

Key Findings of the Banksia Woodland Restoration Project

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Conservation and Attractions**



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1. Introduction to Project and Sites



Objectives of the Banksia Woodland Restoration Project (BWR)

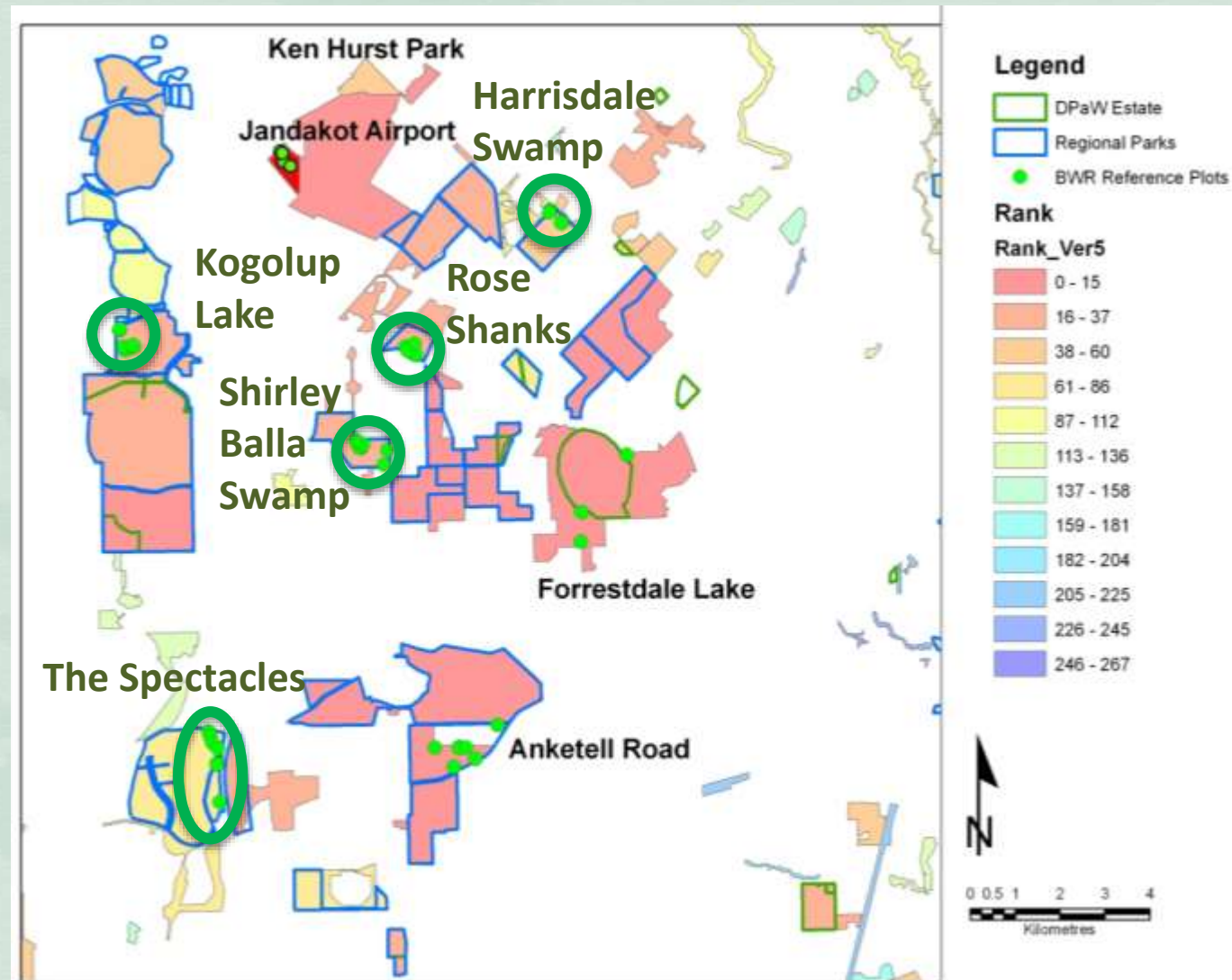
Commonwealth Government offset for land clearing at Jandakot Airport

1. Restore and manage banksia woodland
2. Select sites using rigorous ranking process
3. Use scientific approaches to maximise returns
4. Evaluate relative effectiveness of methods
5. Develop monitoring protocols
6. Support community groups and land managers
7. Collate and share information



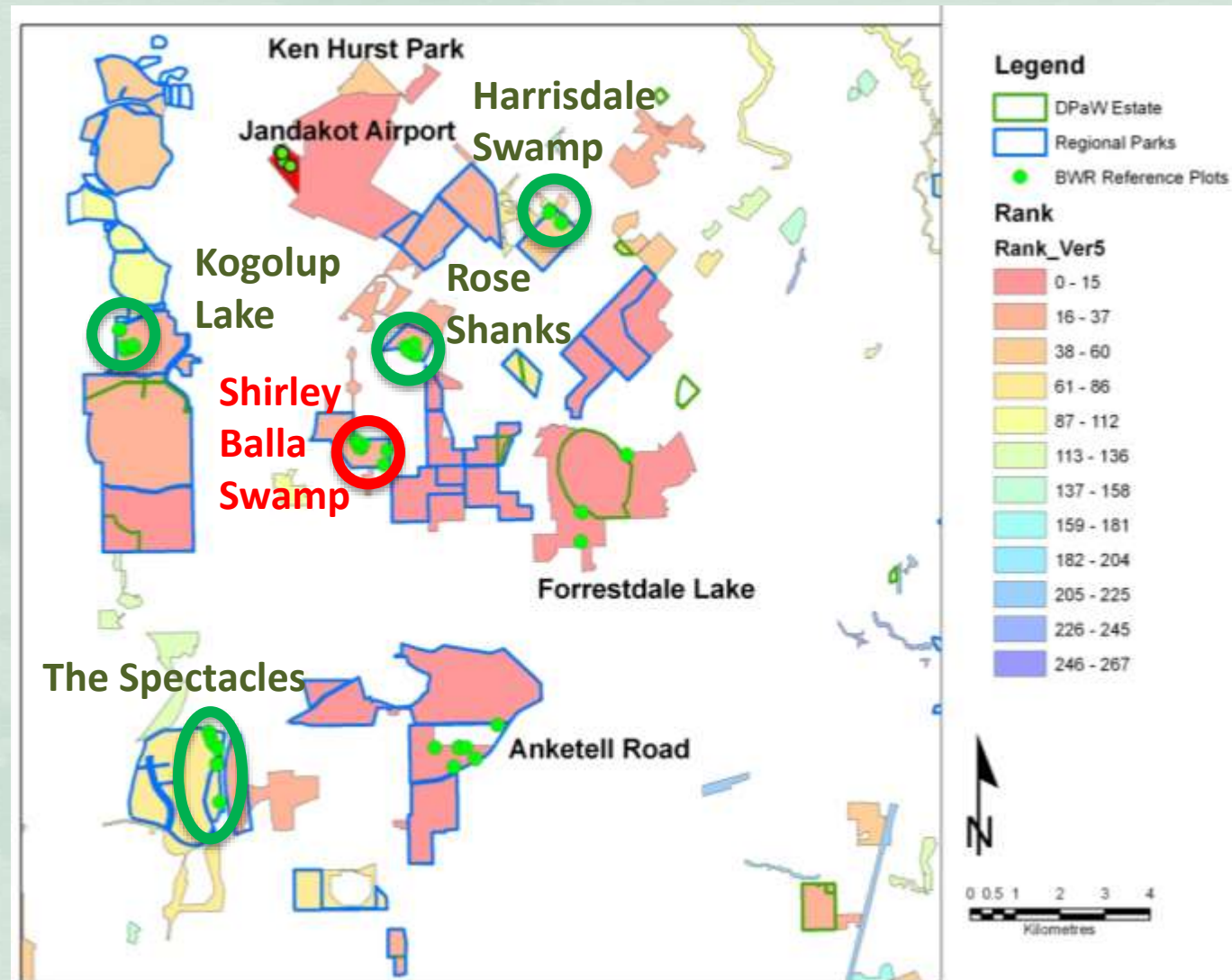
Banksia Woodland Monitoring Sites

- 5 Locations in Jandakot and Beeliar Regional Parks
- 31 quadrats for weed control study
- Close to Restoration sites



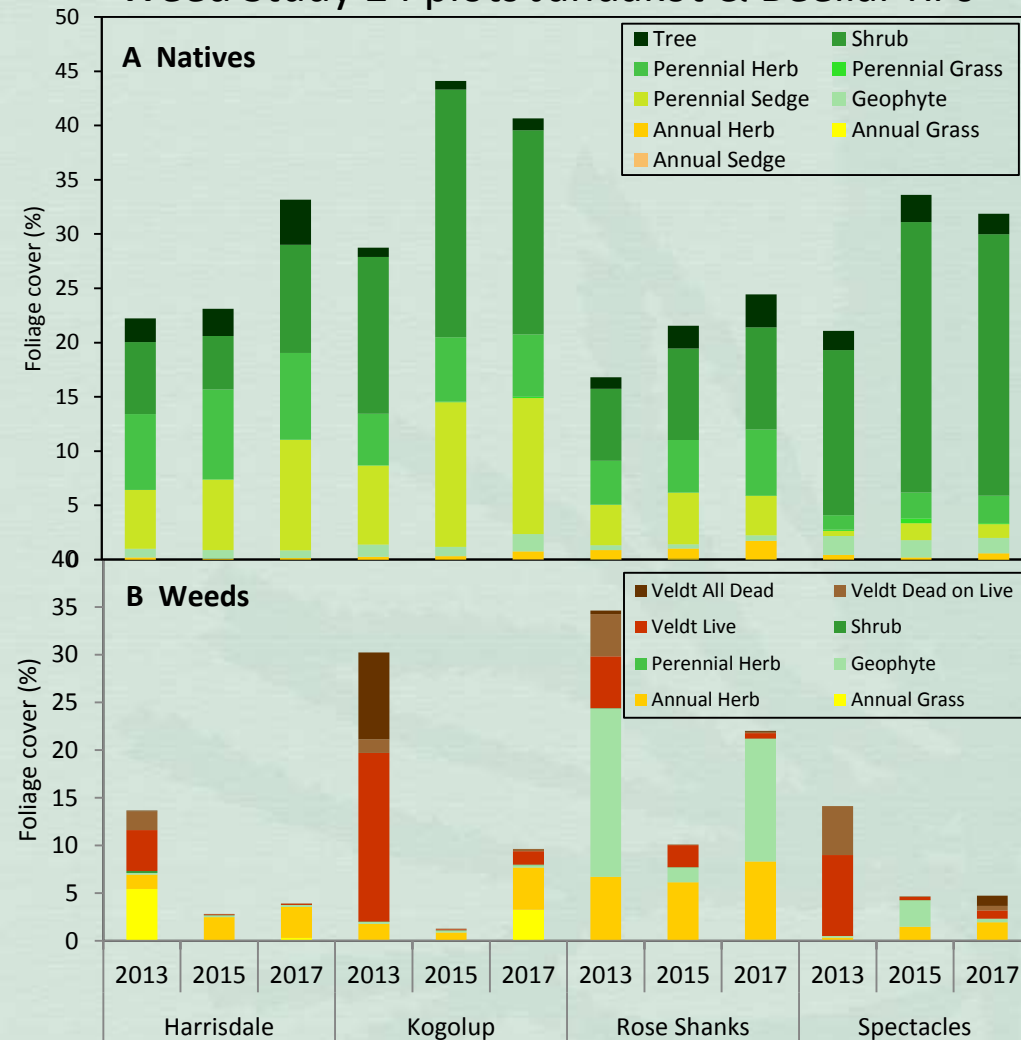
Banksia Woodland Monitoring Sites

- 5 Locations in Jandakot and Beeliar Regional Parks
- 31 quadrats for weed control study
- 1 site impacted by fire in 2014

