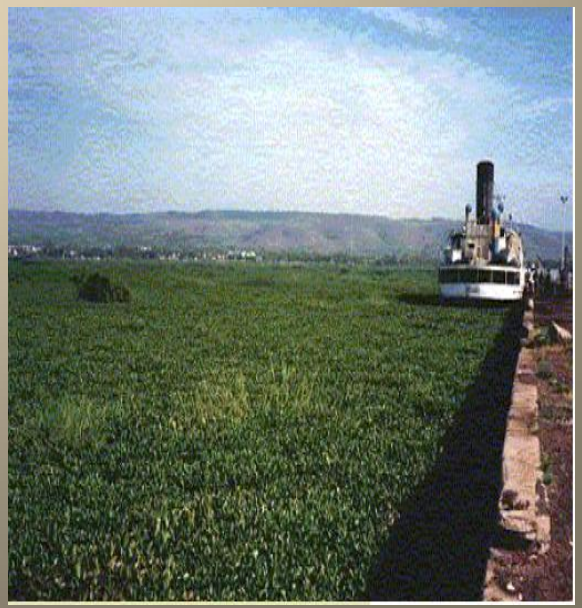
Nile Perch (*Lates niloticus*)

Strawberry Guava
(*Psidium cattleianum*)

Impacts of exotic introductions on populations and habitats

Brown Tree Snake (*Boiga irregularis*)

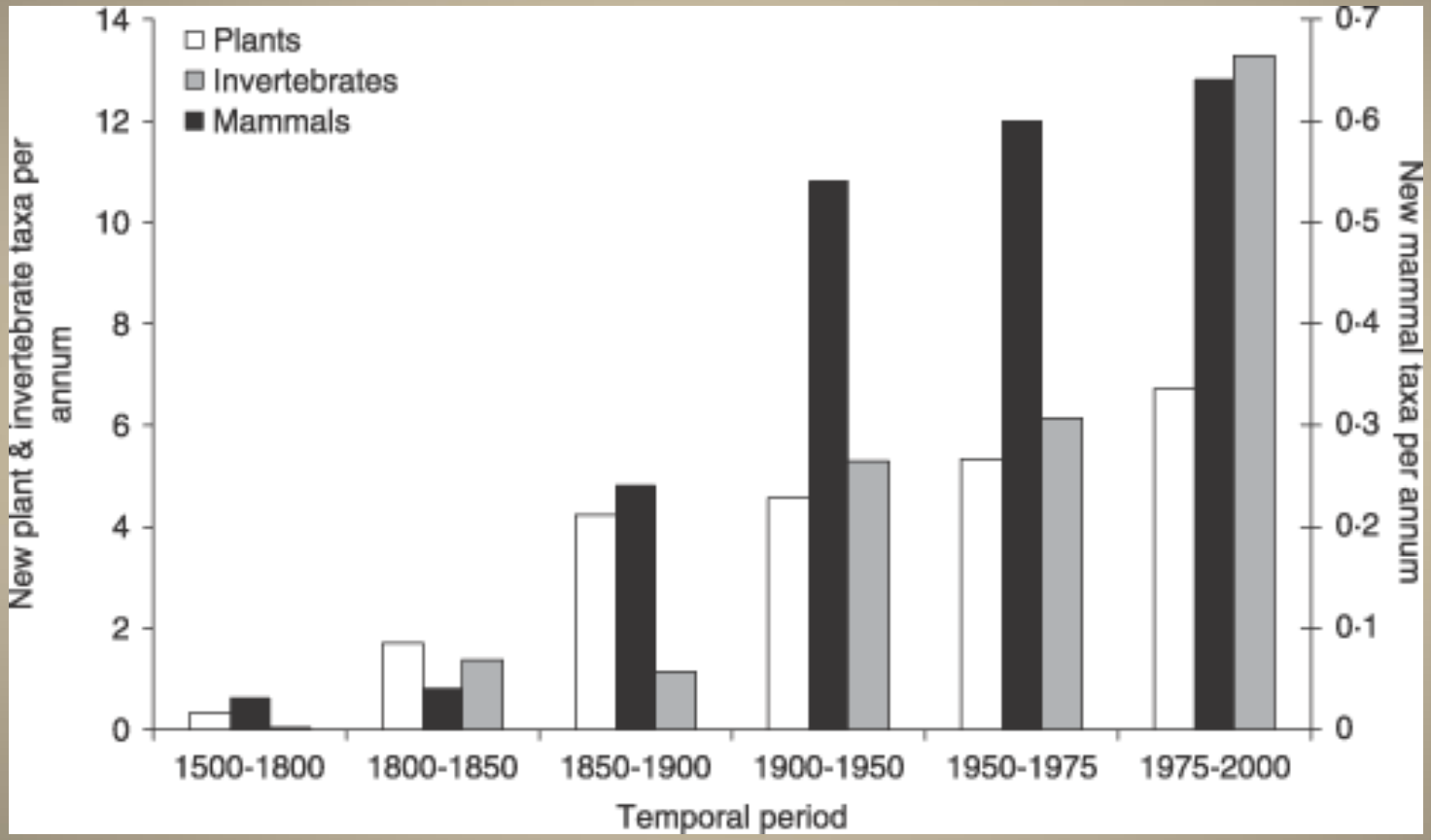
Water Hyacinth (*Eichhornia crassipes*)



Lecture plan

- Changes in movement of organisms over time
- The principle routes for species introduction to new areas
- Impacts on native species and communities
- Why do some species become invasive, while other don’t ?
  - Susceptible habitats
  - Characteristics of a successful invader
  - Rule-based risk assessment for species introductions

Annual rates of increase in the establishment of alien mammals and invertebrate in Europe since 1500 AD

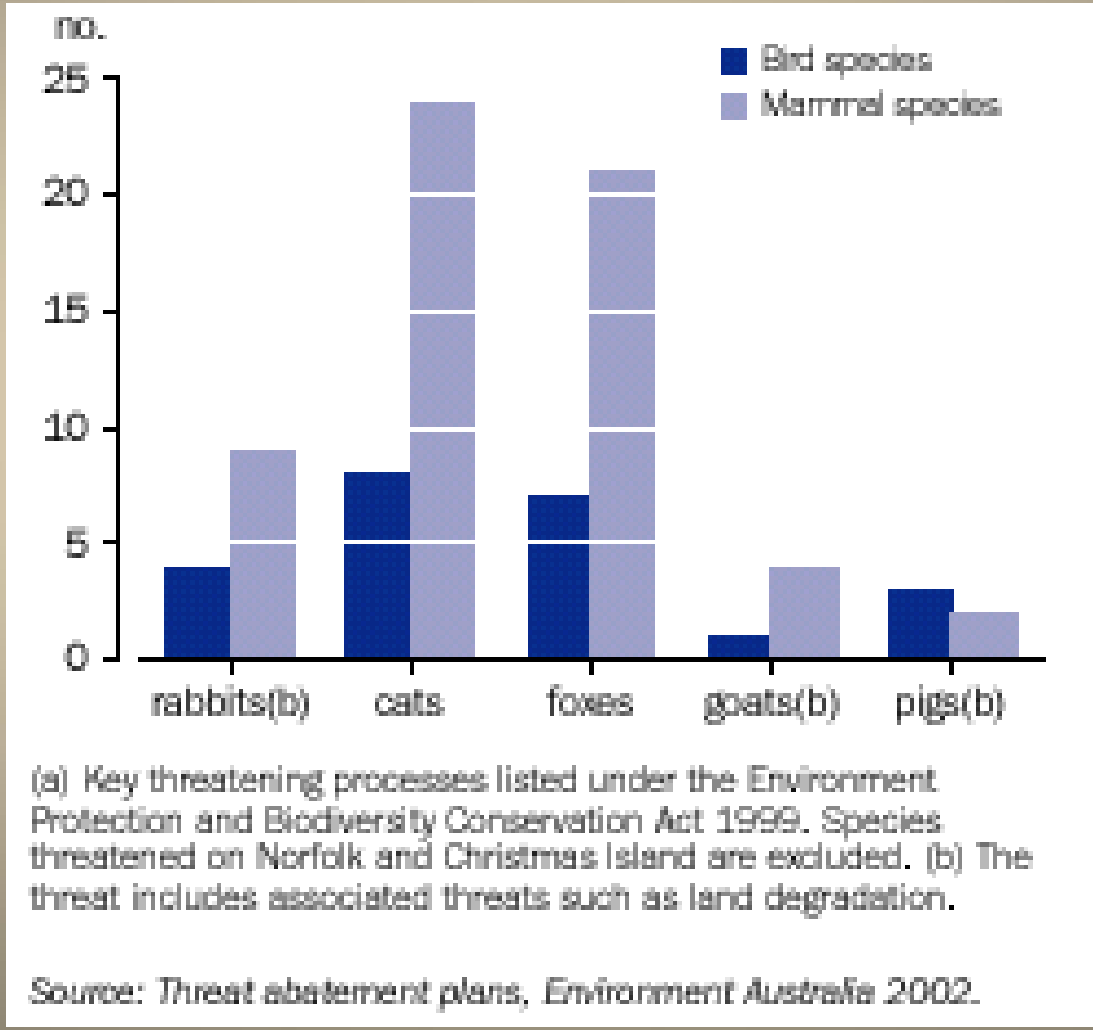


Hulme, P.E. (2009) Trade, transport and trouble: managing invasive species pathways in an era of globalization. Journal of Applied Ecology, 46, 10-18.
DOI: 10.1111/j.1365-2664.2008.01600.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2664.2008.01600.x/full#f1

