The development and validation of a more accurate weed risk assessment tool for evaluating the invasive potential of ornamental plants

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Talk Overview

- Introduction
  - Goals of study
  - The nursery industry and invasive plants
  - Prevention tools – Weed Risk Assessment
- Methods
  - Comparison of WRA models
  - PlantRight WRA Model validation
- Results
  - Model comparison and performance
- Conclusions
- Next Steps

*Photo | California Invasive Plant Council, Beth Hendrickson*

- Develop a tool to prevent new invasive plant introductions from the nursery industry
- Adapt the existing "weed risk assessment" (WRA) tool for this purpose
- Use both models to screen ~180 known invasive and non-invasive plants
- Validate the new WRA model by comparing it's accuracy to the original model

Economic impact of the nursery industry in CA

CA Nursery and Floral Sales - Total Sales and % of Total Agricultural Sales

CANGC Industry Report 2010
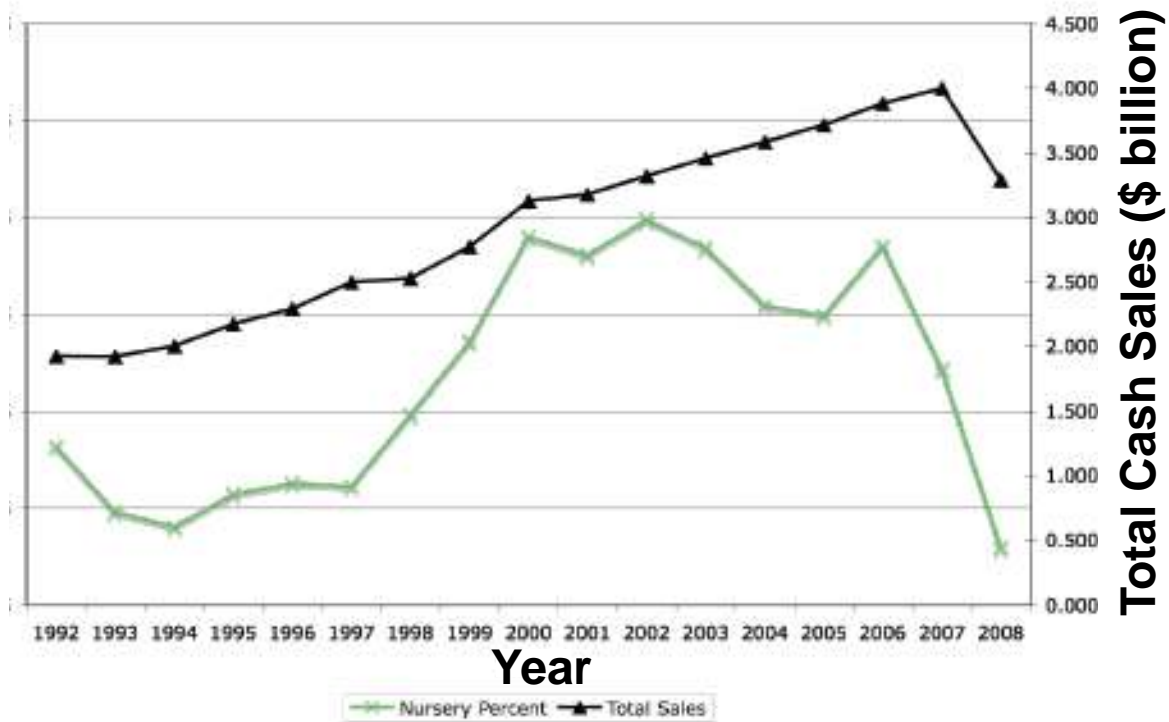
Economic impact of the nursery industry in CA

CA's Top 20 Commodities- With Value of Sales and Rank for 2002-2008

Commodity	2002	2003	2004	2005	2006	2007	2008
	Value of sales (million dollars)						
Milk and Cream	3,833 (1)	4,028 (1)	5,366 (1)	5,223 (1)	4,492 (1)	7,337 (1)	6,924 (1)
Grapes, all	2,567 (2)	2,298 (3)	2,765 (2)	3,198(2)	3,000 (2)	3,076 (2)	2,938 (2)
Almonds	1,201 (6)	1,600 (5)	2,189 (4)	2,337 (4)	2,259 (4)	2,402 (4)	2,343 (3)
Nursery	2,295 (3)	2,437 (2)	2,297 (3)	2,686 (3)	2,890 (3)	2,962 (3)	2,274 (4)
Cattle and Calves	1,229 (5)	1,556 (6)	1,634 (6)	1,740 (5)	1,676 (5)	1,784 (5)	1,823 (5)
Hay, all	925 (10)	852 (10)	1,046 (9)	1,151 (7)	1,060 (9)	1,406 (8)	1,797 (6)
Lettuce, all	1,318 (4)	1,932 (4)	1,749 (5)	1,688 (6)	2,054 (6)	1,697 (6)	1,581 (7)
Strawberries	932 (9)	1,172 (7)	1,206 (7)	1,110 (8)	1,199 (7)	1,411 (7)	1,578 (8)
Tomatoes, all	947 (8)	895 (9)	1,180 (8)	942 (10)	1,166 (8)	1,223 (9)	1,317 (9)
Rice	272(21)	406 (16)	373 (19)	408 (18)	521 (16)	708 (13)	1,183 (10)
Floriculture	1,001 (7)	997 (8)	1,013 (10)	1,020 (9)	999 (10)	1,036 (10)	1,015 (11)

