

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

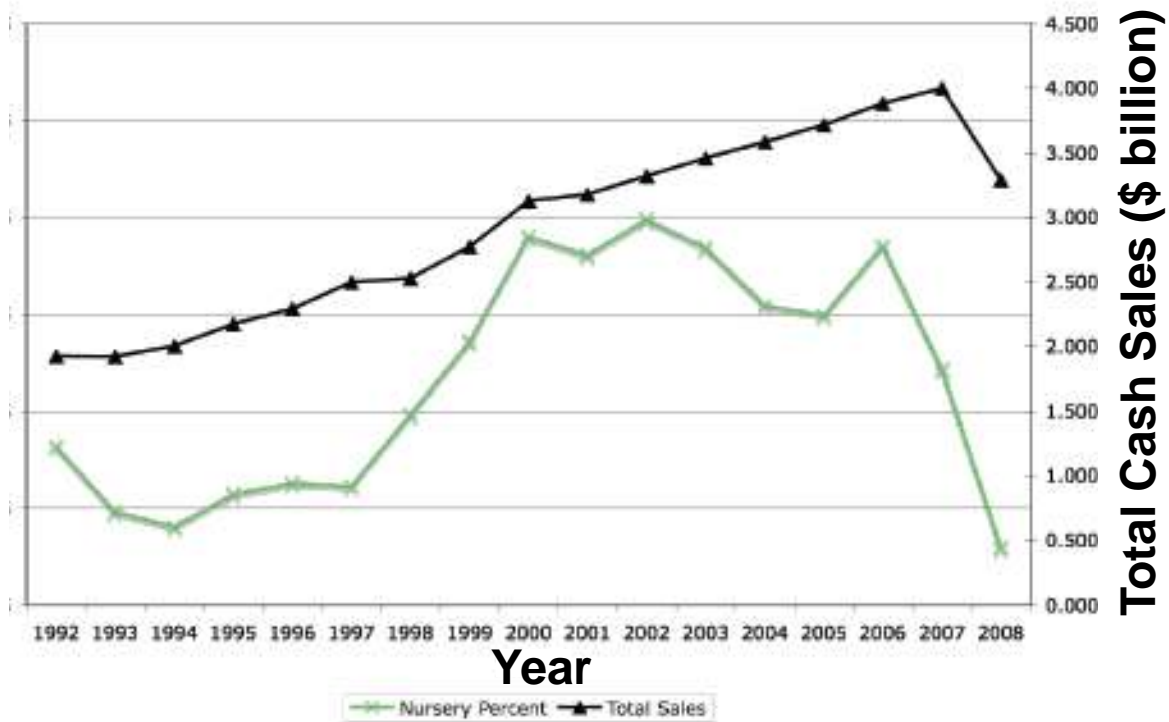
Introduction-*Goals of Study*

- 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



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)



