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Measuring the environmental impacts of invasive plants on freshwater ecosystems

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Introduction

Objectives:

- examine evidence for impact
- assess methods for measuring impact
- identify generalities

Criteria for studies for inclusion:

- peer-reviewed source
- must present methods and data
- examine some aspect of freshwater ecosystems

Introduction

Components of impact

Impact = R x A x E

R = range size (m^2)

A = average abundance (per unit area across range)

E = per capita effect (individual or abundance unit)

Parker et al. 1999. Impacts: toward a framework for understanding the ecological effects of invaders. Biological Invasions 1:3-19.

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Introduction

Plant functional groups:

- submerged
- free-floating
- emergent/ riparian herb
- riparian tree/ shrub

Environmental impact categories:

- ecosystem processes
- communities
- populations
- genetics

Introduction

Methods:

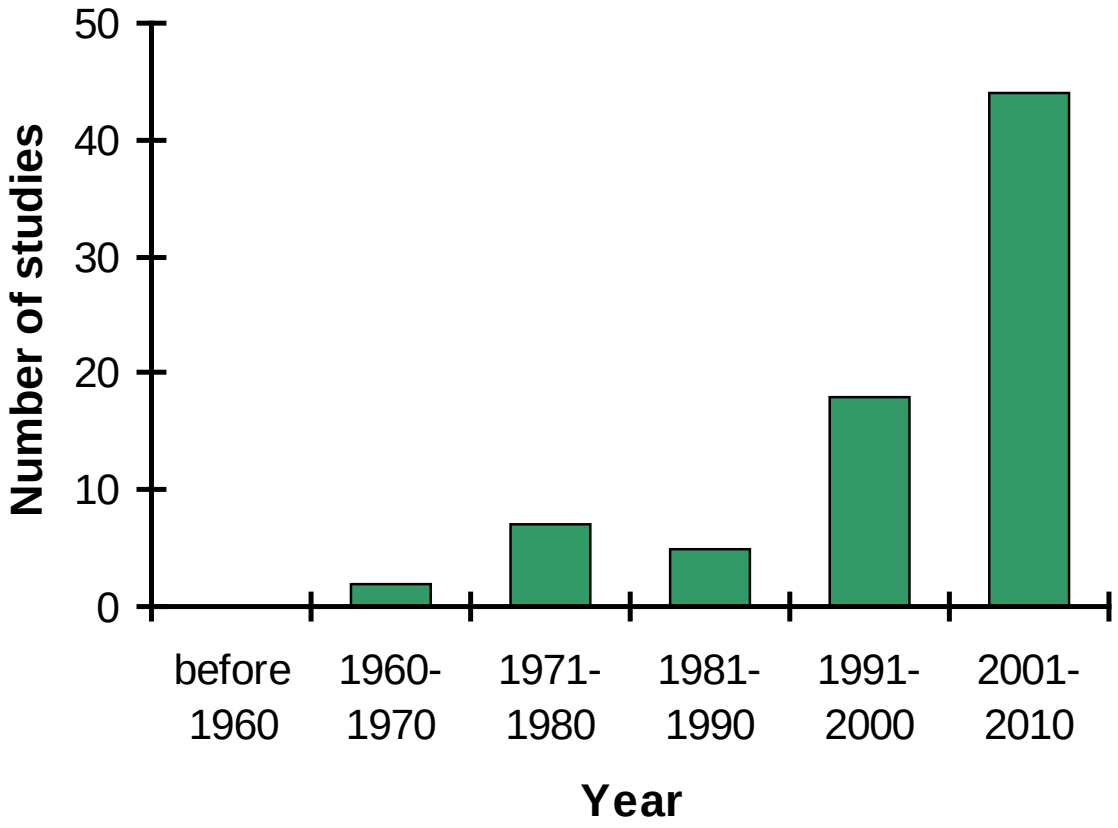
- Searched databases
- Followed references in review papers
- Queried experts in aquatic and riparian plant invasions

but, please send me more references if you can think of any!

