ADDRESSING LIMITATIONS TO SEED RECRUITMENT IN LARGE SCALE RESTORATION

David Merritt, Todd Erickson, Miriam Muñoz-Rojas, Shane Turner, Andrew Guzzomi

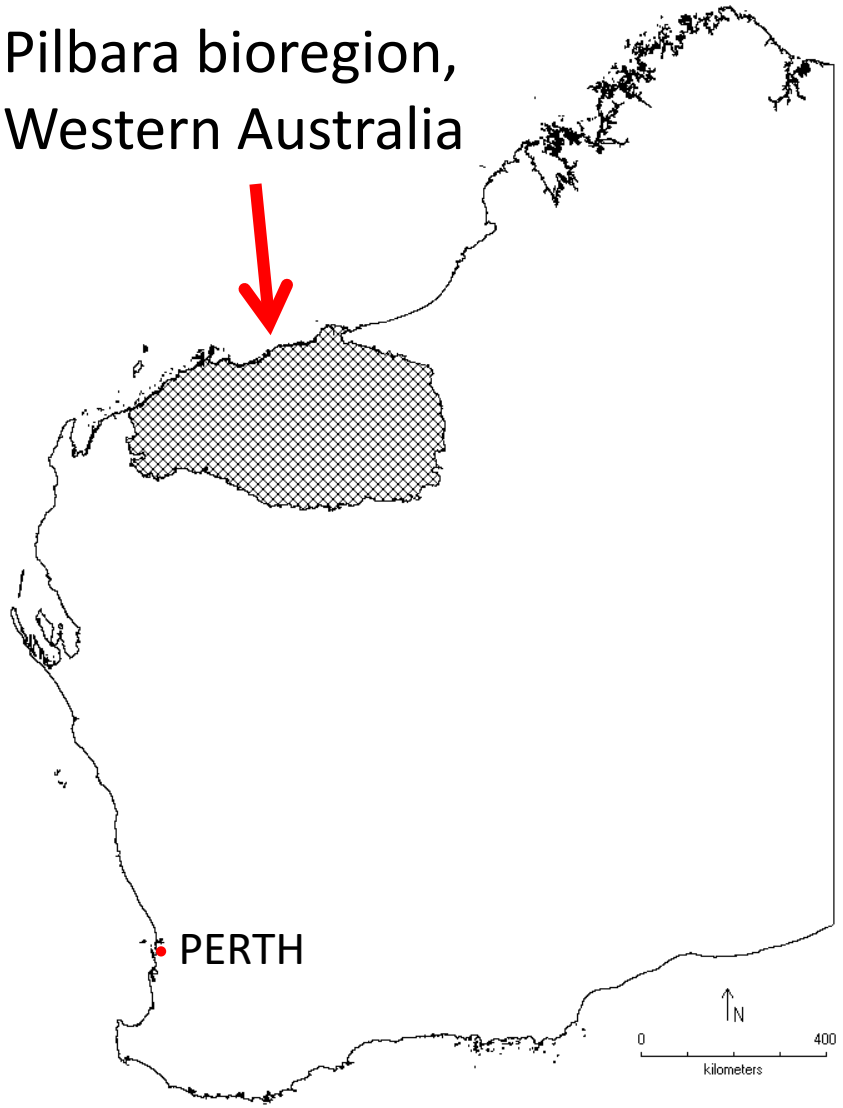
GOVERNMENT OF WESTERN AUSTRALIA
Department of **Biodiversity, Conservation and Attractions**
KINGS PARK SCIENCE
THE UNIVERSITY OF WESTERN AUSTRALIA
Achieving International Excellence

Mine site restoration in the Pilbara

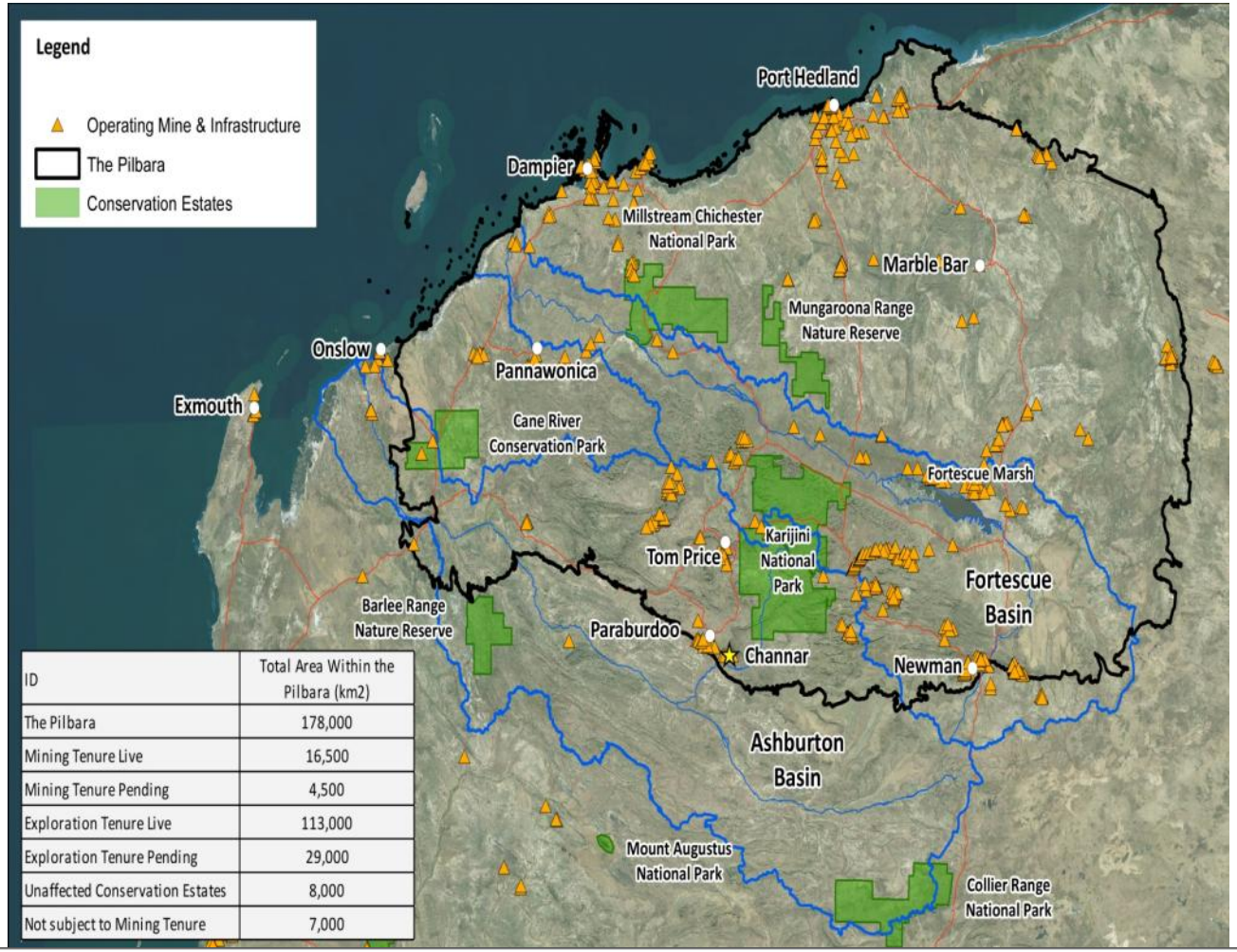
- 180,000 km^2 arid landscapes.
- Low woodlands (*Acacia*, *Eucalyptus*) over hummock grassland (*Triodia*).

