



**Landcare Research**  
**Manaaki Whenua**



**Australian Government**  
**Land & Water Australia**

# **IMPROVING TARGETING OF WEED BIOLOGICAL CONTROL PROJECTS**

Quentin Paynter, Richard Hill, Stanley Bellgard, Murray Dawson



# Background:

In 2008, Landcare Research was asked by Land & Water Australia to develop a national-priority-setting framework to improving targeting of classical weed biological control projects in Australia

We reviewed international ranking procedures, which generally rank weeds by:

1. Weed importance/impacts &
2. Feasibility of biocontrol

# Ranking weeds by importance



- Already extensive work on the former in Australia:
  - Weeds of National Significance (WoNS)
  - National Post-Border (WRM) Protocol
  - Both assess weed importance according to *Invasiveness, Impacts & Distribution (current & potential)*





# Feasibility of biocontrol

We focused on predicting *feasibility* of biocontrol.

Aim: To develop a scoring system, based on factors proven to influence biocontrol success & cost



# Feasibility of biocontrol

Factors used to rank feasibility of biocontrol fall into two main categories

1. 'Socioeconomic' factors
2. 'Ecological' factors

# Socioeconomic criteria

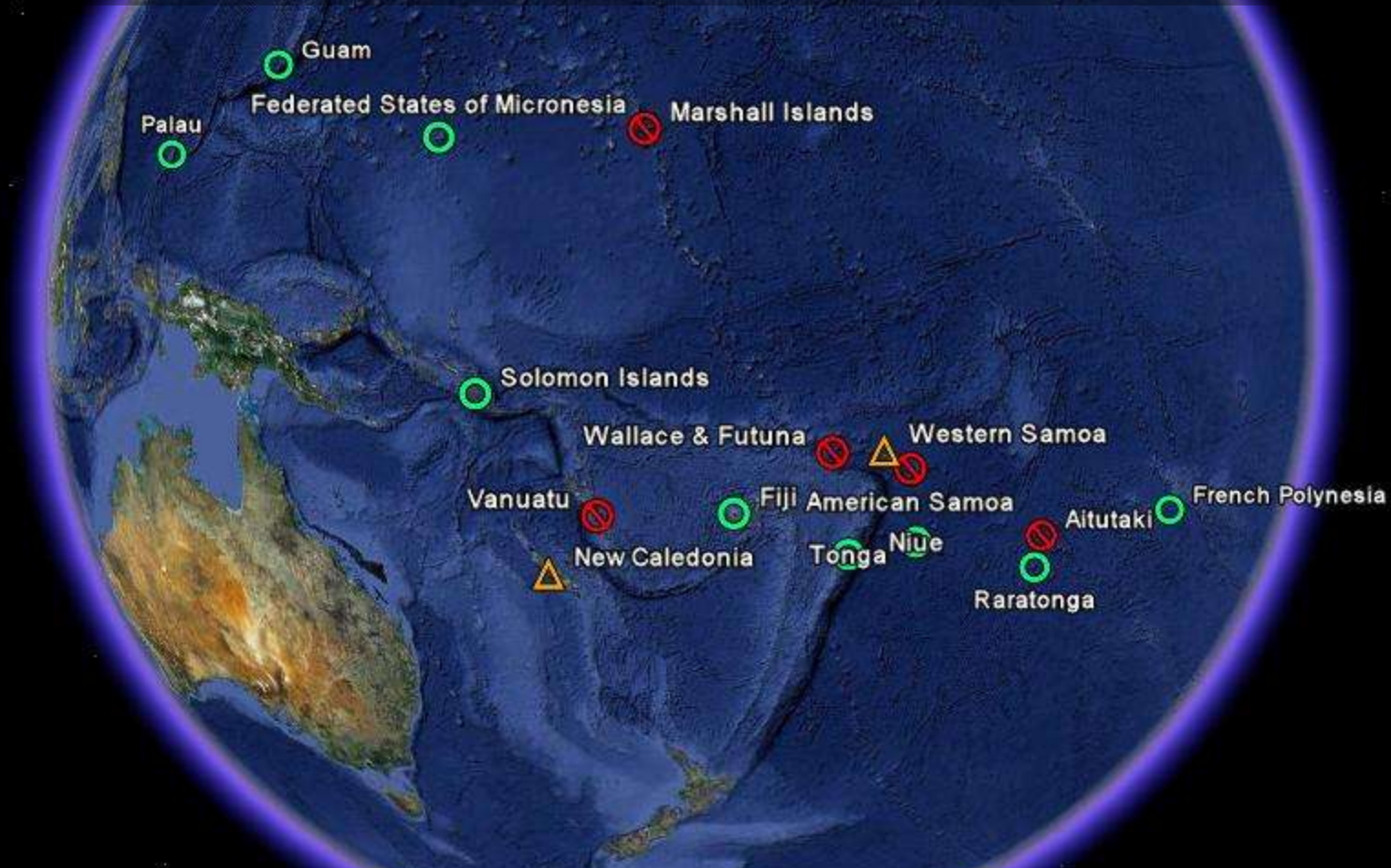


## 1. Origin of weed (native vs exotic)

We consider biocontrol of a weed in its natural range is unacceptable: Native weeds are often ecologically important in natural communities & it is impossible to limit biocontrol agents only to situations where the target native weeds are problems

# Example: *Merremia peltata* in Pacific region

- Considered native to some islands, but an invasive alien in others...uncertainty regarding status should be resolved before biocontrol can proceed<sup>1</sup>



<sup>1</sup>Paynter, Q., Harman, H. & Waipara, N. (2006) Prospects for biological control of *Merremia peltata*. *Landcare Research Contract Report LC0506/177*, Landcare Research, New Zealand.

# Socioeconomic criteria



## 2. Conflicting interests:

Weeds can have value (e.g. crop/pasture plants; resource for honeybees). If a weed has value, conflicts must be resolved before biocontrol can proceed, adding to cost & uncertainty of success

# Examples: Scotch broom in NZ; Patterson's curse in Australia



- Both weeds are valued by beekeepers
- Biocontrol of these weeds was significantly delayed & did not proceed until detailed cost-benefit analyses were performed



