“Species extinction on islands: canaries in the coalmine”

Quentin Cronk

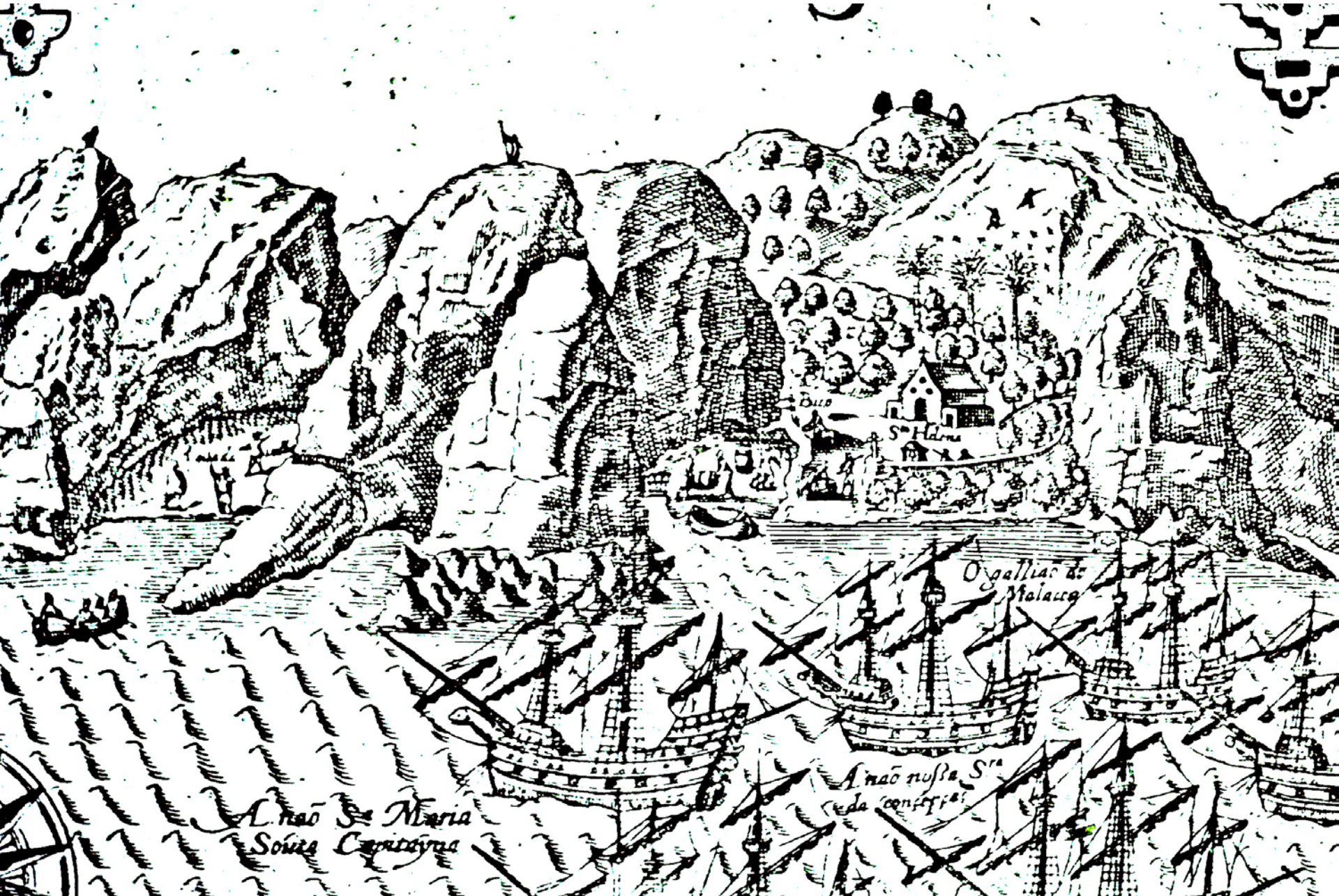
UBC, RBG Kew

A world in miniature

- Continents have vast areas – difficult (but not impossible) to destroy all natural vegetation
- Continental organisms have relatively vast population sizes – difficult to push to extinction
- Islands are small – impacts are comprehensive
- Island organisms have relatively small total populations – easy to push to extinction

Dialogue, discussion, systems approach

Ecological disaster starts in 1502



Soil washed into the sea

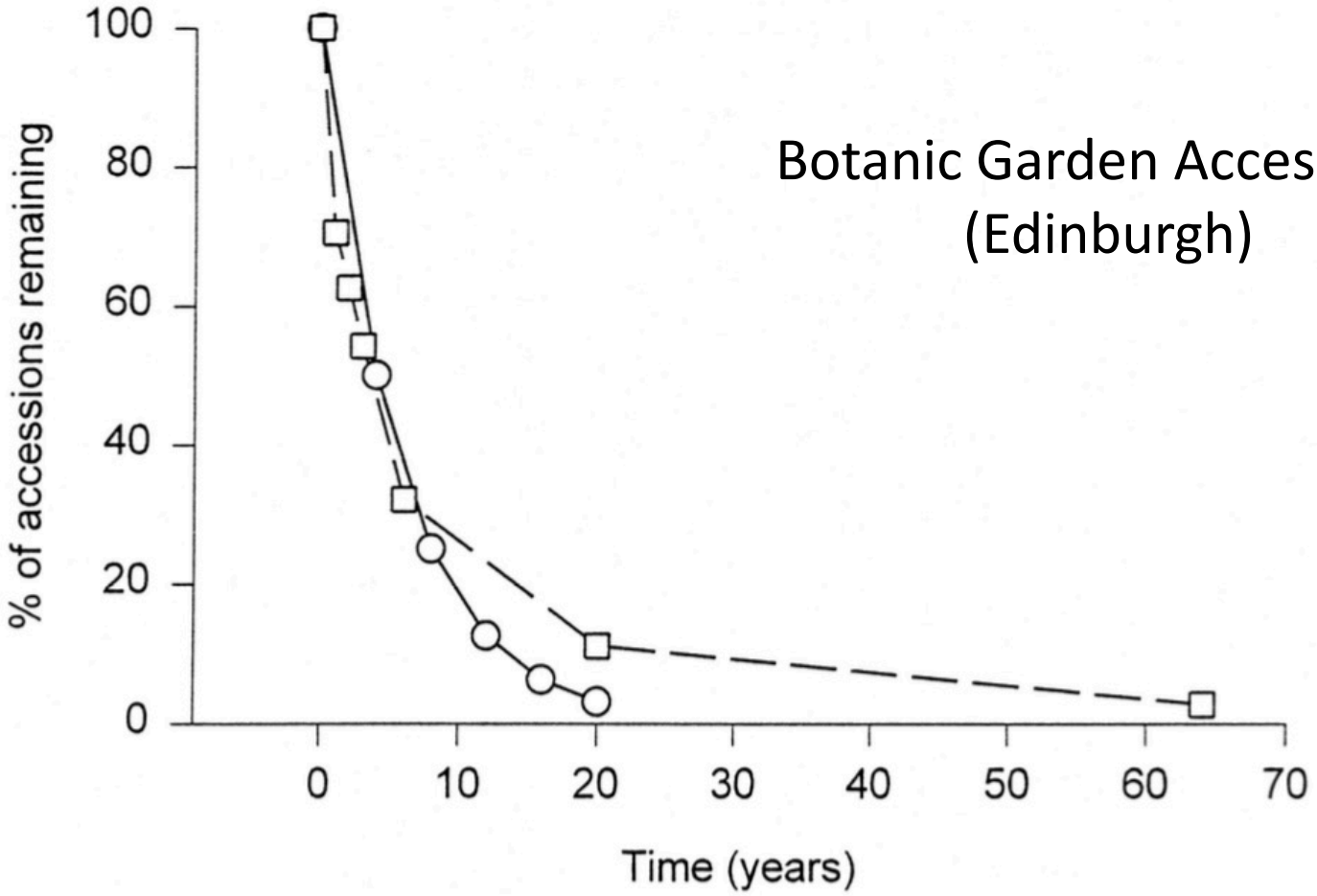
Now: c. 97% of natural habitat lost

“Dwarf ebony” or “silver-leaved blackwood” is extinct (*Trochetiopsis melanoxylon*) - extinct by c. 1790

