





Risk assessment with weed biological control agents

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KNOWLEDGE FOR LIFE

Weed Biological Control

- Weed biological control (still) largely relies on importing non-native natural enemies to reduce population densities of invasive alien plant species (classical biological control, CBC)

- The use of native biocontrol agents is sometimes used in the bioherbicide approach, but uncommon in Europe

- Biological control of native weeds almost non-existent
  > IWM lacks biocontrol component

Weed CBC - a short history

- First deliberate attempt to control an exotic weed using insects imported from its area of origin:
- 1902: several insects released against *Lantana camara* in Hawaii
- 1912: Opuntia species in Australia
- 1914: Opuntia species in South Africa
- In 1926: release of the moth *Cactoblastis cactorum* resulted in nearly complete elimination of Opuntia stricta
- Steady increase of BCW from then onwards

History of pre-release studies

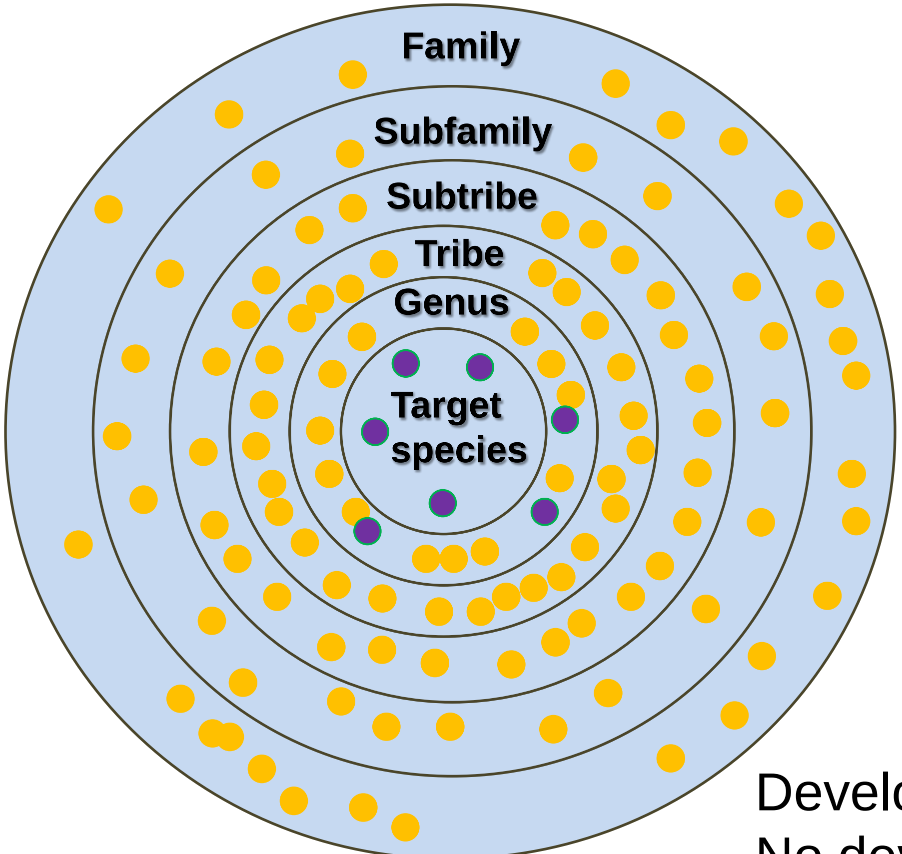
- 1900: Host range studies in Hawaii: observations on the realized host range in area of origin; first “feeding tests”
- 1920s: this foundational methodology was followed and extended during the Australian program against *Opuntia* spp.
- Up until 1950s: mainly no-choice starvation tests with crop species
- From 1960s: various other test designs developed (e.g. multiple-choice, open-field tests)
- From 1990s: experimental tests/modelling approach to predict impact on target weed

Test plant species

- Until 1960s: mostly plants of economic importance
- 1968: Harris and Zwölfer proposed to concentrate on plants closely related to the target weed

  > Determine host range of insect rather than safety of unrelated crop species
- 1974: centrifugal phylogenetic method (Wapshere)

Selection of test plants: centrifugal phylogenetic method (Wapshere 1974)