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



Introduction-Nursery Industry and Invasive Plants

Drivers of new plant introductions

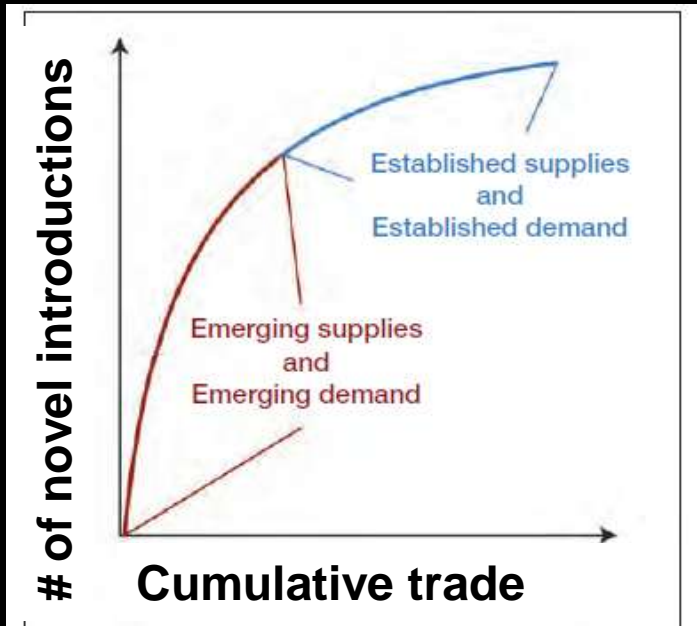
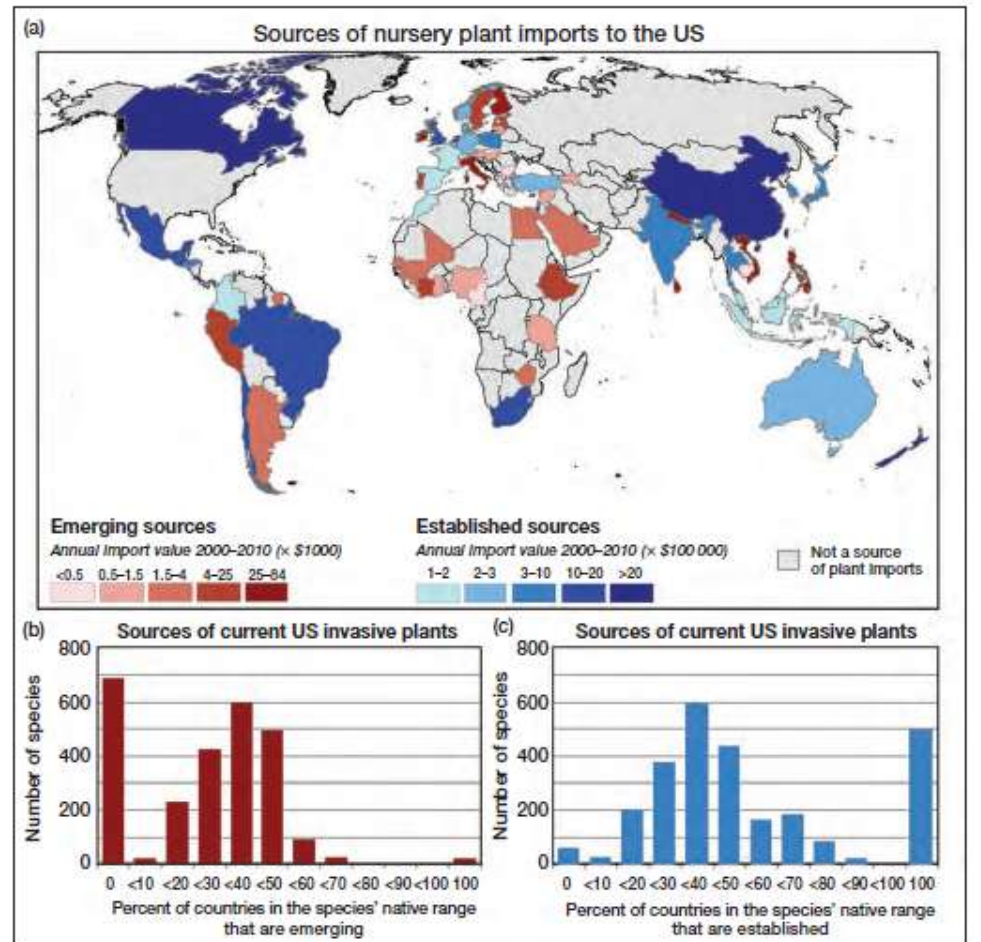


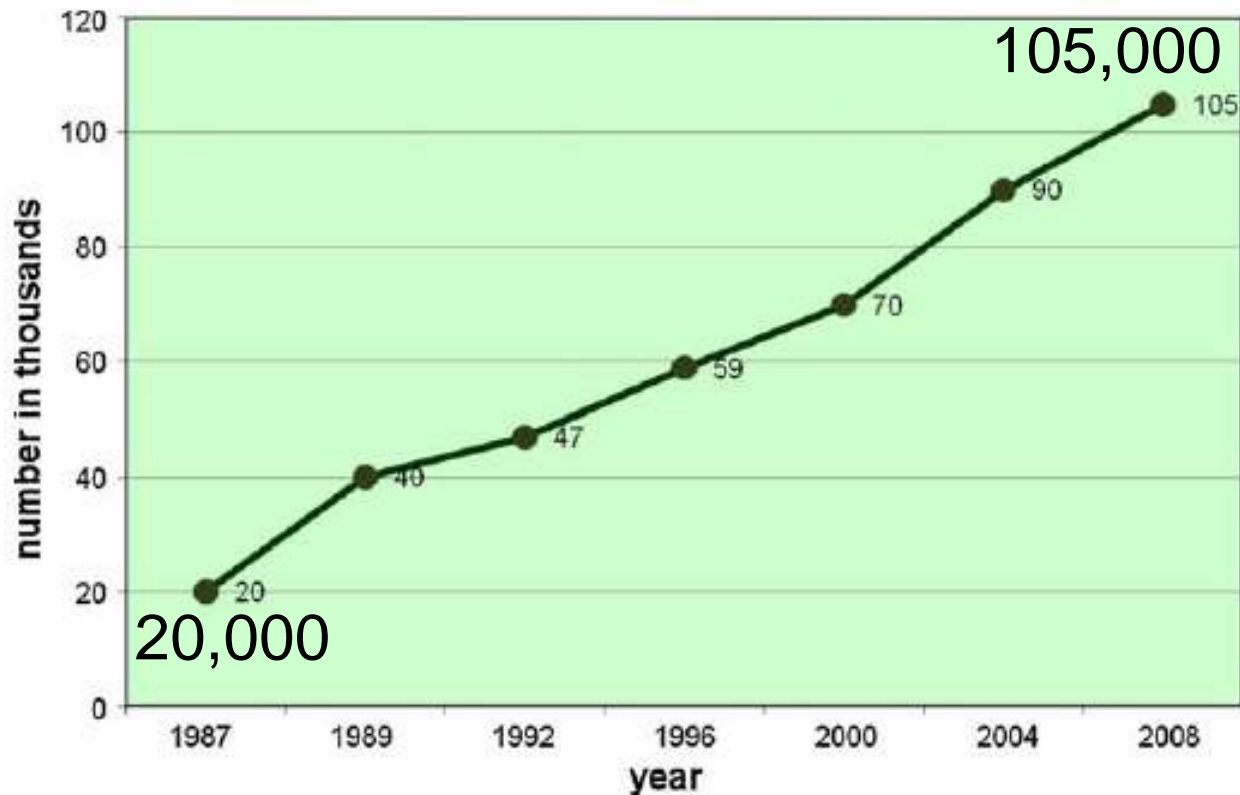
Figure 1. New influxes of non-native invasive species are most prominent in the early stages of new trade partnerships. With established trade partners, invasions continue to rise with increase in trade, but at a slower rate. Adapted from Levine and D'Antonio (2003).

