Version 3

Western Australia's Flora: Origins, Endemism, Rarity and Conservation

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Science Division
Department of Environment and Conservation

Department of Environment and Conservation

Strategic Plan 2008-2017

Vision: Sound science supporting the conservation of WA's biodiversity

- Internal (Science Div.) workshops
- Service Directors
- External input:
  - Dr Steve Morton CSIRO
  - Prof. Richard Hobbs Murdoch Uni
  - Prof. Alistar Robertson UWA
- Other planning processes:
  - State Biodiversity Conservation Strategy
  - Forest Management Plan
  - Regional Nature Conservation Service Plans
  - National priorities

Challenges & Opportunities

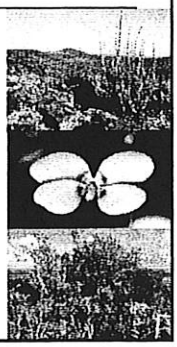
- Grow permanent staff expertise to meet future challenges e.g. Climate Change
- Cost pressures – budget and recruiting issues
- 'Brain drain' as skilled and experienced staff leave the workforce or are attracted to better opportunities
- Grow partnerships and alternative sources of revenue
- Biodiversity Futures Major Research Facility
- Grow partnerships with other Divisions such as Regional Services and Nature Conservation through avenues such as adaptive management projects
- Building/maintaining a science presence in 'remote' areas
- Improve publication performance
- Improve communication/uptake/impact of science
- Improve accommodation & collocation of metro centres

Outline of talk

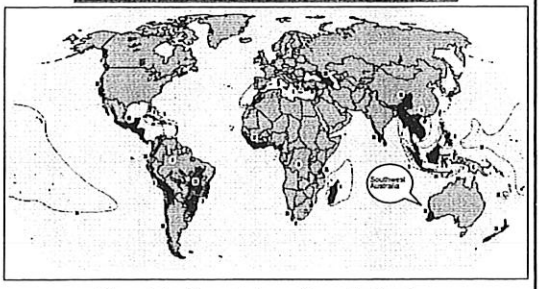
- Patterns of plant diversity in the south-west
- Ancient flora and evolutionary history
- Climate Change
- Taxonomy of the banded ironstone ranges
- Rarity
- Rarity and genetic structure
- Rarity and threat in the flora
  - *Phytophthora* dieback
  - Habitat fragmentation
  - Mining
- Threatened flora
- Ecological studies and implications for recovery
- Recovery of threatened flora
- FloraBase

Patterns of plant diversity in the south-west

- Ancient flora with many relict species
- Large number of species have geographically restricted ranges
- Many species have naturally fragmented disjunct distributions
- High proportion of naturally rare plants in the south-west
- Rare species often have fragmented disjunct distributions with significant genetic variation between populations



The 25 global biodiversity hotspots (Myers *et al.* 2000)

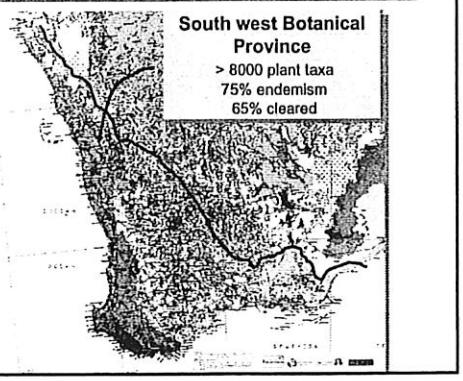


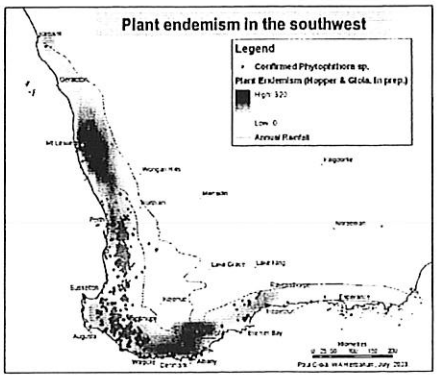
Places richest in endemic species under threat

Conservation International - Aug 2002

Biodiversity hotspots in Western Australia global and national

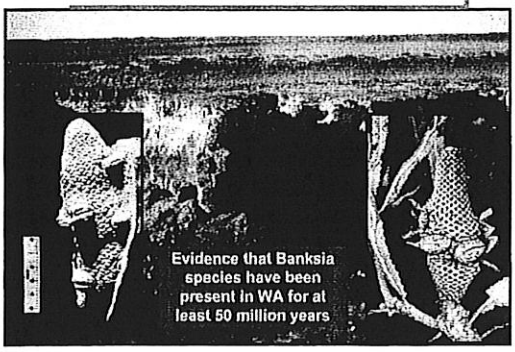
South-west a global biodiversity hotspot for flora





Ancient Flora and Evolutionary History

Fossil record and molecular DNA studies indicate an ancient flora



Major Factors Influencing the Evolution of the South West Flora

- Ancient landscape remaining **unglaciated** and above sea level for 200 million yrs
- No significant mountain uplifting or volcanic activity
- 5 million years ago - onset of aridity and disappearance of rainforests
- Dynamic climatic changes during the late Tertiary - Quaternary (1.6 mill yrs bp to present)

WA Flora - State of Play

- 13,089 taxa (species, subspecies, varieties)
- 2,813 rare, threatened and poorly known
- 388 Threatened flora
- 1,539 unpublished
  - many lack suitable guides to their identification
  - many are poorly known, under-collected or rare
- Estimate 10-15% remain unknown to science
- Over 300 new species described in 2007

Climate Change

Climate change will affect most WA species and ecosystems

- ***Directly:***
  - changed temperature
  - Changed rainfall
  - extreme weather events
  - increased CO_2
- ***Indirectly:***
  - changed fire regimes
  - pests & diseases
  - altered hydrology and water availability
  - land clearing
- **But** – which factors, which species, how and how much with what response?

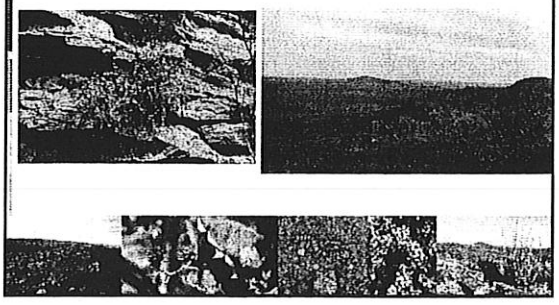
WA species - likely responses to climate change

- **Some will persist** through physical and behavioural change (phenotypic plasticity) and evolutionary adaptation
- **Some will contract** to refugia
- **Some will migrate**
- **Some will become extinct**
- **Major changes to our biodiversity are unavoidable**

Climate change and biodiversity management: what can we do?

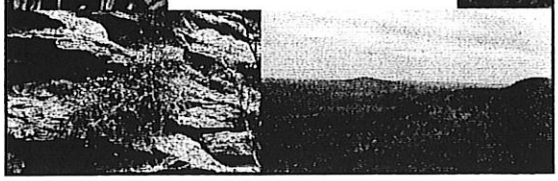
- Maintain or increase existing organic carbon e.g. manage land clearing, revegetation, fire, grazing etc. to increase net phytomass & reduce greenhouse gas emissions
- Assist species and ecosystems to cope e.g. manage other threats and disturbances, such as weeds, ferals, fire; provide migration corridors; enhance gene pools etc.
- Protect vulnerable biota e.g., reserve system design, assisted migration, translocations, off-reserve programs, *ex situ* conservation.

