100 years of continuously successful weed biological control in Australia

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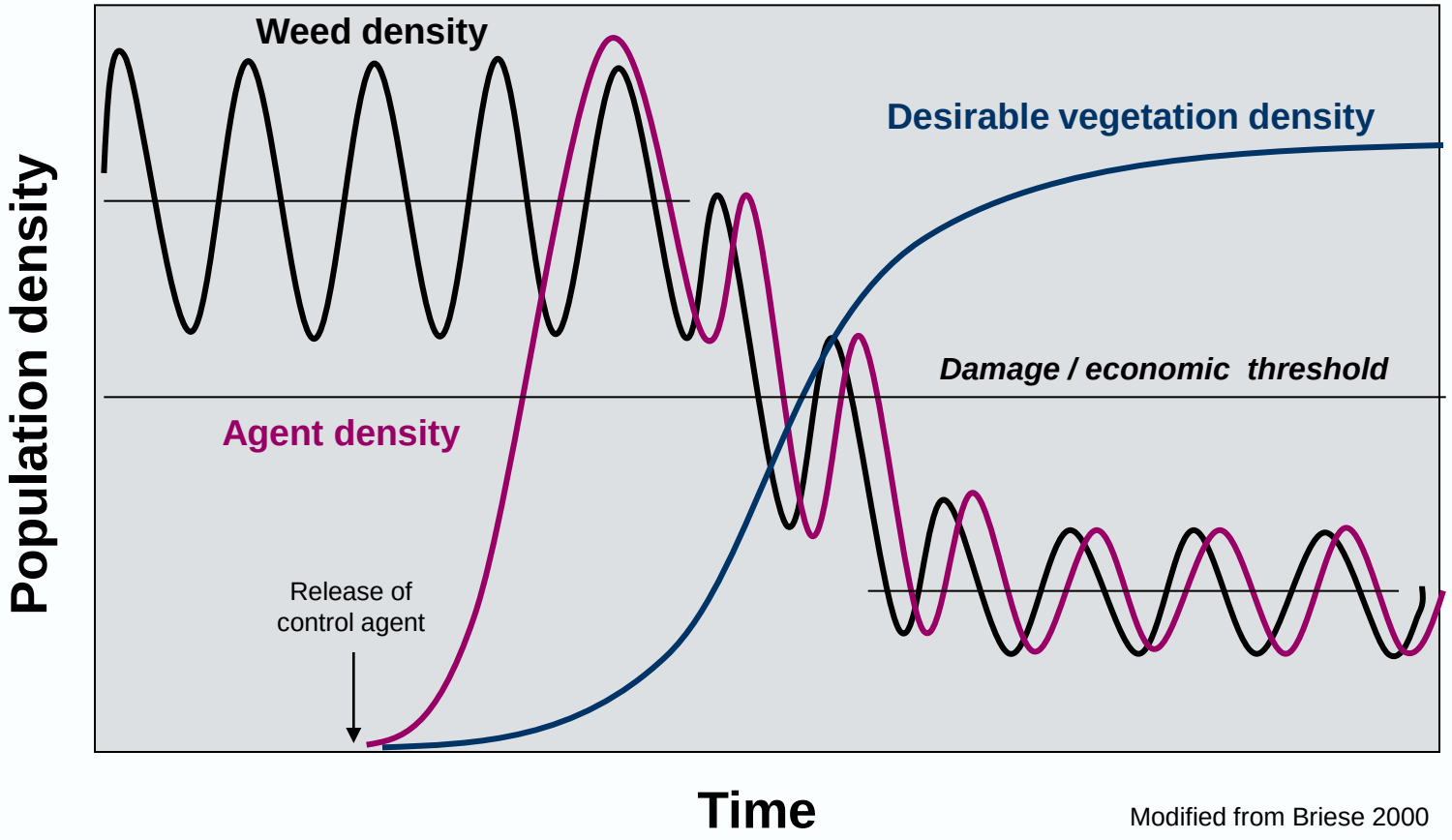
Outline

- **What is weed biological control?**
- Potted history of weed biological control in Australia
- Summary of the benefits to date
- The future

Definition:

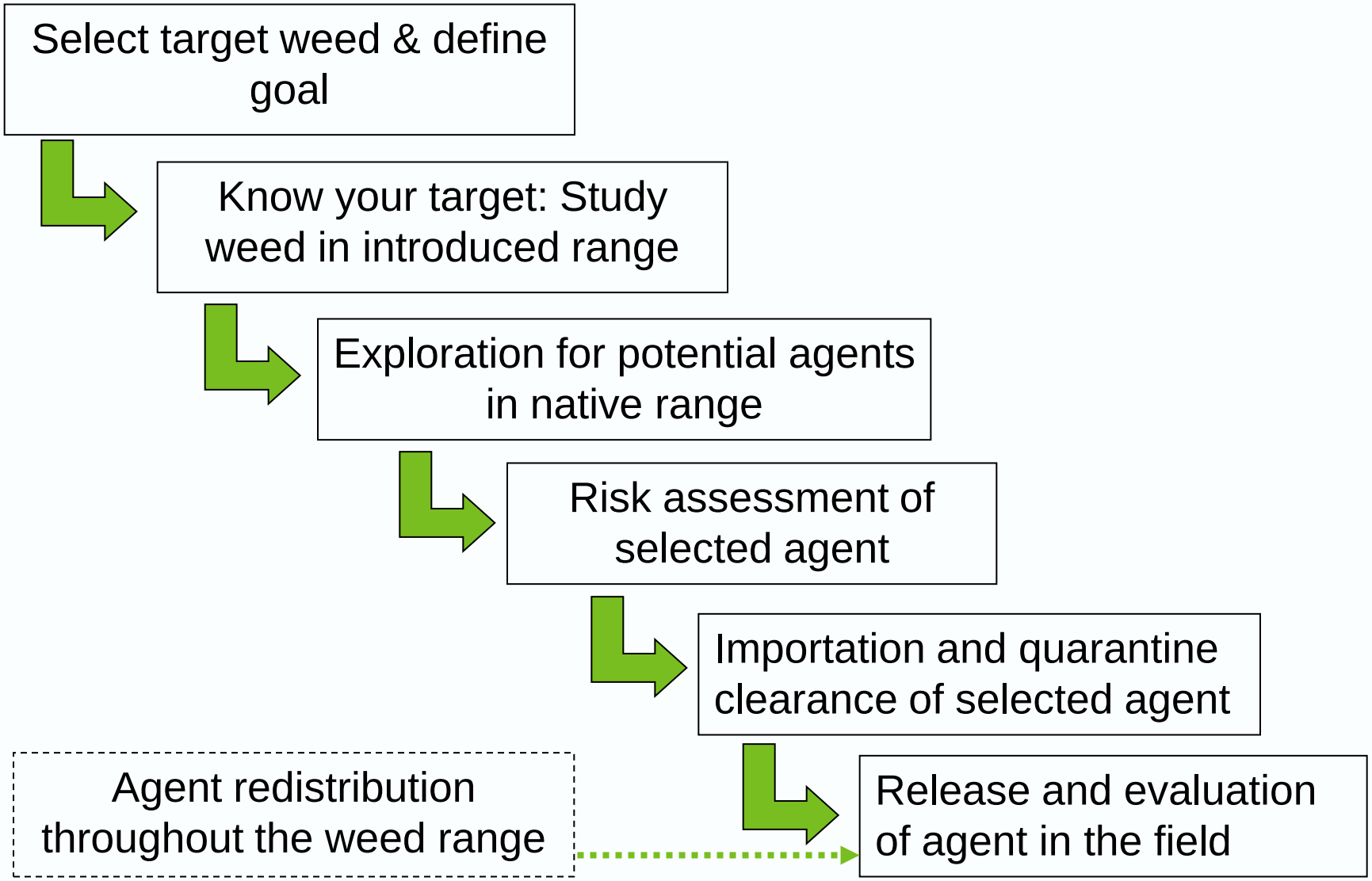
"Biological control" uses host-specific natural enemies (= biocontrol agent) to control pests (H. S. Smith, 1919)

Classical approach: restoring ecological balance - a 20 year endeavour



Modified from Briese 2000

Steps in a biological control program



Agent selection

"*Agent selection is the critical step, and the choice of the best agent is the 'holy grail' of weed biocontrol*"
(Rachel McFadyen 1998)

"*it is doubtful whether such pre-judgements* [of agent efficacy] *are often sufficiently well founded to be acted upon*" (Frank Wilson 1960)

Two Schools of thought in Biological Control

"Lottery Approach"

"Picking-Winners"

Lottery approach

“find them, screen them, release them”

- Unpredictability of biological control prevents selecting winners
- All highly specific natural enemies are potential biological control agents
- Agents attacking all plant parts are all introduced in hopes one will suppress the weed
- More agents released more risk of non-target impacts
- Dogma in tropics where natural enemy diversity and the risk of missing a good agent is high and where taxonomy is poor

“Predicting-winners”

(“one or only a few agents can do the job”)

- Ecological principles applied to agent selection allowing agents to be prioritised on likelihood of high impact on the target
- Only agents targeting key weaknesses in the life cycle of the target for population growth are released.
- Fewer agents released lower risk of non-target impacts through releasing ineffective agents
- Dogma from temperate biocontrol systems where natural enemy diversity is low, agent taxonomy and ecological understanding is good

Why do we need to understand Agent ecology in native range?

