What is the minimum viable population size for rare plant species?

CONFERENCE 2021
BOTANICA SUDALPINA
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UNIVERSITÀ DEGLI STUDI DI MILANO

DiSAA

Projects:

Interventi regionali per favorire la salvaguardia della biodiversità nei siti di Rete Natura 2000. Bando Biodiversità 2015

FraGenziane: Fragmented *Gentiana pneumonanthe* populations, habitats and associated fauna in local ecological network.
Bandi Fondazione Cariplo 2014 – Connessione Ecologica.

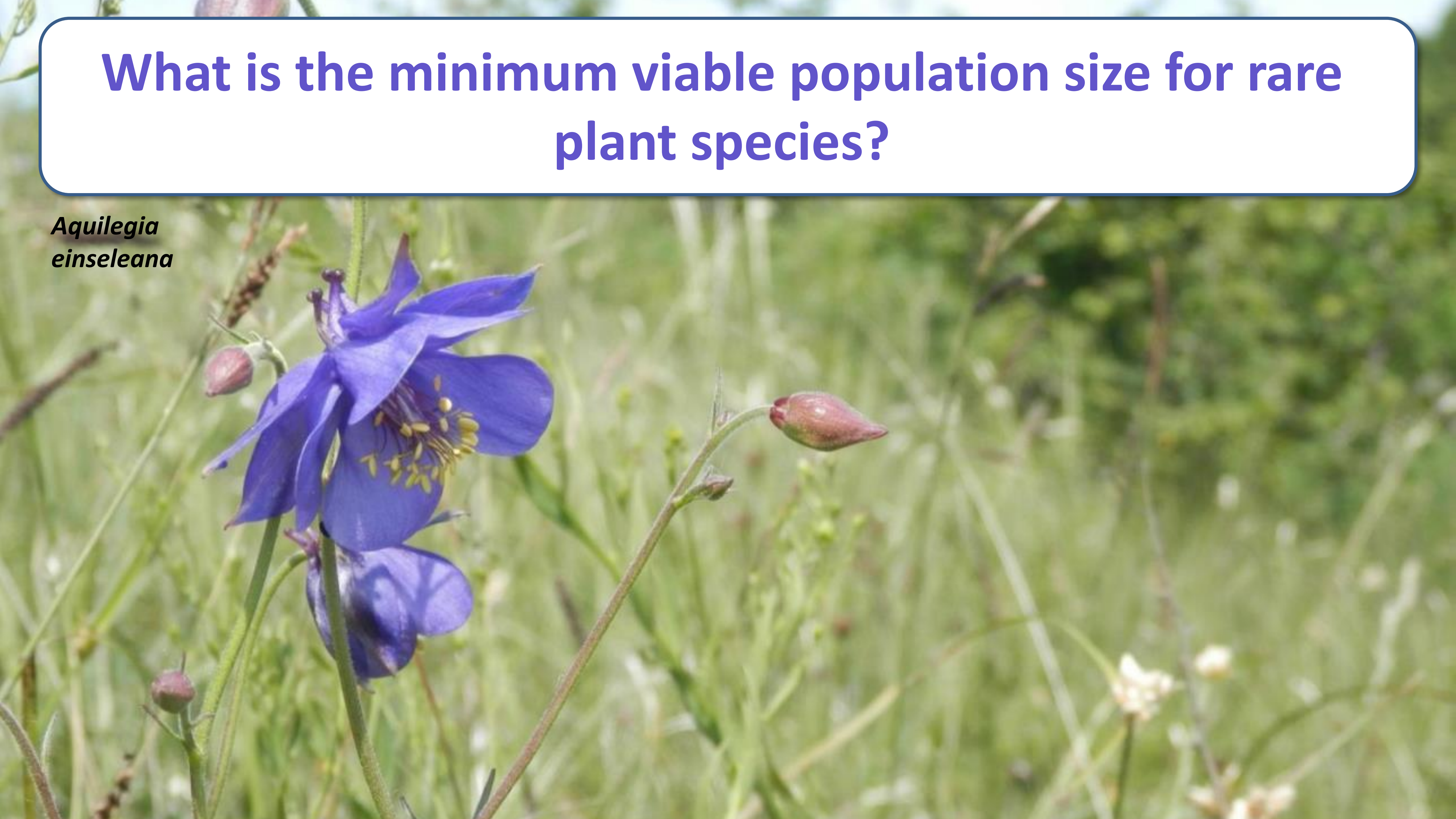
Project ORCHIS: Orchid Restocking and Conservation for Higher altitude Indigenous Species. Tutelare e valorizzare la biodiversità

SPEED: Species **d**istribution modelling and population genomics to calculate extinction risk in a changing climate

+ various research contracts between Parco Monte Barro and Università degli Studi di Milano (DiSAA)

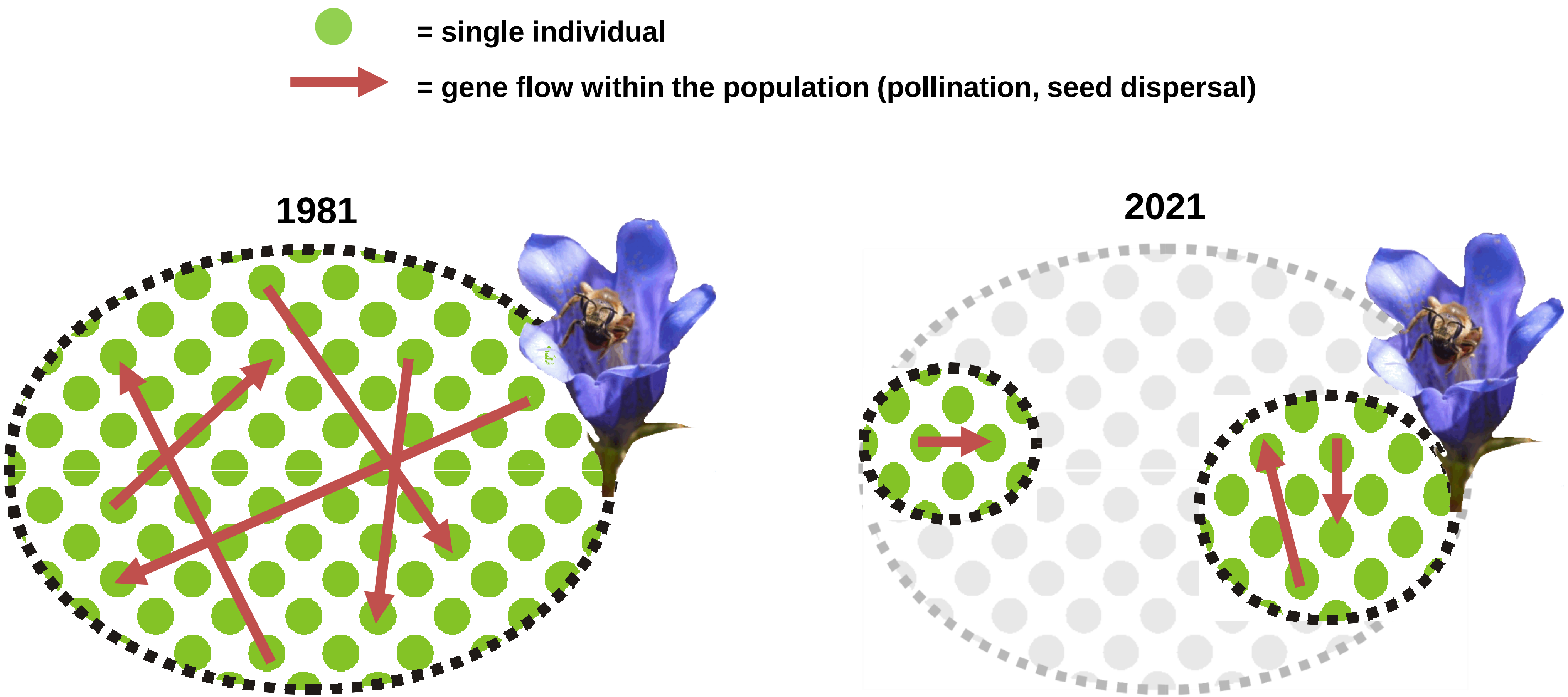
Collaboration with Prof. Bruno E. L. Cerabolini, Università degli Studi dell'Insubria, Varese

What is the minimum viable population size for rare plant species?



Aquilegia einseleana

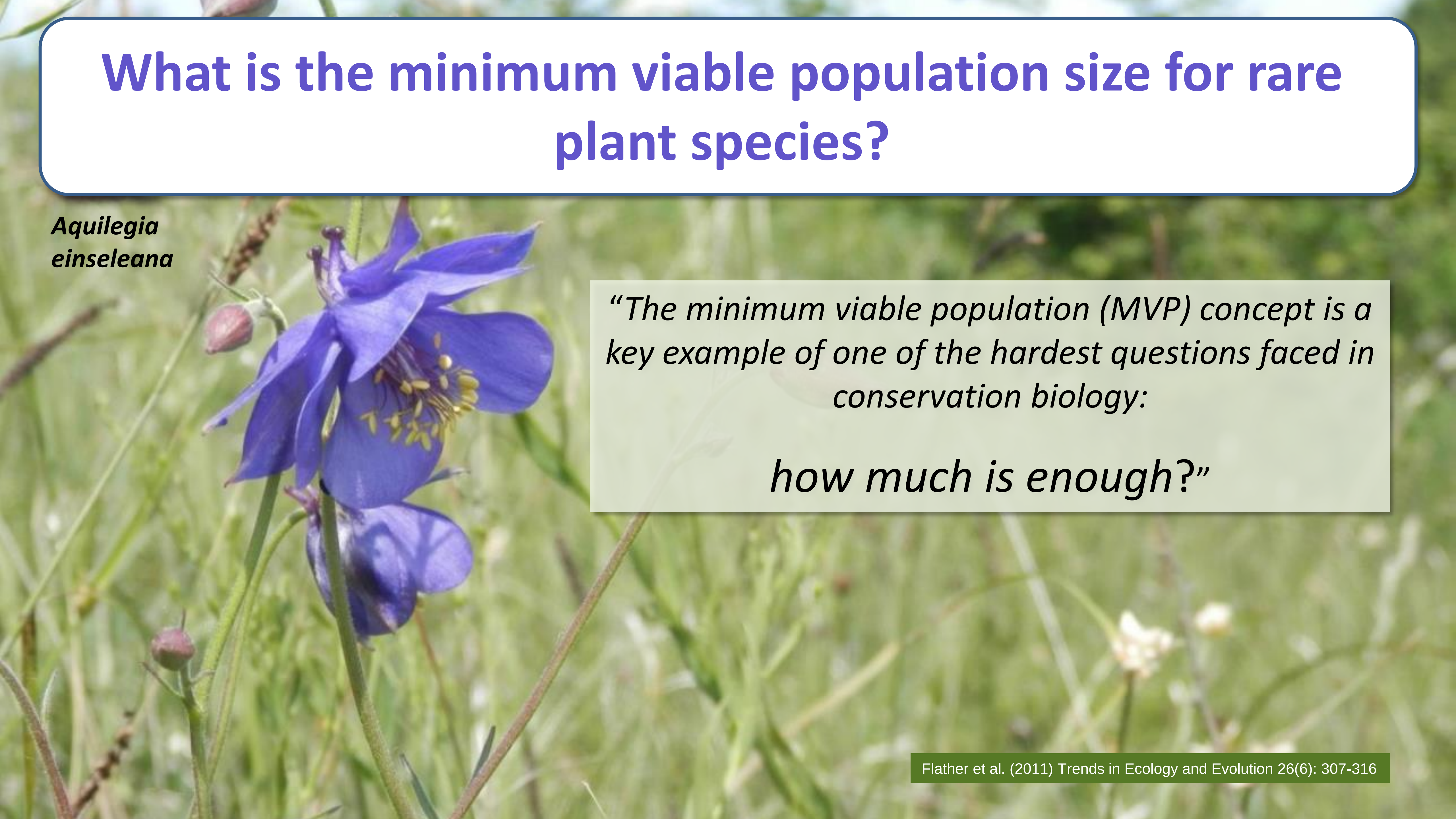
Why is population size so important?



The Allee effect: when population size declines, the flow of genes between sub-populations and individuals becomes more difficult, inbreeding depression occurs and the viability of the entire population is at risk

e.g. Goverde et al. (2002) *Biological Conservation* 104: 293-299

What is the minimum viable population size for rare plant species?



Aquilegia einseleana

"The minimum viable population (MVP) concept is a key example of one of the hardest questions faced in conservation biology:

how much is enough?"

Flather et al. (2011) Trends in Ecology and Evolution 26(6): 307-316

What is the minimum viable population size for rare plant species?

Aquilegia einseleana

"MVP size can be calculated as an estimate of the initial population size needed for there to be a 95% probability of survival 1,000 years into the future"

(estimated using population viability analysis; PVA)

Frankham et al. (2014) Biological Conservation 170: 56–63.

MVP sizes for plants

Table 2 – Summary of median (and bootstrapped 95% confidence bounds) minimum viable population sizes from all available literature (n = number of species; standardized = MVP_{st}; original = MVP_{orig})

	n	MVP_{st}	MVP_{st} 95% CI	MVP_{orig}
Vertebrates				
Birds	48	3742	2544–5244	3310
Fish	8	1,239,727	211,171–2,085,032	500,000
Mammals	95	3876	2261–5095	2901
Herptiles[a]	31	5409	3611–6779	3999
Sum/median	182	4102	3325–5096	3697
Other taxa				
Plants[b]	22	4824	2512–15,992	2097
Insects	5	10,841	1650–103,625	2000
Marine invertebrates[c]	3	3611	1984–1,047,547	2500
Sum/median	30	6111	3165–10,768	2100

*"This resource can be used by conservation practitioners as a **preliminary guide** to the MVP range expected for particular species"*

(In other words, it is not sufficient information to produce a conservation plan for single species.)