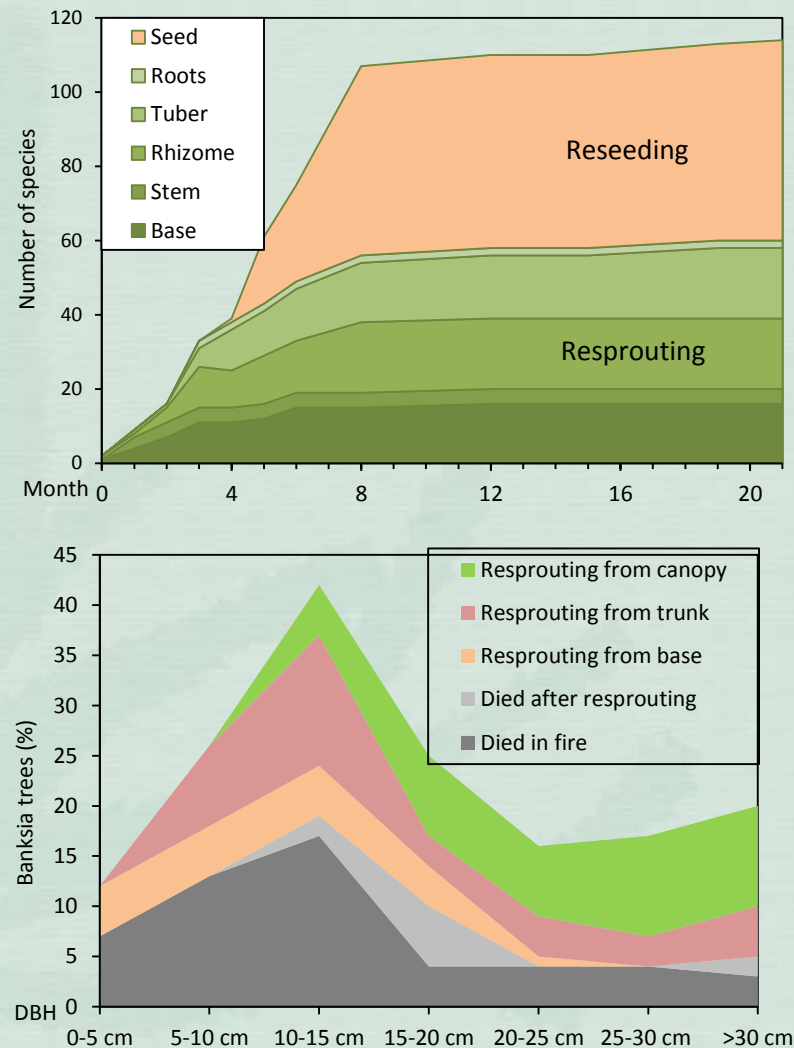


Weed and Fire Studies

Weed Study 24 plots Jandakot & Beeliar RPs



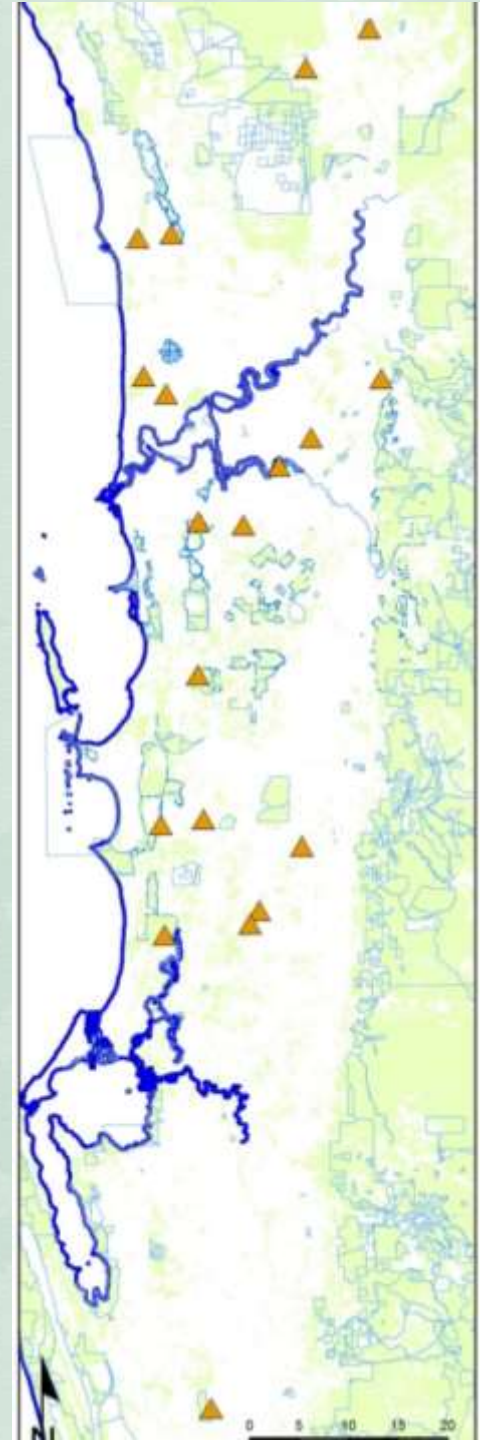
Fire study Shirley Balla Swamp



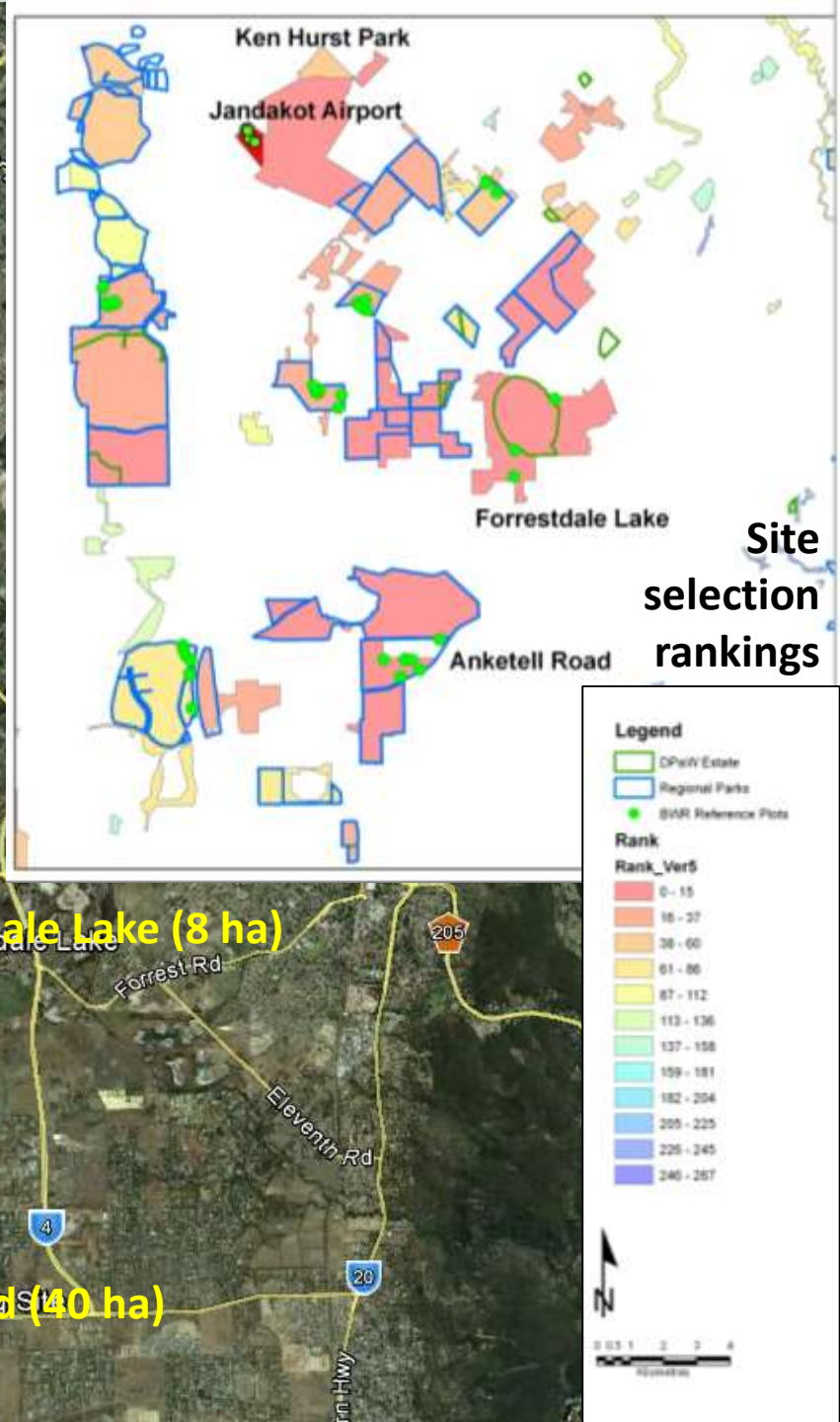
Community Grants



- Grants program with \$300,000 of funding for banksia woodland restoration by community groups and local governments at 20 locations across the Perth metropolitan area.



Topsoil Transfer Sites



Restoration Sites

- Sites were weeds-capes before works commenced
- Massive soil seed bank for weeds
- Weedy topsoil was scraped off

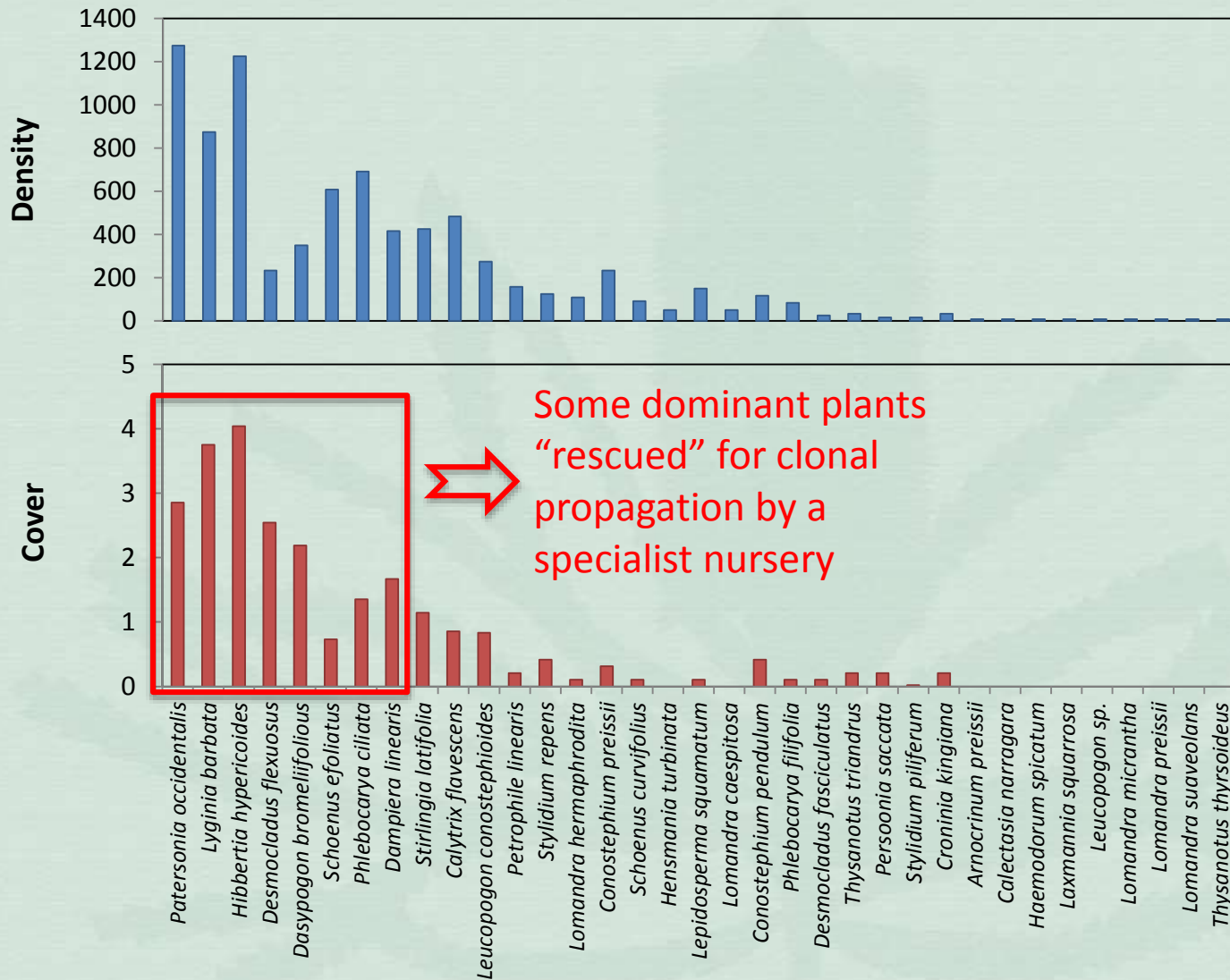


2. Reference Site Data for Setting Completion Criteria



- Jandakot Airport Quadrats and Transects
- Tree positions (DGPS) and crown widths on 150 m transects (4)
- Cover and abundance of all spp. from 10x10m plots (12)
- Tree data from 25x25m plots (12)

Relative Importance of Plants

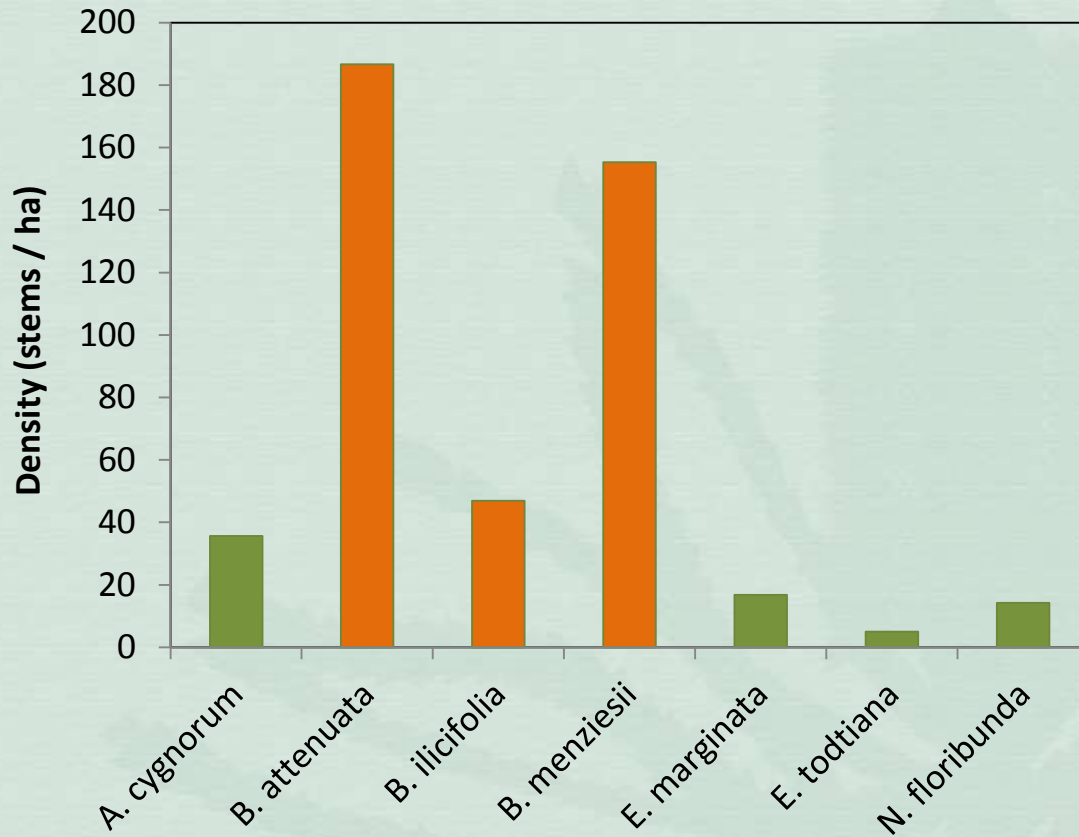


Important Understory Species

Rank importance values were used to assess the relative dominance of understory plants

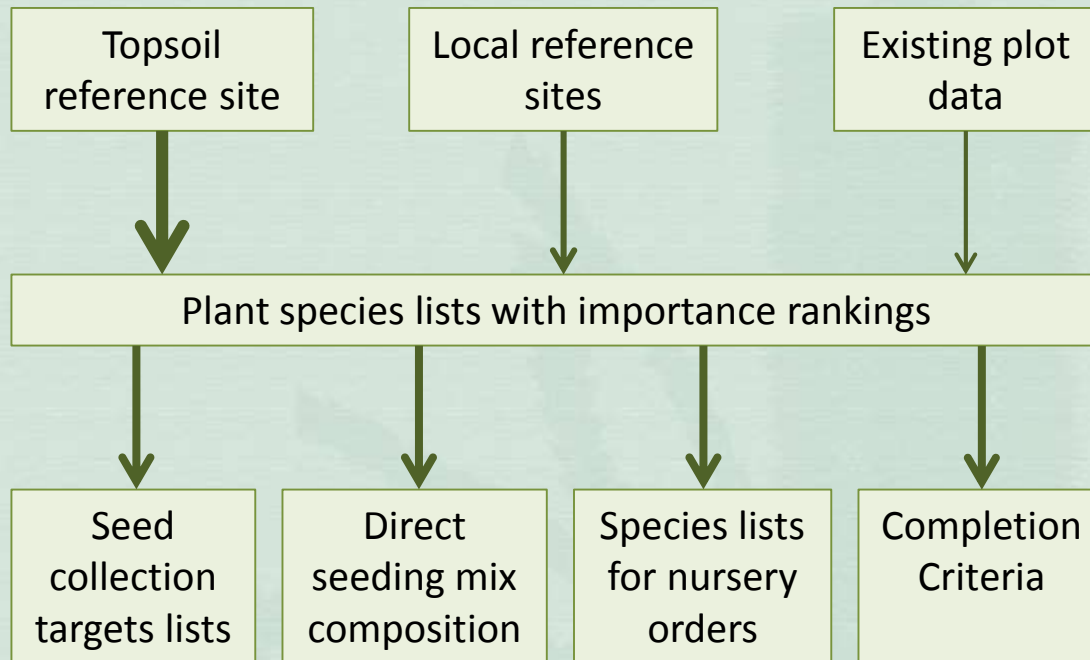
Species	Rank		
<i>Patersonia occidentalis</i>	1		
<i>Eremaea pauciflora</i>	2		
<i>Lyginia barbata</i>	3		
<i>Hibbertia hypericoides</i>	4		
<i>Amphipogon turbinatus</i>	5		
<i>Desmocladus flexuosus</i>	6		
<i>Scholtzia involucrata</i>	7		
<i>Dasypogon bromeliifolious</i>	8		
<i>Schoenus efoliatus</i>	9		
<i>Phlebocarya ciliata</i>	10		

Measuring Tree Dominance



- High spatial variability (>0.5 ha survey area needed)
- Over 400 trees / ha in total
- Over 300 banksia trees / ha (main food for Carnaby's cockatoos)

Use of Reference Site Data in Restoration



Setting Completion Criteria

Criteria	Targets
Overall species richness	Maximise species richness (not measurable)
Species richness per quadrant	Return >60% of native species (10x10m equivalent)
Tree diversity	Return all species of trees
Tree density	300 stems/ha for all trees (varies with habitat)
Carnaby's cockatoo food plants	250 stems/ha for Banksias (in appropriate habitats)
Understorey density	Establish 7000 stems/ha (>50% of reference site)
Understorey diversity	Return >60% of species
Key understorey plants	Monitor 10 most important species separately

*Numeric examples are for Banksia Woodland Restoration Project sites and will need to be adjusted for other habitat types.