Taxonomy Banded Ironstone Ranges



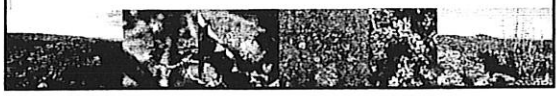
Tetratheca species conservation status:

- Each of the 7 taxa exist as 1 or a few geographically restricted populations
- 6 taxa in areas targeted for mining or already on mine sites
- T. *paynterae* subsp. *paynterae* – 30% of population removed for mining

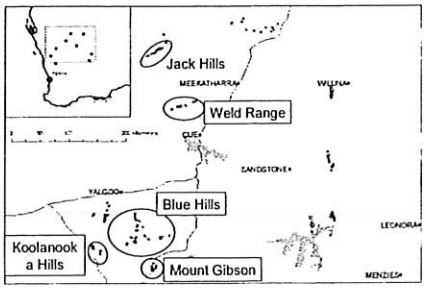


Yilgarn banded ironstone ranges

- Ranges are generally floristically distinct across the Yilgarn
- Often geographically restricted vegetation communities occur with individual ranges
- Pattern may result from relictual nature of ranges and Tertiary climatic change
- May also result form high degree of specialization to very old soils
- Likely to identify more new species as these ranges are surveyed in more detail



Banded Ironstone Ranges in the Yilgarn

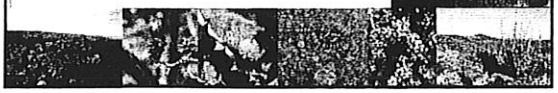


BCI Taxonomy Project objectives

- Resolve the taxonomy and expedite the description of new taxa
  - occurring in areas where they may be vulnerable to future mining activities
    - BIF of the Yilgarn
    - Ravensthorpe Range and Bandalup Hill
  - listed as being of conservation priority
    - across Western Australia
- publish a special issue of 'Nuytsia

Significant Achievements

- 50 Botanists contacted [WA 35, Eastern States 15]
- Contributions from at least 35 local and interstate botanists
- 94 new taxa described
  - 20 families, 34 genera
  - 30 from BIF
- Special issue of the Herbarium peer-reviewed journal "Nuytsia"
- 45 manuscripts

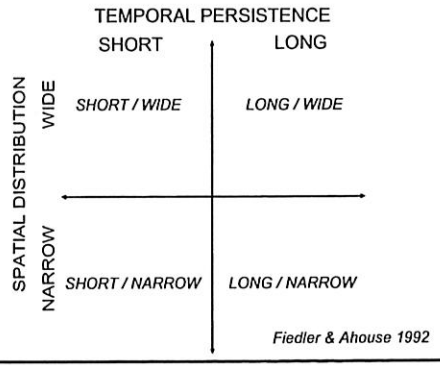


Rarity

Biological rarity

- Rarity is an intuitive, relative, scale dependent concept
- In biology it generally relates to:
  - geographic range
  - habitat specificity
  - abundance of a taxon
- Rare plants are often characterised by :
  - small populations
  - fragmented / isolated populations
  - small geographic range
- Over 2000 plant taxa are currently considered rare in south-west Western Australia, approx. 25% of the flora

Four categories of rarity in vascular plants



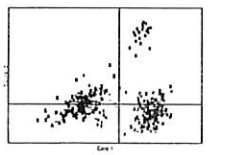
Fiedler & Ahouse 1992

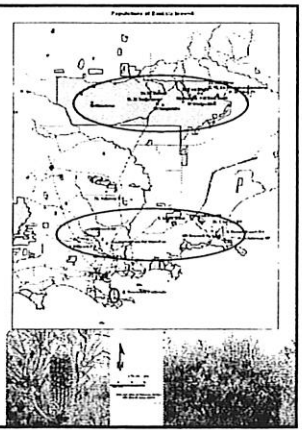
Many causes of rarity

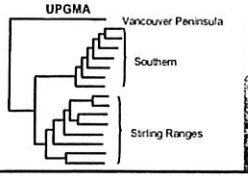
- Geologic and evolutionary history
- Myriad of ecological interactions (e.g. edaphic factors, predation, competition, pollination, fire sensitivity, climate)
- Reproductive biology
- Habitat specificity
- Population dynamics and influence of environmental and demographic stochasticity
- Human activities - habitat conversion, land management, harvesting

Rarity and patterns of genetic structure

***Banksia brownii* population genetic structure**

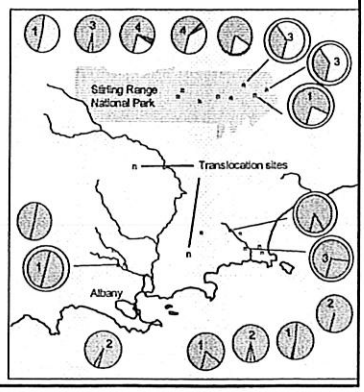


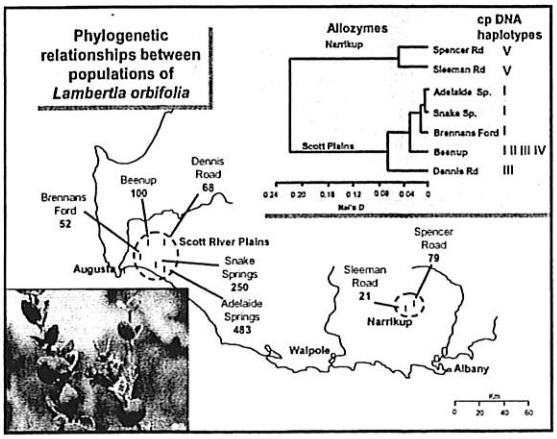


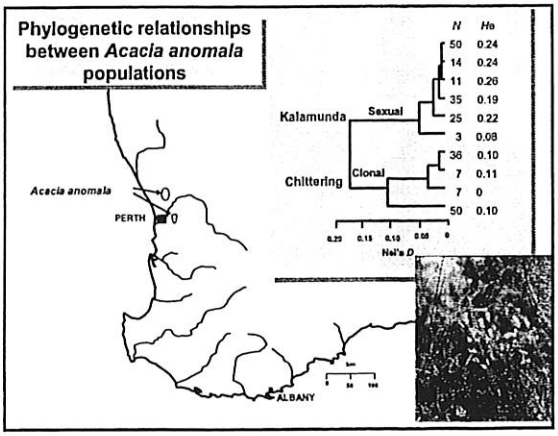


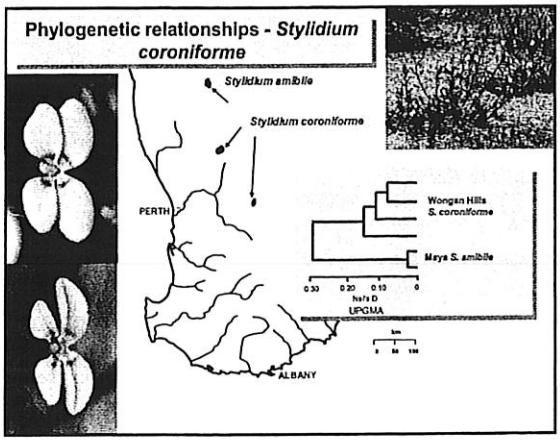
***Banksia brownii* allele frequencies SSR C2 and private allele numbers**