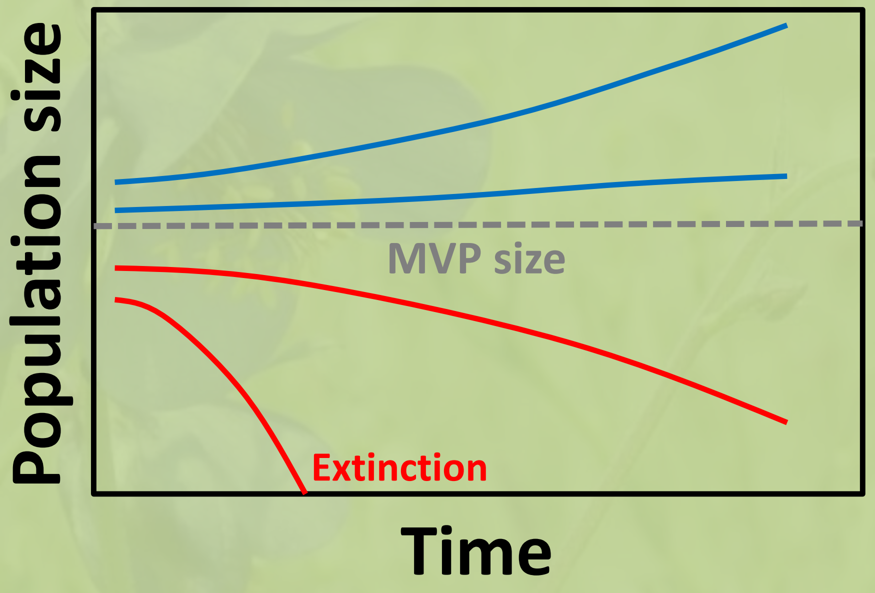
Traill et al. (2007) Biological Conservation 139: 159 - 166

The IUCN Red List Categories

C. Small population size and decline			
	Critically Endangered	Endangered	Vulnerable
Number of mature individuals	< 250	< 2,500	< 10,000

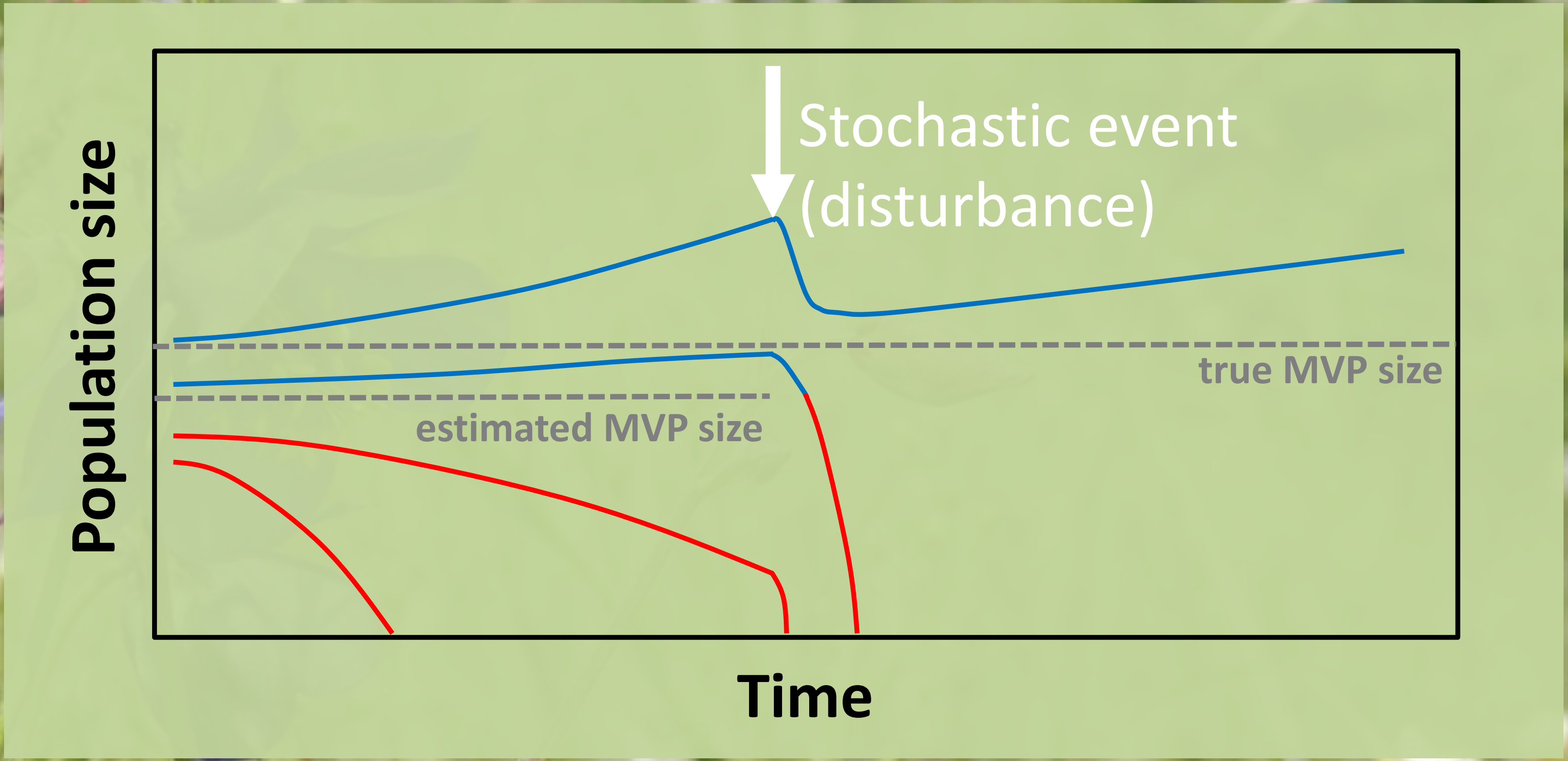
If the MVP of plants in general is around 4800 individuals, do Critically Endangered and Endangered species inevitably face extinction?

Population viability analysis (PVA) predicts persistence



The MVP size is the threshold separating persistence from decline

Stochasticity (random disturbances) increases the MVP size



The true MVP size depends on the magnitude and effect of future stochastic events, and is thus extremely difficult to estimate

Kent, H. (2007). *Types of Stochastic Threats. EEB310: Conservation Biology.* University of Connecticut.

What is the minimum viable population size for rare plant species, in light of stochasticity?

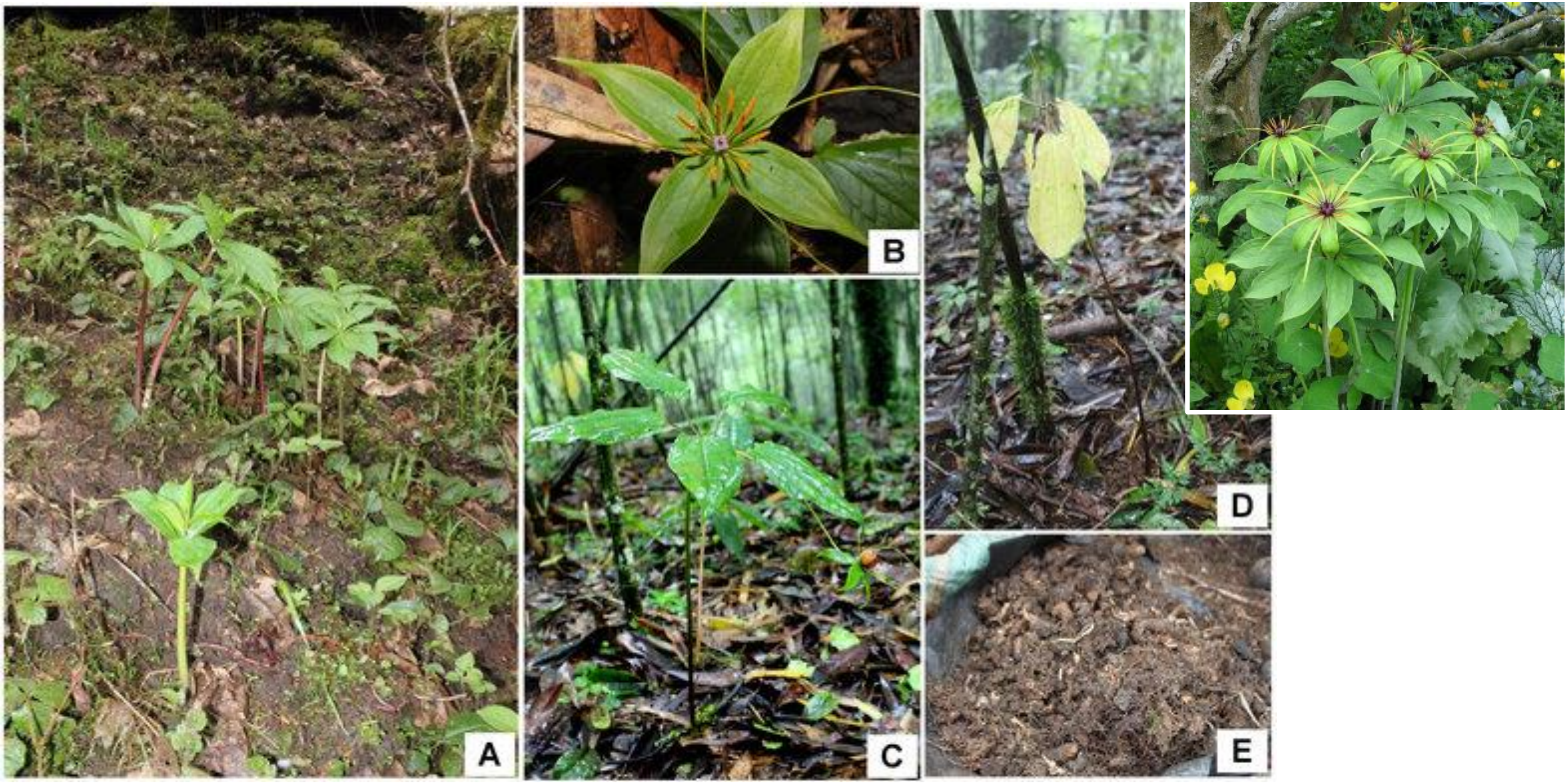
"there is no single 'magic' population size that guarantees population persistence"

Flather et al. (2011) Trends in Ecology and Evolution 26(6): 307-316.

BUT!

- we can include stochasticity in population viability analysis, and it seems to be useful
- we can observe and quantify specific biological thresholds for single species!

PVA including stochastic events (e.g. *Paris polyphylla*)



Roy et al. (2018) Zoos' Print Journal 33(7):19-22

PVA including stochastic events (e.g. *Paris polyphylla*)

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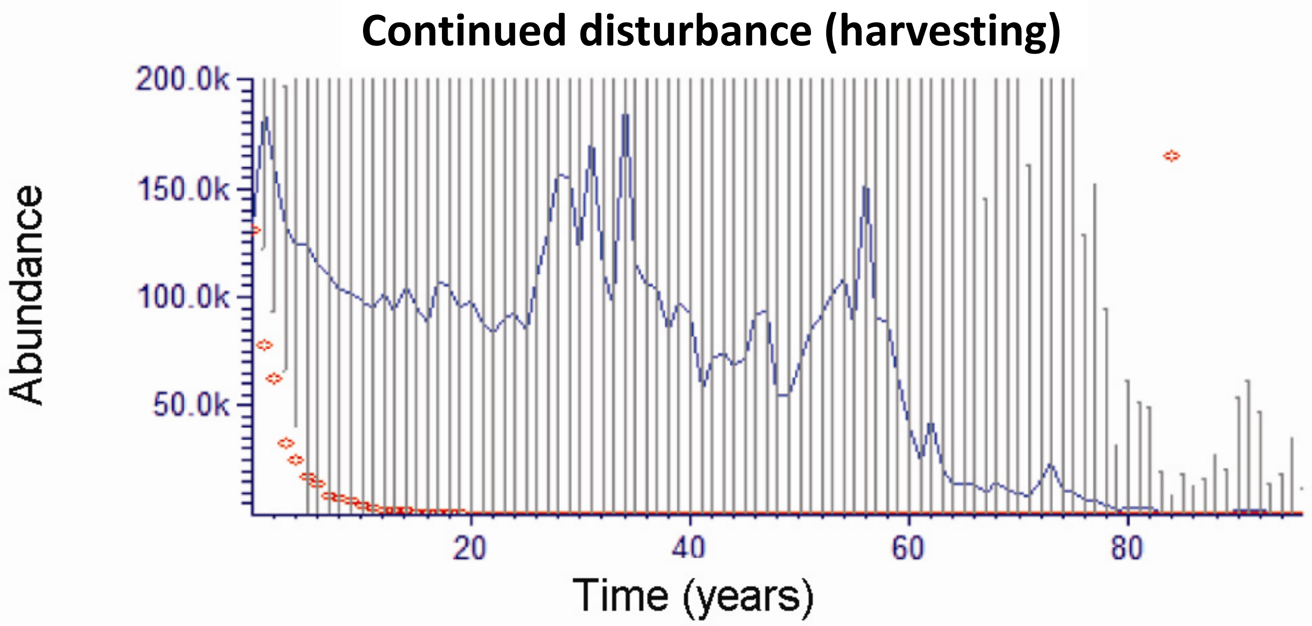
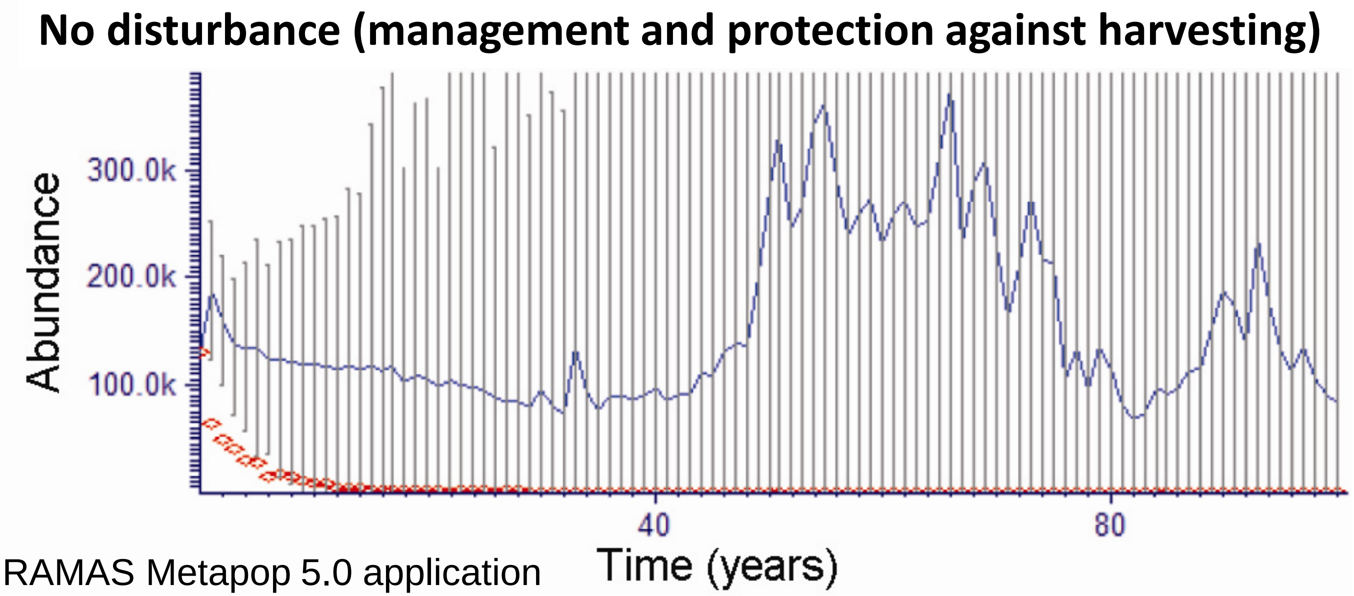




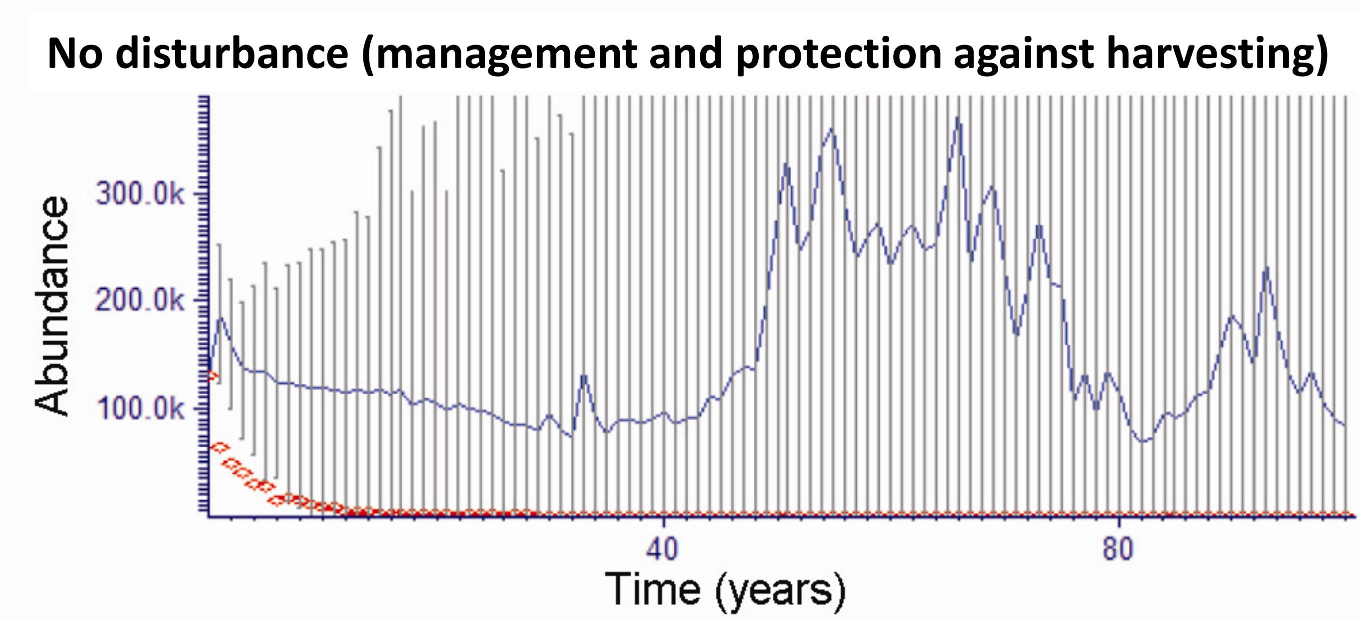
RAMAS Metapop 5.0 application
(www.ramas.com/metapop-6-0)