3. Comparing Methods for Restoration



Main Restoration Sites

Anketell Road in
Jandakot
Regional Park



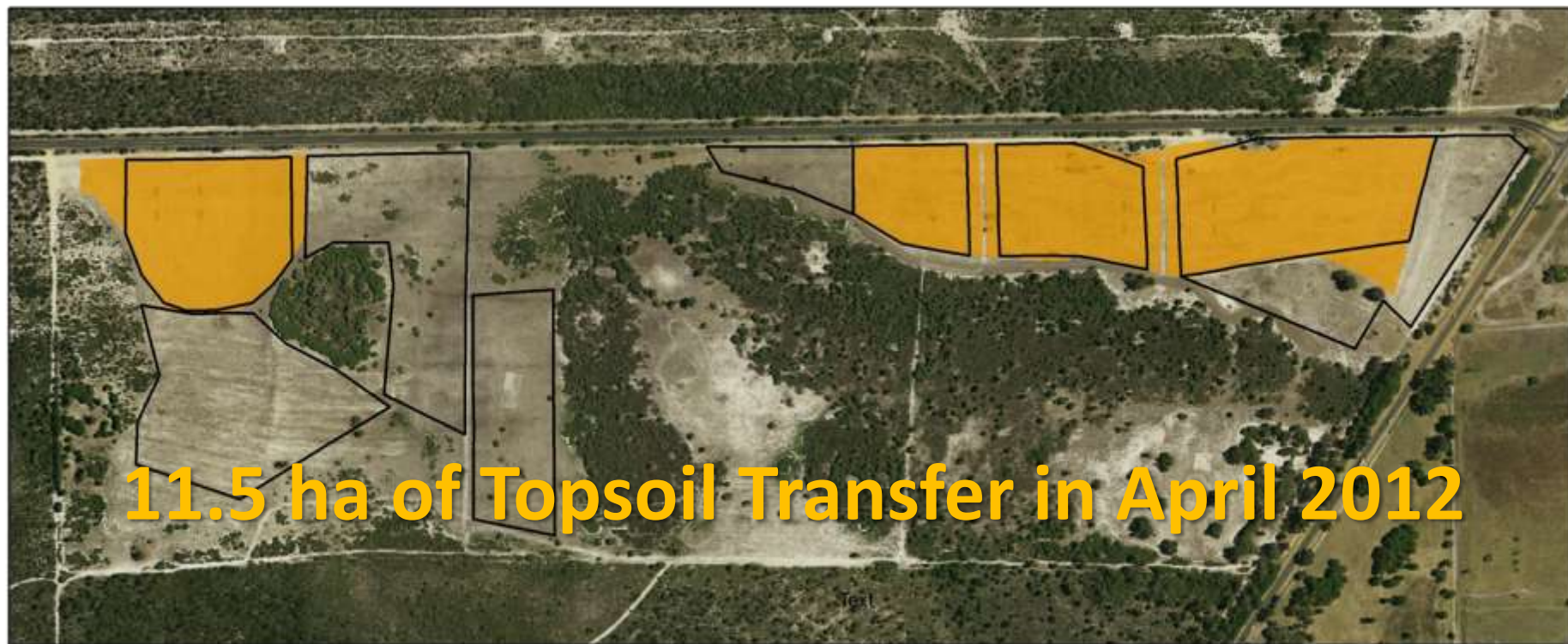
Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994



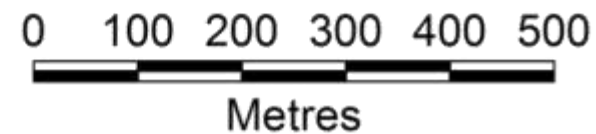
Projection: Universal Transverse Mercator
MGA Zone 50, Datum: GDA94

Produced by the
Department of
Heritage and Wildlife

Forrestdale Lake



11.5 ha of Topsoil Transfer in April 2012



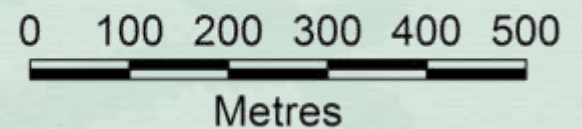
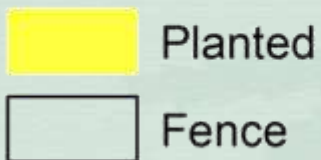
Planting

- Over 46,000 plants of 70 species planted
- 3,500 plants of 24 species from cuttings
- Collaborations with Birdlife Austral, Friends or Forrestdale, etc.



Anketell Road

Planted: 32 hectares



Direct Seeding

Machine seeding



- Machine seeding was used for broad scale restoration
- Hand seeding was used in areas inaccessible by vehicle
- From 2012-2016 16.5 hectares were direct seeded using 45 kg of seed from 80 different species


Hand seeding



Anketell Road

Direct seeded: 15.5 hectares



 Direct seeded

 Fence



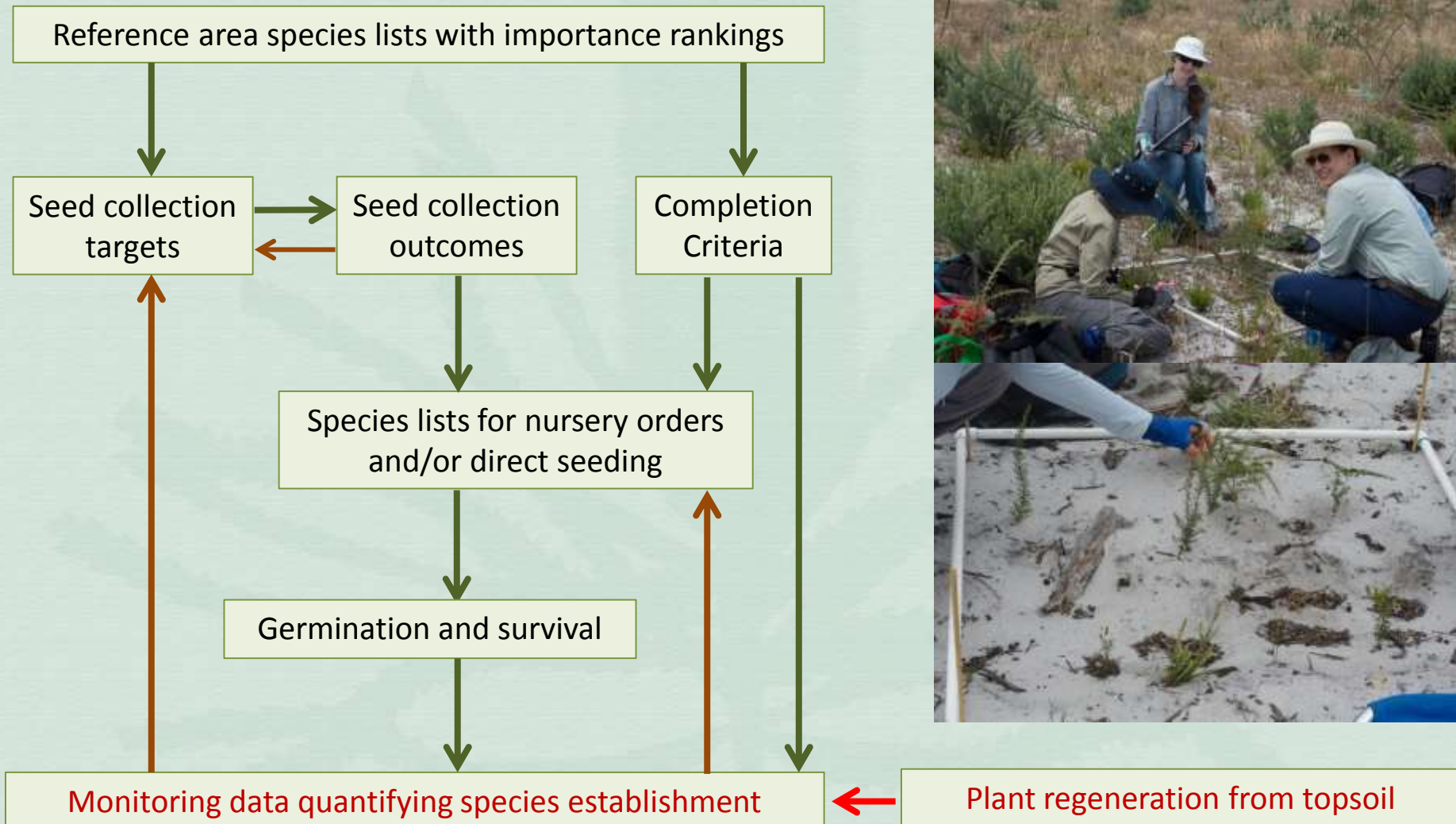
0 100 200 300 400 500

Metres

4. Monitoring

- Completion targets (criteria) are based on diversity, density and cover information from reference sites
- Jandakot Airport topsoil source area is the primary reference site, but but some data from local plots was also used
- Monitoring restored areas uses fixed 1x1, 5x5 or 25 x 25 m plots
- Plant diversity, density and cover compared to reference sites quadrat areas of 10 m² (using 4 adjacent 5 x5 plots)
- The reference site may be atypical (long unburnt, high grazing system)

Adaptive Management Requires Comprehensive Monitoring Data



Monitoring

5x5 metre quadrats



- 5x5 metre quadrat
- Topsoil
- Restoration
- Fence



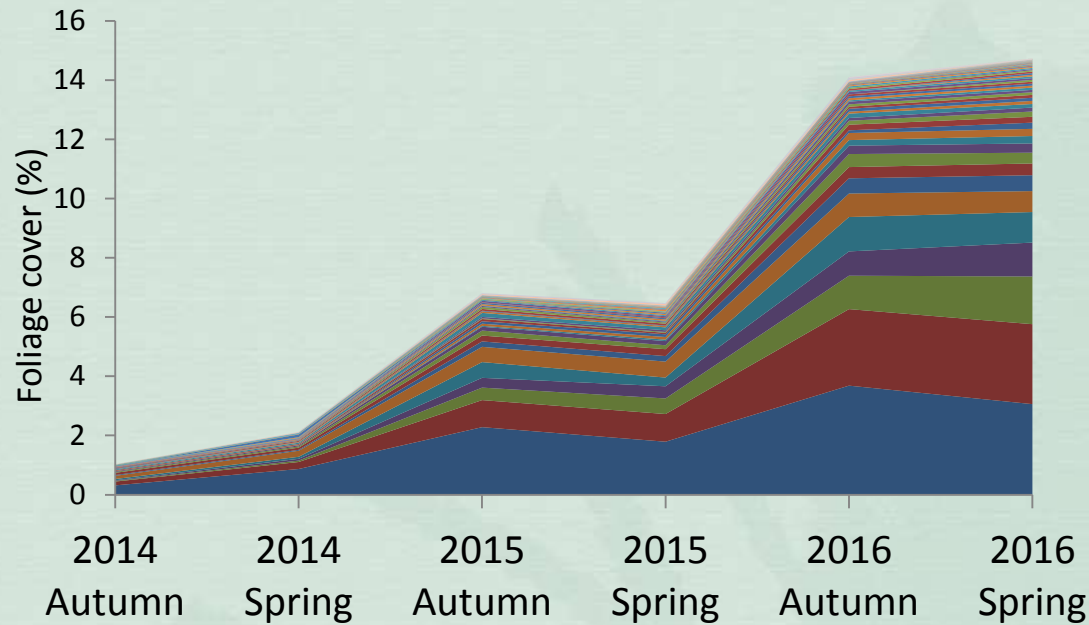
0 100 200 300 400 500
Metres

Total Species Richness

Target	Status in late 2015
Maximise native species richness (78 species were present in 12 reference quadrats)	161 native species in total <ul style="list-style-type: none">• Highly variable spatially• Many singletons in plots



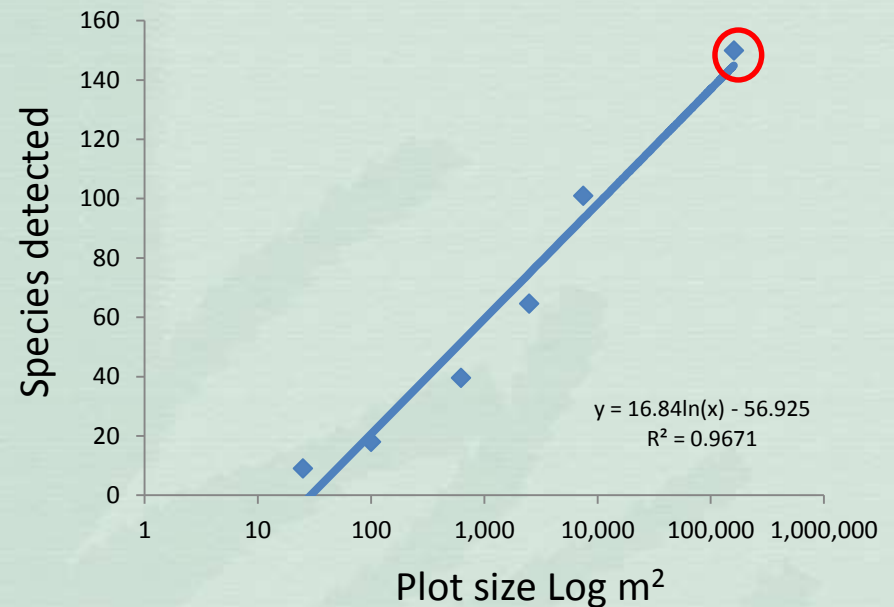
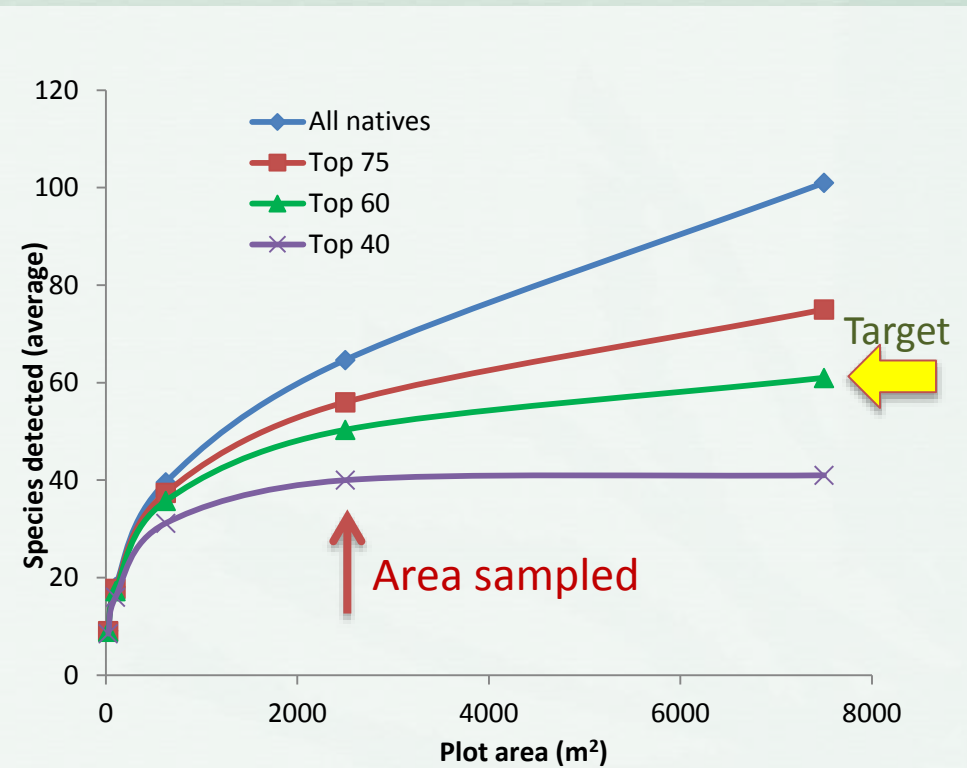
Monitoring Plant Density, Cover & Diversity