The Extinct Plants of St Helena

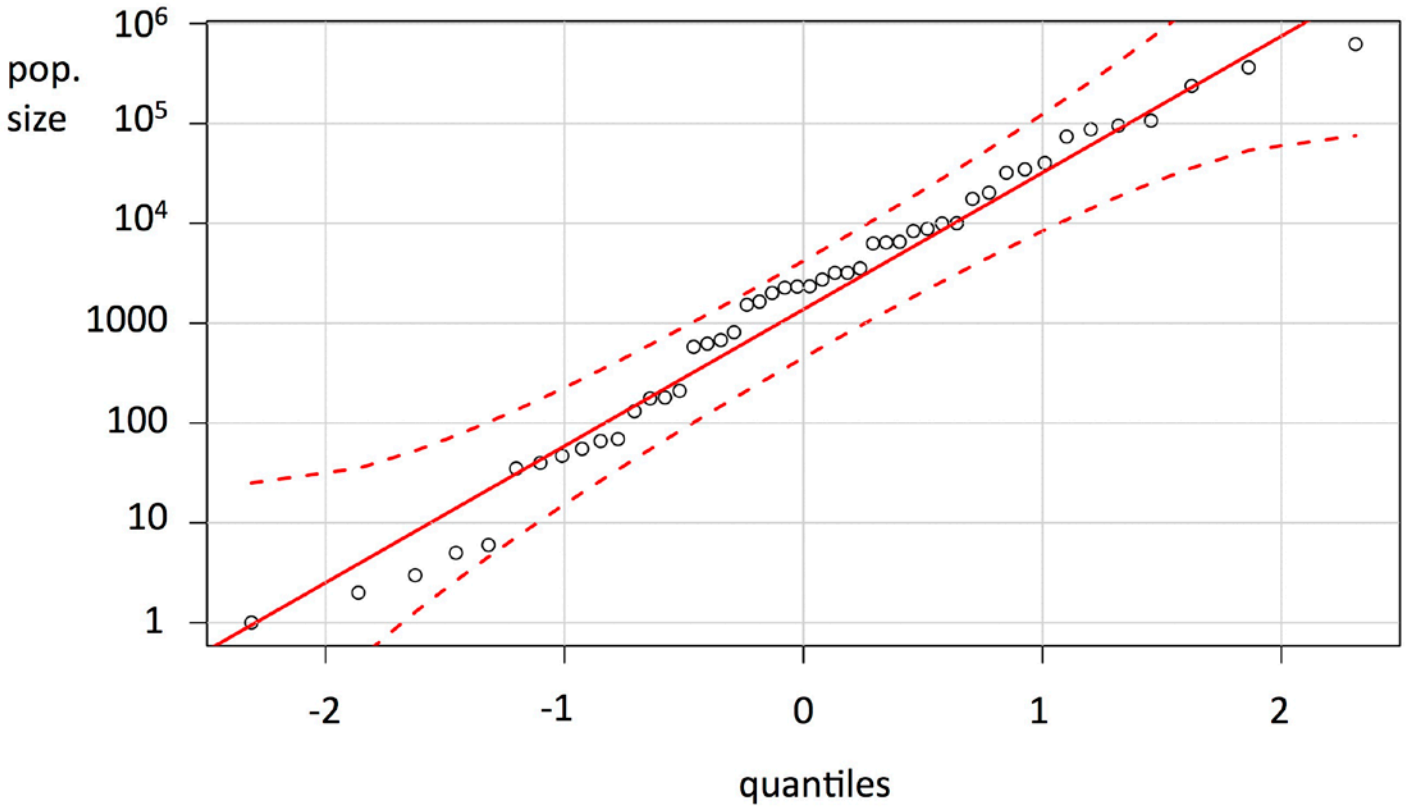
Species	Endemic genus	Date	Cultivated
She cabbage tree	yes (monotypic)	2012	Yes (EW)
St Helena Olive	yes (monotypic)	2002	No (EX)
St Helena redwood	yes	1960	Yes (EW)
Burchell's bellflower	no	1880	No (EX)
Stringwood	no	1871	No (EX)
Roxburgh's bellflower	no	1840	No (EX)
St Helena heliotrope	no	1820	No (EX)
Dwarf St Helena ebony	yes	1790	No (EX)

Cultivation: a warning



Botanic Garden Accessions
(Edinburgh)