Lyngdoh et al. (2018) Current Science 114(3): 532-538

PVA including stochastic events (e.g. *Paris polyphylla*)

In this scenario:

- The MVP is ~9,000 reproductive adults
- introduction of 3,500 plants would be sufficient to change IUCN status from VU to LC



Lyngdoh et al. (2018) Current Science 114(3): 532-538

Population size and genetic diversity effects for *Dracocephalum austriacum*

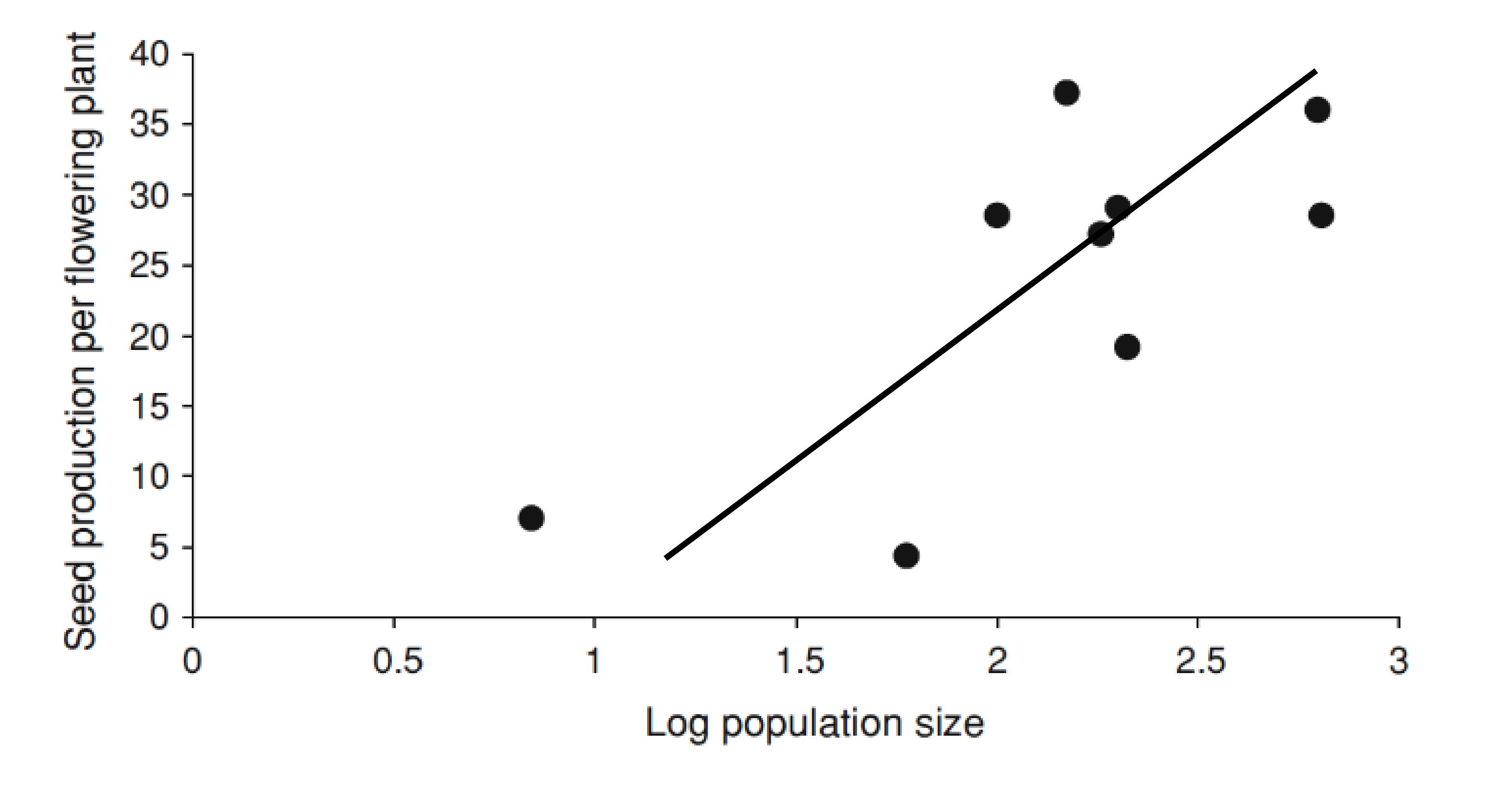
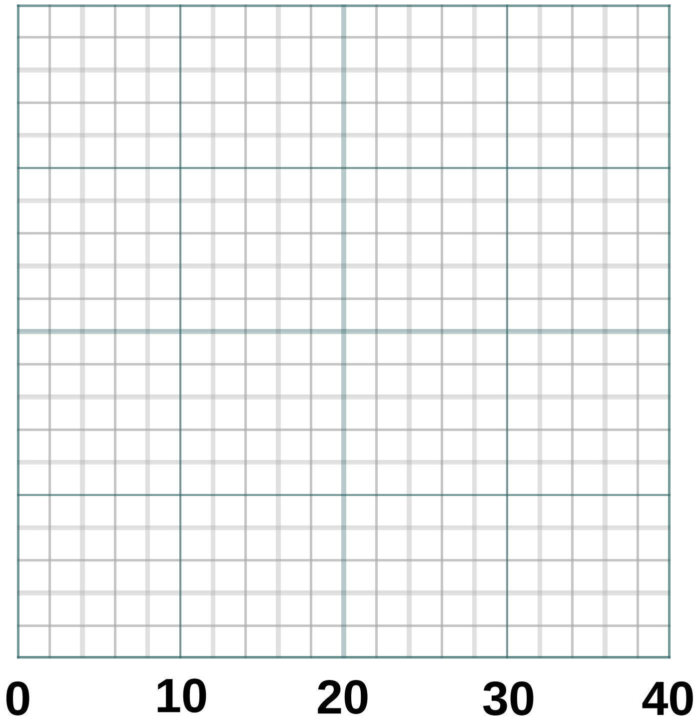


Fig. 3 Relationship between population size and seed production per flowering plant of *Dracocephalum austriacum* ($r = 0.728$, $P = 0.026$)

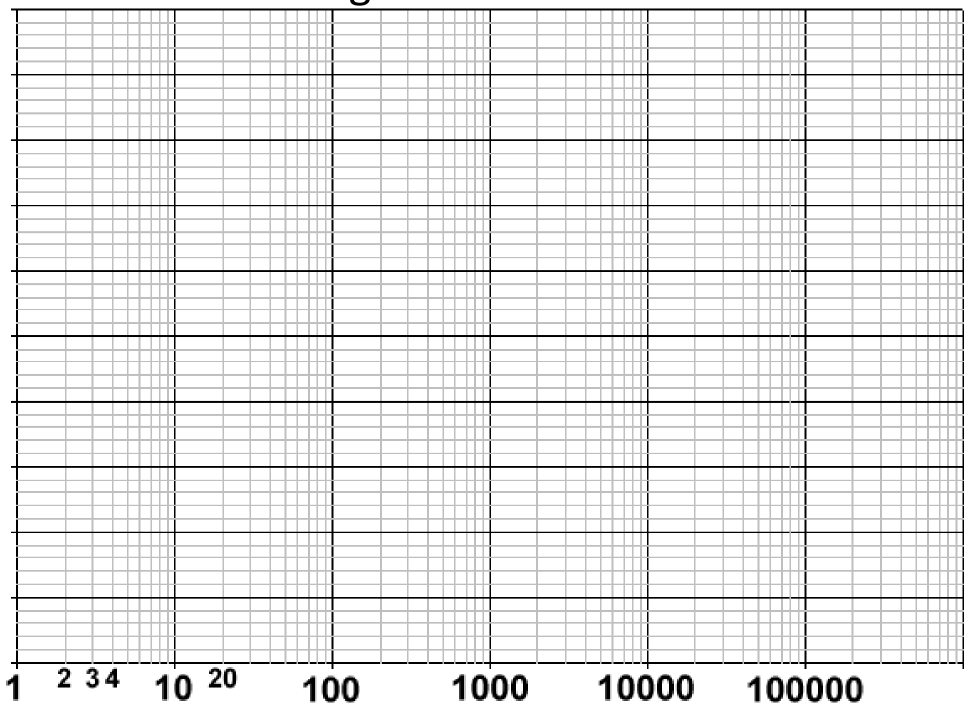
Dostálek et al. (2010) Conservation Genetics 11: 773-783

Population size and genetic diversity effects for *Dracocephalum austriacum*

Linear scale

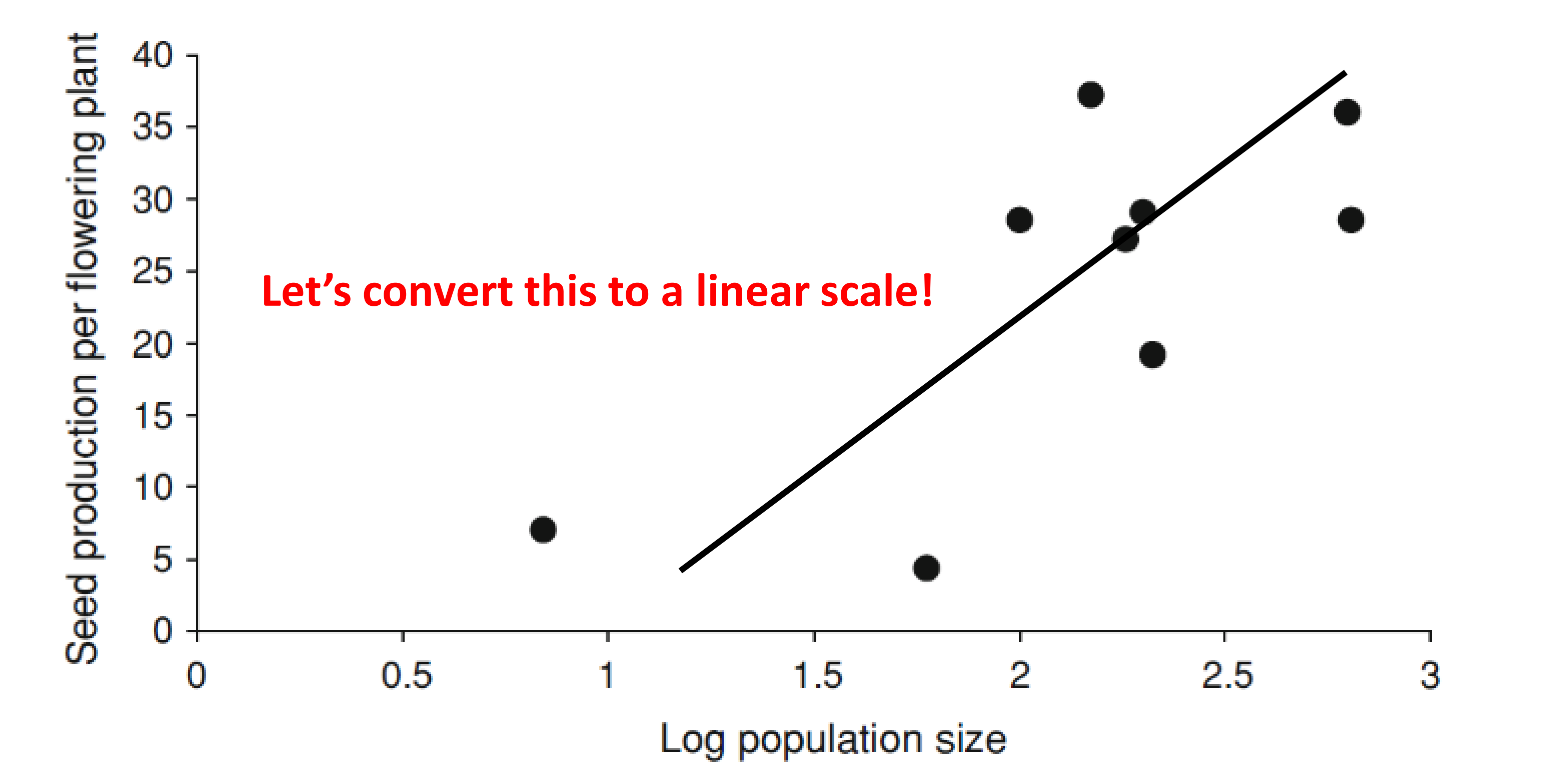


Logarithmic scale



A log scale can allow extremely large numbers to be presented with extremely small numbers, but it ‘distorts’ the distribution of data.