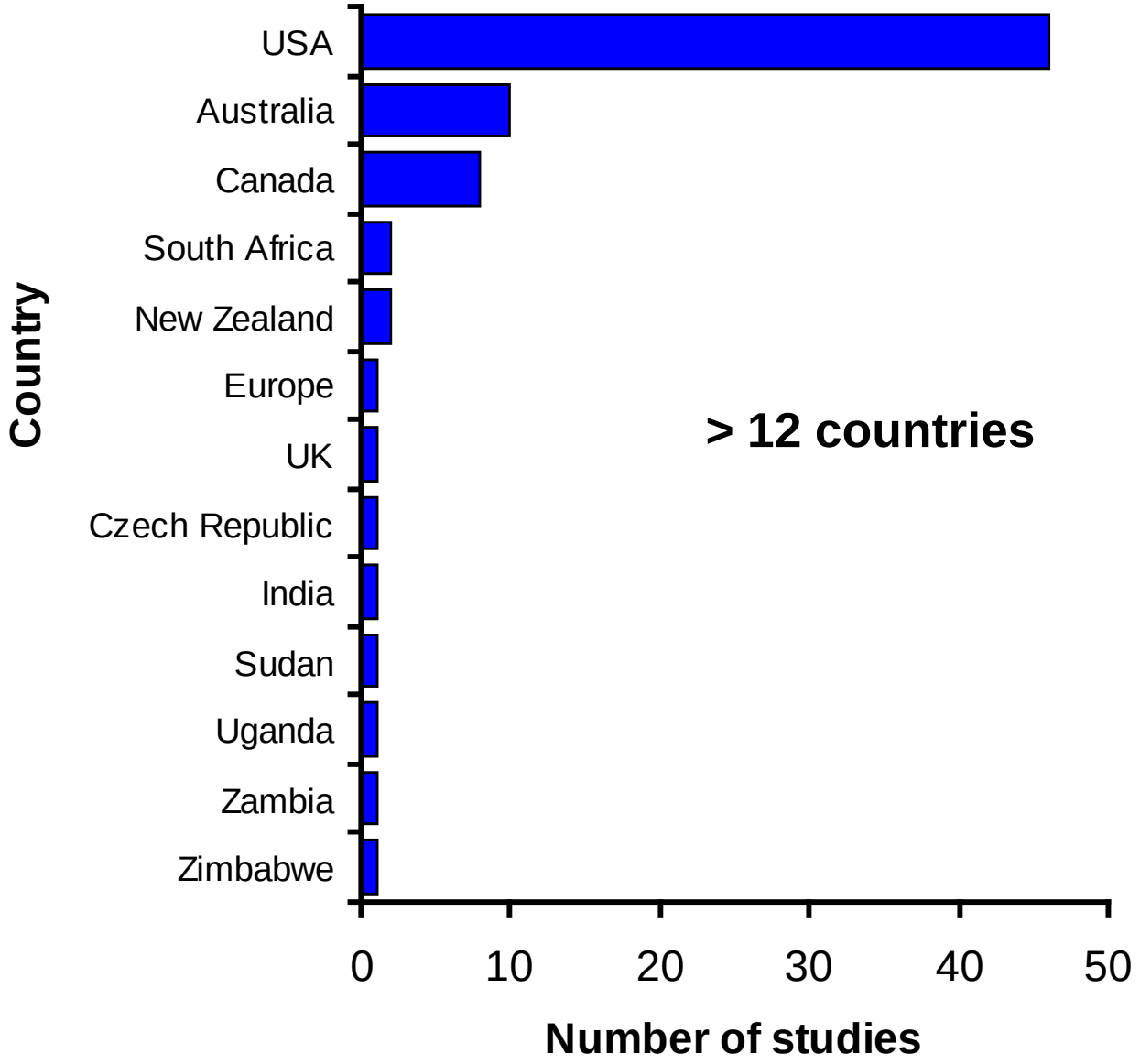
Overview of studies

79 studies

39 plant species



Overview


USA
Australia
Canada
South Africa
New Zealand
Europe
UK
Czech Republic
India
Sudan
Uganda
Zambia
Zimbabwe
Country
> 12 countries
0
10
20
30
40
50
Number of studies

Overview

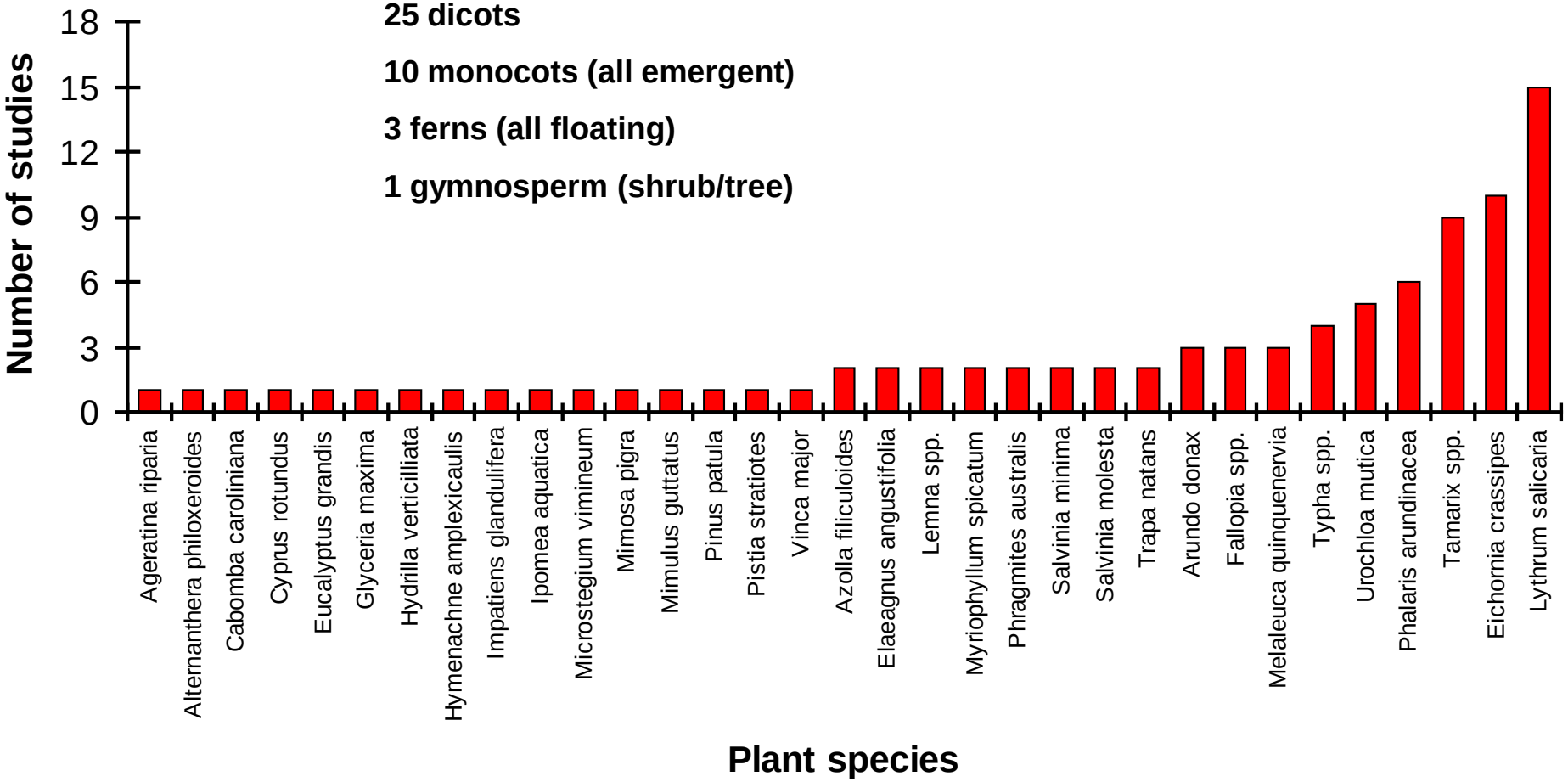
39 species

25 dicots

10 monocots (all emergent)

3 ferns (all floating)

1 gymnosperm (shrub/tree)