CANGC Industry Report 2010

Drivers of new plant introductions

- Advances in plant breeding and propagation
- New housing starts
- Consumer demand
- Interest in novel and exotic plants
- Increased demand for xeriscaping
- Plants that meet water restrictions
- Adapting to climate change scenarios

Bradley et al. 2011

Drivers of new plant introductions

Sources of nursery plant imports to the US
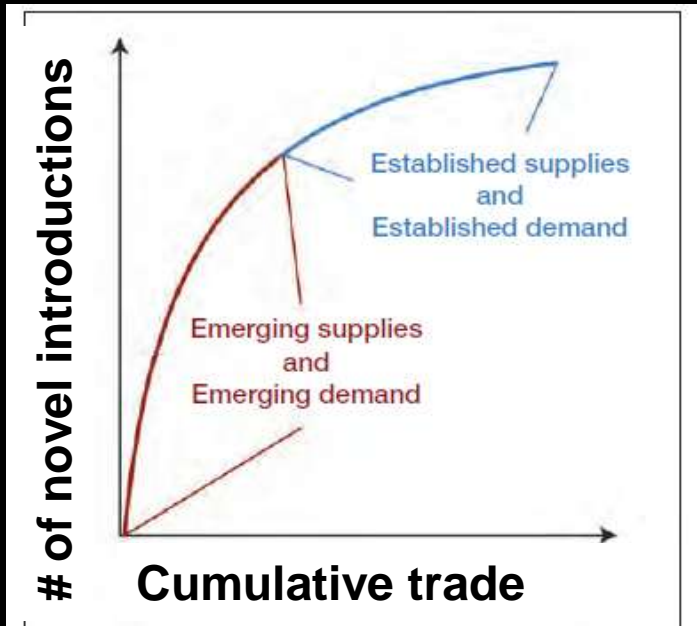
Figure 1. New influxes of non-native invasive species are most prominent in the early stages of new trade partnerships. With established trade partners, invasions continue to rise with increase in trade, but at a slower rate. Adapted from Levine and D'Antonio (2003).

Bradley et al. 2011
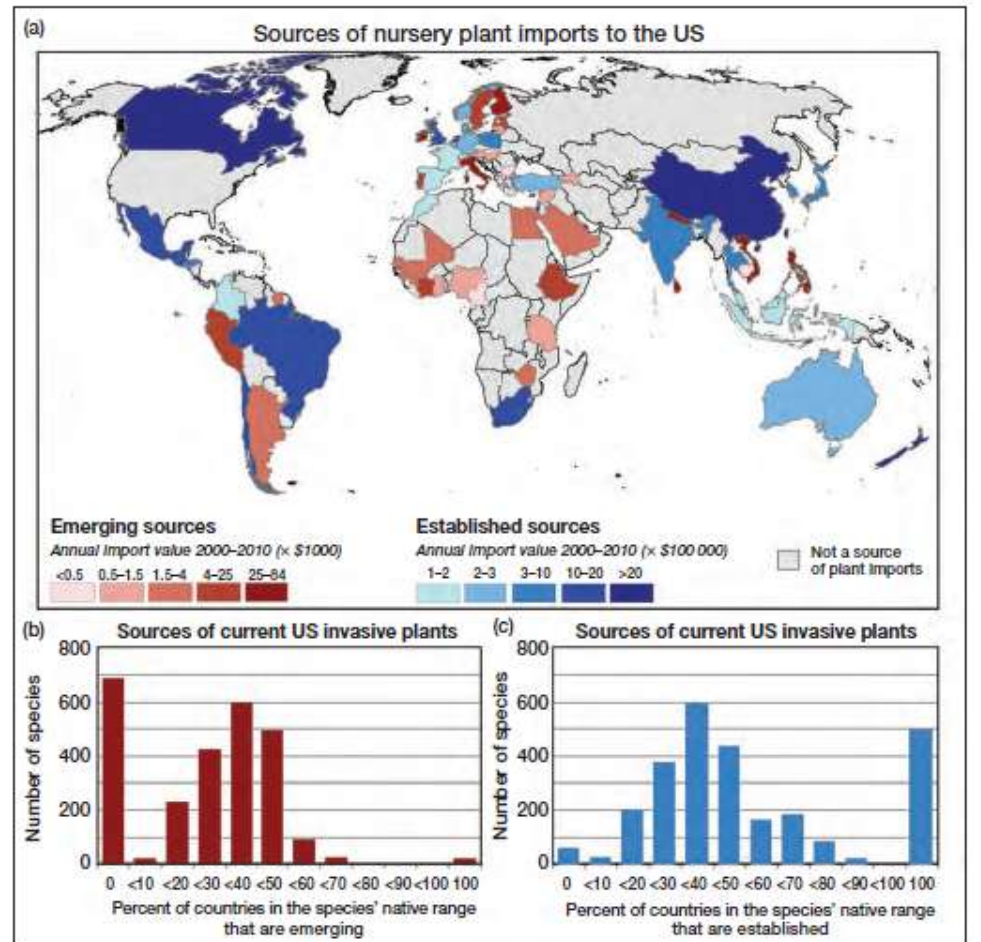
Rate of new plant introductions

Number of commercially available cultivars (1987 to 2008)