Population size and genetic diversity effects for *Dracocephalum austriacum*



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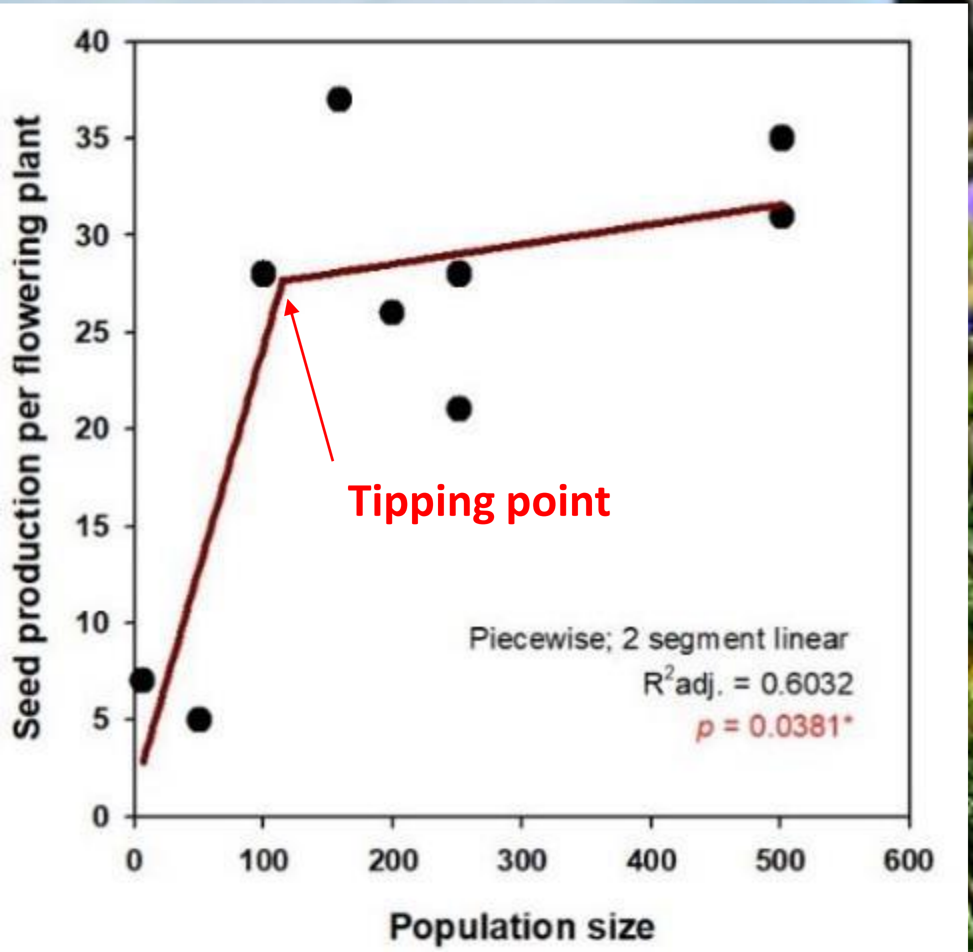
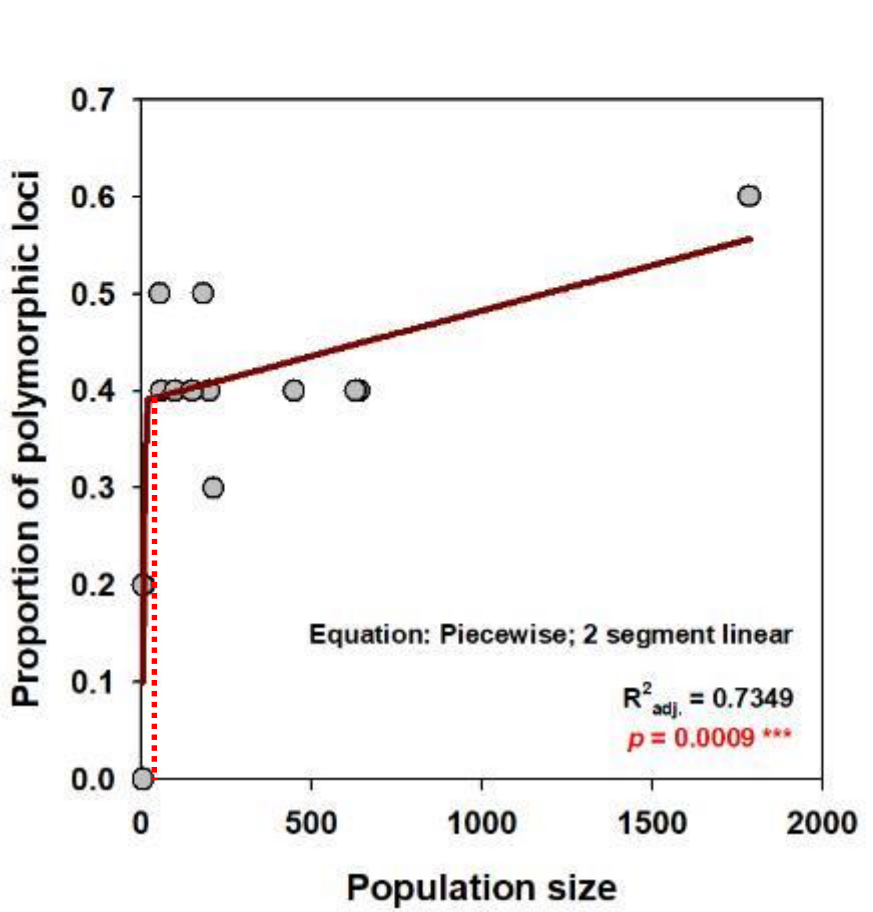


When populations are smaller than 100 plants, the loss of just a few plants will greatly reduce seed production

Dostálek et al. (2010) Conservation Genetics 11: 773-783

Population size and genetic diversity effects for *Dracocephalum austriacum*



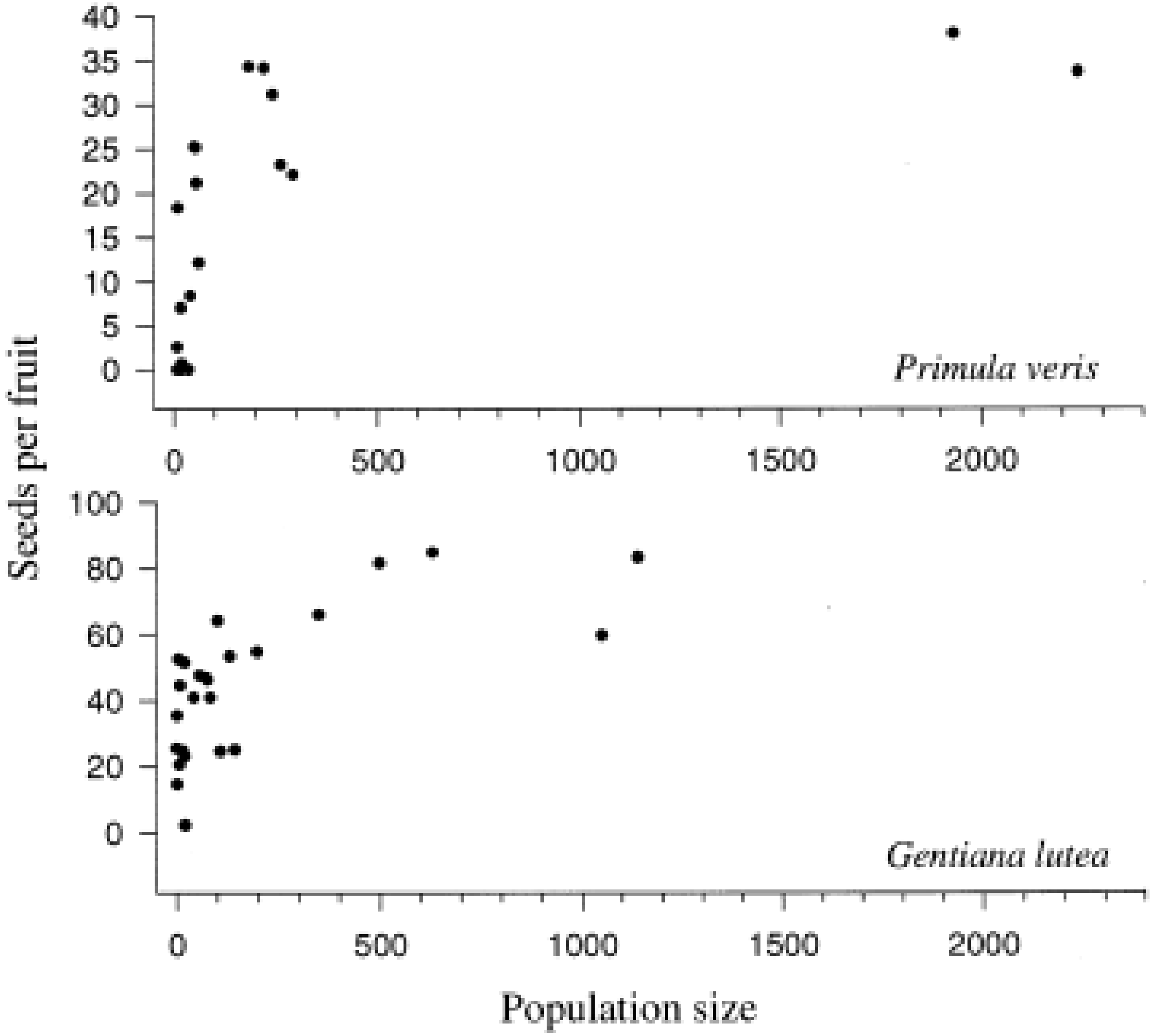
"More is better", but a population size of ~20 plants seems to represent a dangerous tipping point*

*suggested by only one measure of genetic diversity

Genetic diversity is related to morphological and functional diversity

Dostálek et al. (2010) Conservation Genetics 11: 773-783

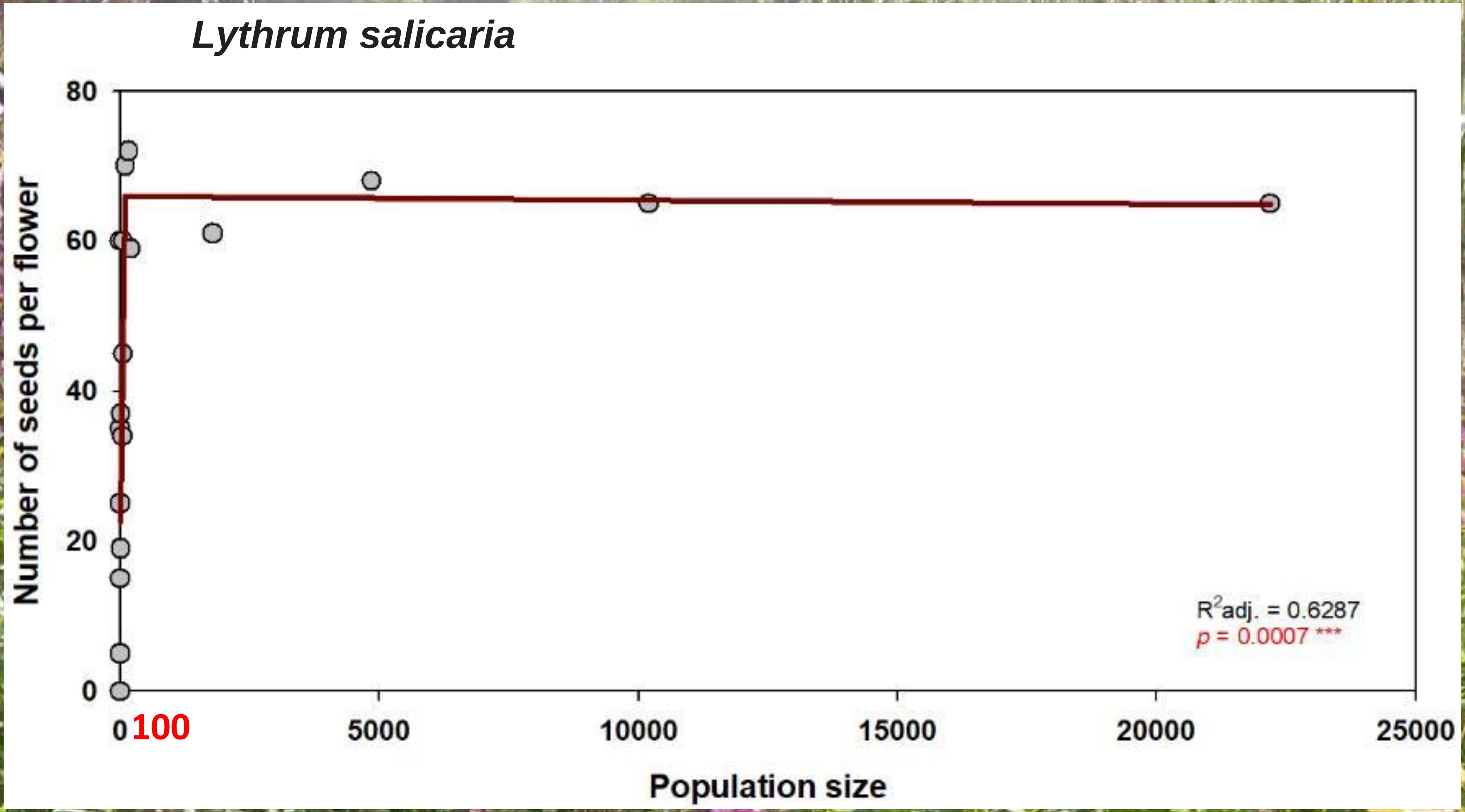
Population size and reproductive output



"Reproduction was depressed most strongly in populations consisting of less than c. 200 (*P. veris*) and c. 500 plants (*G. lutea*)"

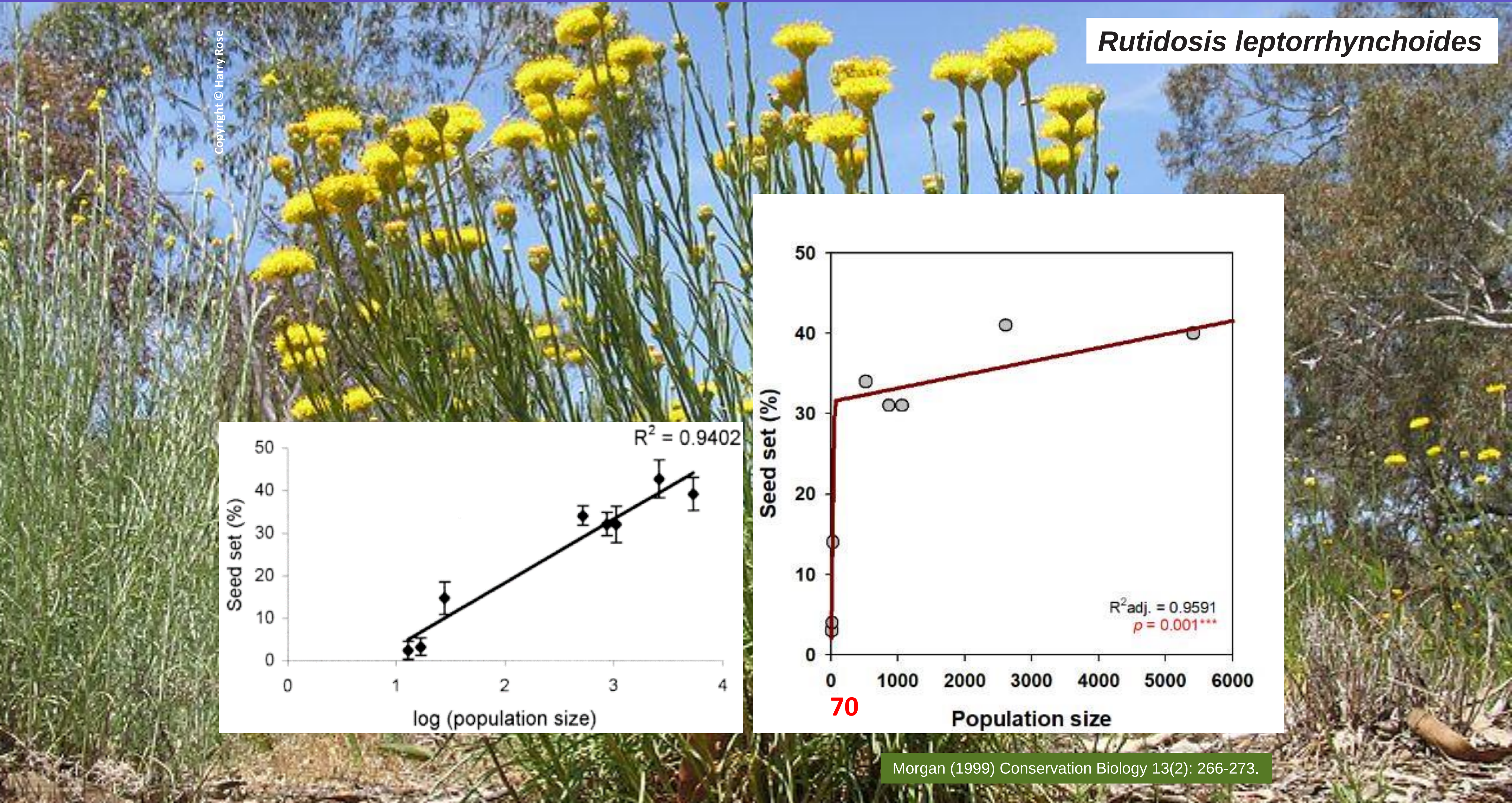
Kéry et al. (2000) Journal of Ecology 88: 17-30

Population size and reproductive output



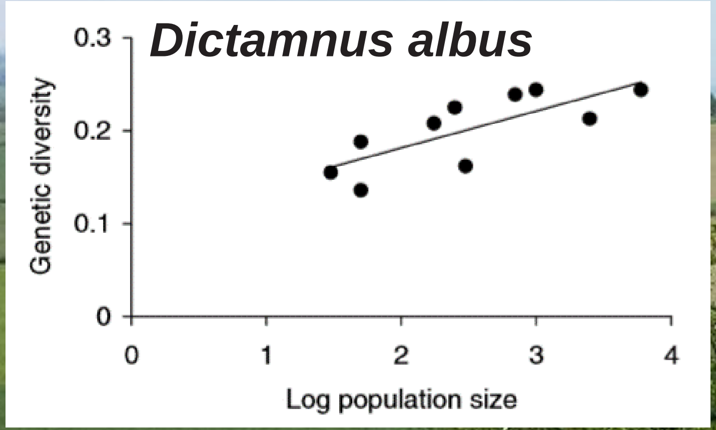
Ågren (1996) Ecology 77(6): 1779-1790.