3 ways biological control agents can be effective

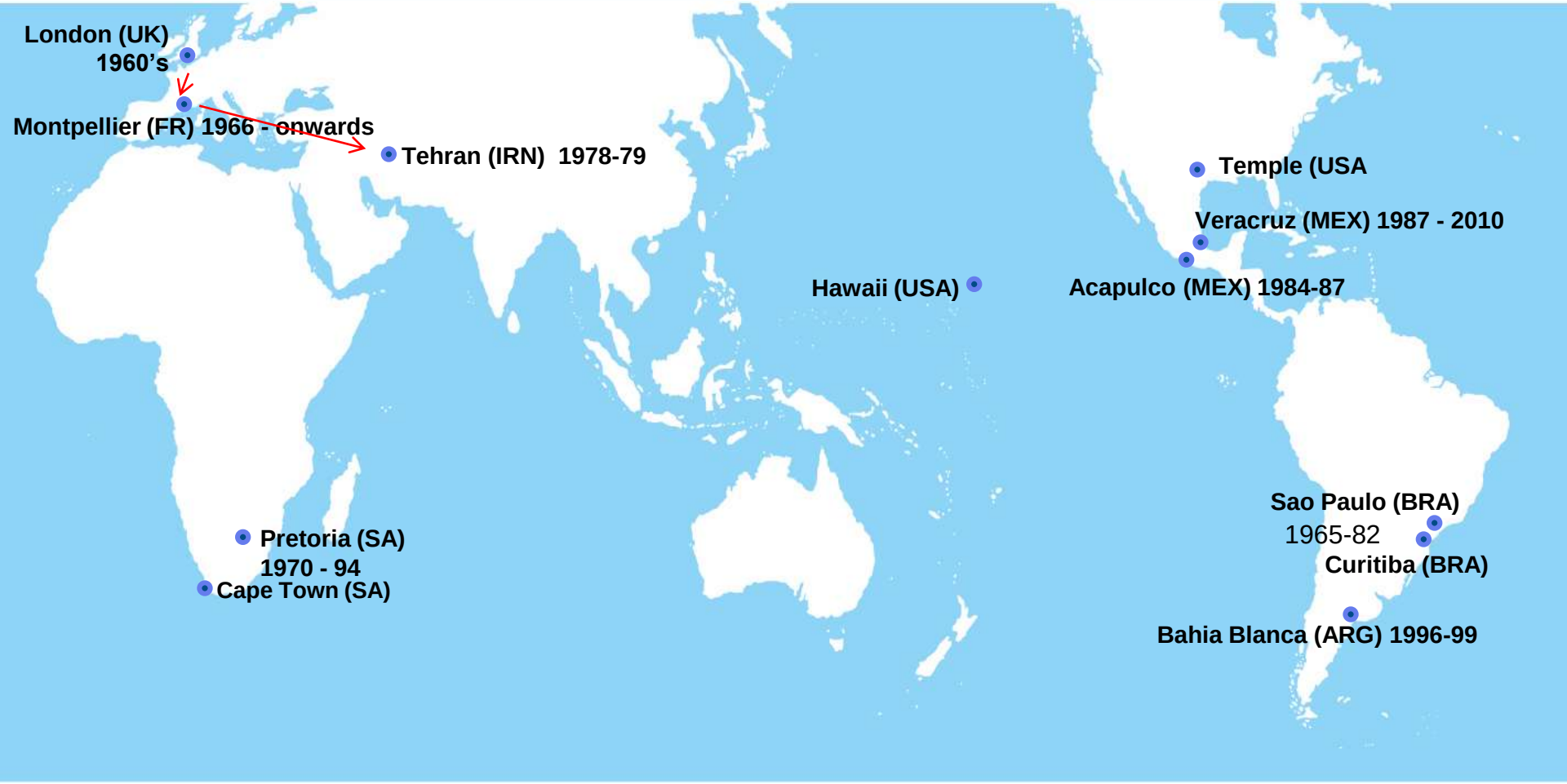
If in native range agents are:

i) *regulated by their parasites/predators*
Release → enemy escape – high agent impact

ii) *regulated by host plant availability*
Release → density response - high agent impact

iii) *Pre-adapted to novel environmental conditions*
Release → newly invaded habitats - high agent impact

Map of all Australian overseas biological control field stations



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How did it all start?

- 1903 QLD Dept Ag imported *Dactylopius ceylonicus* cochineal for *Opuntia vulgaris* (not prickly pear) but culture died out
- 1913-1914 QLD imported 3 more *Dactylopius* spp. *Cactoblastis cactorum* and a disease
- 1914 *D. ceylonicus* was released in QLD and controlled *O. vulgaris*
- 1921-1940 19 insect agents released against 7 *Opuntia* and 12 agents established

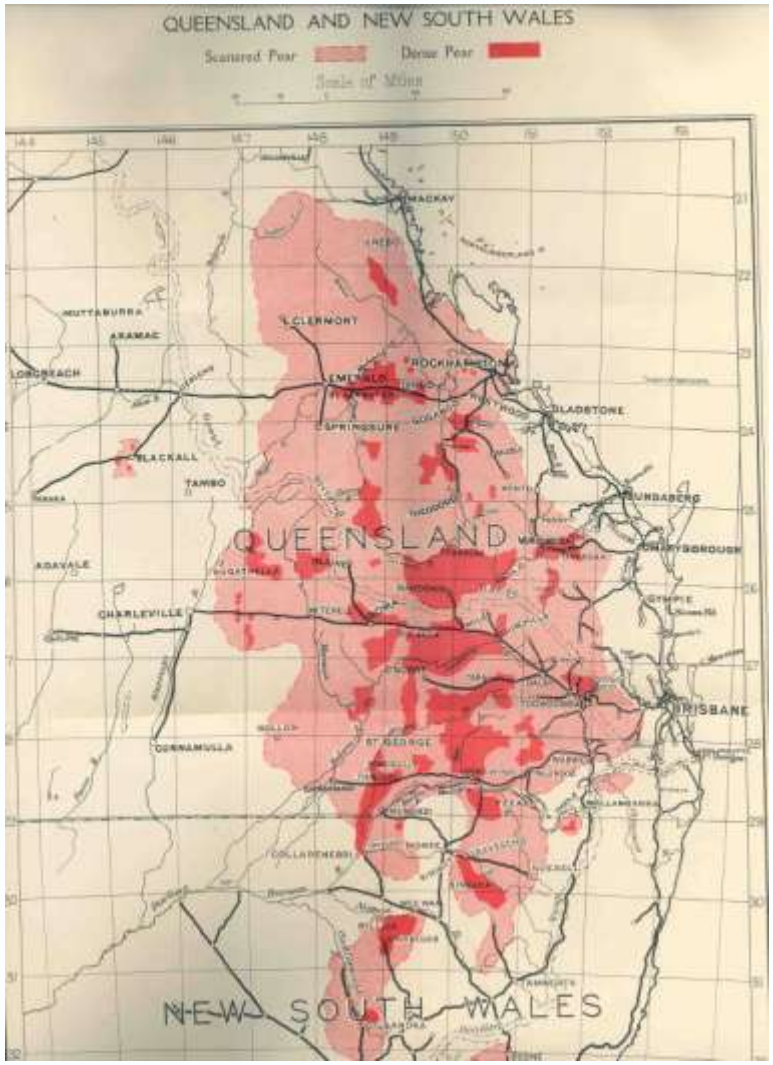
First peak in activity

- 1929 new programs targeting Noogoora bur (*Xanthium occidentale)*, St John's wort (*Hypericum perforatum)* and ragwort (*Jacobaea vulgaris)*
- 1930-34 *Chrysolina* released against St John's wort (Vic/NSW)
- 1939 direct introduction of gorse (*Ulex europaeus*) seed weevil (*Exapion ulicis*)
- 1952 new program against crofton weed (*Ageratina adenophora)*
- 1960's programs almost petered out (down to 2-3)

