant families are also dominant taxa throughout the southwest so that *Banksia* woodlands are floristically representative of Western Australia's southwestern flora.

Well drained, deep, leached and nutrient poor quartz sands and quartz sand over limestone, form the characteristic edaphic habitat of *Banksia* woodland on the Swan Coastal Plain.

Banksia woodlands represent an ecosystem of serious conservation concern, while at the same time, are poorly studied and documented. Of greatest concern is the rate of the clearance and degradation of Banksia woodlands especially in urban and suburban areas. Essentially the once extensive Banksia woodlands on the Swan Coastal Plain are extensively fragmented with considerable reduction in the area they occupy.

Banksia woodland reserves i.e. areas that are not cleared for urban or other use, are threatened by a variety of perturbations, for which there is little research information available for managing the disturbance factors. Among the most important are:

<u>*Weeds*</u>

More than one hundred weed species have been recorded within *Banksia* woodland. *Banksia* woodland communities appear to be more susceptible to weed invasion than many other plant communities in the southwest of Western Australia and this may have led to habitat loss and biodiversity harm.

Fire

High intensity summer fires affect mediterranean climatic areas and the *Banksia* woodlands are no exception. The woodlands have been neglected in terms of the effects of fire. With recent urbanization and human population on the increase, the fire regime is likely to have been altered. Fire has the potential to promote weed invasion, which in turn, leads to an increase in flammability of the vegetation. Furthermore, frequent fires have the potential to eliminate species that rely on regeneration through seed production and subsequent seedling recruitment. On the other hand, fire can favour recruitment especially in fire-adapted vegetation.

Groundwater Extraction

The water resources on the Swan Coastal Plain are recharged directly from rainfall. The water is used by the Perth metropolitan region for a large range of purposes. Ground-water levels are generally at their lowest during autumn, prior to the first wet season rains.

Feral Animals

A variety of 'introduced' animals have become feral in *Banksia* woodland. These include rabbits, rodents, cats, foxes and dogs. The overgrazing and selective grazing of rabbits is a threat to the survival of some plant species while seed consumption by rodents reduces recruitment potential.

Climate changes

Since the 1980's, there have been extended periods of below average annual rainfall and above average temperature. In the Perth district, between 1929 and 1999, annual precipitation decreased by about 15% while temperatures increased by about 1 °C.

Inter-Related Perturbations

A major problem in understanding the effects and relative importance of the various perturbations is that most of them are inter-related and indeed their effects may be synergistic. For example frequent fires combined with grazing and fragmentation will lead to degradation of the vegetation much faster than would be expected from the effects of the three disturbers measured in isolation. Indeed, the invasion of weeds is much faster in the presence of soil disturbance or frequent fires.

For all these reasons conservation and management of these habitats are a considerable challenge and depend very much upon the knowledge of past land use, type of original vegetation, frequency and magnitude of significant disturbances and surrounding land-use.
Degree of vegetation degradation is difficult to assess especially in the absence of long-term studies on the plant communities. Information of vegetation changes are difficult to obtain because changes in vegetation in response to management and natural perturbations are most likely to occur over many decades, beyond the average time of research projects.
In 1999 a fortuitous discovery in the Kings Park and Botanic Gardens archives of a 1939 map with the positions, along transects, of individual plants of 13 dominant native tree and shrubs species, occurring in a portion of the Kings Park bushland allowed the possibility of quantifying vegetational changes over time. The same transects were resurveyed with the aim to determine whether the composition and the structure of the vegetation had changed in 60 years.