- 795mt iron ore worth $63b in 2017.
- Mining disturbance exceeds 2300 km^2.
- Ministerial requirement to restore vegetation comparable to the pre-disturbed landscape (= high diversity).

- Large deficit of topsoil = seed input.
- Seeding with non-treated seeds and limited knowledge of seed quality, storage, and germination capabilities.



Operating mines and infrastructure

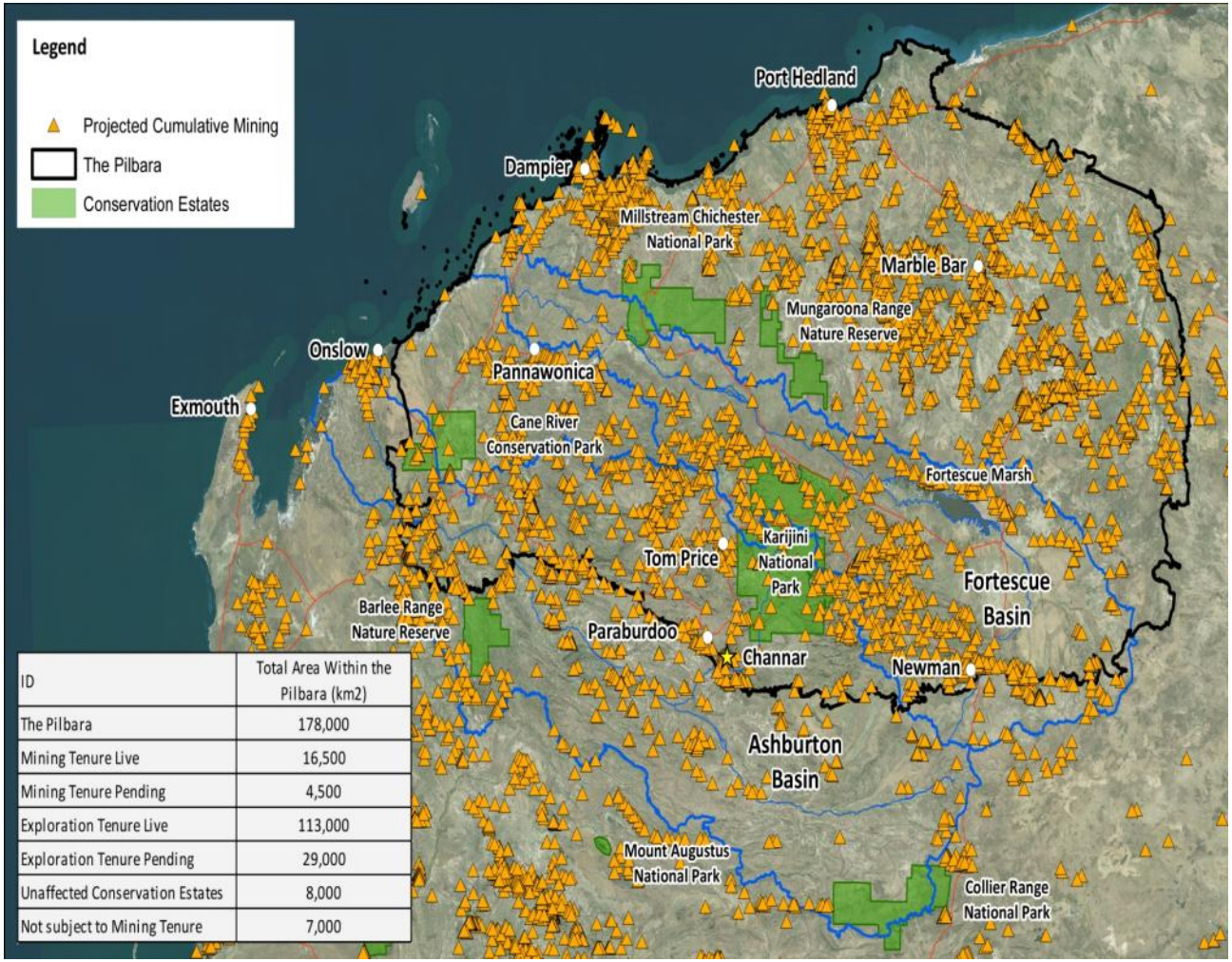


ID	Total Area Within the Pilbara (km2)
The Pilbara	178,000
Mining Tenure Live	16,500
Mining Tenure Pending	4,500
Exploration Tenure Live	113,000
Exploration Tenure Pending	29,000
Unaffected Conservation Estates	8,000
Not subject to Mining Tenure	7,000

