GISERA Stakeholder Workshop 24 Feb 2017

Development and general outlines of the research project

Alexander N. Schmidt-Lebuhn

NATIONAL RESEARCH COLLECTIONS AUSTRALIA

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CSIRO

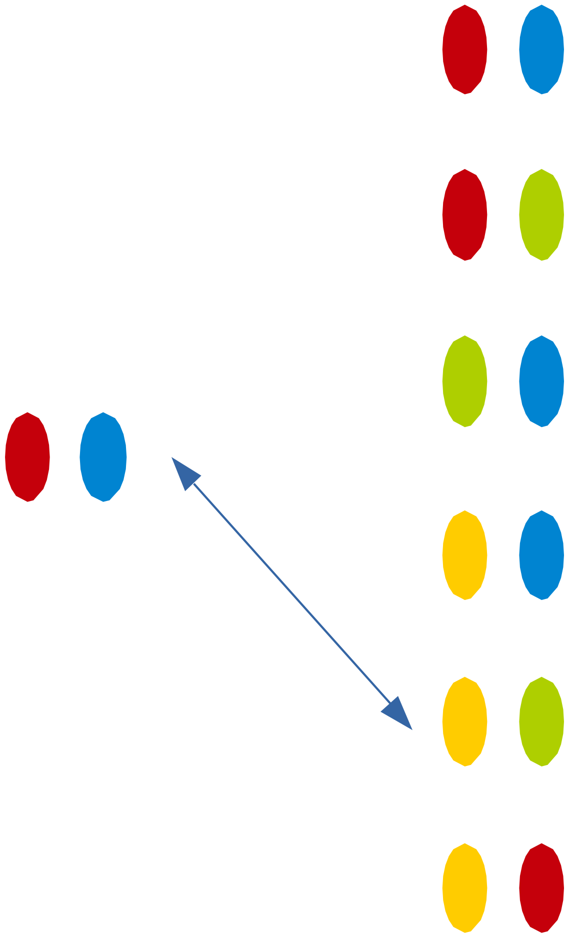
Background

Previous GISERA Queensland project:

"Ensuring biodiversity offset success – the right kind of seed for a rare daisy (*Rutidosis lanata*)"

No good seed set

Sporophytic self-incompatibility



General issue

Species are different

Need to understand their biology to…

...know what a viable population looks like

Population Viability Analysis (PVA)

Various models

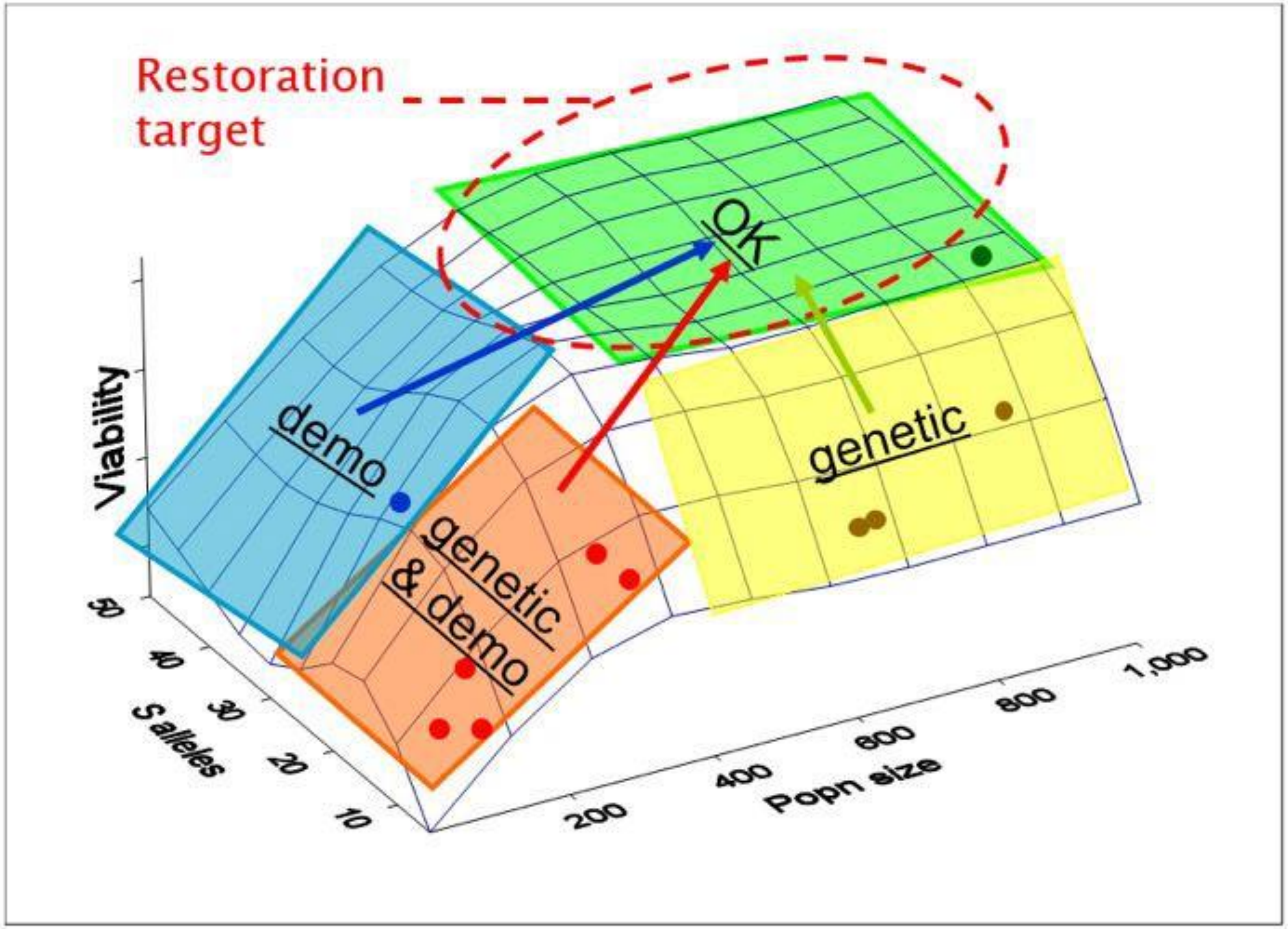
Usual approach:

- Enter size / age structure / etc of a population

- Obtain probability of population still existing in e.g. 100 years

Birth of a project idea

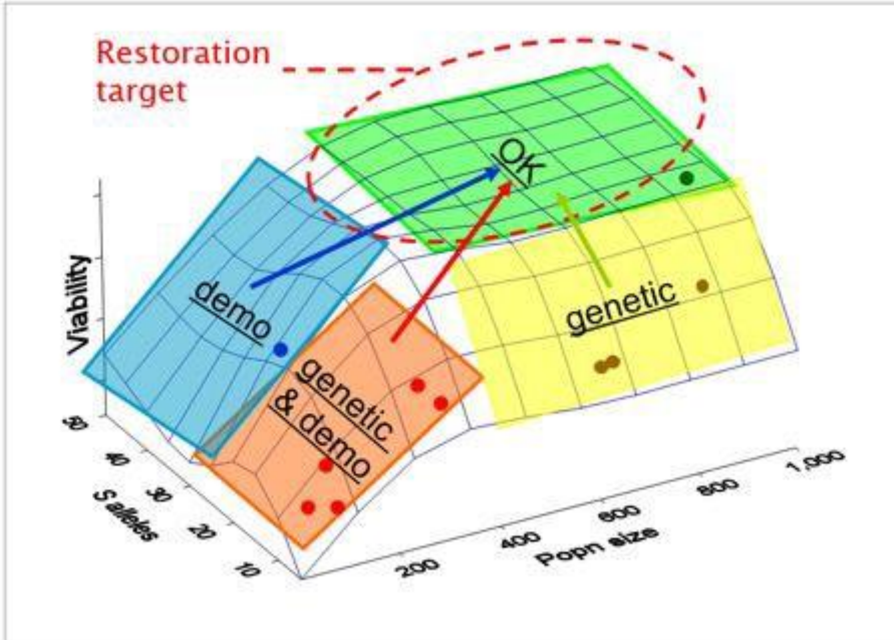
Presentation at GISERA knowledge transfer session 27 May 2016, Brisbane



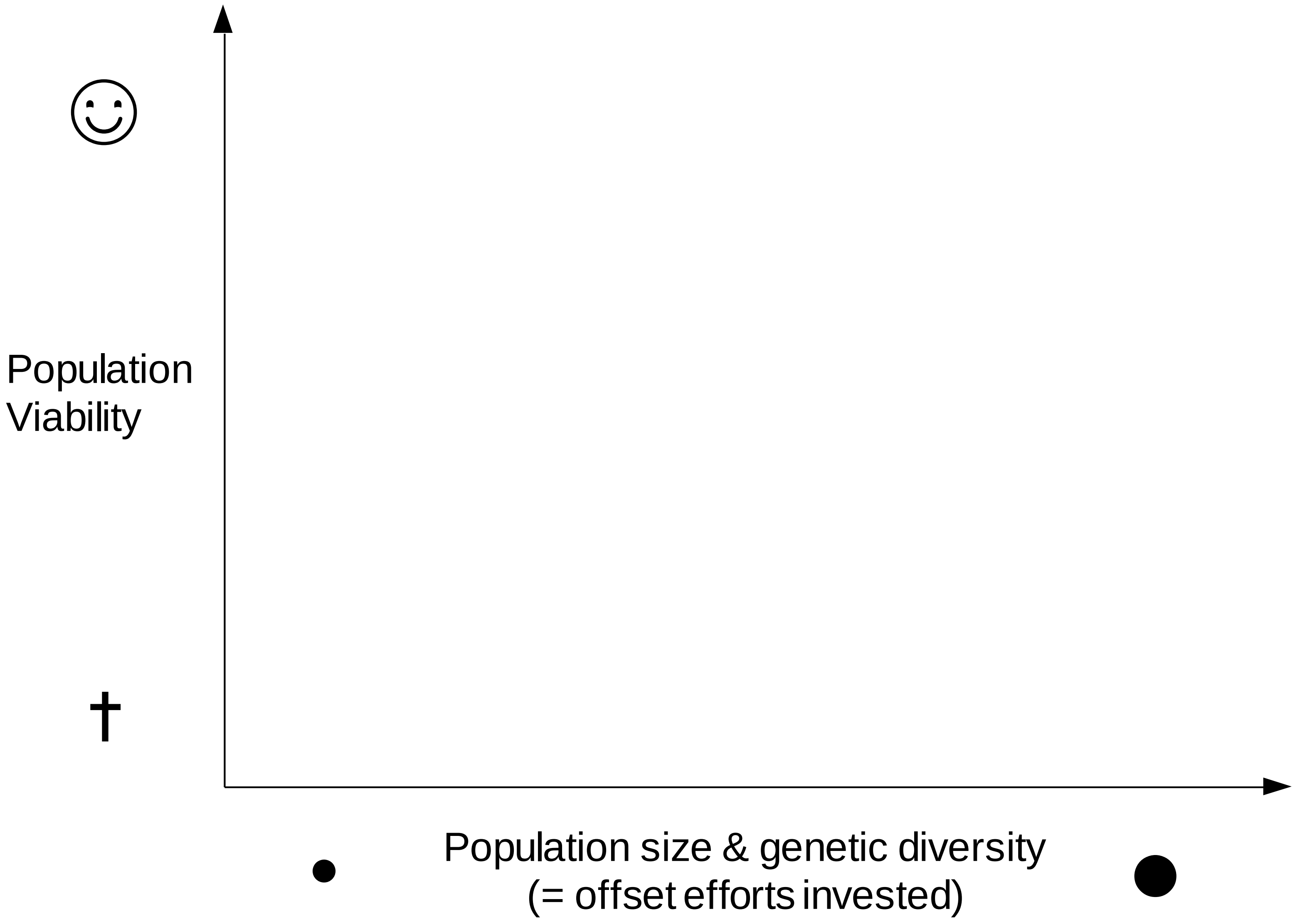
Birth of a project idea

Approach:

- Simulate populations of different sizes & genetic diversity
- Find viable population size & diversity



Finding the sweet spot



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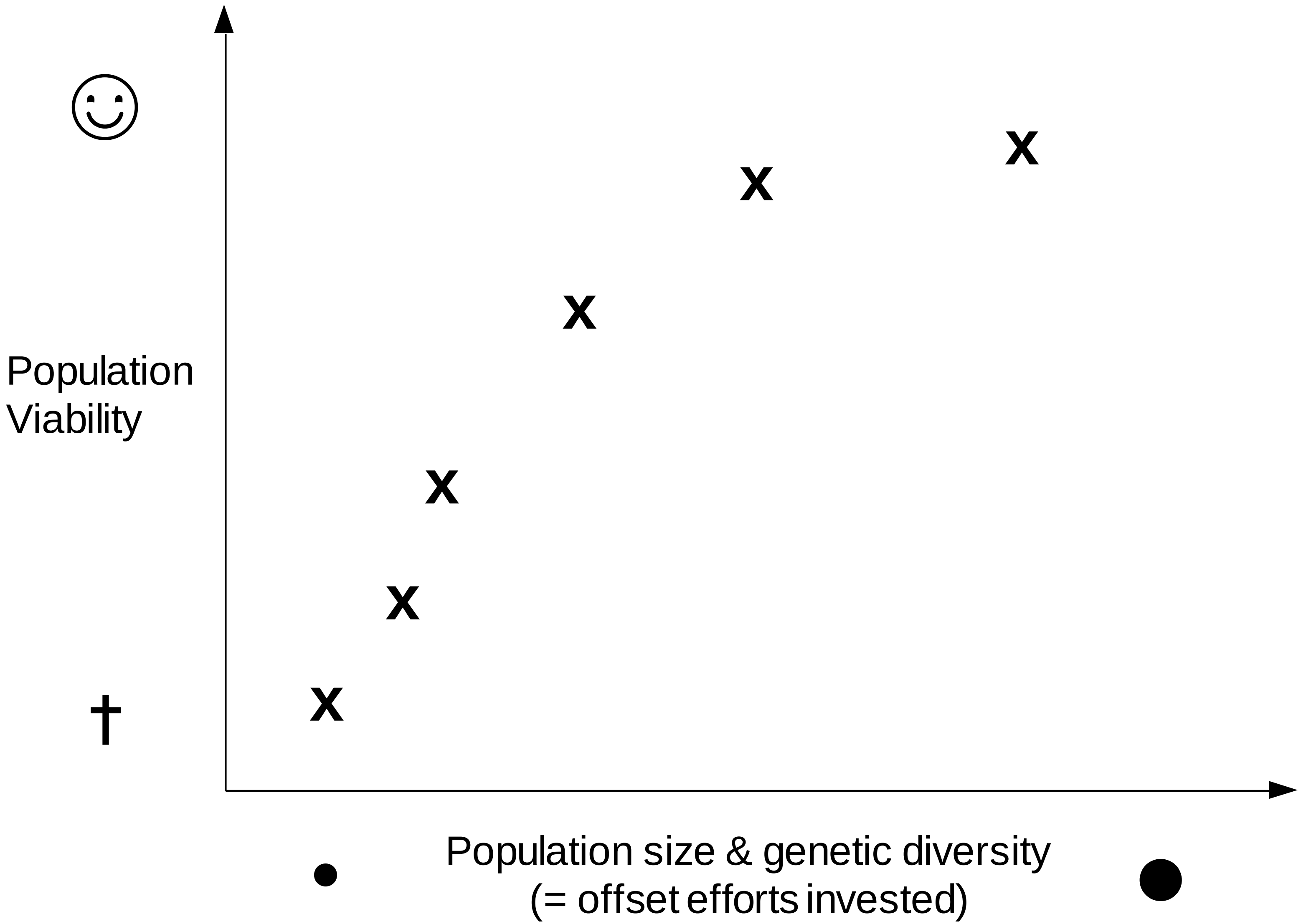