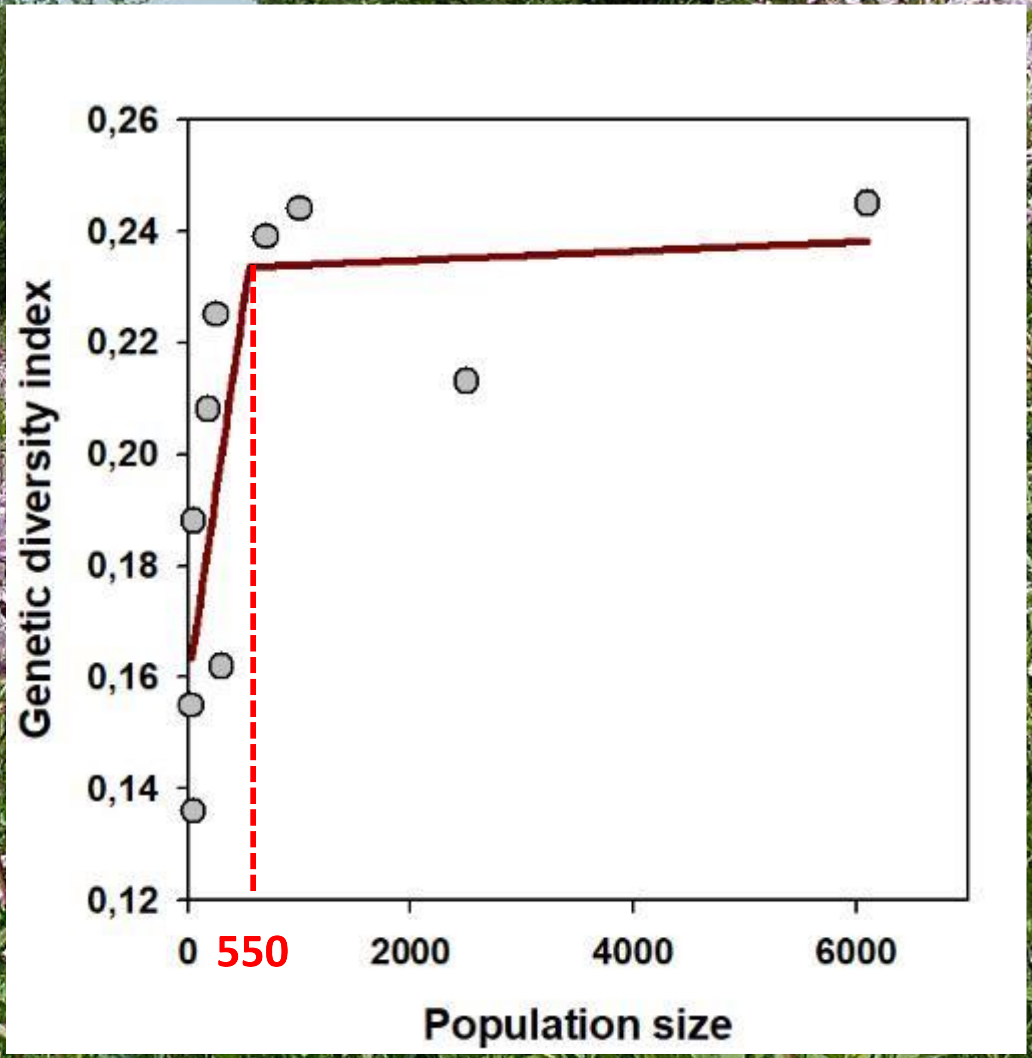
Population size and reproductive output



Morgan (1999) Conservation Biology 13(2): 266-273.

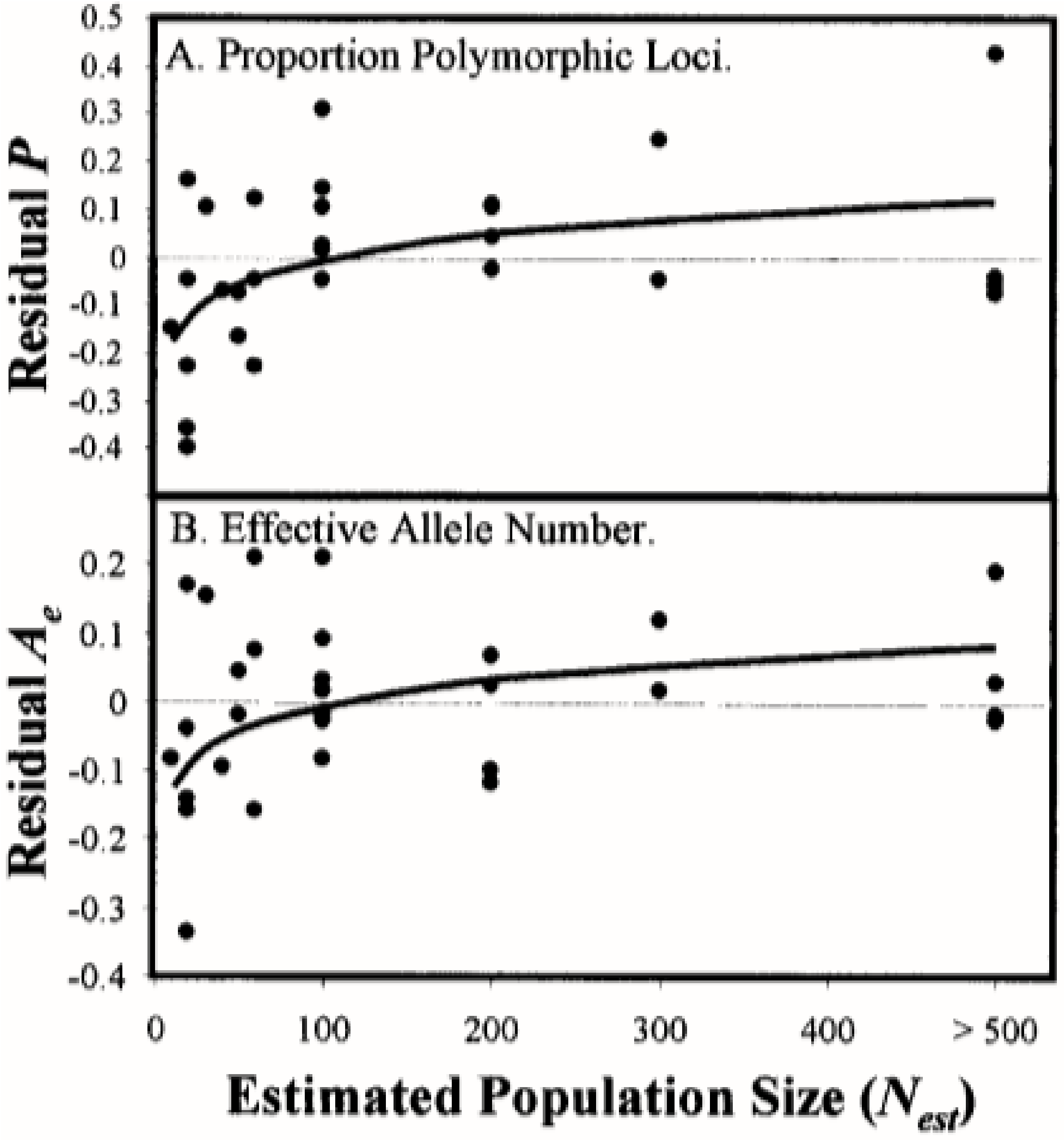
Population size and genetic diversity



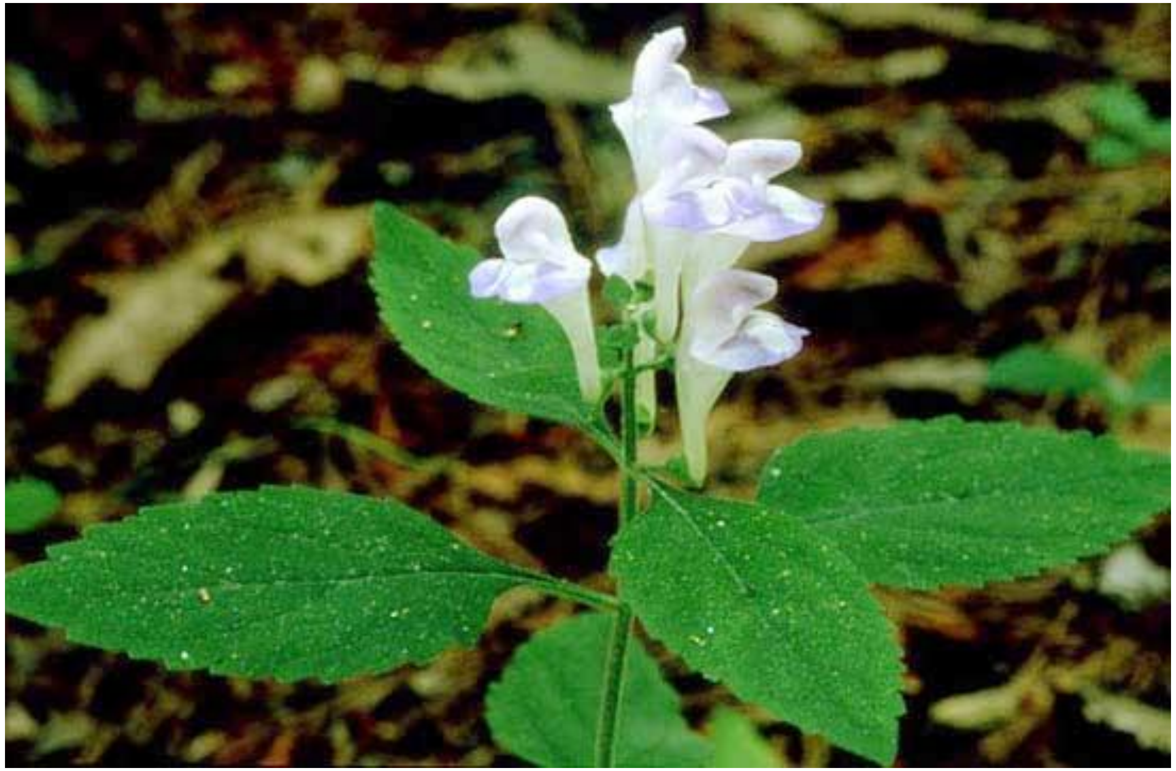


Hensen & Oberprieler (2005) Conservation Genetics 6: 63–73.

Population size and genetic diversity

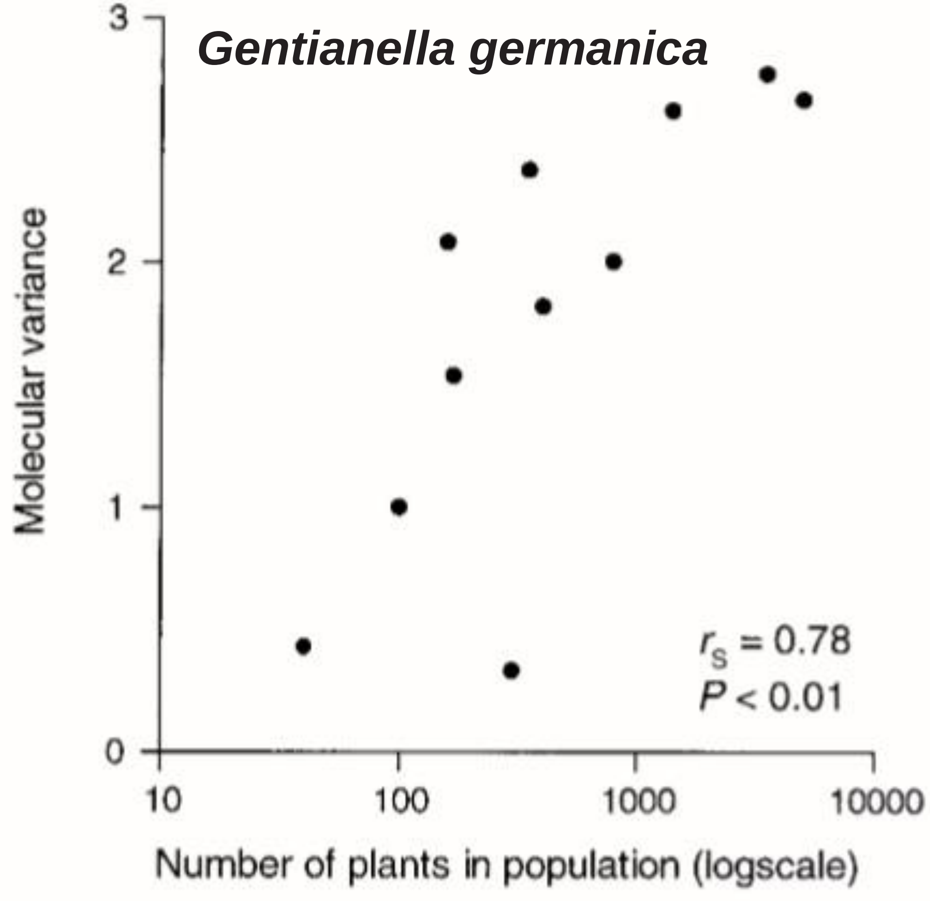


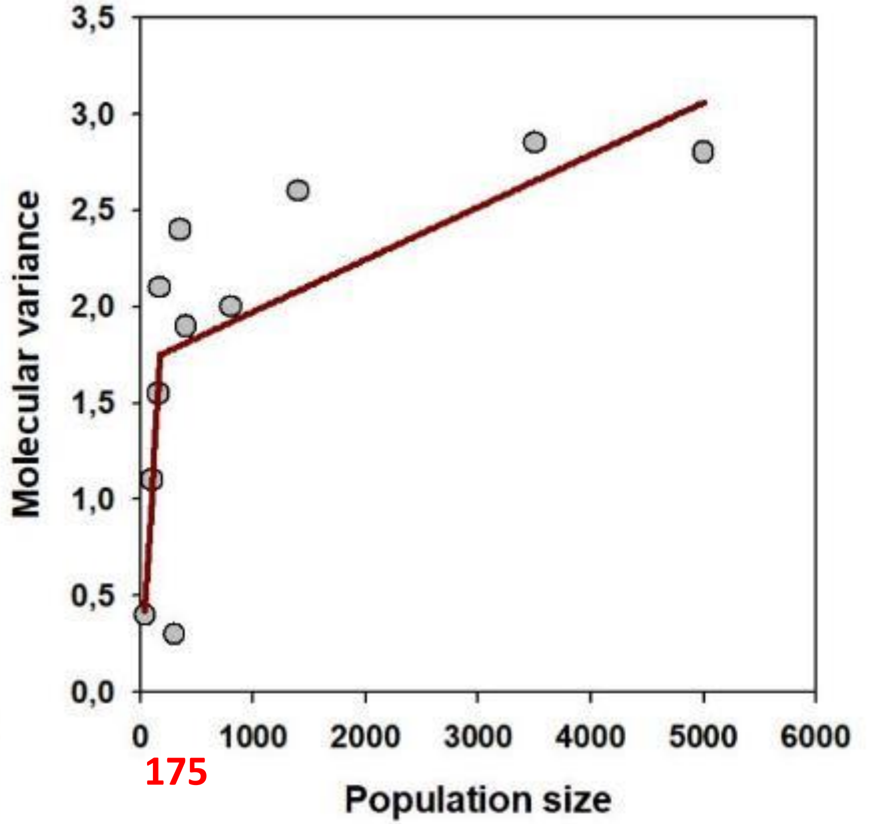
Scutellaria montana



Cruzan (2001) Evolution 55(8):1569-1580.