105,000

20,000

Drew et al. 2008
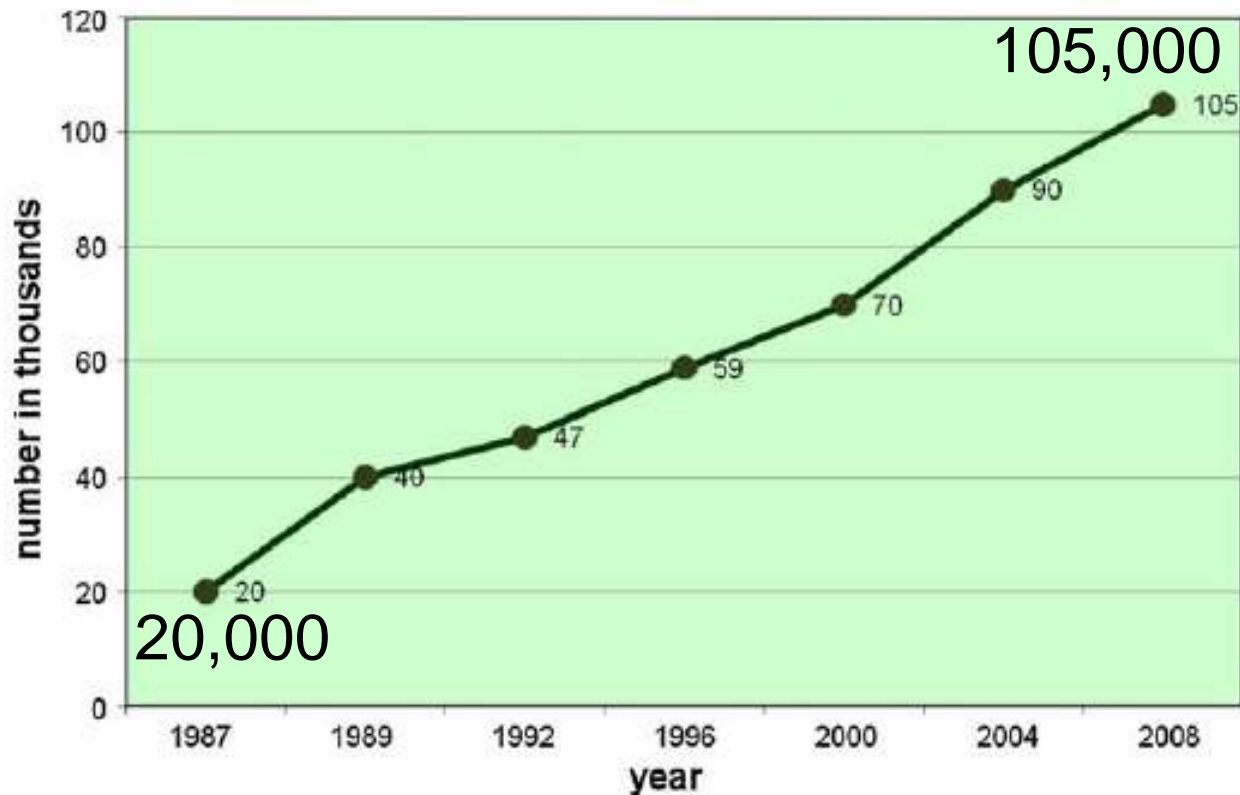
What % of invasive plants were introduced through horticulture into CA?

Legend:
- Horticultural/ornamental
- Seed/other contaminant
- Dye, medicinal, forage
- Aquarium trade

Pie chart values: 48%, 37%, 13%, 2%

Bell et al. 2003
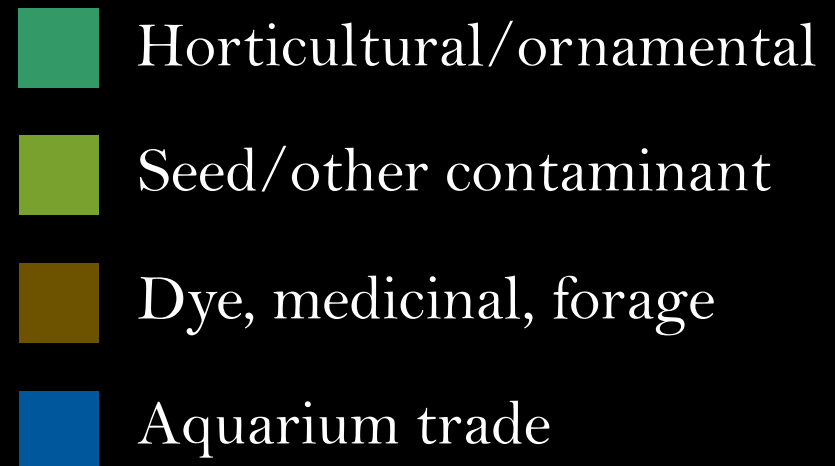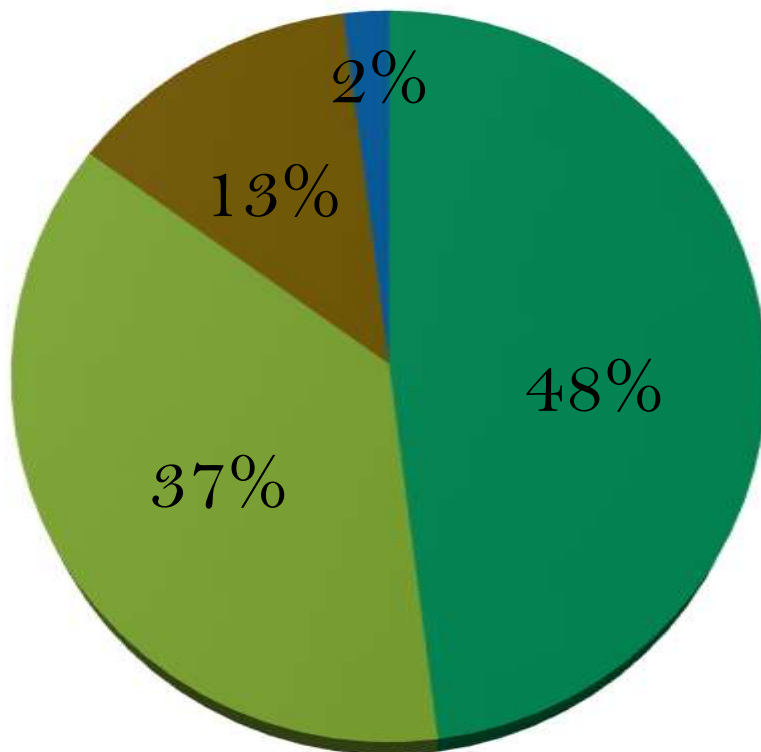
What Traits Make a Plant Invasive?