How devastating ?
Number of extinctions from known causes

	Habitat loss	Over-exploitation	Species introduction	Other
Mammals	19	23	20	1
Birds	20	11	22	2
Reptiles	5	32	42	0
Fishes	35	4	30	4
% of known extinctions	28.3	27.1	**42.3**	2.3

Top five invasive animal species in Australia



(a) Key threatening processes listed under the Environment Protection and Biodiversity Conservation Act 1999. Species threatened on Norfolk and Christmas Island are excluded. (b) The threat includes associated threats such as land degradation.

Source: *Threat abatement plans, Environment Australia 2002.*

The principle routes for species introduction to new areas

1. Colonisation by people

Rabbits

Polynesian Rat
- Oahu's `Ewa plains, Hawaii
- Extinction of Avifauna

2. Horticulture, agriculture and forestry

Numerous Pinus *species*

Leucaena leucocephala

Lantana camara

Role of Botanic Gardens in Species Introductions

Table I. Botanic garden collections inferred as sources for the introduction, early cultivation or dissemination of 19 out of 34 plants listed to be among the world's worst invasive species[a]. Species nomenclature follows [17]

Botanic garden	Hotspot[b]	Date	Species invading	Refs
Pamplemousses, Mauritius	MIOI	1810	*Psidium cattleianum*	[34]
		1785	*Hiptage benghalensis*	
		1837	*Lantana camara*	
		1863	*Schinus terebinthifolius*	
Curepipe, Mauritius	MIOI	1890	*Ligustrum robustum*	[35]
Peradeniya, Sri Lanka	WGSL	1894	*Clidemia hirta*	[5]
		1905	*Eichhornia crassipes*	
		1926	*L. camara*	
		1888	*Miconia calvescens*	
		1888	*Ulex europaeus*	
Calcutta, India	-	1840	*Chromolaena odorata*	[5]
		1809	*L. camara*	
Darwin, Australia	-	1890	*Mimosa pigra*	[5]
Brisbane, Australia	-	1932	*H. benghalensis*	[36]
		1924	*S. terebinthifolius*	[37]
Singapore, Singapore	S	1903	*E. crassipes*	[38]
		1910	*Spathodea campanulata*	
Bogor, Indonesia	S	1894	*E. crassipes*	[39]
		1949	*Mikania micrantha*	
		1920	*Cecropia peltata*	
Wahiawa, Hawaii	PM	1941	*C. hirta*	[5]
Harold L. Lyon Arboretum, Hawaii	PM	1920	*Ardisia elliptica*	[40]
		1920	*P. cattleianum*	
Harrison Smith, Tahiti	PM	1937	*M. calvescens*	[5]
Yahoué, New Caledonia	NC	1870	*L. camara*	[41]
Amani, Tanzania	EAM	1930	*C. hirta*	[5]
		1930	*L. camara*	
		1930	*S. campanulata*	
Limbe, Cameroon	GFWA	1910	*C. peltata*	[5]
Kisantu, Zaire	GFWA	1900	*C. odorata*	[5]
Cape Town, South Africa	CFR	1830	*Acacia mearnsii*	[6]
Mayaguez. Puerto Rico	CI	1930	*Melaleuca quinquenervia*	[5]
Cinchona, Jamaica	CI	1883	*Hedychium gardnerianum*	[42]
		1883	*Cinchona pubescens*	

[a]Data are also provided regarding the putative date of introduction and the location of the site within a biodiversity hotspot.

[b]Global biodiversity hotspot codes: CFR, Cape floristic region; CI, Caribbean islands; EAM, Eastern Afro-montane; GFWA, Guinean forest of West Africa; MIOI, Madagascar and Indian Ocean islands; NC, New Caledonia; PM, Polynesia and Micronesia; S, Sundaland; WGSL, Western Ghats and Sri Lanka.

Eichhornia crassipes in Vietnam

Strawberry Guava (*Psidium cattleianum*) forming an impenetrable thicket in Hawaii

3. Accidental transportation

Ballast

North Pacific Seastar

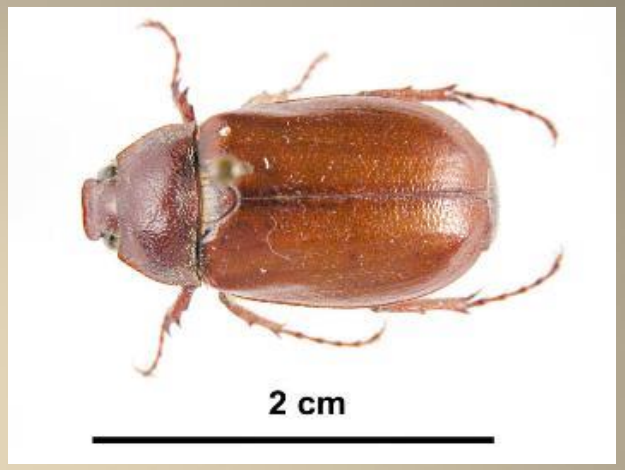
Stowaways

Avian Pox – transferred from Chicken to native birds in Hawaii

4. Biological Control

Cane toad (*Bufo marinus*) – north Queensland

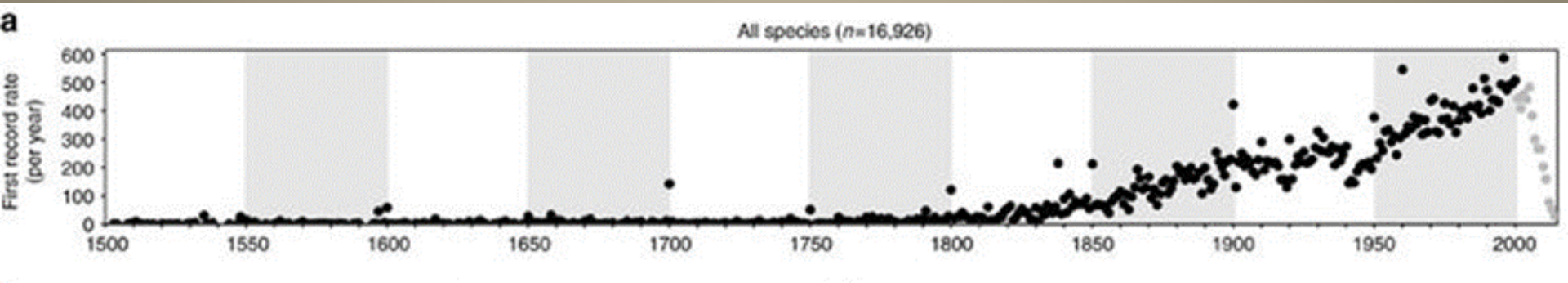
Distribution of Cane Toads in Australia



The sugar cane industry introduced 60,000 toads to control two pests of sugar cane, the Grey-backed Cane beetle and the Frenchie beetle. The cane toad was not effective as a biological control agent and it is considered a pest in Australia because they:

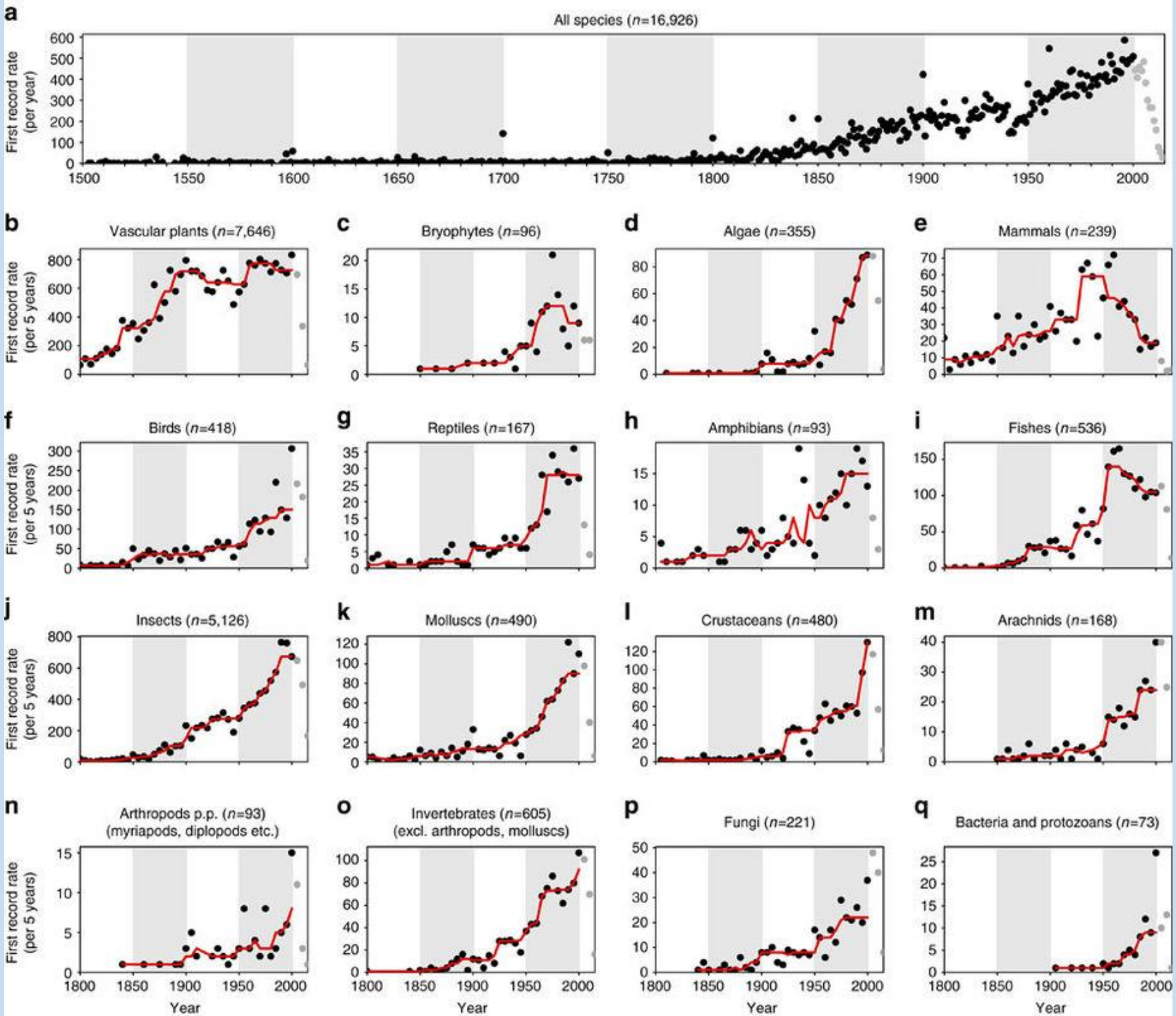
- poison many native animals, pets and the occasional humans with their toxins
- prey on native fauna
- compete for food with vertebrate insectivores such as small skinks
- may carry diseases that are can be transmitted to native frogs and fishes.

When were non-native species first recorded ?



- Database of 45,813 first records of 16,926 established alien species
- Annual rate of first records worldwide has increased during the last 200 years, with 37% of all first records reported most recently (1970–2014)
- Inter-continental and inter-taxonomic variation can be largely attributed to the diaspora of European settlers in the nineteenth century and to the acceleration in trade in the twentieth century
- Highlights that past efforts to mitigate invasions have not been effective enough to keep up with increasing globalization

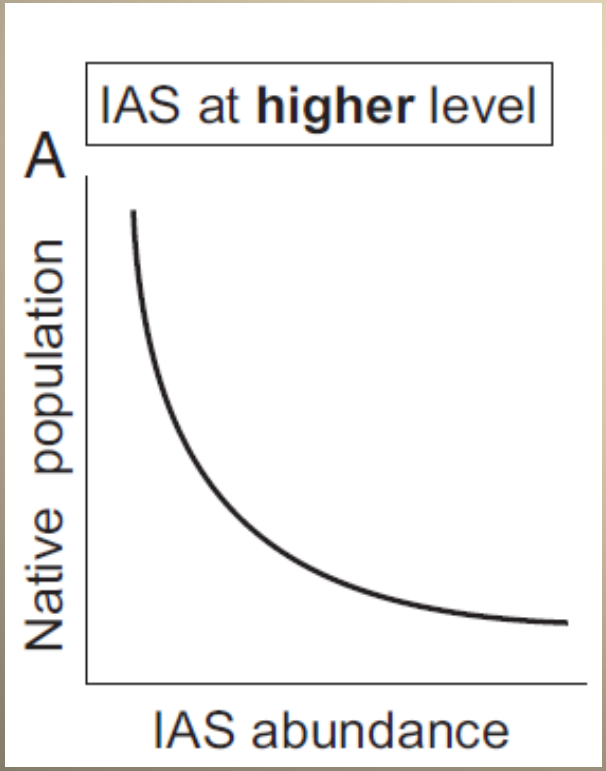
Seebens, H. et al. (2017) No saturation in the accumulation of alien species worldwide. *Nature Communications*. https://www.nature.com/articles/ncomms14435


a
All species (n=16,926)
First record rate (per year)
b
Vascular plants (n=7,646)
c
Bryophytes (n=96)
d
Algae (n=355)
e
Mammals (n=239)
First record rate (per 5 years)
f
Birds (n=418)
g
Reptiles (n=167)
h
Amphibians (n=93)
i
Fishes (n=536)
j
Insects (n=5,126)
k
Molluscs (n=490)
l
Crustaceans (n=480)
m
Arachnids (n=168)
n
Arthropods p.p. (n=93)
(myriapods, diplopods etc.)
o
Invertebrates (n=605)
(excl. arthropods, molluscs)
p
Fungi (n=221)
q
Bacteria and protozoans (n=73)
Year

Name some examples of non-native invasive species in the UK or your home country. How did it get here ? What impact(s) is it having ?