Mines Source: Department of Mines and Petroleum, Mindex database: "Site _Stage" = Operating

Tenure Source: Australian Government Department of the Environment , Pilbara IBRA Region ; Department of Mines and Petroleum, Tenement database ; and The Department of Environment and Conservation, DEC Managed Lands & Waters

Projected cumulative mining



ID	Total Area Within the Pilbara (km2)
The Pilbara	178,000
Mining Tenure Live	16,500
Mining Tenure Pending	4,500
Exploration Tenure Live	113,000
Exploration Tenure Pending	29,000
Unaffected Conservation Estates	8,000
Not subject to Mining Tenure	7,000

Mines Source: Department of Mines and Petroleum, Mindex database: "Site _Stage" = Operating

Tenure Source: Australian Government Department of the Environment , Pilbara IBRA Region ; Department of Mines and Petroleum, Tenement database ; and The Department of Environment and Conservation, DEC Managed Lands & Waters

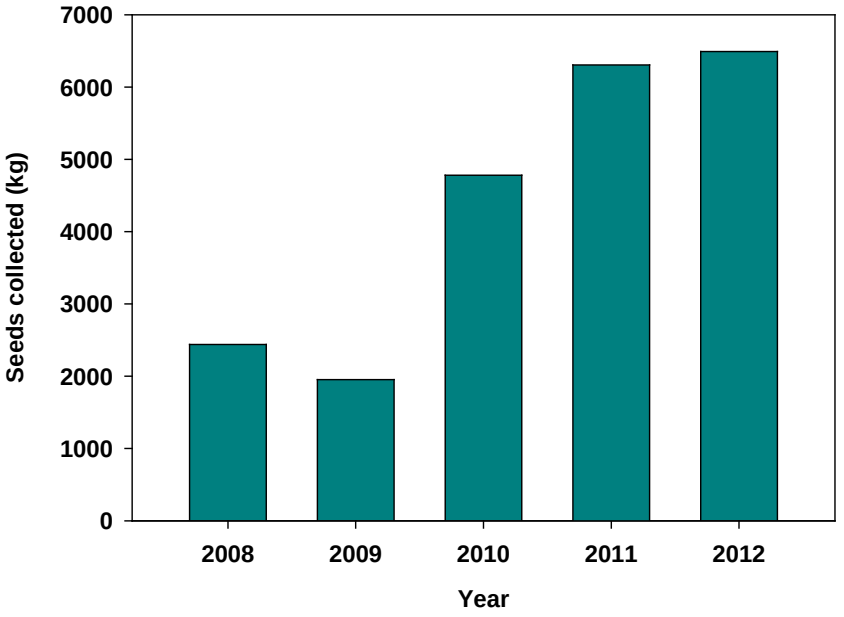
With our present capacity:
Arid zone landscapes – limited topsoil

Pilbara region of Western Australia

120,000 ha (1200 km^2) requiring rehabilitation

Equates to 600 tonnes wild collected seed at 5 kg/Ha.

Current collection capability: 6 tonnes pa.



Source: Wildlife Licensing, Nature Protection Branch, DPaW (2014)

Significant and increasing demand for wild seed is coupled with huge losses in restoration

Seedling Establishment

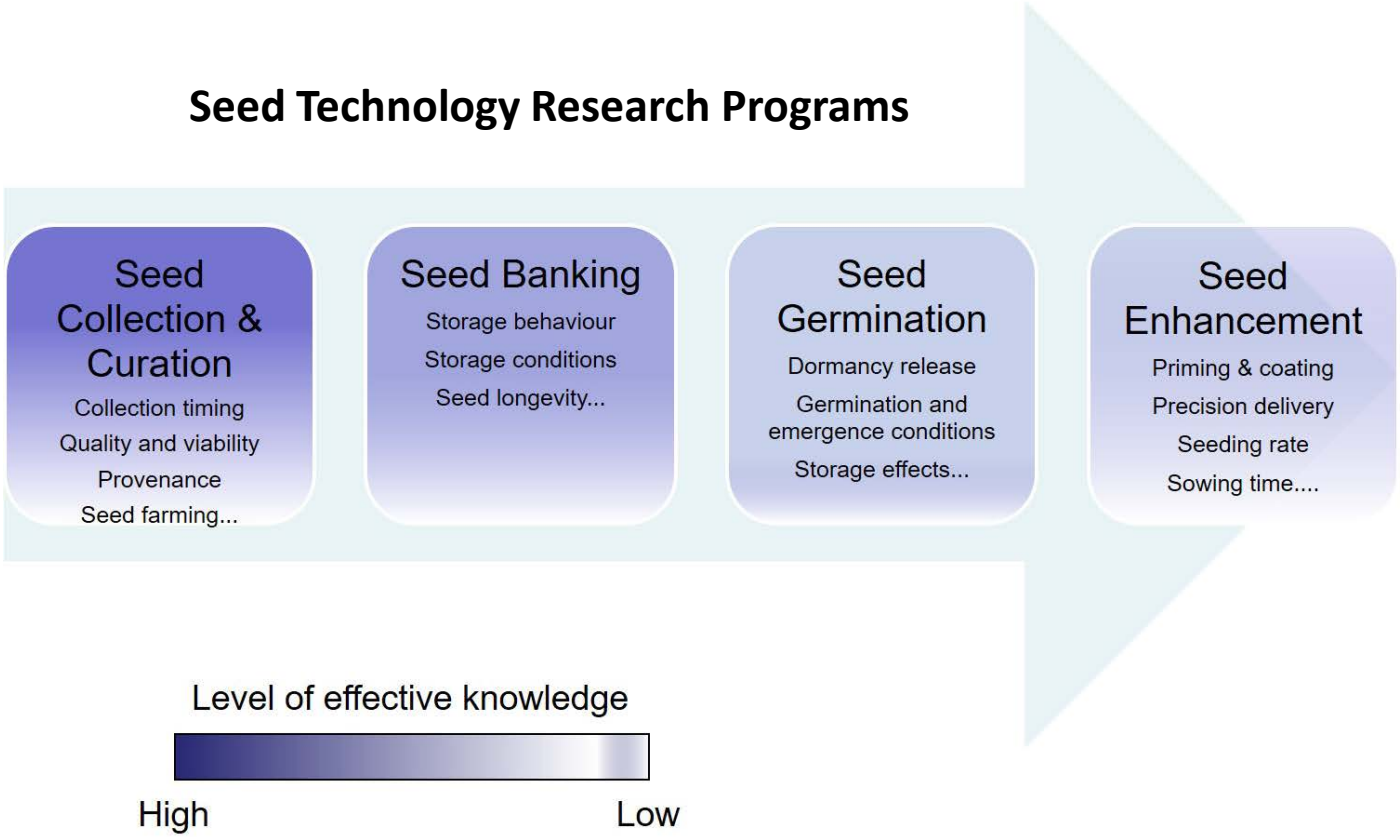
Region	Biome	Establishment Rate (%)
Australia	Mediterranean woodland	0 – 17%[A]
Australia	Arid shrubland	0 – 8%[B]
Australia	Tropical rainforest	1 – 33%[C]
USA	Sagebrush Steppe	5 – 30%[D]
USA	Arid grassland	7 – 17%[E]