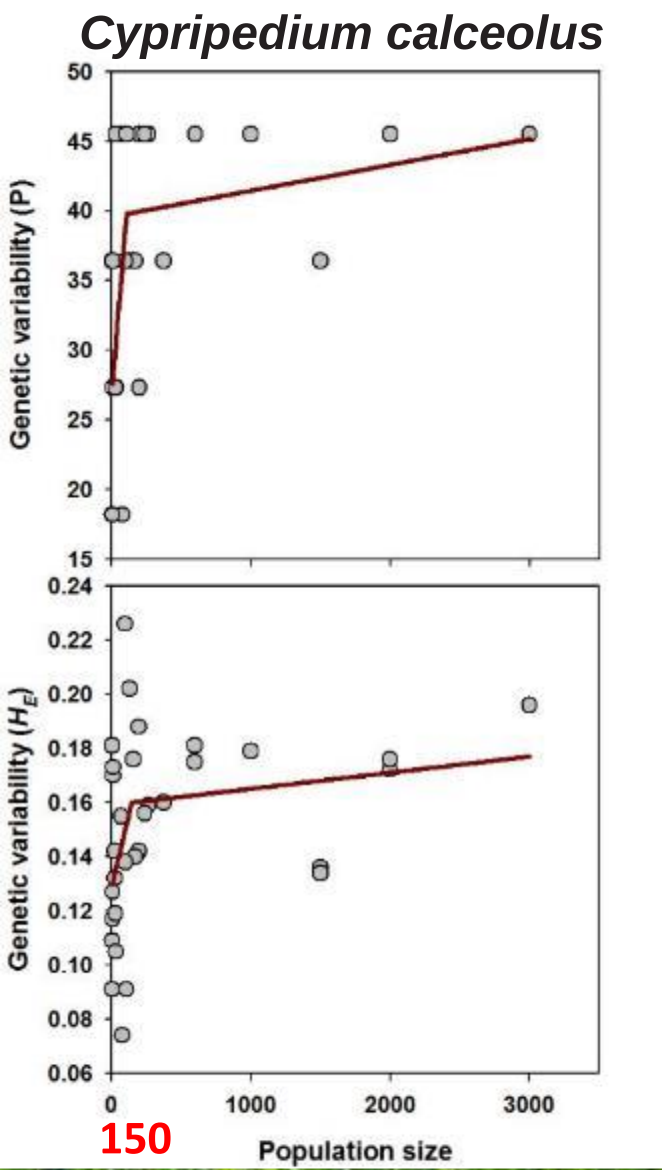
Population size and genetic diversity





Fischer & Matthies (1998) American Journal of Botany 85(6):811-819.

Population size and genetic diversity



Brzosko et al. (2011) Plant Systematics and Evolution 295: 83-96.

Population size and genetic diversity

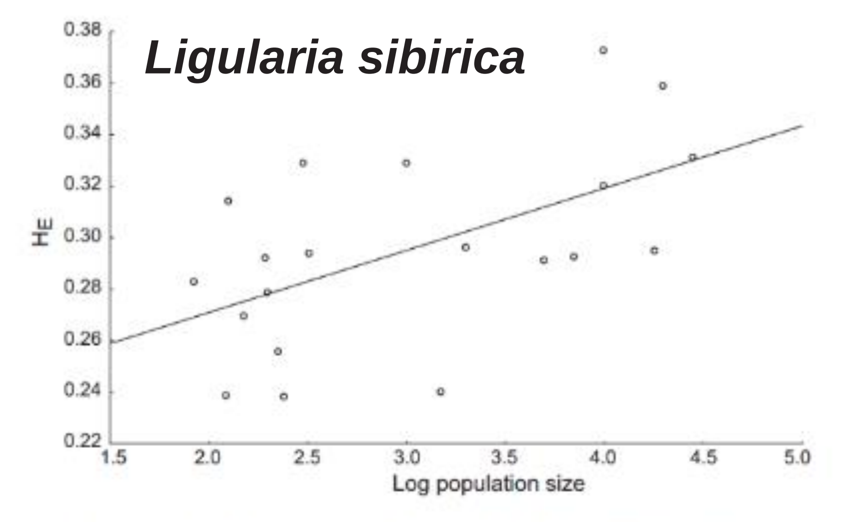
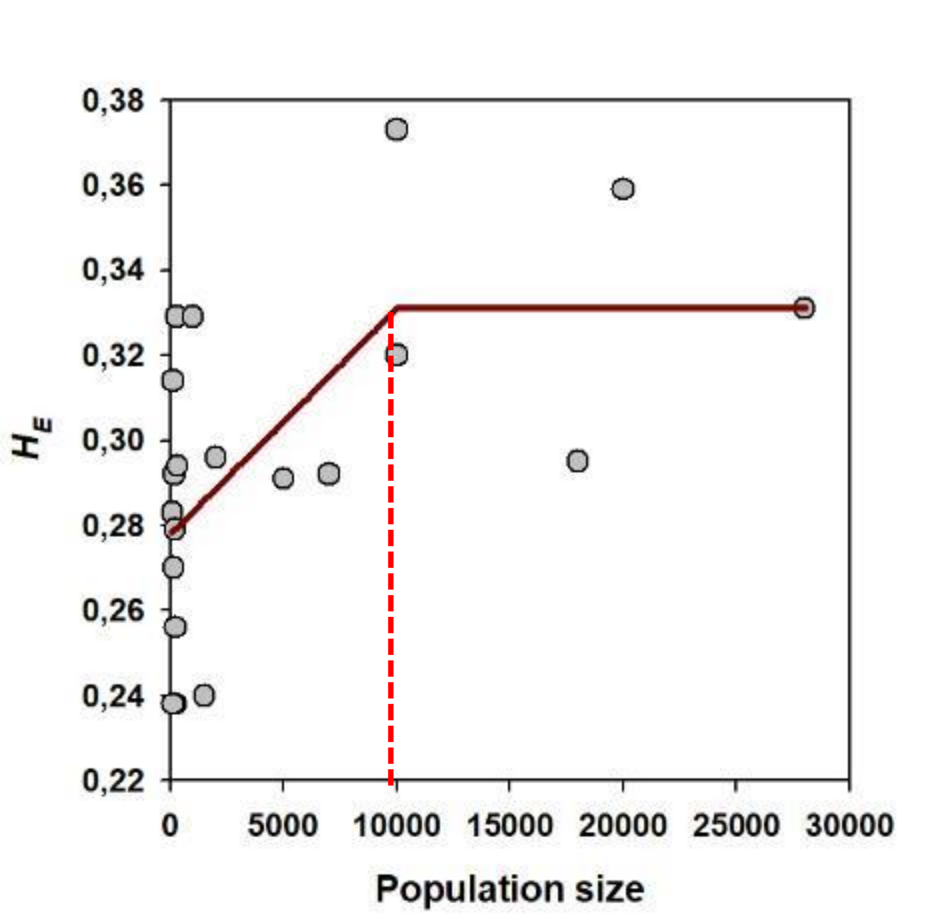
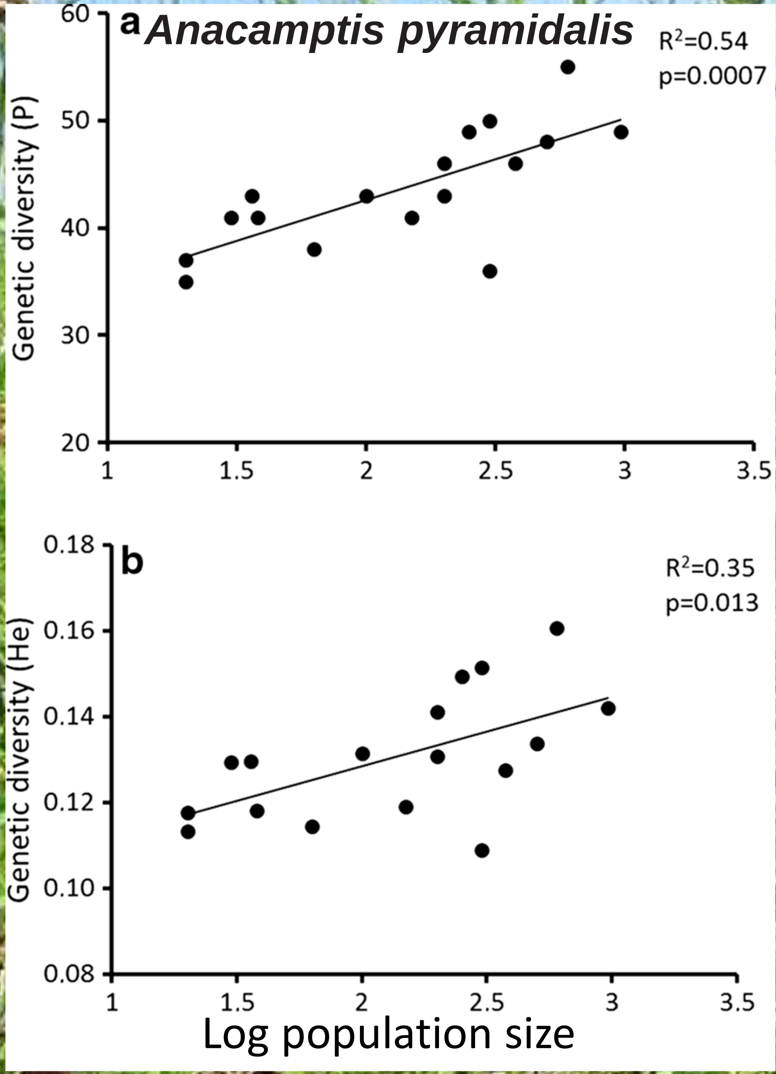


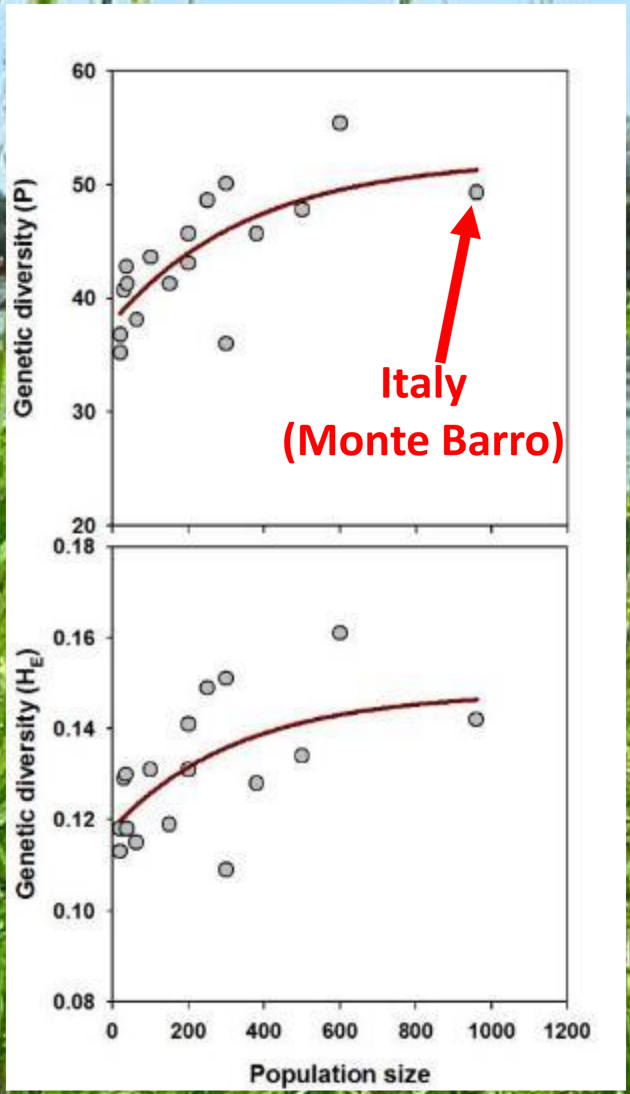
Fig. 3. The relationship between estimated population size and expected heterozygosity of *L. sibirica* ($r = 0.561$; $P = 0.01$).



Smídová et al. (2011) Flora 206: 151-157

Population size and genetic diversity

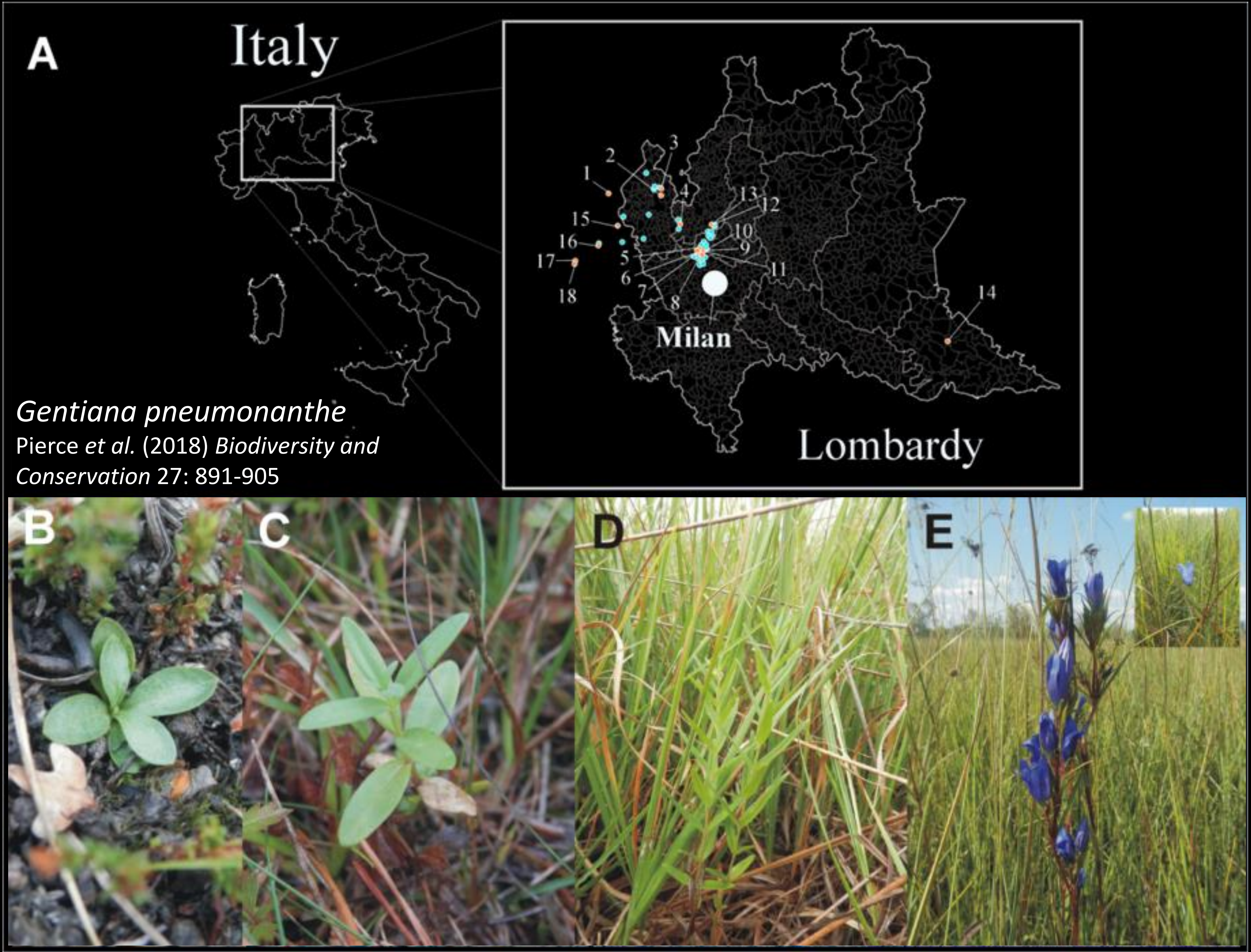




Joachim Lutz

No clear tipping point, but a general decline in the order of **several hundred plants**.

Ilves et al. (2016) Plant Systematics and Evolution 302: 1227-1238.