The Inventory (2013) – Phil Lambdon and Shayla Ellick



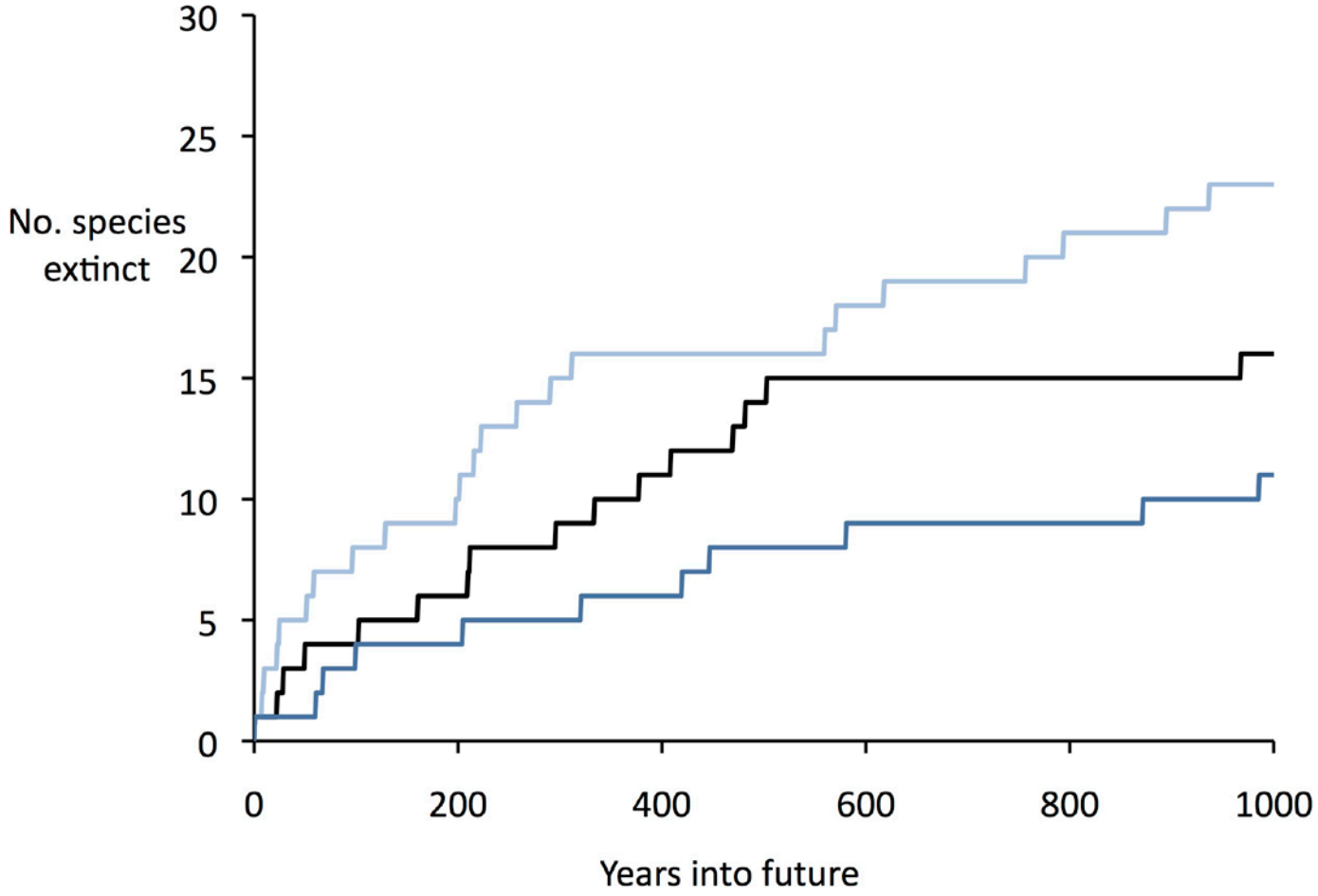
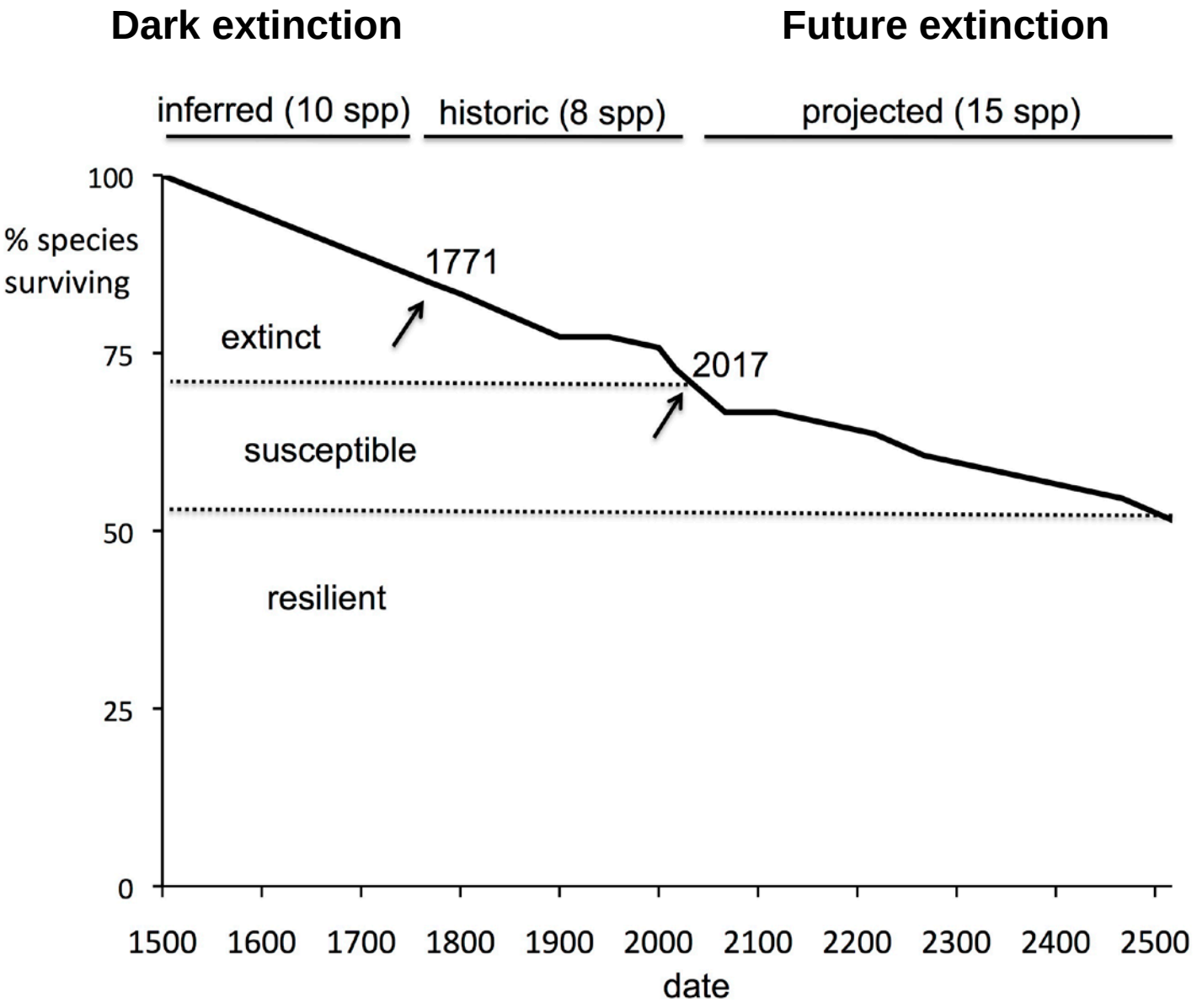
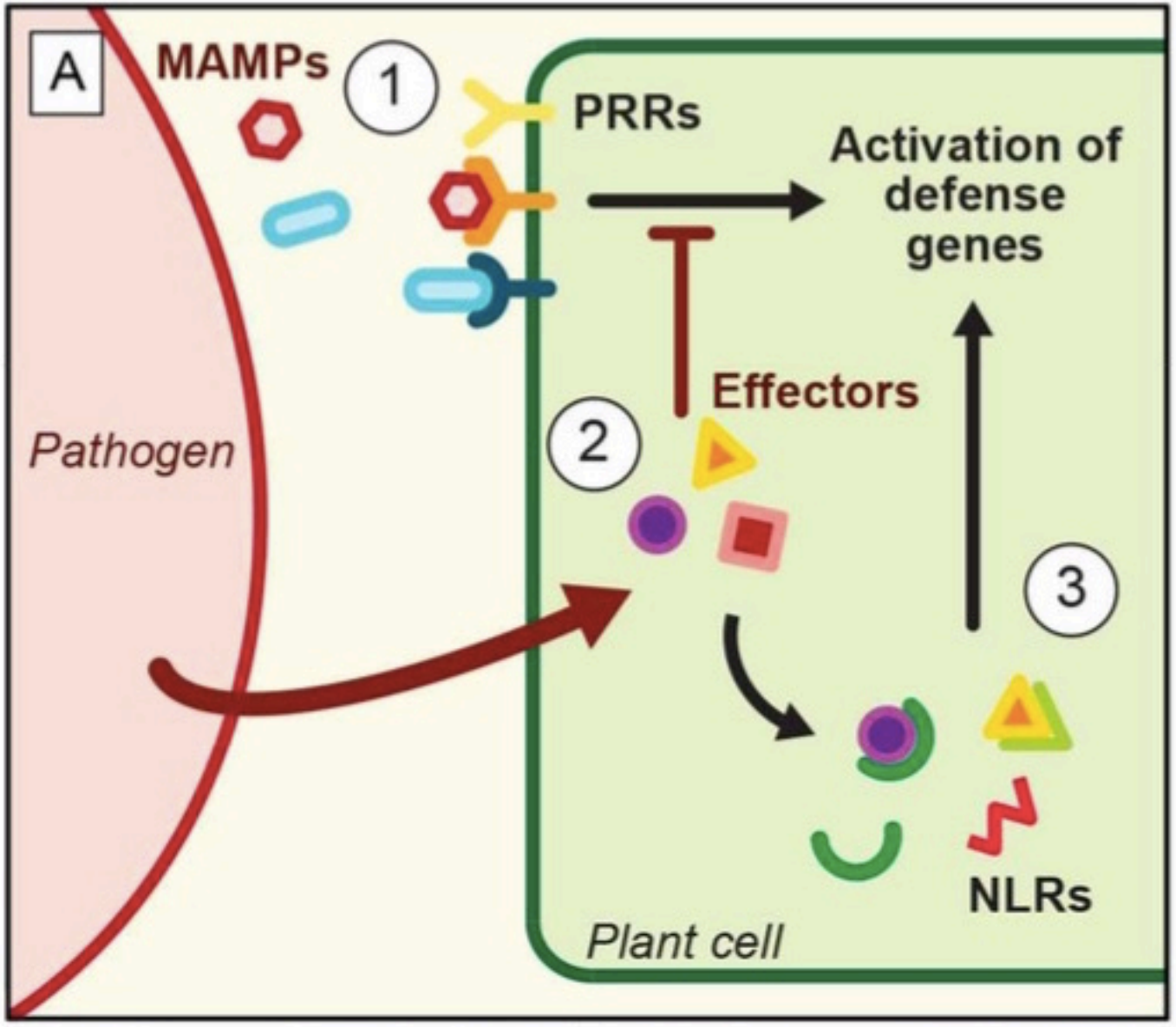

30
25
No. species
extinct
20
15
10
5
0
0
200
400
600
800
1000
Years into future

Figure 2


Dark extinction
Future extinction
inferred (10 spp)
historic (8 spp)
projected (15 spp)
100
% species surviving
75
50
25
0
1771
2017
extinct
susceptible
resilient
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
date

St Helena Olive (***Nesiota elliptica***) – monotypic endemic genus

EXTINCT – A sad loss



PLANT IMMUNE SYSTEM

Todesco & Cronk, Molecular Ecology, 2017.