Source: [A]Turner *et. al.* (2006);[B]Commander *et. al.* (2013), Golos (2012);[C]Doust *et. al.* (2007); [D]Chambers (2000); [E]James *et. al.* (2011);

Merritt and Dixon, (2014). *State of the World's Forest Genetic Resources*, FAO and Bioversity International.

Research focus for seed use in restoration

- Majority of recruitment failure is between germination and emergence.
- Poor management of seed quality and dormancy further contributes to lack of recruitment.
- Holistic management of seeds is necessary for diverse seed mixes.
- Need to engineer the niche through seed enhancement and growth media management.

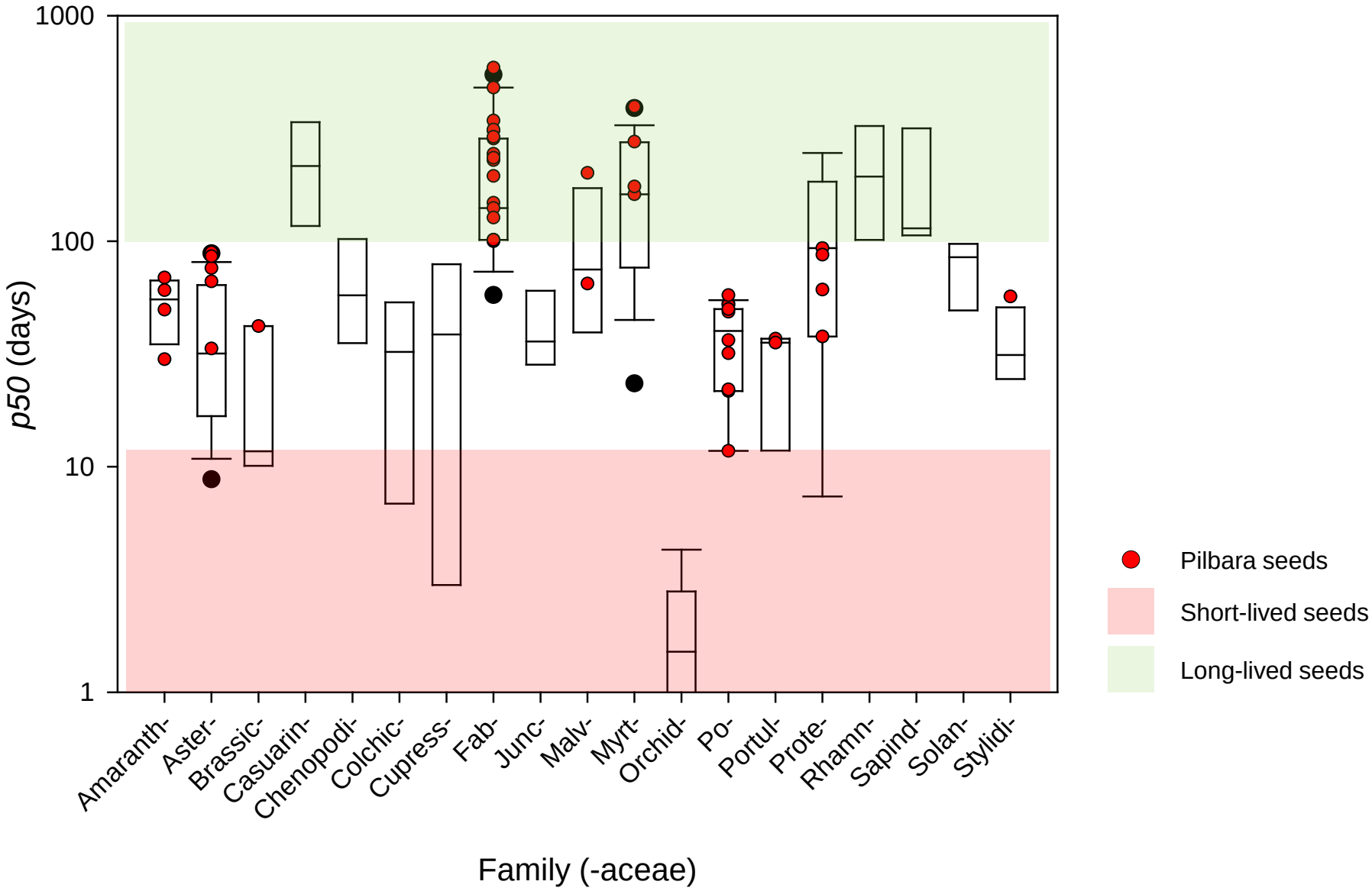


Seed banking in industry for restoration

- Pros
  - Cool storage temperature.
  - Most accessions labelled with species name.