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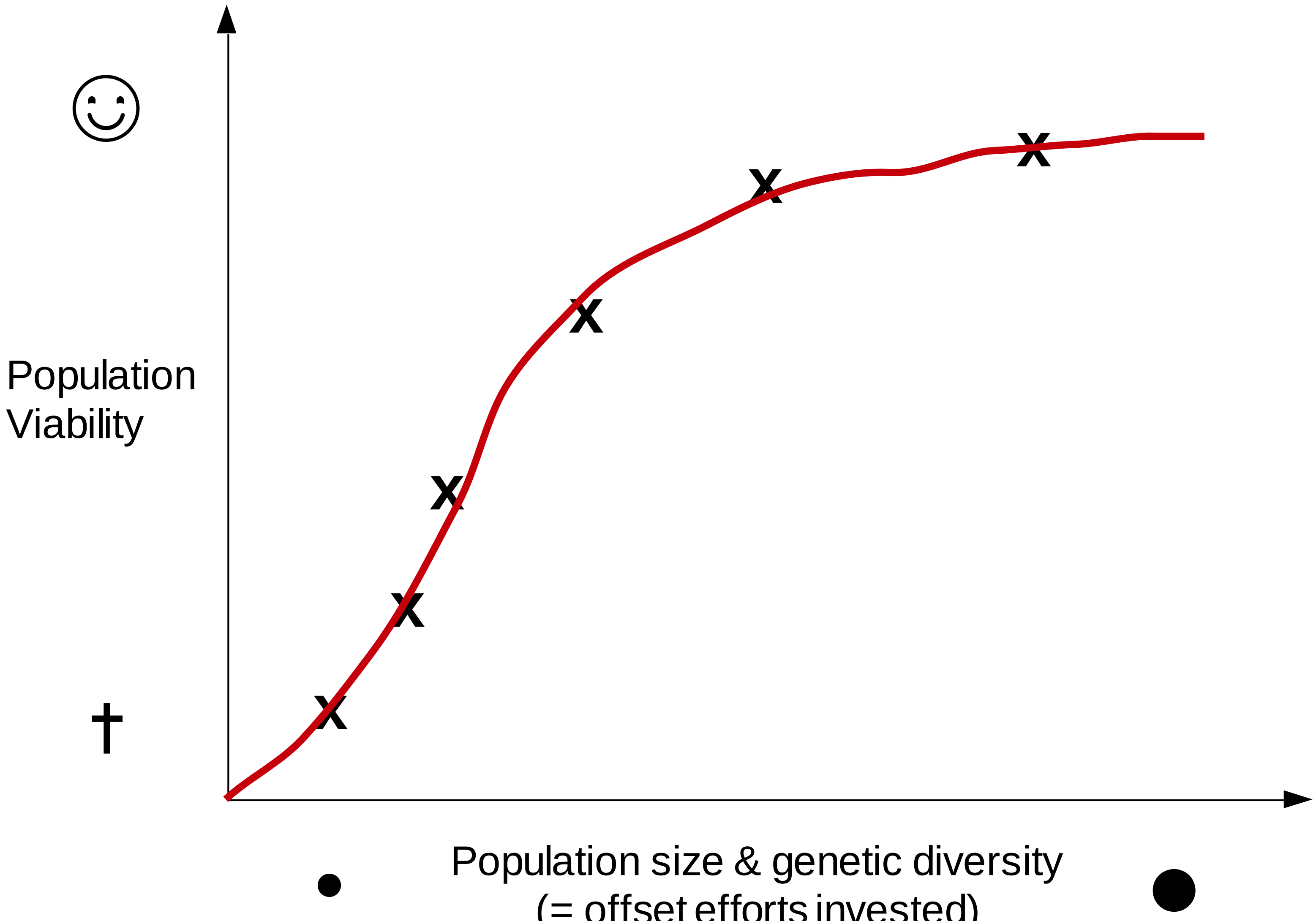

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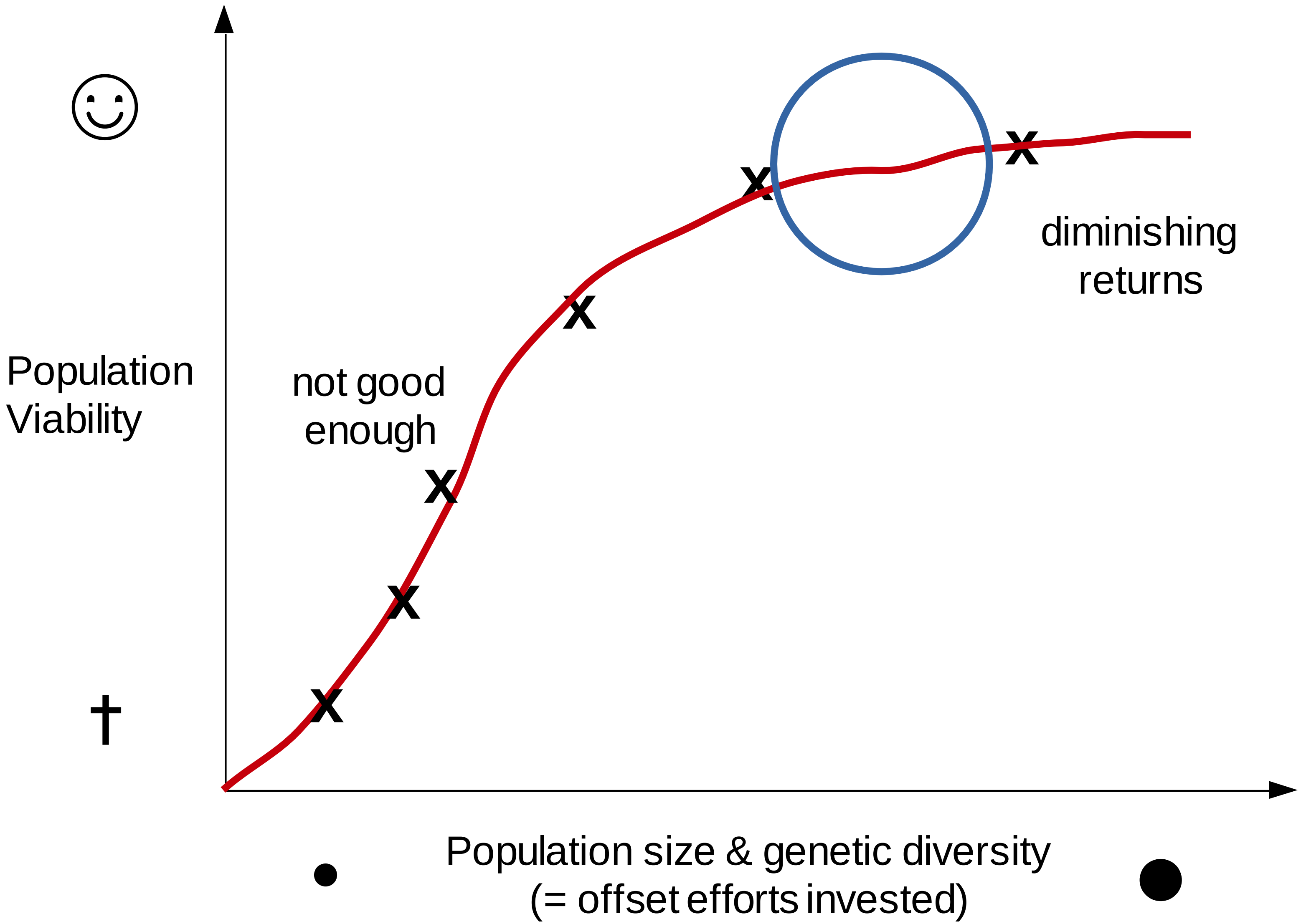

Thanks for your attention

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Genetics and mating system

Alexander N. Schmidt-Lebuhn

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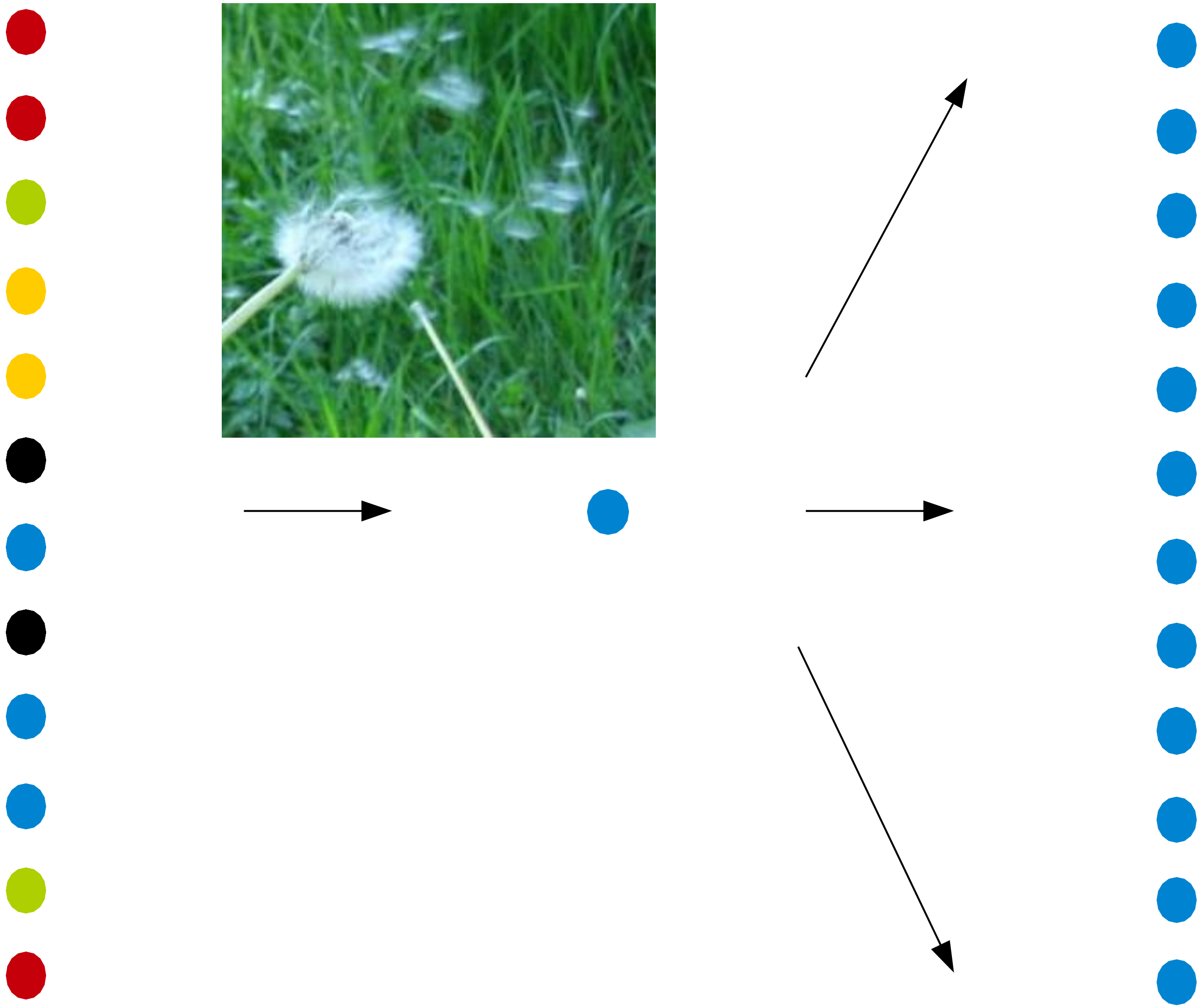
Why do we need to care about genetics in Population Viability Analysis?

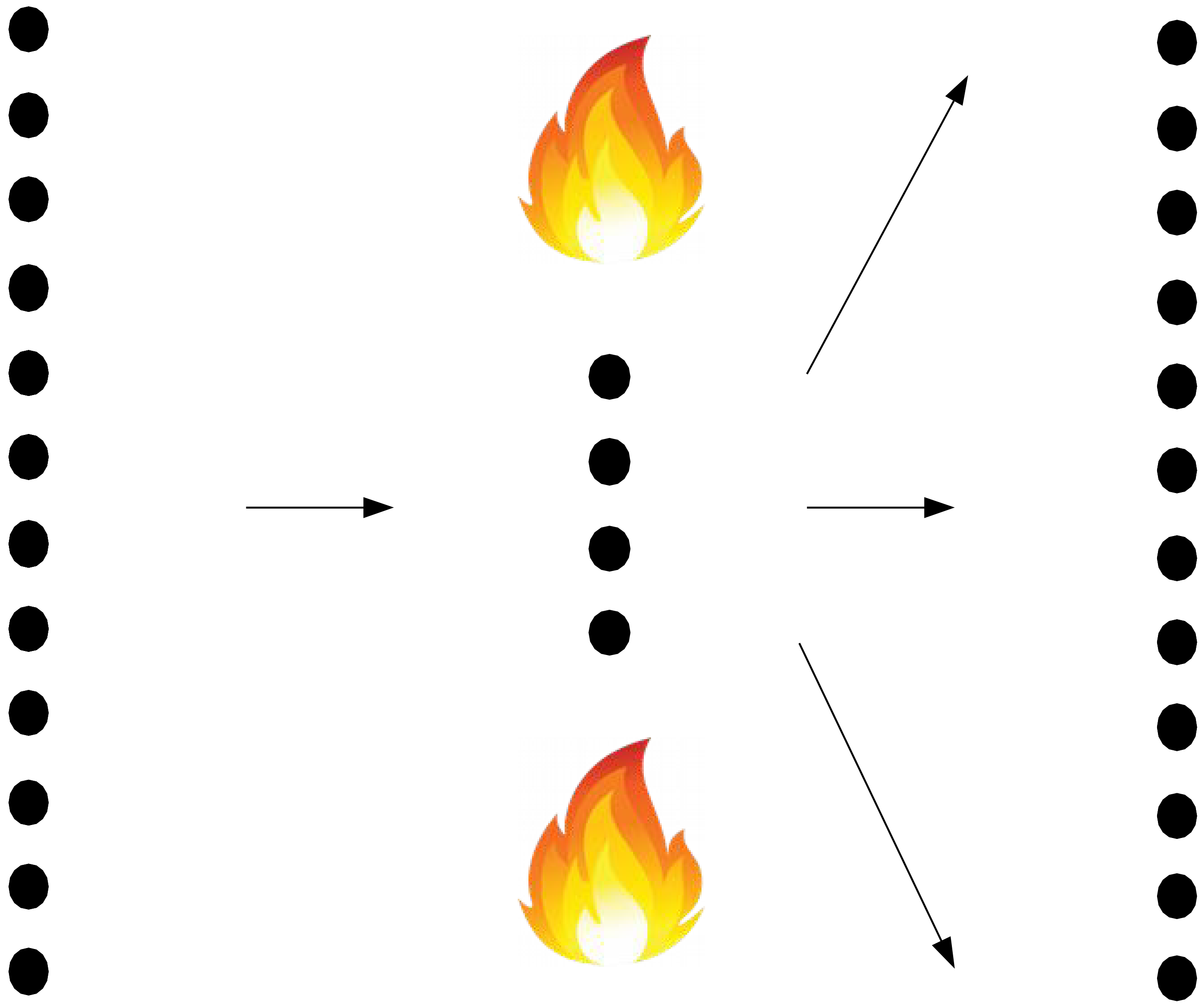
What are potential problems with small population size?

When is it a big problem, and when is it not so much?