Jarvis, P.J., *et al.* (2006) *Biological Control*, **39**, 135-146

Delfosse, E. S. (1985) *Proc. VI Int. Symp. Biol. Cont. Weeds*

# Socioeconomic criteria



## 3. Factors affecting “effort required”:

- *Biocontrol target elsewhere*: “Repeat” programs less effort than new programs (overseas surveys, host-range testing etc. already done)
- *Relatedness of a weed to native/commercially important plants*: Biocontrol agent screening cost is closely correlated to ‘risk’ & the closer a weed is related to potential non-target plants, the bigger the risk
- *Ease of working in the native range of the weed* (e.g. acquiring relevant permits to collect/export candidate agents);
- *Presence/absence of literature information regarding the identification, & biology of candidate agents & phylogenetics of the target weed*

# Ecological feasibility: analytical approach

- We compiled a list of traits identified during our literature review as hypothetically important determinants of biocontrol success
- We searched CAB Abstracts & Google for quantitative information regarding (1) success of biological control against weeds in Australia, South Africa & continental USA (long history of weed biocontrol) & (2) plant traits of those weeds

# Ecological feasibility: analytical approach



- Quantitative impact data collected in several ways (e.g. % cover; stems  $m^{-2}$ ; weed biomass): converted into an “impact index” (I) to allow comparison between weeds
- Impact index defined as the proportional reduction in weed density, due to biocontrol; e.g.: If a weed density was reduced from 33 to 3.8 stems  $m^{-2}$ , following biocontrol then:
  - Reduction in stem density =  $3.8 - 33 = -29.2$  stems  $m^{-2}$
  - Impact index (I) =  $-29.2/33 = -0.885$

# Ecological feasibility: analytical approach



- If multiple data for a weed, we calculated an average unless data updated previous measurements, e.g. following release of another agent(s)
- If no biocontrol agents established or anecdotal reports of “trivial impact” we assumed biocontrol impact = zero, even if quantitative data lacking
- Impact & trait data for 27, 23 & 30 weeds in Australia, S Africa & USA (overall 72 spp.; some present in > country)
- We averaged impacts for congeneric weed spp. with identical traits: reduced number of species/genera analysed to 57