MAMP = microbe-associated molecular pattern
PRR = Pattern recognition receptor (kinases, pattern-triggered immunity – PTI)
NLR = NBS-LRR domain gene (effector triggered immunity – ETI)

Some concepts: **Living dead**

- "An individual stripped of the ecological circumstances that allow it to be a reproductive member of its population, but which is living out its physiological life. Living dead are most easily observed as large trees remaining on the agroscape" (D.H. Janzen)

(1) Loss of functioning ecosystem
(2) Genetic damage

Rainforest relict in the Costa Rica agroscape

Photo: David Zabner

Latent extinction - reduction of all populations of a species to 'living dead'

"We live a perceptual lie as we bustle about our agroscapes. That single stately green *Dipteryx* or *Hymenaea* or *Swietenia* or *Enterolobium*, standing in a field, pasture, or roadside, is often just as dead as if it were a log in the litter or the back of a logging truck." – *D.H. Janzen*

Why does plant extinction take so long?

- **Relaxation time** – extinction lag time, i.e. time to equilibrium (Jared Diamond 1972)
- **Extinction debt** – number of latently extinct species in a perturbed, but still equilibrating, ecosystem (David Tilman 1994). Species in the extinction debt are those committed to extinction but not yet extinct

How do we pay off extinction debt?

- Capacity to **self-sustain populations**
- Capacity to **adapt to changing environments**. (The environments in which St Helena species evolved no longer exist)
- Capacity to **provide ecosystem function**
- **Connection with people**

Action

- **functional ecosystem** to provide ecological function (ecological restoration) – Peaks team, Millennium Forest
- **functional genome** to provide genetic fitness and evolvability (genetic restoration) – rosemary polycross
- **community engagement** – open days, volunteer groups, dialogue, buy in

MOLECULAR ECOLOGY

Molecular Ecology (2015) **24**, 2610–2618 doi: 10.1111/mec.13139

FROM THE COVER

Genetic rescue of small inbred populations: meta-analysis reveals large and consistent benefits of gene flow

RICHARD FRANKHAM*†

**Department of Biological Sciences, Macquarie University, Sydney, NSW 2109, Australia, †Australian Museum, 6 College St, Sydney, NSW 2010, Australia*

Abstract

Many species have fragmented distribution with small isolated populations suffering inbreeding depression and/or reduced ability to evolve. Without gene flow from another population within the species (genetic rescue), these populations are likely to

Conservation Biology 30.1 (2016): 33-41.

Conservation Biology

Essay

Adaptive introgression as a resource for management and genetic conservation in a changing climate

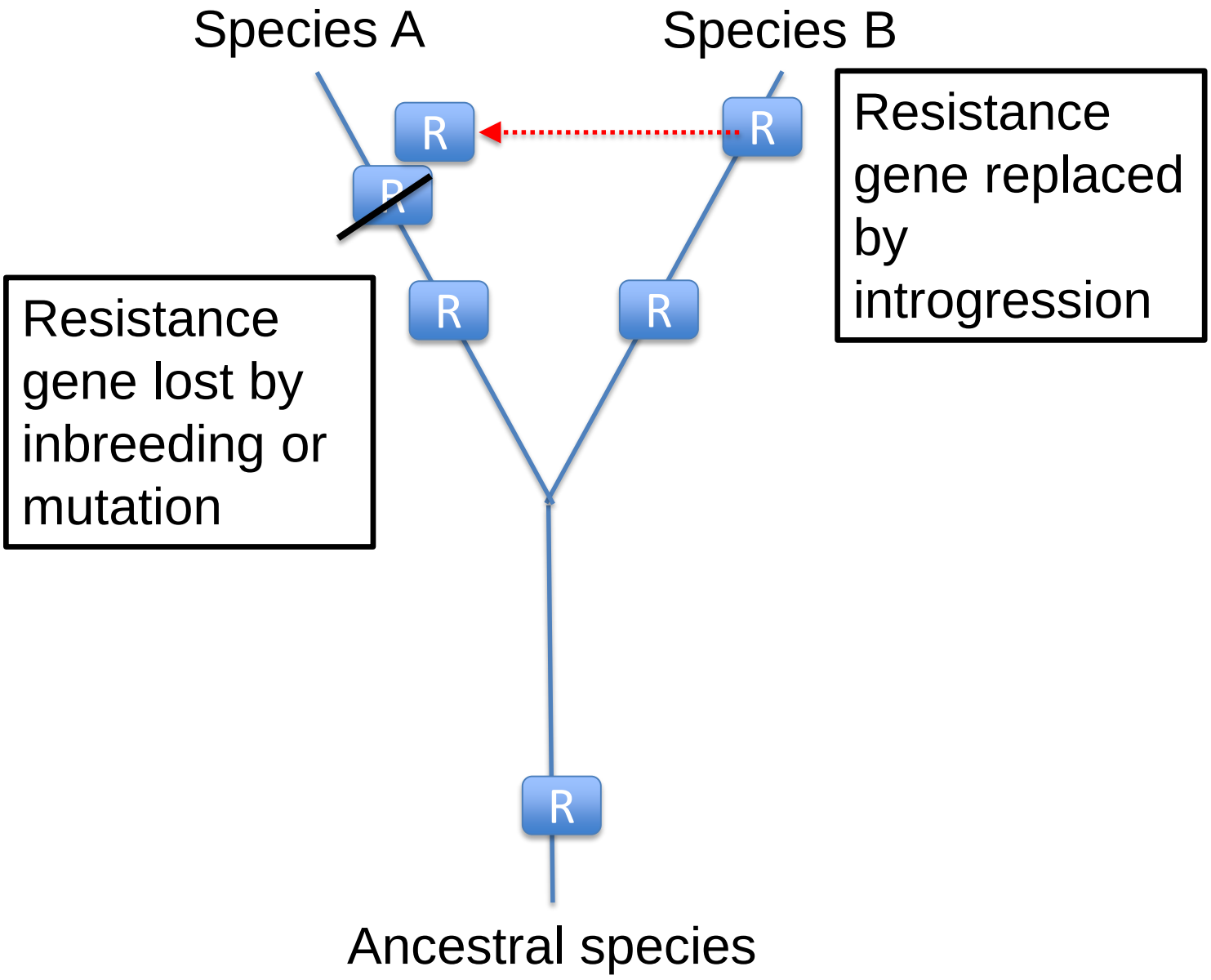
Jill A. Hamilton*† ¶ and Joshua M. Miller‡

*Department of Evolution and Ecology, University of California, Davis, CA, 95616, U.S.A.
†Department of Biological Sciences, North Dakota State University, Fargo, ND, 58102, U.S.A.
‡Department of Biological Sciences, University of Alberta, Edmonton, Alberta, T6G 2E9, Canada

Abstract: *Current rates of climate change require organisms to respond through migration, phenotypic plasticity, or genetic changes via adaptation. We focused on questions regarding species' and populations' ability*

Dedication: the success of conservation in St Helena depends on the skill and determination of St Helenians