>30% of private alleles in extinct populations

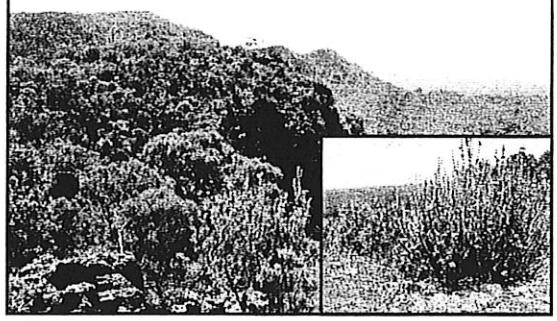



Phylogenetic relationships between populations of *Lambertia orbifolia*
Allozymes
cp DNA haplotypes
Narrikup
Spencer Rd V
Sleeman Rd V
Adelaide Sp. I
Snake Sp. I
Brennans Ford I
Scott Plains
Beenup I II III IV
Dennis Rd III
Nei's D
Dennis Road 68
Beenup 100
Brennans Ford 52
Scott River Plains
Augusta
Snake Springs 250
Adelaide Springs 483
Spencer Road 79
Sleeman Road 21
Narrikup
Walpole
Albany
Km

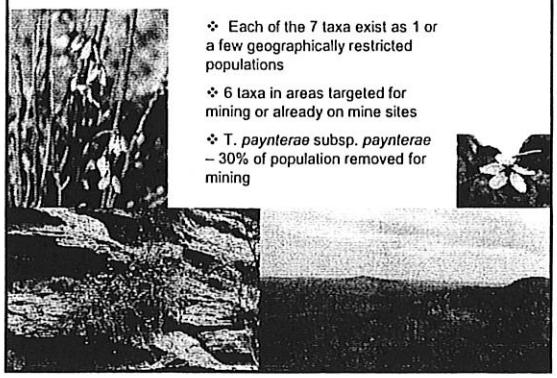

Phylogenetic relationships between *Acacia anomala* populations
N He
50 0.24
14 0.24
11 0.26
35 0.19
25 0.22
3 0.08
36 0.10
7 0.11
7 0
50 0.10
Kalamunda
Sexual
Chittering
Clonal
Nei's D
Acacia anomala
PERTH
ALBANY


Phylogenetic relationships - *Stylidium coroniforme*
Stylidium amabile
Stylidium coroniforme
PERTH
Wongan Hills *S. coroniforme*
Maya *S. amabile*
Nei's D
UPGMA
ALBANY

Helena and Aurora Range – *Tetratheca aphylla* subsp. *aphylla*



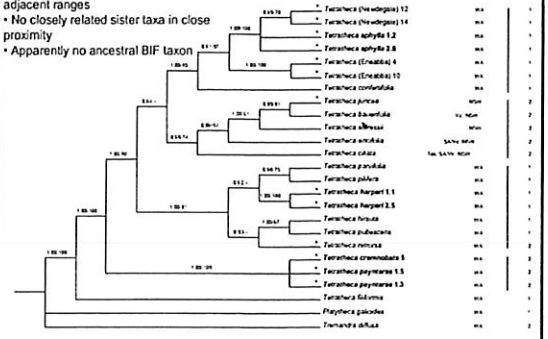
***Tetratheca* species conservation status:**



- Each of the 7 taxa exist as 1 or a few geographically restricted populations
- 6 taxa in areas targeted for mining or already on mine sites
- T. *paynterae* subsp. *paynterae* – 30% of population removed for mining

Phylogenetic relationships among *Tetratheca* species

- Phylogenetically distinct taxa on adjacent ranges
- No closely related sister taxa in close proximity
- Apparently no ancestral BIF taxon



Butcher R et al. (2007). Australian Systematic Botany. 20, 126-138

Conclusions

A significant component of the flora consists of rare and geographically restricted species that:

- Have patchy (fragmented) / disjunct population systems
- Show significant population genetic structure and consist of more than one distinct evolutionary lineage (multiple conservation units, ESU's)
- Are often phylogenetically distant from closely related congeners and are likely relictual (Tertiary ?)

Implications for Conservation

Significant population genetic and phyleogeographic structure within species will have implications for:

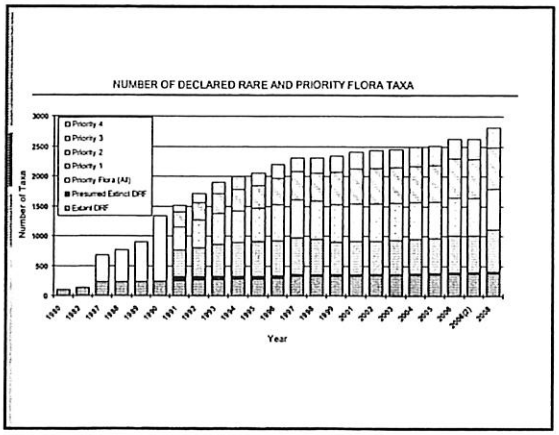
- Germplasm collection strategies:
  - Rare and threatened taxa
  - Vegetation rehabilitation / habitat restoration
- Recovery and translocation of threatened taxa
- Planning habitat restoration (provenance variation)
- The commercial utilisation of local native species
- Conservation of genetic resources and reserve design

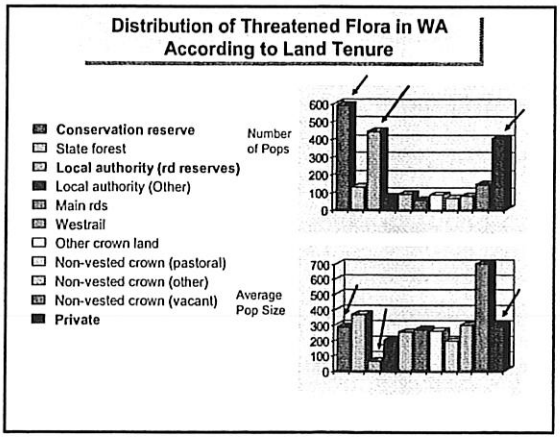
Rarity and threat

Rarity and Threat in SW Australia

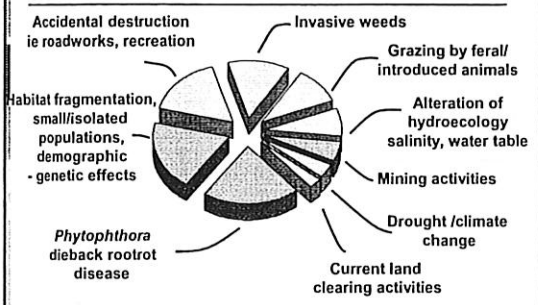
Significant component of the south west flora:

- Occurs in the agricultural region where 75% of native vegetation is cleared
- Exists in remnants of native vegetation of varying size, shape and connectivity
- Occurs In a landscape where disturbance and hydrological regimes have changed
- Occurs In a landscape where exotic weeds and diseases have been introduced and are prevalent