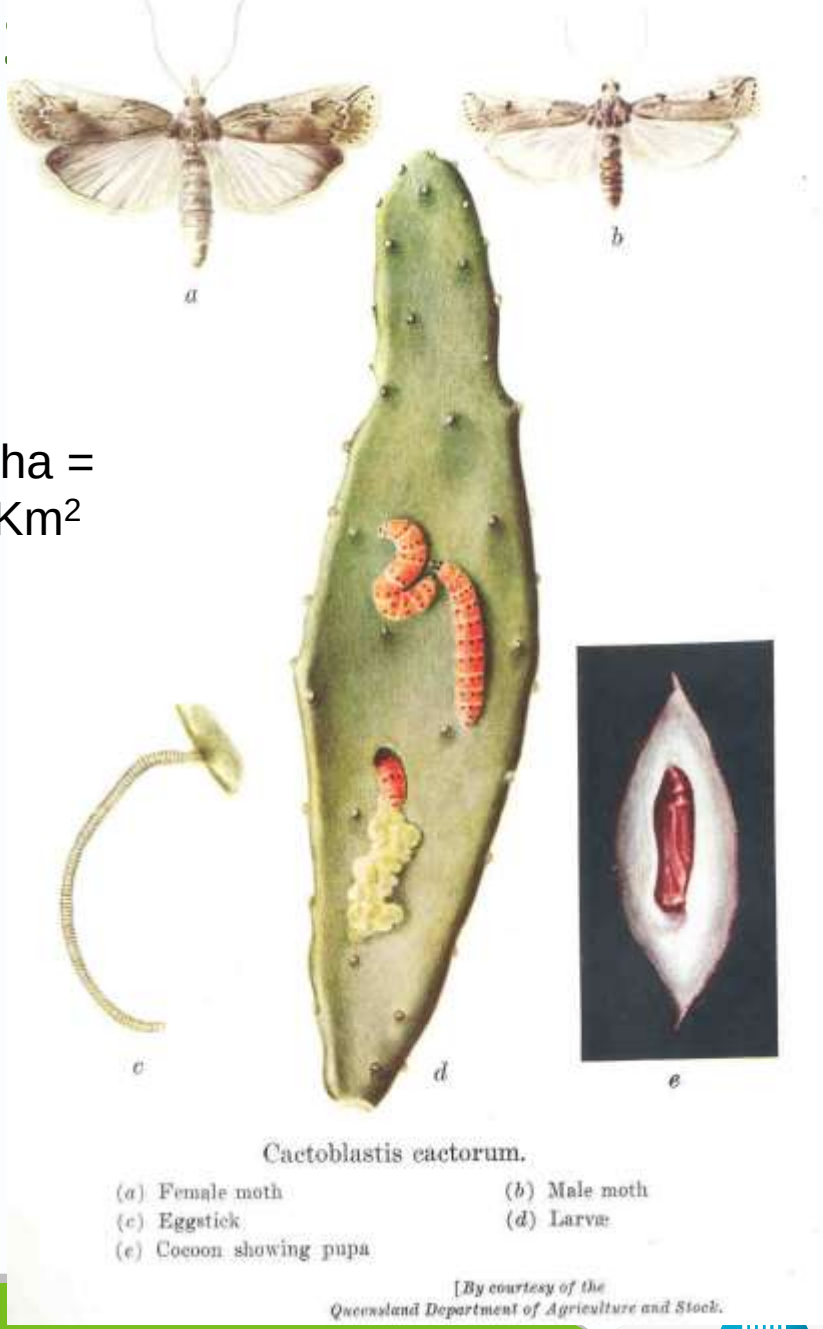
1914 first 2 releases in Australia – *Dactylopus ceylonicus* on *Opuntia vulgaris* ex Brazil via India/Sri Lanka - succesful control

1914 first 2 releases in Australia: *Epinotia lantana* & *Agromyza lantanae* on lantana ex Mexico via Hawaii - no control

Opuntia & Cactoblastis 1914 - 19
1 of 19 agents being considered!



25M ha =
25K Km^2



Early stages showed a classic population cycle ...

- decrease 1930-32
- rebound 1933
- permanent decline 1933-35


Successful control led to false belief biocontrol was a silver bullet strategy


BOONARGA

Later developments ...

- 1930's benefits of climate matching demonstrated
  – Frank Wilson on St John's Wort
- 1970's first time Australian native plants tested
- 1971 first release of a plant pathogen
  – *Puccinia chondrillina*
- 1974 Wapshere's – "*centrifugal phylogenetic testing*" revolutionised risk assessment
- 1980's field based host specificity testing
  – Jim Cullen for Heliotropium program

Aquatic weeds
...*the most successful targets*


Water hyacinth
Eichhornia crassipes
Photo by A. Murray
Copyright 2001 Univ. Florida

Water skates for work on water Hyacinth

First releases 1975

Successes in Queensland in 1980s

Led to Australia's most successful aid program in weed management

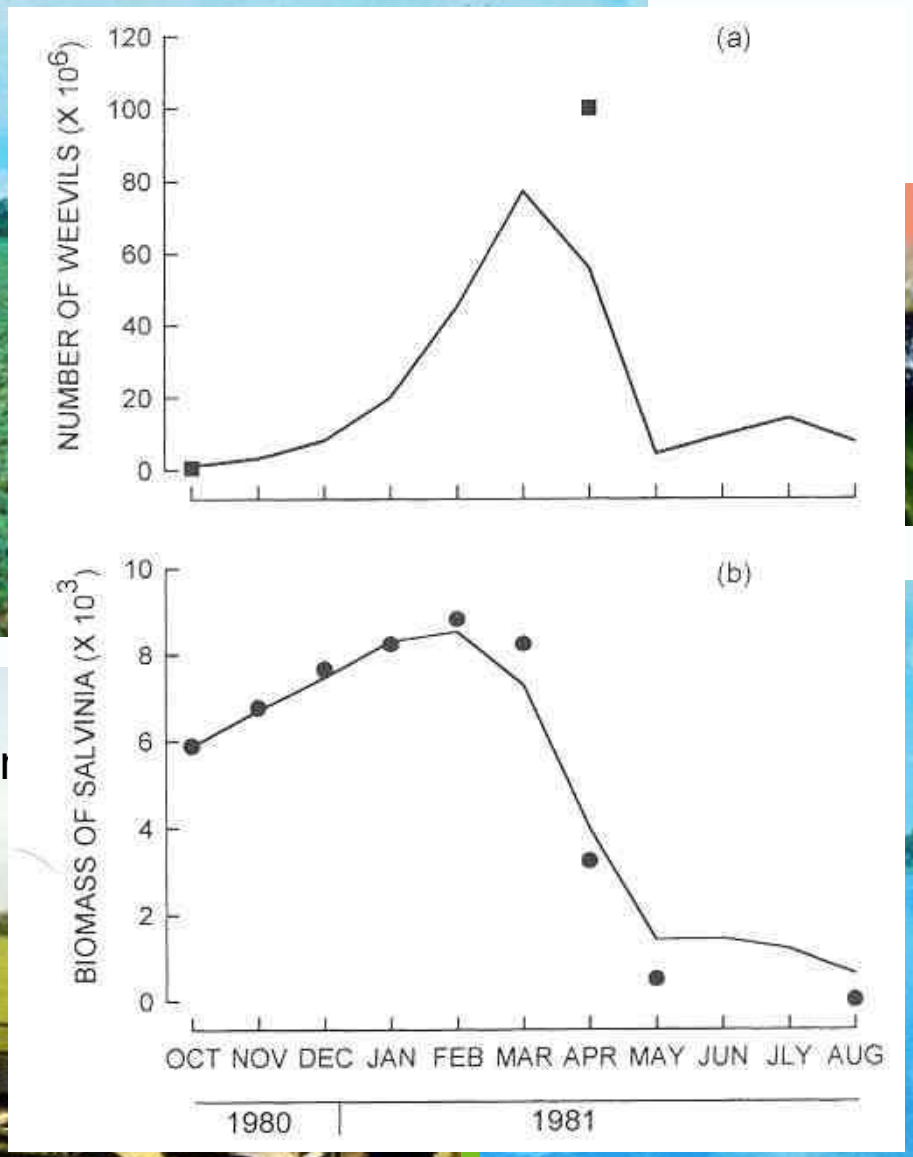
"*the best overseas aid I have seen Australia give Africa was a handful of weevils*"
Hon Barry Jones : Science Minister