Founder effect and bottlenecks



Founder effect and bottlenecks



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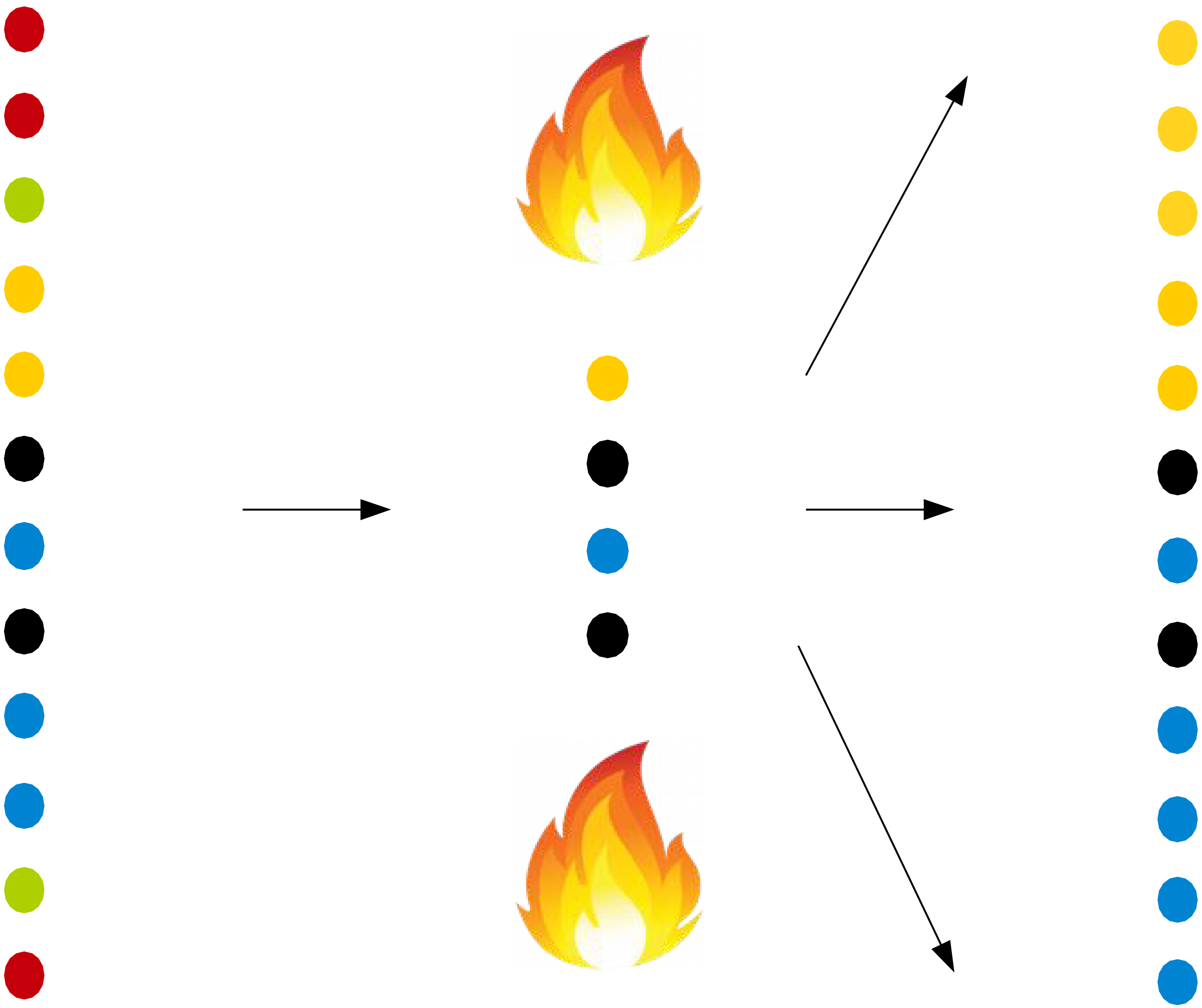

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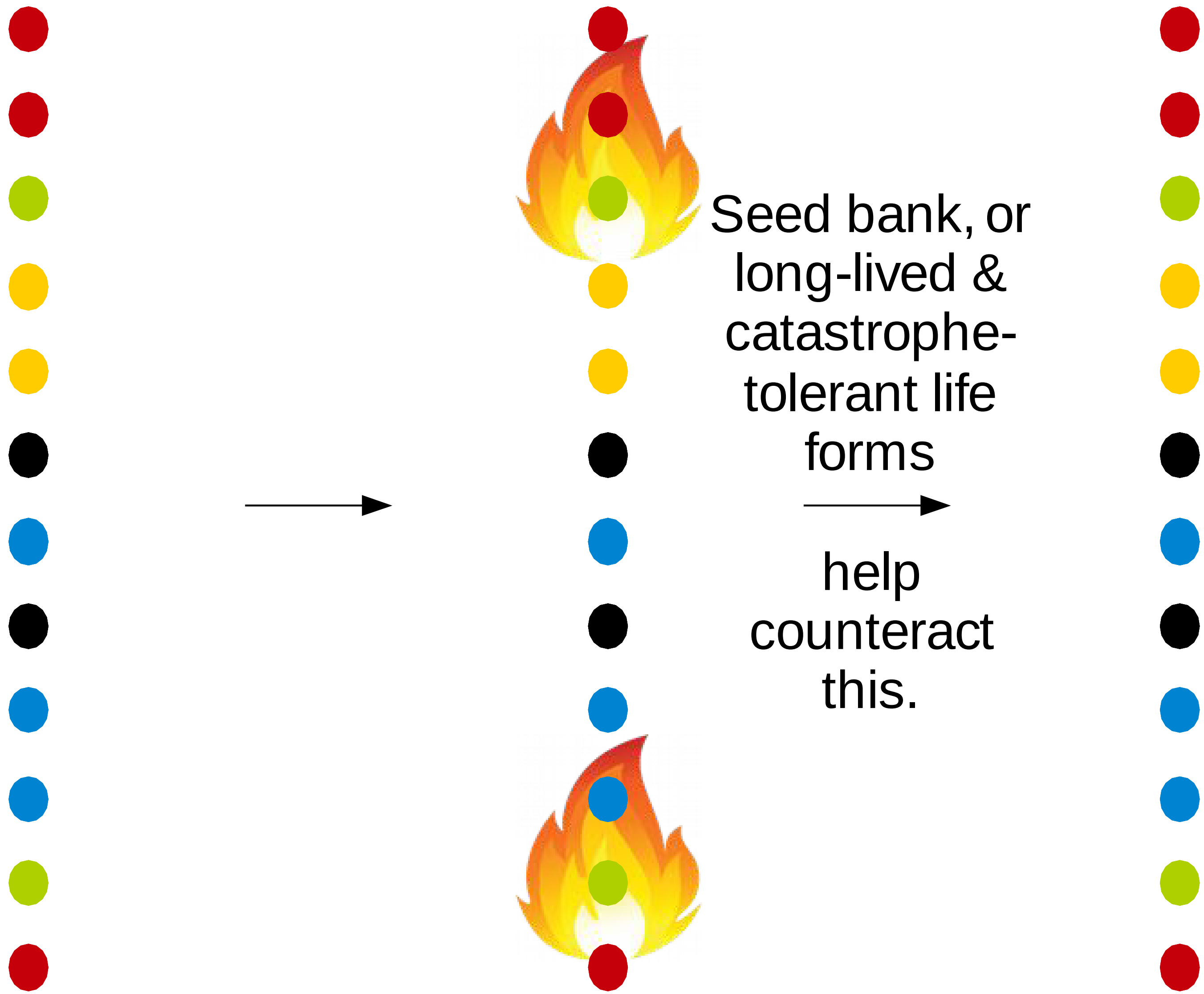
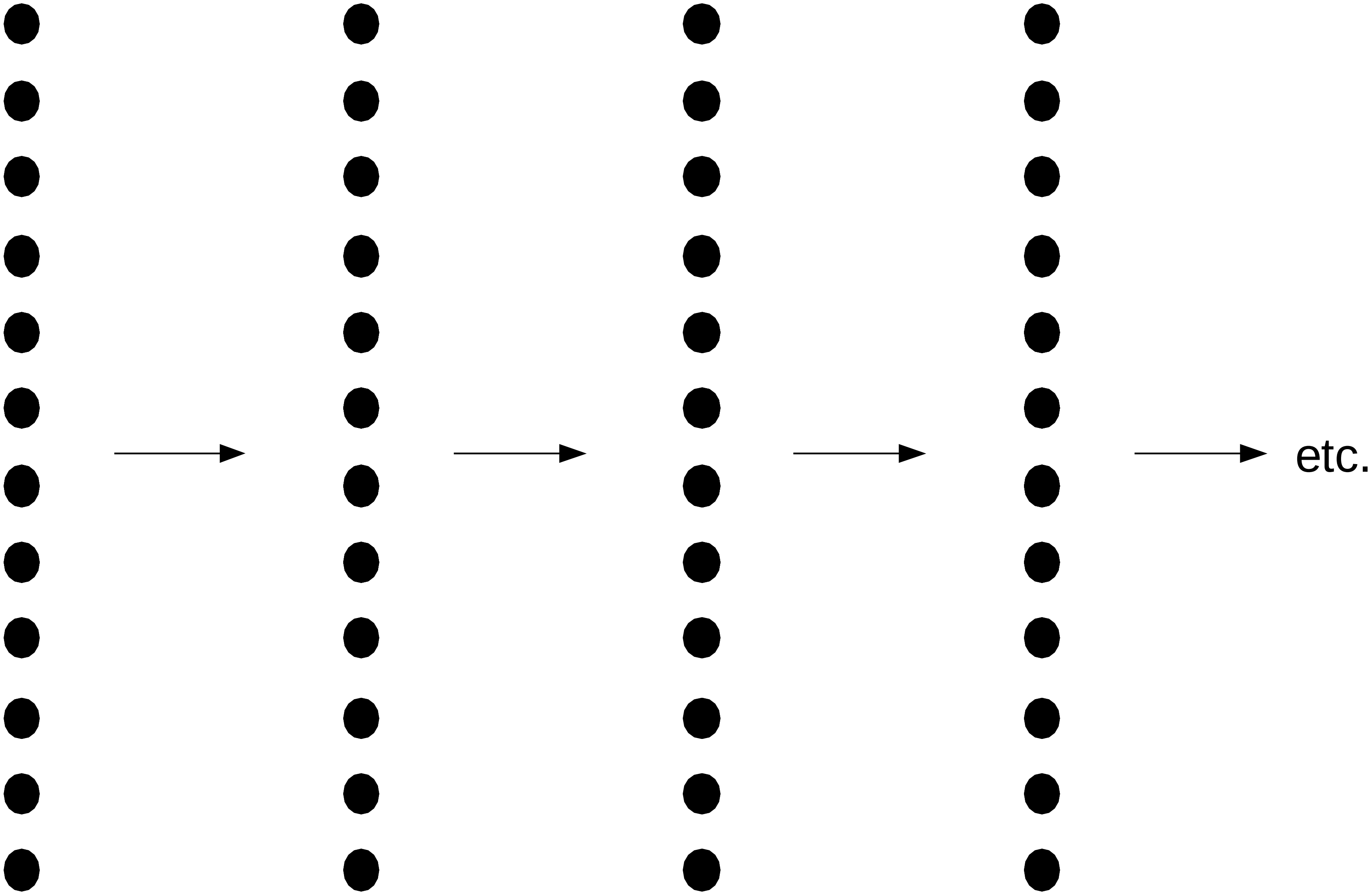


Genetic drift



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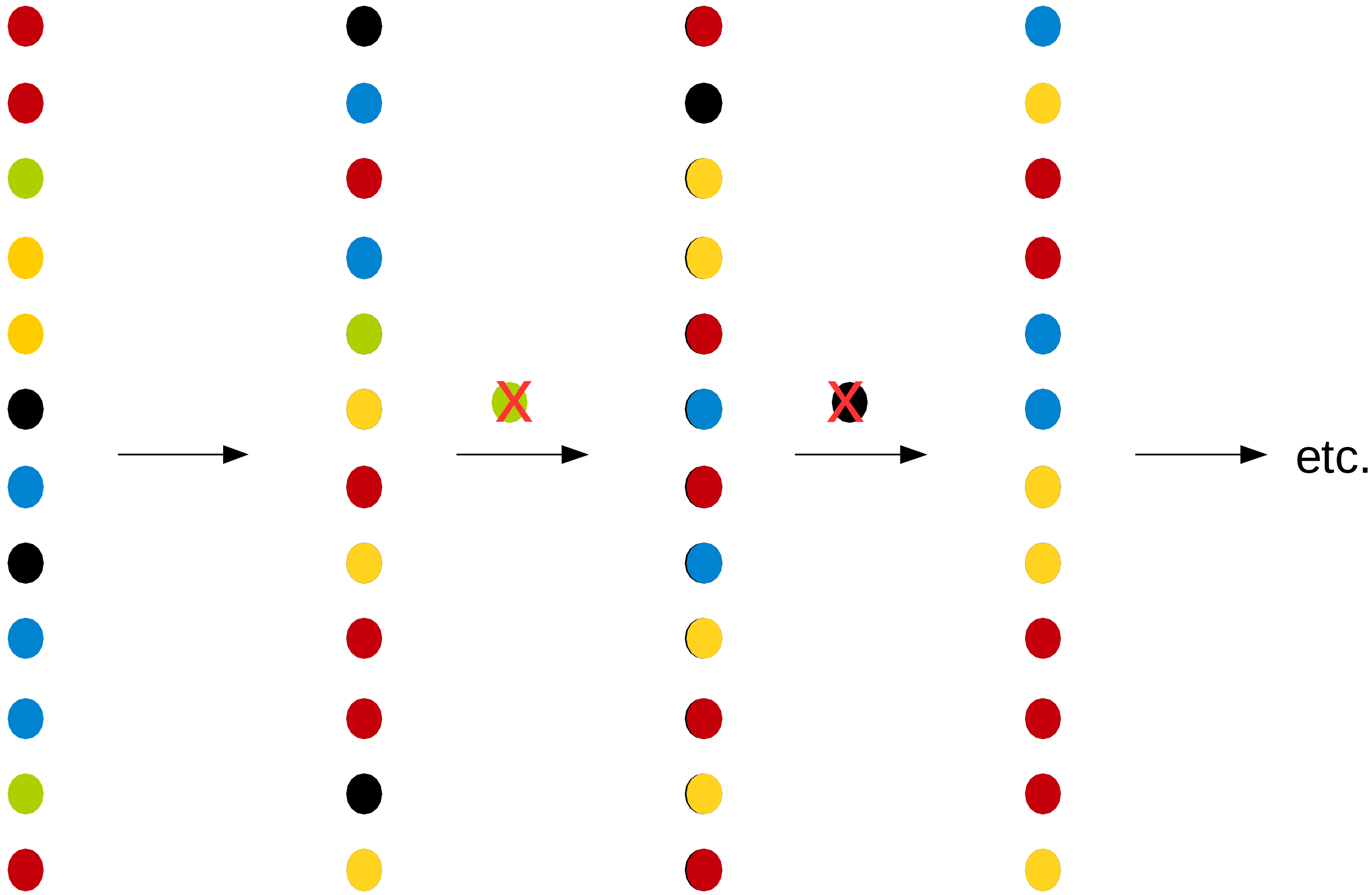


Genetic drift

Each new generation is a random sample of previous generation's genetic diversity

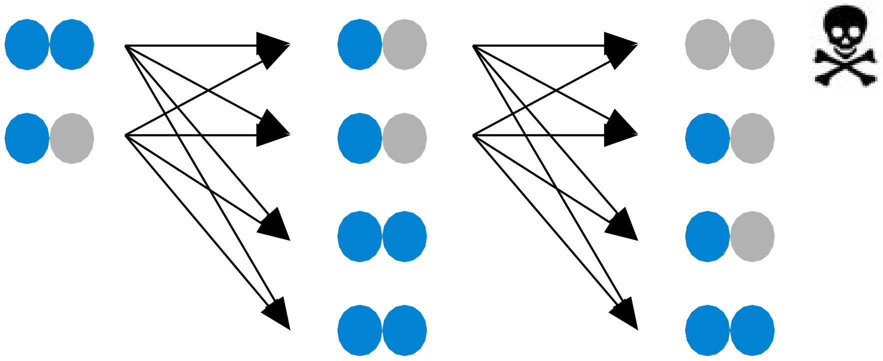
Always a chance that rarer alleles are lost

The smaller the population, the stronger genetic drift

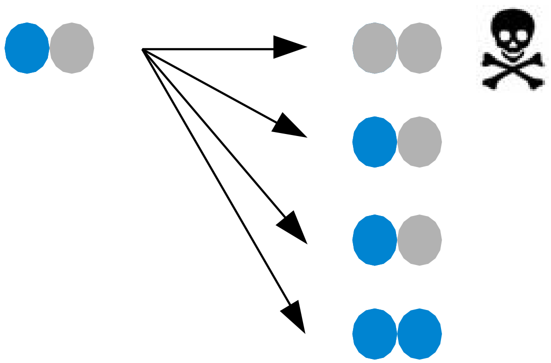
Consequence: natural selection works less well