Threats to Declared Rare (Threatened) Flora in Western Australia

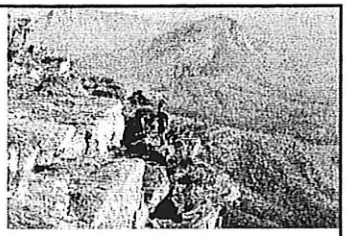


Case studies: rarity and threat

- *Dryandra montana*
- *Verticordia fimbrilepis*
- *Banksia brownii*
- *Lambertia fairalii*
- *Phytophthora* dieback
- Habitat fragmentation
- Mining

Dryandra montana

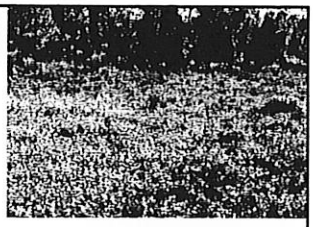
Eastern Stirling Range montane thicket and heath community



- Extremely localised distribution
- Highly susceptible to *Phytophthora*
- Total plants:
  - 46 mature plants
  - 5 juveniles
  - 15 seedlings

Verticordia fimbrilepis* subsp. *fimbrilepis

- Long lived woody shrub
- Insect pollinated
- Mass flowering
- Geographically regional
- Patchy distribution
- Sometimes locally abundant,
- Threatened due to habitat loss/fragmentation
- Threatened by invasive weeds



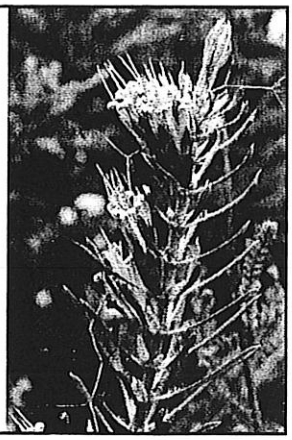
Banksia brownii

Geographically regional

- Highly susceptible to *Phytophthora*
- 10 populations extinct
- 3 populations near extinction
- 12 populations extant
  - 7 populations 4 to 200
  - 5 populations 1000 –2000
- All populations infected
- All populations in decline
- Phosphite control can be effective

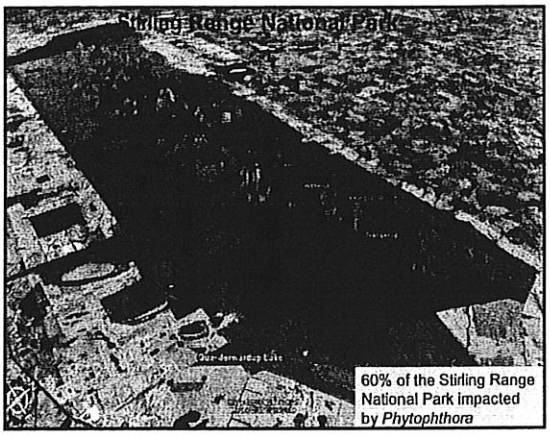
Lambertia fairallii

- 2 populations (SE Ellen recently extinct)
- Success 300+/- mature, 300 juveniles.
- SW of Gog: 300+ mature 1000+/- juveniles,
- *P. cinnamomi* sprayed with phosphite 2003, however most of population removed from infection at present.



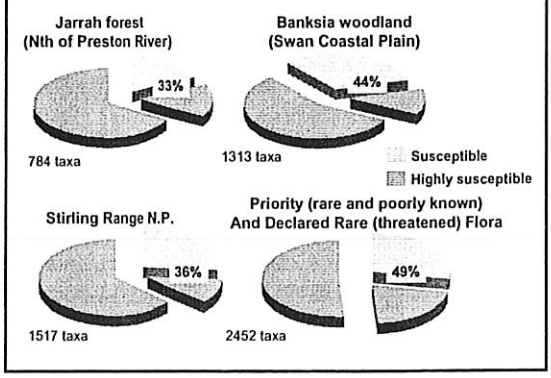
***Lambertia echinata* sub sp. *echinata*: conservation status**

- Highly susceptible to *Phytophthora*
- 3 populations (all infected; all in decline)
- Total 76 plants
- Translocation of 190 plants failed
- Phosphite appears ineffective

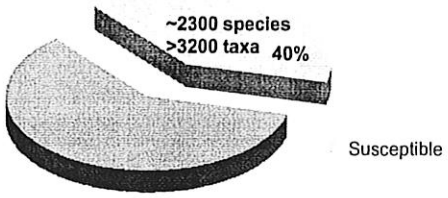


60% of the Stirling Range National Park impacted by *Phytophthora*

Susceptibility of flora to *Phytophthora*



Susceptibility of flora in the South West Botanical Province



Total in south west Botanical Province
5710 species and > 8,000 taxa

Key questions associated with land clearing and habitat fragmentation

- What impact does the loss of species from remnants have on species persistence?
  - Of particular concern is the loss of mutualisms between some plant species and their animal pollinators
  - Or the loss of predators which regulate herbivore populations
- What impact do changes in abiotic environment (e.g. hydrology) have on species persistence?
- What impact do introduced pathogens, feral predators, environmental weeds have on species persistence?
- What impact do changes in the fire regime have on a species persistence?
- **What impact does population size and landscape context have on species persistence**

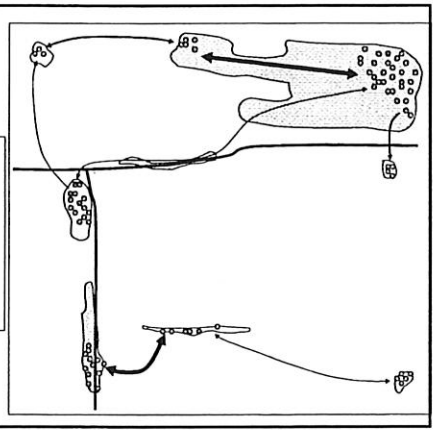
Large scale habitat destruction and fragmentation effects

Calothamnus quadrifidus, Eucalyptus wandoo

- Inbreeding
- Reproductive output
- Gene flow

The fragmentation of habitat is a major and pervasive threat to species and ecosystems in south-west Australia

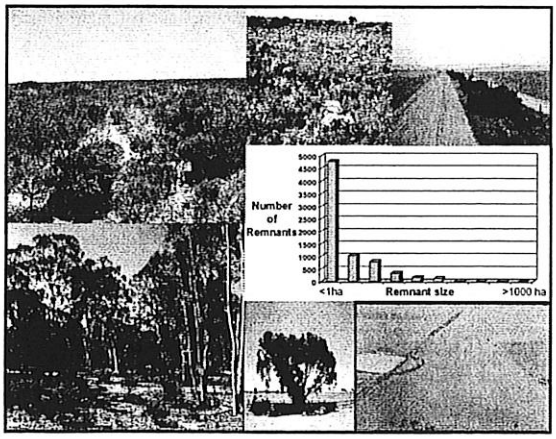
Gene flow in fragmented landscapes may be affected by **remnant:**
size
shape
quality
connectivity