Sources of nursery plant imports to the US

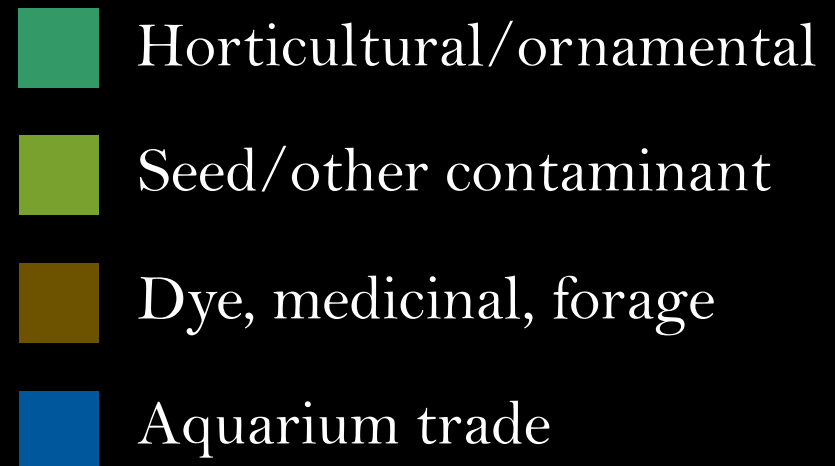
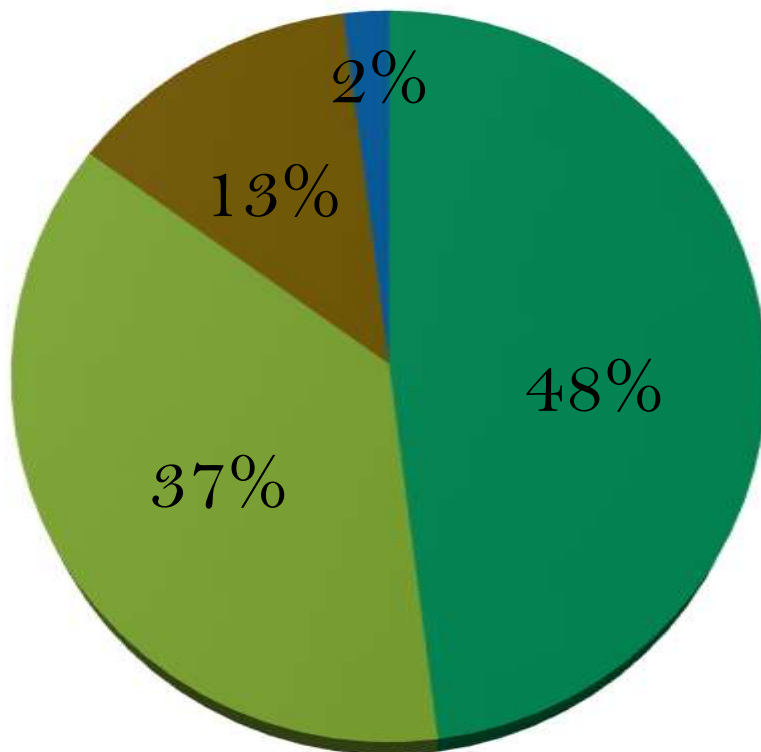


Rate of new plant introductions

Number of commercially available cultivars (1987 to 2008)



What % of invasive plants were introduced through horticulture into CA?



What Traits Make a Plant Invasive?