Small populations lose fitness, ability to adapt

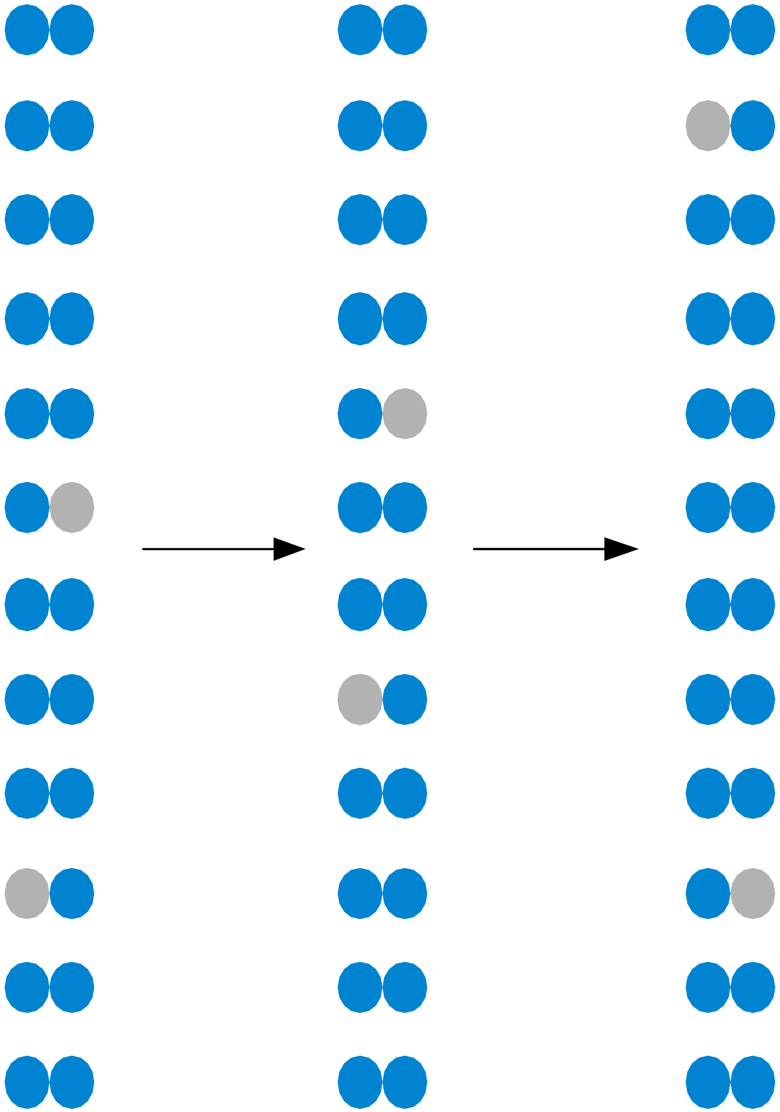
Inbreeding



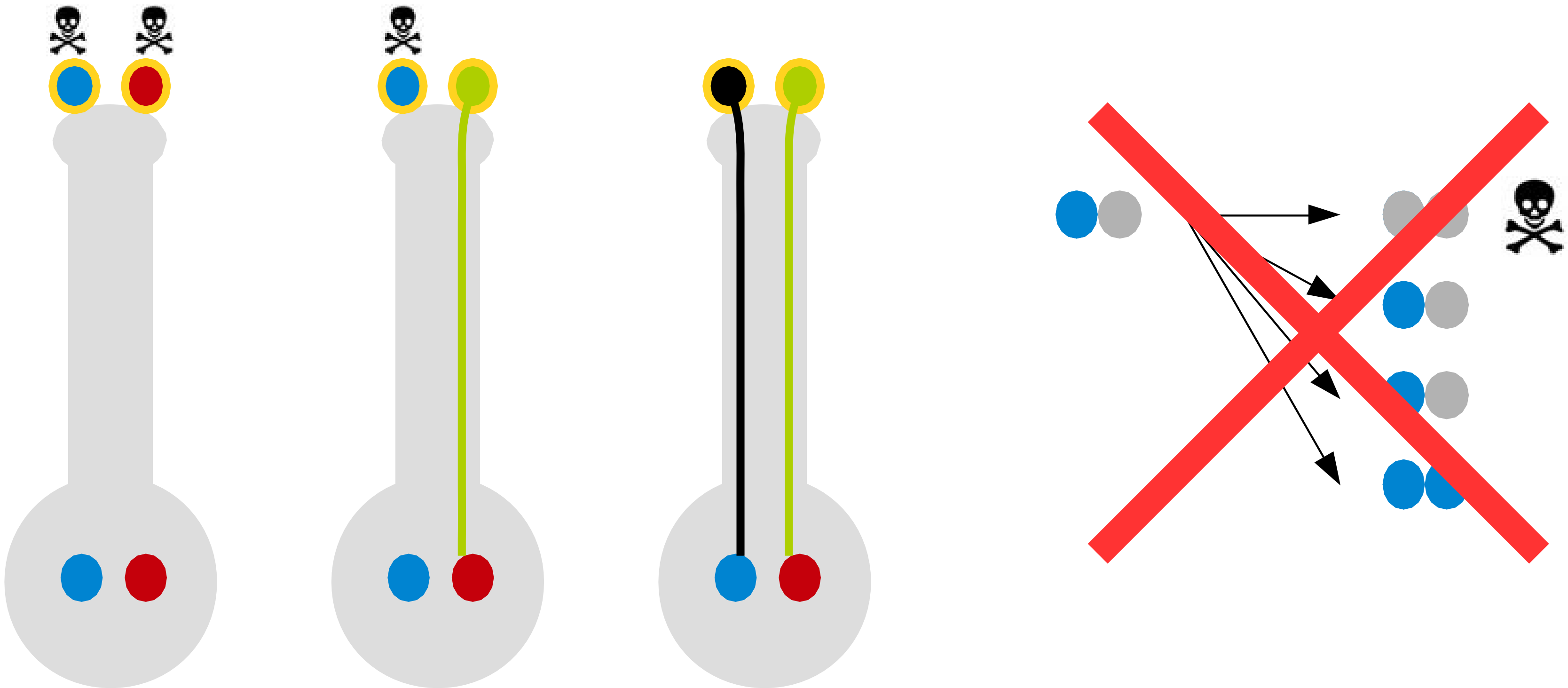
Self-pollination



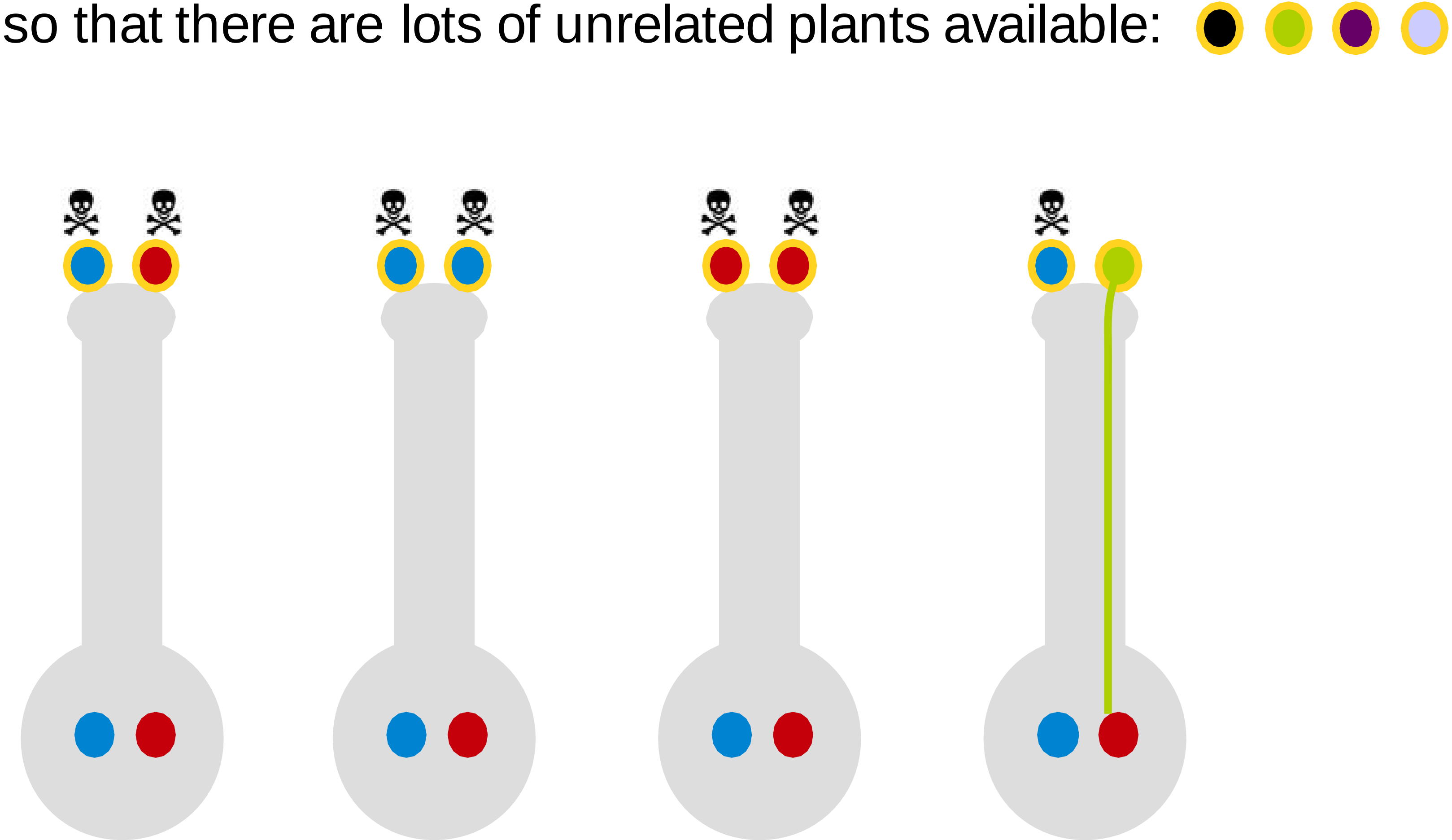
Inbreeding less likely in large populations



Self-incompatibility avoids inbreeding...

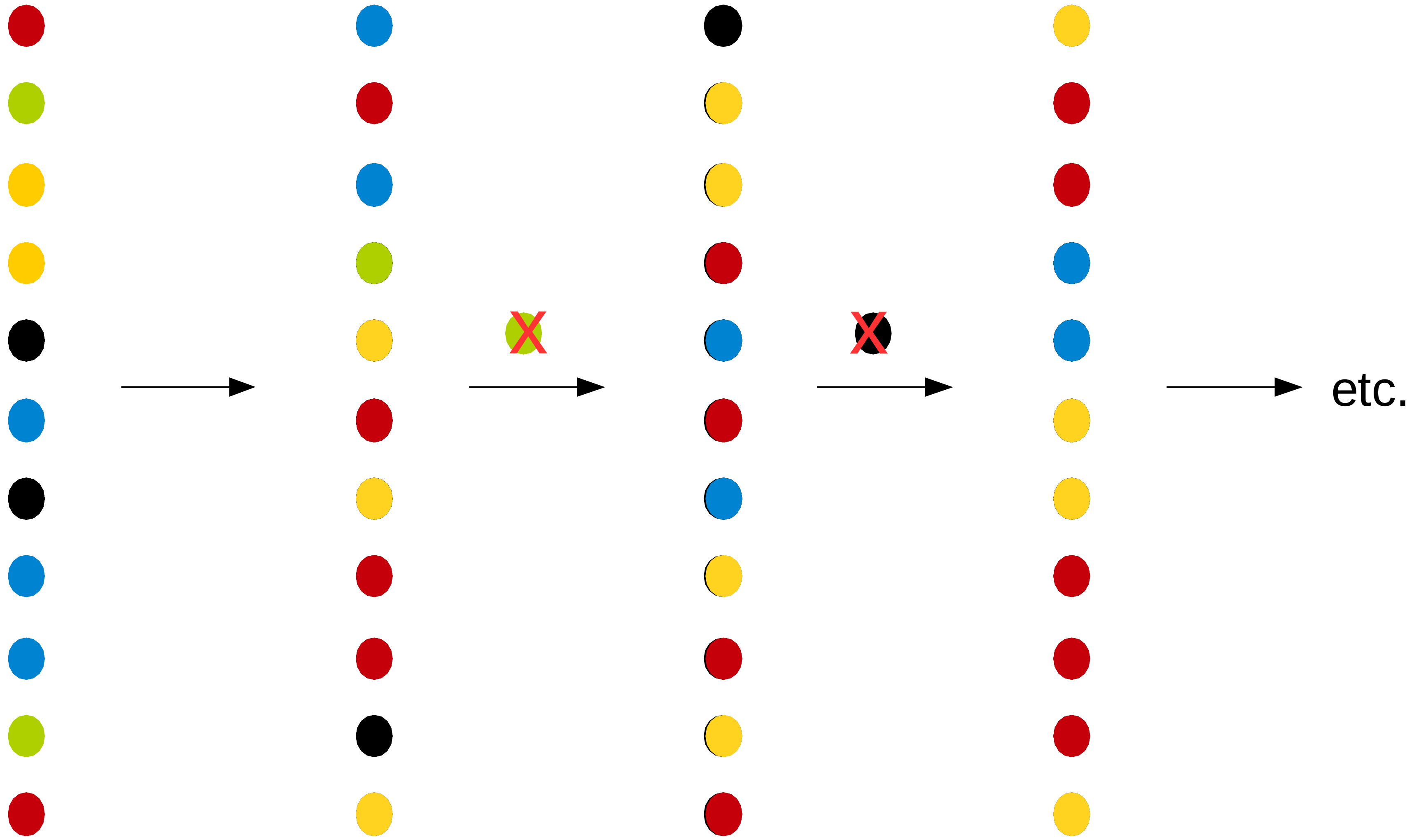


...but still requires large populations,
so that there are lots of unrelated plants available:



If not:
Low mate availability → low seed set → low population viability

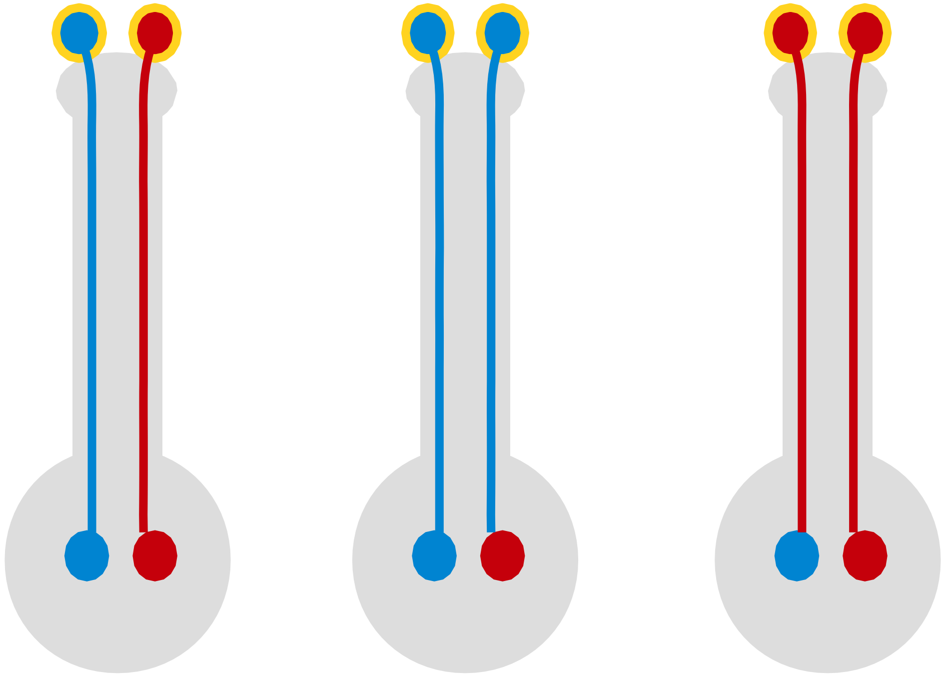
Genetic drift (again):
Loss of self-incompatibility markers in small populations



Naturally self-compatible / self-pollinating plants

No problem with mate availability

→ all else equal, minimum viable population size may be lower

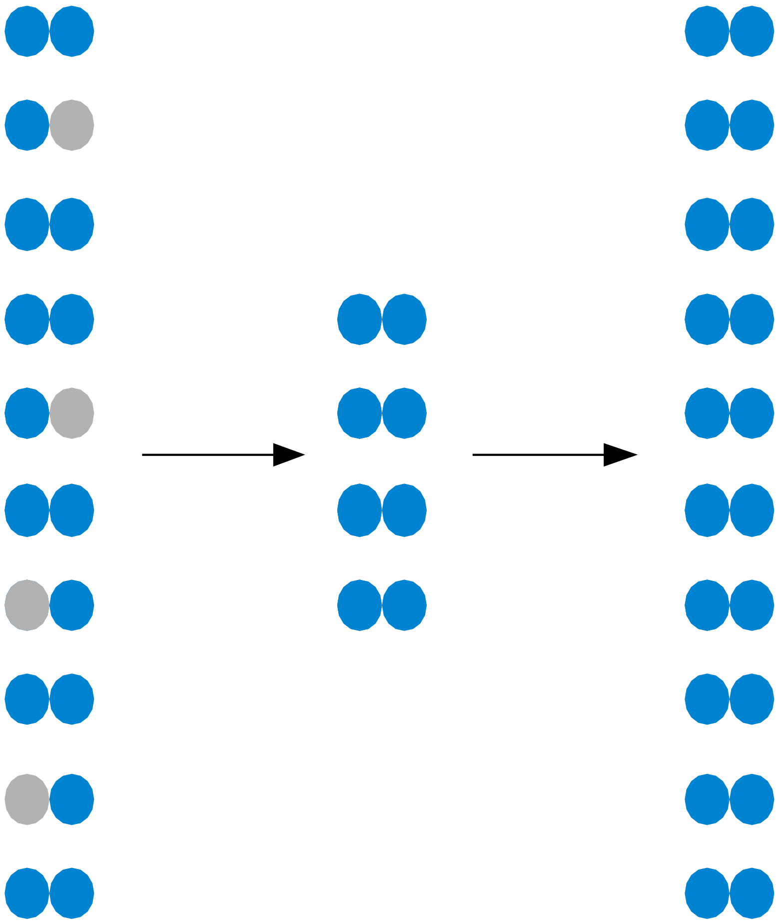


Another advantage: can establish population with single seed (e.g. many weeds)

Self-pollinators have been *purged* of *genetic load*

Otherwise it wouldn't work

(but probably evolutionary dead end?)