- Broad germination

- Establish rapidly

- Use up limited resources

- Weather/soil tolerant

- Resistant to pests   and disease
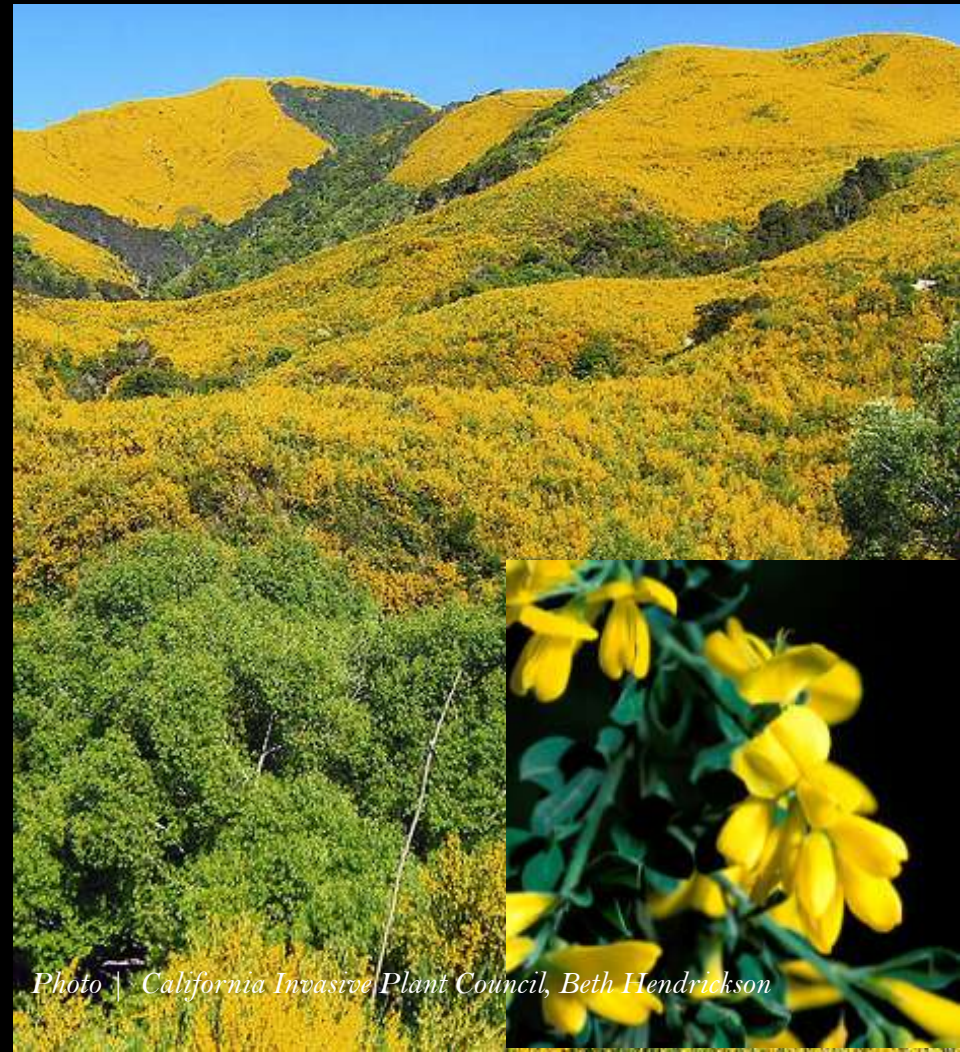
Photo | California Invasive Plant Council, Beth Hendrickson

Invasive Traits

- Broad germination
- Establish rapidly
- Use up limited resources
- Weather/soil tolerant
- Resistant to pests and disease

Ornamental Traits

- Abundant flowers
- Easy to propagate
- Grows quickly
- Weather/soil tolerant
- Resistant to pests and disease