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

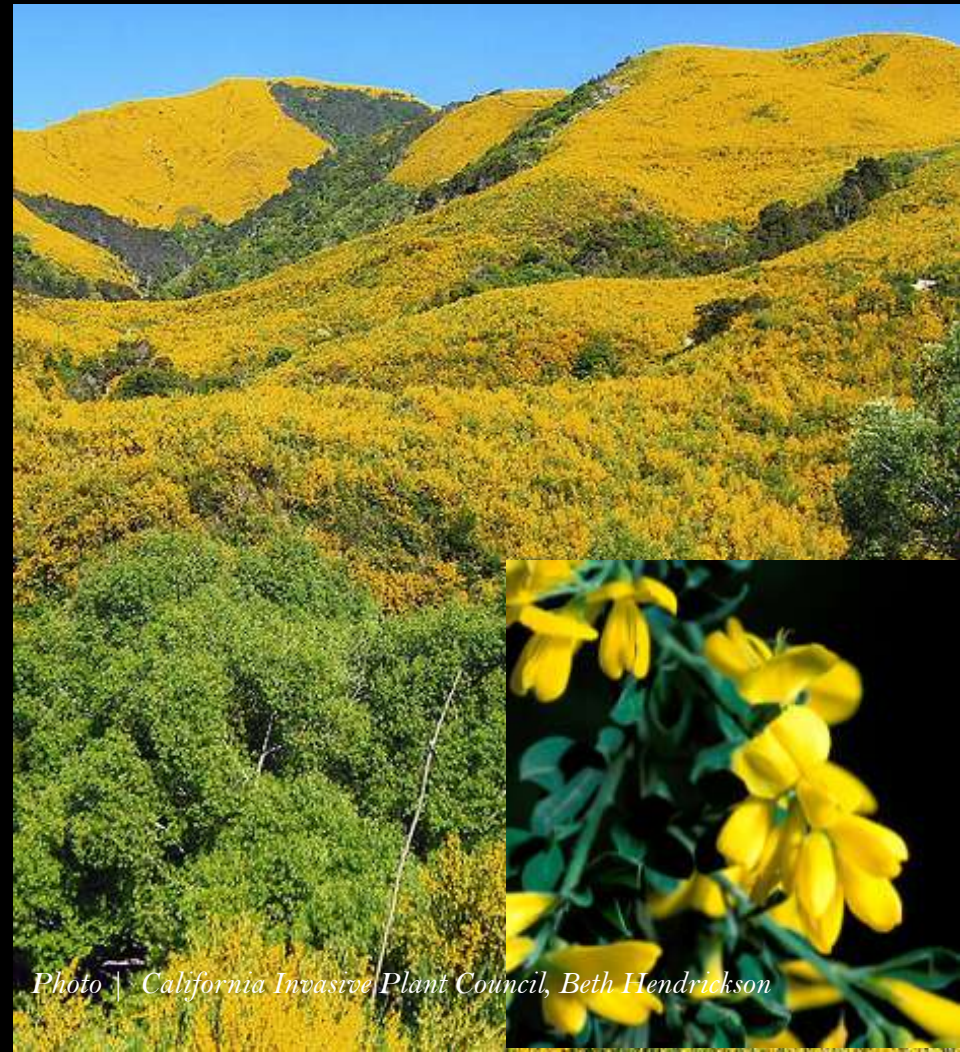


Photo | California Invasive Plant Council, Beth Hendrickson

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

Pre-entry weed risk assessment				Outcome Score	Example
Protect	Get	Species	Help	Protect	
Risk	Score	Update	Save	Report	
A. Biogeography/Historical					
1	1.01	Is the species highly domesticated?			V
1	1.02	Has the species become naturalized where grown?			M
1	1.03	Does the species have a wide distribution?			M
2	2.01	Species is not to Australia at introduction (low, intermediate, high)			2
2	2.02	Quality of climate match data (low, intermediate, high)			V
2	2.03	Best climate match by environmental variables?			V
2	2.04	Native or introduced in regions with extended dry periods?			V
2	2.05	Does the species have a history of invasion elsewhere outside its native range?			V
B. Weed Elsewhere					
3	3.01	Naturalized beyond native range?			M
3	3.02	Established by introduction?			M
3	3.03	Used in agriculture?			N
3	3.04	Invaded natural areas?			N
3	3.05	Invaded wetlands?			N
C. Biology/Ecology					
4	4.01	Produces spores, berries or seeds?			M
4	4.02	Aerially dispersed?			M
4	4.03	Unpalatable to grazing animals?			M
4	4.04	Unpalatable to grazing animals?			M
4	4.05	Toxic to animals?			M
4	4.06	Host for introduced weed and pathogens?			M
4	4.07	Common origin or subspecies native to Australia?			V
4	4.08	Dispersal via human or animal movement?			V
4	4.09	Is a shade tolerant plant at some stage of its life cycle?			V
4	4.10	Grows on infertile soils?			V
4	4.11	Climber or smothering growth habit?			V
4	4.12	Forms dense thickets?			V
5	5.01	Annual?			M
5	5.02	One?			M
5	5.03	Highly fertile seeds?			M
5	5.04	Overwinter?			M
6	6.01	Presence of substantial reproductive failure in native habitat?			V
6	6.02	Produces viable seeds?			V
6	6.03	Herbivore naturally?			M
6	6.04	Self-sufficiency or specialist?			M
6	6.05	Reproductive success in native habitat?			M
6	6.06	Reproduction by vegetative regeneration?			M
6	6.07	Minimum germination time (years)?			V
7	7.01	Propagules likely to be dropped accidentally (planting in heavily infested areas)?			V
7	7.02	Propagules dispersed intentionally by people?			V
7	7.03	Propagules likely to escape as a produce contaminant?			V
7	7.04	Propagules attached to wind dispersal?			N
7	7.05	Propagules with sharp seed?			N
7	7.06	Propagules in dispersal?			N
7	7.07	Propagules dispersed by other animals (potential)?			N
7	7.08	Propagules with sharp seed?			N
8	8.01	Perennial seed production (perennial)?			V
8	8.02	Survives first 6 months of propagation (perennial)?			V
8	8.03	Well controlled by herbicides?			V
8	8.04	Tolerant to herbicides, isolation of a herbicide?			V
8	8.05	Effective natural enemies present in Australia?			V
Outcome Score					
Example					
Total risk score of species					
Very positive					
Biogeography/Historical					
Biology/Ecology					
Weed elsewhere					
Undesirable traits					
Plant type					
Reproduction					
Dispersal mechanisms					
Persistence attributes					
Very negative					