Impacts on native species and communities Hypotheses

IAS is a predator of the native

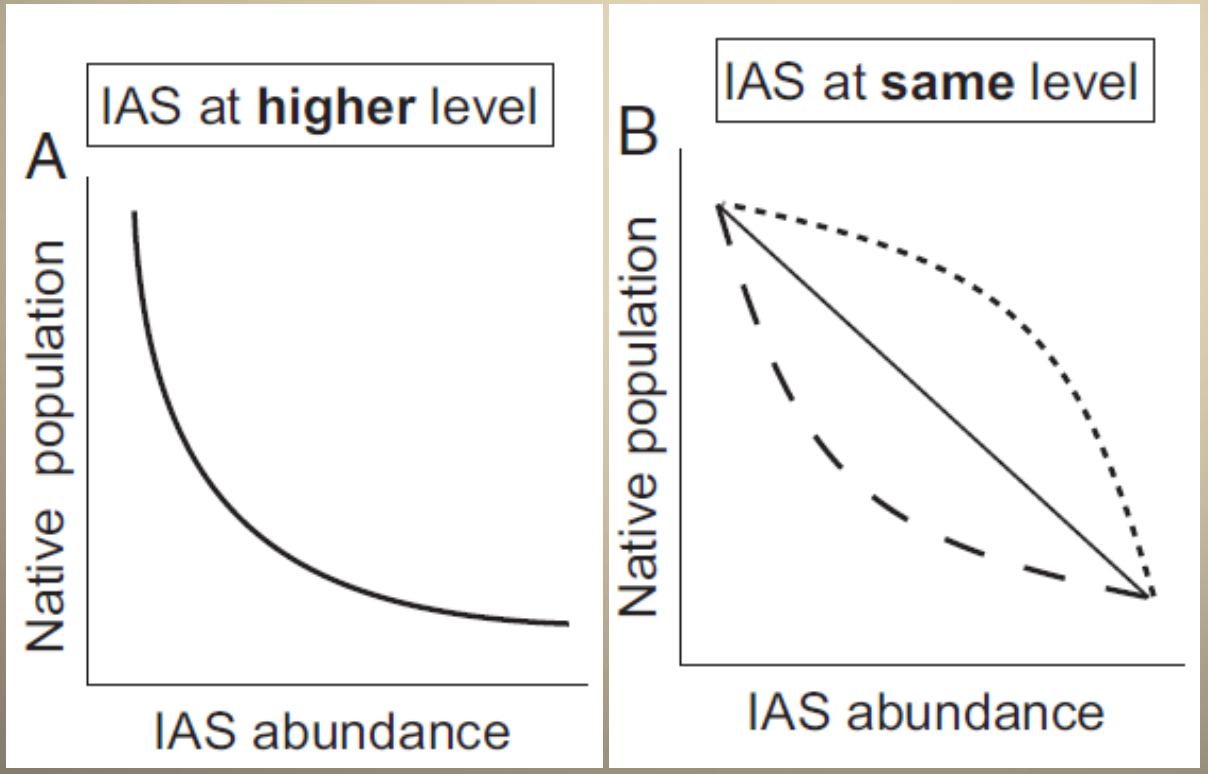


Impacts on native species and communities

Hypotheses

IAS is a predator of the native

IAS is a competitor of the native



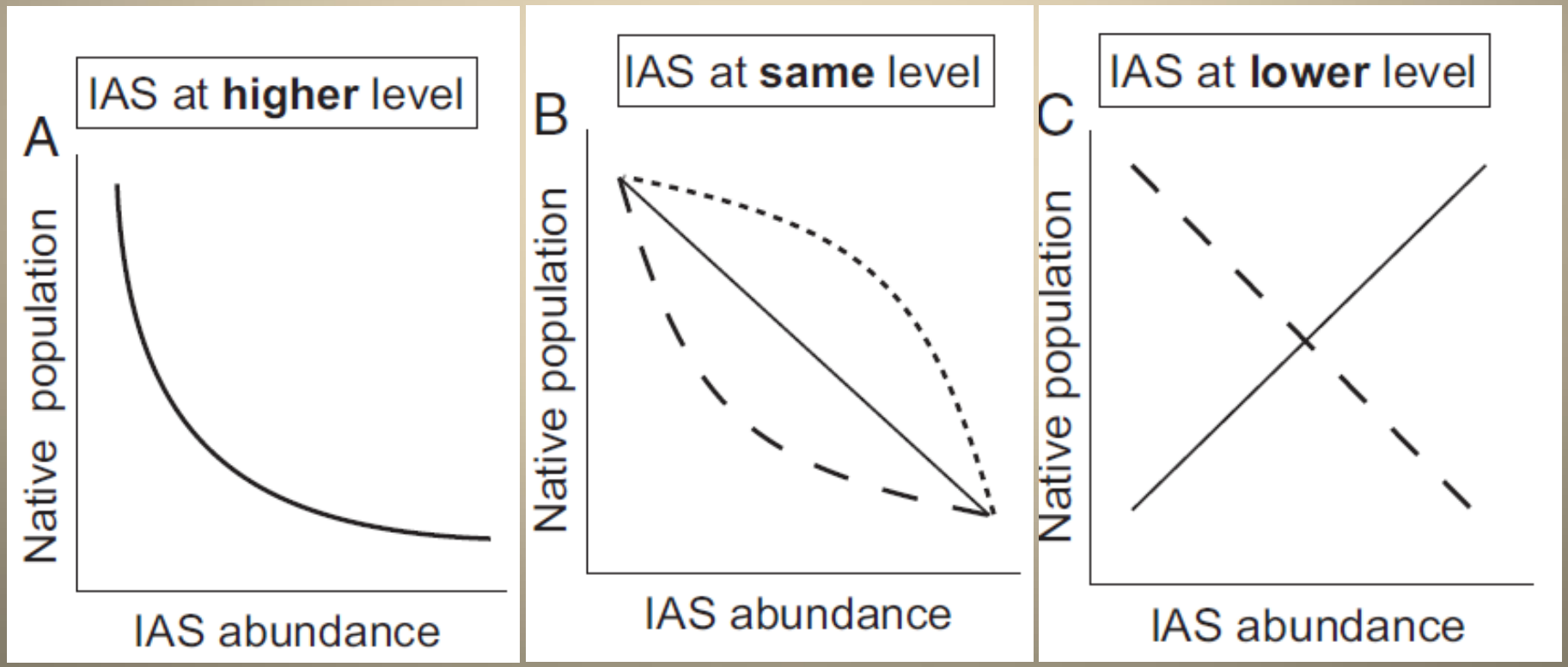
Impacts on native species and communities

Hypotheses

IAS is a predator of the native

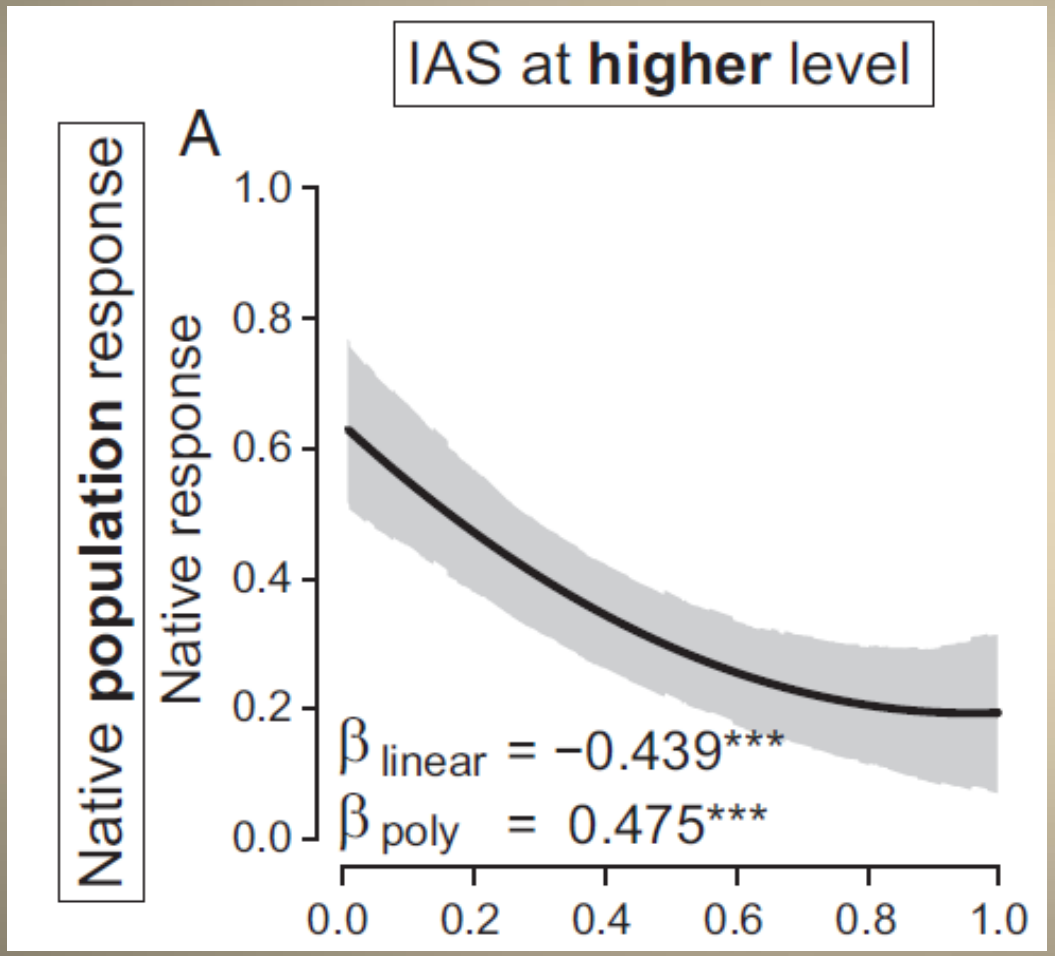
IAS is a competitor of the native

The IAS is food for the native



What do the data show?