WRA models – Australia

- 49 Questions
  - *Biogeography/Historical*
    - Domestication/Cultivation
    - Climate and Distribution
    - Weed Elsewhere
  - *Biology/Ecology*
    - Undesirable Traits
    - Plant Type
    - Reproduction
    - Dispersal Mechanisms
    - Persistence Attributes
- Used in Australia & other parts of the world

Pheloung et al. 1999

Photo | AQIS

WRA models – Worldwide

Region	% Accuracy-invasive plants	% Accuracy-non-invasive plants
Australia	90	60
Hawaii, Pacific Islands	95	66 (85 w/ secondary screening)
Czech Republic	100	64 (83 w/ secondary screening)
Japan (Bonin Islands)	93	64
Florida	92	73
Spain	94	21 (casual species)
Italy	93	75
Various	90	70 (77 w/ secondary screening)

Chong et al. 2011, Daehler and Carino 2000, Gassó et al. 2010, Gordon et al. 2008a, b, McClay et al. 2010, Nishida et al. 2009, Onderdonk et al. 2010

WRA models – USDA-APHIS-PPQ

- 94% for major-invaders
- 97% for non-invasive plants
- Screenings take 1-2 days
- Amount of time for plants to clear quarantine unknown

APHIS

Biol Invasions
DOI 10.1007/s10530-011-0061-4

ORIGINAL PAPER

Development and validation of a weed screening tool for the United States

Anthony L. Koop · Larry Fowler · Leslie P. Newton · Barney P. Caton

Abstract The Australian weed risk assessment has been promoted as a simple and effective screening tool that can help prevent the entry of weeds and invasive plants into new areas. On average, the Australian model identifies major-invaders more accurately than it does non-invaders (90% vs. 70% accuracy). While this difference in performance emphasizes protection, the overall accuracy of the model will be determined by its performance with non-invaders because the frequency of invasive species among new plant introductions is relatively low. In this study, we develop a new weed risk assessment model for the entire United States that

false positives or false negatives. The new screening tool we developed reduced the number of species requiring secondary evaluation from 12%. We expect that the new weed risk assessment model should significantly enhance the United timeliness and accuracy in regulating potential

Keywords Weed risk assessment · ROC · Predictive screening tool · Base-rate effect · Australian WRA

Introduction

Koop et al. 2011

WRA models – USDA-APHIS-PPQ

- USDA-APHIS-PPQ now requires pre-import risk analysis to "evaluate the ability of a species to spread outside cultivation" (NAPPRA)

- Modeled after Australia's Weed Risk Assessment model

- Impact of NAPPRA to nursery industry imports unknown

WRA models – PlantRight

- Invasive History
- Climate Match
- Difficulty of Control
- Impacts of Native Plants/Animals
- Reproductive Strategies
- Dispersal
- Growth Rate

Goals for the PlantRight WRA model

- Adapted from the Australian WRA model
- Develop specifically for screening ornamental plants for invasiveness
- Increase accuracy in predicting non-invasive plants
- Develop capability to screen plants early in the research, development or production process (prior to import/quarantine)
- Provide rapid screenings, quick results
- Match invasiveness to specific regions or climate zones
- Provide real-time assessments of invasiveness that update with new data

PLVNT RiGHT

Species selection

41%
Invasive

59%
Ornamental
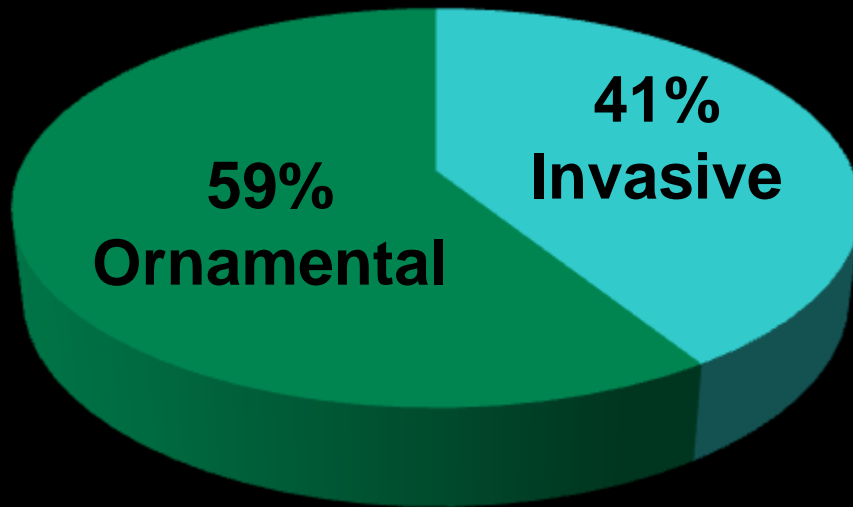
- 177 plants total screened

❖95 Ornamentals (*UC Davis Arboretum All-Stars)*

❖82 Invasive Plants (*Cal-IPC Inventory)*

Photo | UC Davis Arboretum

Photo | Bob Case, Cal-IPC
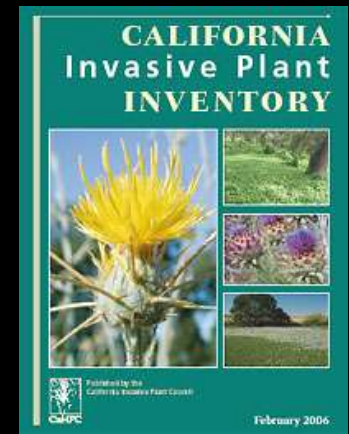
Species categorization