# Ecological feasibility – traits analysed

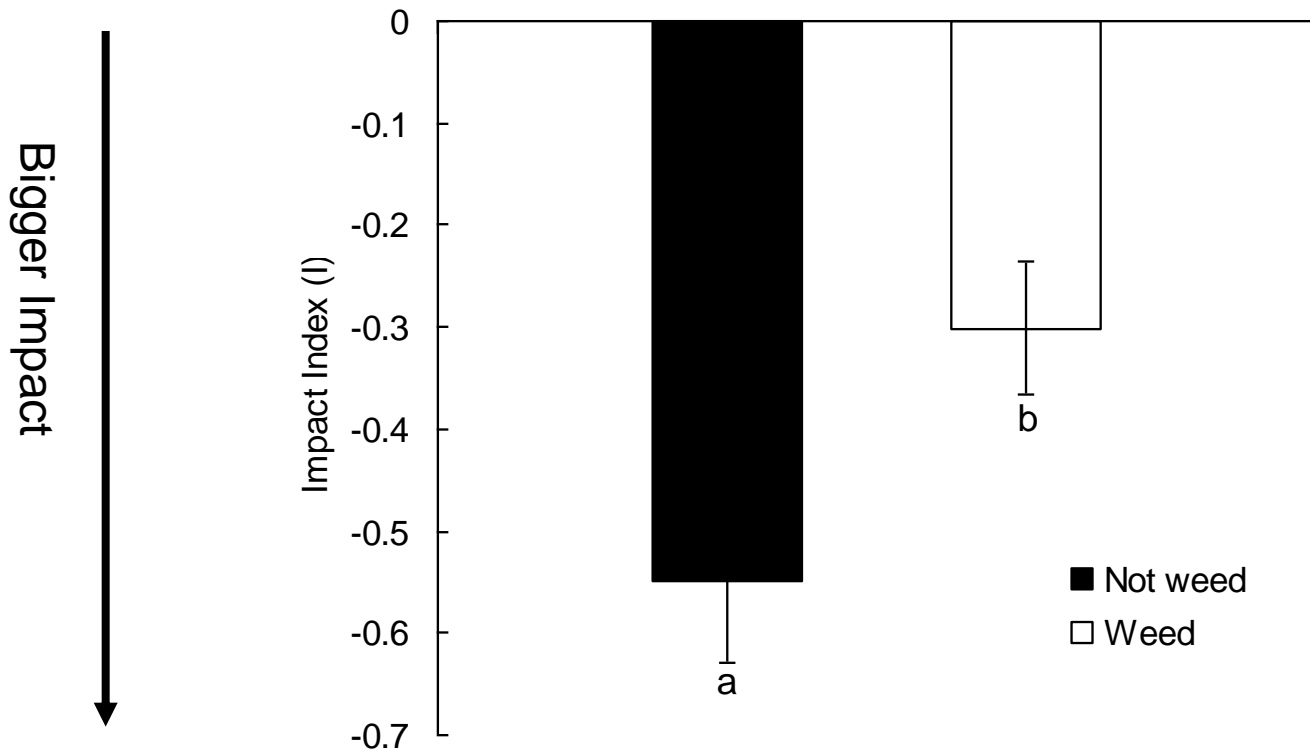


1. Traits analysed were all based on hypotheses published in the literature;
2. Not all could be included in analysis due to insufficient data for some traits (so potential for future improvements)