- Cons
  - Most labelling missing collection year, location, accession number.
  - Species ID not verified.
  - Species diversity low.
  - Volume of seed low relative to restoration area.
  - No information on seed quality available.
  - Seeds not dried prior to storage.
  - Seeds packaged in plastic or hessian bags.
  - Little knowledge of seed pre-treatments required.
  - Storage duration exceeds 10 years for seeds in hessian bags.
  - Seeds left outside in the sun.

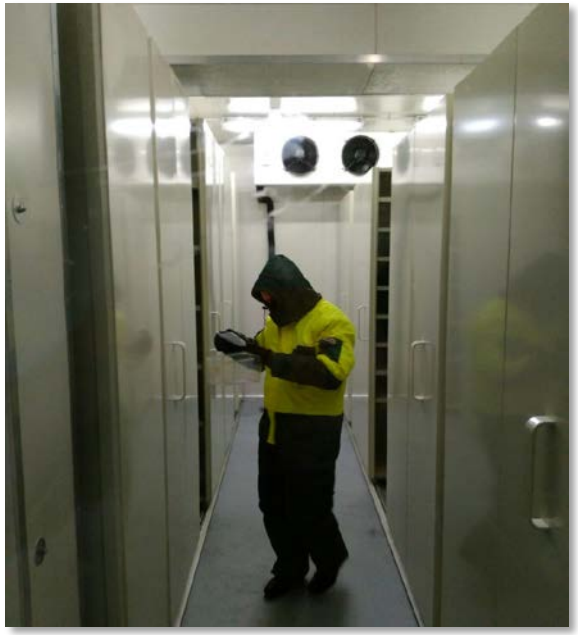
Seed longevity is a complex trait



N=207

Merritt *et.al.* (2014). *Biodivers. Conserv.* **23**:1081–1104

Restoration seed banking



Protection of seed quality is paramount.
Flexibility in storage conditions is ideal.

Storage conditions should consider:

- Seed type (longevity, storage behaviour, dormancy type).
- Storage duration.
- Designated end use of seeds.

On-demand seed pre-treatments at scale

- Simple, reliable and repeatable.
- Applicable to large quantities of seed.

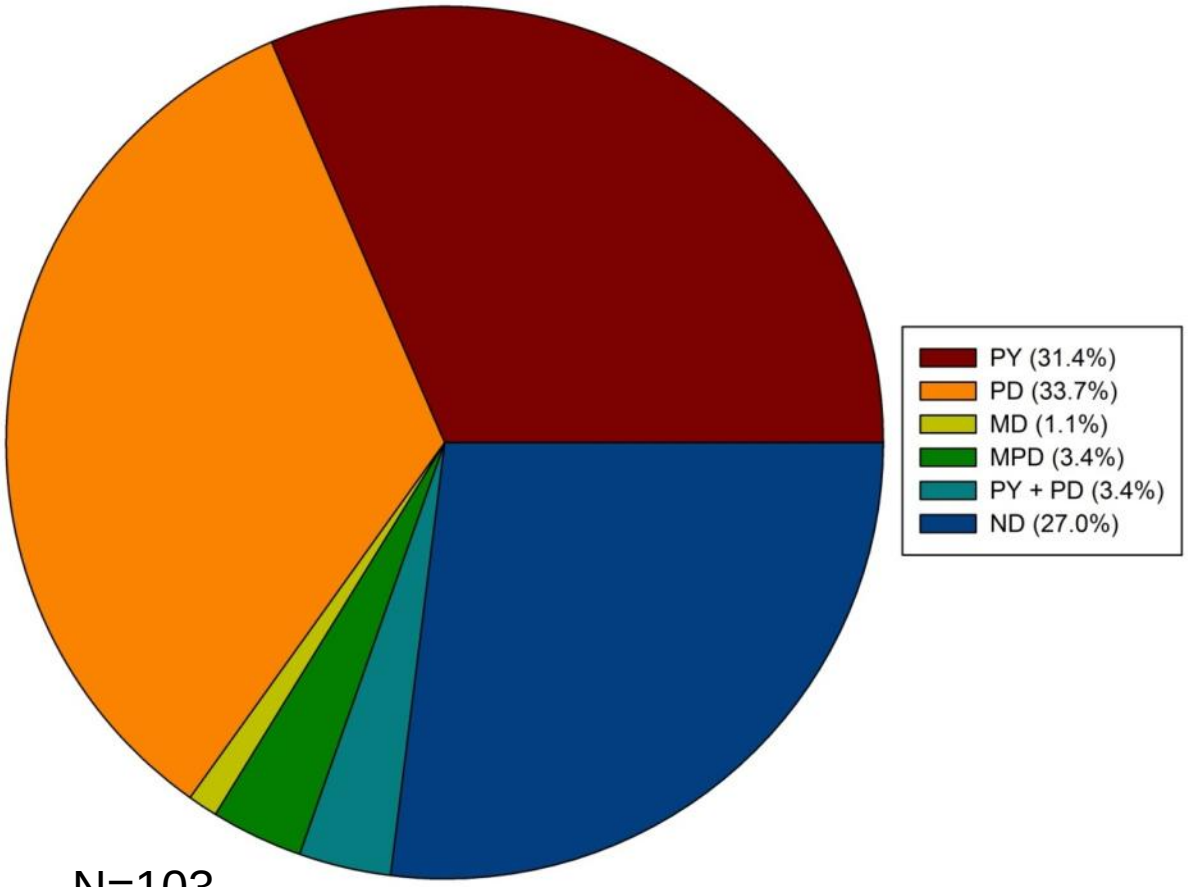
Easy for some……

……not so easy for others.