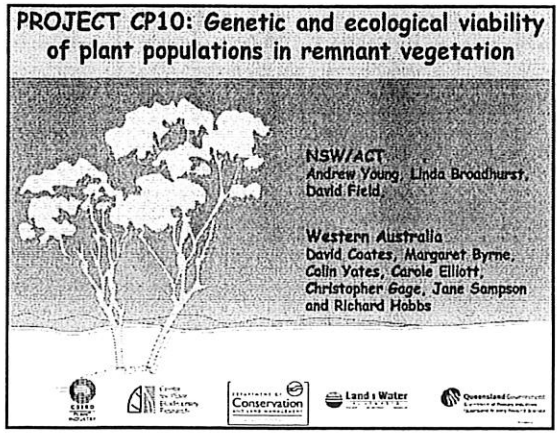


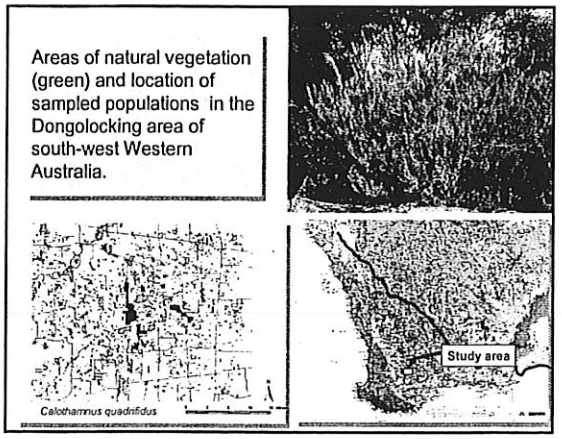
Vegetation in Dongolocking area following land clearing

heathlands

wandoo woodlands


Number of Remnants
<1ha
Remnant size
>1000 ha


PROJECT CP10: Genetic and ecological viability of plant populations in remnant vegetation
NSW/ACT
Andrew Young, Linda Broadhurst, David Field
Western Australia
David Coates, Margaret Byrne, Colin Yates, Carole Elliott, Christopher Gage, Jane Sampson and Richard Hobbs
Conservation
Land & Water


Areas of natural vegetation (green) and location of sampled populations in the Dongolocking area of south-west Western Australia.
Study area
Calothamnus quadrifidus

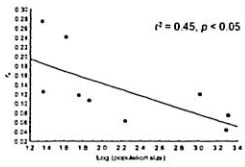
Calothamnus quadrifidus sites

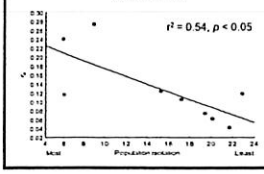
Pop	Population Location	Landscape context	Pop. size (no. plants)
M	Hill Rd	Disturbed road verge	1
K	Hill Rd	Disturbed road verge	3
T	Parnell Rd	Undisturbed road verge	3
L	Hill Rd	Disturbed road verge	4
J	Dongolocking Rd	Undisturbed road verge	13
N	Tipcurren Rd	Disturbed road verge	22
B	Toolban South Rd/Old Line Rd junction	Large undisturbed remnant	23
D	Deelyerdine Rd	Small undisturbed remnant	26
G	Dongolocking Rd	Undisturbed road verge	173
S	Wishbone Rd	Disturbed road verge	64
O	Roberts - private property	Small undisturbed remnant	74
C	Toolbin Rd South	Disturbed Road Verge	57
R	Grey Rd , Harrismith Rd junction	Undisturbed road verge	42
P	Temby - private property	Small undisturbed remnant	205
Q	Temby - private property	Small undisturbed remnant	174
H	White Well Rd	Undisturbed road verge	485
E	Dongolocking Nature Reserve A19096	Large undisturbed remnant	645
F	Dongolocking Nature Reserve A19096	Large undisturbed remnant	1938
A	Dongolocking Nature Reserve A19090	Large undisturbed remnant	2014
I	Hurtle Creek Nature Reserve 20070	Large undisturbed remnant	1029

Calothmnus quadrifidus

- Long-lived woody shrub
- Bird – mammal pollinated
- Common but patchy distribution in scrub/heath

Calothamnus quadrifidus
Relationship between population size / isolation and correlated paternity

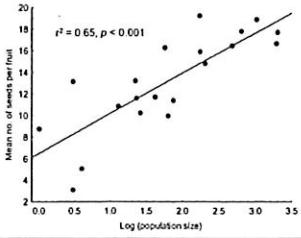




- As populations become smaller and more isolated fewer fathers contribute pollen to seed production on individual plants.
- Over time this will lead to increased inbreeding in small isolated populations

Calothamnus quadrifidus

Relationship between population size and number of seeds per fruit



Consequences as populations get smaller

- Fewer seeds produced per fruit (increased seed abortion)
- Thresholds of size (100-200 plants?)

Direct evidence for increased inbreeding depression

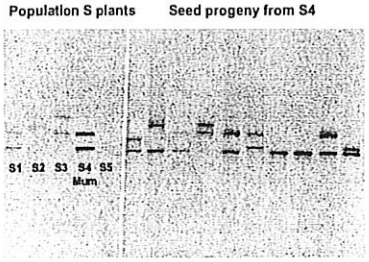
Eucalyptus wandoo

- **Long-lived tree**
- **Insect / bird pollinated**
- **Common but patchy distribution. Key component of woodland remnants.**

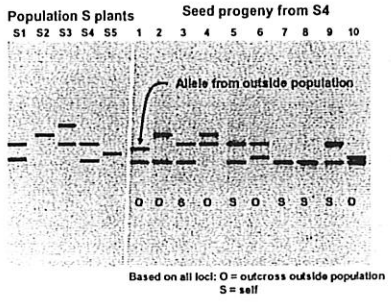
***Eucalyptus wandoo* sites**

	Population Location	Landscape context	Pop size (no plants)
J	Ben Ord Rd	Disturbed road verge	2
L	Springhurst Rd	Disturbed road verge	5
S	Ward Rd	Disturbed road verge	5
K	Ben Ord Rd	Disturbed road verge	9
R	Fox Rd	Disturbed road verge	40
O	Painters Rd	Distrurbed road verge	40
F	Rowells Rd	Distrurbed road verge	47
N	Wickepin Rd - Shire reserve	Undisturbed small remnant	173
C	114 Rd - Shire reserve	Undisturbed small remnant	107
G	Murray Rd/Wishbone Rd	Undisturbed small remnant	493
E	Wickepin Rd - Shire reserve	Undisturbed small remnant	244
Q	Dongolocking Nature Reserve 19083	Undisturbed large remnant	761
M	Nippering Rd - Shire reserve	Disturbed small remnant	1698
B	Dongolocking Rd - Shire reserve	Undisturbed small remnant	605
I	Dwelyerdine Rd - rd reserve	Disturbed small remnant	704
H	Wedin Reserve	Undisturbed large remnant	14732
D	Dongolocking Nature Reserve 19083	Undisturbed large remnant	17556
P	Robinson Rd - Shire reserve	Undisturbed large remnant	2581
A	Dongolocking Rd - Shire reserve	Undisturbed small remnant	2315