Vegetation changes over time (chapter 2)

Results of the vegetation differences between the 1939 and the 1999 surveys showed that there have been substantial changes in the composition and structure of the woodland. In term of tree species, the most significant trends have been an increase in the density and relative frequency of *Allocasuarina fraseriana* and *Corymbia calophylla* and a decrease in the density and relative frequency of *Banksia attenuata* and *B. menziesii*. Furthermore *B. grandis* has become rare, while *B. ilicifolia* is almost locally extinct. As a consequence, the vegetation changed from open woodland dominated by *B. attenuata, A. fraseriana* and *B. menziesii* and to a lesser extent *Eucalyptus marginata* and *E. gomphocephala* to a more closed formation dominated by *A. fraseriana* with low stature eucalypts and an understorey dominated by *Dryandra sessilis* and *Acacia saligna*.
Sudden autumn death syndrome in banksia occurs in a small proportion of all size classes of *B. menziesii* and *B. attenuata* without any apparent prior decrease in plant health and changes in the micro-habitat would have distorted the natural recruitment pattern. The combination of plant death and lack of recruitment has been instrumental in the decline in banksia species in Kings Park
The causes of the changes outlined are complex and increasing drier climate or decline in groundwater levels may be implicated, but the changes are more likely due to a complex matrix of interactions between different factors, the more important being weed invasion biotic interactions and altered fire regimes.

The research reported in this thesis aims for a better understanding of the features and different stages of *Banksia* spp. recruitment in an environment such as the Kings Park bushland urban remnant. To have a better understanding of these processes the study was conducted both in urban bushland and in suburban areas outside the central Perth district.
All the sites (described in Chapter 1) were located within banksia woodland vegetation and occurred on the Swan Coastal Plain in the Perth Region.
The sites were:
1) urban remnant banksia woodland (Kings Park, Bold Park Bushland and Murdoch University bushland).
2) semi-pristine banksia woodlands (Jandakot Regional Park, Ridge State Forest).

Investigations in the different locations allowed comparisons within and between urban and suburban areas helping to better understand the recruitment pattern and the reasons which led to the vegetation changes in Kings Park.

The different stages of recruitment investigated and discussed in this thesis are: seed production and dispersal, seed germination and seedling establishment, seed predation. All these stages are crucial phases of the recruitment process. Several of the experiments and investigations on some specific stages of recruitment also included other species such as *A. fraseriana*, *D. sessilis*, *E. marginata*, *A. saligna*, and *A. pulchella*. Experiments in which other species were used included: seed bank germination trial, post-dispersal seed predation, and seed germination.
To test the hypotheses proposing a link among patterns of seed production and dispersal and seed predation with those of seedling recruitment a combination of surveys and experiments was undertaken.

Seed production and dispersal (chapter 3)
On the Swan Coastal Plain *B. attenuata* and *B. menziesii* have a small degree of serotiny, in particular the first can be considered weakly serotinous and the latter not serotinous at all. The seasonal monitoring both of seed production (from the inflorescence) and seed dispersal (when the woody follicles open) showed that the two species released seeds at different times of the year. *B. attenuata* from Summer to Autumn, and *B. menziesii* from Spring to Summer. Similar trends were detected in surveys undertaken in post-fire conditions. This difference favours the recruitment of the first species, especially in the presence of disturbance such as

frequent wildfires and severe seed predation. *B. attenuata* released over twice as many viable seeds compared to *B. menziesii*. Most of the seed released from the tree in inter-fire conditions are viable and germinants occurred beneath the tree canopy.

Seed predation (chapter 4)

One of the factors that can limit seedling recruitment is the predation of seeds both before or after dispersal from the mother plant. In this thesis, experiments and surveys were carried out with the intention of investigating type and extent of predation.

Pre-dispersal predation is responsible both for the consumption of seeds while they are on the infructescence protected by the woody follicles and for the 'snap' of the infructescence from the stem and consequent death of the seeds in the infructescence. Within the investigated locations Kings Park and Ridge State Forest have higher level of pre-dispersal predation than other areas examined. The post-dispersal seed predation study investigated the occurrence and the features of seed predation on several dominant tree and shrub species which compete in the woodland. Surveys and experiment, both in inter-fire and post-fire environment highlight the fact that when experimental units were unprotected from vertebrate predation, seeds removal levels were higher especially in Kings Park (and to a lesser degree in Bold Park) where, in Winter, approximately 75% of the banksia seeds were consumed. Moreover, *Banksia* seed predation occurred regardless of the number of seeds in the experimental unit highlighting the fact that predation is not related to the density of seeds.

Presence of leaf litter, weeds and plant material in the experimental unit reduced predation values.