Less deleterious alleles → again, small populations more viable

Summary

Loss of genetic diversity due to:

- Small populations (drift)
- Extreme events (bottleneck)

Potential consequences:

- Loss of fitness because drift overwhelms selection
- Loss of potential to adapt to change
- Inbreeding → loss of fitness
- Low seed set in self-incompatible plants

Consequently, **it really matters for population viability** if species is

- Self-compatible, self-compatible, or mixed mating
- Has a long-term seed bank or is long-lived (or not)
- Is resistant or vulnerable to extreme events

Thanks for your attention

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Plant popula*on viability modeling

Workshop: Biological traits and ecological aspects for plant popula*on viability: what do we need to consider?

Francisco EncinasMViso| Research scien,st

24 February 2017

Project and workshop objec*ves

- **Project objec*ve:**
  - Science8based guidelines for plant popula,on offse@ng.
- **Workshop objec*ves:**
  - Iden,fy a list of plant species from Queensland CSG areas.
  - Iden,fy key life8history traits and ecological aspects for popula,on viability.
  - Classify the species into several groups based on their life8history traits.

Plant popula*on offseQng

- We need more scien,fic8based evidence to improve current prac,ces of biodiversity offse@ng.
- Biodiversity offse@ng requires the offset to result in a gain that would not have otherwise occurred.
- In our case, we want to re8establish plant popula,ons with high popula,on viability.
- Mathema,cal/simula,on models (like those used in Popula,on Viability Analysis (PVA)) can help to es,mate popula,on sizes of long8term viability.

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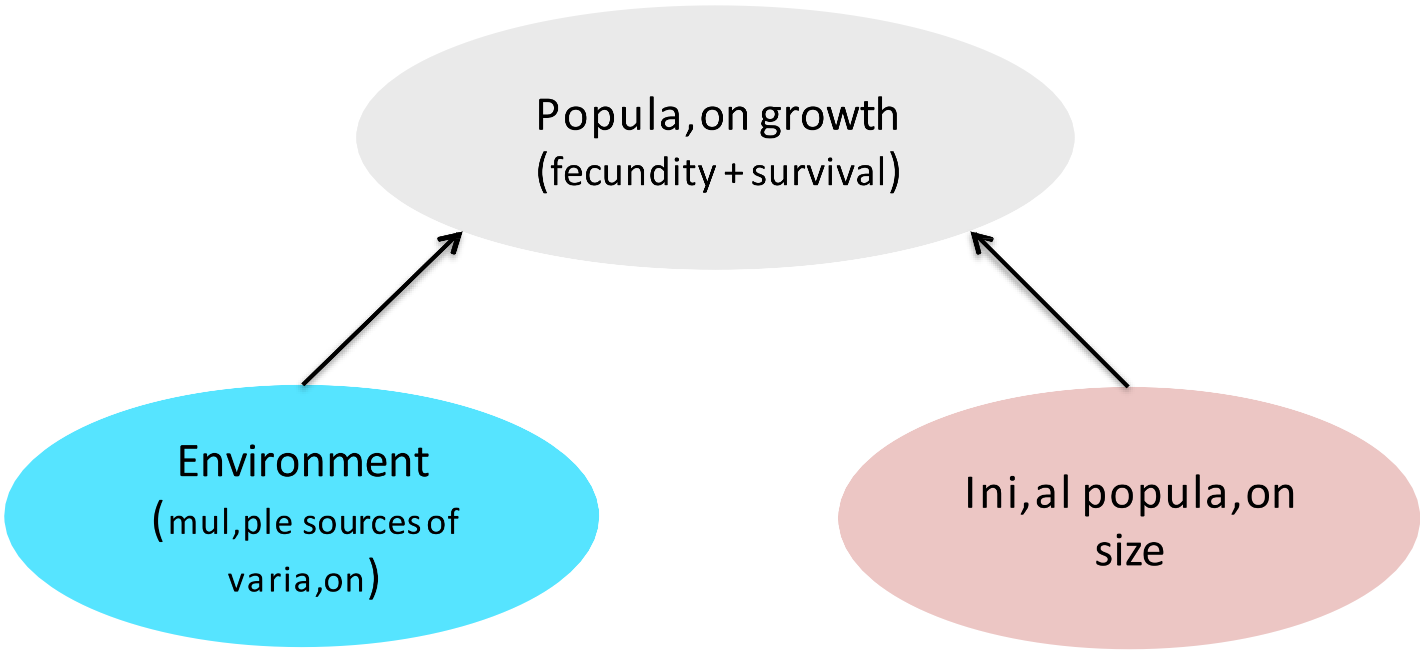
What is a Popula*on Viability Analysis (PVA)?

PVA is a range of modeling tools used to es,mate future size and risk of ex,nc,on of popula,ons.

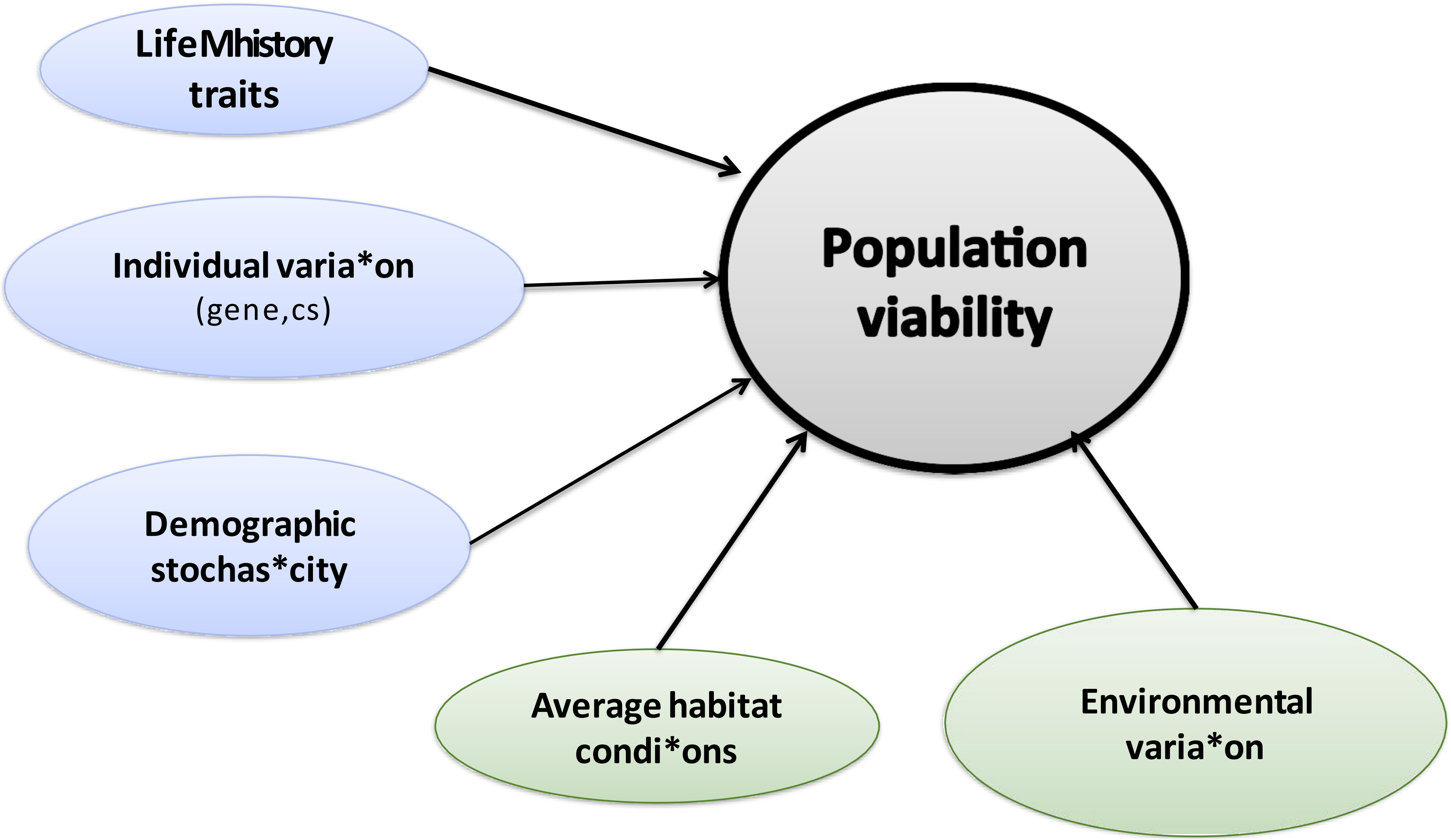
PVA model



When PVAs are useful?

- Assessing vulnerability: Predict popula,on size and probability of ex,nc,on in a specific ,me frame (viability).
- Impact assessment: assess impact of human ac,vi,es (e.g. pollu,on).
- Ranking management op,ons: species reintroduc,on, weed control, habitat restora,on, design of nature reserves.
- Se@ng goals for restora,on.

Factors affec*ng popula*on viability



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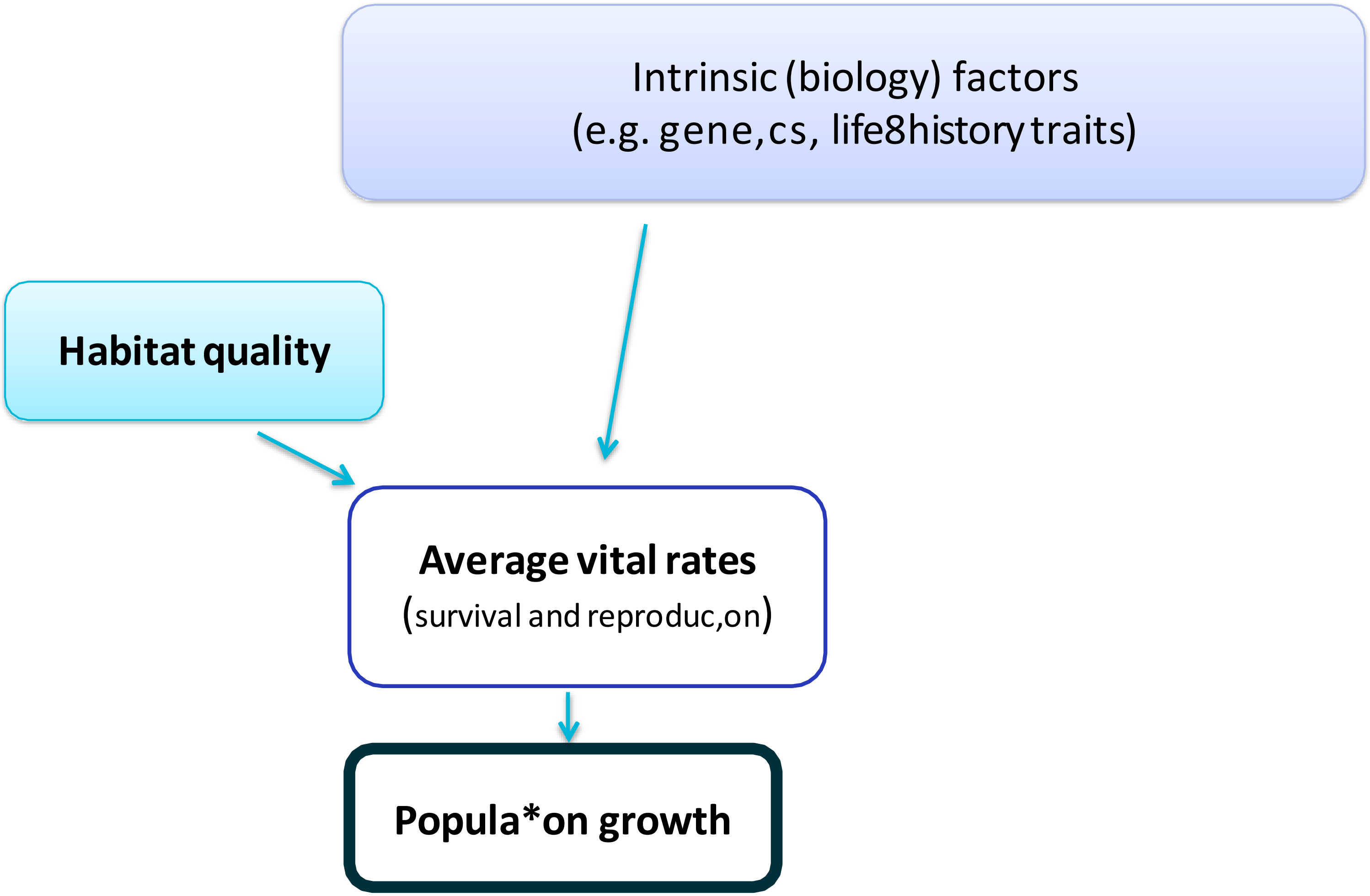


Factors affec*ng popula*on viability

Intrinsic (biology) factors
(e.g. gene,cs, life8history)

Habitat quality

Environmental varia*on

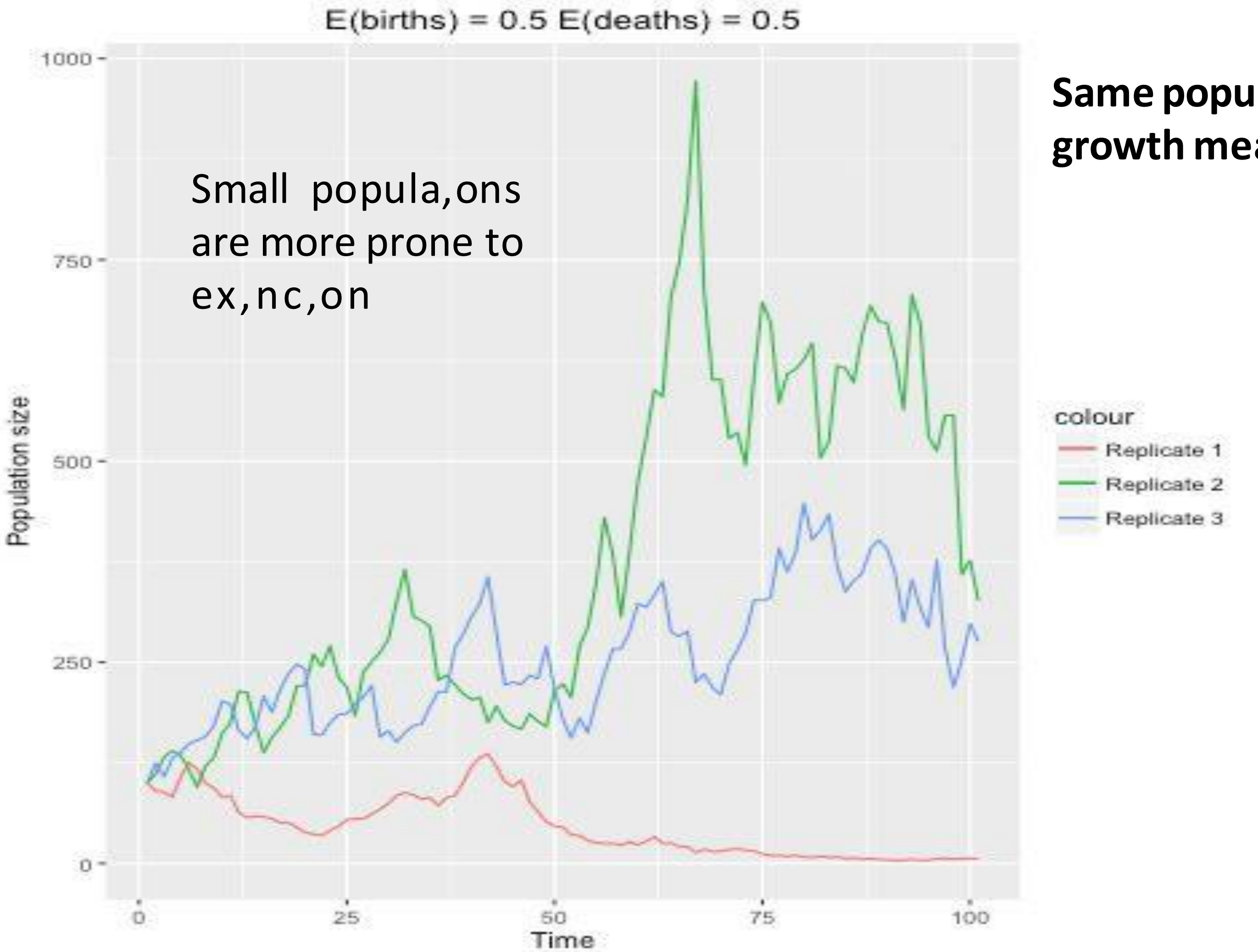
Average vital rates
(survival and reproduc,on)

Temporal variability in vital rates

Popula*on growth

Ex*nc*on risk

Demographic stochas*city



Small popula,ons are more prone to ex,nc,on

Same popula*on growth mean λ = 1

Plant lifeMhistory traits

- **Ma*ng system (e.g. selfMincompa*bility)**
- **Seed germina*on**
- **Pollina*on and seed dispersal mode (wind or animal)**
- **Genera*on *me**
- **Adult survival (longevity/ age at sexual maturity)**
- **Iteroparity/semelparity**
- **Seed bank (seed dormancy):**
  - Mostly in annual species
  - Reserve of viable seeds in the soil
  - Buffer environmental varia,on and reduce ex,nc,on risk.