Species	Designation	Listed
Acacia boormanii	Non-Inv.	All-Star
Acacia dealbata	Limited	Cal-IPC; moderate
Acacia melanoxylon	Moderate	Cal-IPC; limited
Acca sellowiana (Feijoa sellowiana)	Non-Inv.	All-Star
Acer rubrum	Non-Inv.	---
Acroptilon repens	High	CDFA, Cal-IPC; moderate
Aegilops triuncialis	High	CDFA, Cal-IPC; high
Ageratina adenophora	Limited	Cal-IPC; moderate
Arbutus 'Marina'	Non-Inv.	All-Star

Rankings:
- High
- Moderate
- Limited
- Non-Invasive

Listed by:
- UCD Arboretum
- CDFA
- CISAC
- Cal-IPC

WRA screening procedure (data collection)

Protocol by Gordon et al. 2010

Comparison of Australian and PlantRight WRA models

- Model accuracy (*avg. scores +/-SD*)
- Rate of false positives and false negatives
- Compare scores for each species to the apriori invasive ranking
- Compared time to complete WRA evaluation (Student's T-test)
- Model performance (Receiver Operating Characteristic (ROC) curve analysis)

Results-*Model comparison and performance*

Australian WRA

PlantRight WRA

Question Category Pheloung	# Questions Pheloung	Question Category Plant Right	# Questions Plant Right
Domestication/cultivation	3		
Climate & Distribution	5	Climate match	2
Weed elsewhere	5	Invasive History	4
Undesirable traits	12	Growth rate; Impacts	5
Plant type	4		

Reproduction
  - vegetative (1)
  - sexual (8)
	9	Reproductive Strategies
		  - vegetative (5)
		  - sexual (5)
			10

Dispersal mechanisms	8	Dispersal	4
Persistence attributes	3	Difficulty of control	2
Total	**49**		**27**
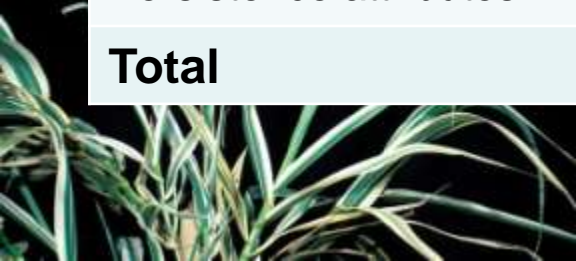
Results-*Model comparison and performance*

PlantRight WRA
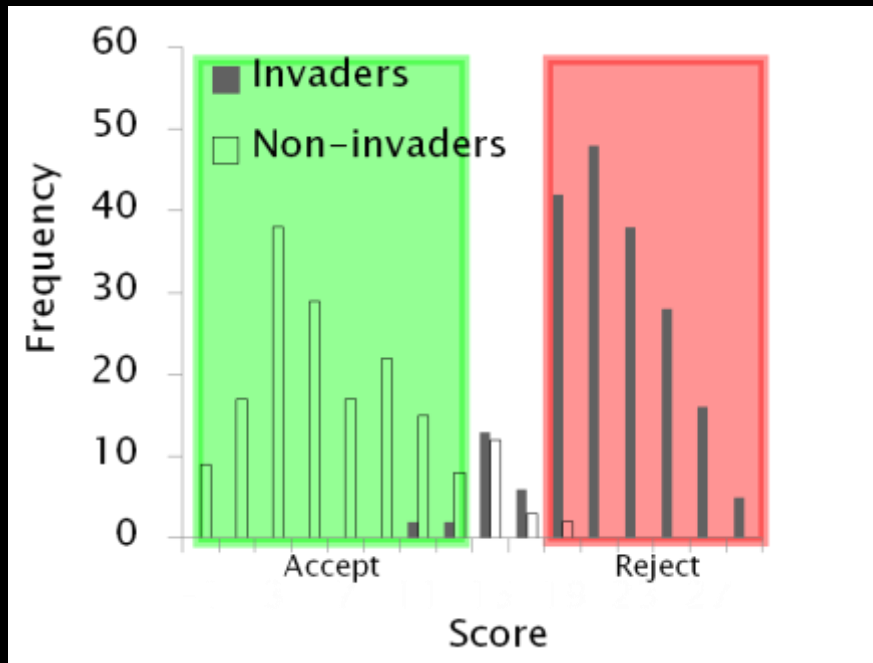
Reject (Invasive) = >19
Accept (Non-invasive = <14
Evaluate Further = 15-18