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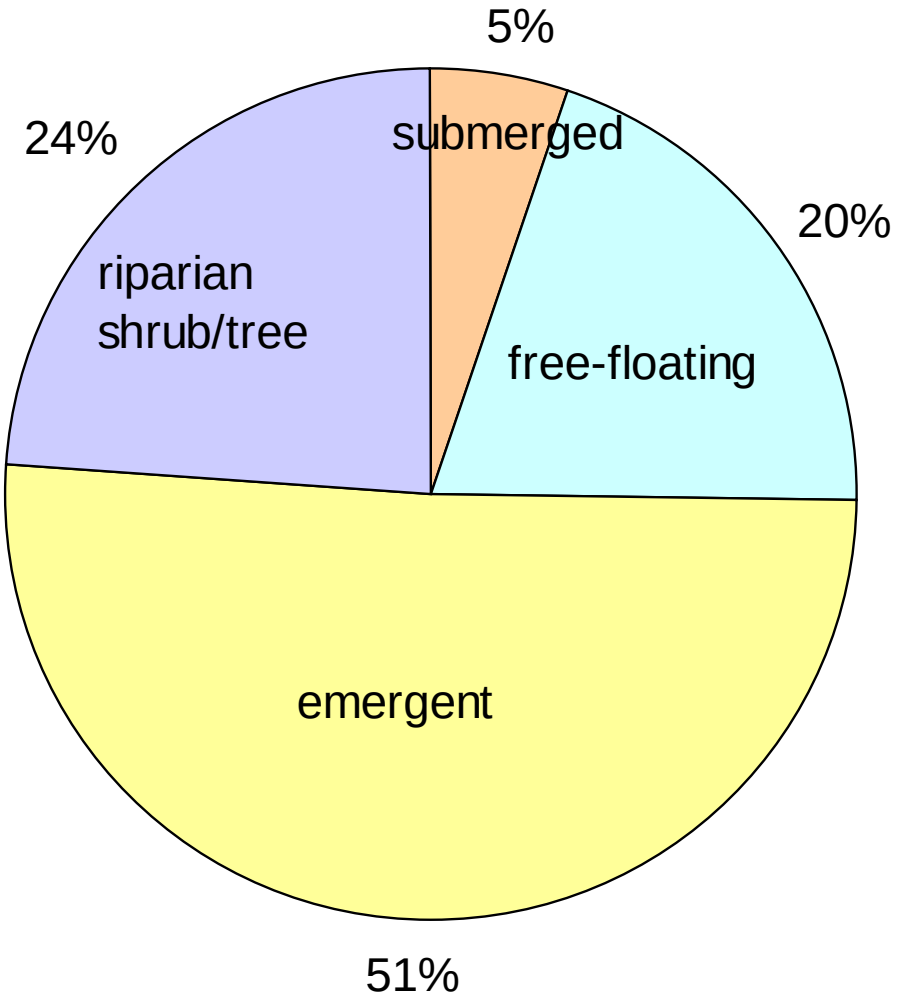
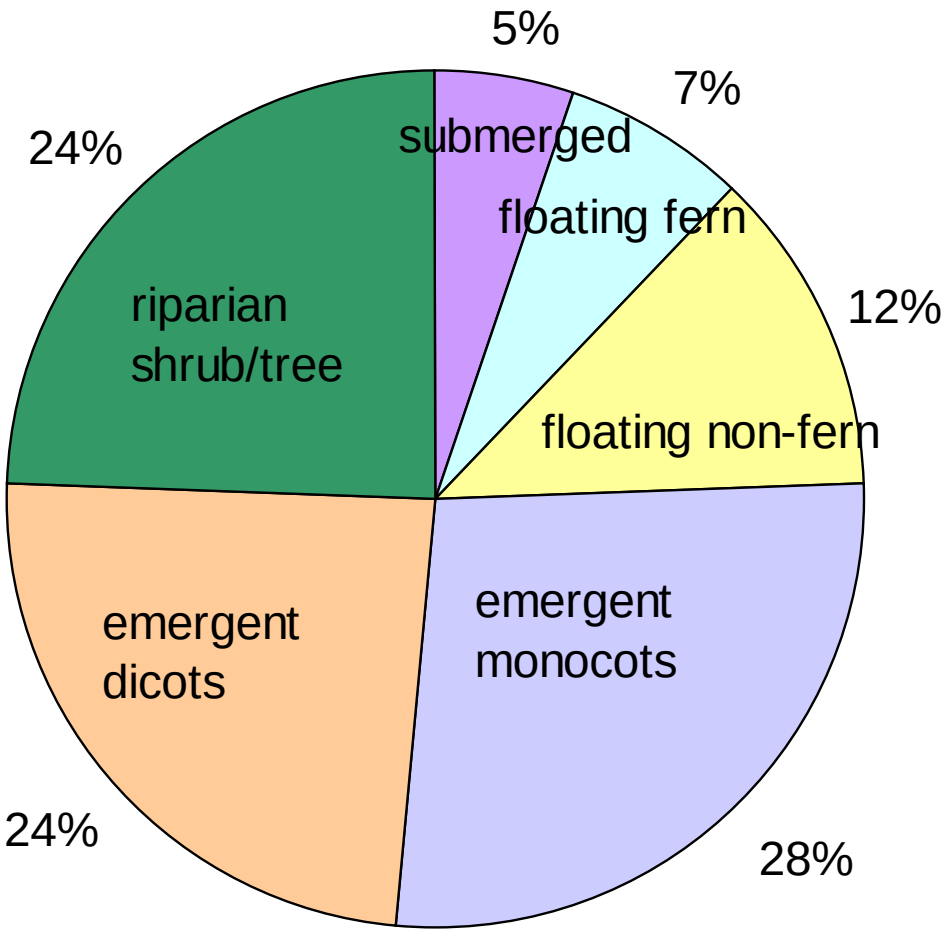


Proportion of studies in each category

Overview



Proportion of studies in each category

Impacts: Genetic changes

Hybridisation:

Evidence for scale of impact:

Typha angustifolia (Europe?) and *Typha latifolia* (NA) = *Typha x glauca*

at 3 sites in midwest USA only 12% of genets were pure *T. latifolia*

Hybridisation evident but no measurement of effect:

Phragmites australis (European and North American lineages)

Phalaris arundinacea (European and North American lineages)

Spartina alterniflora (Europe) and *Spartina foliosa* (NA)

Cabomba caroliniana

Impacts of invasive plants: Submerged

Submerged: 4 studies

Myriophyllum spicatum

one lake BACI design

- some fish species numbers reduced and some increased
- reduction in epiphytic invertebrate abundance and diversity
- reduction in benthic invertebrate abundance
- reduced dissolved oxygen
- no effect on temperature