meta-analysis of 76 studies in 23 papers

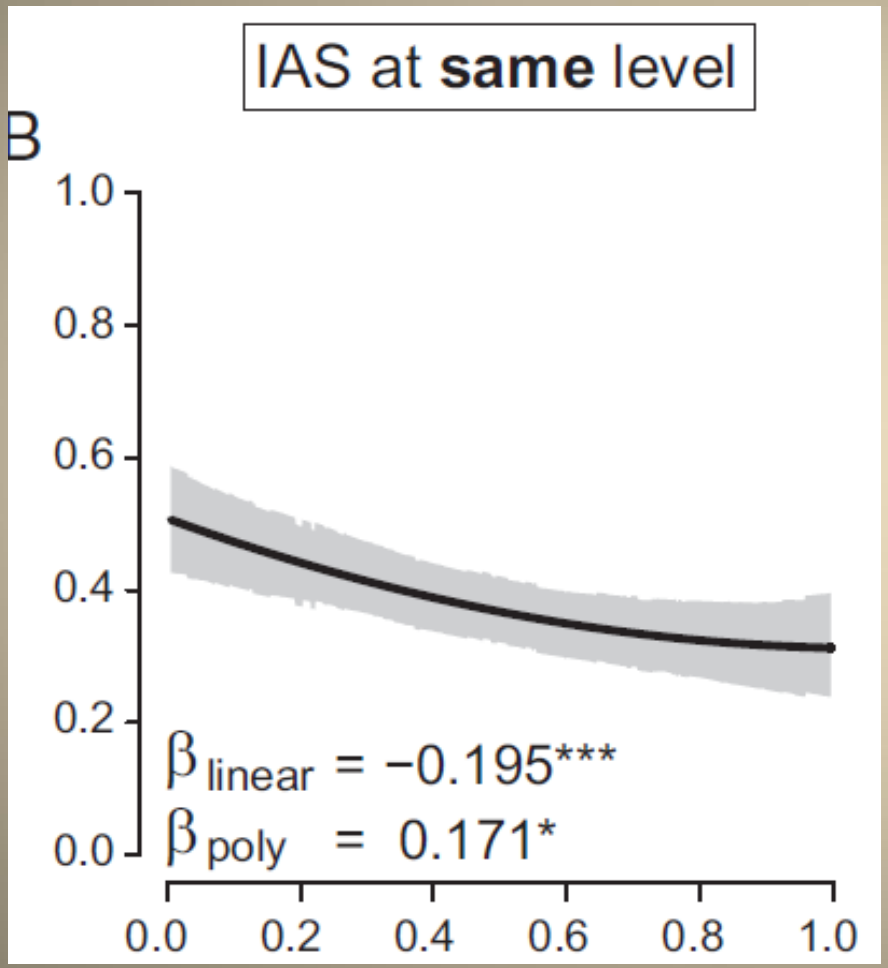


IAS is a predator of the native

Bradley et al. 2020. Disentangling the abundance–impact relationship for invasive species | PNAS

What do the data show?

meta-analysis of 178 studies in 44 papers

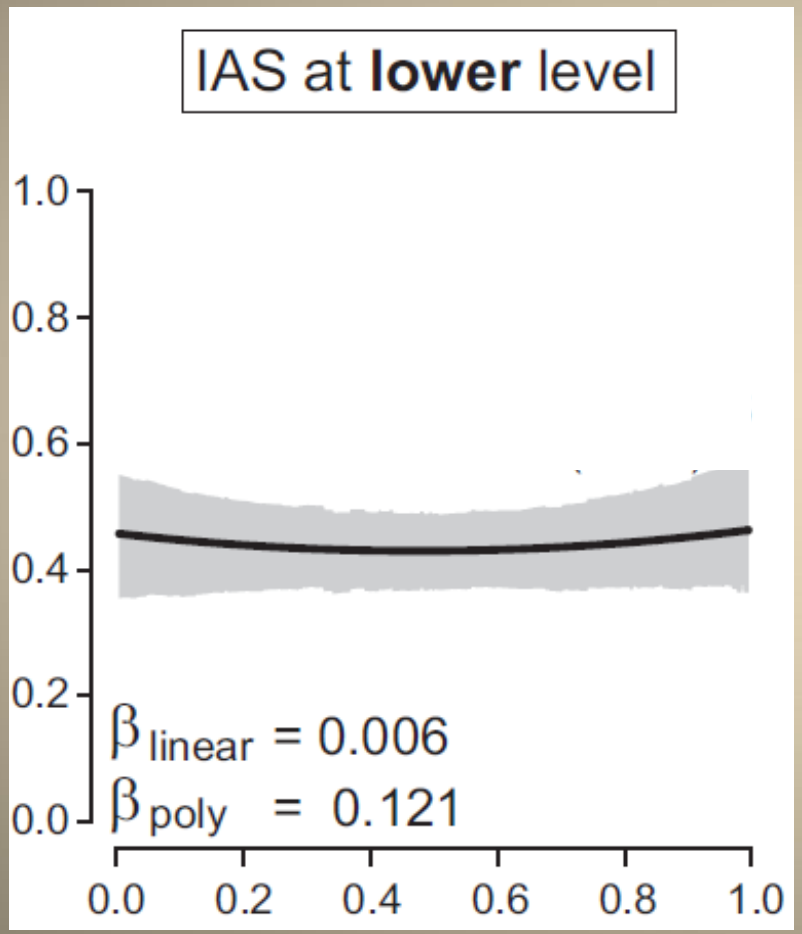


IAS is a competitor of the native

Bradley et al. 2020. Disentangling the abundance–impact relationship for invasive species | PNAS

What do the data show?

meta-analysis of 132 studies in 12 papers



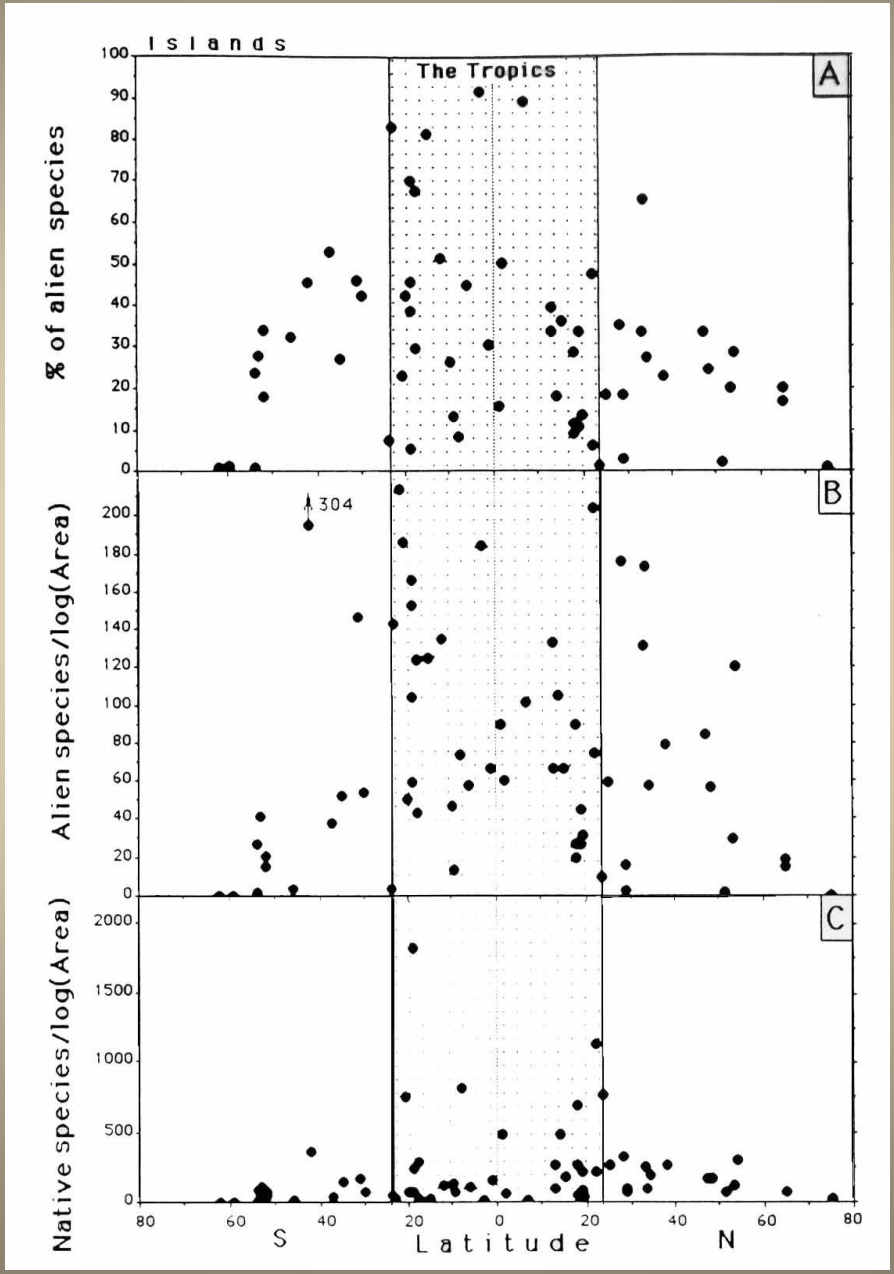
IAS is food for the native

Bradley et al. 2020. Disentangling the abundance–impact relationship for invasive species | PNAS