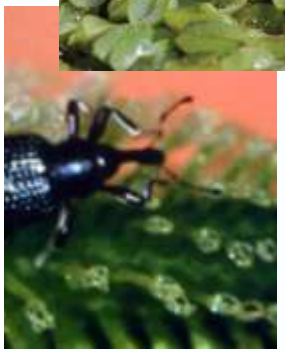

Salvinia molesta

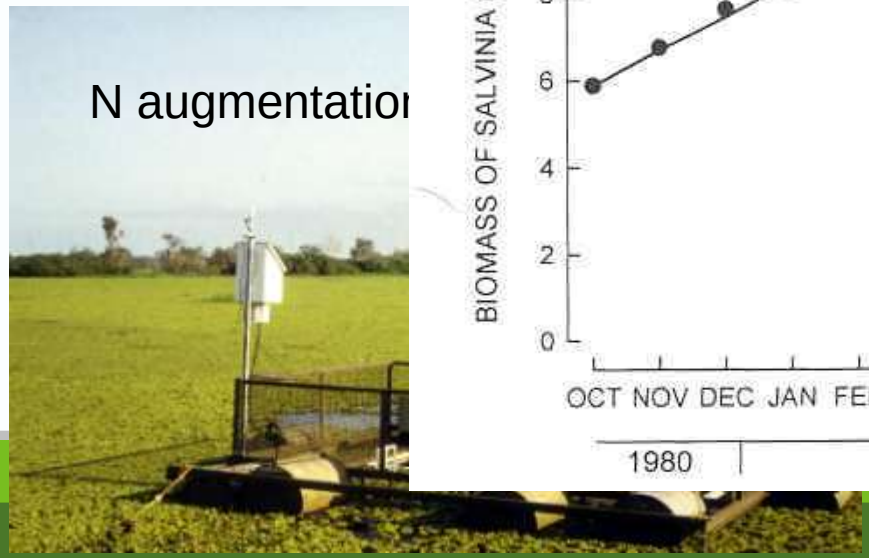
Salvinia weevil

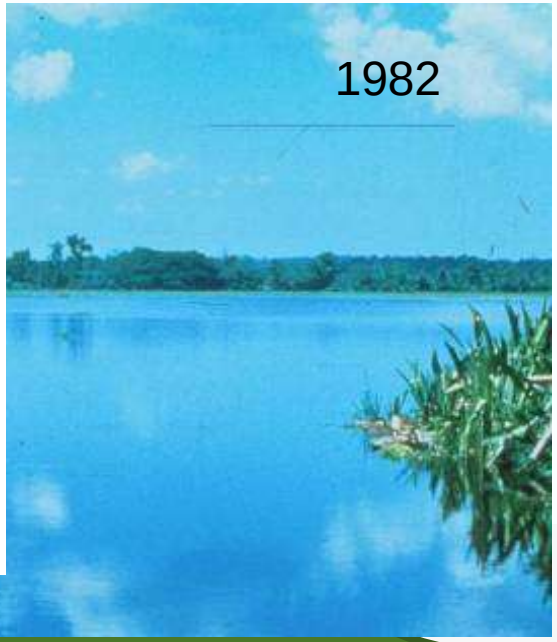
Cryptobagous salviniae released in 1980

Cyrtobagus salviniae on *Salvinia molesta* – manipulate C:N ratio - this time with temperature



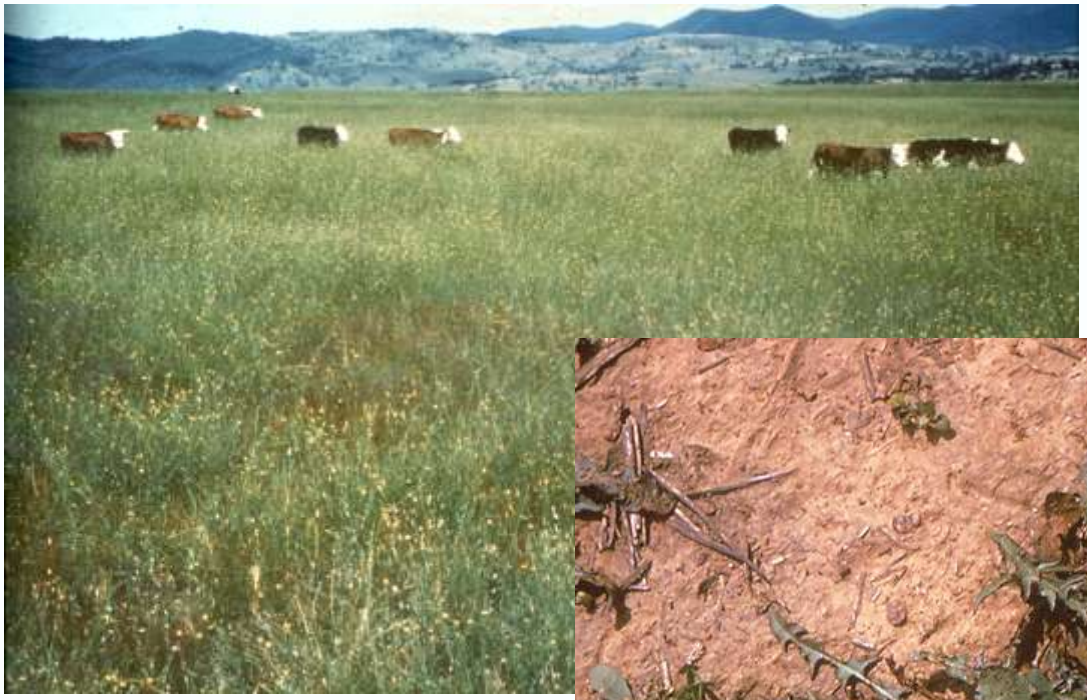






Cropping weeds
– two firsts for Australia

Skeleton weed – *Chondrilla juncea*



Success led to revival of weed biological control in Australia in 1970's

Invertebrate agents – little impact

Skeleton weed root moth
Bradyrrhoa gilveolella
released 1974

Chondrilla gall mite
Aceria chondrillae
released 1971

First AU case of genotyping agent to host
- using electrophoresis

Tony Wapshere predicted a rust would be better so *Puccinia chondrillina* was 1st plant pathogen weed biocontrol agent ever released

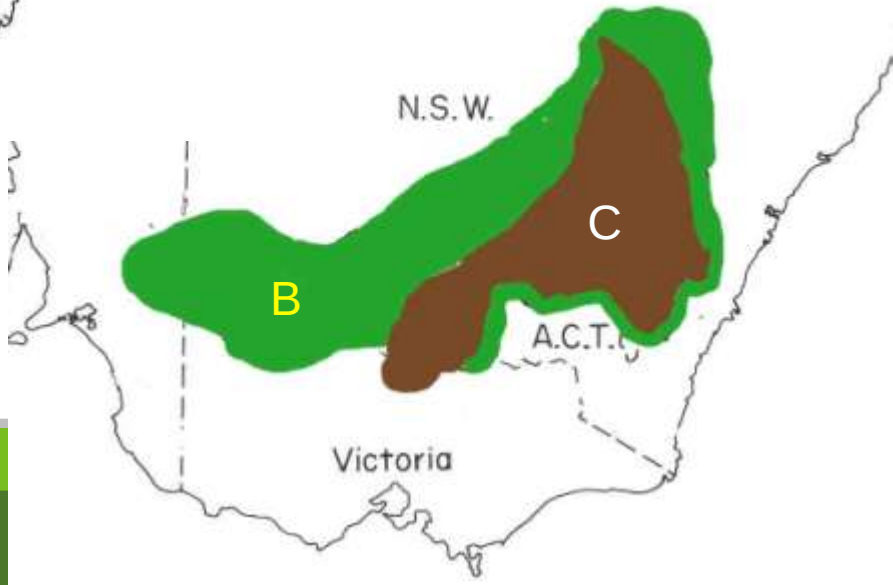
1971

Early 1970's

Changes in genotype frequency following the introduction of *Puccinia chondrillina*