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



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

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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 States' timeliness and accuracy in regulating potential

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

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



Australian Government

Department of Agriculture, Fisheries and Forestry
Biosecurity

WRA models – PlantRight

Section A) Evaluator Info		Section B) Grower Info	
Evaluator's Name:	Christiana Conner	Grower's Name:	N/A
Affiliation:	Sustainable Conservation	Title:	N/A
Telephone:	415-977-0360	Company:	N/A
Email:	conner@slonson.org	Telephone:	N/A
Date of Evaluation:	3/3/2011	Email:	N/A
Evaluation Time (hrs):	9:25 AM to 9:51 AM = 25 minutes	Address:	N/A

Section C) Plant Taxonomic Info:		Answer	Confidence Level (1-10)	Source(s) of Information
Scientific Name (Genus + species):	Carpobrotus edulis		9	Tropics
Synonyms (if any):	Carpobrotus edulis, Mesembryanthemum edulis		9	Tropics
Common Name(s):	Highway iceplant, hottentot fig, freeway iceplant, sea fig			Woods of California and Other Western States
Family:	Asclepiaceae		9	Tropics
Variety/Cultivar:	Unknown		-	-
Are there other varieties or cultivars, how many:	C. edulis var. chrysophthalmus, C. edulis subsp. Panziformis		9	Tropics

Section D) Plant Pre-screening Info:		Answer	Confidence Level (1-10)	Source/Notes/Comments
Has the taxon been assessed with WRA in California or in the biogeographical region?	Yes		9	CISAC, Cal-IPC
Is the taxon on an established invasive plant or noxious weed list for California?	Yes		9	CISAC, Cal-IPC
What plant materials are being evaluated? (seeds, root cuttings, whole plants, cuttings or bulbs):	Plant			
What country or region is the plant material from?	Unknown		-	-
What is the plant's native country or range?	Native to South Africa		9	Weeds of California and Other Western States
Is the plant present in California?	Yes-naturalized throughout coastal CA, Channel Islands, mostly to 100m.		9	Weeds of California and Other Western States
Is the plant commercially available in California?	Yes		9	Sunset Western Garden Book

E) Impacts on Native Plants/Animals				
(g) Length of flowering - Seed production continues for more than 3 months each year? (or more than one time per year)	Y	T	Weeds of California and Other Western States	9: Flowers from April to October, sometimes year-round, but peaks in spring.