Dormant seeds

Non-dormant seeds

Seed dormancy types in the Pilbara



N=103

Physiological Dormancy (PD)
Asteraceae
Poaceae
Eremophila
Grevillea
Goodenia
Maireana

Physical Dormancy (PY)
Fabaceae
Sapindaceae

Non-dormant (ND)
Eucalyptus
Corymbia
Hakea

PY+PD
Malvaceae

MPD
Hibbertia

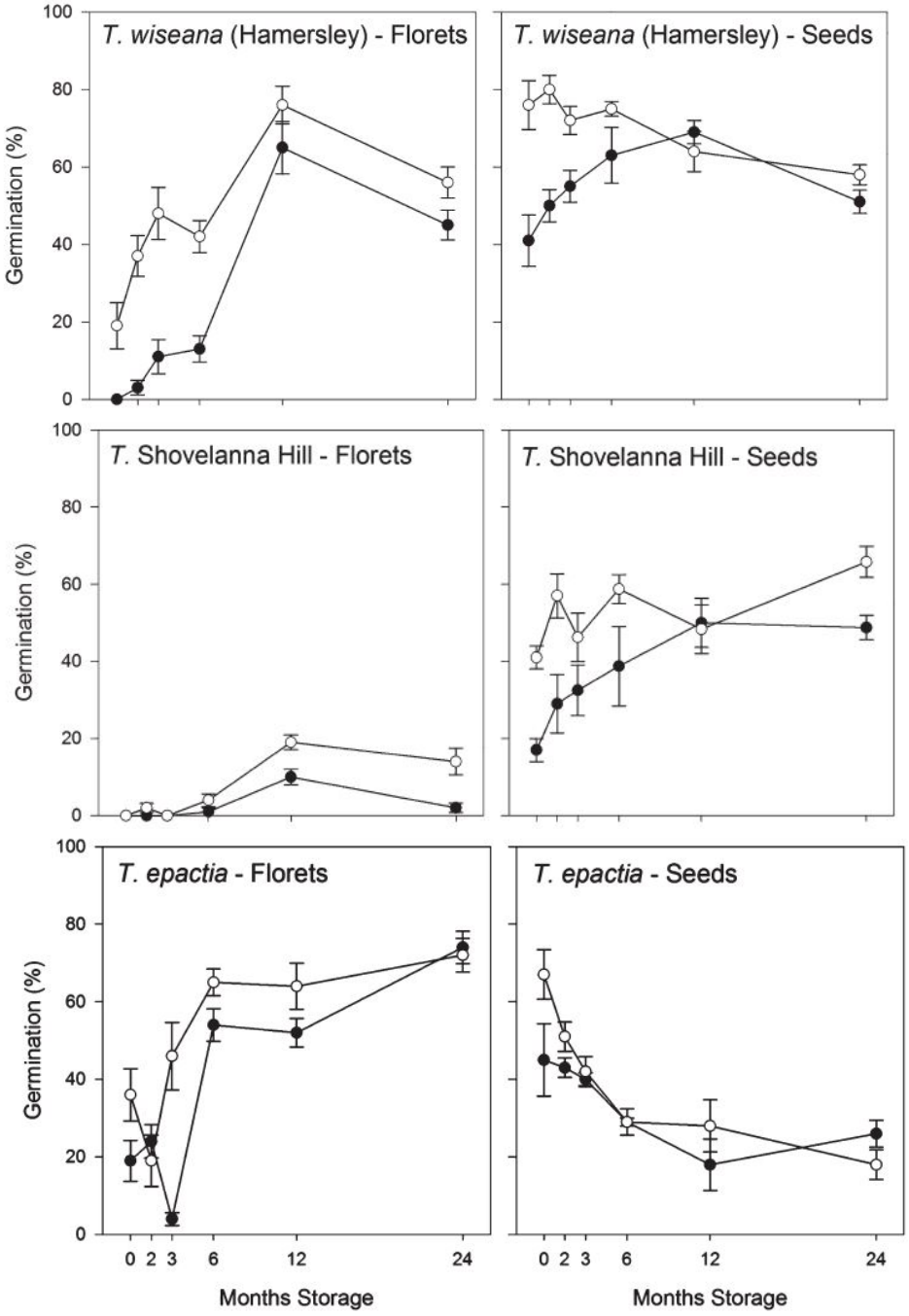
Erickson et.al. (eds) (2016). *Pilbara Seed Atlas and Field Guide*

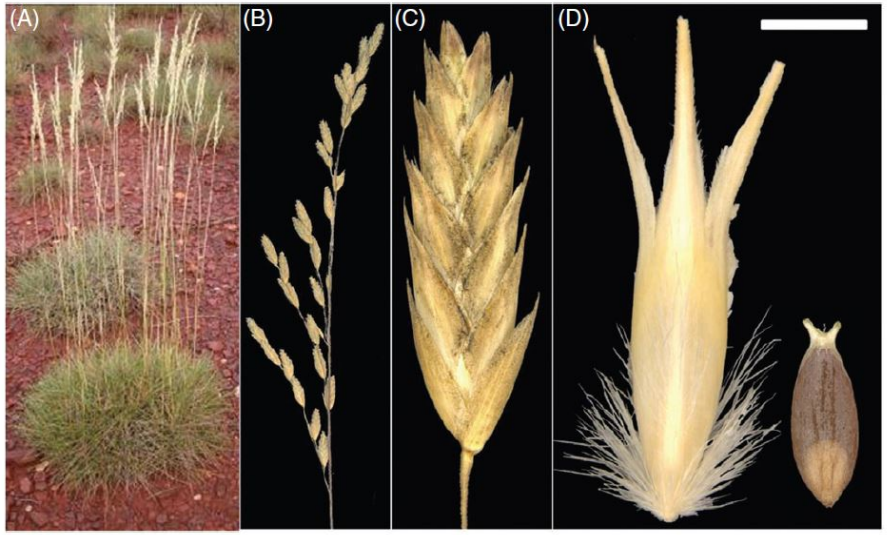
Seed ecology has a clear role in developing germination methods

- Timing of seed maturation and seed dispersal.
- Soil temperature fluctuations (seasonal and diurnal).
- Rainfall data.
- Dormancy type.

- Design experiments that define the influence of temperature, moisture, light, other external cues as appropriate to the environment.