Burdon et al. 1981

Early 1980's



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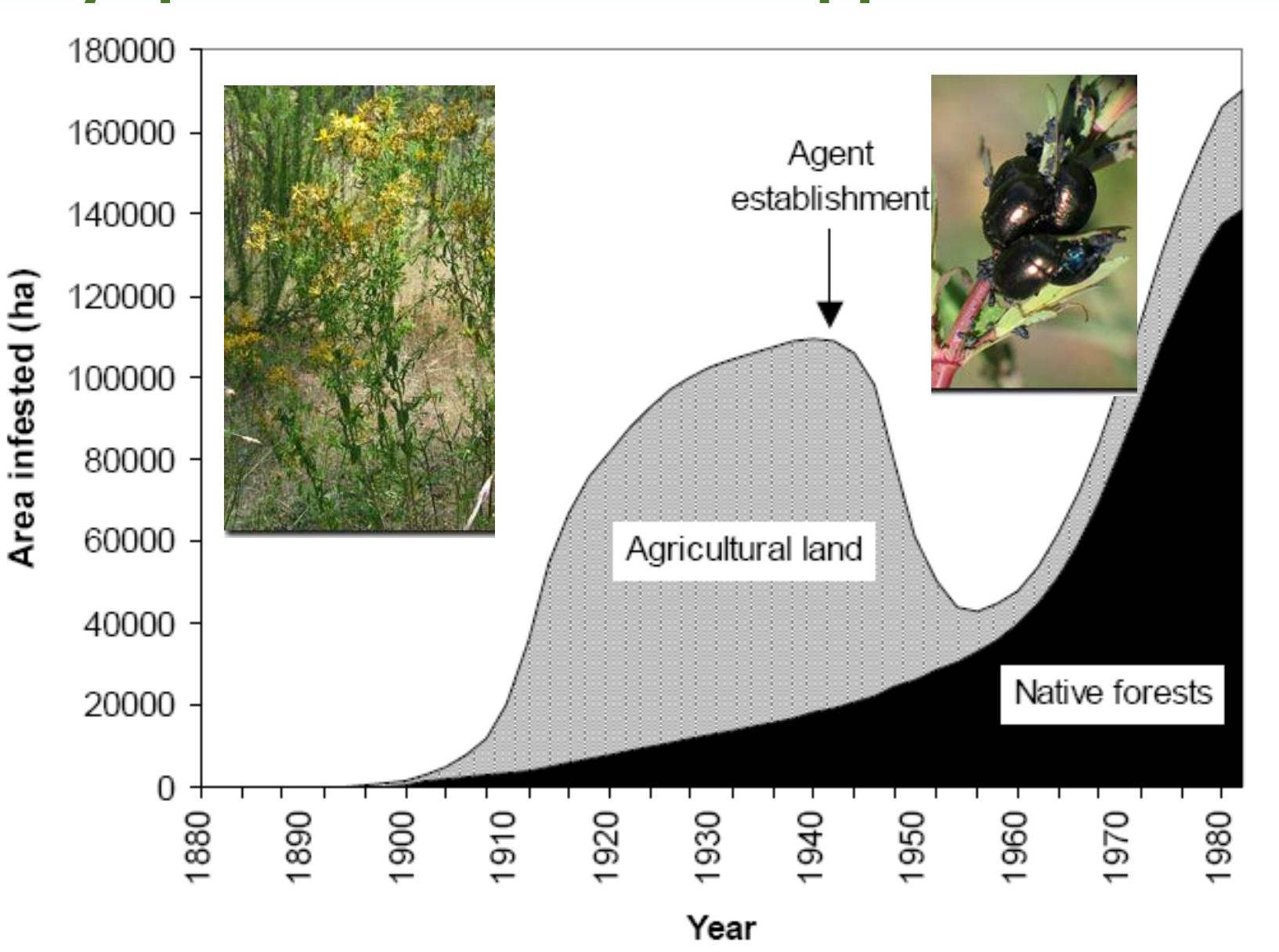
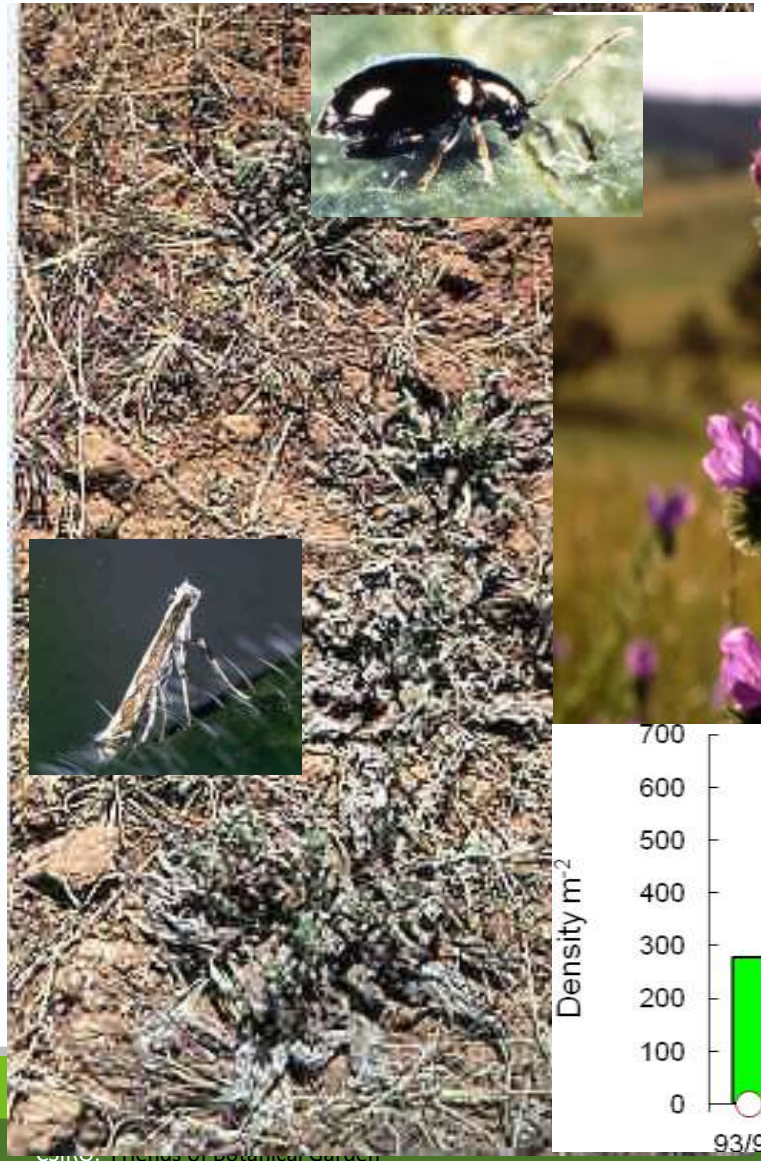
Pasture weeds
– persistence pays off

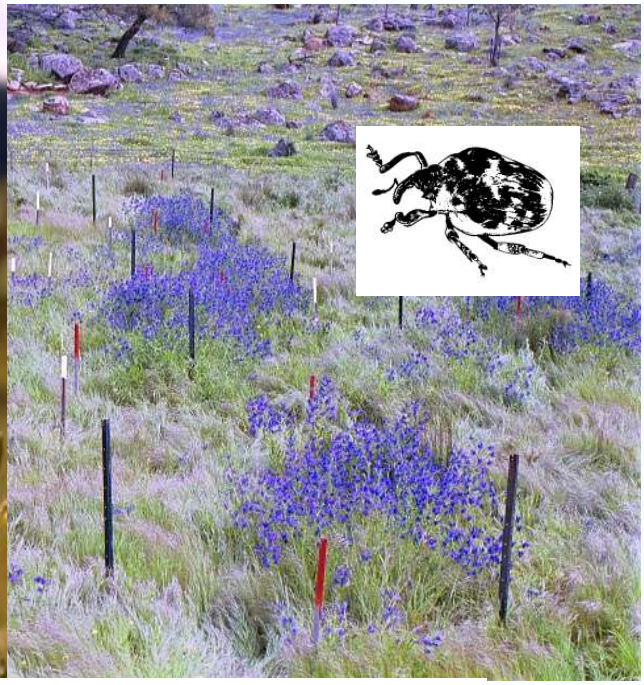
St John's wort infestation circa 1930

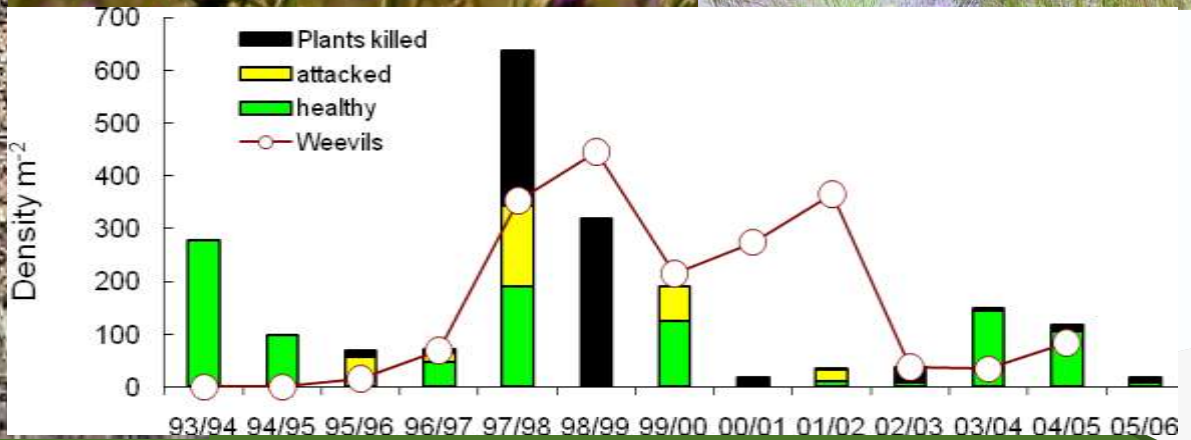
Hypericum perforatum St John's wort – always planned as an IWM approach