- Annuals and weeds in 1x1m plots
- Perennial cover in 5x5m plots
- Trees in 25x225m plots



Species Area Relationships for Monitoring – Common Plants



- Detection of all plants requires plots to cover the entire area

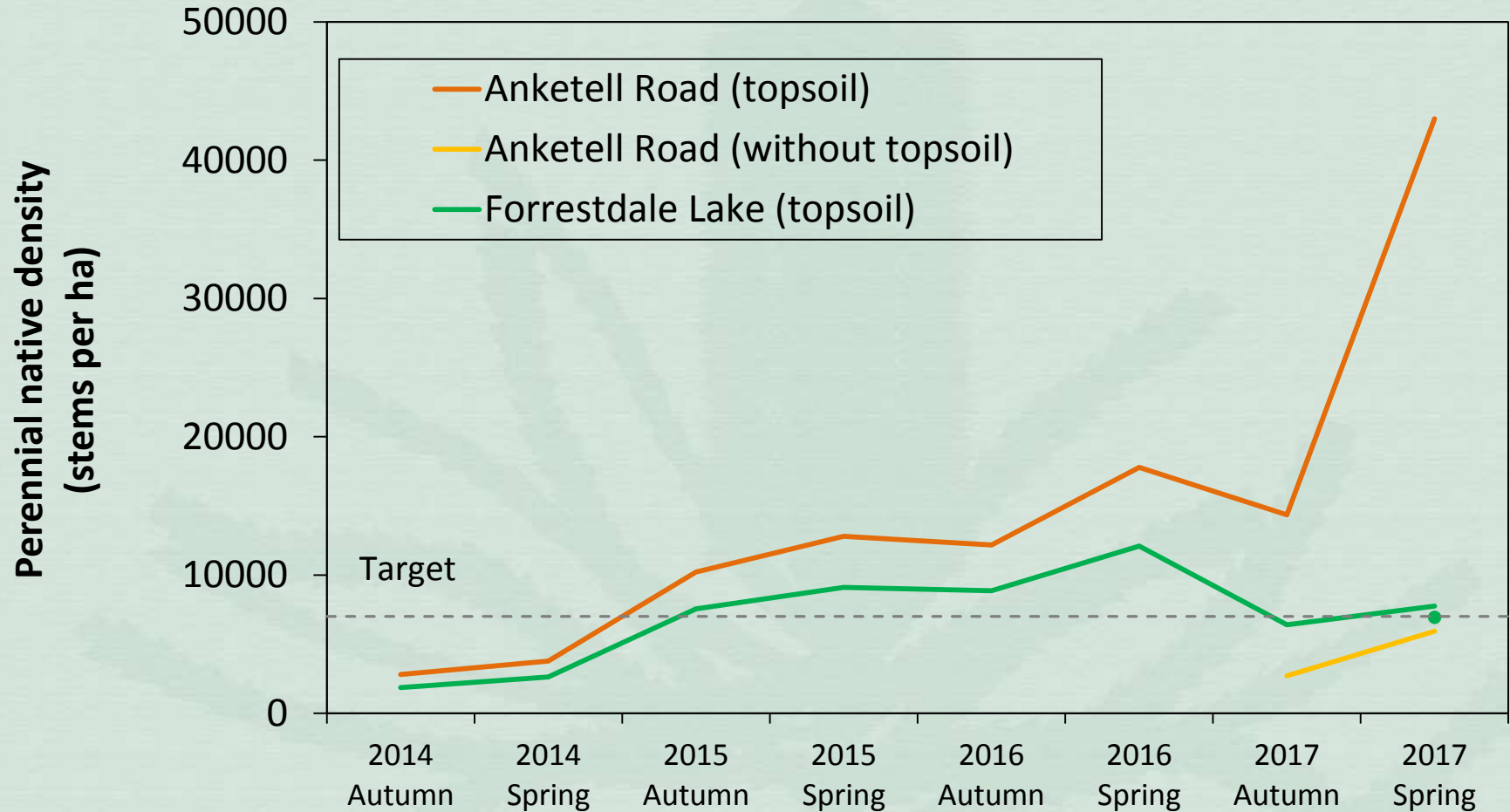
Seedling Density in 1 m² plots

- Plot with 39 seedlings of perennial natives (mean = 12, range = 0-42)
- Annual native average = 49 (0-163)

Most germinated seedlings
died in 2014/15 in driest
summer on record



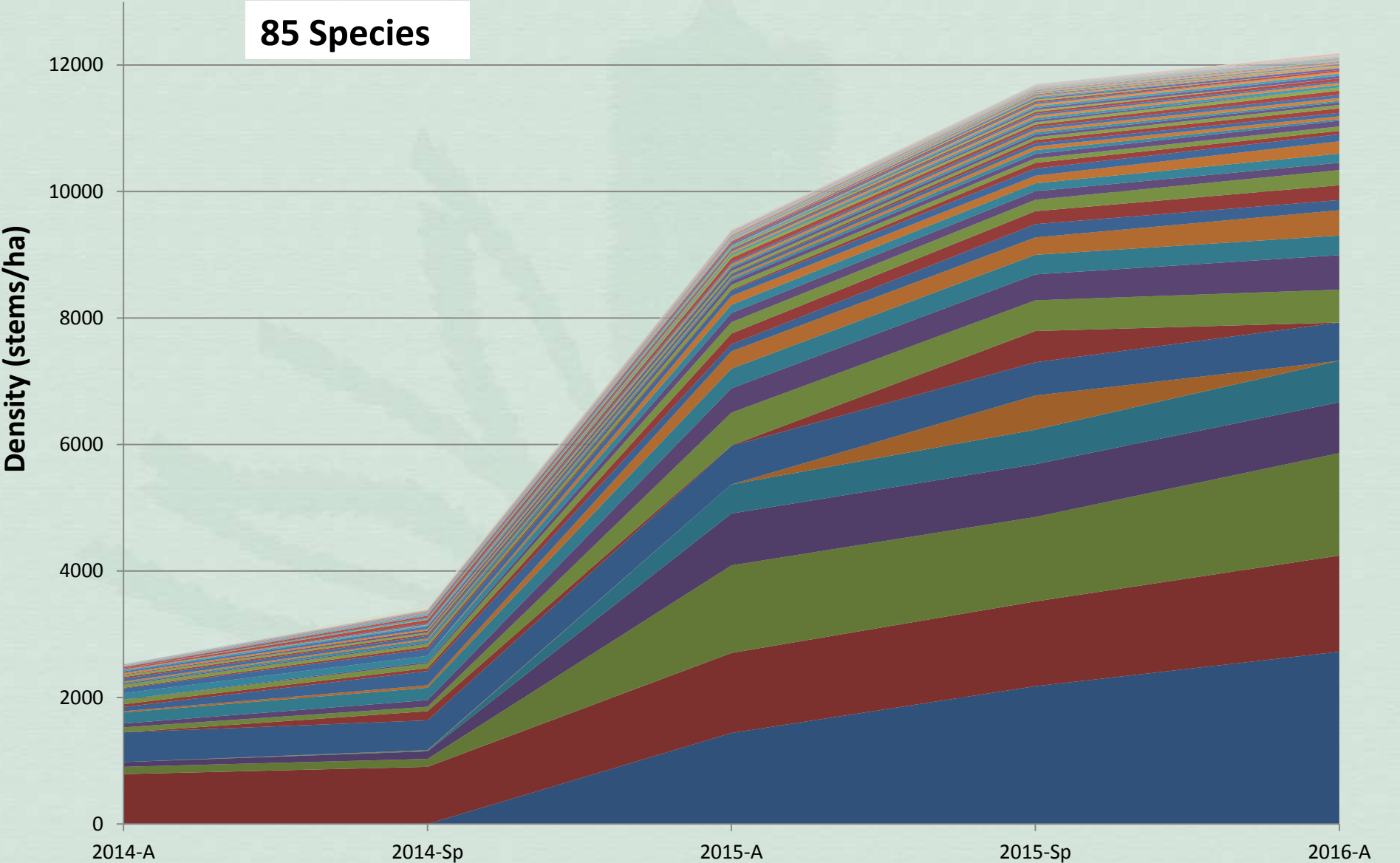
Plant Density



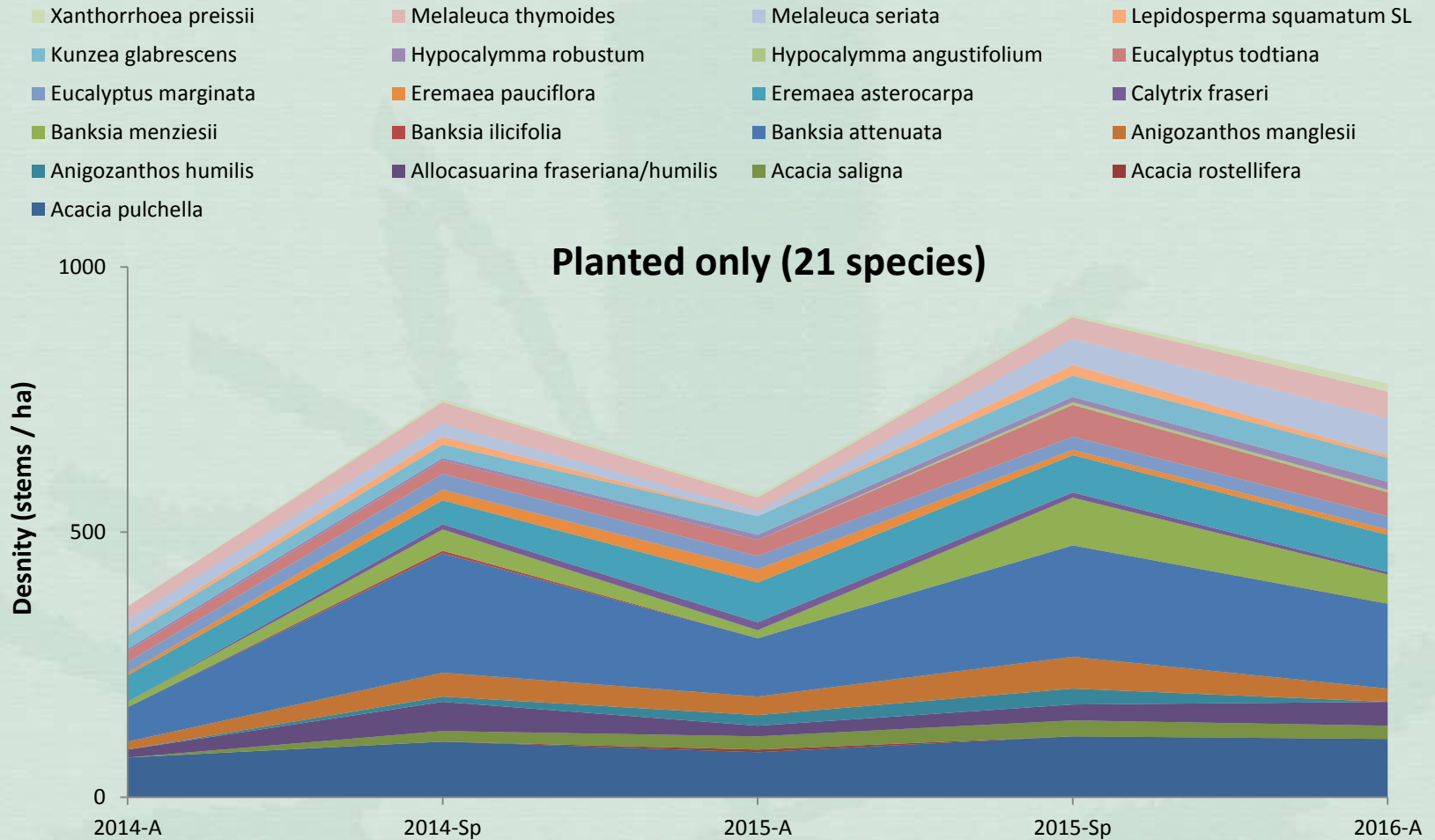
- Stems per ha from 144 - 5 x 5 m quadrats

Plant Density from Topsoil and Planting

85 Species



Density of Planted Species Only



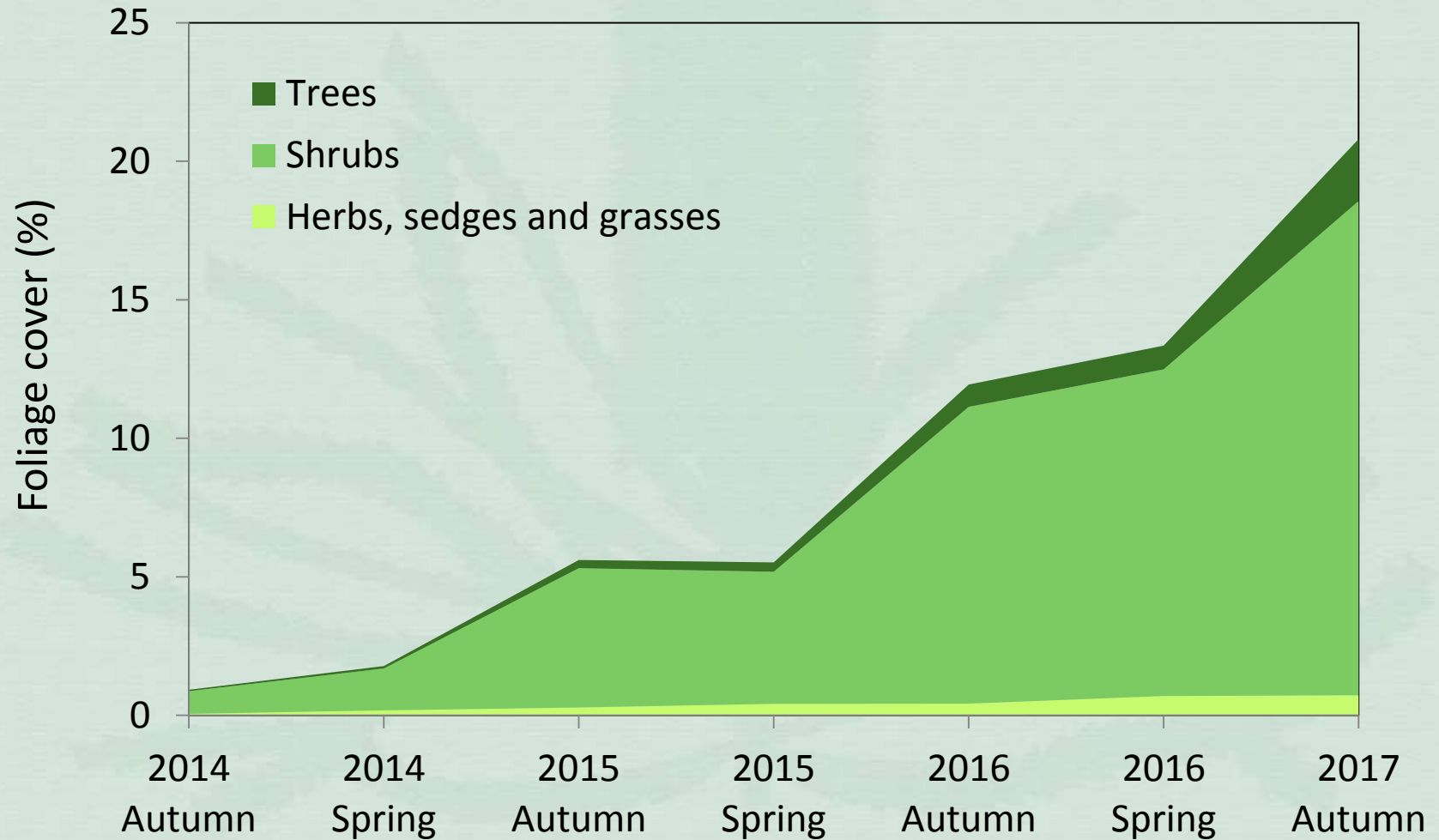
A Complementary Approach

- Topsoil provided high species richness, plant density and many recalcitrant species
- Topsoil alone lacks overstorey species and others with canopy seed
- Direct seeding and planting alone often lacks smaller herbs and annuals
- Thus a combination of methods (topsoil, direct seeding, planting) is most effective