3 other studies:

***M. spicatum*: in one lake over 11 years plant species richness declined from 20 to 7 species (no stats)**

***Cabomba caroliniana*: one lake, compared one invaded with one non-invaded location (pseudo-replication)**

***Hydrilla verticillata*: 2 experimental ponds, compared hydrilla with *Vallisneria spp*. (replication, no stats)**

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Water hyacinth (*Eichhornia crassipes*)

Impacts of invasive plants: Floating

Free-floating (15 studies)

Ecosystem processes

Dissolved oxygen: 6 studies found a decrease in dissolved oxygen under weed mats

3 studies on *Eichhornia crassipes*

2 studies on *Azolla filiculoides* and *Lemna minuta*

1 study on *Salvinia molesta* and *S. minima*

Evapotranspiration: 3 studies found an increase in water loss due to evapotranspiration (all on *Eichhornia crassipes)*

(but see Allen 1997 for methods and "cloths-line effect")

2 studies were pseudo-replicated and results were not included

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Impacts of invasive plants: Floating

Community diversity and composition

2 studies found an decrease in benthic invertebrate diversity (*Azolla filiculoides* and *Salvinia molesta)*

1 found decreases and increases in benthic and epiphytic invertebrate diversity and abundance depending on site and season *(Eichhornia crassipes)*

1 found increases in epiphytic invertebrate diversity and abundance depending on site and season *(Salvinia molesta)*

Populations

1 study found decreases fish and amphibian species diversity and abundance *(Azolla filiculoides)*

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Purple loosestrife *(Lythrum salicaria)*

Impacts of invasive plants: Emergent

Emergent/riparian herb: 38 studies

Ecosystem processes

3 studies found increased N in soils under invasive species (2 *Typha x glauca; Phragmites australis*) while 1 found a reduction in N (*Microstegium vimineum*)

1 study found reduced P in soils (*Lythrum salicaria*) while one found increased P (*Typha x glauca)*

3 found increased litter (2x *Typha x glauca, Fallopia japonica)*

3 found increased decomposition rate of plant material *(Alternanthera philoxeroides, 2 x Lythrum salicaria)* over native species

2 found increased channel siltation, but in already heavily modified habitats, cane fields (*Urochloa mutica*) and cleared pastures (*Glyceria maxima*)

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Impacts of invasive plants: Emergent

Plant Communities

10 studies found decreases in plant community diversity (3x *Lythrum salicaria,* 2x *Typha x glauca*, 2x *Phalaris arundinacea*, 2x *Fallopia japonica, Ageratina riparia, Urochloa mutica, Hymenachne amplexicaulis, Arundo donax, Fallopia spp., Phragmites australis*)

1 study found increased plant diversity (*Lythrum salicaria)*

5 studies found no difference in plant community diversity (2x *Lythrum salicaria, Impatians glandulifera, Mimulus guttatus, Phalaris arundinacea, Vinca major*)

1 study found a reduction in native plant abundance (*Fallopia japonica)*

1 study was pseudo-replicated and results were not included

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Impacts of invasive plants: Emergent

Invertebrate communities

5 studies found reduced invertebrate diversity (2x *Phalaris arundinacea, Fallopia japonica*, *Lythrum salicaria, Arundo donax*)

3 studies did not detect a difference (*Urochloa mutica, Glyceria maxima, Hymenachne amplexicaulis)*

5 studies found reduced invertebrate abundance (2x *Urochloa mutica*, *Phalaris arundinacea, Fallopia japonica*, *Arundo donax*)

2 studies did not detect a difference (*Urochloa mutica, Hymenachne amplexicaulis)*

4 studies found invertebrate composition different (2x *Urochloa mutica, Glyceria maxima, Hymenachne amplexicaulis)*

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Impacts of invasive plants: Emergent

Populations

Plants

Phalaris arundinacea associated with reduction of the endangered *Howellia aquatica*

Phalaris arundinacea can outcompete blue vervain (*Verbena hastata*)

Birds

Urochloa mutica associated with reduced numbers of Australian pratincole and little curlew, but not intermediate egret and magpie goose

Amphibians

American toad (Bofu americanus) tadpoles, but not Gray tree frog (*Hyla versicolor*) tadpoles, had lower survival in water with extracts of *Lythrum salicaria* compared with extracts of *Typha latifolia*.

Reduced green frog (*Rana clamitans*) foraging success in stands of *Fallopia japonica.*

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Mimosa (*Mimosa pigra)*

Impacts of invasive plants: Shrub/tree

Riparian shrub/tree: 17 studies

Ecosystem processes

2 studies found changes in river morphology (2x *Tamarix spp*.)

1 study found reduced stream flow vs. grassland (*Eucalyptus grandis, Pinus patula*)

2 studies found no difference in transpiration rates (2x *Tamarix ramosissima*)

1 study found increased soil N (*Elaeagnus angustifolia*)

4 studies were pseudo-replicated and results were not included

Impacts of invasive plants: Shrub/tree

Plant communities

2 studies found a reduction in plant diversity (2x *Melaleuca quinquenervia*)

Populations

Plant

Populus deltoides can outcompete *Tamarix spp.* across six substrates and 3 watering regimes

Animal

Caddisfly (*Lepidostoma unicolor*) growth reduced on *Arundo donax* litter, but similar between *Tamarix spp.* and two native host species (*Salix spp.* and *Populus fremontii*)

General trends among groups

Light reduction

Submerged

Hydrilla verticilliata

Cabomba caroliniana

Floating

Azolla filiculoides and *Lemna minuta*

Emergent

Typha x glauca

Shrub/tree

Mimosa pigra

Impact generalisations by group

Submerged (one study)