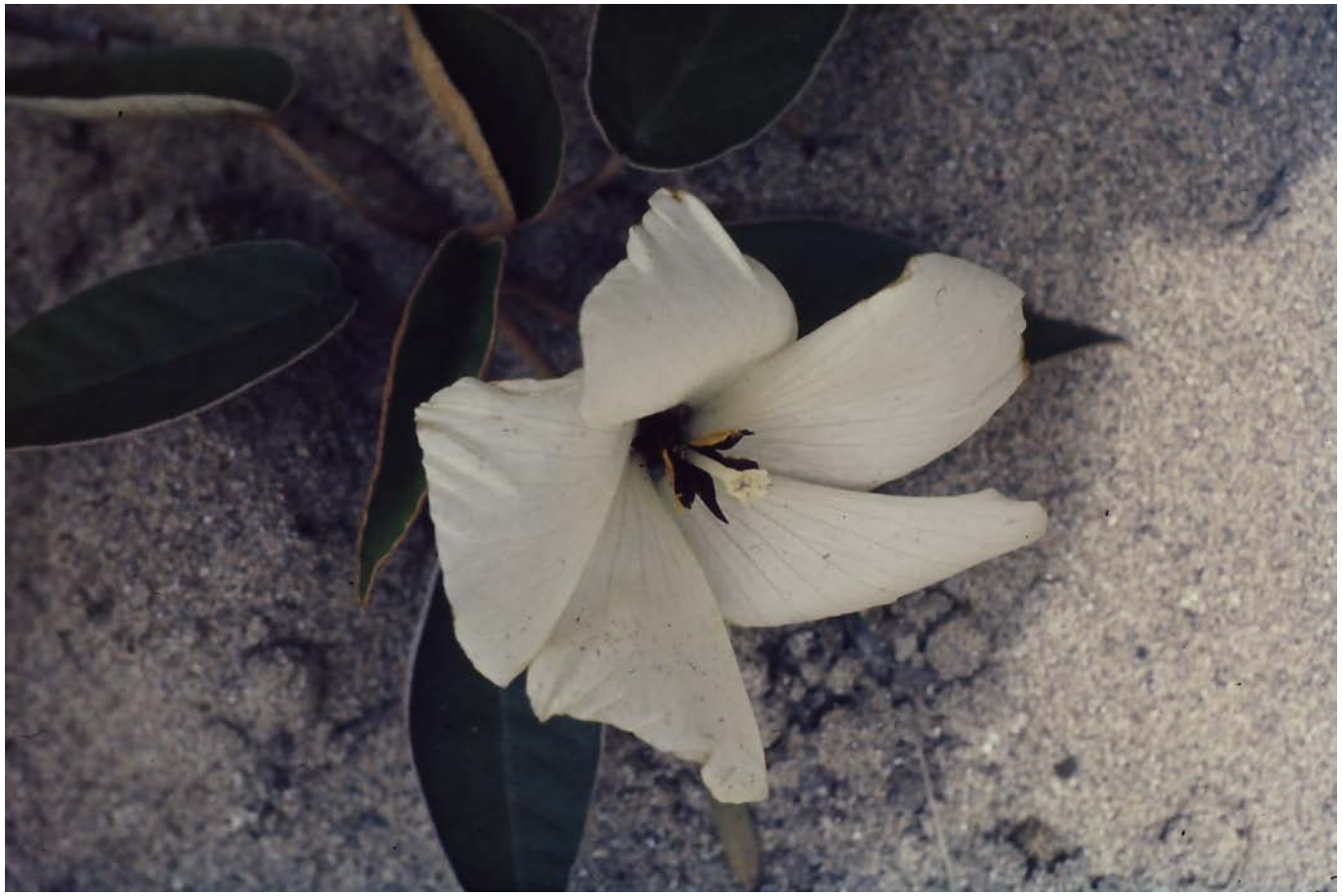
George Benjamin and his team, 1995

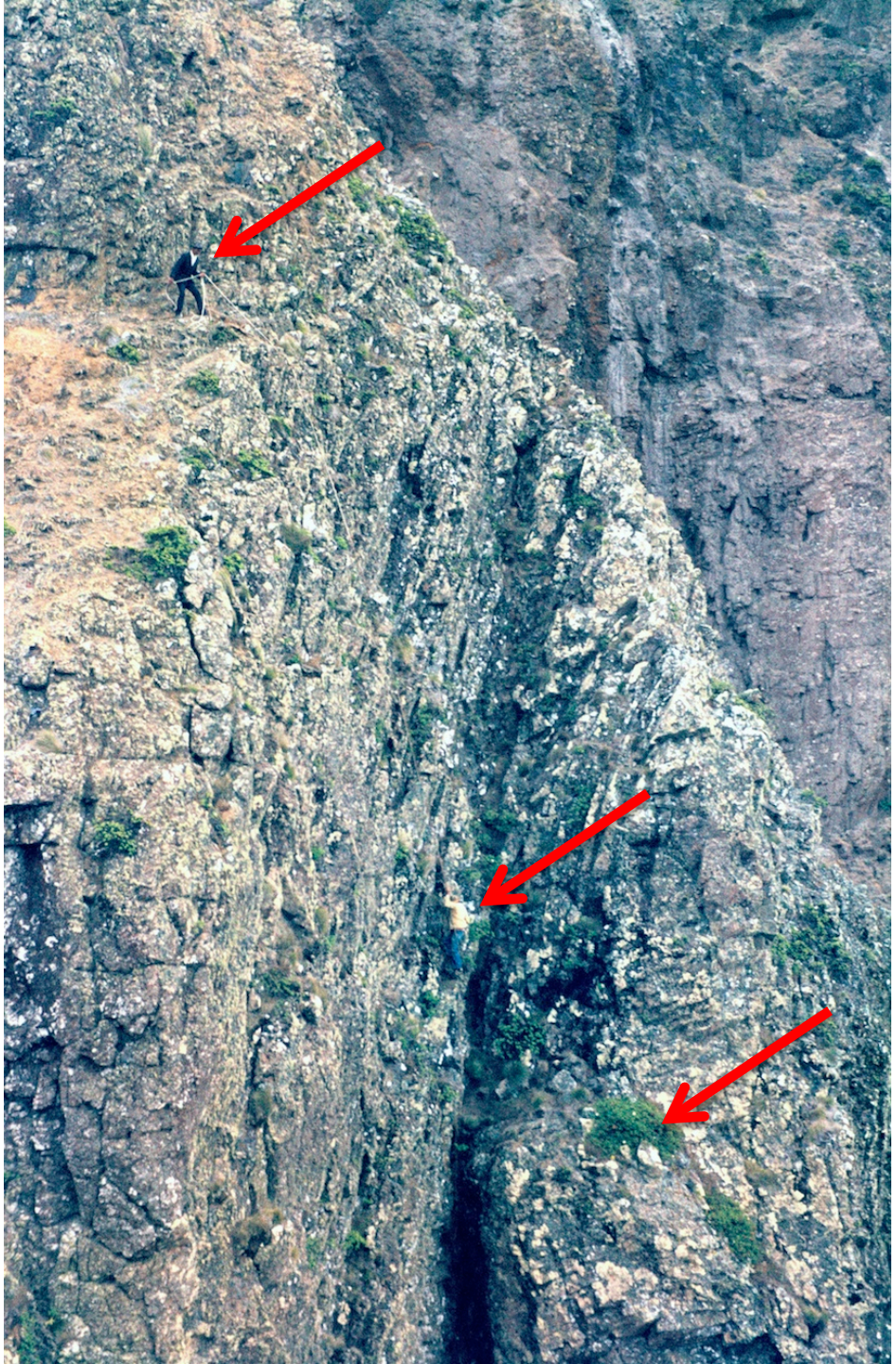

Species A
Species B
R
R
R
R
R
R
Resistance gene replaced by introgression
Resistance gene lost by inbreeding or mutation
Ancestral species