Gentiana pneumonanthe

Pierce *et al.* (2018) *Biodiversity and Conservation* 27: 891-905

In collaboration with:
Alberto Spada (DiSAA)
Elizabetta Caporali (Dip. Bioscienze)

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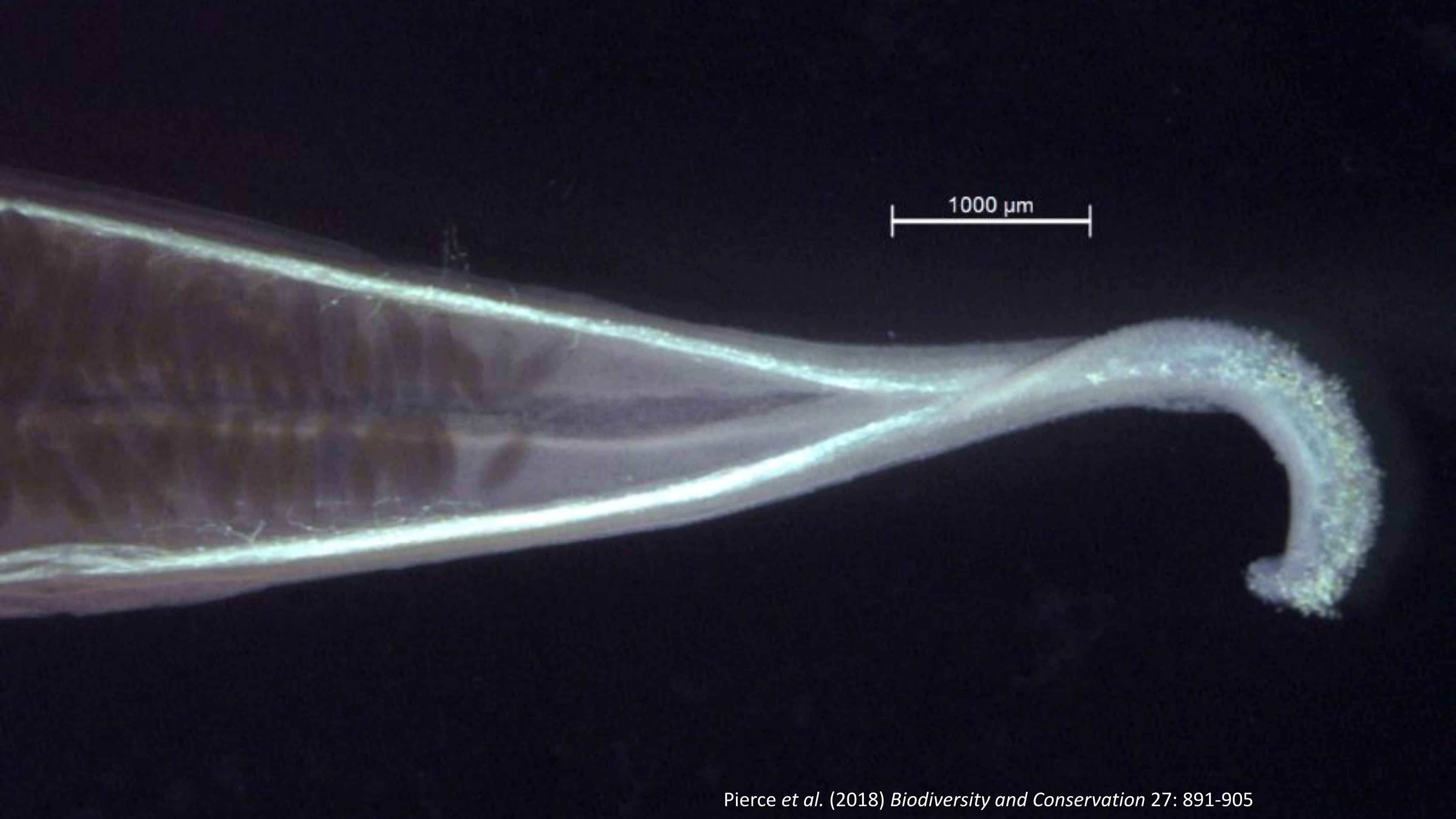

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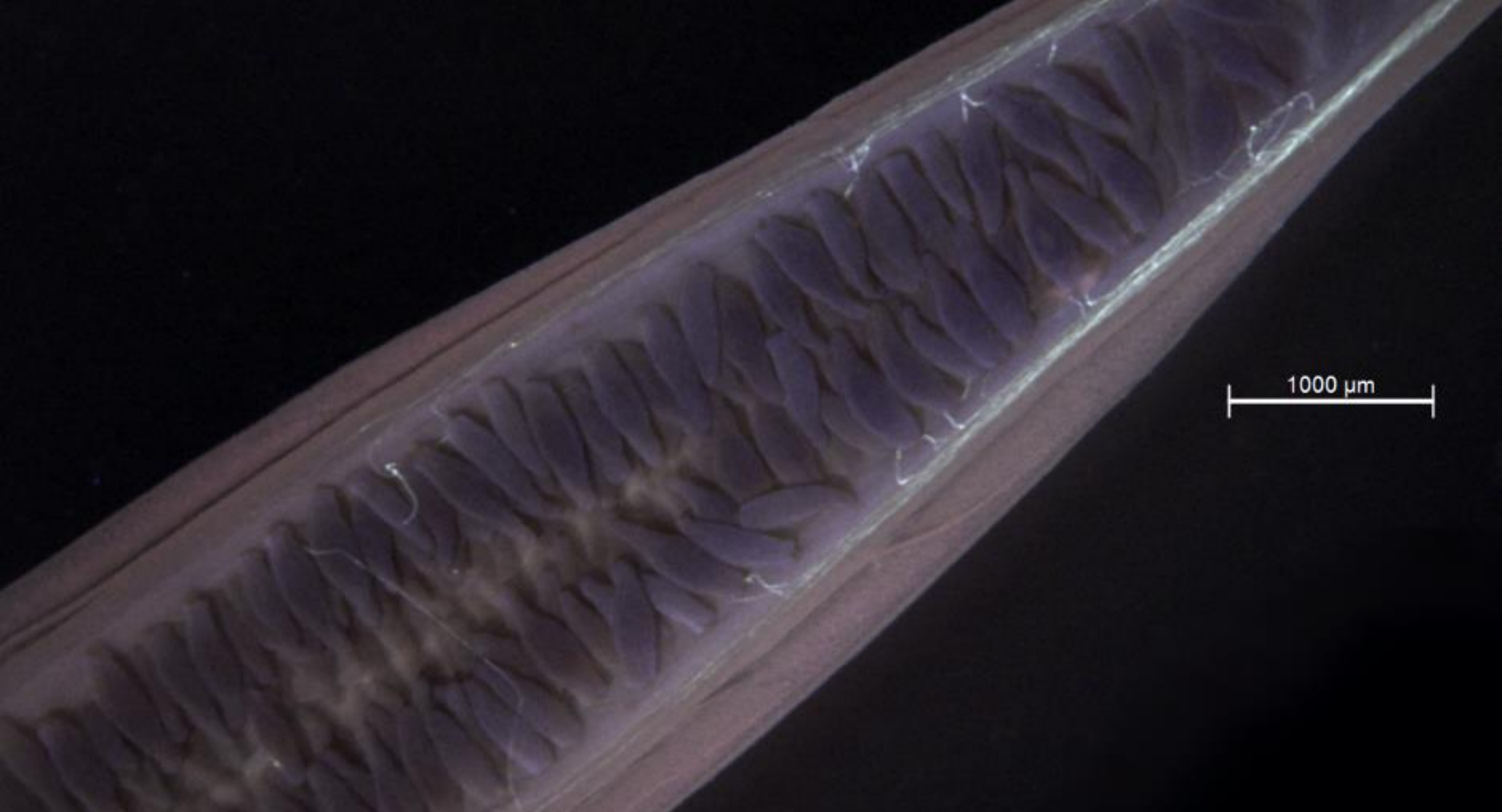

Pierce *et al.* (2018) *Biodiversity and Conservation* 27: 891-905

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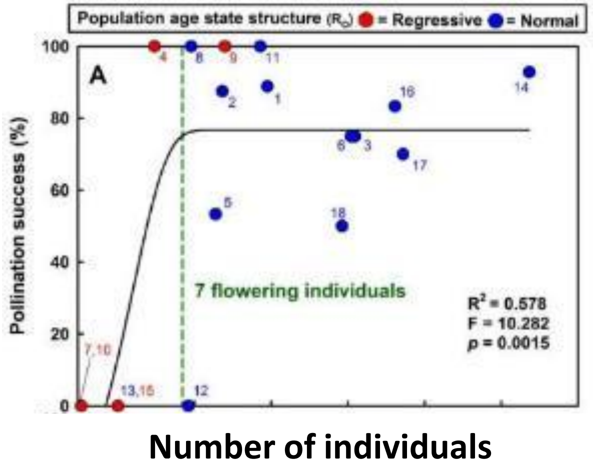
What is the population size threshold for reproductive success?



In terms of pollination success:
~7 flowering individuals

Pierce *et al.* (2018) *Biodiversity and Conservation* 27: 891-905

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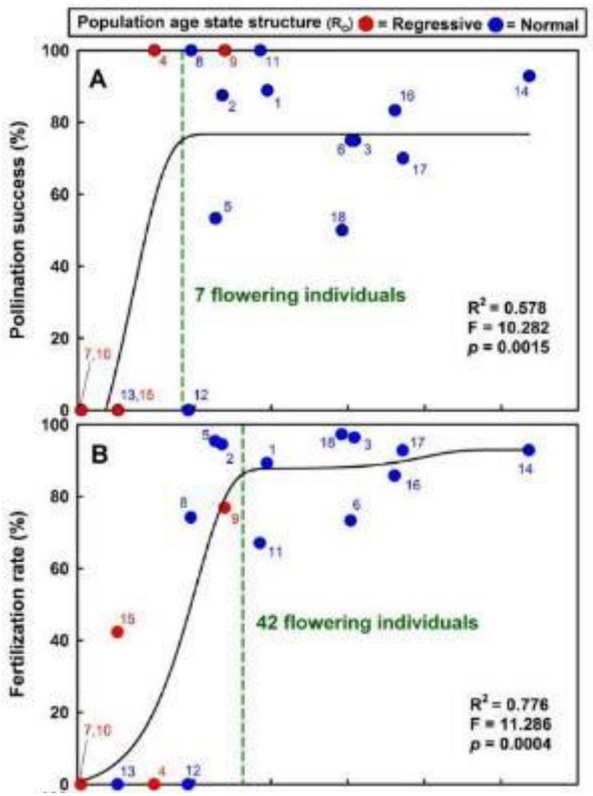
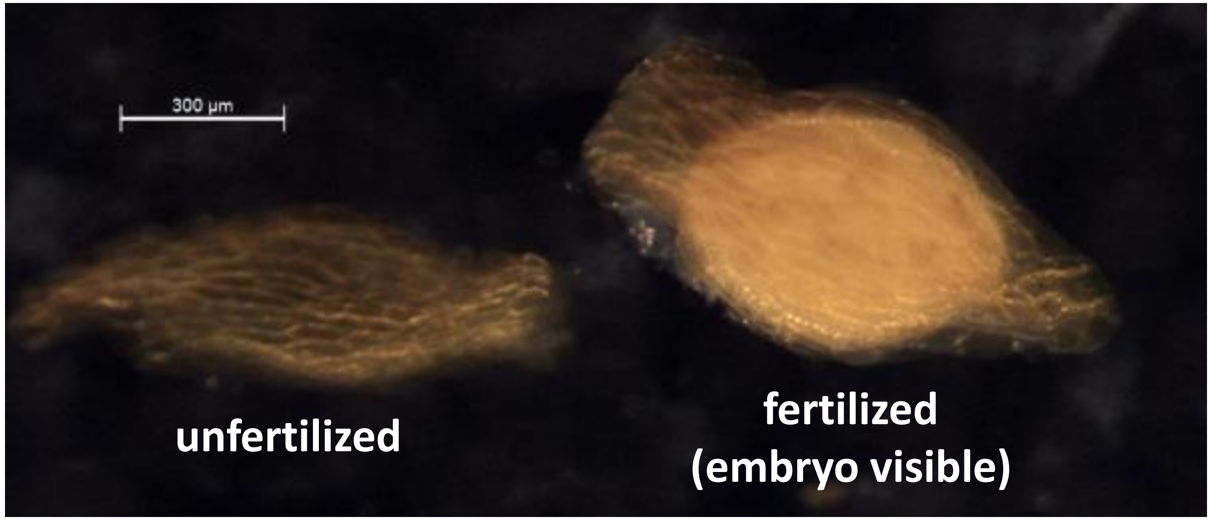


Number of individuals

In terms of the fertilization of ovules: ~42



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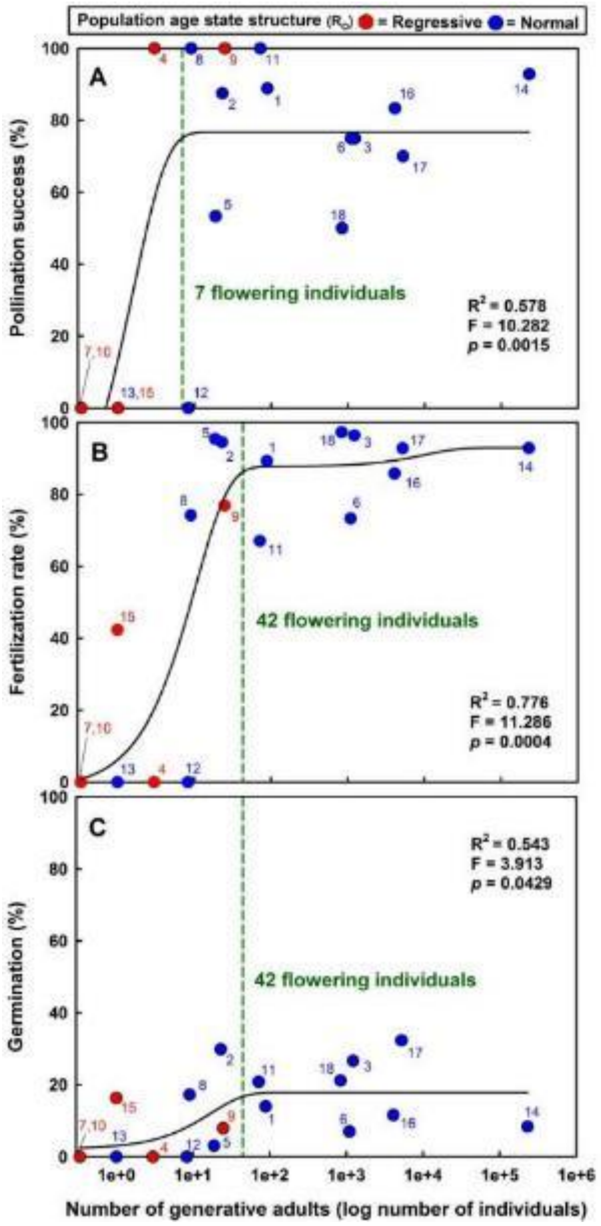
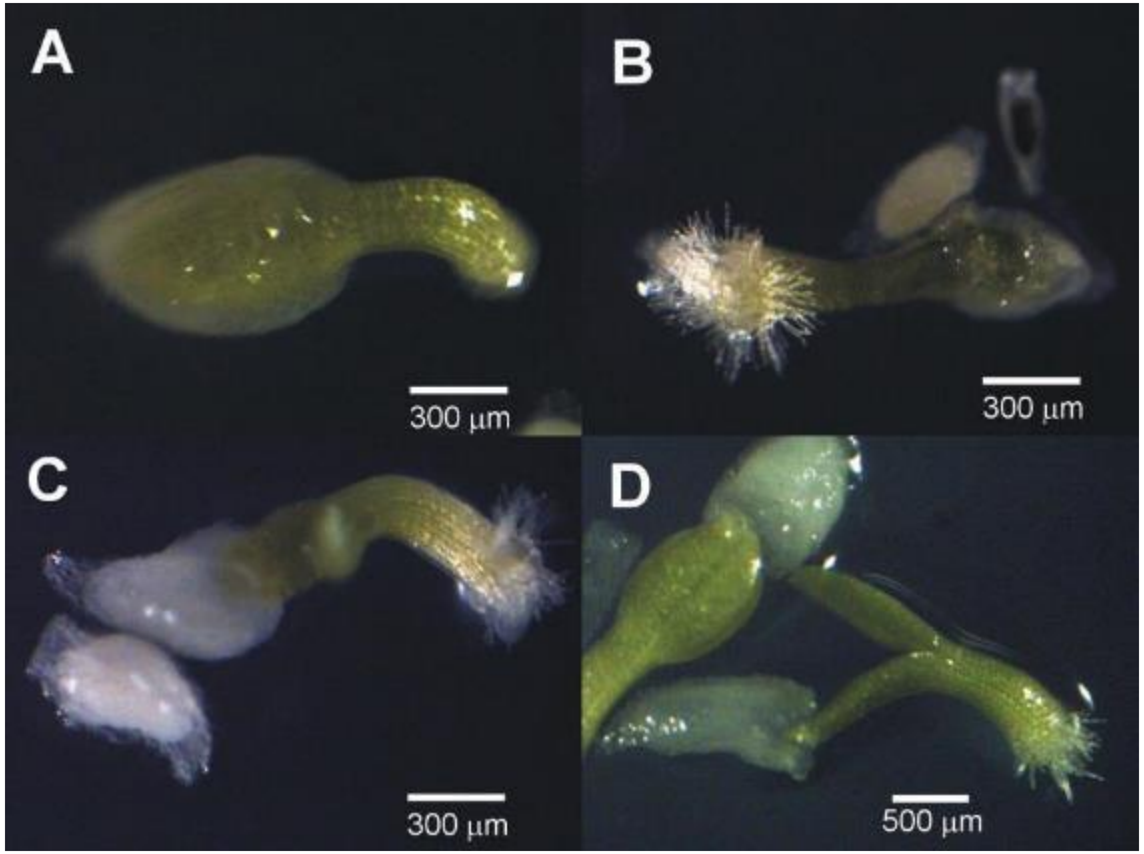