Australian WRA
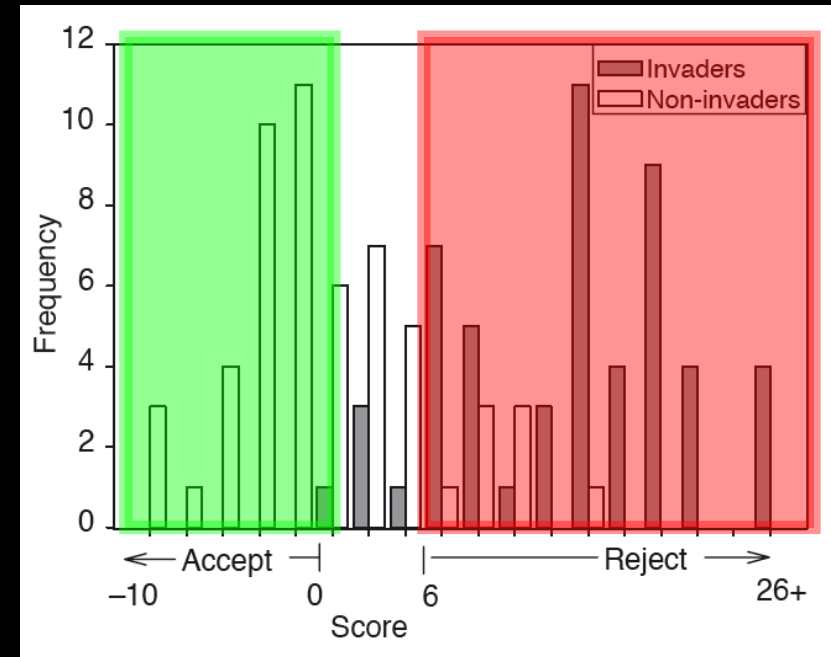
Reject (Invasive) = >6
Accept (Non-invasive = <1
Evaluate Further = 1-6

Number of plants screened

No. of species evaluated	Australian WRA			PlantRight WRA		
	Eval. #1	Eval. #2	Eval. #3	Eval. #1	Eval. #2	Eval. #3
All Invasive	79	81	81	79	81	81
Highly Invasive	33	33	33	33	33	33
Moderately Invasive	26	26	26	26	26	26
Limited Invasiveness	20	22	22	20	22	22
Non-Invasive	48	93	96	48	93	96
Total # of plants screened	**127**	**174**	**177**	**127**	**174**	**177**

Average time to complete WRA

16% reduction   **4% reduction**   **3% reduction**

- Pheloung
- Plant Right

Minutes

100 · 80 · 60 · 40 · 20 · 0

64.2 · 54.2 · 92.7 · 89.4 · 50.1 · 49.3

Evaluator #1 · Evaluator #2 · Evaluator #3
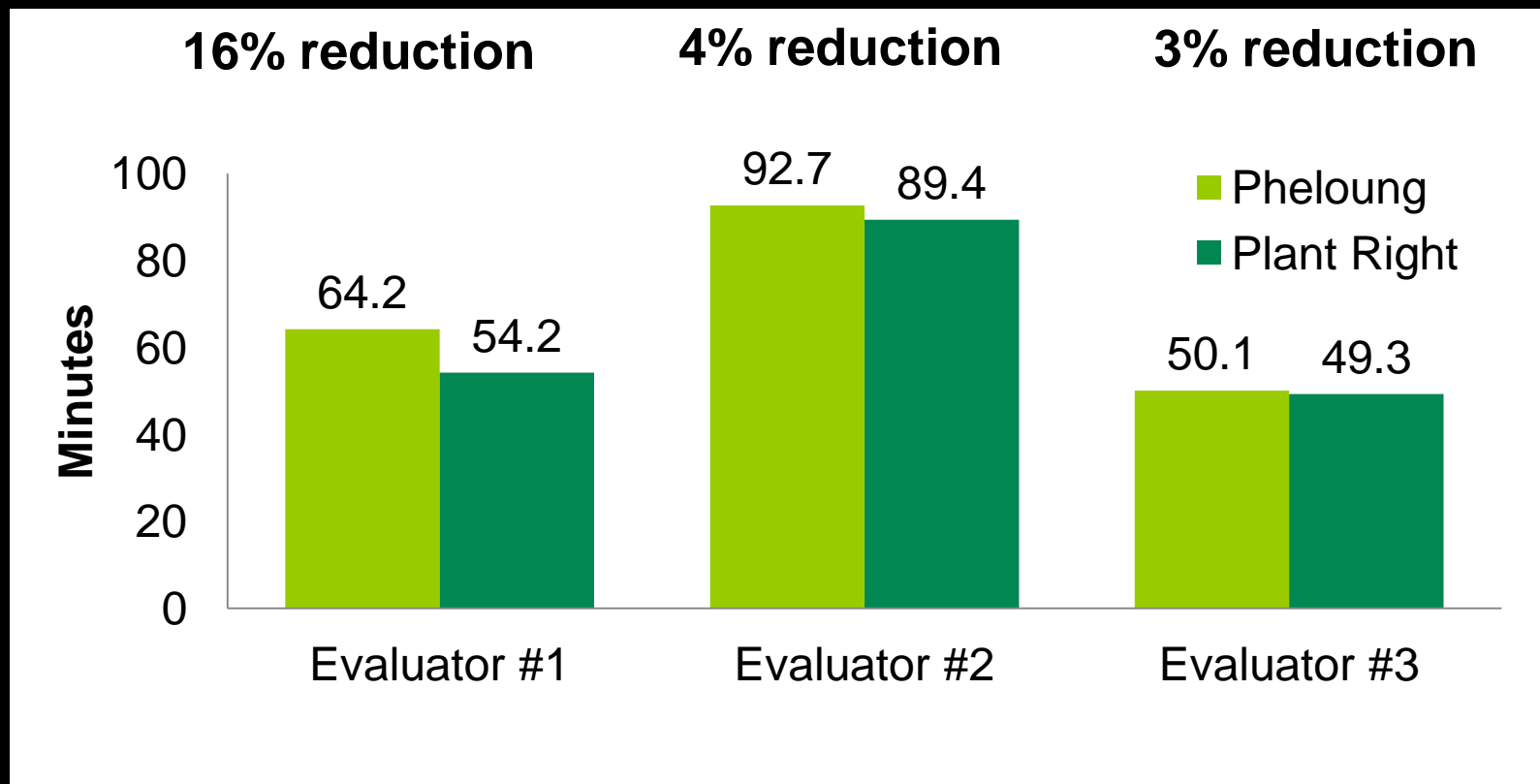
Average WRA score + standard deviation