St Helena

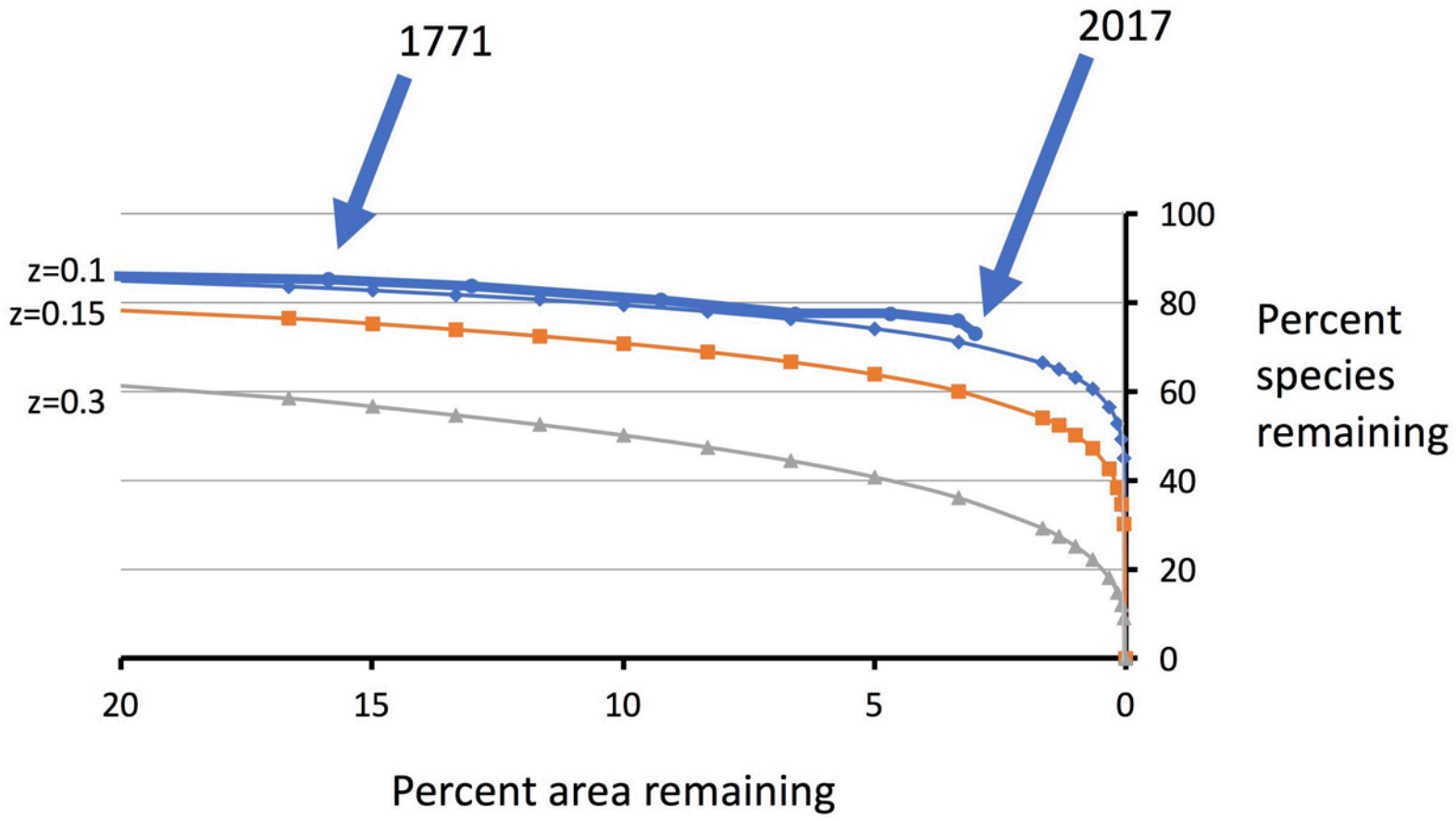
Conservation

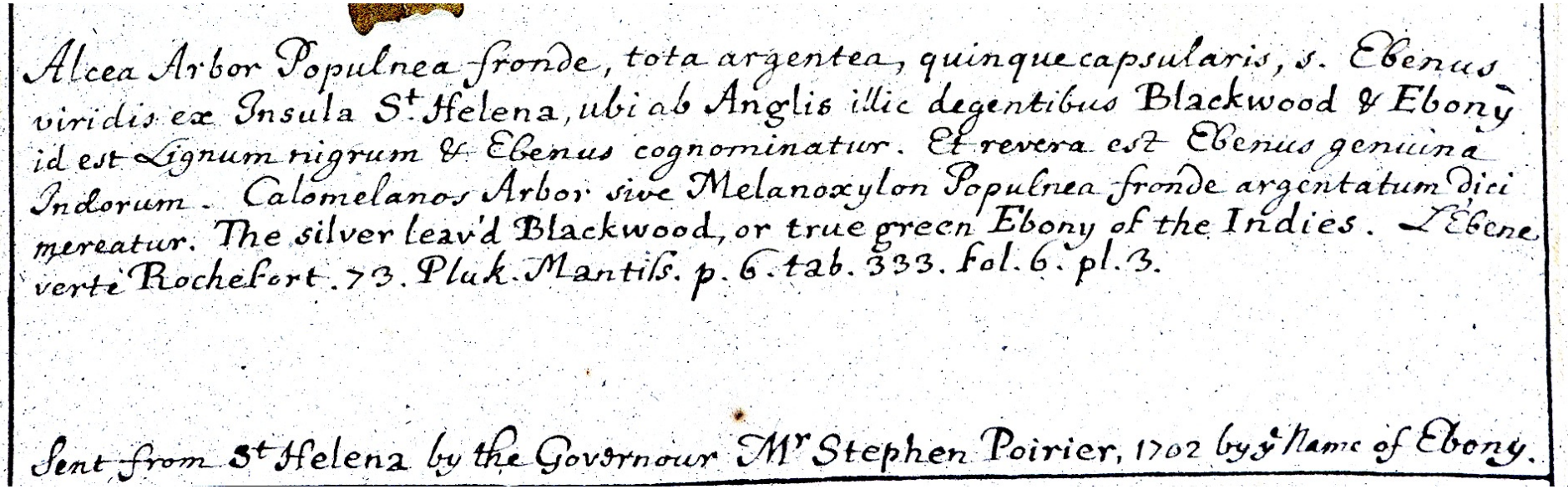
First *T. ebenus* flower seen since c. 1860





Except…


1771
2017
z=0.1
z=0.15
z=0.3
100
80
60
40
20
0
Percent species remaining
20
15
10
5
0
Percent area remaining


Alcea Arbor Populnea fronde, tota argentea, quinque capsularis, s. Ebenus viridis ex Insula S^t Helena, ubi ab Anglis illic degentibus Blackwood & Ebony id est Lignum nigrum & Ebenus cognominatur. Et revera est Ebenus genuina Indorum. Calomelanos Arbor sive Melanoxylon Populnea fronde argentatum dici mereatur. The silver leav'd Blackwood, or true green Ebony of the Indies. L'Ebene verte Rochefort. 73. Pluk. Mantiss. p. 6. tab. 333. fol. 6. pl. 3.

Sent from S^t Helena by the Governour M^r Stephen Poirier, 1702 by y^e Name of Ebony.

Trochetiopsis melanoxylon – described as “tota argentea” - is quite different from extant ebony (*Trochetiopsis ebenus*). Sadly this has never been seen since Banks and Solander collected it in the 18th century.

Ebony (*Trochetiopsis ebenus*) only found in subfossil state

The Extinct Plants of St Helena

Species	Endemic genus	Approximate extinction date in wild	Cultivated
Acalypha rubra	no	1871	No (EX)
Nesiota elliptica	yes (monotypic)	2002	No (EX)
Lachanodes arborea	yes (monotypic)	2012	Yes (EW)
Trochetiopsis erythroxylon	yes	1960	Yes (EW)
Trochetiopsis melanoxylon	yes	1790	No (EX)
Wahlenbergia burchellii	no	1880	No (EX)
Wahlenbergia roxburghii	no	1840	No (EX)
Heliotropium pannifolium	no	1820	No (EX)

DARK EXTINCTION?

Trochetiopsis erythroxylon (St Helena redwood)

Work of Rebecca Cairns-Wicks has restored the maximum fitness but redwood still lacks “ecosystem competence” in the new highly invaded ecosystems that have replaced its natual habitats: it is an “ecological ghost” or “shadow species”