Mimic the environment





Erickson et *al* (2016) *Rest. Ecol.* 24(S2): S64-S76

Restoration Seedbank Initiative

GOVERNMENT OF WESTERN AUSTRALIA

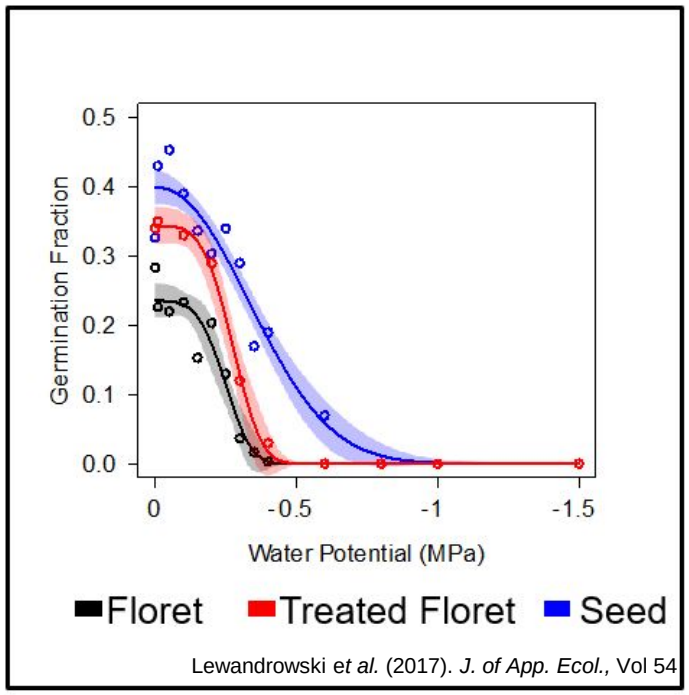
KINGS PARK & Botanic Garden
BOTANIC GARDENS & PARKS AUTHORITY

THE UNIVERSITY OF WESTERN AUSTRALIA

BHP

Seed regeneration traits

Dormancy
Germination
Speed of germination
Emergence depth
Base water potential
Soil temperature/moisture influences
Seed persistence



Lewandrowski *et al.* (2017). *J. of App. Ecol.*, Vol 54

Lewandrowski *et al* (2017). *J. of App. Ecol.* 54: 997-1007

Seed enhancement and delivery

Priming

Improved vigour:

- Increased speed germination.
- Greater uniformity germination.
- Increased stress tolerance.

Coating and pelleting

Enhanced delivery:

- Uniformity of size and weight.
- Incorporation of chemical/biological agents.
- Reduced predation.

Direct seeding

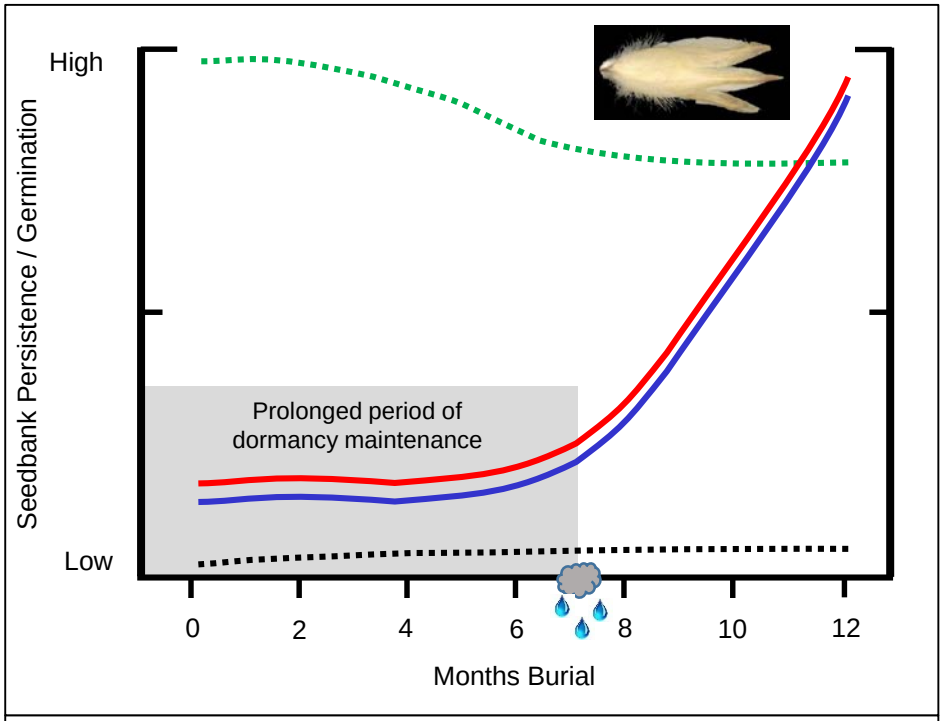
Mechanised delivery:

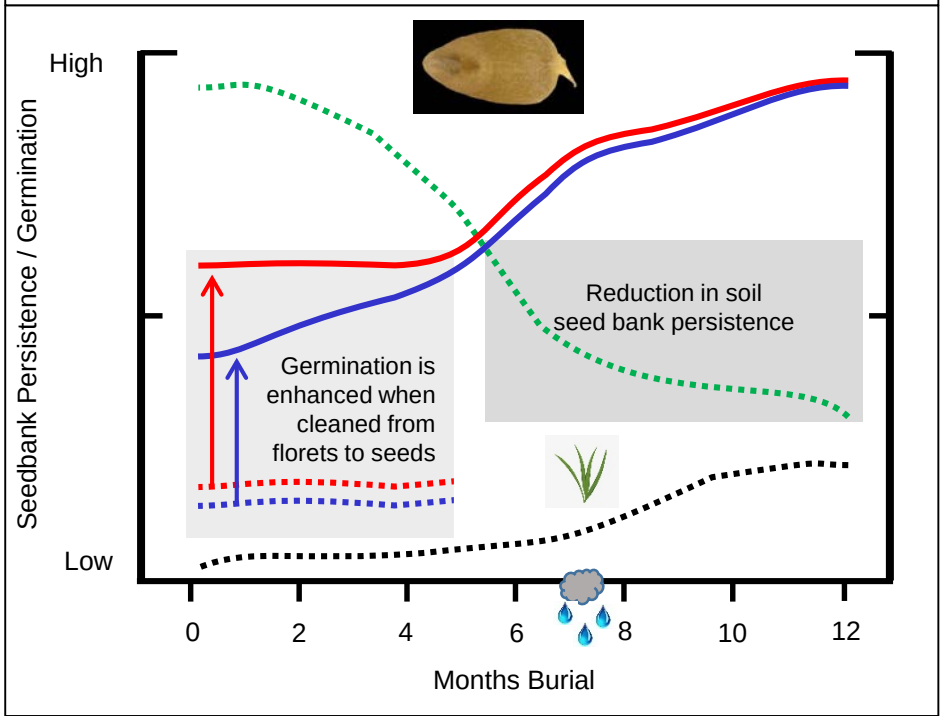
- Precision sowing of mixed species.
- Defined seeding rate.
- Controlled sowing depth.