Floating

reduction in dissolved oxygen

reduced benthic invertebrate diversity

Emergent

increased litter

reduced plant diversity

reduced invertebrate diversity and abundance

changed invertebrate community composition

negative impact on plant, bird, and amphibian species

Shrub/ Tree

reduced plant diversity

Common issues in studies

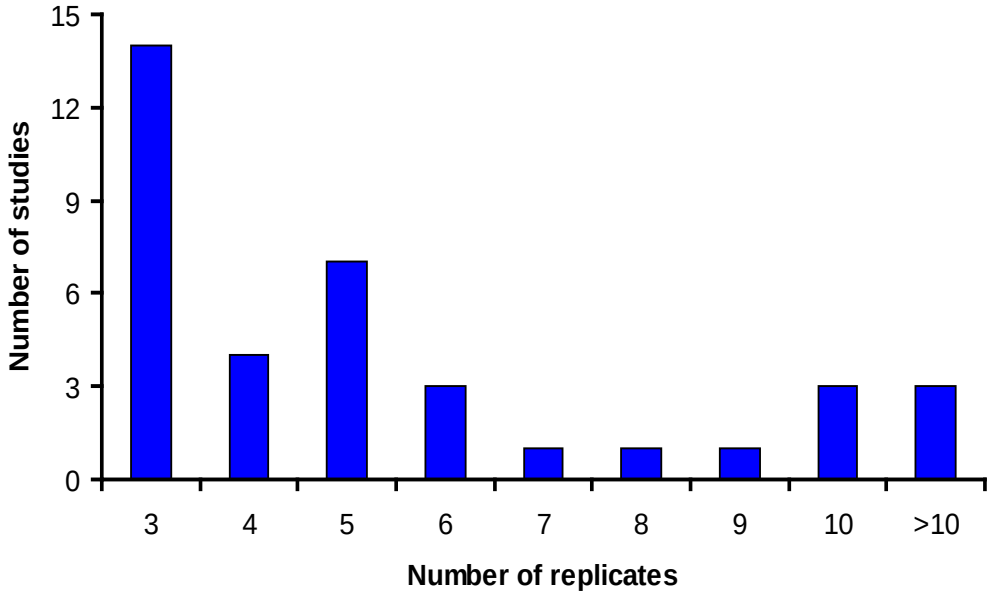
Sample size: inference of no effect

Is a null result an effect of low sample size and high variability or does it indicate no effect of the invasive plant?

No study used power analysis and many review papers cite studies with a null result as indicating no effect.

36% could have been improved by using power analysis.

Recommendation: Power analysis should be done to indicate whether the sample size was large enough to detect an effect.

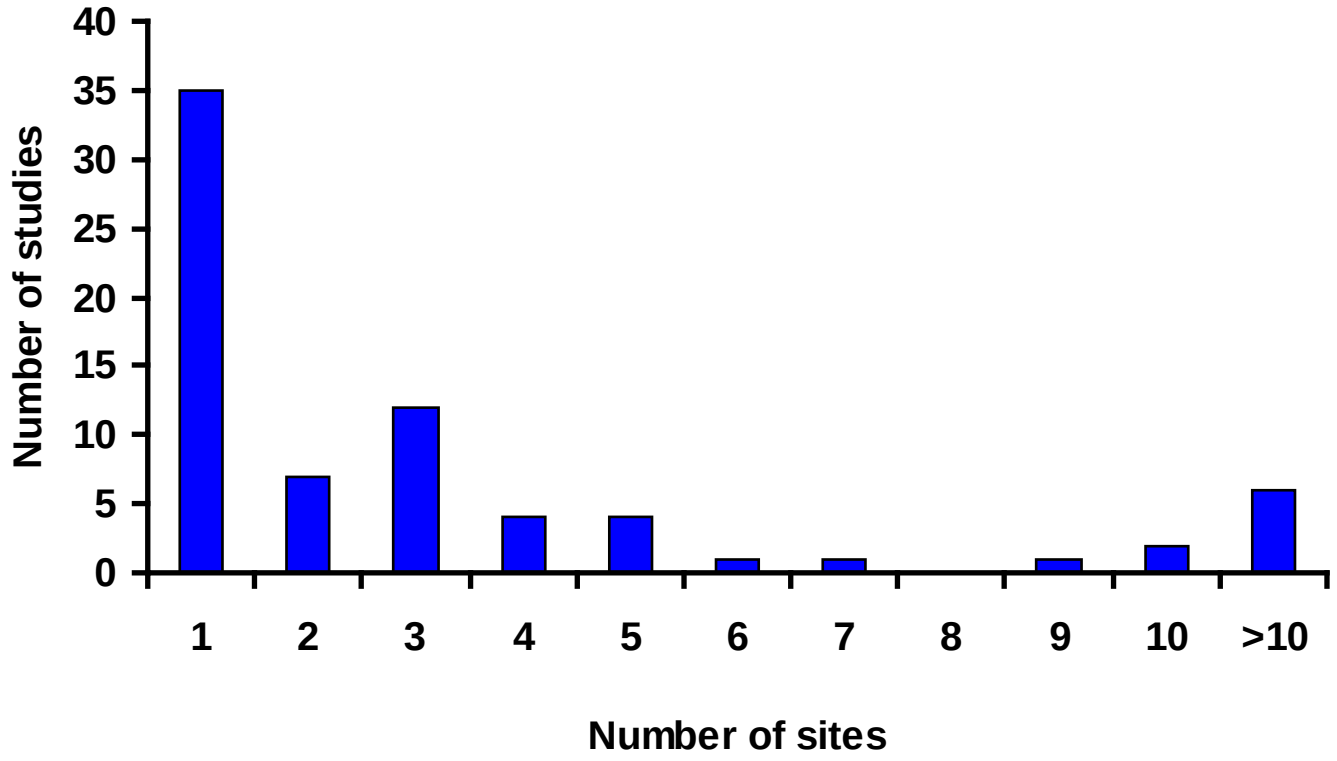


Scope of study: number of study sites

Most studies (51%) examined effect at one site.

Are the effects at one site representative of other locations?

Recommendation: Measure effects at multiple locations.



Proper replication for statistical analysis

Most studies used statistics appropriately (61%).