Plant lifeMhistory traits

Can we ‘group’ plant species according to their lifeMhistory strategies?

Plant lifeMhistory traits

Trade-offs

Reproduc, on ⟷ Survival

Fast-slow axis

fast8growing
short8lived species

slow8growing
long8lived species

Plant lifeMhistory traits

Trade-offs

highly reproduc*ve, iteroparous species

poorly reproduc*ve, semelparous plants

Reproductive strategy axis

Cirsium arvense

Araucaria cuninghamii

Fast-slow axis

fast8growing
short8lived species

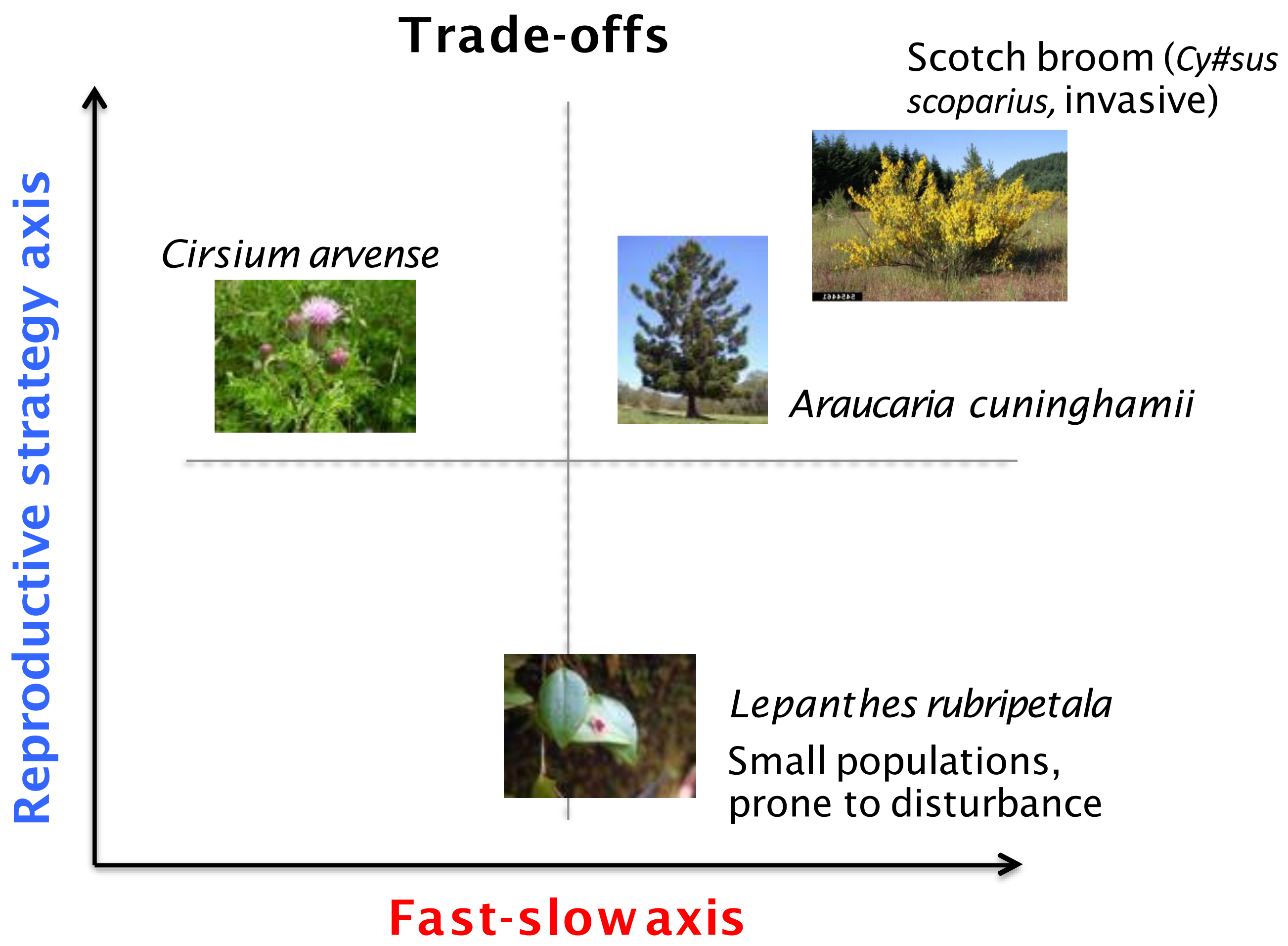
slow8growing,
long8lived species

Salguero8Gomez et al (2016) PNAS

Plant lifeMhistory traits

highly reproduc,ve, iteroparous species

poorly reproduc,ve, semelparous plants



fast8growing short8lived species

slow8growing long8lived species

Salguero8Gomez et al (2016) PNAS

Plant lifeMhistory traits and environmental factors

- **Episodic recruitment:**
  - Episodic recruitment depends on disturbances (e.g. fire)

Example:

Recruitment events of *B. hookeriana* are linked to fire frequencies.

PVA model needs to consider episodic recruitment events (Menges & Dolan, 1998)

Banksia hookeriana

Environmental varia*on

Temporal varia*on: Catastrophes and Bonanzas

- Catastrophes: extremely bad years (e.g. severe droughts, diseases, fire).
- Bonanzas: extremely good years (e.g. fire, floods).

Giant columnar Saguaro ca c, in Arizona 8rare freezing events increase mortality > 50 %. Average annual mortality is 5 %

Popula*on size ≠ popula*on viability

The Bu`on wrinklewort *(Ru#dosis leptorrhynchoides)* **example**:

- Perennial herb
- Insect8pollinated
- Self8incompa,ble ma,ng system

Ecology:

- Endemic of grassland environments SE Australia

Popula*on size ≠ popula*on viability

	Stirling Ridge	Capital Circle	Captains Flat	Jerrabom berra	West Block
# Flowering plants	**70000**	**220**	**161**	**9**	**5**
Growth rate	**0.99**	**0.97**	**1.03**	-	-
f_{SR}	**1.29** (0.23)	**1.94** (0.82)	**2.86** (0.78)	0	0

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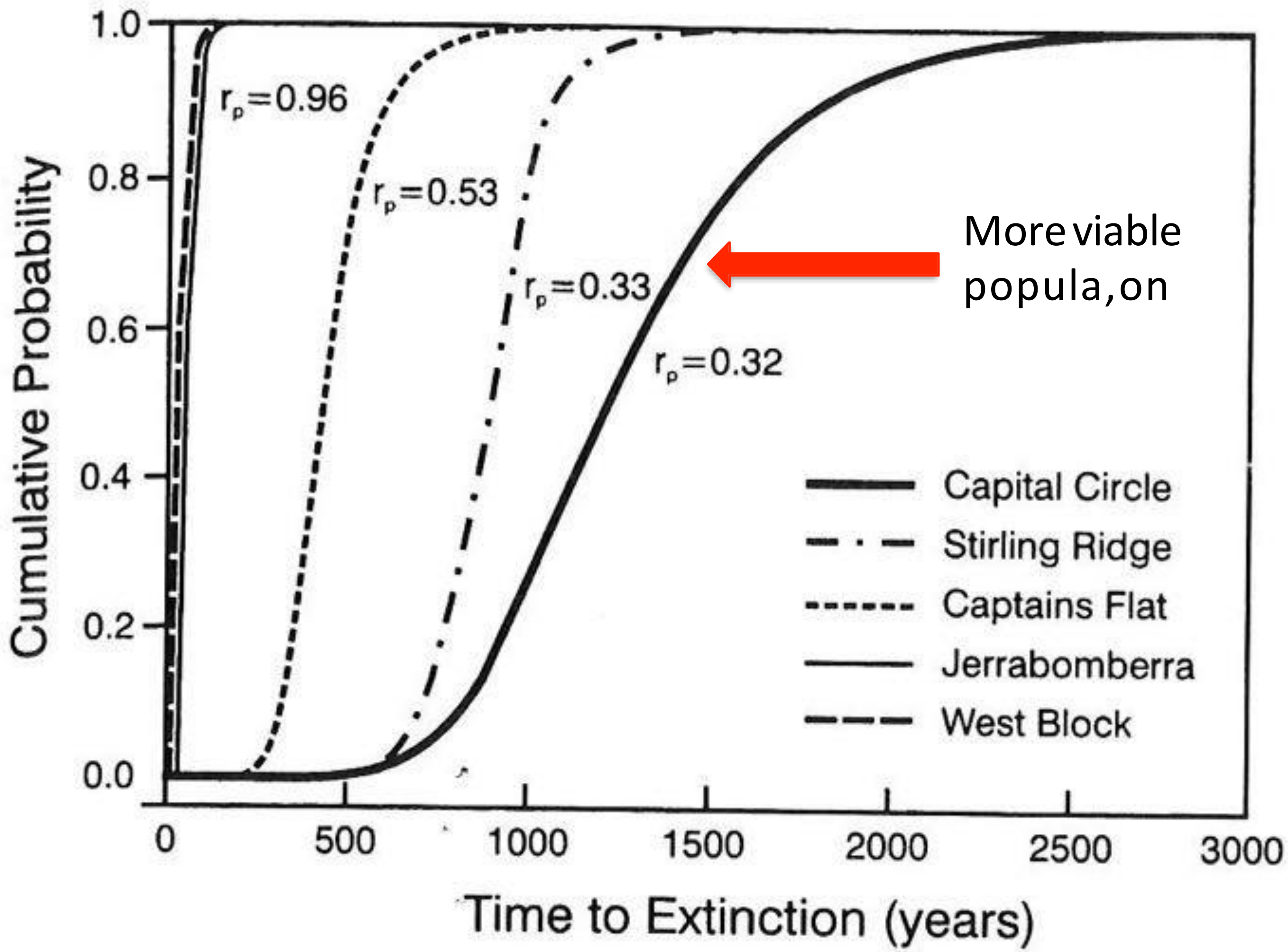


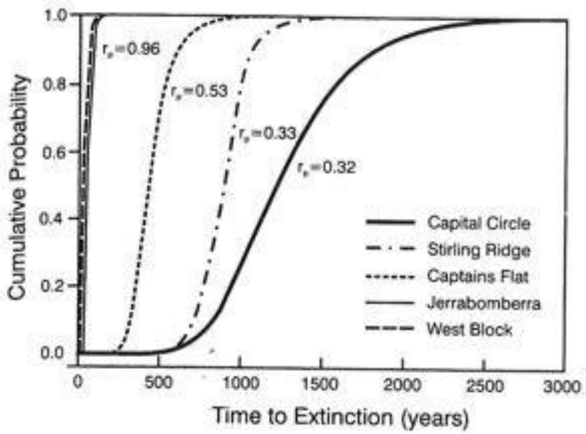
More viable popula,on

Classic PVA

PVA model(s) (and data)

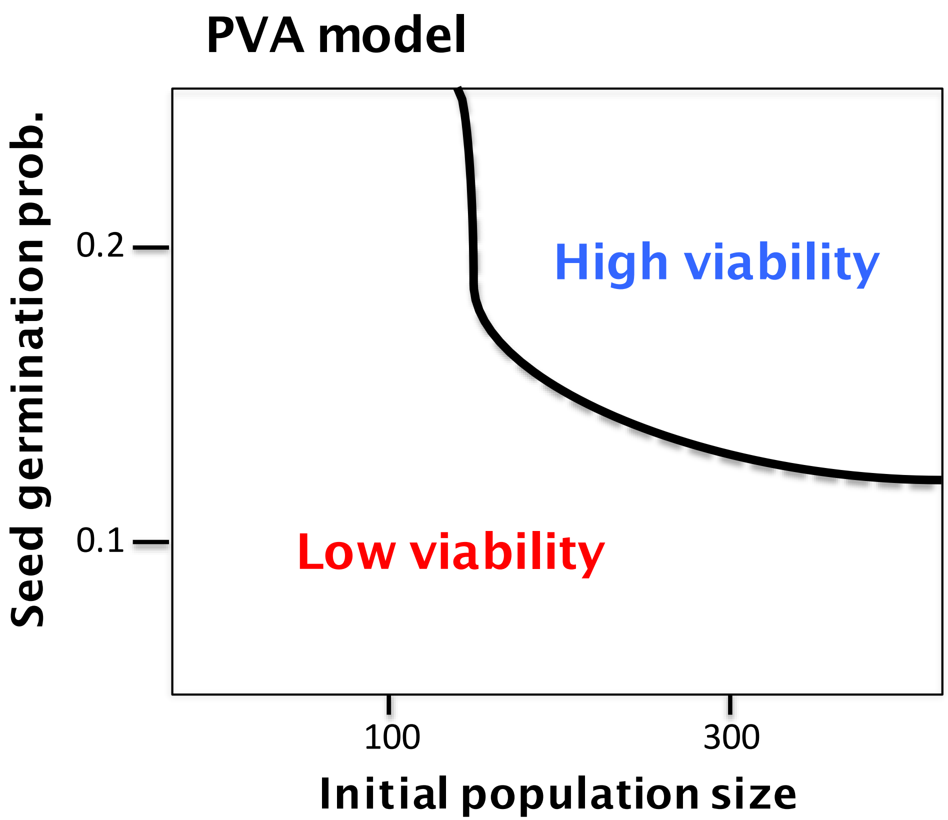
Threatened species (population)

Quantitative predictions of:
Quasi-extinction risk
Population size for next 20 years



How good or bad population(s) of species X is (or are) going to be in 50 years?