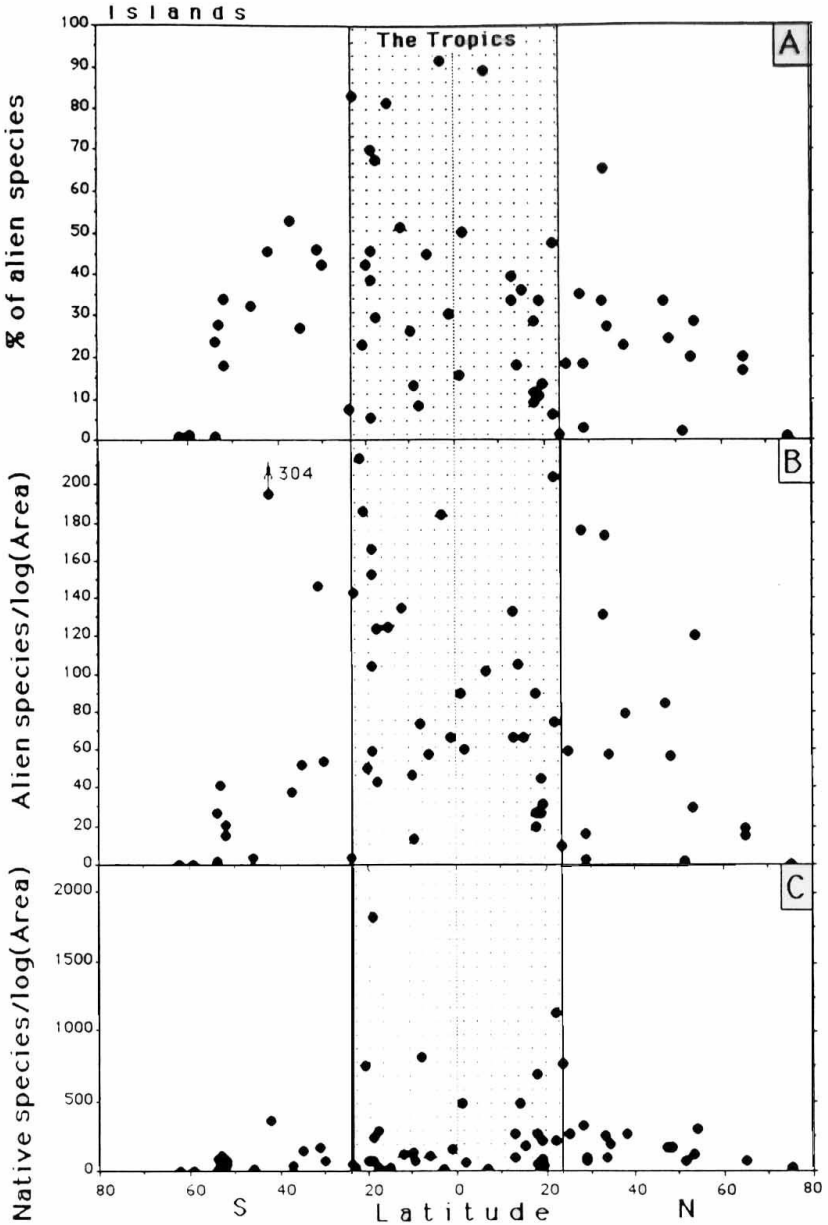
Questions for Management of IAS

- Are certain regions or habitats likely to be more susceptible to invasions and why ?
- Why do some species become invasive, while other don’t ?
- Are there characteristics which make a species more likely to be a successful invader ?
- Are there “rules” that allow us to predict if a species will become invasive ?

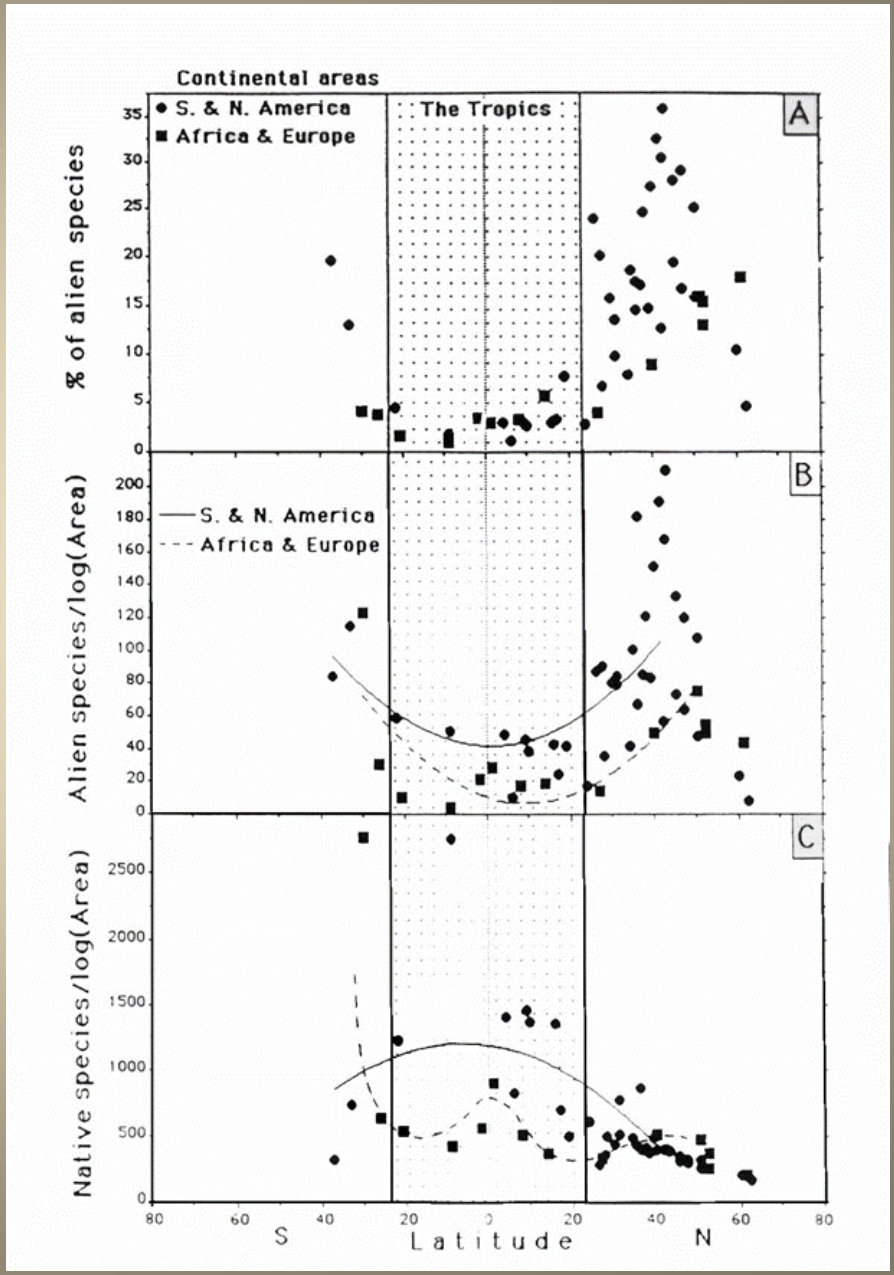
Islands


Islands
The Tropics
A
B
C
% of alien species
Alien species/log(Area)
Native species/log(Area)
304
100
90
80
70
60
50
40
30
20
10
0
200
180
160
140
120
100
80
60
40
20
0
2000
1500
1000
500
0
80
60
40
20
0
20
40
60
80
S
Latitude
N