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

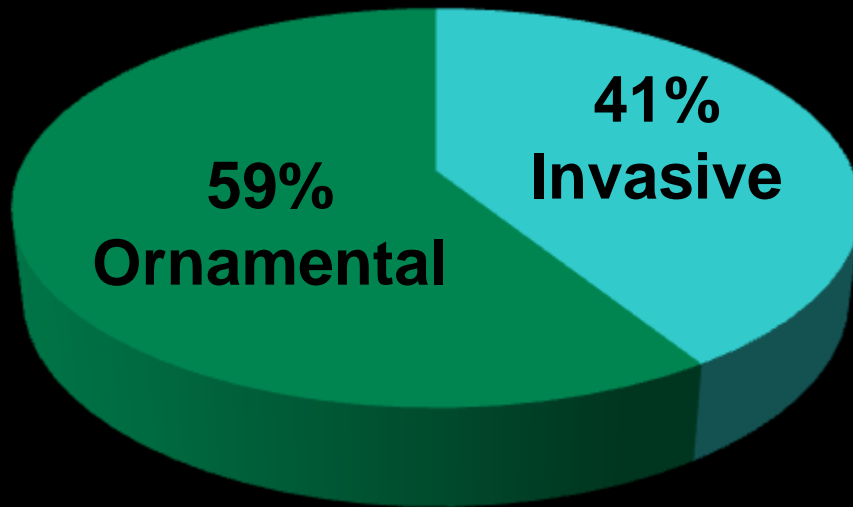


Goals for the PlantRight WRA model

- 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



Species selection



- 177 plants total screened

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

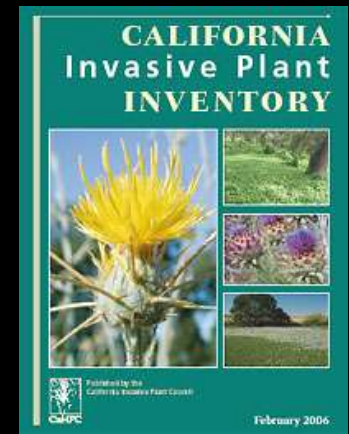
- ❖ 82 Invasive Plants (*Cal-IPC Inventory*)



Photo | UC Davis Arboretum



Photo | Bob Case, Cal-IPC



Species categorization

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

Rankings:

- High
- Moderate
- Limited
- Non-Invasive

Listed by:

- UCD Arboretum
- CDFA
- CISAC
- Cal-IPC



Materials - PlantRight WRA model validation

WRA screening procedure (data collection)

UC DAVIS UNIVERSITY LIBRARY

Google

Tropicos®

PlantRight Seebacher Weed Risk Assessment (WRA) form for comparison tests (not for distribution)

Section A) Evaluator Info

Evaluator's Name: Christina Conner
 Institution: Sustainable Conservation
 Telephone: 415-877-0380
 Email: conner@conservation.org
 Date of Evaluation: 9/9/2011
 Evaluation Time (hrs): 9:25 AM to 9:57 AM = 28 minutes

Section B) Grower Info

Grower's Name: [redacted]
 Title: [redacted]
 Company: [redacted]
 Telephone: [redacted]
 Email: [redacted]
 Address: [redacted]

Section C) Plant Taxonomic Info

Scientific Name (Genus + species)	Answer	Confidence Level (1-5)	Source(s) of Information
<i>Carpobrotus edulis</i>		5	Tropicos
<i>Carpobrotus edulis</i> , <i>Messembryanthemum edulis</i>		5	Tropicos
Common Name(s)	Highway iceplant, hotarrot fig, freeway iceplant, sea fig	5	Woods of California and Other Western States
Family	Asclepiadaceae	5	Tropicos
Variety/Cultivar	Unknown	--	--
Are there other varieties or cultivars, how many?	<i>C. edulis</i> var. <i>chrysophthalma</i> , <i>C. edulis</i> subsp. <i>parviflorus</i>	5	Tropicos

Section D) Plant Pre-screening Info

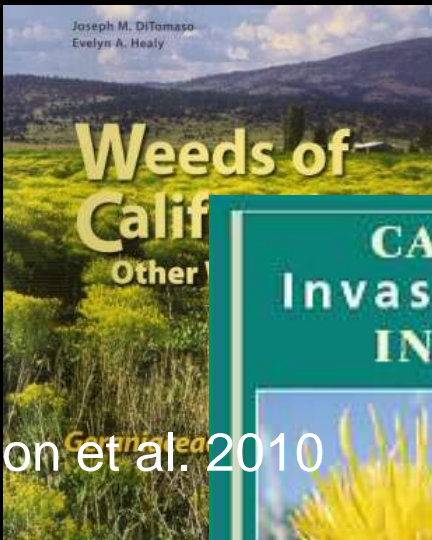
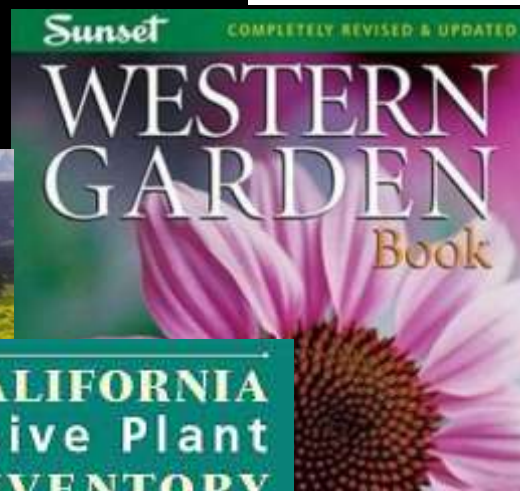
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Has the tax on been assessed with WRA in California or in the biogeographical region?	Yes	5	CSAC, Cal-IPC
Is the taxon on an established invasive plant or noxious weed list for California?	Yes	5	CSAC, Cal-IPC
What plant materials are being evaluated? (seeds, root cuttings, whole plants, cuttings or bulbs)	Plant	--	--
What country or region is the plant material from?	Unknown	--	--
What is the plant's native country or range?	Native to South Africa	5	Woods of California and Other Western States
Is the plant present in California?	Yes, naturalized throughout coastal CA, Channel Islands, mostly to 100m.	5	Woods of California and Other Western States
Is the plant commercially available in California?	Yes	5	Sunset Western Garden Book

At Risk: High

Flg Length of flowering: Seed production continues for more than 3 months each year? (or more than one time per year?)	Y	1	Woods of California and Other Western States	5	Flowers from April to October, sometimes year-round, but peaks in spring.