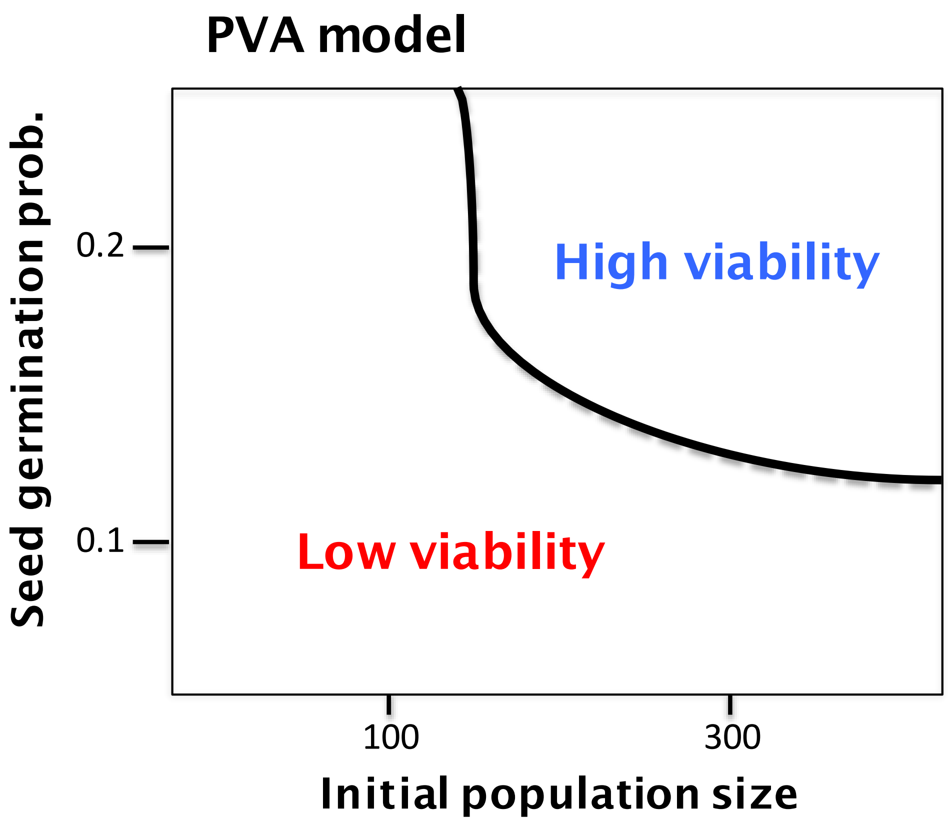
Reverse PVA



PVA model can also be used to estimate population sizes of high viability according to:

- Certain initial conditions (e.g. number of seedlings)
- Different values of life-history parameters.
- Environmental conditions (e.g. frequency of catastrophes).
- Data can be used to parameterize the model.

Reverse PVA



PVA model can also be used to estimate population sizes of high viability according to:

- Certain initial conditions (e.g. number of seedlings)
- Different values of life-history parameters.
- Environmental conditions (e.g. frequency of catastrophes).

We predict what we need → Operationally more efficient for management and restoration goals

Can we model all species?

Ideally, we will make a model for each species, however:

1) We don't have information (and data) for all species.

2) We have time constraints …

3) Similarities between species respect to their life-history traits allow us to make some general conclusions and management directions.

Can we model all species?

Examples:

Group 1

Herb
Insect-pollinated
Annual
Seed bank
High turnover

Group 2

Shrub
Bird-pollinated
Iteroparous
Perennial
SI mating system

Group 3

Woody
wind-pollinated
Iteroparous
Perennial

What we need to know

- Which species?
- Biology of the species nominated, what life-history traits should be consider in the model?
- Any environmental factors important for population viability?
- What useful output you need? population sizes? Demographic structures? Number of populations? MVP?
- Do you have data (e.g. count-based data) for some of the species nominated?

Thank you

Australian Na*onal Herbarium/ NRCA
Francisco Encinas8Viso
Research scien,st
t +61 2 6246 5846
e francisco.encinas8viso@csiro.au

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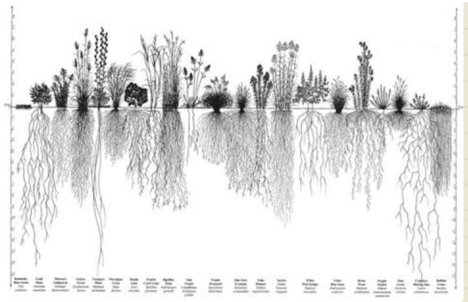
The importance of within species trait variation for effective conservation

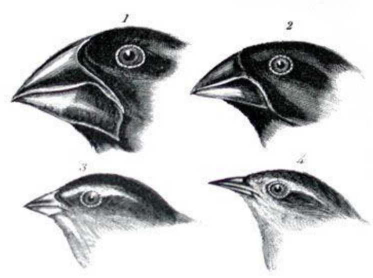
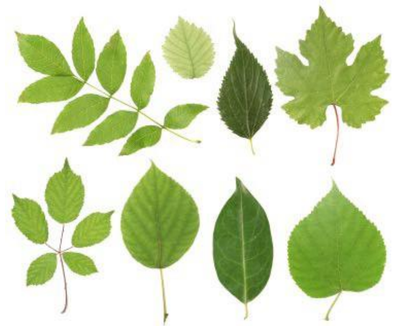
Margaret M Mayfield

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

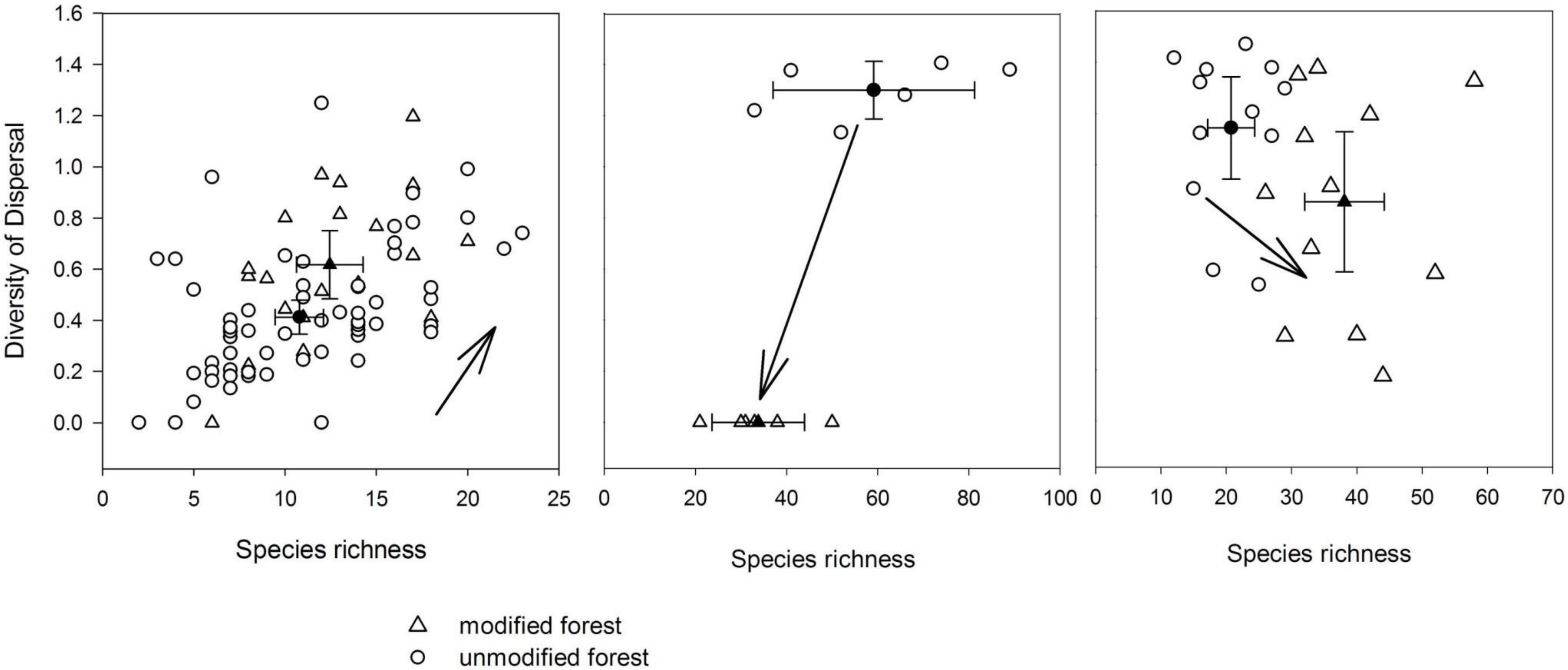
What are functional traits?

- Any feature of an organism that is important for its response to or effect on the environment (biotic/abiotic)
- Plant traits often describe:
  - Physiological responses to the environment
  - Life history strategies
  - Interactions with soil
- Animal traits often describe:
  - Habitat requirements
  - Diet
  - Trophic guild
  - Breeding system

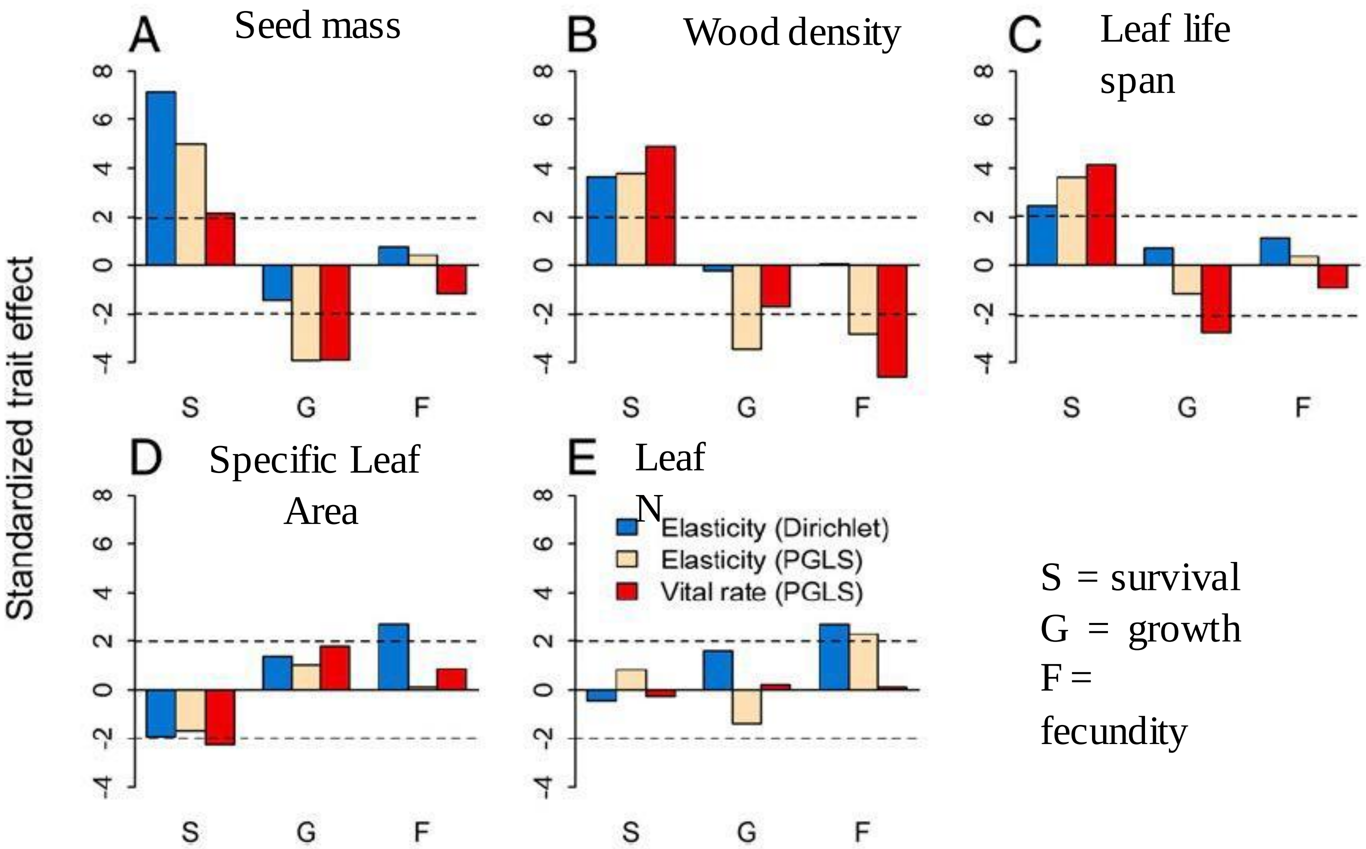



Traits and diversity



Mayfield et al. 2010

Using traits to understand species and their relationships with the world around them



S = survival
G = growth
F = fecundity

Adler et al. 2014

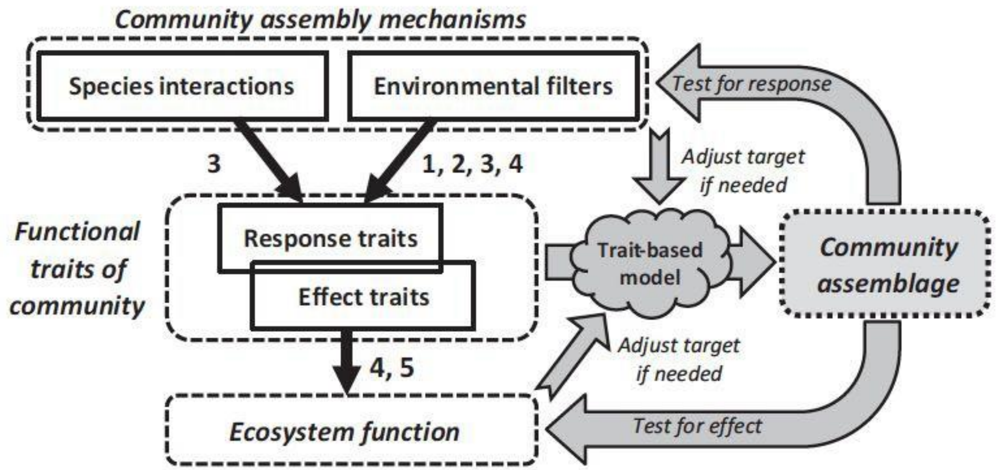
Which traits to focus on?

- What is the goal of the project?
  - Recovery?
  - Restoration?
  - Rehabilitation?
  - Ecosystem services?
- What are the ecosystem stressors?
  - Past?
  - Present?
- What trait information is available?
  - Easy vs. hard traits
  - Corrected traits

(a) Examples of stressors and the functional trait targets that can be established to restore degraded ecosystems

Ecosystem stressors →	Restoration goals →	Possible trait targets
1) Land-use change	Restore lost community	Traits of reference sites
2) Climate change	Restore resilient community	Traits resilient to future climate
3) Invasive species	Control and exclude non-natives	Traits of invasive species
4) Abiotic degradation	Rehabilitate site conditions	Trait dominance (mass ratio)
5) Species loss	Maintain primary productivity	Trait diversity (complementarity)

(b) Translating response-and-effect traits into species assemblages that can be manipulated by practitioners and tested in the field



Laughlin

Availability of Trait Data

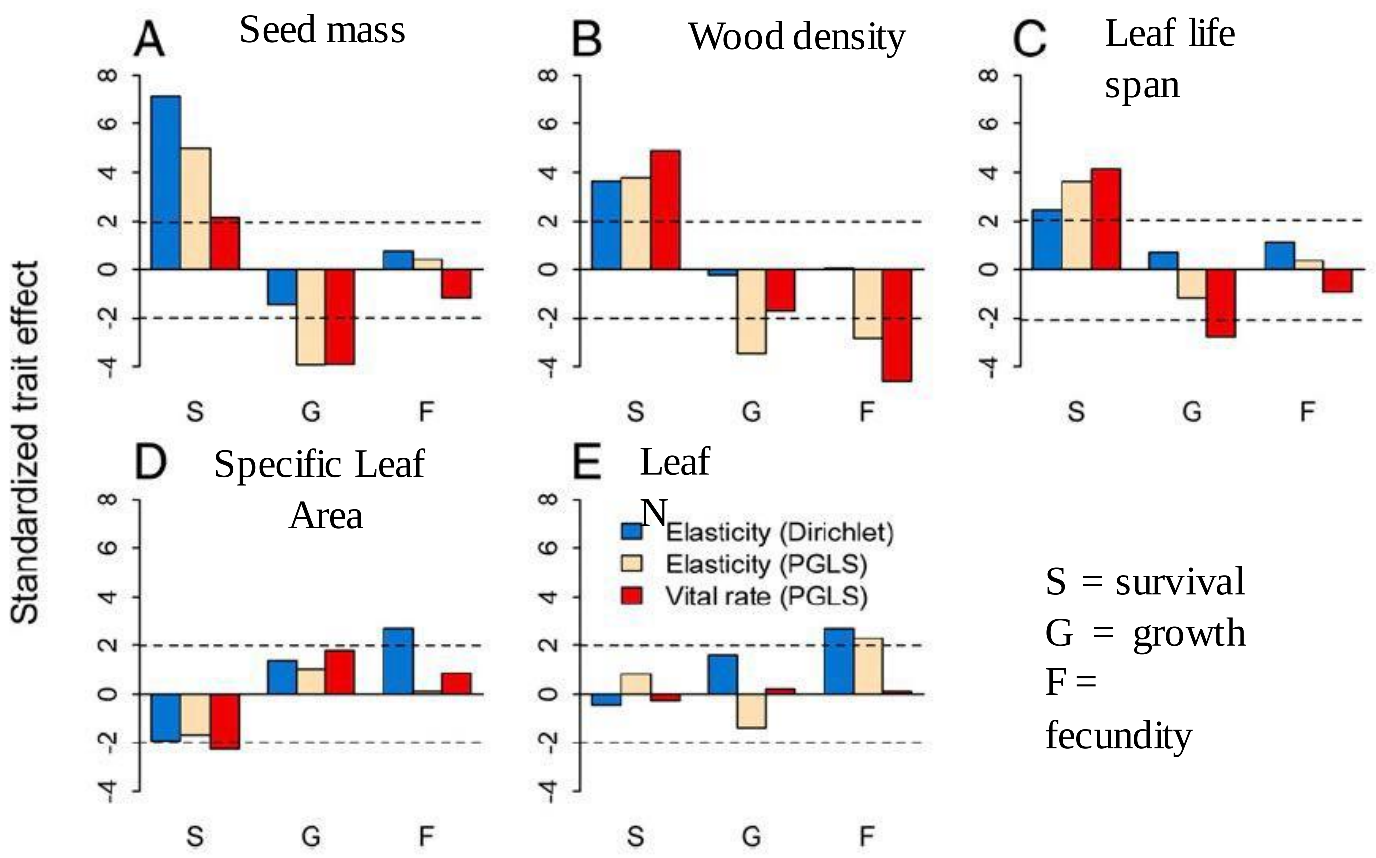
- Easy Traits for Plants
  - Seed mass
  - Specific Leaf Area
  - Height
  - Wood Density

Table 1. The common challenges faced by plants and some suggested traits.