Average score +/- SD	Australian WRA			PlantRight WRA		
	Eval. #1	Eval. #2	Eval. #3	Eval. #1	Eval. #2	Eval. #3
All Invasive	22.4 ± 4.6	20.9 ± 6.0	24.7 ± 5.4	23.1 ± 3.0	21.4 ± 3.6	20.7 ± 4.4
Highly Invasive	22.7 ± 4.0	23.7 ± 4.2	26.7 ± 5.8	24.1 ± 2.1	23.2 ± 3.0	23.4 ± 2.8
Moderately Invasive	21.6 ± 4.9	20.7 ± 6.6	24.0 ± 5.0	22.5 ± 3.2	21.0 ± 3.5	19.3 ± 4.0
Limited Invasiveness	23.0 ± 5.0	16.8 ± 5.2	22.4 ± 4.2	22.1 ± 3.5	19.2 ± 3.1	18.1 ± 4.8
Non-Invasive	6.7 ± 6.8	-0.2 ± 4.9	10.0 ± 5.1	9.6 ± 4.8	5.0 ± 4.1	8.5 ± 3.5

Accuracy – invasive categories lumped

	#1	#2	#3
Plant Right Model			
% accuracy for non-invasive	100	98	99
% accuracy for invasive	97	99	88
Need Further Evaluation			
# non-invasive	4	9	4
# invasive	11	1	14
Pheloung Model			
% accuracy for non-invasive	88	24	4
% accuracy for invasive	100	100	100
Need Further Evaluation			
# non-invasive	24	15	12
# invasive	1	0	1

% of the time the WRA model categorized a plant as **invasive**

% Reject	Australian WRA			PlantRight WRA		
	Eval. #1	Eval. #2	Eval. #3	Eval. #1	Eval. #2	Eval. #3
All Invasive	100	100	100	99	98	88
Highly Invasive	100	100	100	100	100	100
Moderately Invasive	100	100	100	100	96	83
Limited Invasiveness	100	100	100	95	93	71
Non-Invasive	75	12	96	5	0	0
*excludes evaluate further						

*% of the time the WRA model categorized a plant as **non-invasive***

% Accept	Australian WRA			PlantRight WRA		
	Eval. #1	Eval. #2	Eval. #3	Eval. #1	Eval. #2	Eval. #3
All Invasive	0	0	0	1	2	12
Highly Invasive	0	0	0	0	0	0
Moderately Invasive	0	0	0	0	4	17
Limited Invasiveness	0	0	0	5	7	29
Non-Invasive	25	88	4	95	100	100

*excludes evaluate further

Species miscategorized by PlantRight WRA

Category	Evaluator #1	Evaluator #2	Evaluator #3
Moderately Invasive species accepted	None	*Salsola paulsenii*	*Hedera canariensis* *Piptatherum miliaceum* *Verbascum thapsus*
Limited Invasiveness species accepted	*Stipa capensis*	*Stipa capensis*	*Cakile maritima* *Cotoneaster pannosus* *Erigeron karvinskianus* *Sollya heterophylla* *Stipa capensis*
Non-invasive species rejected	*Phormium tenax*	None	None

% of the time the WRA model categorized a plant in ***evaluate further*** *category*

% Evaluate Further	Australian WRA			PlantRight WRA		
	Eval. #1	Eval. #2	Eval. #3	Eval. #1	Eval. #2	Eval. #3
All Invasive	0	1	0	1	14	19
Highly Invasive	0	0	0	0	3	6
Moderately Invasive	0	0	0	4	12	31
Limited Invasiveness	0	5	0	0	32	23
Non-Invasive	31	27	17	19	4	4

Conclusions

Region	Study	Number of plants assessed	% Accuracy- invasive plants	% Accuracy- non-invasive plants
Australia	Pheloung et al (1999)	370	90	60
Hawaii, Pacific Islands	Daehler et al (2004)	192	95	66 (85 with secondary screening)
Czech Republic	Křivánek and Pyšek (2006)	180 (woody)	100	64 (83 with secondary screening)
Japan (Bonin Islands)	Reprinted in Gordon et al (2008a)	130	93	64
Florida	Gordon et al (2008b)	158	92	73
Spain	Gassó et al (2010)	197	94	21 (casual speices)
Italy	Crosti et al (2010)	20	93	75
various	Gordon et al (2008a)	Average across multiple studies	90	70 (77 with secondary screening)
California	**Australian WRA**	68-127 **(174)**	**100**	**39**
California	**Plant Right WRA**	68-127 **(174)**	**95**	**99**

- Complete statistical analyses for this study, submit paper
- Create rapid pre-screening tool for screening large plant inventories
- Refine WRA to screen plants at the subspecies level (cultivars and hybrids)
- Incorporate Climex climate matching into WRA tool to evaluate the regional suitability of plants
- Use rapid pre-screening WRA tool to evaluate the common ornamental plants in California

Contact

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