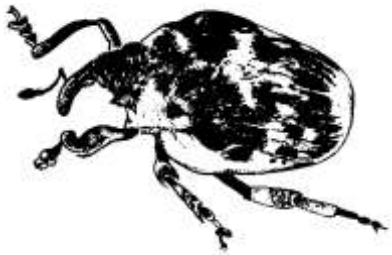
Paterson's curse, *Echium plantagineum*: $1B benefit

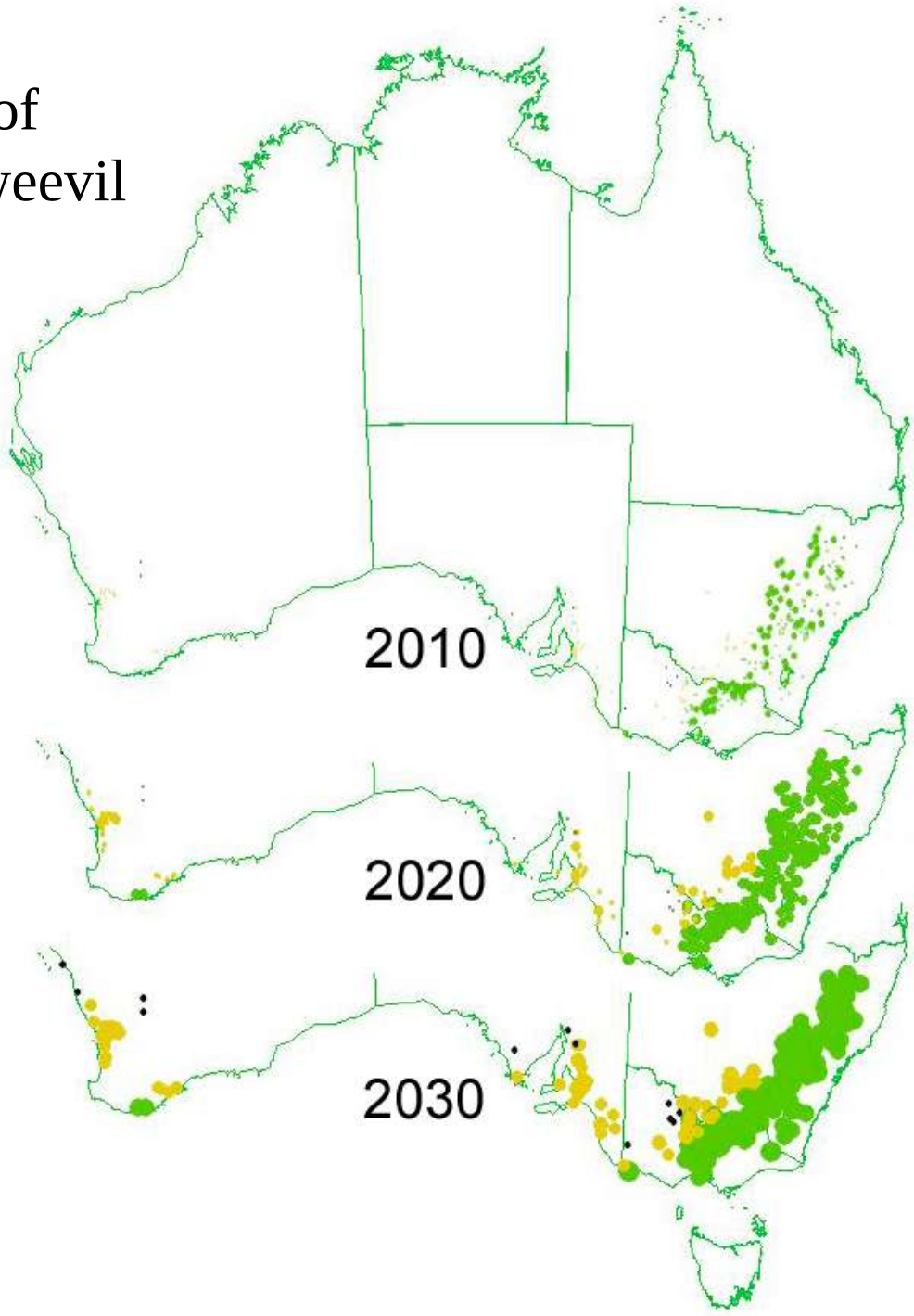






Spread of impact of Paterson's curse weevil released in 1992





Environmental weeds
– *most recent successes*

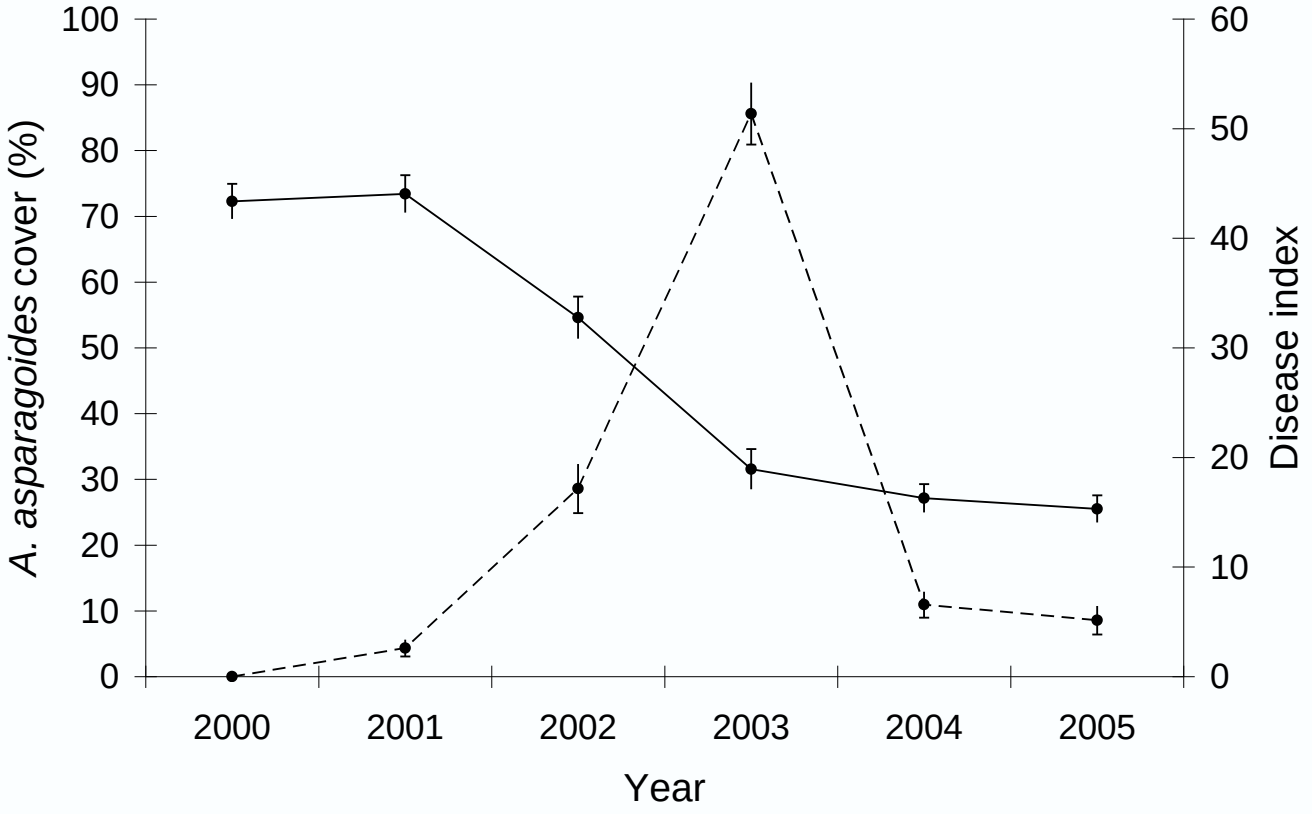
Bitou bush/boneseed the first Australian Env weed target in 1984

Rubber vine - *Cryptostegia grandiflora*

the rust *Maravalia cryptostegiae* released in 1994

40% reduction of live plants and stems and significant reduction in seedling recruitment

Bridal creeper rust - impact



Released 2001

2000

2005

Bridal creeper rust - impact

Released 2001

2000

2005

Leguminous shrubs – yes they can be controlled !