Assumption:

The host-range of specialist herbivores is restricted to plants belonging to a specific phylogenetic clade, e.g. to a plant genus or to a subtribe

Development: host
No development: non-host

Assessment of host-specificity

<u>General approach:</u>

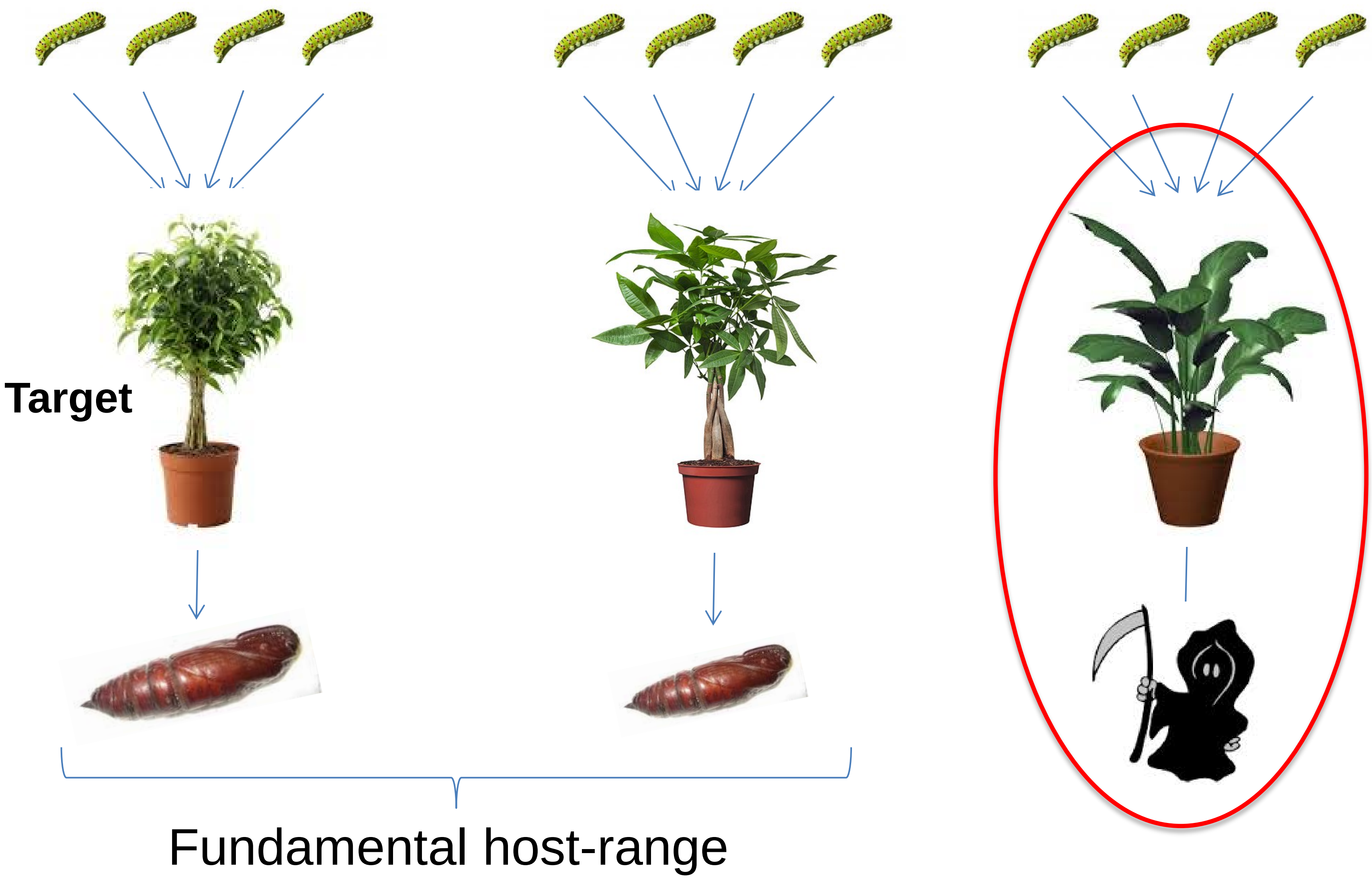
- Select some 50-100 test plant species
- Study the biology of the herbivore, e.g. determine stage that finally selects host (e.g. ovipositing female)
- Conduct feeding and oviposition tests, e.g.:

5-10 years

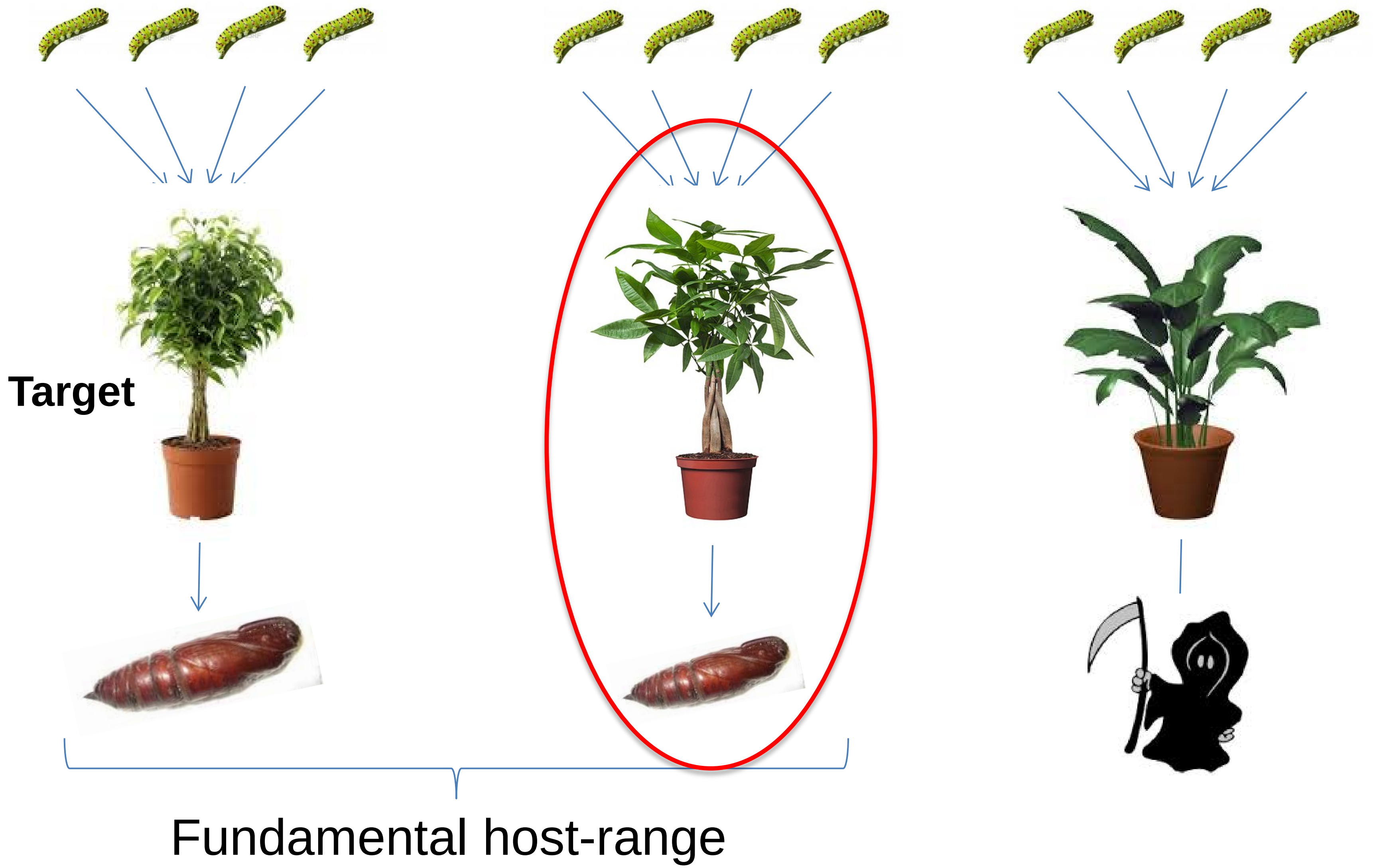
1. Test all plants under restricted (usually no-choice) conditions
2. Select plants attacked under 1. and test these under less restricted conditions
3. Select plants attacked under 2. and test these under as natural conditions as possible