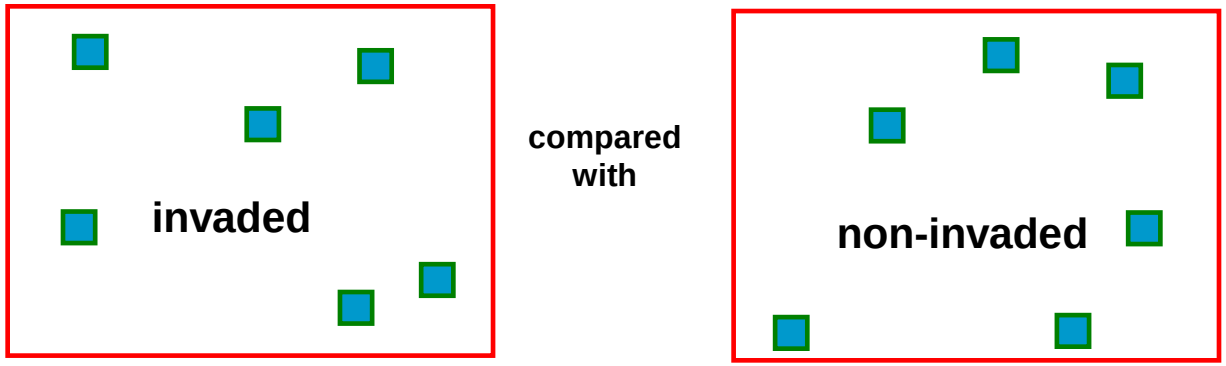
However,

13 studies (16%) would have benefited with a better design to allow statistical analysis

and

7 studies (9%) were not properly replicated, although statistical analysis was used.

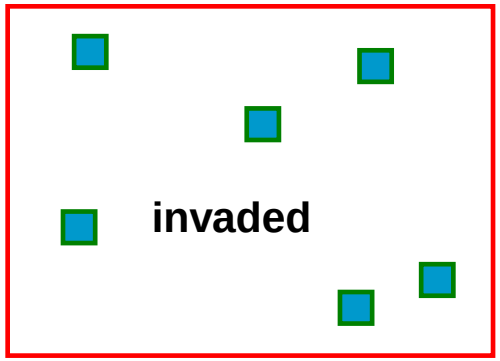
Proper replication for statistical analysis



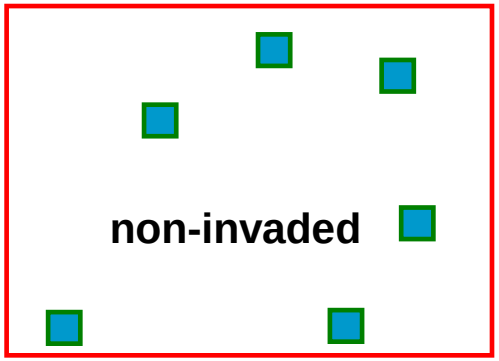
How many replicates are there?

Proper replication for statistical analysis

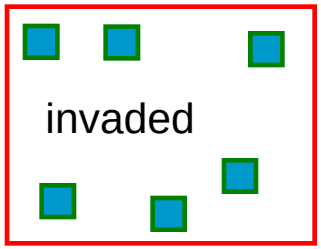
Replication = 1

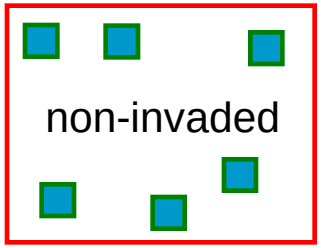


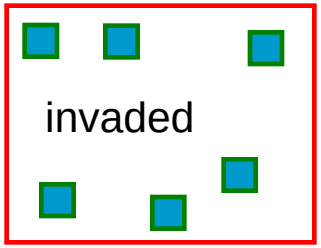
compared with

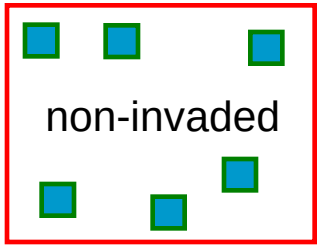


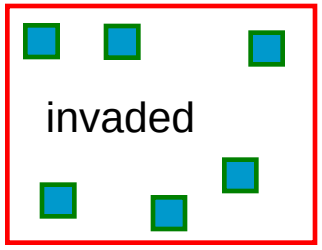
Replication = 3

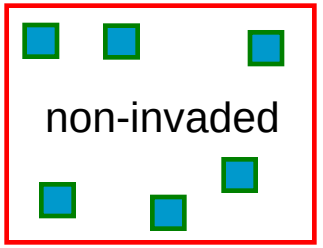












Recommendation: design surveys with appropriate replication

Space-for-time methodology

Space-for time studies can be very useful,

but

assume the environmental conditions would lead the same level of impact over time.

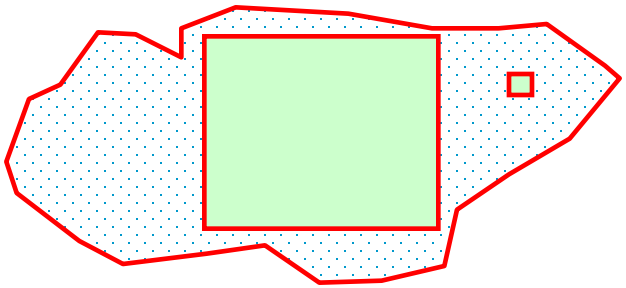
43% of the applicable studies made some comparison of similarity among sites.

Recommendation:

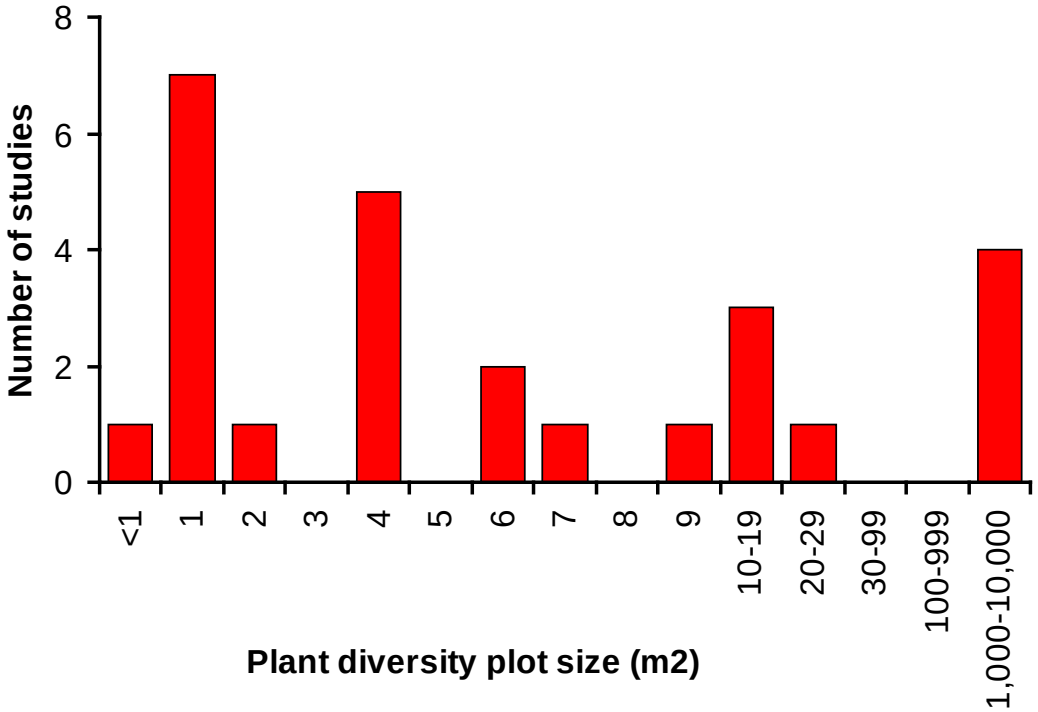
identify and include environmental variables.