Cape broom successful control

Genista monspessulana

Psyllid *Arytinnis hakani* first “released” 2004

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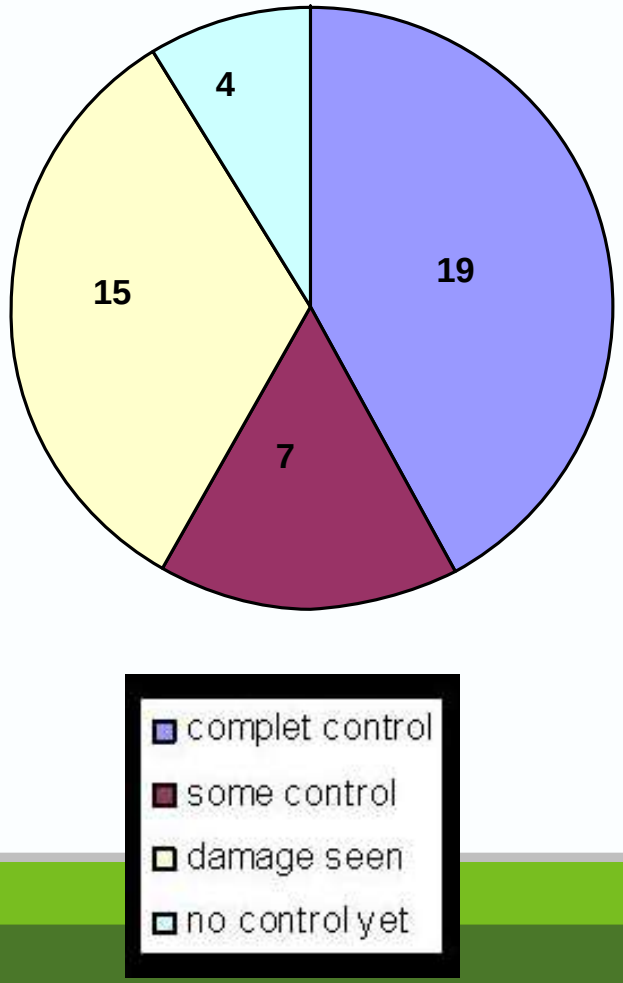
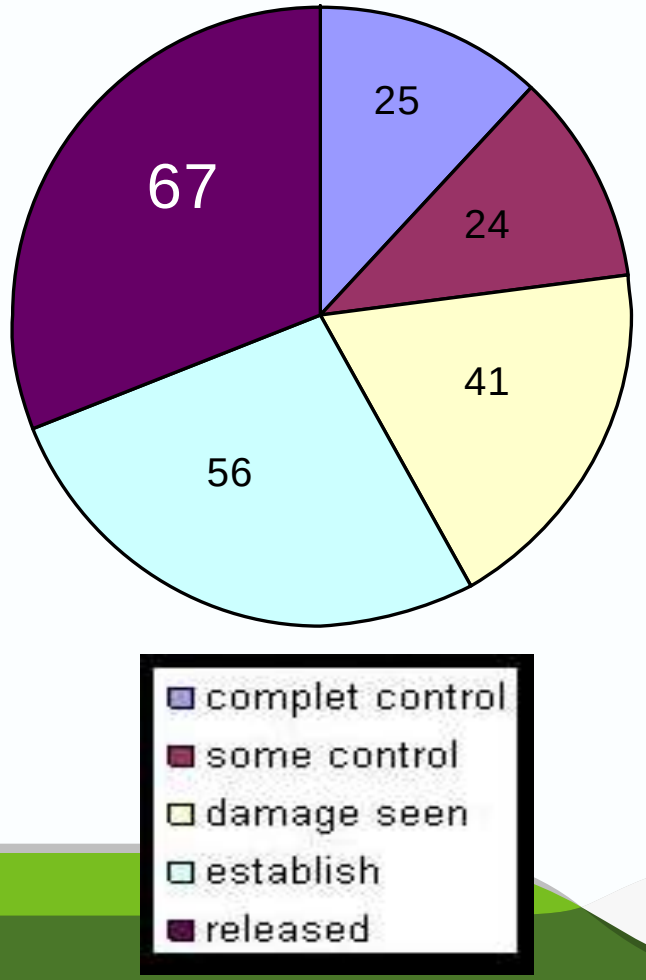
Weed biological control success in Australia

Number of Target Weeds (42%)



Number of Released Agents (12%)



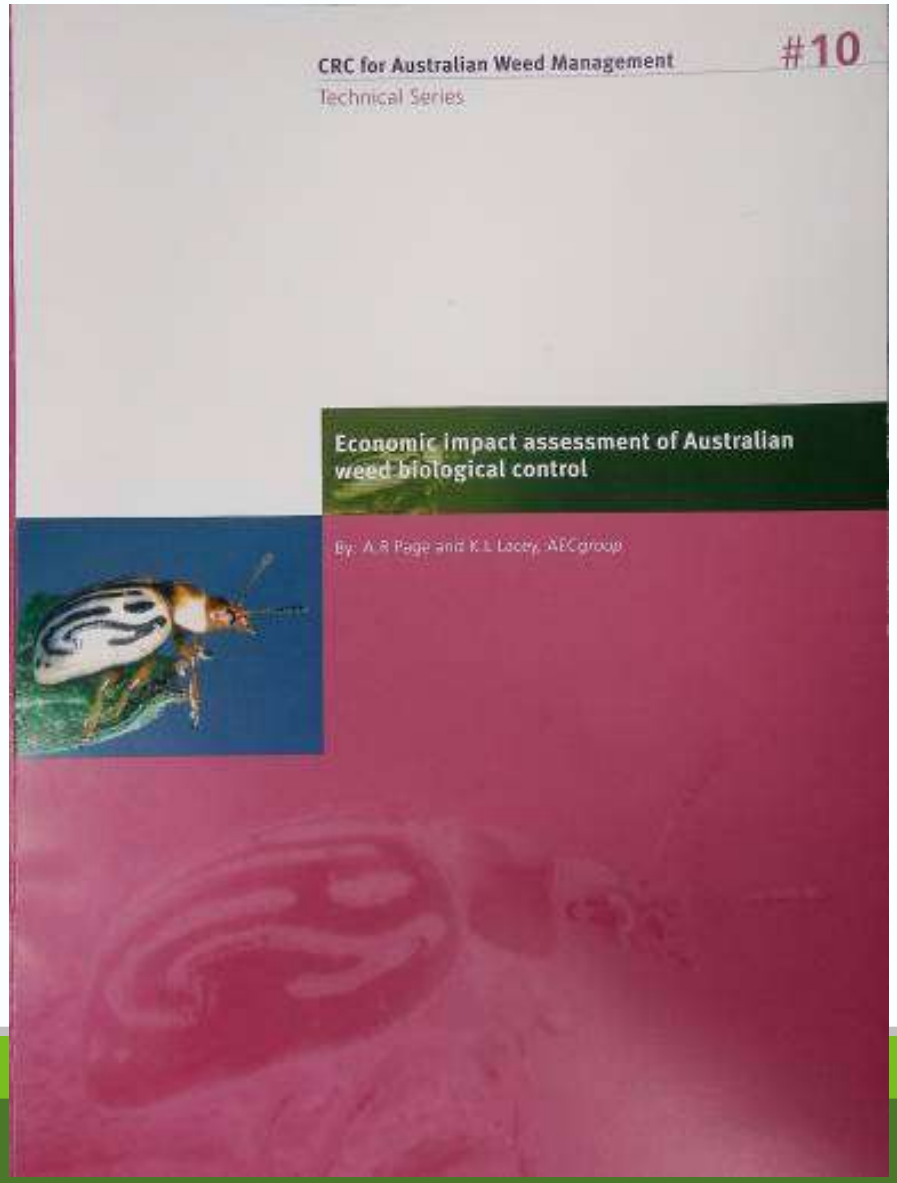
What makes an effective biological control agent?

Good agents

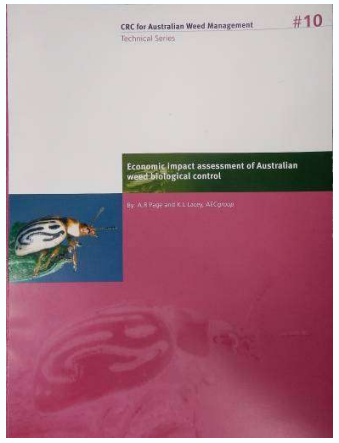
- Rapid reproducers
- Attack early in target life cycle
- Widespread across habitats, climates & seasons
- Still present at low target densities
- Can “outbreak” and/or kill target in native range
- *Beetles* & *Pathogens* work best

Economic assessment

Page & Lacey 2005 *Economic impact assessment of Australian weed biological control* – Weeds CRC publication



- All projects completed by 2005
- 36 projects included (2 excluded due to lack of data)
- 48% returned some economic benefit
- Overall BCR of 23:1



High return on investment

Average investment of $4.3 million/year since 1903 ➤ Average return of $95.3 million/year since 1903