Challenge	Hard trait	Easy trait
1. Dispersal		
Dispersal in space	Dispersal distance	Seed mass, Dispersal mode
Dispersal in time	Propagule longevity	Seed mass, seed shape
2. Establishment		
Seedling growth	Seed mass Relative Growth Rate	Seed mass Specific Leaf Area (SLA) Leaf Water Content (LWC)
3. Persistence		
Seed production	Fecundity	Seed mass, Above-ground biomass
Competitive ability	Competitive effect and response	Height, Above-ground biomass
Plasticity	Reaction norm	SLA, LWC
Holding space / longevity	Life span	Life history Stem density
Acquiring space	Vegetative spread	Clonality
Response to disturbance;	Resprouting ability	Resprouting ability
stress and disturbance avoidance	Phenology, Palatability	Onset of flowering, SLA, LWC

Weiher et al. 1999

Using traits to understand species and their relationships with the world around them

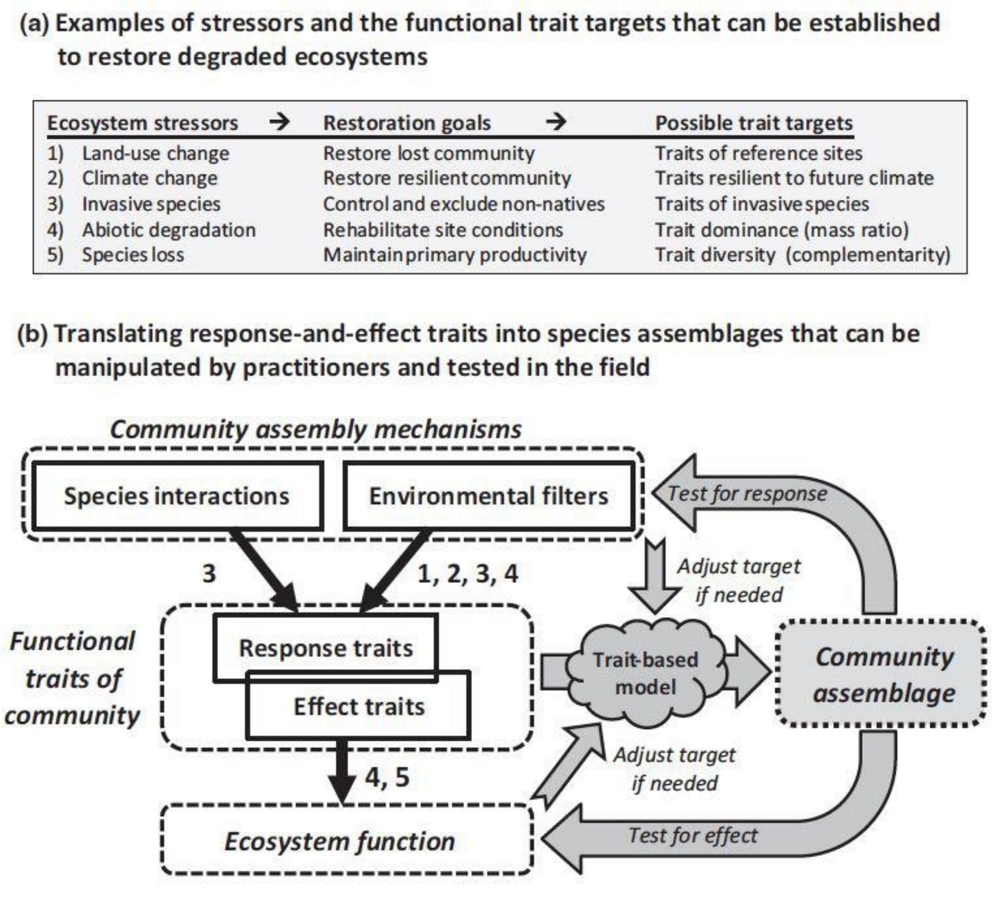


S = survival
G = growth
F = fecundity

Adler et al. 2014

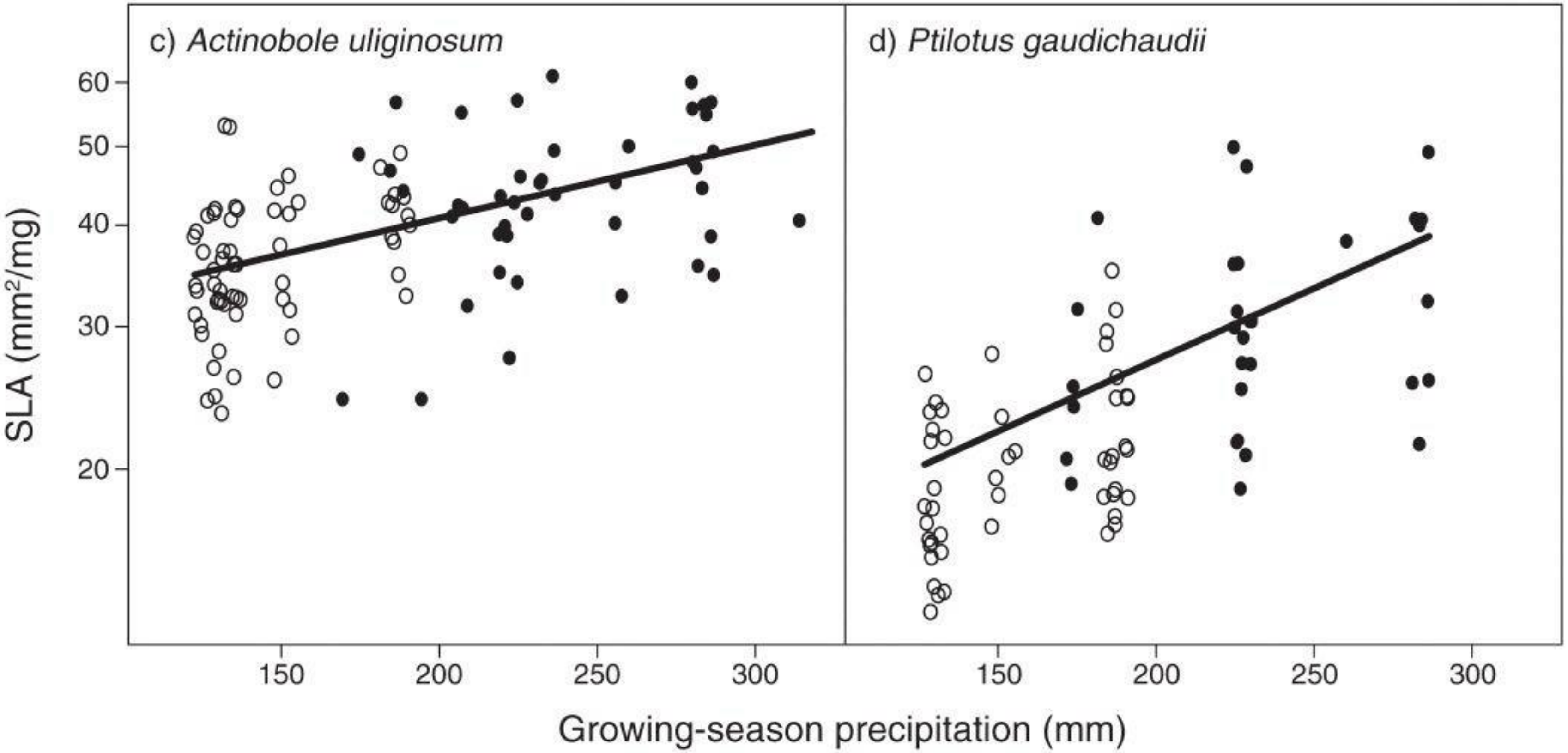
Traits and the future: intraspecific trait variation

- Limits of mean trait values
  - Where were they measured?
  - Traits can vary within species as much as between species
- Using traits for restoration or planned translocation
  - Where is the project?
  - Where are you sourcing individuals?
  - What trait values are found in source?
  - Will source trait values drive desirable outcomes?



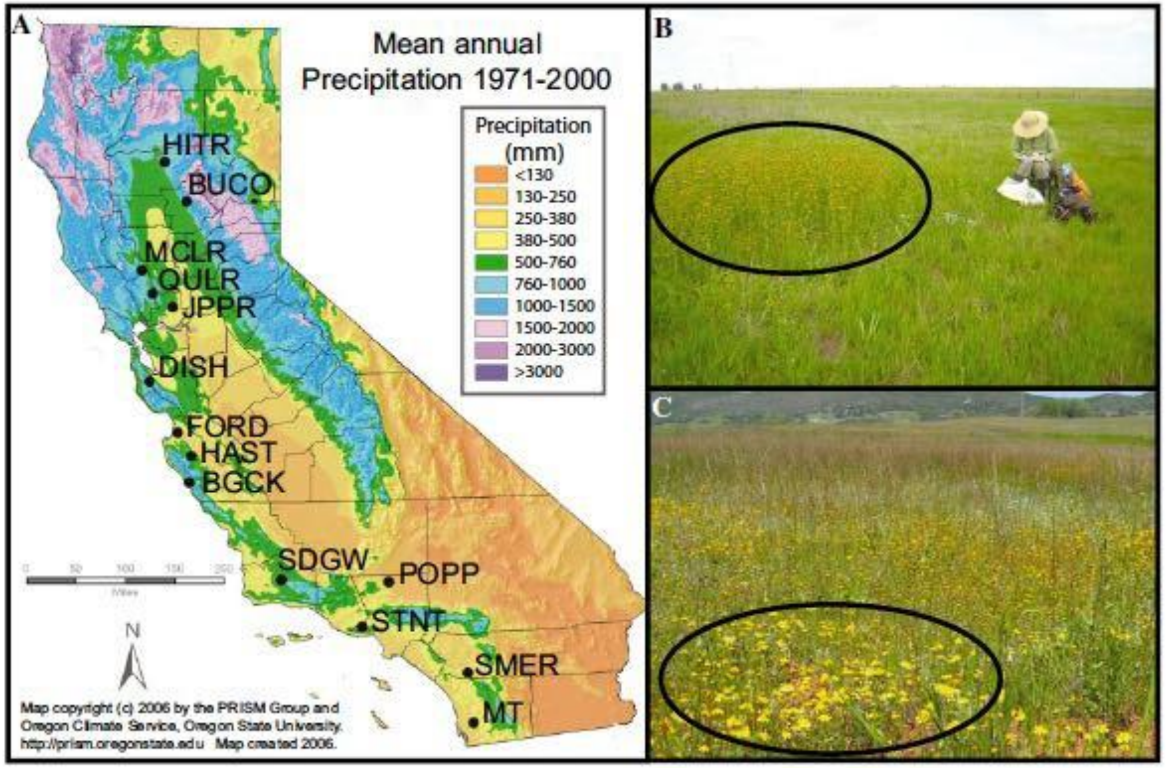
Laughlin

Intraspecific trait variation across the environment



Dwyer et al. 2014

Assumed relationships between traits and the environment not always correct!

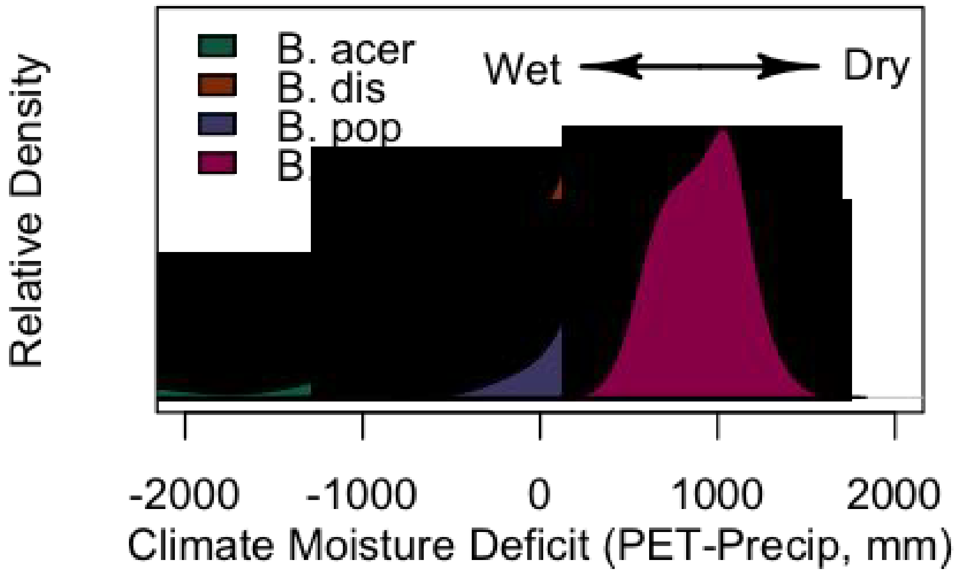


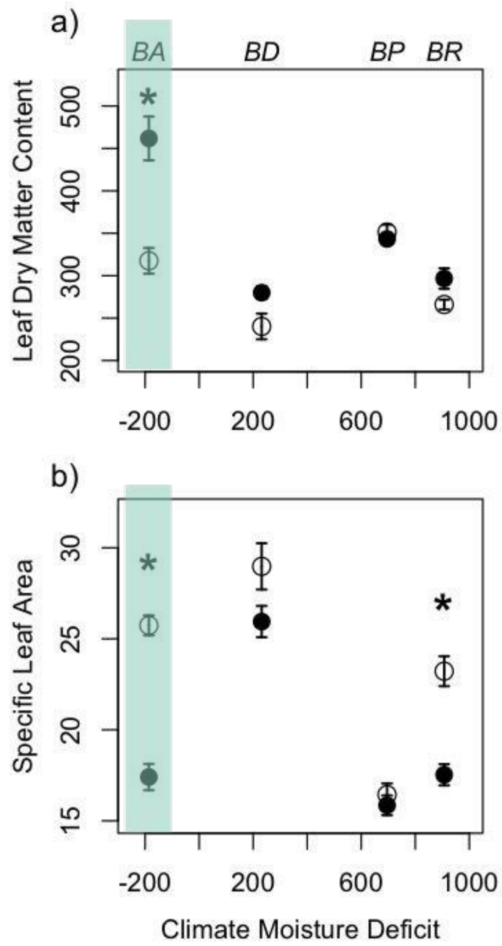
Only use tested relationships!

Mayfield et al. 2014

Trait variation between life stages

Queensland *Brachychiton* species.





SLA and LDMC did not fit with drought tolerance expectations for adults.

Reynolds et al. In

Summary

- Traits can provide an excellent framework for developing more effective conservation plans

- BUT….
- They are not a cure all
- Should use them in specific reference to:
  - Specific project goals
  - Site environmental/threat conditions
  - Source Individuals should be assessed for specific trait values
  - life history stage differences in traits need to be considered

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