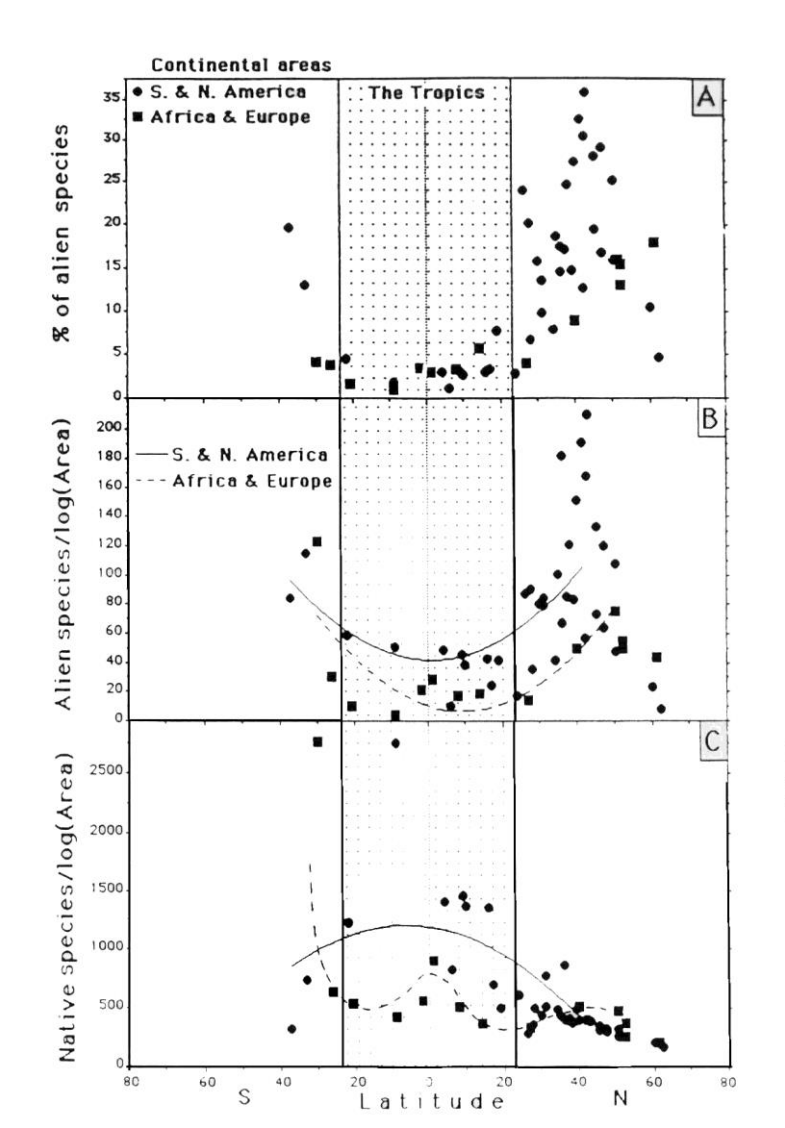
Islands



Continents



Invasive organisms: what we do know ?



Temperate continental ecosystems have more IAS than tropical ecosystems

Invasive organisms: what we do know ?

- Invasions are much more likely on islands than continental areas.
  - Species-poor
  - More disturbed
  - Species are less resistant
  - Propagule pressures higher on islands
- Impact often greater on island
  - Endemics
  - Isolation
- No difference between tropical and temperate islands

Invasive organisms: what we do know ?

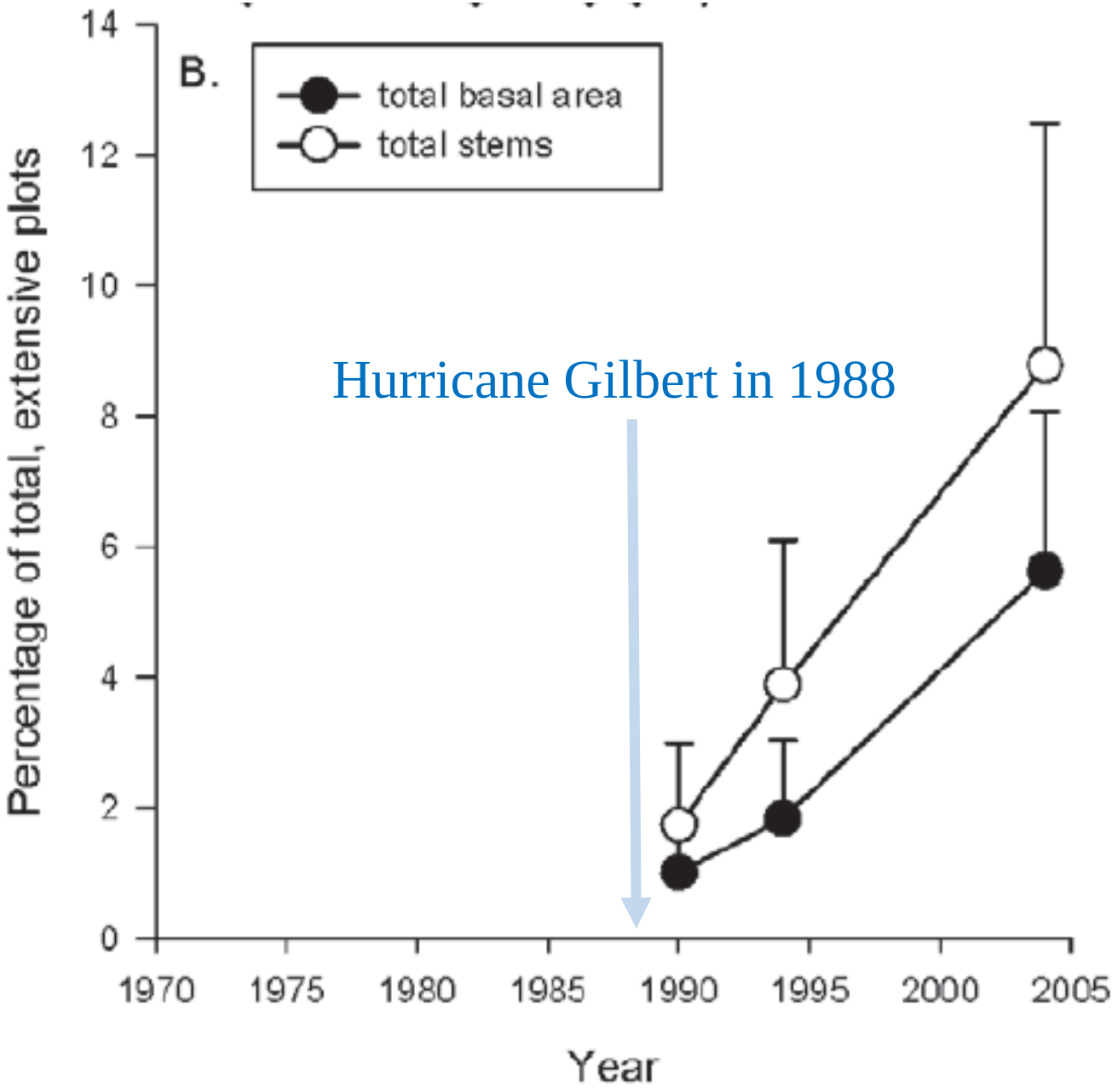
Invasions are much more likely when the ecosystem is already disturbed, either by man or as a result of other causes….

Invasive plants introduced by botanic gardens

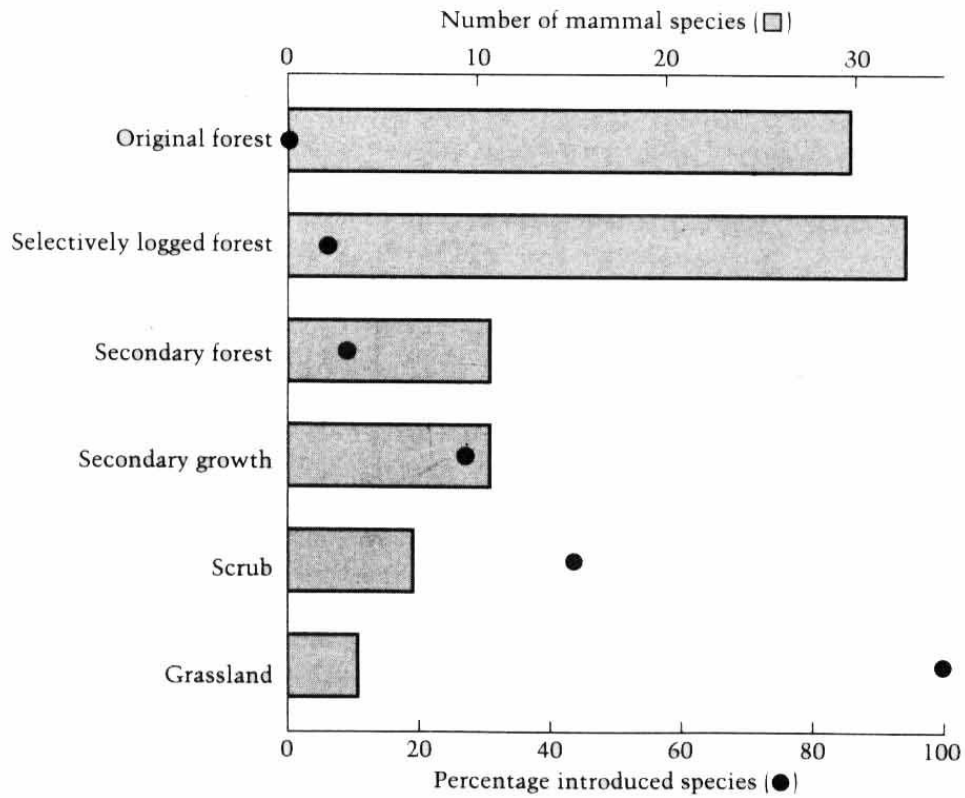
Pittosporum undulatum "mock orange"

- Introduced to Cinchona BG, Jamaica, in 1883
- Invades natural forests in Blue Mountains after hurricanes

Invasion of *Pittosporum undulatum* into natural forests in Jamaica following a hurricane in 1988



Habitat degradation and exotics



7.3 Progressive degradation of Southeast Asian forests by logging and farming not only decreases the number of species of non-flying native mammals, but increases the percentage of introduced species. Only introduced rats are present in the final grassland stage. (From Harrison 1968.)