- highly inbred
- reduced in stature
- physiological symptoms
- early mortality

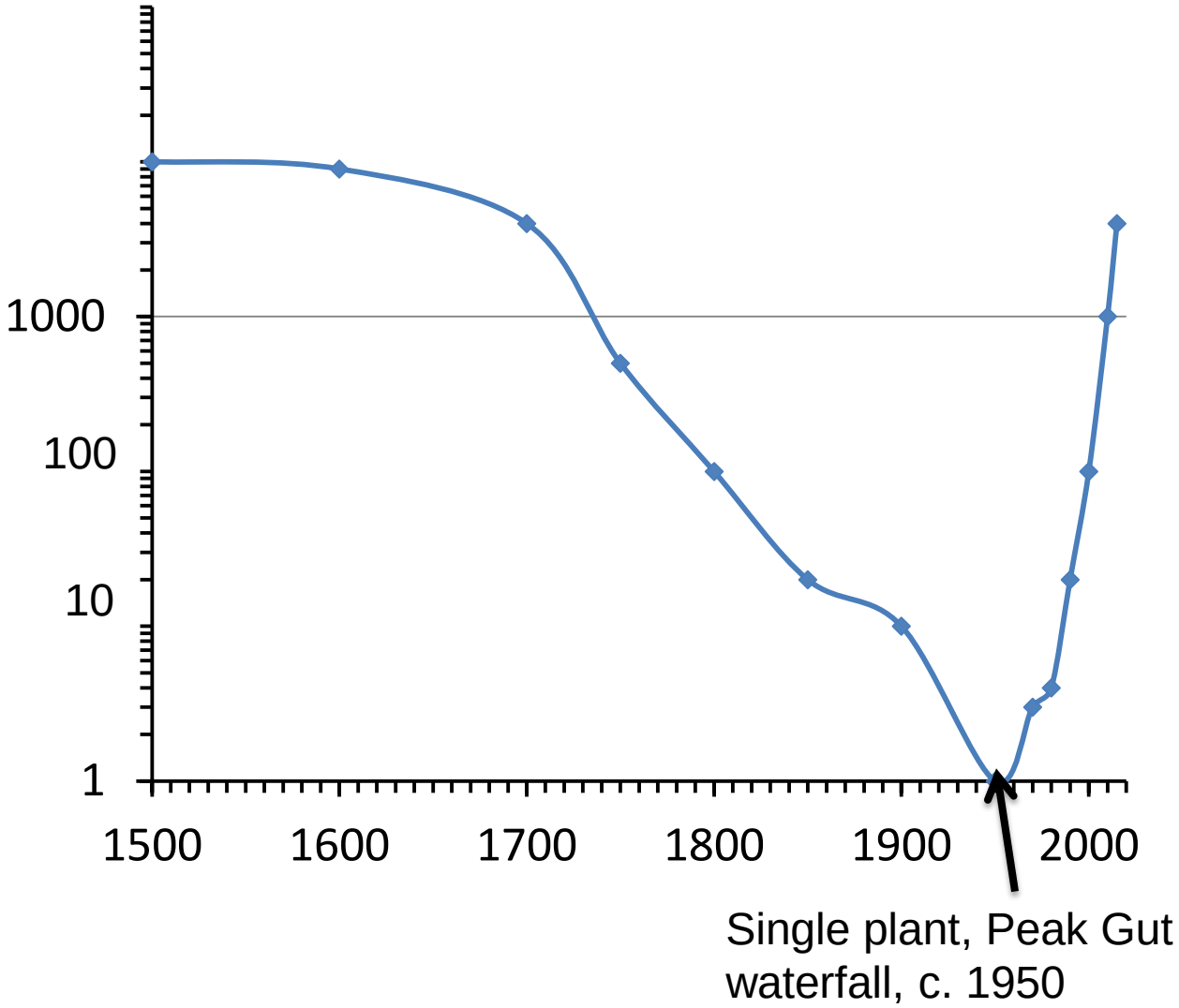
Interspecific hybrid (*Trochetiopsis x benjamini*) shows hybrid vigour– a magnificent, fast growing, long lived, environmentally tolerant plant

Fig. 1. A drawing by W. J. Burchell, dated 27.12.1807, of 'The Great Redwood Tree at Longwood'. In the background are gumwood trees *Commidendron robustum*.

Cronk (1983) The decline of the redwood *Trochetiopsis erythroxylon* on St Helena. **Biological Conservation** 26: 163-174

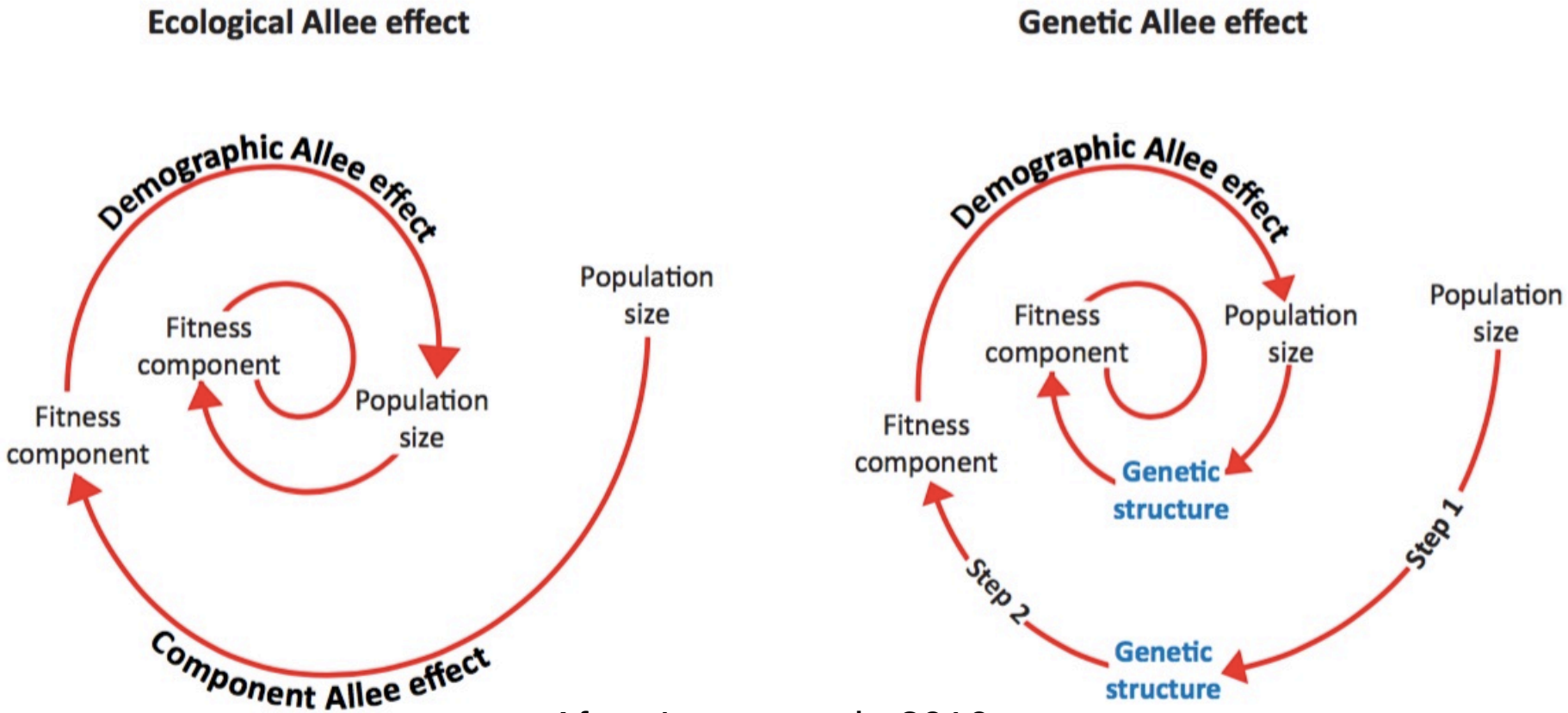
St Helena Redwood (extinct in wild)