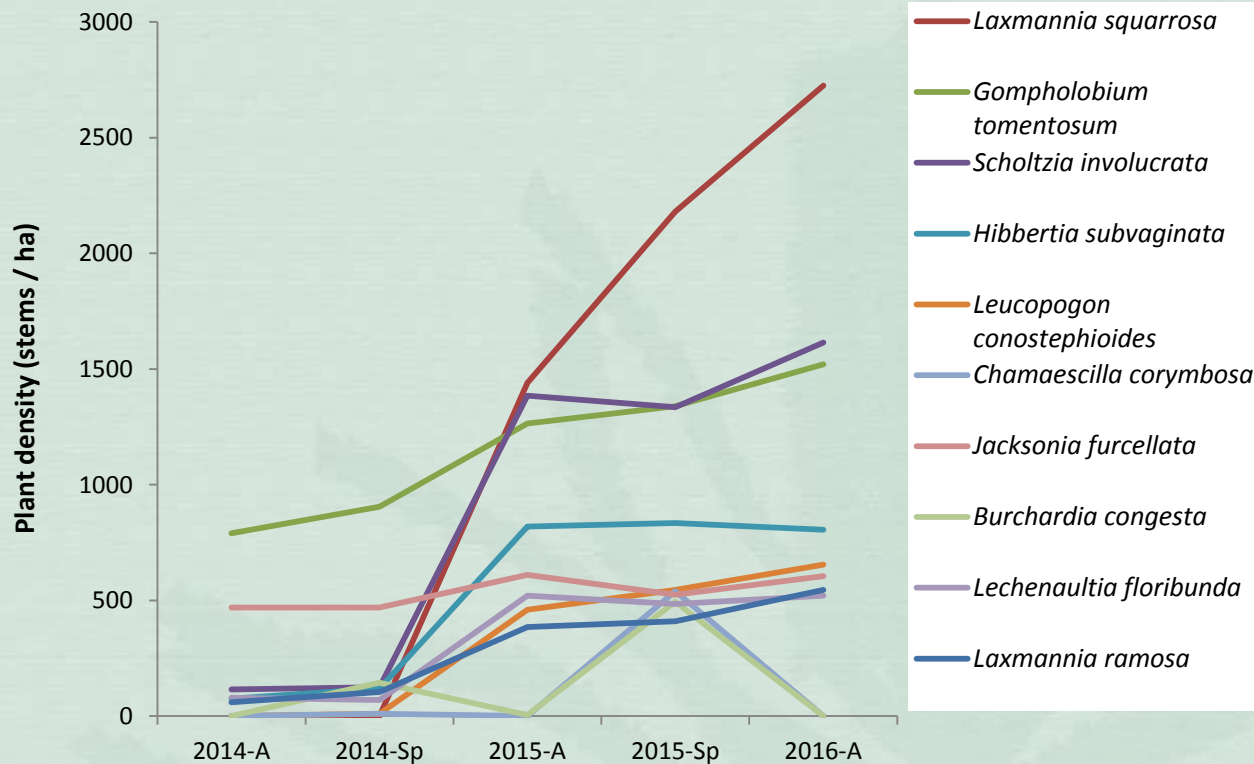


Foliage cover

5x5 metre quadrats



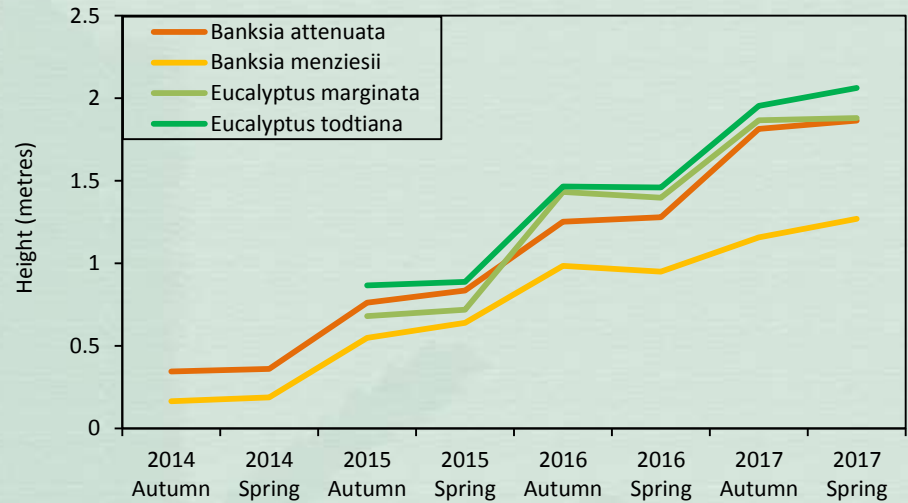
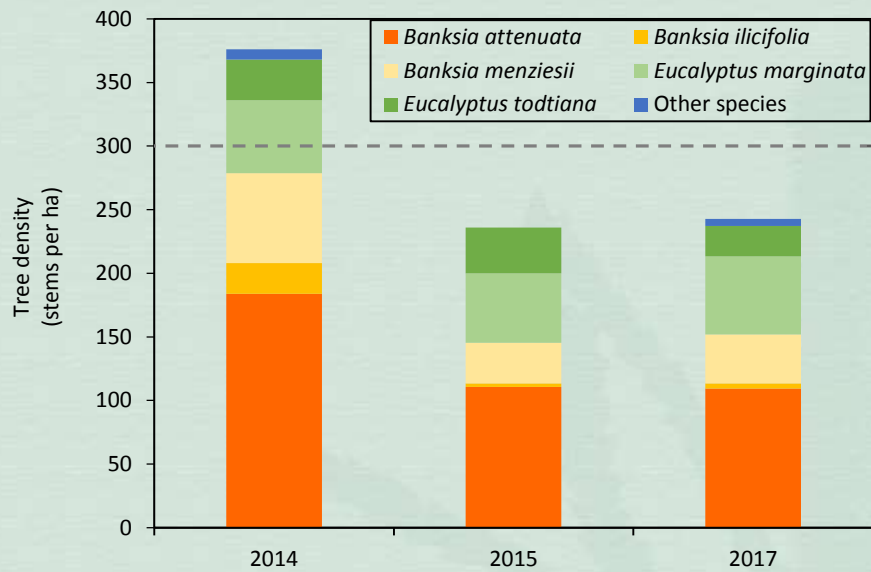
Restoration Outcomes: Dominant Species



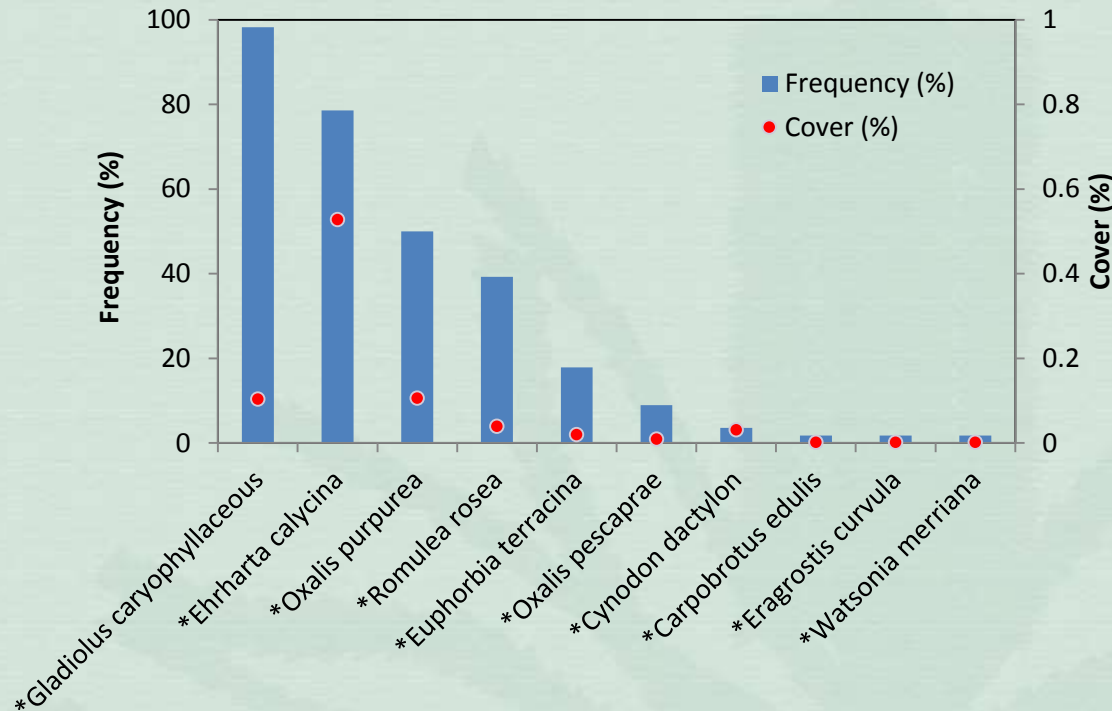
Graph for top 10 native plants by cover. This is dominated by *Jacksonia furcellata* and *Adenanthos cygnorum* – disturbance opportunists from topsoil.

Annual plant cover is initially dominated by weeds and *Podotheca gnaphalioides*, a native disturbance opportunist.

Tree Density and Growth



Restoration Outcomes: Perennial Weeds



Some perennial weeds are common but have low cover (all $< 1\%$).

Annual weeds are more frequent and have higher cover.

Anketell Road in 56 - 5 x 5 m quadrats in spring 2015. Red dots show total cover (scale on right).

Comparing Restoration Potential of Species

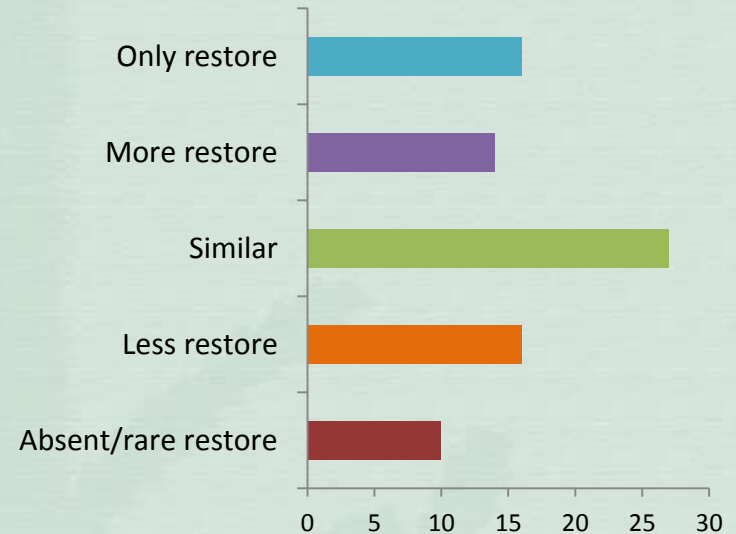
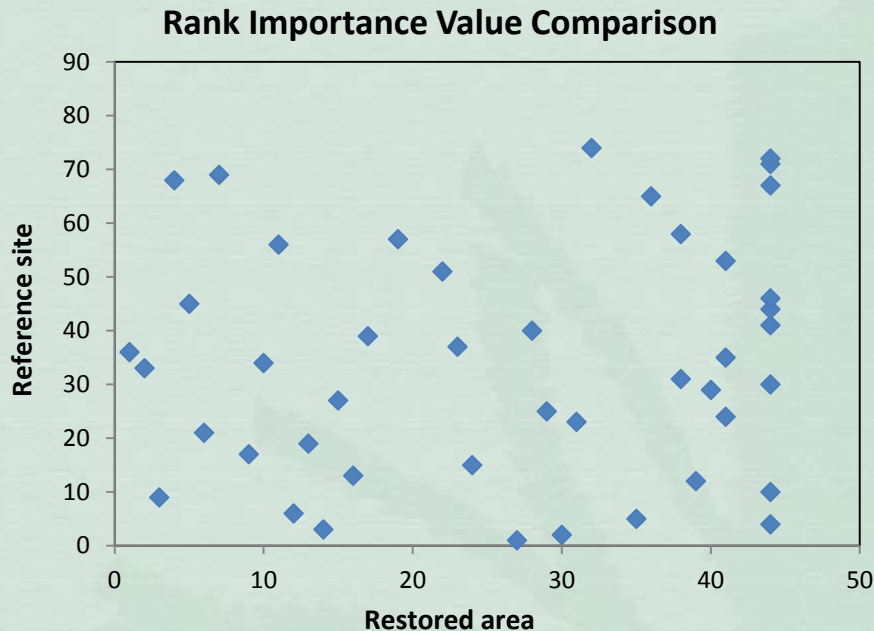


Seed quality and germinability determine nursery outcomes



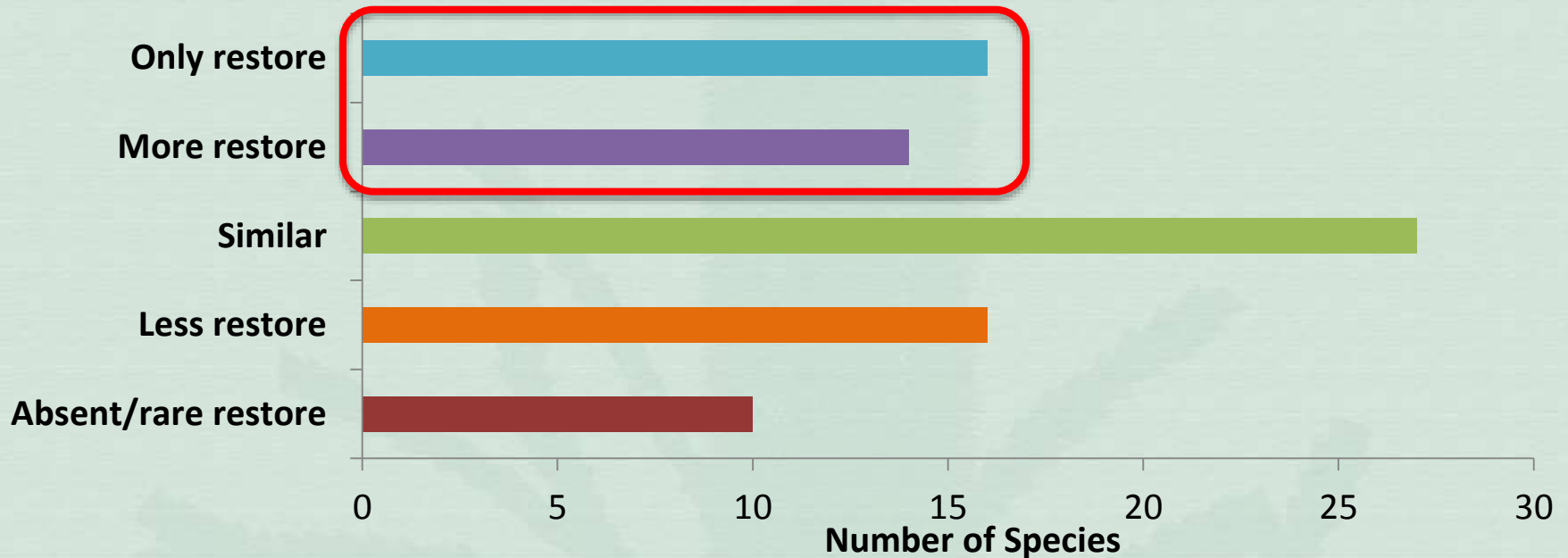
Successful clonal propagation of sedges

Restoration Potential Summary



- Plant diversity is similar (in this case) but vegetation structure differs initially in young banksia woodland on restoration sites
- Long-term trends?