Appropriate spatial scale for diversity studies

Species richness is associated with the sample area.



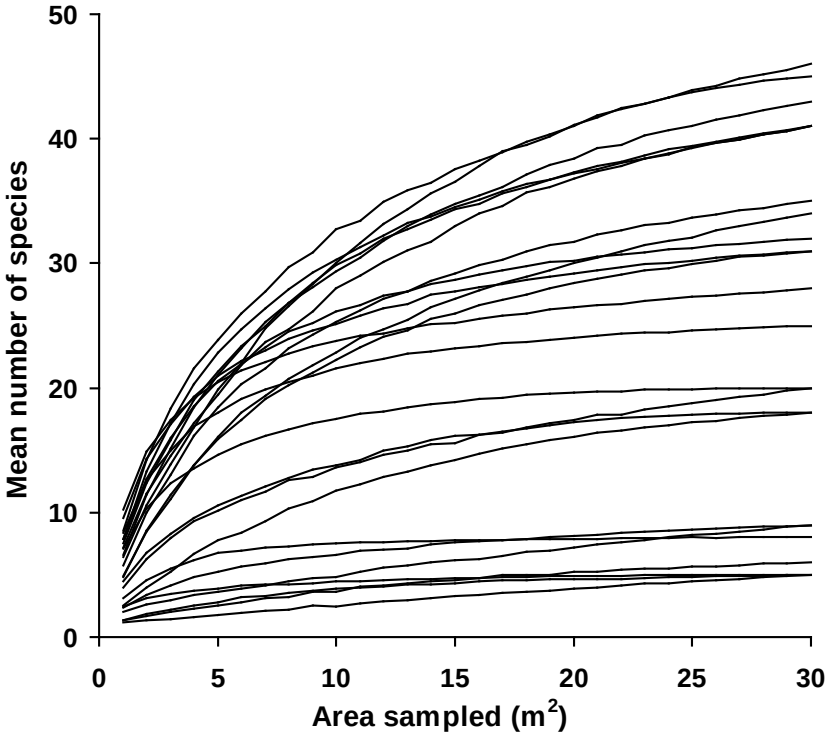
At what spatial scale is the effect occurring?



Appropriate sampling effort for diversity studies

Species richness is affected by sampling effort.

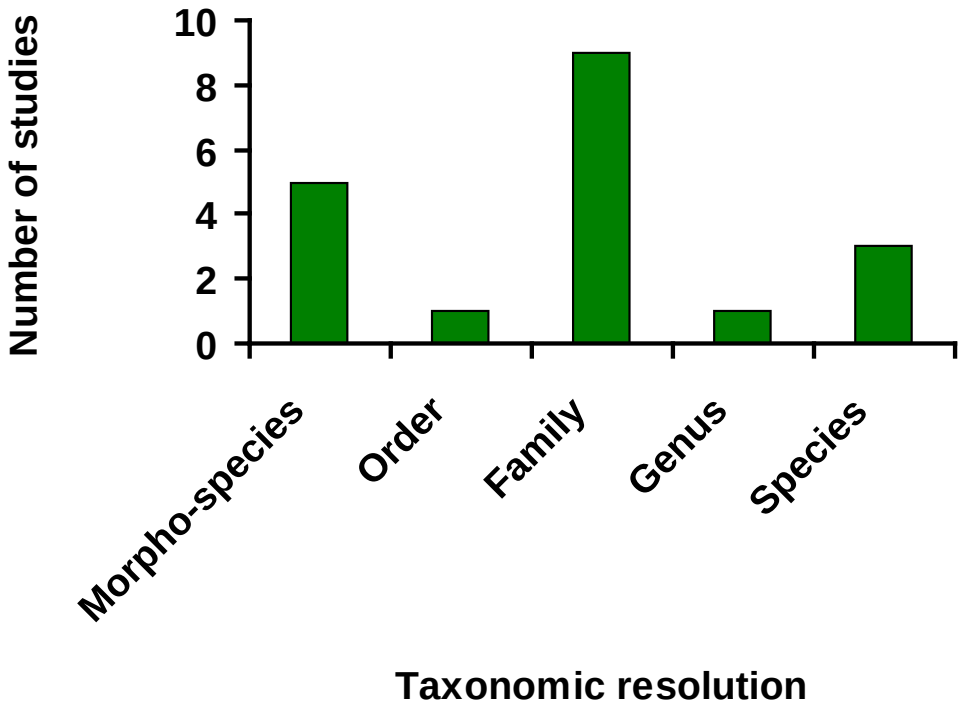
Only 6% of applicable studies examined whether the sampling effort was adequate to measure diversity.