Estimated census population 1500-2015

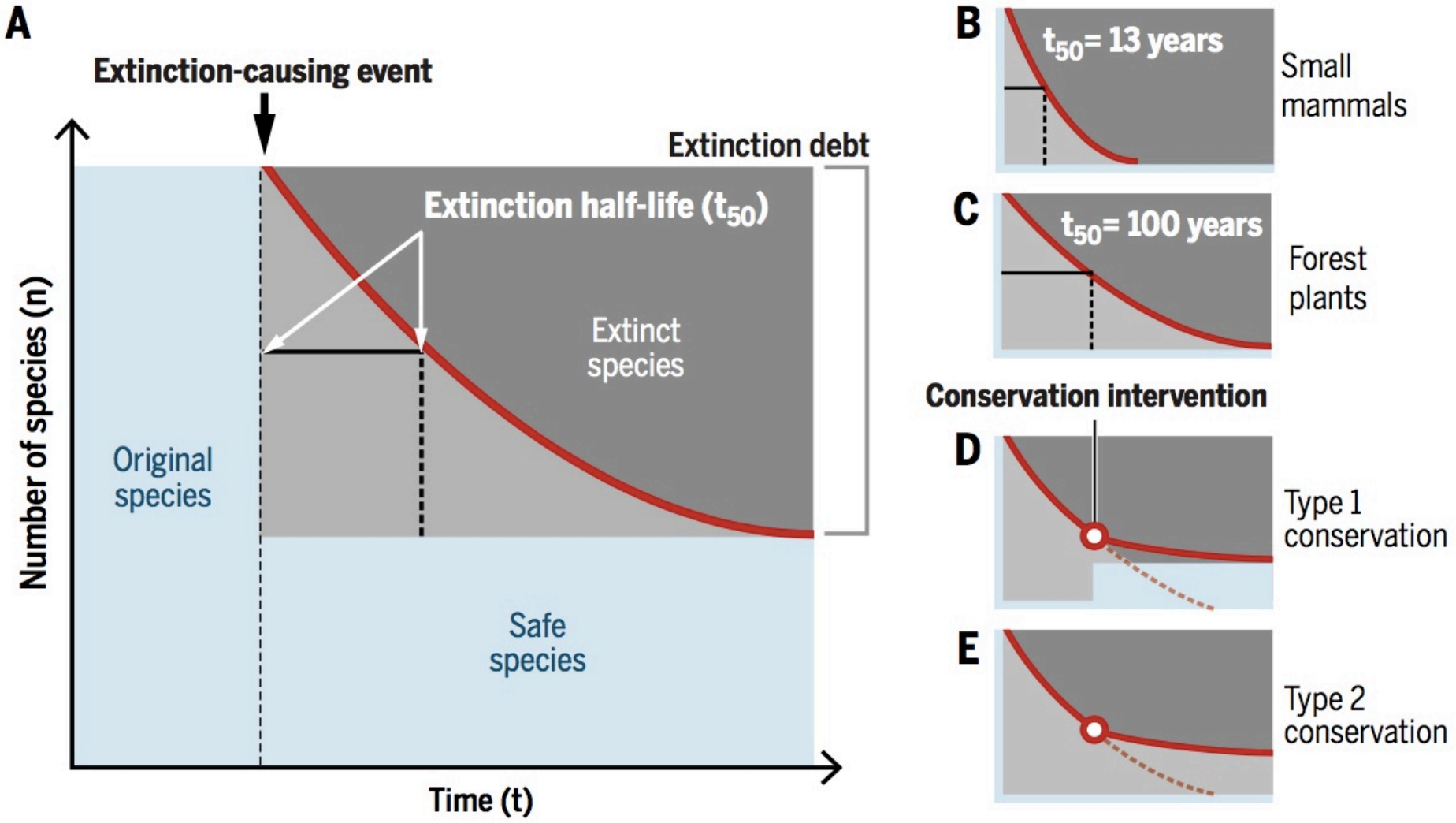


Allee effect

- correlation between population size and mean individual fitness



After: Luque et al., 2016



Cronk, Q. (2016) Plant extinctions take time. Science 353: 446-447.

Table of extinction of selected St Helena plants

Species	Functionally extinct	Census extinction	Cultivated
Acalypha rubra	18th C	19th C	No
Commidendrum rotundifolium	18th C	1 plant in wild	Yes
Nesiota elliptica	19th C	21st C	No
Lachanodes arborea	19th C	21st C	Yes
Trochetipsis erythroxylon	18th C	20th C	Yes
Trochetiopsis melanoxylon	18th C	c. 1790	No
Wahlenbergia linifolia	20th C	c. 20-40 plants in wild	No*
Heliotropium pannifolium	17th C	c. 1820	No

Relaxation time on St Helena

- Plants functionally extinct in 18th - 19th century
- Relaxation time of 100-300 years
- 19th century extinction debt has taken up to >100 years to reach “census extinction”

Genomic selection

- Use whole genome sequencing to maximise genetic gain

Optimal contribution selection

- Optimise mating
- Maximise genetic gain while minimizing co-ancestry
- In “extinct in wild species”, such as *T. erythroxylon*, humans control all regeneration and breeding – therefore feasible to maximise genetic gain of species

Urgent research needs

- co-ordinated genomic sequencing on all “ultra-rare” or “extinct in wild” species, including historical materials
- determine inbreeding, distribution of genetic diversity between individuals, effective population size (N_e)
- genomics-guided genetic restoration, adaptive introgression

ACKNOWLEDGEMENTS

UBC

Kew

ROYAL BOTANIC GARDENS

QUEEN MARY

UNIVERSITY OF LONDON

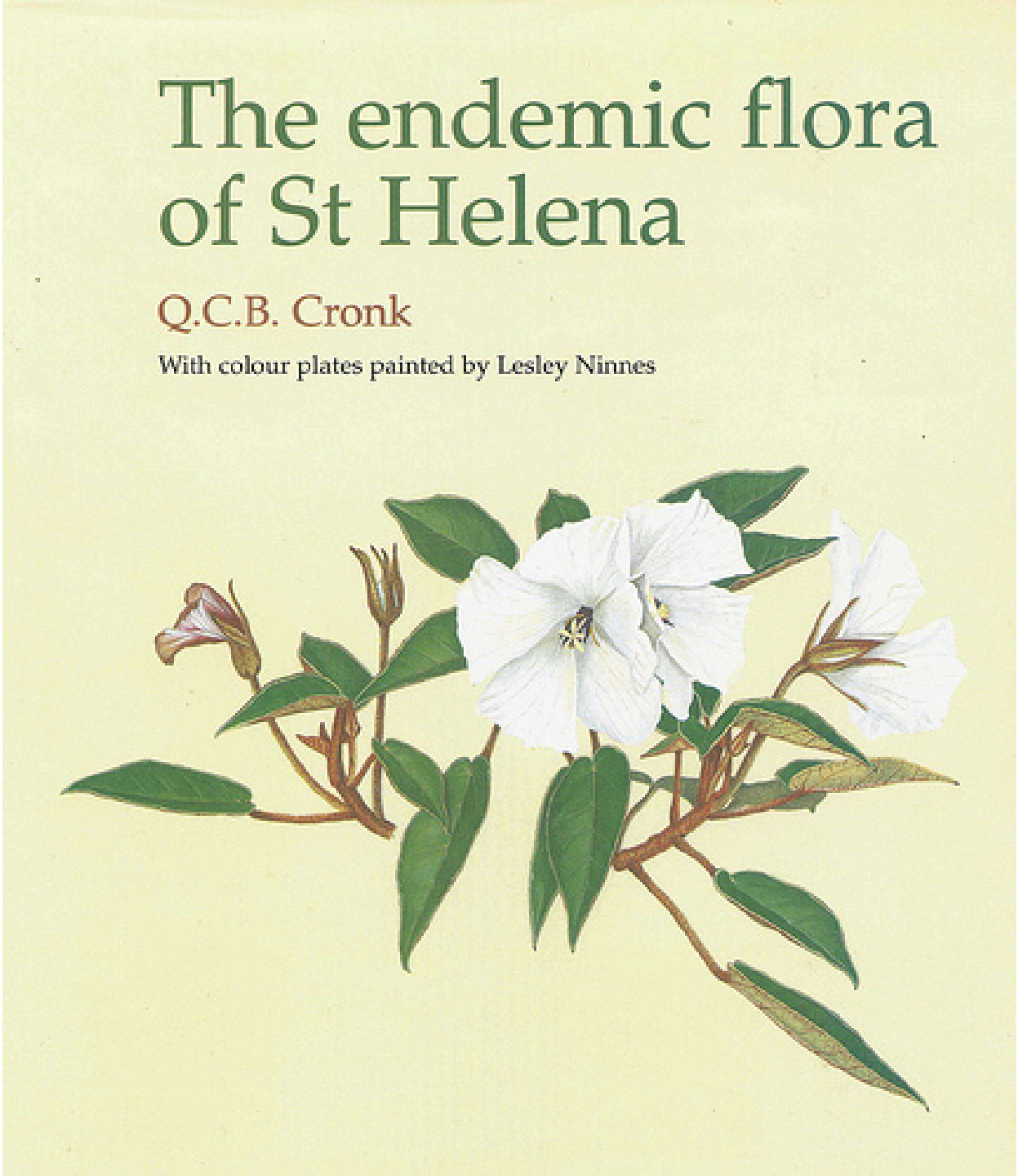
Living dead in botanic gardens

- Half-life of living collections low (c. 4 years)

- *Trochetiopsis erythroxylon* [extinct in wild] has been introduced, lost and re-introduced c. 3 times at Kew; no introduction appears to have lasted more than 30 years. *(Mann, D., Cronk, Q. & Rae, D. (2000) The river of diversity: perspectives on the use and management of living collections in botanic gardens. RBGE.)*

T. ebenus formerly used for inlay work – as in this Boer war era tray

Book – describes both species and illustrates *T. ebenus*



“Dwarf ebony” or “silver-leaved blackwood” (*Trochetiopsis melanoxylon*) - extinct by 1800