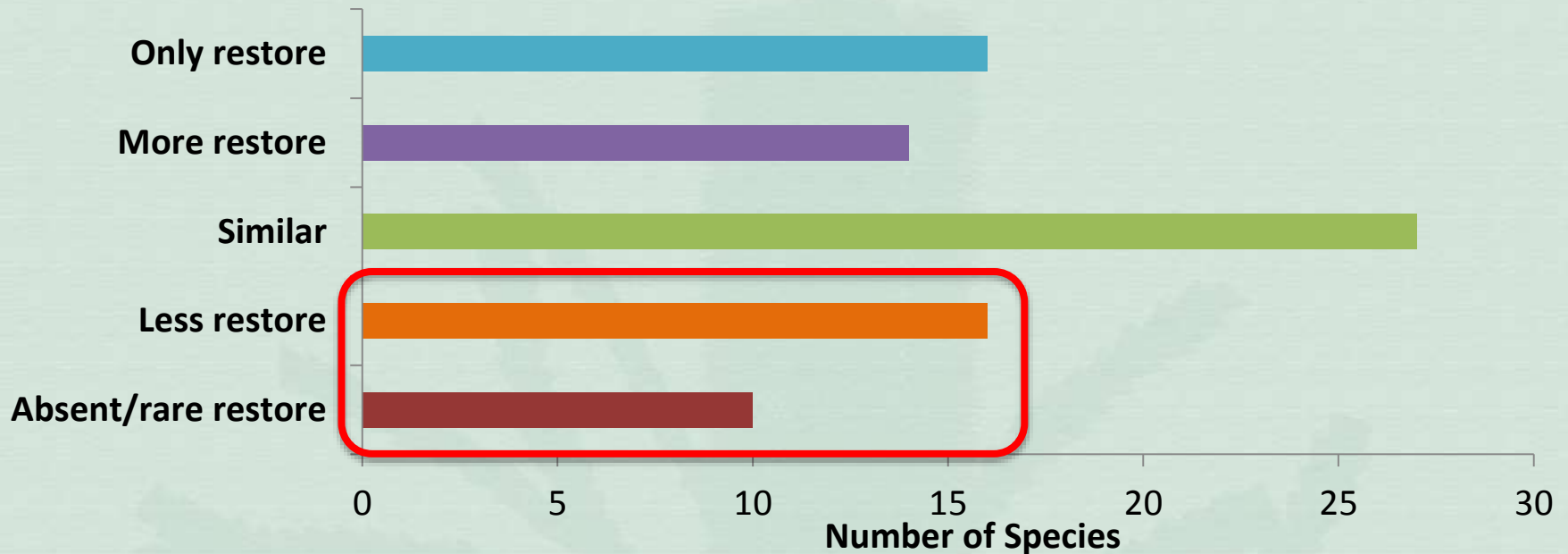
Common Native Plants in Revegetation



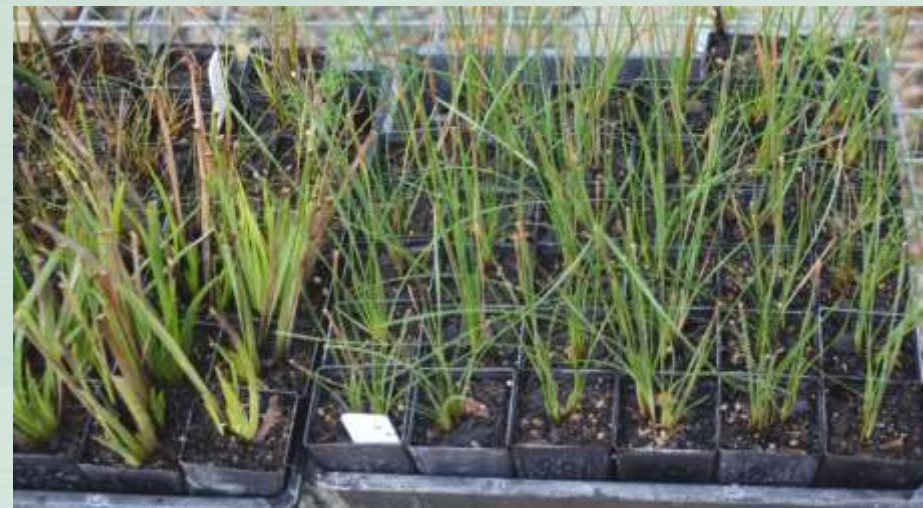
- Disturbance opportunists
- From topsoil seed bank
- Decreasing dominance?
- Abundant flowers and seeds



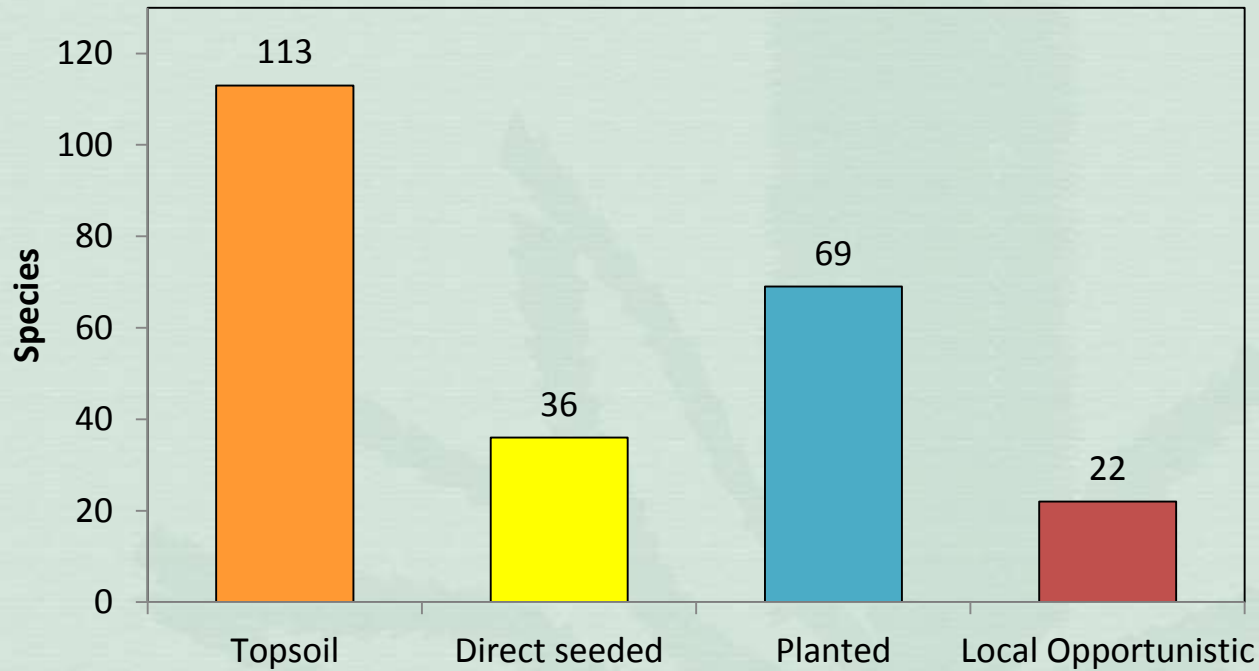
Uncommon Native Plants in Revegetation



- Low seed or germination
- Resprouting species
- Increasing dominance?
- Clonal Propagation



Restoration Outcomes: Plant Sources



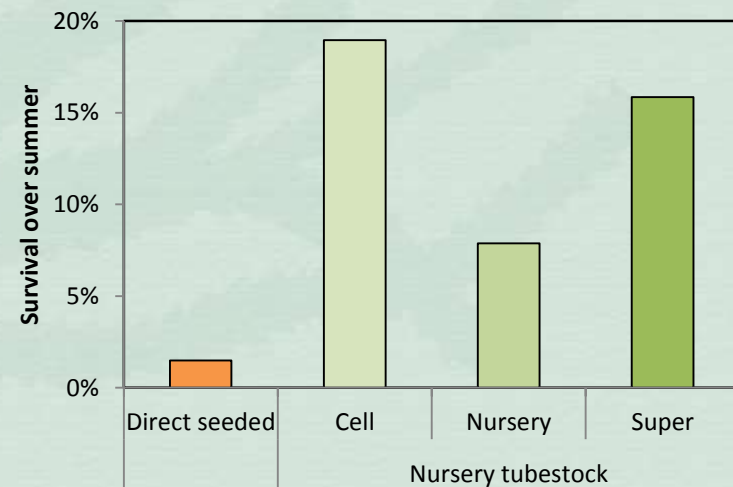
- 160 native plant species by year 4
- Continuum from opportunist to recalcitrant species



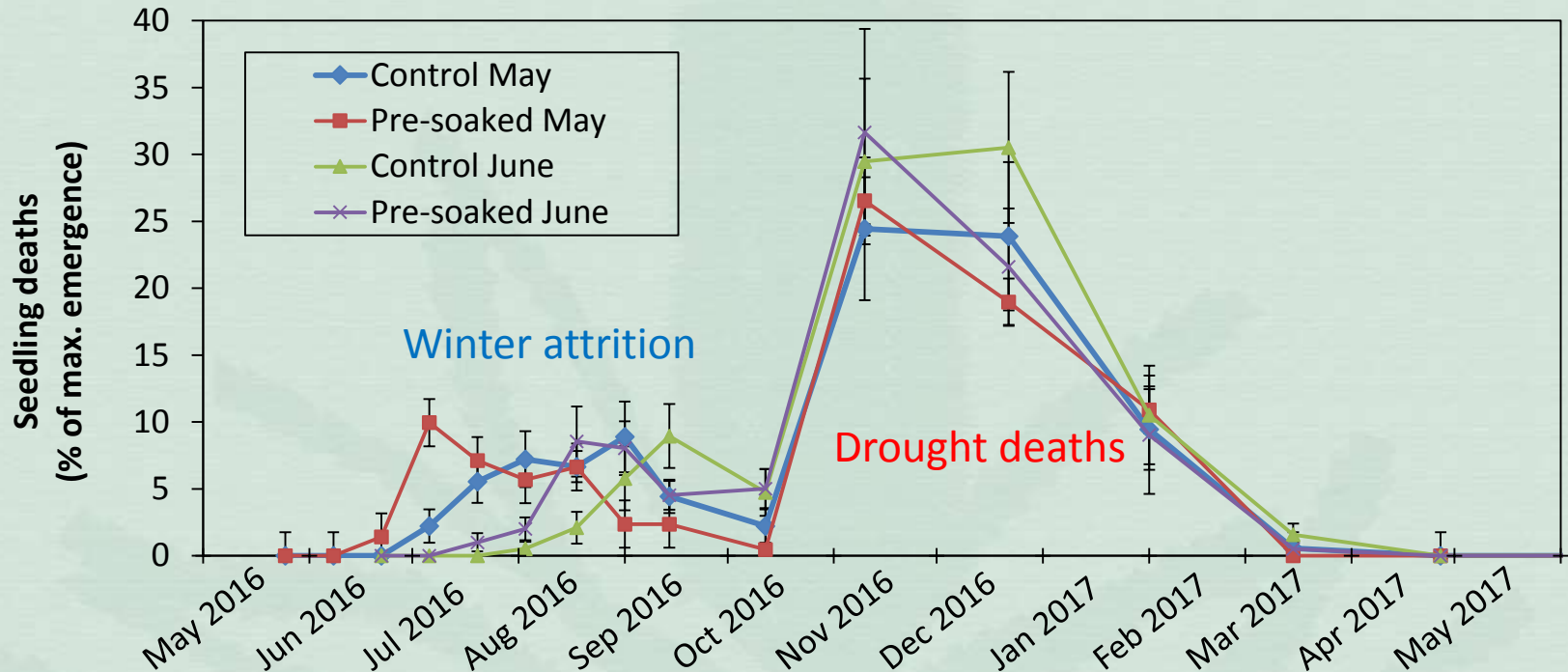
Seed Germination and Survival



- Banksia seedling mortality is often high due to invertebrate grazing in winter and severe drought in summer
- Seedlings of most other plants are more resilient than banksias

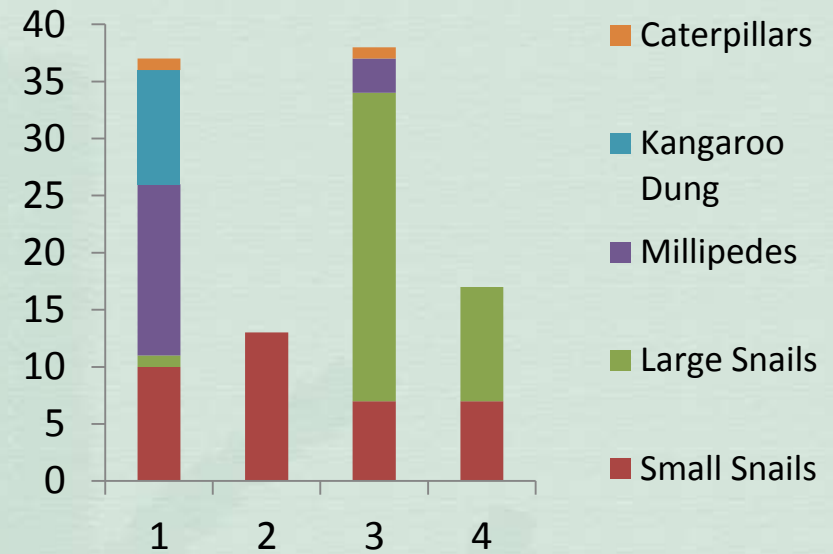


Tree Seedling Mortality Rates



- Direct Seeded *Banksia attenuata* from a 2016 seed germination trial. Deaths from June to October are mostly due to snail and insect grazing and deaths occurring from October to March are due to drought stress.