INVASIVE SPECIES COUNCIL OF CALIFORNIA
www.iscc.ca.gov

USDA
 cdfa
 CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE



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)

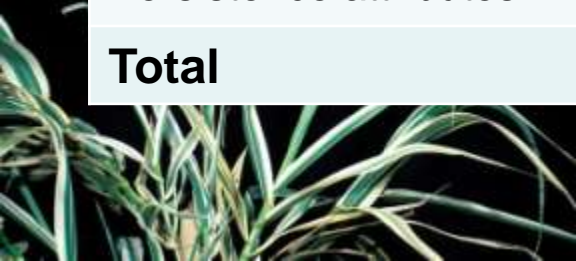


Results-Model comparison and performance

Australian WRA

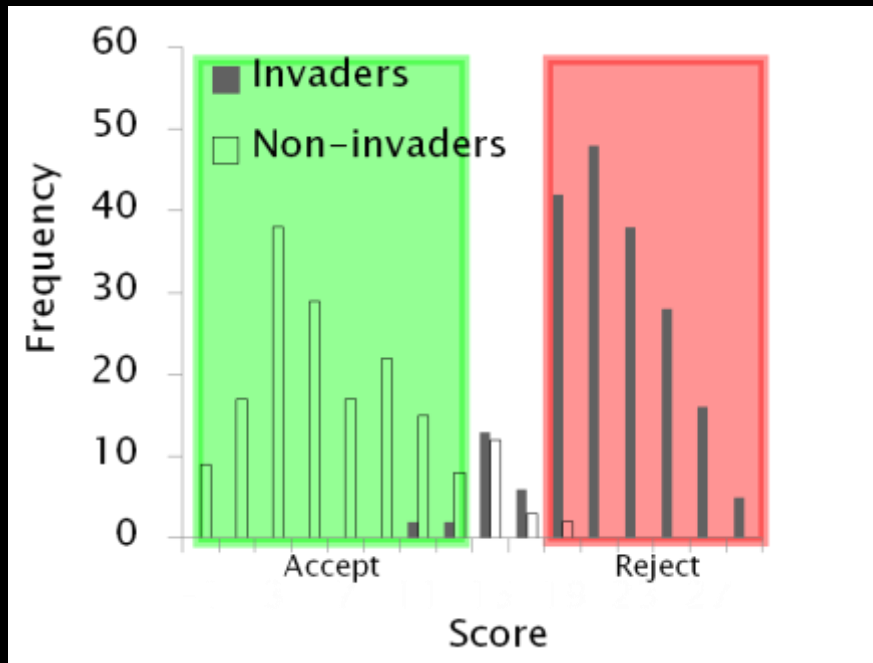
PlantRight WRA

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



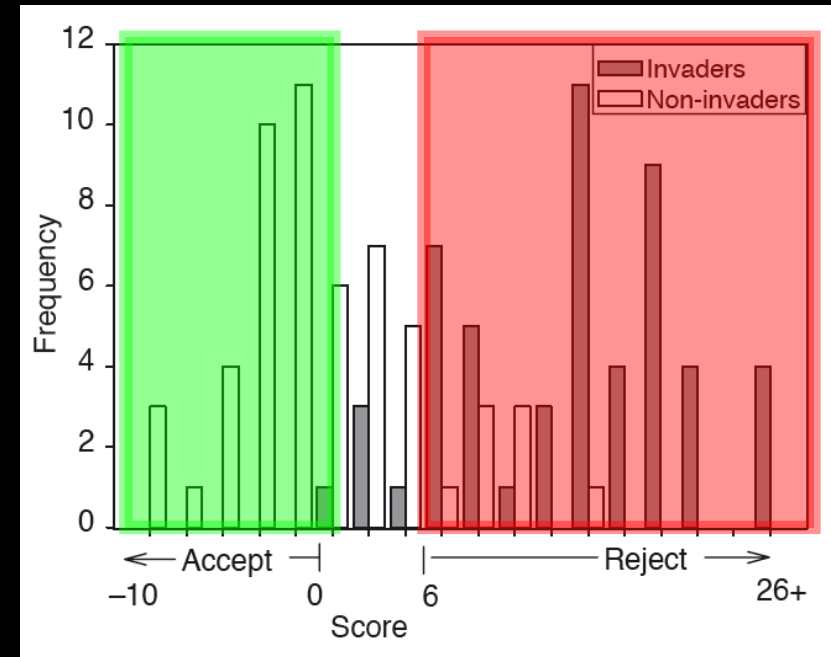
Results-Model comparison and performance