In terms of the germination of 'good' seeds (containing embryos): ~42



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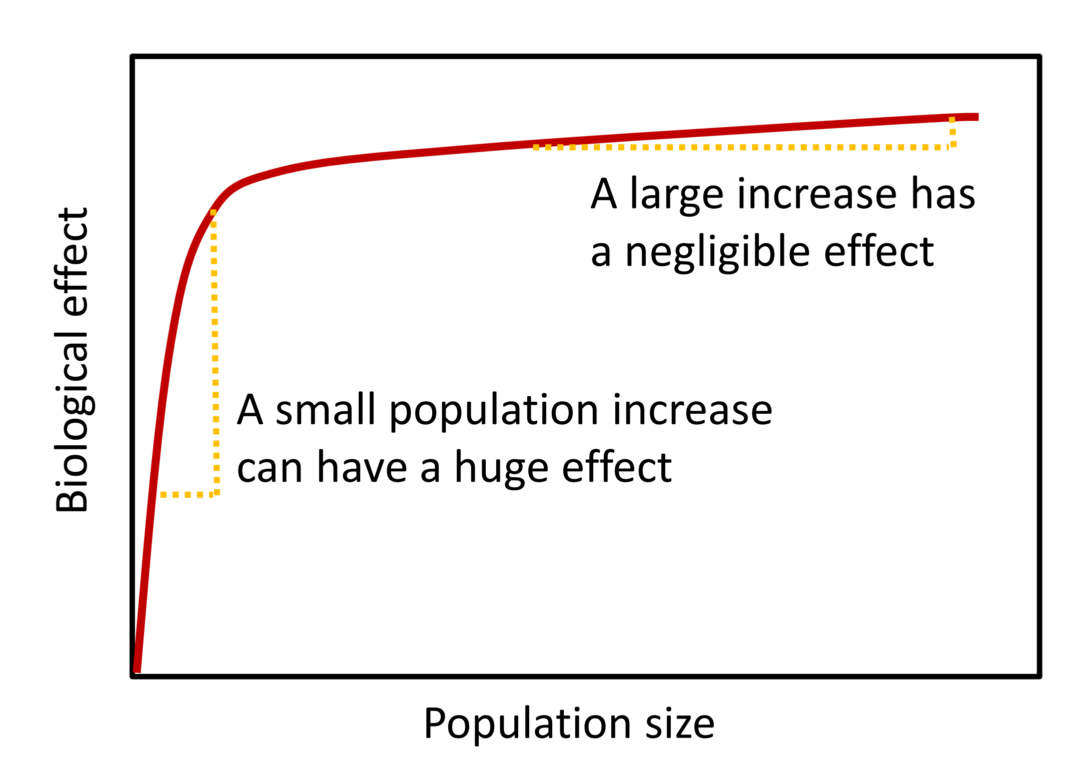
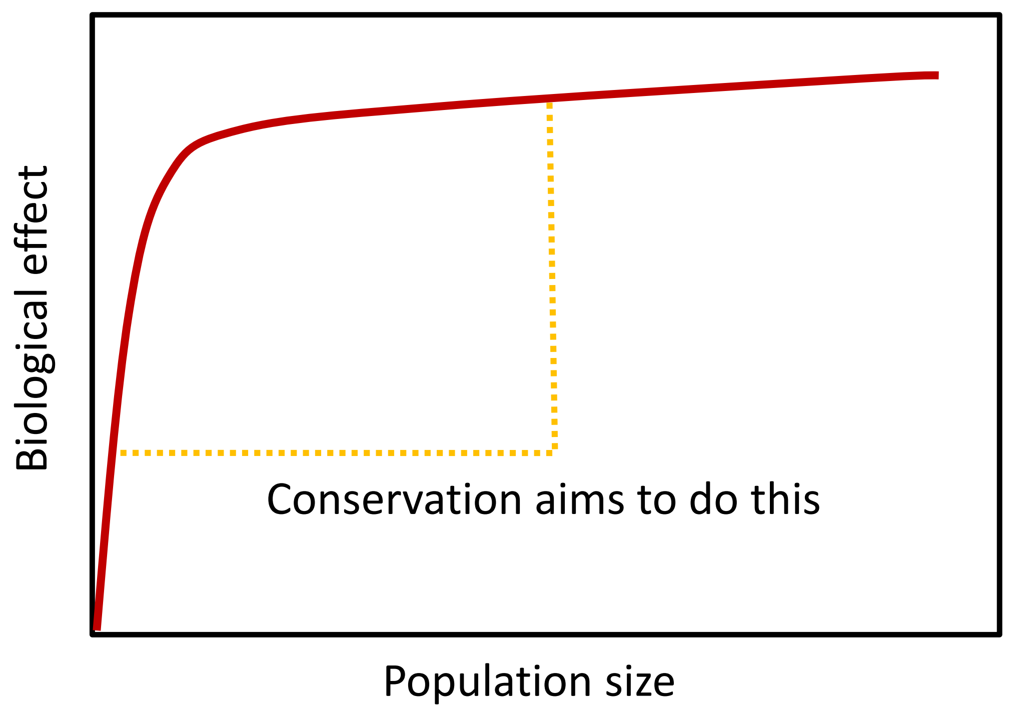
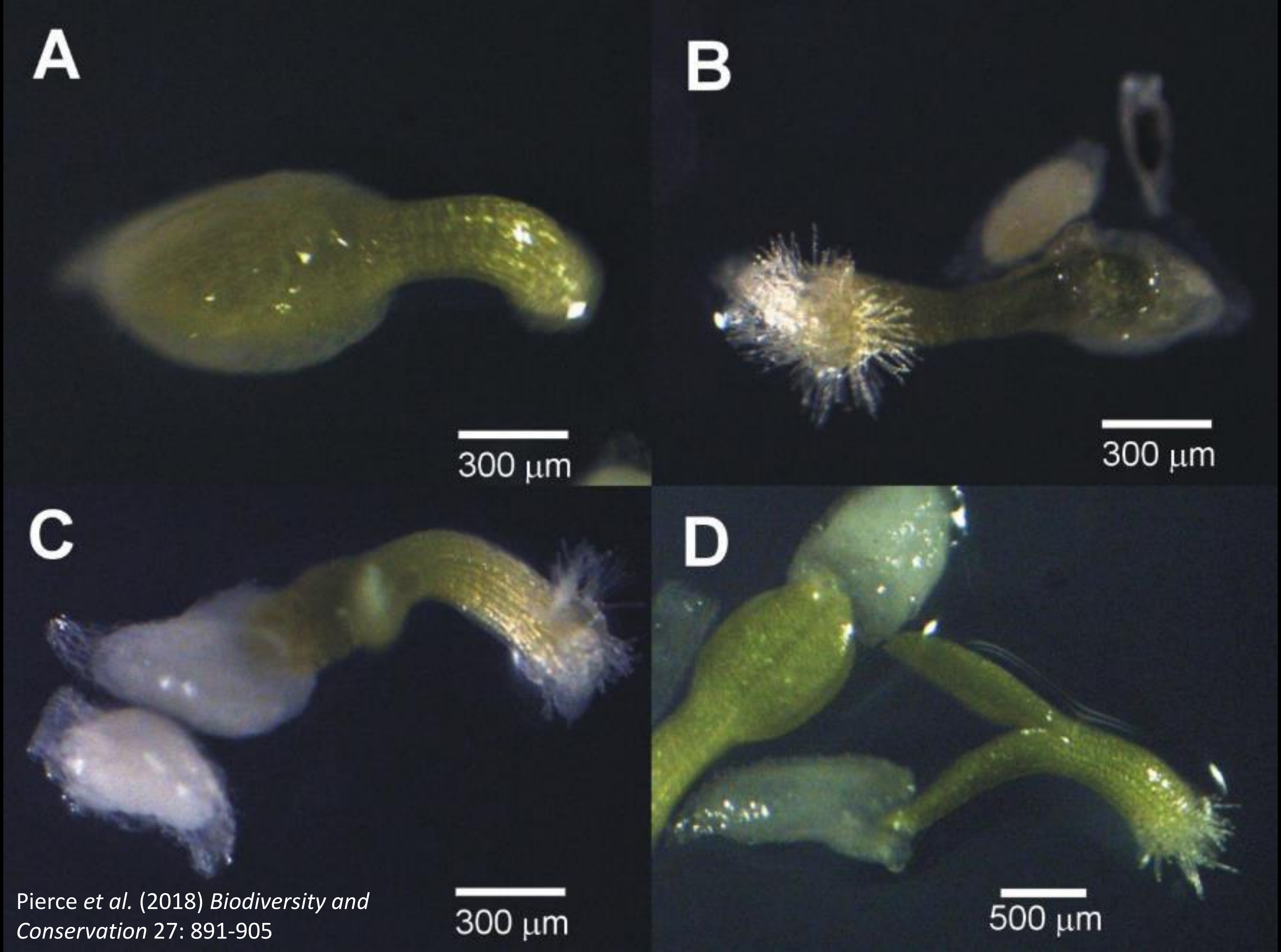

A large increase has
a negligible effect
A small population increase
can have a huge effect
Biological effect
Population size


Biological effect
Conservation aims to do this
Population size

Population reinforcement

getting populations above critical tipping points



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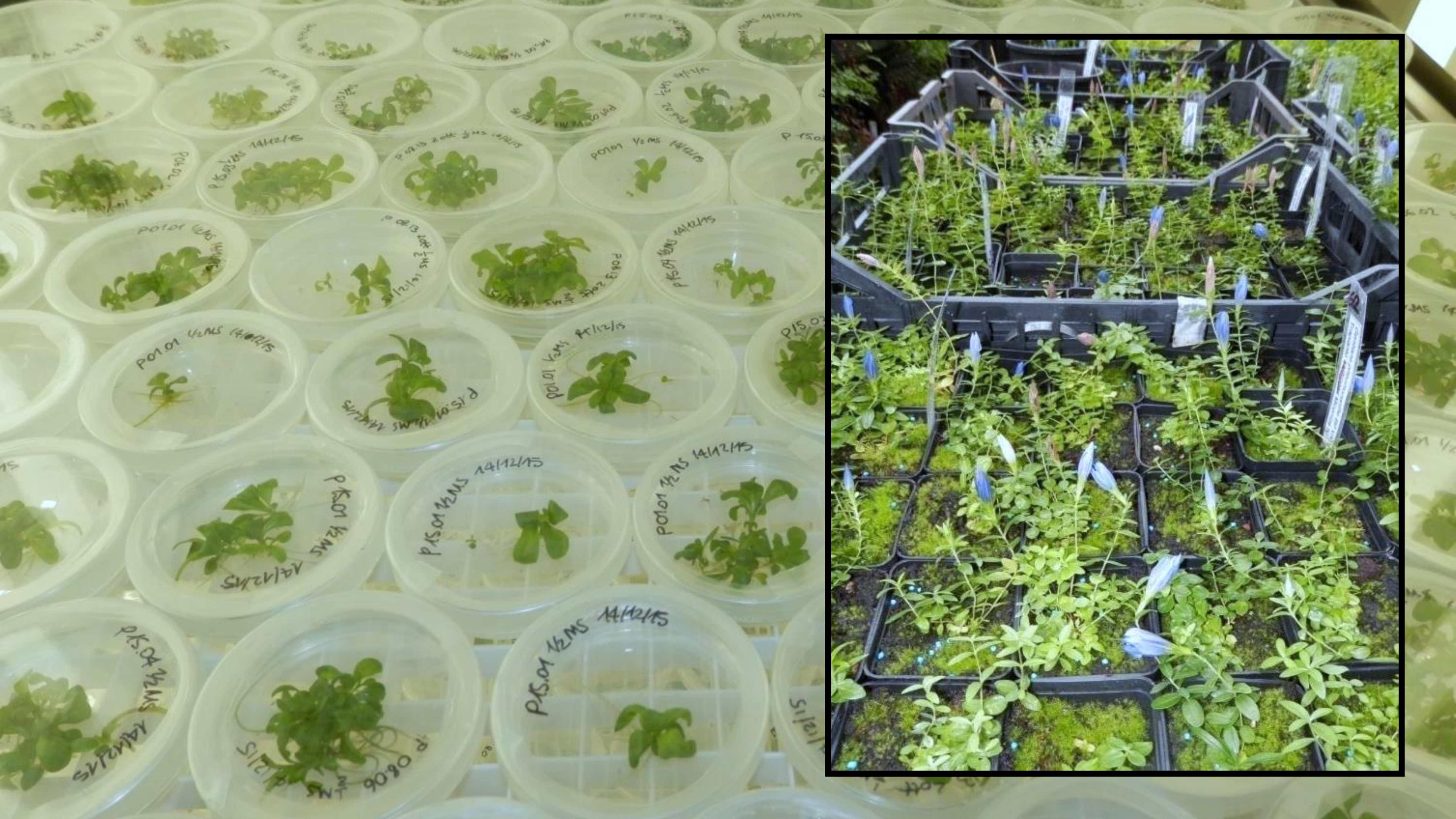

Pierce *et al.* (2018) *Biodiversity and Conservation* 27: 891-905

A year after population reinforcement, the new plants flower

A total of 1199 plants were used to reinforce 12 populations [Website]

Pierce *et al.* (2018) *Biodiversity and Conservation* 27: 891-905

Conclusions

- There is no ‘magic number’ for minimum population size, but as a general guide most genetic and reproductive ‘tipping points’ are evident at population sizes of around 50 – 500 plants

- Population reinforcement is likely to have the most impact on populations smaller than ~500 individuals

- BUT, tipping points may be much higher for some species, and stochastic effects suggest we should maintain higher numbers to avoid extinction due to random disturbance events

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