Who is Eating My Seedlings?

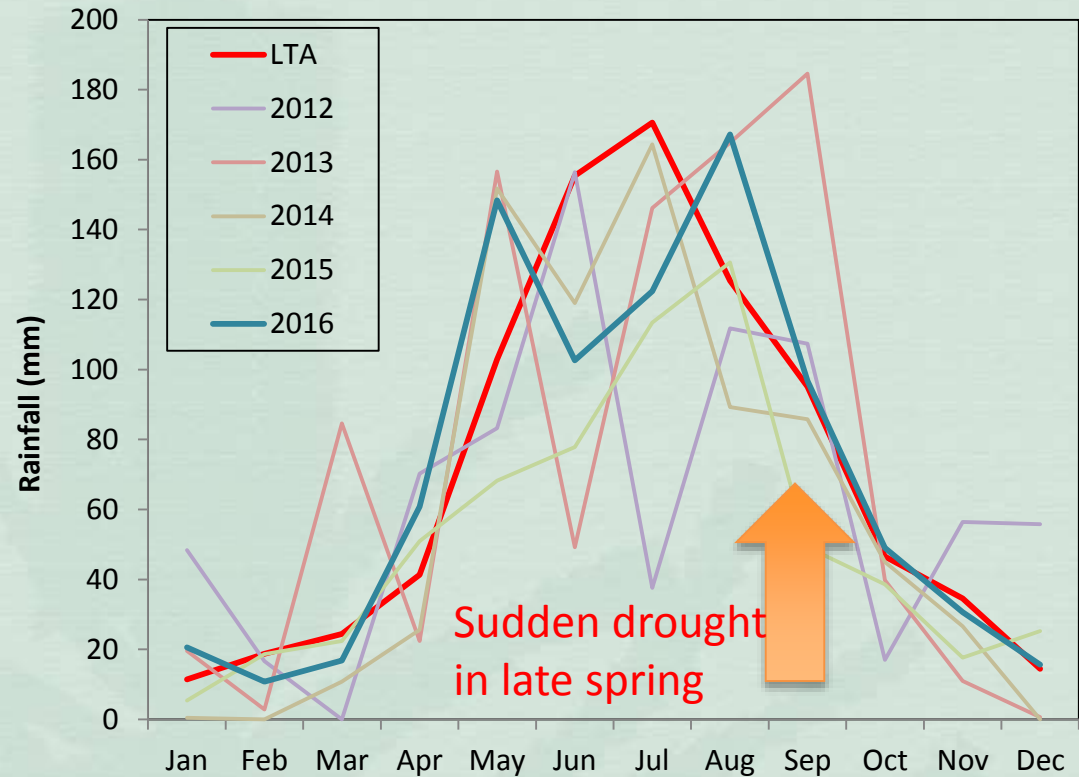
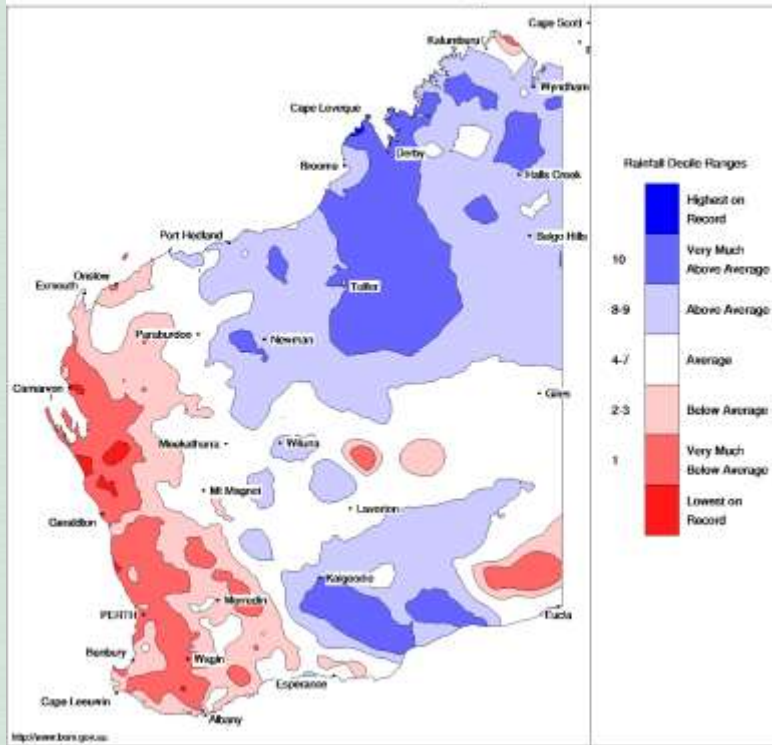


- Visible threats to seedlings

The Challenge of Survival

Rainfall deficits 2012-2015

Western Australian Rainfall Deficits 1 March 2012 to 28 February 2015
Distribution Based on Gridded Data
Australian Bureau of Meteorology



- Several years of planting and seeding are now required to spread the risk of high summer mortality

Outcomes Based on Completion Criteria

Criteria	Target	Anketell Road topsoil	Forrestdale Lake topsoil	Anketell Road no topsoil
Total native species richness	Maximise native species richness	Total of 160-162 native spp. (highly variable spatially)		71 native spp.
Average native perennial species richness per 10x10m	Return 60% reference quadrats (19 spp.)	30	20	11
Tree diversity	Presence of all trees at reference plots	All present		
Tree density (stems / ha)	>300	243	183	362
Carnaby's cockatoo food plants (banksias) /ha	250	152	167	222
Average understory species richness per 10x10m	Return 60% of average in reference quadrats (17 spp.)	28 (17 – 42)	18 (12 – 25)	9 (1-18)
Total density of native perennials per 10x10m	Establish 7,000 stems per ha	20,107	6,950	2,675
Annual native plants	No target set (density is very much lower in reference sites)	17 species 4% foliage cover	15 species 2% foliage cover	10 species 6% foliage cover
Key understory species	Top 10 most important species from reference plots	All are present, most are common		Not relevant
Weed cover	Manage serious weeds, especially perennials, monitor annuals	Perennials: 1% Annuals: 4%	Perennials: 1% Annuals: 8%	Perennials: 5% Annuals: 6%

Variability within Sites

Two quadrats in the same part of Anketell road



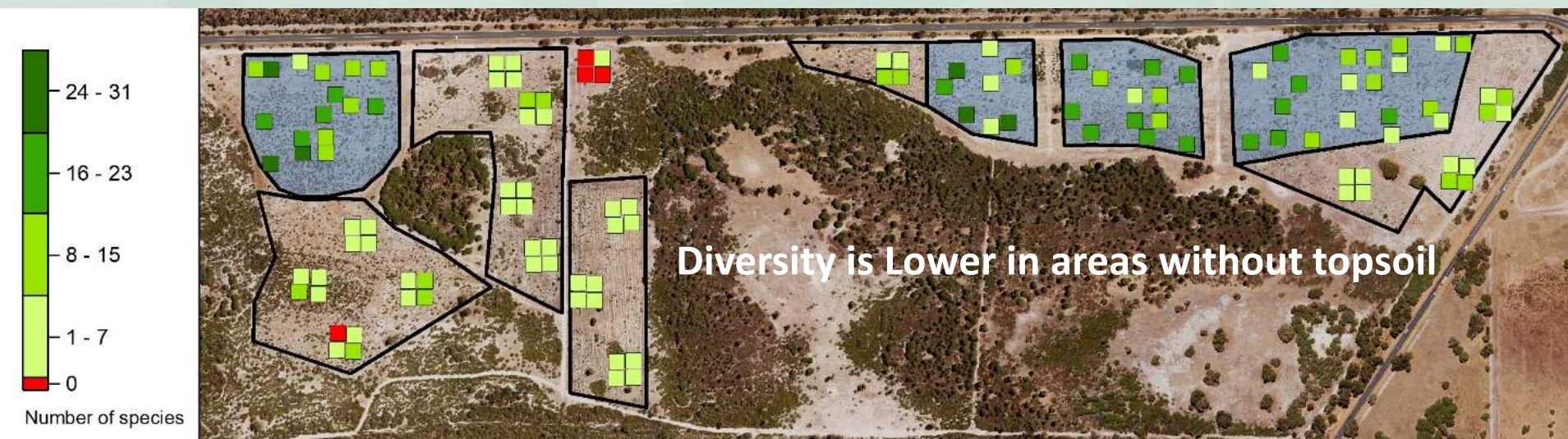
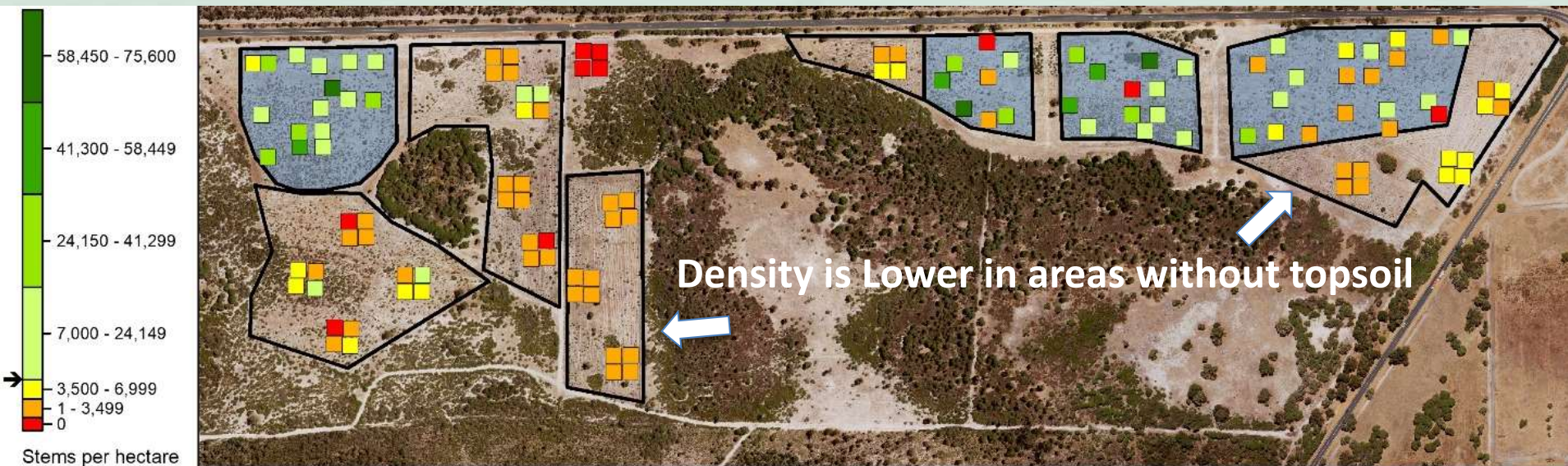
Highest native cover: 57%



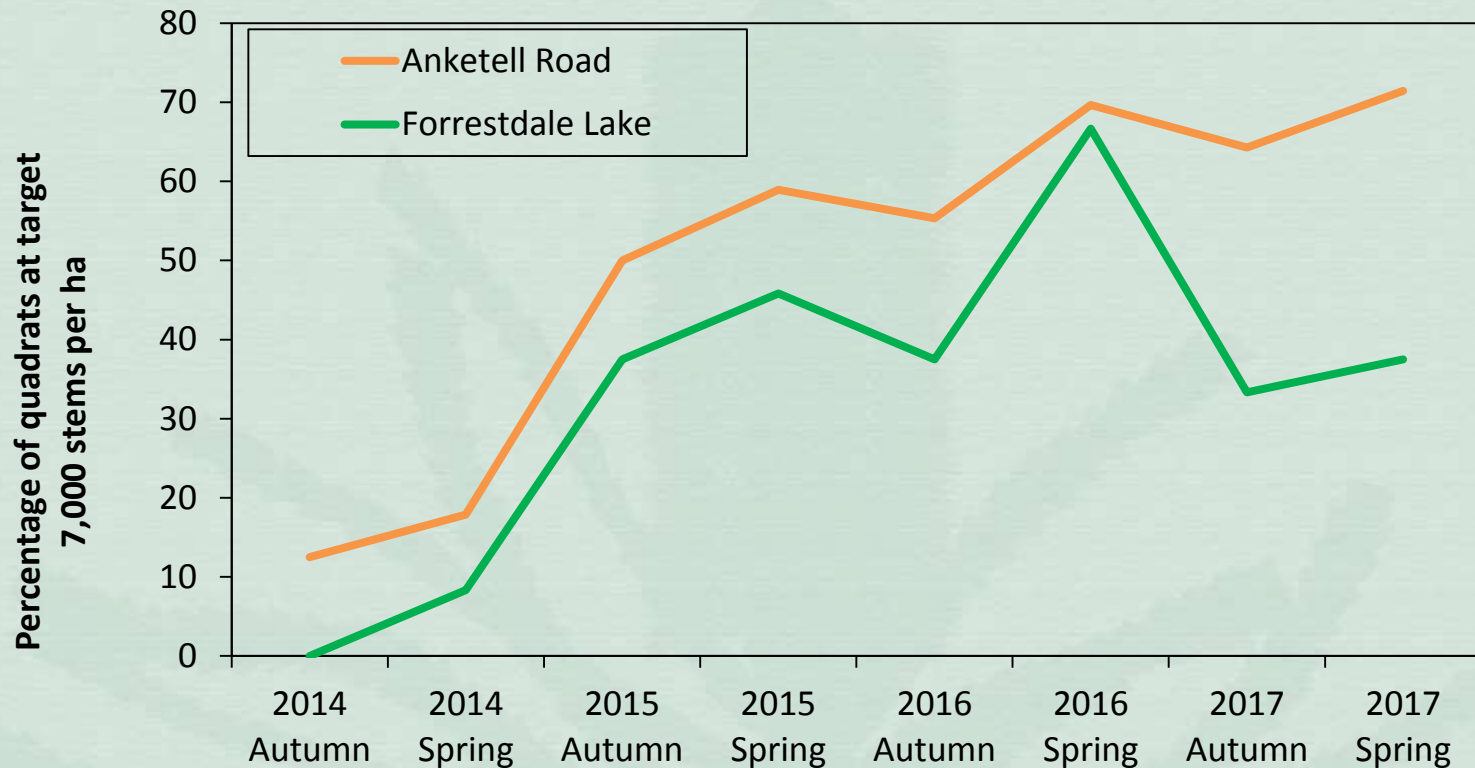
Lowest native cover: <1%



Density & Diversity Variations



Measuring Area Reaching Targets



- Soil quality issues with Forrestdale Lake limit possible outcomes (buildings and historic land use)