# Plant traits correlated to success

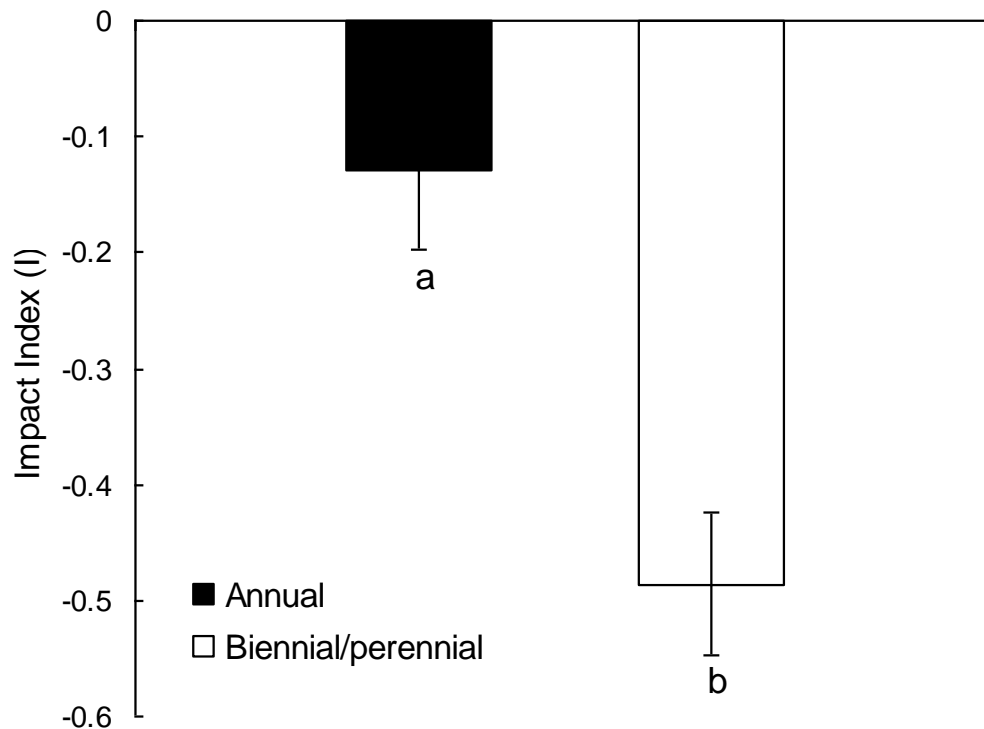
- Average impact of biocontrol was lower against species recorded as weeds in the native range





# Plant traits correlated to success

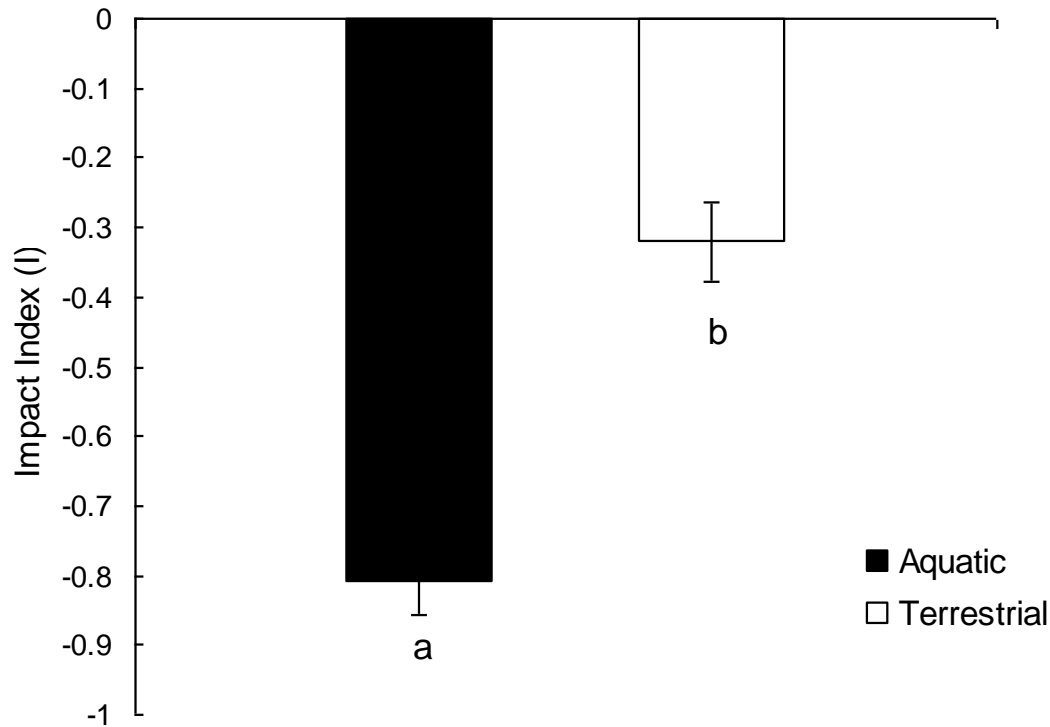
- Average impact was lower against annual species