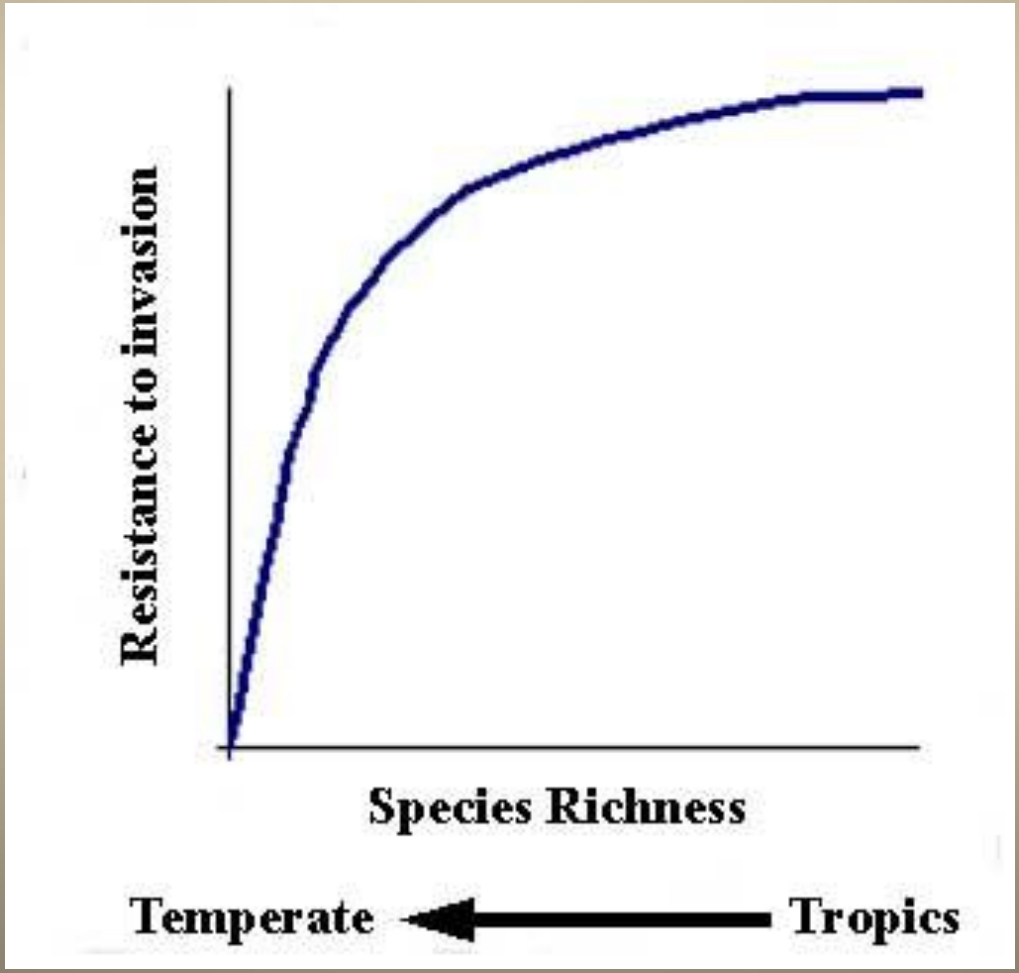
Primack (2002)

How do we explain the differences in invasibility of tropical and temperate continental areas ?

1. The amount of disturbance
2. Period of introductions/disturbance
3. Seed immigration is higher in temperate zone

   E.g. UK – a nation of gardeners and 31% of the flora is exotic

4. Differences in invasion resistance between continental tropical areas and continental extratropical areas due to natural biotic and/or abiotic factors Elton (1958)



Questions

- Why do some species become invasive, while other don't ?
- Are certain habitats likely to be more susceptible to invasions and why ?
- Are there characteristics which make a species more likely to be a successful invader ?
- Are there "rules" that allow us to predict if a species will become invasive ?

Characteristics of invaders

1. High rates of reproduction
2. Long-lived
3. High dispersal rates
4. Single-parent reproduction
5. Vegetative or clonal reproduction
6. High genetic variability
7. Broad diet (polyphagous)
8. Broad native range
9. Habitat generalists
10. Human commensal

Guidance for addressing the Australian Weed Risk Assessment questions

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Summary

This paper provides guidance on how to address the 49 questions of the Australian Weed Risk Assessment (WRA) system. The WRA was developed in Australia in 1999, and has since been widely adapted for different regions. As interest in implementation and results comparison has increased, the issue of consistency in answering and scoring the questions has become important. As a result, this guidance was developed during the 2007 International WRA Workshop. Suggestions on search methods, data sources and examples are also provided.

Keywords: Invasive, prevention, weed risk assessment.

Introduction

The Australian Weed Risk Assessment system (hereafter 'WRA') was originally developed as a tool for use by the government of Western Australia to assess the weed potential of plants proposed for introduction into that state. Subsequently, the system was modified, tested, and adopted by the Australian Government Department of Agriculture, Fisheries and Forestry following public consultation. The outcomes of assessments are used for ongoing updates of a permitted seeds list contained within a proclamation of the Australian *Quarantine Act 1908*. The WRA system determines quarantine risks associated with plant imports and is considered to be consistent with Australia's international rights and obligations as a member of the International Plant Protection Convention. The WRA system has also been adopted for use within the New Zealand Biosecurity Act of 1993.

A report on the WRA and a manual for its implementation using an Excel spreadsheet are available (http://www.daffa.gov.au/ba/reviews/weeds/system). However, any modifications, particularly where the scoring system is changed, would mean that the performance assessment contained in the report (Pheloung *et al*. 1999) is no longer valid. Clarified and slightly modified guidance on how to address the WRA questions (http://www.botany.hawaii.edu/faculty/daehler/wra/screening_criteria.pdf) was developed for a test of the WRA in Hawaii (Daehler and Carino 2000) and Hawaii and the Pacific Islands (Daehler *et al*. 2004). Some combination of the original and modified guidance was likely used in later tests of the WRA in the Czech Republic (Křivánek and Pyšek 2006), Bonin (Ogasawara) Islands of Japan (Kato *et al*. 2006), Florida, US (Gordon *et al*. 2008b), Japan (Nishida *et al*. 2008), and central Italy (Crosti *et al*. 2009). Although comparison of the results of tests across geographies revealed similar accuracy (Gordon *et al*. 2008a), differences in interpretation of the questions reduces consistency of application (Onderdonk *et al*. 2010). Our objective in this paper is to provide more complete guidance on addressing the WRA questions, and sources of information to ease implementation of this tool as it is applied to new geographies. We hope that this effort will facilitate more consistent application of the WRA and reduce unintended variation in that implementation.

These clarified guidelines (Table 1) were developed during the second International WRA Workshop (14–15 Sept. 2007) and ninth annual conference on the Ecology and Management of Alien Plant Invasions held in Perth, Australia (17–21 Sept. 2007), both held in Perth, Australia. The guidance is consistent with the original intent of the WRA, and build on the information found on the Australian WRA website (http://www.daffa.gov.au/ba/reviews/weeds/system). Scoring for the WRA remains as posted on that website and here in Appendix 1. The clarified guidelines are largely consistent with the interpretation used by the Australian Government in its operation of the system as a quarantine screening tool.

General guidance

Answer the WRA questions for the taxon that has been proposed for introduction

Summary

- Principal routes for species introduction are:
  - Colonisation
  - Horticulture, agriculture and forestry
  - Accidental transportation
  - Biological control
- Impacts vary depending on trophic level
- Invasions are much more likely on islands than continental areas
- Temperate ecosystems are more invasible than tropical ecosystems
- Invasions are much more likely when the ecosystem is already disturbed

References

- Bellingham, P.J., Tanner, E.V.J & Healey, J.R. (2005) Hurricane disturbance accelerates invasion by the alien tree *Pittosporum undulatum* in Jamaican montane rain forests. *Journal of Vegetation Science*, **16**, 675-684.

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- Seebens, H. et al. (2017) No saturation in the accumulation of alien species worldwide. *Nature Communications*. https://www.nature.com/articles/ncomms14435