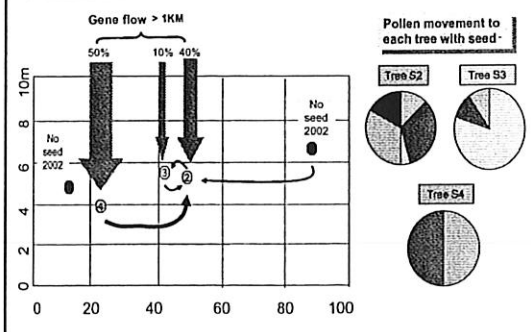
Paternity analysis - SSR locus EMBRA 6

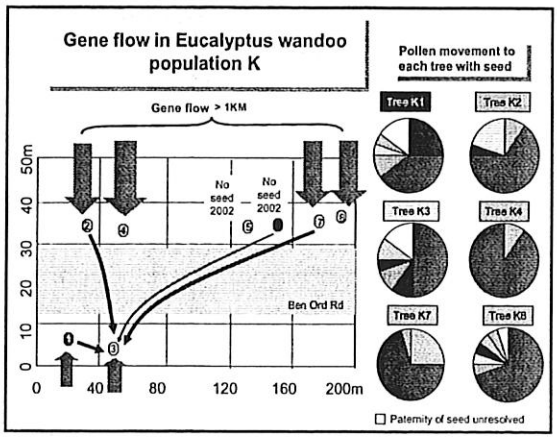


Paternity analysis - SSR locus EMBRA 6



Gene flow in Eucalyptus wandoo population S





Key issues

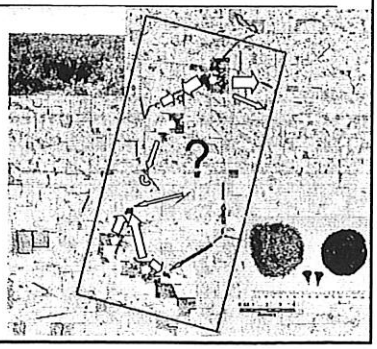
- Thresholds of size (100 – 200 plants?) and possibly isolation below which population persistence is unlikely
- Small and or isolated populations / remnants are less suitable as sources of seed for re- vegetation
- High levels of gene flow in *E. wandoo* and *C. quadrifidus* despite fragmentation- but is genetic rescue possible
- Paddock trees and small vegetation remnants are likely to be critical for gene flow in the landscape but may not themselves be viable

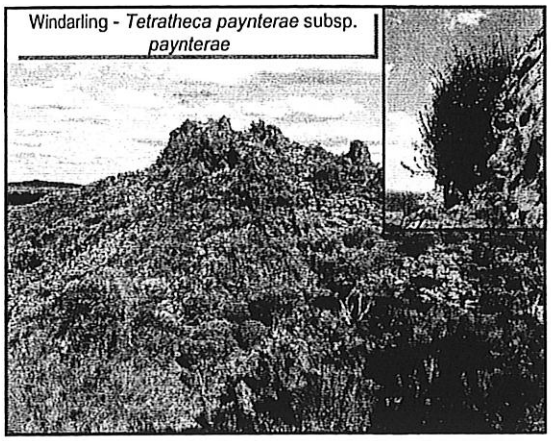
Gene Flow in a Highly Fragmented Landscape

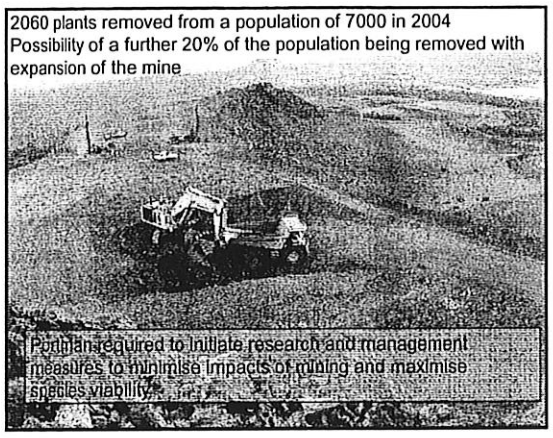
Tanya Llorens, David Coates, Margaret Byrne, Colin Yates
Heidi Nistelberger

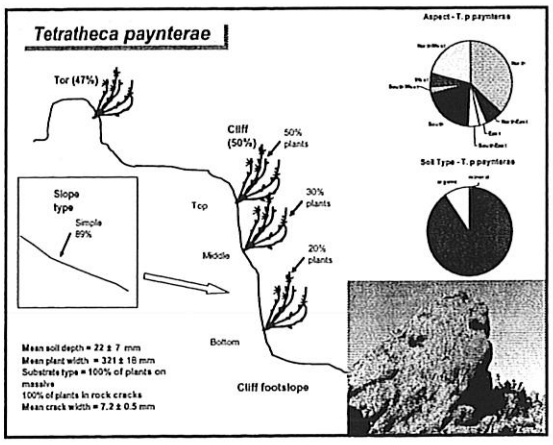
Quantify patterns of pollen movement by tracking gene flow using DNA markers

- How important are small and large remnants as pollen sources?
- What influence is landscape configuration having on connectedness between remnants?

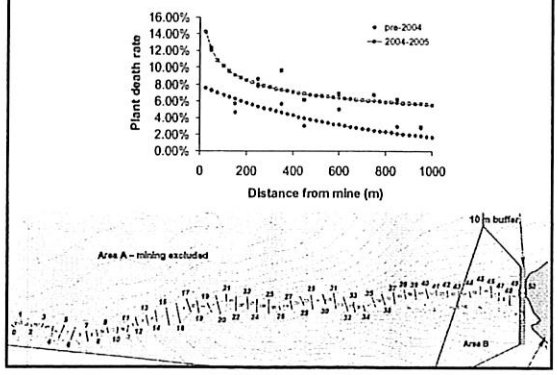



Windarling - *Tetratheca paynterae* subsp. *paynterae*

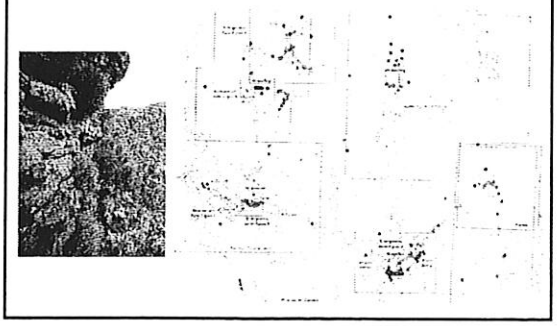

2060 plants removed from a population of 7000 in 2004
Possibility of a further 20% of the population being removed with expansion of the mine
Portman required to initiate research and management measures to minimise impacts of mining and maximise species viability


Tetratheca paynterae
Tor (47%)
Cliff (50%)
50% plants
30% plants
20% plants
Top
Middle
Bottom
Slope type
Simple 89%
Cliff footslope
Mean soil depth = 22 ± 7 mm
Mean plant width = 321 ± 18 mm
Substrate type = 100% of plants on massive
100% of plants in rock cracks
Mean crack width = 7.2 ± 0.5 mm
Aspect - T. p paynterae
Soil Type - T. p paynterae

T. paynterae adult plant mortality 2004-2005 summer



Distribution of Rare and Priority Flora in the Die Hardy Range - Bungalbin Hill Area

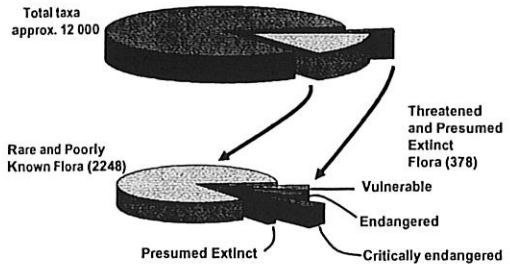


Threatened Flora

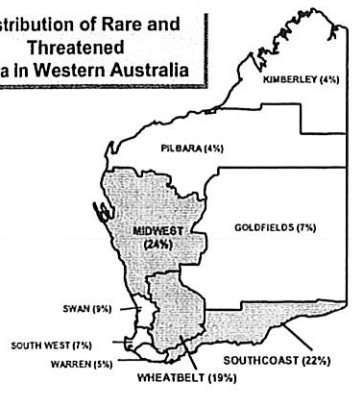
Threatened plant species in WA

- 391 plant taxa are listed as threatened under IUCN guidelines (14 presumed extinct)
- Although many were probably naturally rare habitat destruction and degradation are the most likely reasons for their threatened status
- Ongoing threats associated with the contemporary landscape are contributing to the continued decline of remaining populations