# Plant traits correlated to success

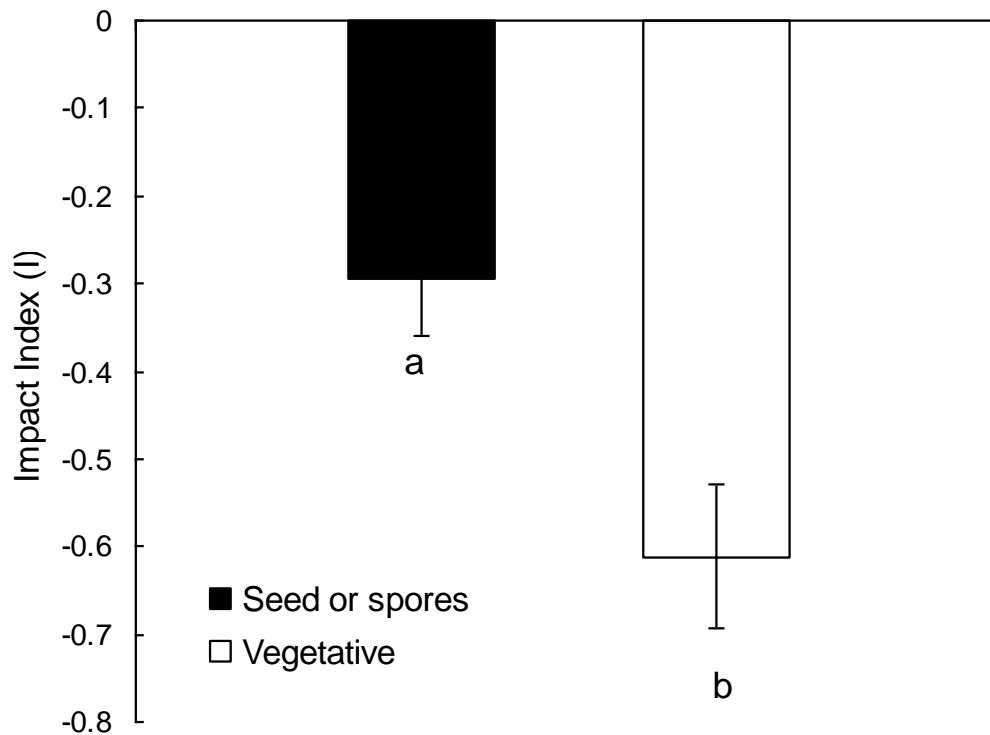
- Average impact was lower against terrestrial versus aquatic/wetland species





# Plant traits correlated to success

- Average impact was greater against species capable of vegetative reproduction





# Plant traits not affecting success

We excluded traits from our scoring system if they were not statistically significant, *except* **phylogenetic relatedness of a weed & non-target plants**

Non-target attack on native plants was a minor consideration in the past e.g. successful biocontrol of *Hypericum perforatum* & *Carduus* thistles in the USA unlikely under today's regulations (significant, predictable, non-target attack)

So, despite the lack of evidence from past programs we assume this trait IS important because things have changed!



# Other traits affecting success

We could not analyse some traits, but we assume they are important on basis of previously published evidence:

- Chaboudez & Sheppard (1995): tropical annuals are more susceptible to biocontrol than temperate annuals (only one predominantly tropical/sub-tropical annual (*Parthenium hysterophorus*) was represented in our datasets)
- Thomas & Reid (2007): environmental weeds are more amenable to biological control than agricultural weeds (we didn't have all information for US & South African weeds)

# Developing a scoring system

## Ecological feasibility



Score differentials for each trait based on quantitative data (e.g. if average biocontrol impact was 3x higher for aquatic versus terrestrial weeds, it scored 3x more for that trait)