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

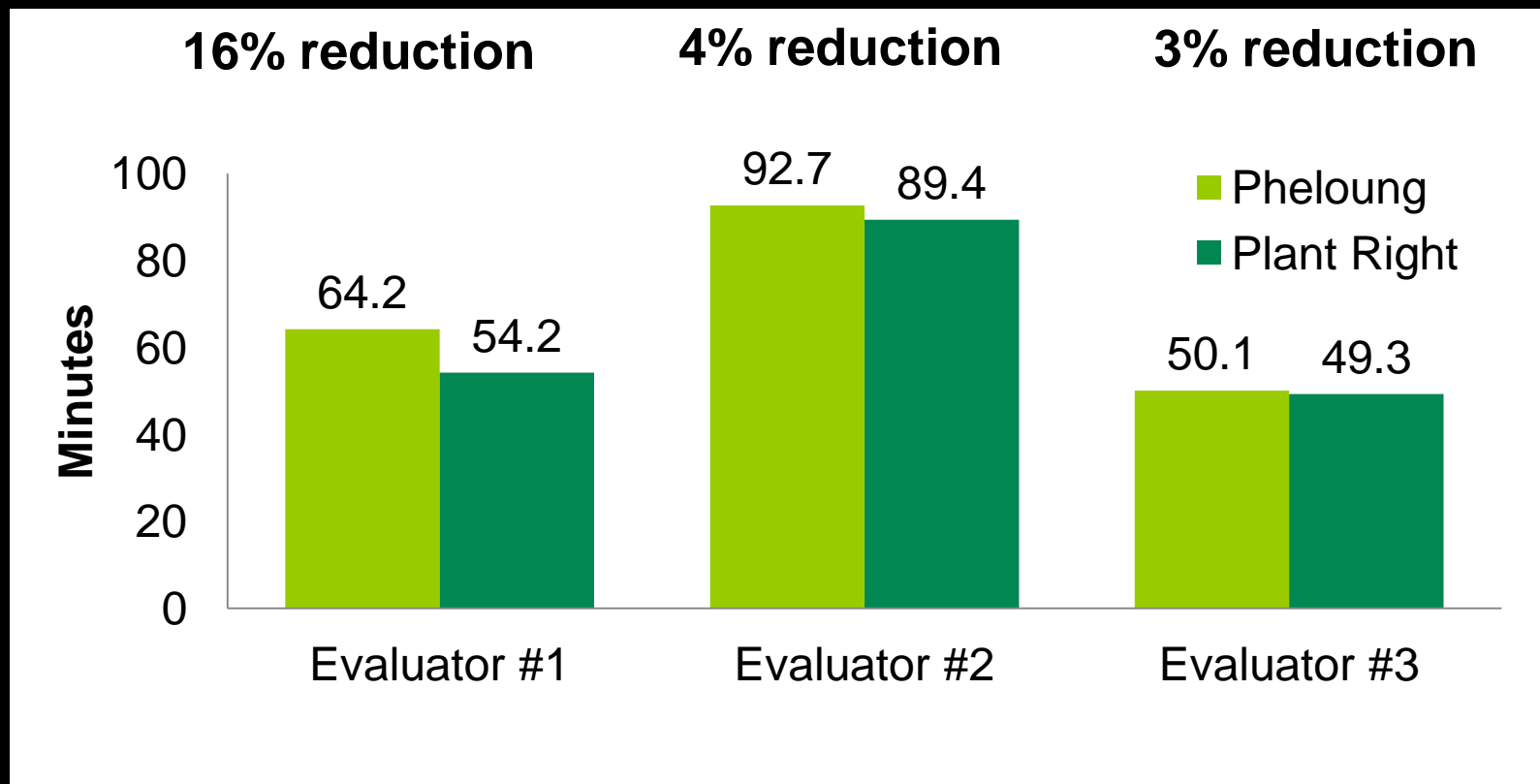
Results-Model comparison and performance

Number of plants screened

No. of species evaluated	<i>Australian WRA</i>			<i>PlantRight WRA</i>		
	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



Results-Model comparison and performance

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

Results-Model comparison and performance

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

Results-Model comparison and performance

*% 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
<i>All Invasive</i>	100	100	100	99	98	88
<i>Highly Invasive</i>	100	100	100	100	100	100
<i>Moderately Invasive</i>	100	100	100	100	96	83
<i>Limited Invasiveness</i>	100	100	100	95	93	71
<i>Non-Invasive</i>	75	12	96	5	0	0

*excludes evaluate further



Results-Model comparison and performance

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

% Accept	Australian WRA			PlantRight WRA		
	Eval.	Eval.	Eval.	Eval.	Eval.	Eval.
	#1	#2	#3	#1	#2	#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



Results-Model comparison and performance

Species miscategorized by PlantRight WRA

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

Results-Model comparison and performance

% 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

Next Steps

- 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



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