Proportion of threatened (critically endangered, endangered and vulnerable) rare and poorly known flora in Western Australia

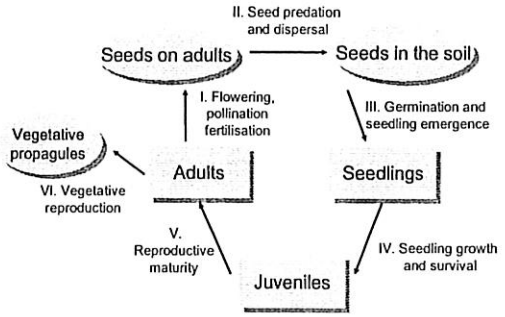


Distribution of Rare and Threatened Flora in Western Australia

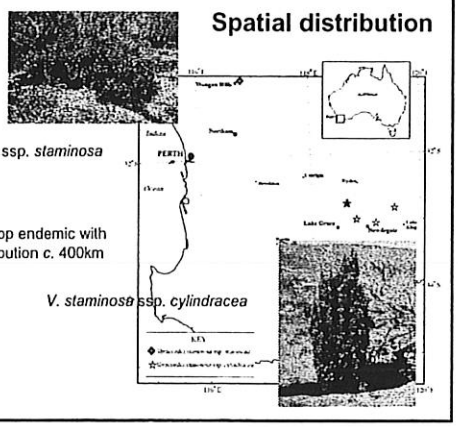


Ecological studies and recovery

Stages and transitions in the plant life cycle



Spatial distribution



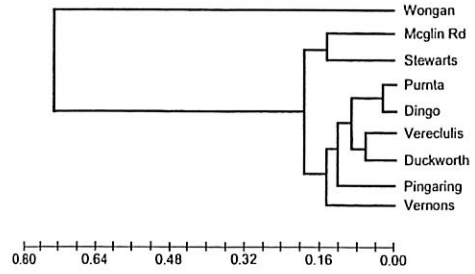
V. staminosa ssp. *staminosa*

Granite outcrop endemic with disjunct distribution c. 400km

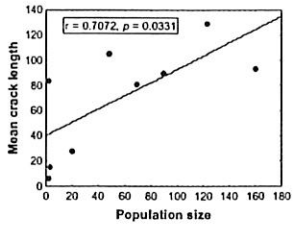
V. staminosa ssp. *cylindracea*

Temporal persistence

Phylogenetic relationships among populations of Verticordia staminosa

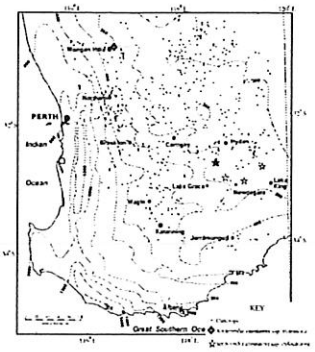


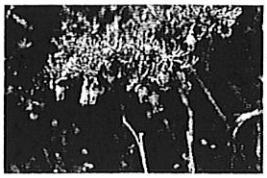
Taxon ecology - habitat specificity within outcrops



V. staminosa *is very habitat specific, being restricted to growing within cracks in the granite*

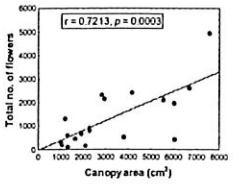
Taxon ecology- habitat specificity, location of granite outcrops across the landscape

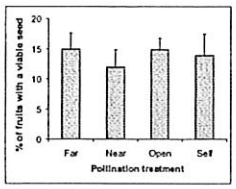




Reproductive biology

- Bird pollinated, but introduced honeybee now the most frequent flower visitor
- Flowers abundantly
- Self-compatible

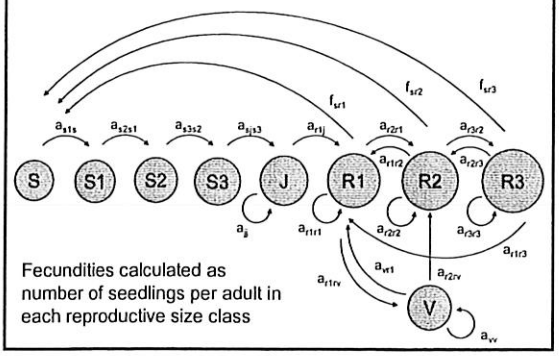




Environmental stochasticity and population dynamics

- Rainfall variation (161-675 mm, mean 392 mm)
- Fire (two fires in 20 years on a granite complex to the north-east, receiving 90 mm less rainfall)
- We investigated the influence of both sources of environmental stochasticity on population dynamics and viability with a stage structured transition matrix model built using the software RAMAS metapop v.5

Conceptual stage structured model of life cycle pathways for *V. staminosa* ssp. *staminosa*



Fecundities calculated as number of seedlings per adult in each reproductive size class

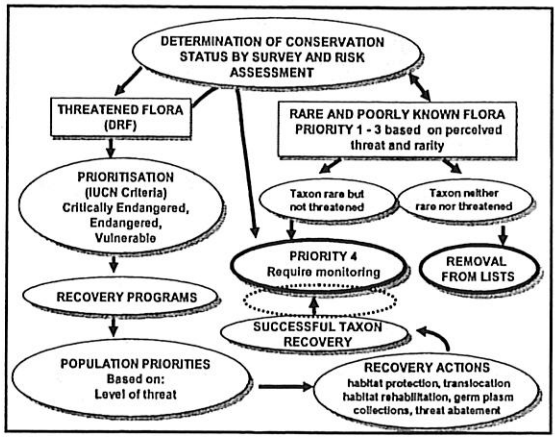
Conclusions

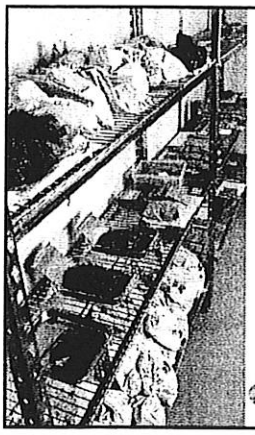
The results concur with the hypothesis that the interaction of environmental history and population biology are more important than ecological factors such as habitat specificity and intrinsic characters like reproductive biology for understanding rarity in *V. staminosa* ssp. *staminosa*

Conservation implications

- Land-tenure and need to protect granite rock habitats
- Enhanced greenhouse effect and climate change
- Climate models predict for a range of emission scenarios that winter wet season rainfall will decline across most of southwestern Australia
- Population Viability modelling indicates that under increased aridity the population will decline
- If continued monitoring shows an increase in adult mortality we should be concerned – increased incidence of fire maybe particularly important in this respect