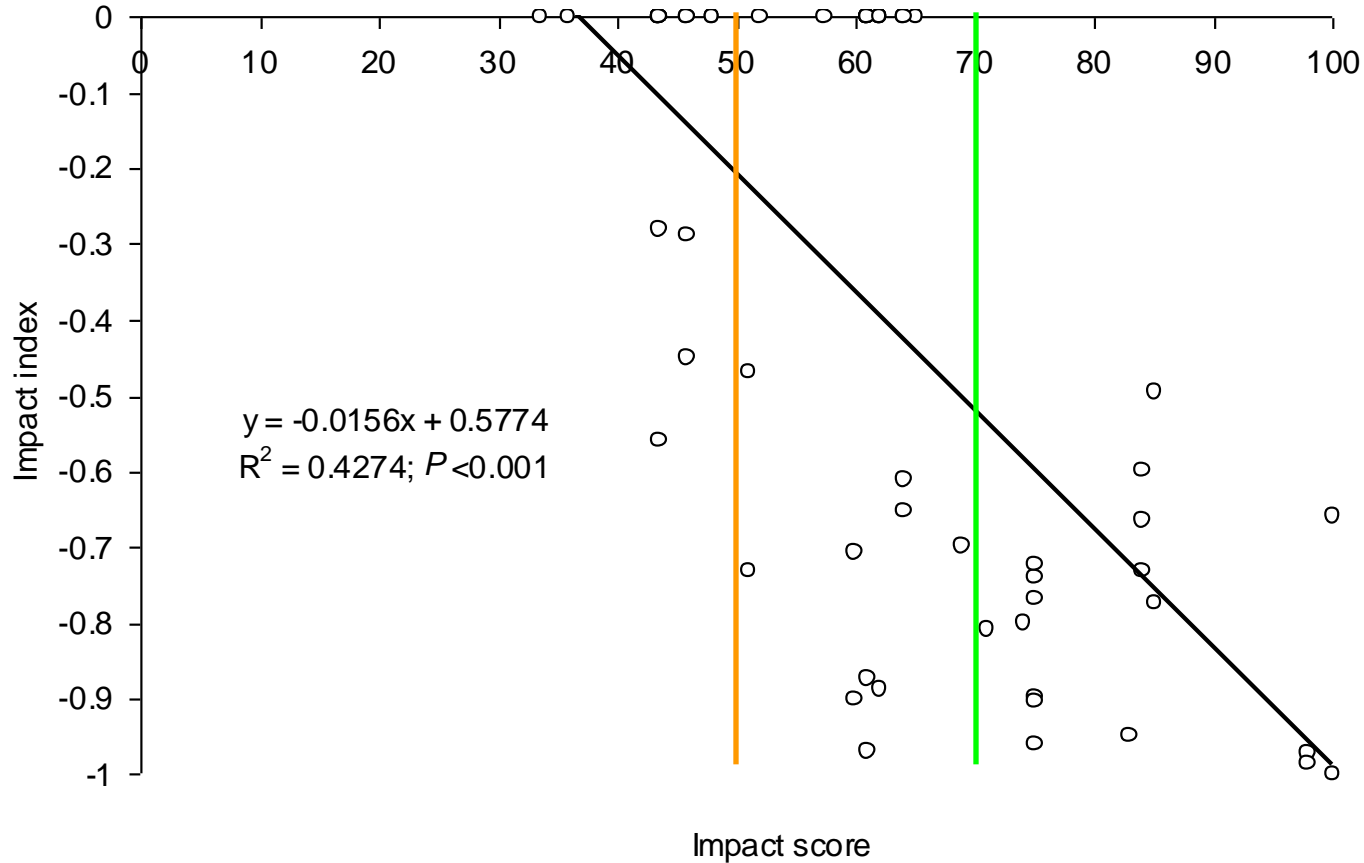
Weighting of traits based on % variance explained in our analysis.

Success of the scoring system tested by correlating feasibility scores with the impact indices

Sensitivity analysis/optimisation performed by adjusting weightings to maximise r-squared: Weightings of important factors were increased & less important factors were reduced, keeping maximum score 100 points

# Developing a scoring system

## Ecological feasibility



Score < 50

Difficult targets: none  
achieved an impact index  
of -0.6 (but some got close)

Score 50-70

Medium targets: 38% Impact  
index between -0.6 & -1

Score > 70

Good targets: 94% Impact  
index between -0.6 & -1

# Incorporating knowledge from other programs

1st analysis assumed all programs novel.