Recommendation: use species accumulation curves to examine sampling adequacy

Taxonomic challenges

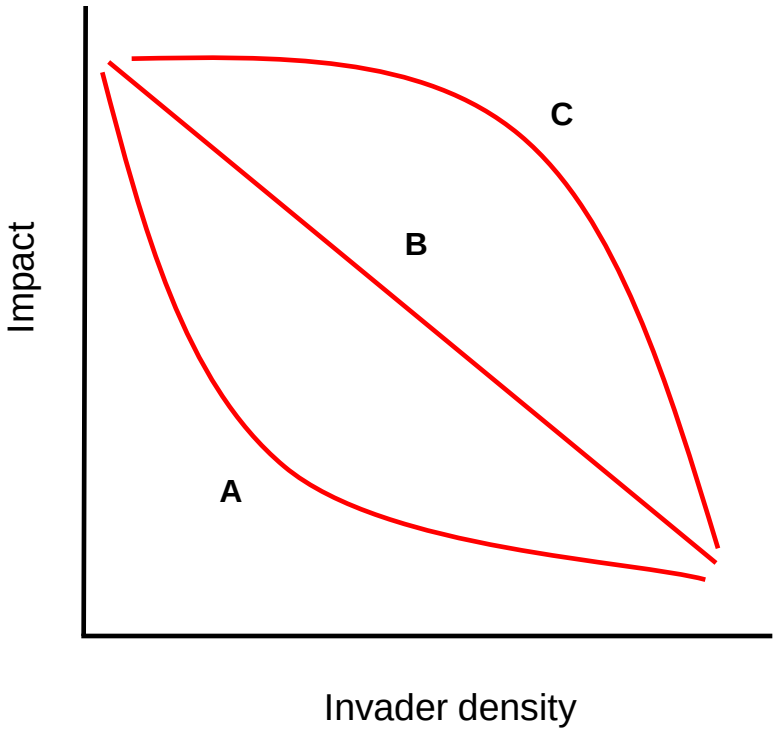
Taxonomic resolution of invertebrates was usually to Family or morpho-species (74% of relevant studies).



Recommendation: more effort into invertebrate taxonomy is required.

Functional form of relationship

Very useful to know how impact is related to density.



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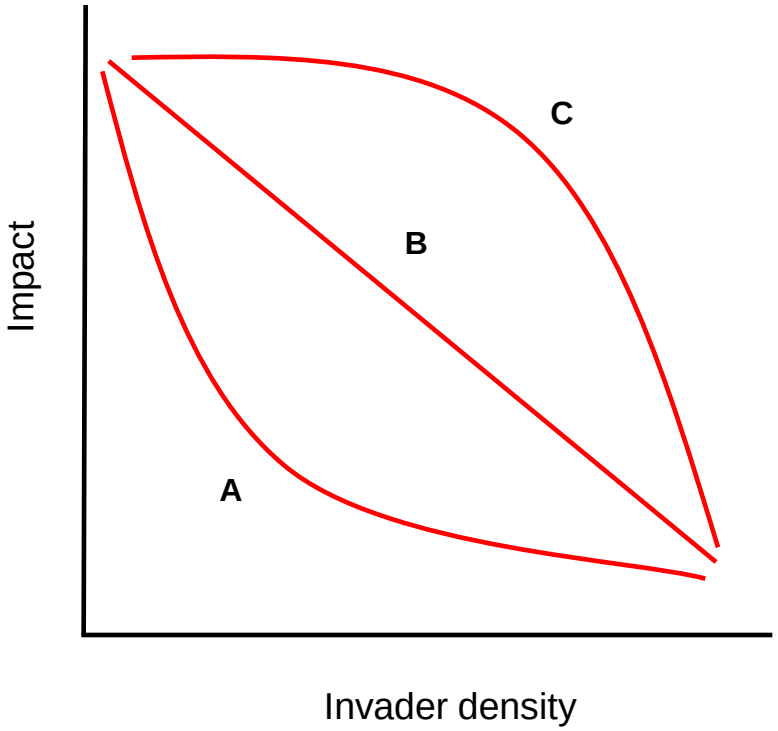

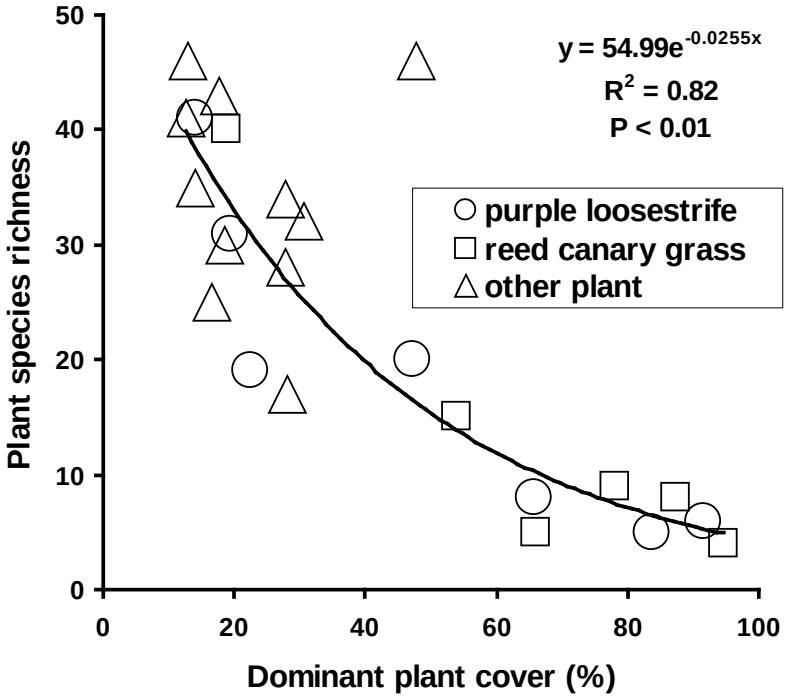

Recommendation: measure impact along a gradient of invader density

BACI Design

Before-after, control-impact is a very powerful design but only 3 studies of 54 relevant studies used this design.

Opportunities:

- studies that used space-for-time can go back and examine whether their predictions were true after invasion
- biological control monitoring can examine whether invaded sites become more like non-invaded (control) sites after introduction of the biological control agent (eg. Landis et al. 2003; Barton et al 2007)

Putting it all together

Components of impact

Impact = R x A x E

R = range size (m^2)

A = average abundance (per unit area across range)

E = per capita effect (individual or abundance unit)

Conclusions

Studies examining environmental impacts of plant invasion have been increasing in number.

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Cause and effect is difficult to assess due to inability to randomly assign “invaded” treatments in natural environments.

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More attention needs to be paid to experimental design, particularly for diversity studies.

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Impact studies are difficult to conduct due to inability to randomly assign “invaded” treatments in natural environments.

More attention needs to be paid to experimental design, particularly for diversity studies.

There are opportunities for Biological Control to strengthen cause and effect arguments.

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Salvinia in Kakadu NP, NT, Australia

Thank You

Please send me relevant publications:
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