No attempt was made to investigate the specific identity of the predator but observations, time of removal and specific 'bait-devices' helped to determine that 'hard beak' cockatoos may be considered responsible for pre-dispersal predation and rodents for post-dispersal predation. Invertebrates such as ants are likely to be responsible for post-dispersal predation/removal of the small seeded species.

Seed germination and seedling establishment (chapter 5)

The research in this chapter tried to assess the role of the germination process, of banksias and the other key species of the Kings Park bushland, in the changes of the bushland vegetation that were detected over 60 years.

In all the surveys and experiments the "germination behaviour" of *B attenuata, B. menziesii* and *B. grandis* were similar. *B. ilicifolia* displayed a comparable trend, only with lower germination values. Most of the germination occurred on sandy soil, while presence of weeds and of a thick layer of leaf litter reduced germination numbers for the *Banksia* species.

Also for the other investigated species recruitment is altered by the presence of weeds and of a thick layer of leaf litter. In the bushland, consequently, plant recruitment is associated with the different micro-site habitats in which seeds can germinate.

In all the surveys described in this chapter *Banksia* spp. germinate more on bare sandy soil, both after fire or in semi-natural unburned bushland.

In post-fire conditions seedlings are also associated with "burn residuals" (Lamont et al. 1993). In inter-fire conditions, on the other hand, most of the seedlings occur on sandy soil followed by substrata with native vegetation or mulch.

When *Banksia* seeds were added to different types of micro-site habitats results varied extremely according to the exclusion of vertebrate from the experimental units. Where vertebrate had access, banksia germinants were fewer compared to where vertebrate were excluded.

All the experiments, both in the greenhouse or in the bushland, showed that in the presence of soil moisture, seeds of *Banksia* spp. germinate starting from the third week. Thus the timing of seed release is of great importance as the longer the time spent in the soil seed bank (*Banksia* spp., however, belong to the transient soil seed bank) the more the seeds are exposed to predation, fire or other causes of death.

In a field experiment concluded after 3 years, most of the seeds that had been sown in the soil and had germinated had died. Recruitment occurred only in areas on sandy soils and with low competitions, of the 4,000 seeds sown just 47% germinated and only 2% of seedlings were still alive at the end of the experiment.

Final conclusion (chapter 6)

Conservation of banksia woodlands especially in urban and suburban remnants is a significant task both for environment managers and conservationists. Remnants make an essential contribution to biodiversity conservation, consequently preservation and enhancement of biodiversity in urban and suburban remnants become important especially considering that many of these areas are impacted by various types of non-natural disturbances and are isolated islands of vegetation.

This research, thanks to the re-surveying of vegetation transects undertaken 60 years before, had the capability to confirm and quantify the decrease of banksia species (which until now was only assumed).

Seed predation, both before and after seed release greatly affect banksia seed availability in Kings Park. Furthermore unfavourable sites for germination such as a thick layer of leaf litter and weeds are a great obstacle for establishment. The other dominant species, such as *A. fraseriana*, *A. saligna* and *D. sessilis* on the contrary do not seem to reduce their recruitment potential as predation (or removal) is not conspicuous and the various substrata do not reduce the ratio between the number of germinants and seedlings that survive. These small seeded species, furthermore, produce yearly many more seeds than do the *Banksia* spp. in relation to plant size.

In order to boost banksia recruitment different management actions could be taken. In particular weed and thick layers of leaf litter must be removed and a sandy soil substratum should be prepared especially in the areas where, even in the presence of banksia trees, the number of seedlings is low. Furthermore vertebrate predation must be reduced through capture or removal of pests such as rats. Considering the importance of the Kings Park feeding ground for the survival of cockatoos and the difficulty of moving the birds to areas of less conservation concern, the amount of seed predated by birds should be returned to the soil seed bank. These actions need to be carried out within the general management action plan and need to be monitored. Failure of banksia sapling recruitment could increase in the future and without proper management intervention, there may be local extirpation of some banksia species. Also dominant species under certain conditions of poor dispersal and recruitment may not be able to replace the dead old trees (especially *Banksia* spp. that have a relatively short life span) and the local isolated population may be in danger of collapse.