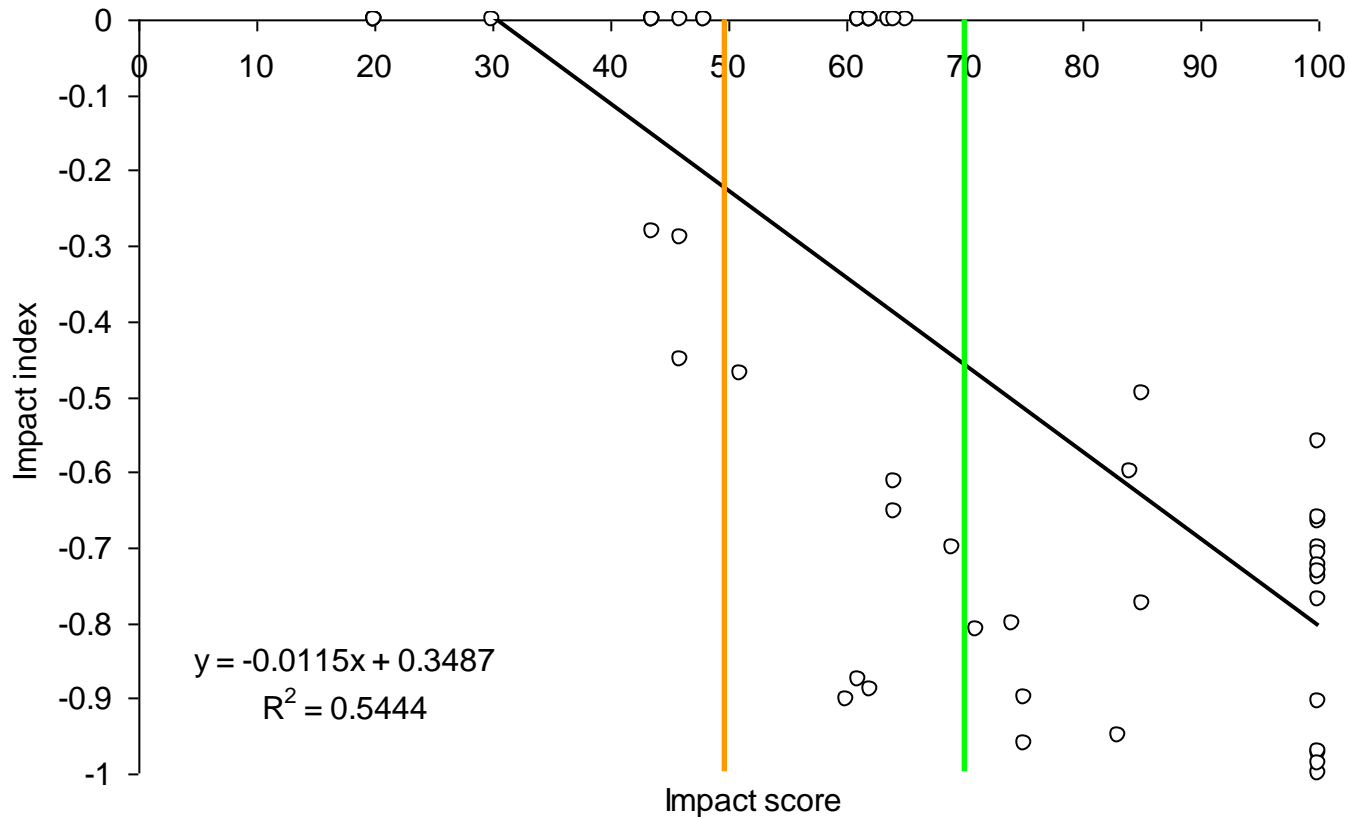
The best predictor of success is precedent:

A second analysis scored weeds that were previously targeted: previously successful targets were given a “top score”; targets with variable, low or no success overseas, given progressively lower scores

# Incorporating knowledge from other programs



R-squared higher, indicating past success useful indicator



Score < 50

Difficult targets: none  
achieved an impact index of -  
0.6 (but some got close)

Score 50-70

Medium targets: 33% Impact  
index between -0.6 & -1

Score > 70

Good targets: 87% Impact  
index between -0.6 & -1

# Application of the framework to Australian weed targets



Overall score = Weed impact score x  
biocontrol feasibility score x 1/effort score

Weed impact score = WoNS score, scaled so max  
score = 100

Max biocontrol feasibility score also = 100

Effort included as the lower the effort, the more  
programs that can be conducted per \$. Considered  
less important than the other 2 criteria – arbitrarily  
worth 50 points