Photo Monitoring 1



Spring 2014

Photo Monitoring 2



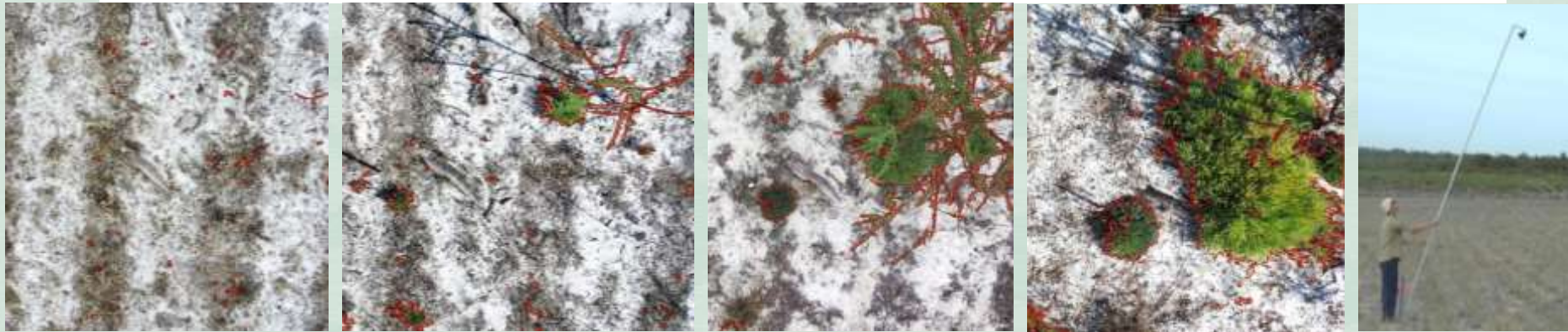
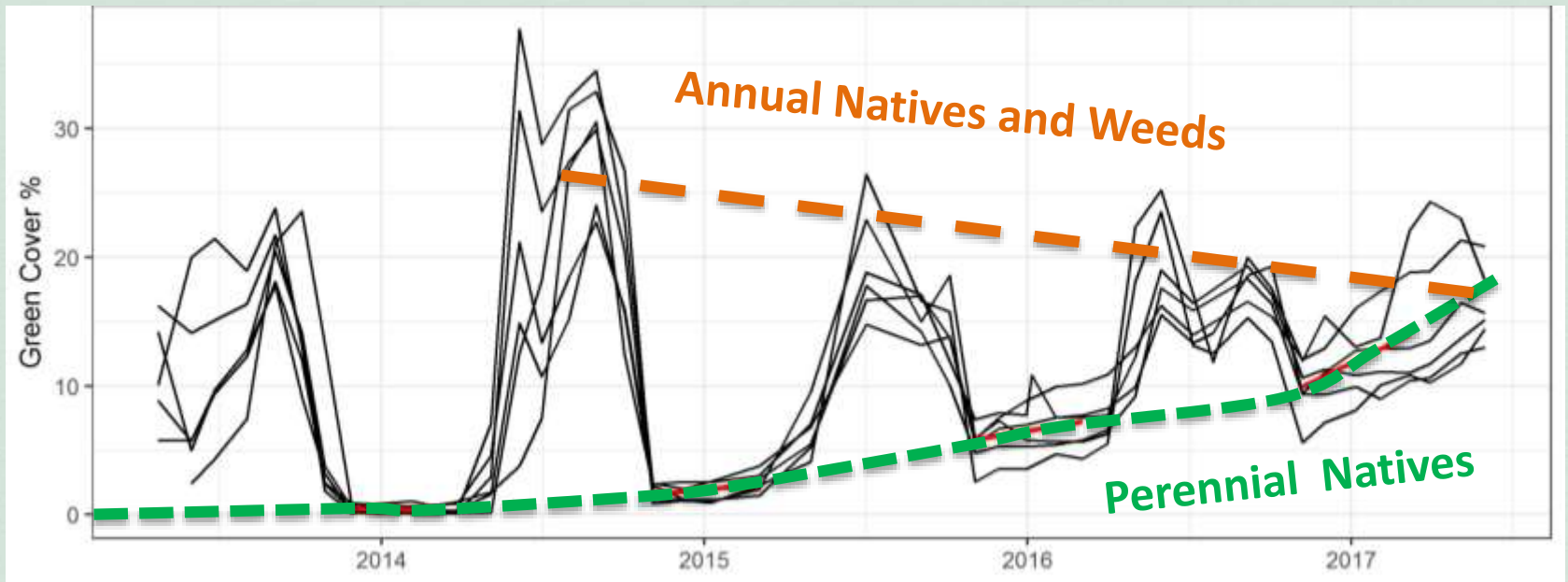
Spring 2015

Photo Monitoring 3



Spring 2016

Monitoring Total Cover



Ricky Van Dongen & Bart Huntley GIS Branch, DBCA (Anketell Rd)

Downward photos processed for total cover by computer algorithm (eCognition)

5. Sustainable Restoration



Long-term Sustainability & Ecological Functions



Pollination



Row 1 - native
bees

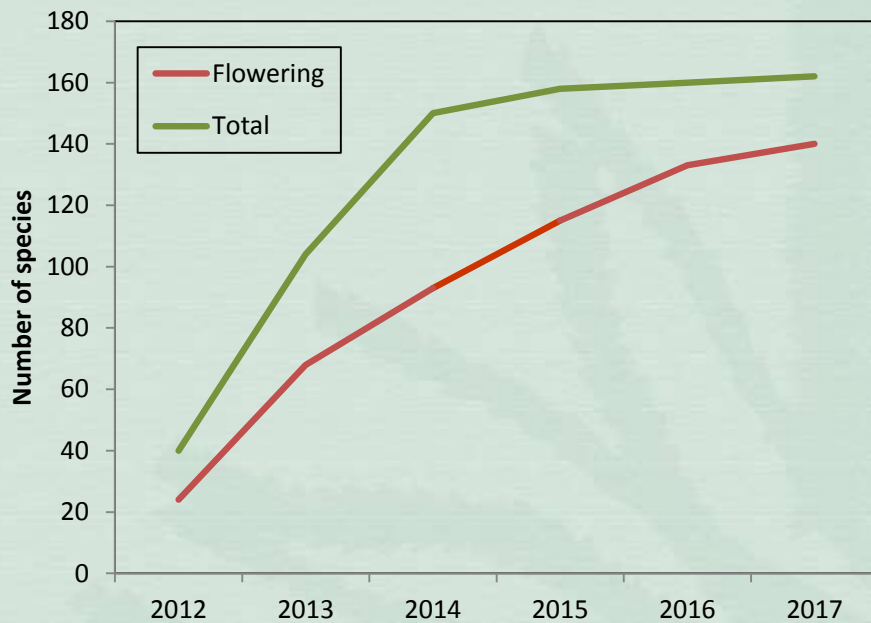
Row 2 – wasps

Row 3 - flies
and butterflies

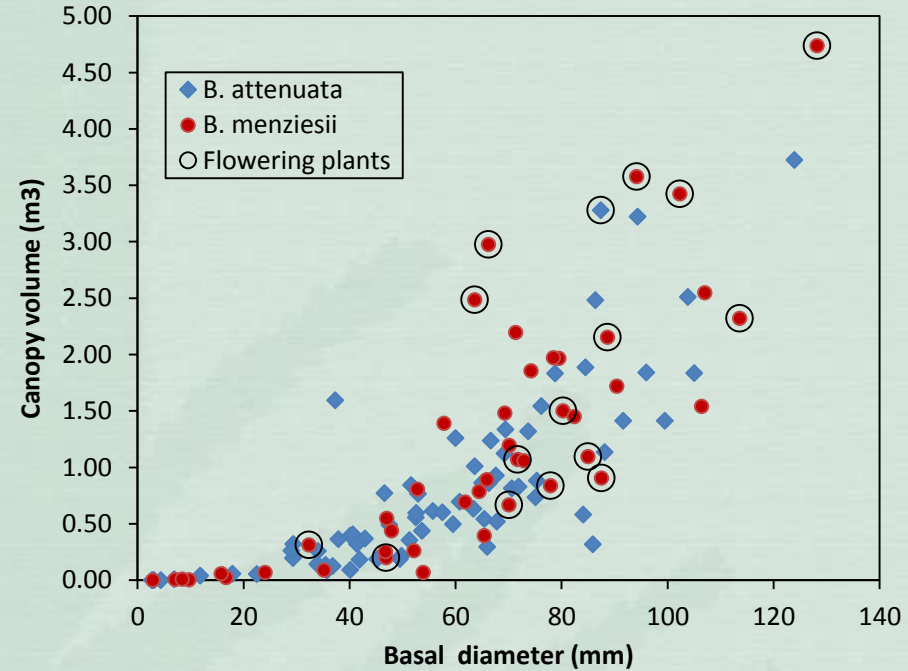
Row 4 -
beetles

Flowering and Seed Set

All plants



Banksias



Harmful Ecological Interactions



Pigface is often spread by rabbits and kangaroos



Galls were common on acacias by year 4



Kangaroo grazing was severe in unfenced areas

- Grazing, weed dispersal and parasites of native plants

Summer Drought & Turnover of Species



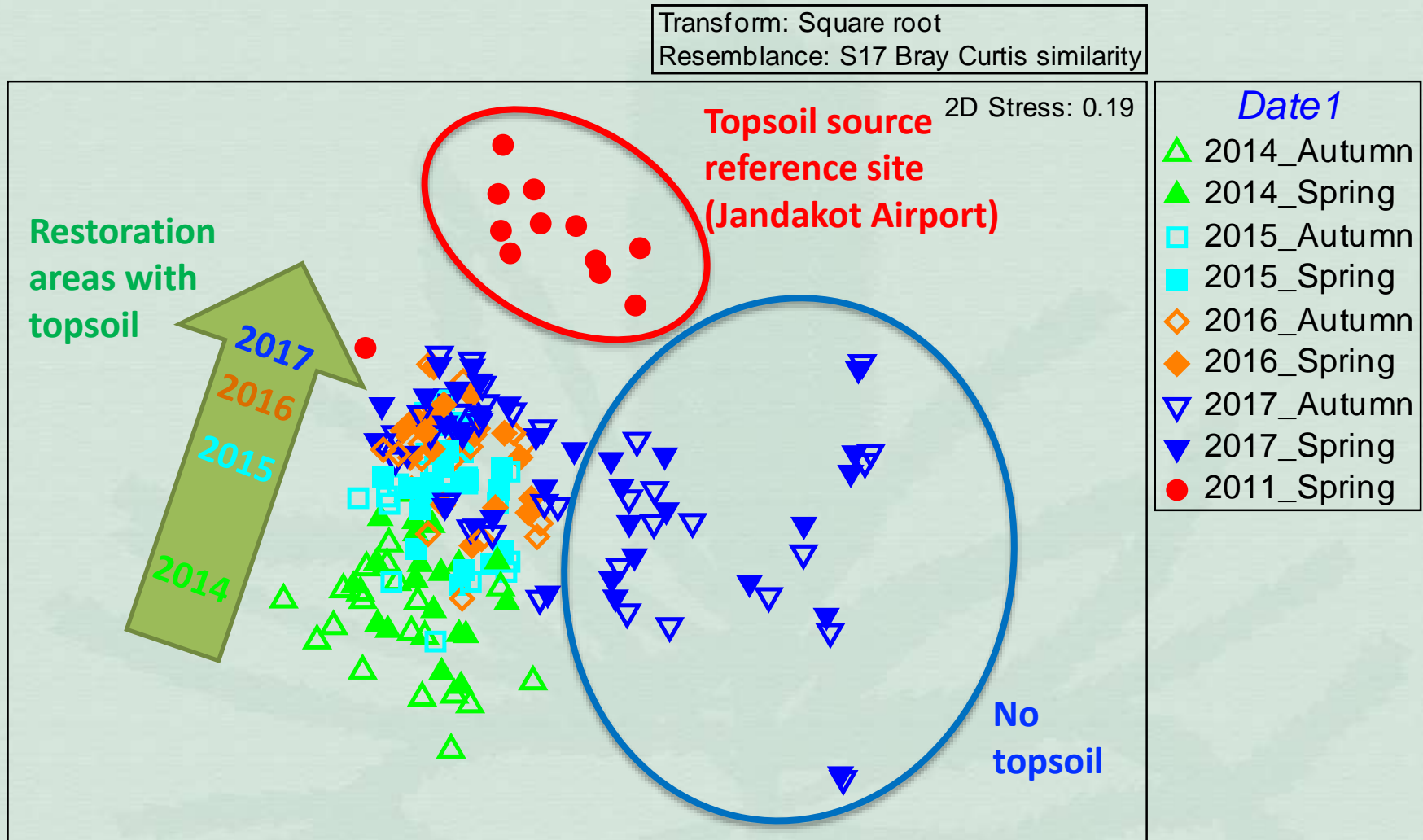
- Some disturbance opportunists declining by year 5
- More susceptible to severe summer drought

Disturbance Opportunists

- Common plants in restored areas that were uncommon or not detected at Jandakot Airport (a long unburnt site)



Floristic Recovery Trends



- MDS plots of relative dominance using plant cover

Conclusions I

1. Grazing and control was essential and weed control very important
2. Effective seed quality control and germination treatments were important
3. Comprehensive reference site and monitoring data was required to guide restoration
4. Restoration methods had a major impact on plant cover and diversity and produced different plant community types
5. Banksia trees had higher mortality than most other species

Conclusions II

6. Rapid tree growth, flowering, seed-set and second generation seedlings have been observed
7. Ecological processes such as turnover of species and biological interactions like flowering and pollination are important and need to be studied more
8. Recovery trends vary due to plant functional groups
9. Recovery trends and timing can possibly be extrapolated but long-term monitoring is required
10. Information required for effective restoration of key species needs to be collected and shared
11. Major problems with offset regulation and management occurred during the BWR project

6. Knowledge Gaps & Research Opportunities



Most common request from community groups (Feb 2016):

- Share results and data to help manage native plants in restoration sites.

Data Required for Effective Restoration

- Species lists for restoration sites with:
 1. Habitat type (e.g. upland)
 2. Soil/hydrology preferences
 3. Relative importance of spp.
 4. Seed collection/germination issues
 5. Flowering and seed dispersal times
 6. Restoration potential and issues
 7. Animal associations (e.g. Carnaby's cockatoo food plants)
 8. Fire recovery type and frequency
 9. Resilience to weeds and other disturbances
 10. Susceptibility to pests and diseases



Revegetation Report Card *Banksia attenuata*

Factor	Data
Seed Collection	0-101 seeds per tree (average 15), Jan-Feb
Seed preparation	Difficult (heat required to open cones)
Seed storage	Requires low humidity and temperature
Seed germination	High (30-95%), Inhibited by high temperature
Topsoil seed bank	No
Direct seeding results	Moderate (0-400 seedlings/ha)
Seedling survival (severe summer drought)	Low in first year (3-20%)
Tubestock survival (severe drought)	Low in first year (10-20%)
Grazing susceptibility	High (kangaroos, rabbits, invertebrates)
Growth rates	Fast (0.3-1 m/year height)
First flowering	> 5 years
Other impacts on seedlings	Grazing, parasitic galls, weeds



Restoration Realities

Species related (1, 2) and site specific (3) factors ranked in according to their importance in banksia woodland restoration

1. Seed collection	2. Propagation	3. Survival
1. Canopy stored seed	1. Germination easy	1. Weed competition
2. Seed easy to collect	2. Seed treatments	2. Poor soil quality
3. Seed collectible in sufficient numbers	3. Germination slow and/or erratic	3. Grazing by invertebrates
4. Seed quality poor	4. Seed viability low	4. Diseases and pests
5. Seed very hard to get	5. Clonal division only	5. Grazing by large animals
6. Viable seed almost impossible to get	6. Almost impossible to propagate	6. Severe drought