Recovery of threatened flora





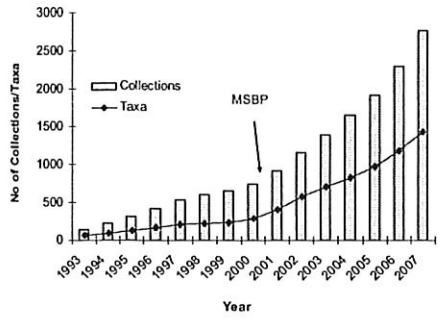
Threatened Flora Seed Centre

- Established 1993 to focus on *Phytophthora* threatened taxa
- 1382 taxa - 2283 collections
- 283 threatened taxa
- 647 taxa listed as rare and poorly known (Priority listed taxa)

Seed conservation audit (June08)

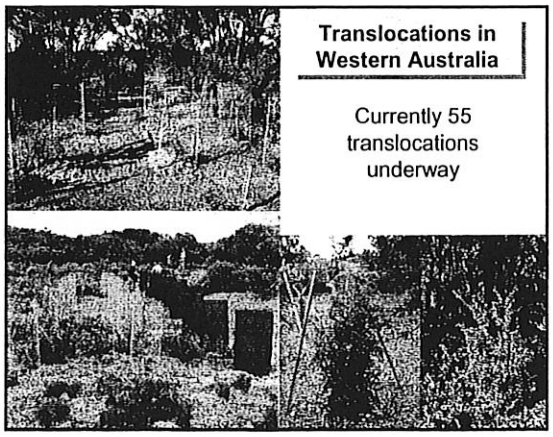
TFSC collections	MSB Duplicated
• 2283 collections	• 772 collections
• 1382 taxa	• 738 taxa
• 283 threatened	• 55 threatened
• 647 priority	• 417 priority
• 452 common	• 266 common

Capacity Building



Translocations in Western Australia

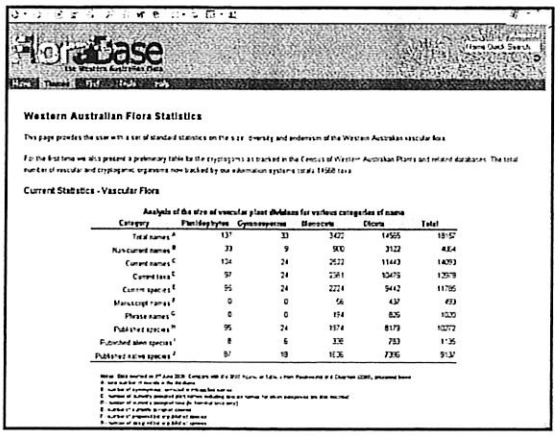
Currently 55 translocations underway



Global Strategy for Plant Conservation Target 8 for 2010 achieved

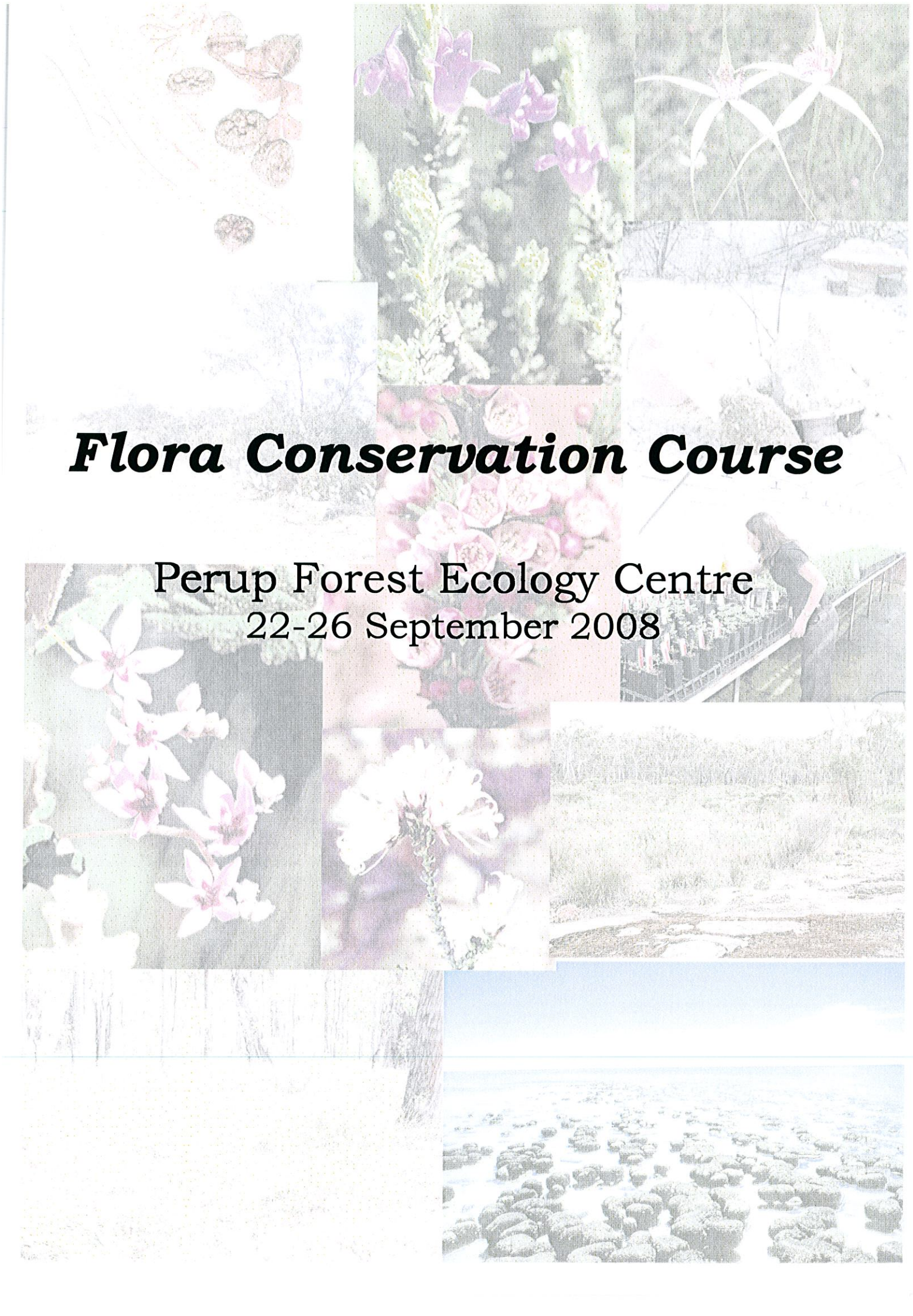
70% (60% required) of WA threatened flora in *ex situ* conservation and 13% (10% required) used in reintroduction

FloraBase



Western Australian flora and major conservation issues

- Manage and ameliorate major threatening processes
  - Habitat fragmentation – small population effects
  - Altered hydrological regimes
  - *Phytophthora* dieback
  - Inappropriate fire regimes
  - Invasive weeds
- Understand the interactions between small population effects, fire regimes and weed invasion/competition
  - Small remnant management
  - Rangelands management
- Taxonomic knowledge of the flora
  - 1539 taxa (13%) not formally named
  - 458 taxa (18.6%) DRF and Priority Flora not formally named
  - 1903 taxa are rare but conservation status not known
  - Very poor knowledge of non vascular flora (2033 out of 100,000+)



Flora Conservation Course

Perup Forest Ecology Centre
22-26 September 2008