Rank	Weed	Total Im Importan 1/Effort
1	<i>Salvinia molesta</i>	1370.85
2	<i>Eichhornia crassipes</i>	499.50
3	<i>Harrisia martini</i>	378.79
4	<i>Opuntia aurantiaca</i>	378.79
5	<i>Opuntia imbricata</i>	378.79
6	<i>Opuntia monocantha</i>	378.79
7	<i>Opuntia stricta</i>	378.79
8	<i>Pistia stratiotes</i>	303.03
9	<i>Spartina anglica</i>	267.16
10	<i>Senecio jacobaea</i>	265.92
11	<i>Alternanthera philoxeroides</i>	259.74
12	<i>Cabomba caroliniana</i>	209.61
13	<i>Chrysanthemoides monilifera</i>	208.86
14	<i>Solanum elaeagnifolium</i>	204.33
15	<i>Hypericum perforatum</i>	198.41
16	<i>Macfadyena unguis-cati</i>	192.31
17	<i>Prosopis spp.</i>	190.64
18	<i>Ulex europaeus L.</i>	187.01
19	<i>Tamarix aphylla</i>	176.82
20	<i>Schinus terebinthifolia</i>	174.63

# RESULTS



Ranking, including  
“completed” targets

Most of the top 20  
are/have been  
biocontrol targets in  
Australia

& many are  
successful targets  
(e.g. 9/top 10)

# RESULTS: “Completed targets” excluded



Rank	Weed	Impact score	Importance score	Impact × Importance	Effort score	Total Impact × Importance × 1/Effort) score
1 (6)	<i>Spartina anglica</i>	90	62.34	5610.39	21.00	267.16
2 (3)	<i>Alternanthera philoxeroides</i>	100	67.53	6753.25	26.00	259.74
3 (1)	<i>Cabomba caroliniana</i>	100	79.65	7965.37	38.00	209.61
4 (7)	<i>Chrysanthemoides monilifera</i>	64	84.85	5430.30	26.00	208.86
5 (8)	<i>Solanum elaeagnifolium</i>	100	51.08	5108.23	25.00	204.33
6 (9)	<i>Macfadyena unguis-cati</i>	77	64.94	5000.00	26.00	192.31
7 (10)	<i>Prosopis</i> spp.	50	99.13	4956.71	26.00	190.64
8 (18)	<i>Ulex europaeus</i> L.	56	70.13	3927.27	21.00	187.01
9 (12)	<i>Tamarix aphylla</i>	59	77.92	4597.40	26.00	176.82
10 (13)	<i>Schinus terebinthifolia</i>	76	59.74	4540.26	26.00	174.63
11 (4)	<i>Parkinsonia aculeata</i>	62	100.00	6200.00	38.00	163.16
12 (15)	<i>Nassella neesiana</i>	52	78.35	4074.46	26.00	156.71
13 (16)	<i>Nassella trichotoma</i>	52	77.06	4006.93	26.00	154.11
14 (-)	<i>Genista monspessulana</i>	59	52.38	3090.48	21.00	147.17
15 (2)	<i>Hymenachne amplexicaulis</i>	85	82.68	7028.14	48.00	146.42
16 (14)	<i>Rubus fruticosus</i> agg.	48	93.07	4467.53	31.00	144.11
17 (20)	<i>Anredera cordifolia</i>	76	50.65	3849.35	28.00	137.48
18 (5)	<i>Salix</i> spp.	75	77.49	5811.69	43.00	135.16
19 (-)	<i>Argemone ochroleuca</i>	59	35.50	2094.37	17.00	123.20
20 (11)	<i>Thunbergia grandiflora</i>	76	64.50	4902.16	40.00	122.55

# Approach



Feasibility of biocontrol success	Success more likely Less serious weed Medium priority	Success more likely More serious weed Highest priority
	Success less likely Less serious weed Lowest priority	Success less likely More serious weed Medium priority
		Weed Importance

Determining highest & lowest priorities is straight forward.

Medium priority: two options: should we select by importance (bottom right), although biocontrol success is less likely, or by predicted success (top left), although weeds are less important?

# Conclusions



- The framework is a major advance on previous systems: evidence–based criteria & appears to be particularly good at identifying “winners”
- Biocontrol can succeed against “medium” & “difficult” targets & benefits of integration of biocontrol with other options were not considered
- We should not reject biocontrol of difficult targets, but should consider the need for integration at start of program (this framework informs whether integration likely to be required)
- Prioritisation could be improved if thresholds for success were known

# The future



- Research questions are being developed to improve predictive power & reduce level of uncertainty in the framework.
- The framework will be updated, as more weed biocontrol impact data become available, & expanded to include data from other countries (e.g. New Zealand!)
- We used the WoNS ranking score for weed importance – but any other score can be substituted, provided it is calibrated to complement the effort & feasibility scores:



Download report at:

<http://lwa.gov.au/products/pn22434>