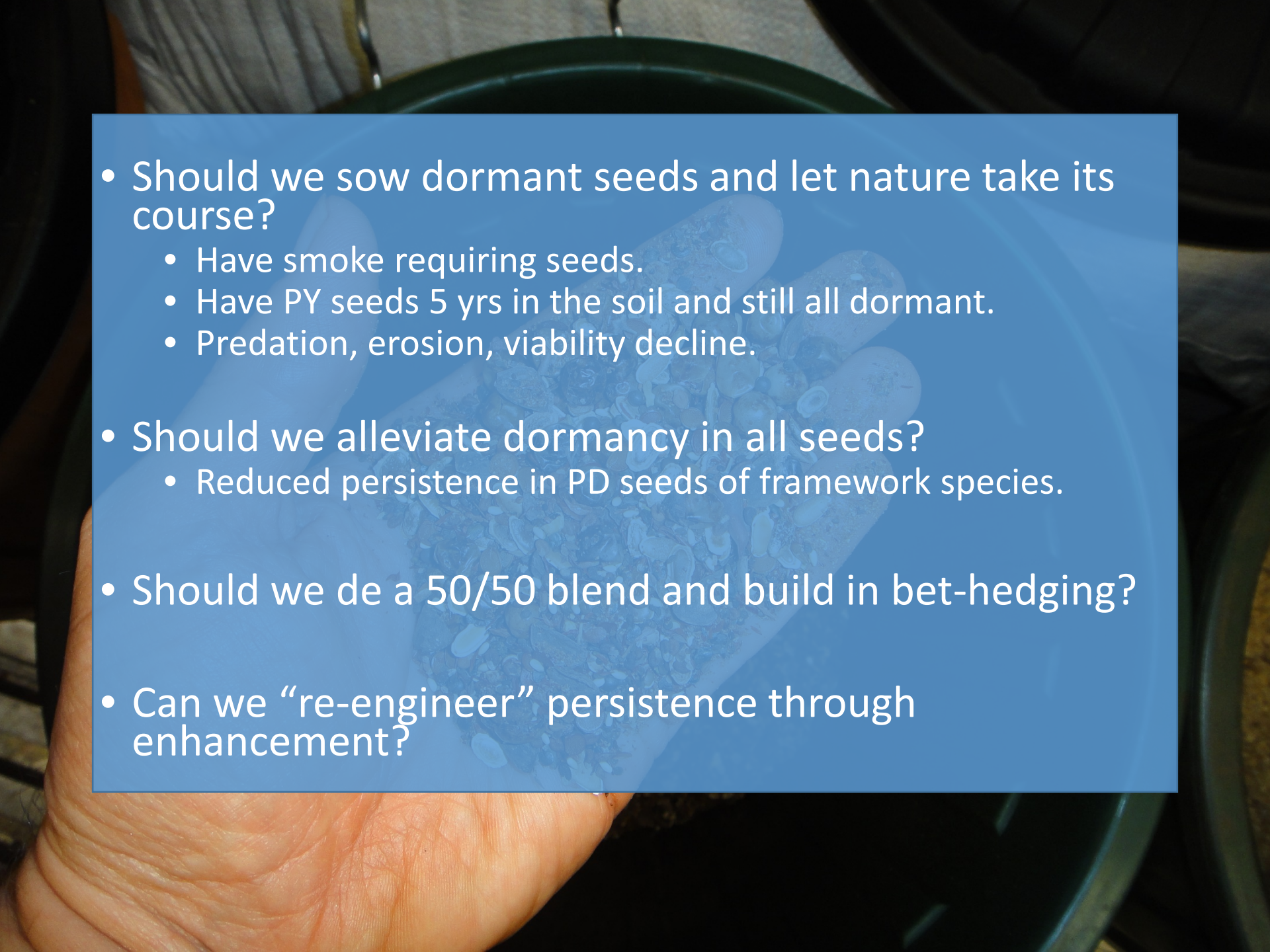
Lab germ of viable retrieved seeds/florets

% seeds/florets germ in field

% viable seeds/florets remaining in field







- Should we sow dormant seeds and let nature take its course?
  - Have smoke requiring seeds.
  - Have PY seeds 5 yrs in the soil and still all dormant.
  - Predation, erosion, viability decline.
- Should we alleviate dormancy in all seeds?
  - Reduced persistence in PD seeds of framework species.
- Should we de a 50/50 blend and build in bet-hedging?
- Can we “re-engineer” persistence through enhancement?

Acknowledgements

Todd Erickson
Miriam Munoz Rojas
Shane Turner
Andrew Guzzomi
Amber Bateman
Alison Ritchie
Olga Kildisheva
Emma Dalziell
Wolfgang Lewandrowski
David Symons
Christine Best
Elvan Ling
Monte Masarei

Matt Madsen
Jeremy James
Scott Abella
Steve Wishart
Tony Webster
Stephen White
Pamela Chester
Leanne VanDenAvoort
Barry Jilbert
Blair Parsons
Glen Steven