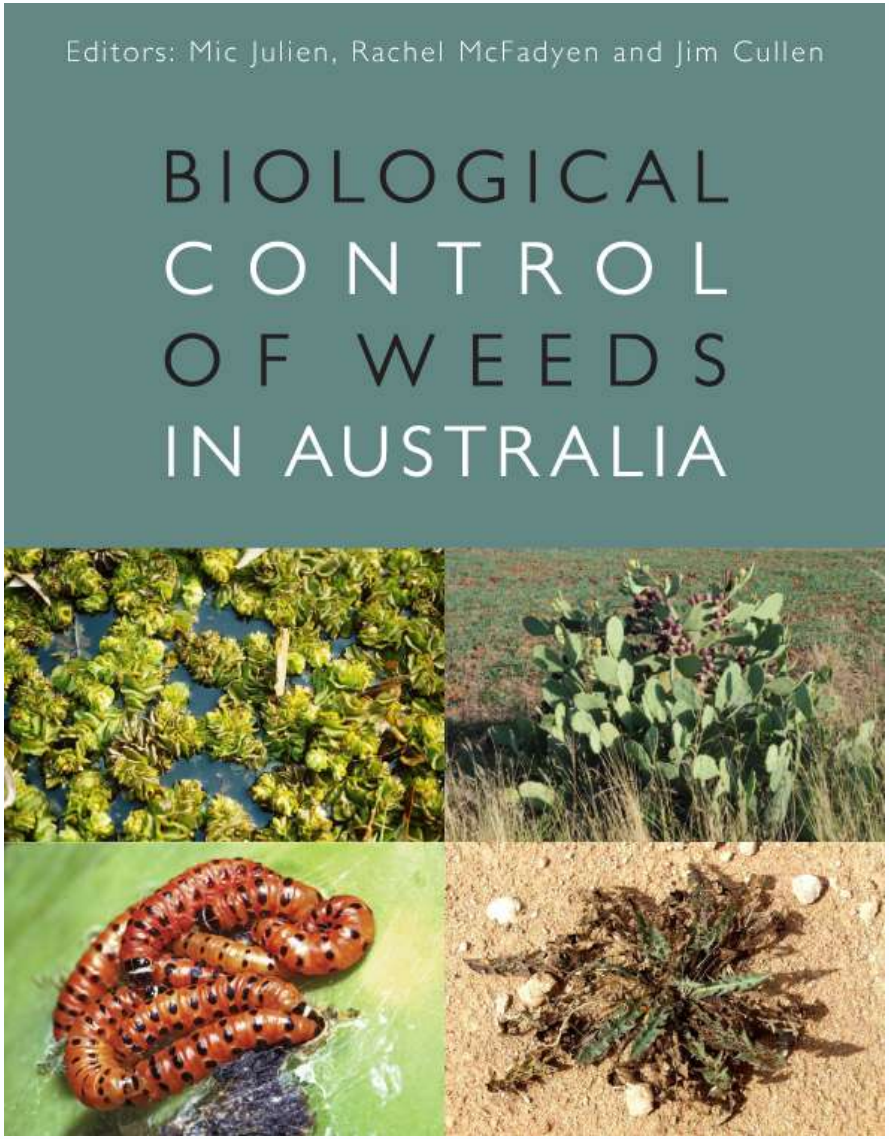
Every $1 invested returns ➤
- $17.40 to agriculture
- $3.80 to society
- $1.90 to government

Page & Lacey 2006

Top 10 weed biological control programs ranked by BCR

	Weed	No. of years research	Total investment ($m in 2004/05 $$)	Net present value ($m in 2004/05 $$)	Benefit-cost ratio
1	Prickly pear	35	21.1	3100.4	312:1
2	Skeleton weed	5–10	12.7	1412.8	112:1
3	Rubber vine	21	3.6	232.5	108:1
4	Annual ragweed	7	0.6	52	103:1
5	Paterson's curse	approx. 30	23 (est.)	1178	52:1
6	Ragwort	29	7.9	94.2	32:1
7	Salvinia/water hyacinth/water lettuce	20	5.1	76.5	27:1
8	Harrisia cactus	5	1	18.6	23:1
9	Giant sensitive plant	11	1.7	20.2	18:1
10	Slender thistle	11	2.1	20.9	14:1

Page & Lacey 2006



Our first century

73 biocontrol programs against 83 weeds

Economic, environmental and scientific benefits

14 very successful programs

11 unsuccessful

All plant forms

Negligible non-target issues

Last review – Frank Wilson 1960 – 10 biocontrol programs – 2 successes

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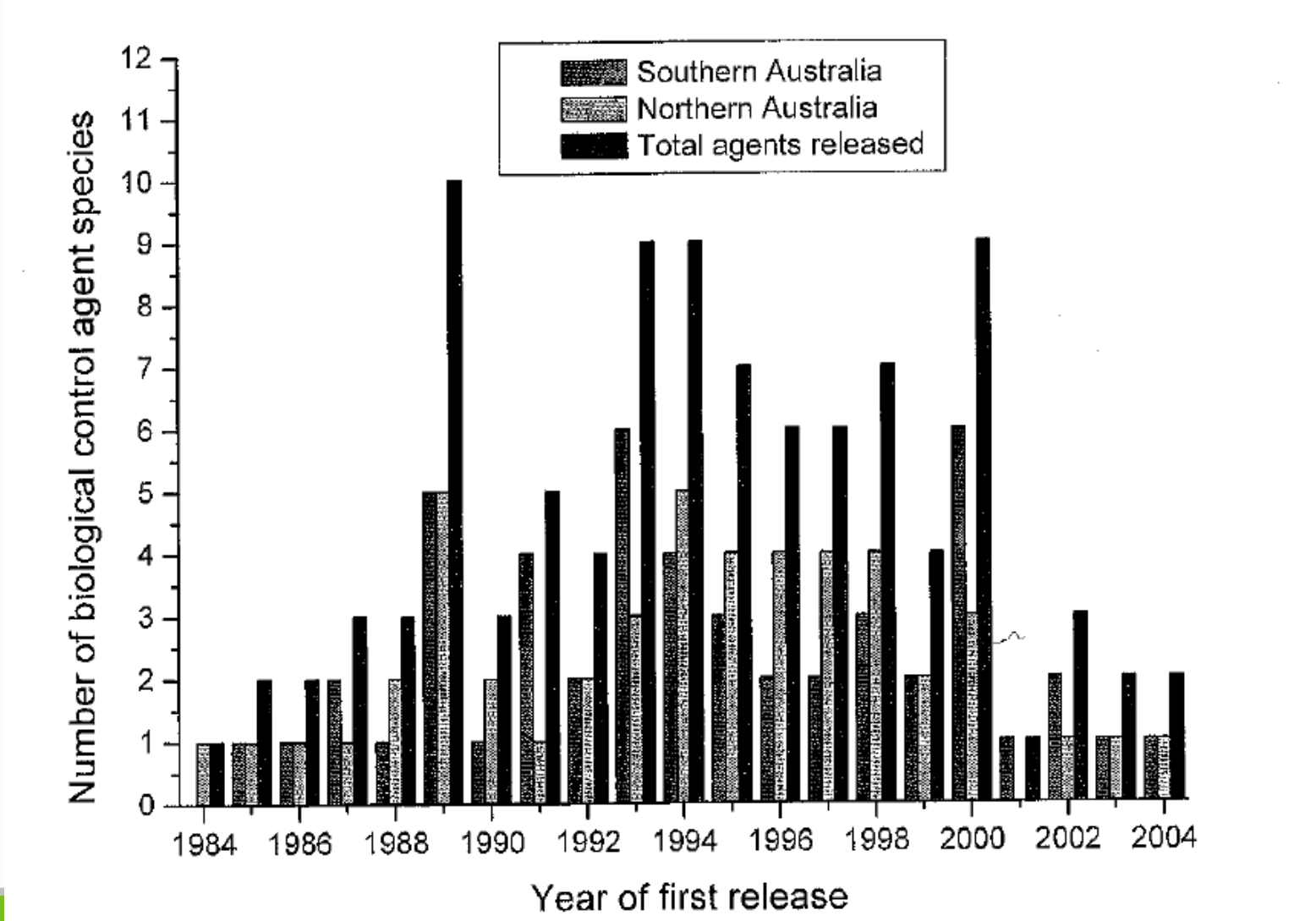
Releases peaked in the 1990s



Reduction in National capacity (Scientist FTEs)

Entity	Greatest capacity (1980s to early 1990s)	Present
CSIRO	13	1.5
Queensland	9	1.5
Victoria	8 (15 technical staff)	2 (0 technical staff)
Tasmania	1	0
New South Wales	2	0.5
Northern Territory	2	2
Total	33	7.5

(Palmer et al. 2014)

Where to now?

- Greatly reduced National capacity.
- Fewer and fewer projects
- Loss of biocontrol skills
- Declining public awareness/understanding (benefits & risks)
- Outsourcing the science we led the world at
- Lost benefits to Australia

Weed biological control remains both effective, science-based & full of future benefits as long as we can still do it!

Thank you