- Make predictions on host-range of the ecological biological control candidate in the new range

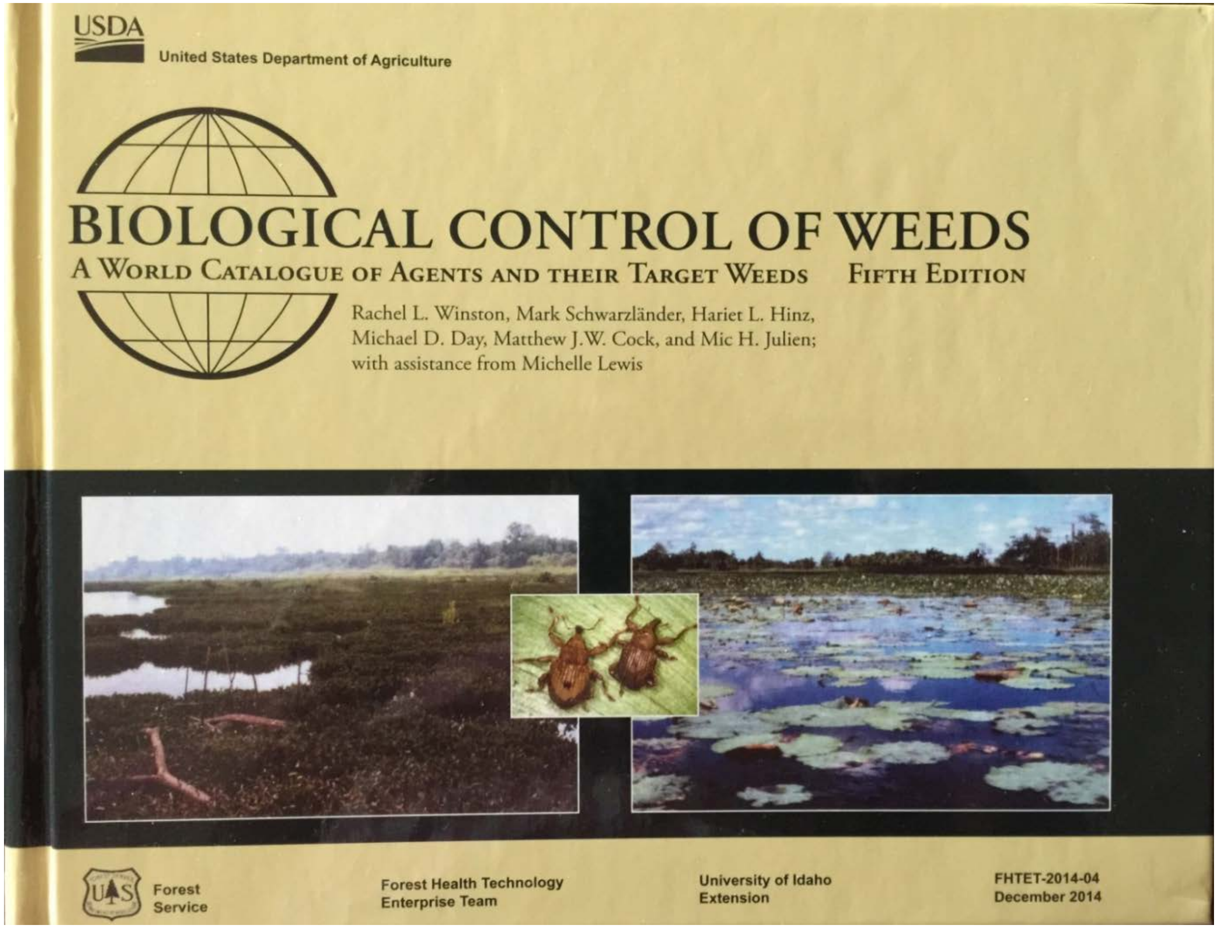
Assessing the fundamental host-range



Assessing the realized host-range



Biological Control of Weeds
A World Catalogue of Agents and their Target Weeds
5th Edition



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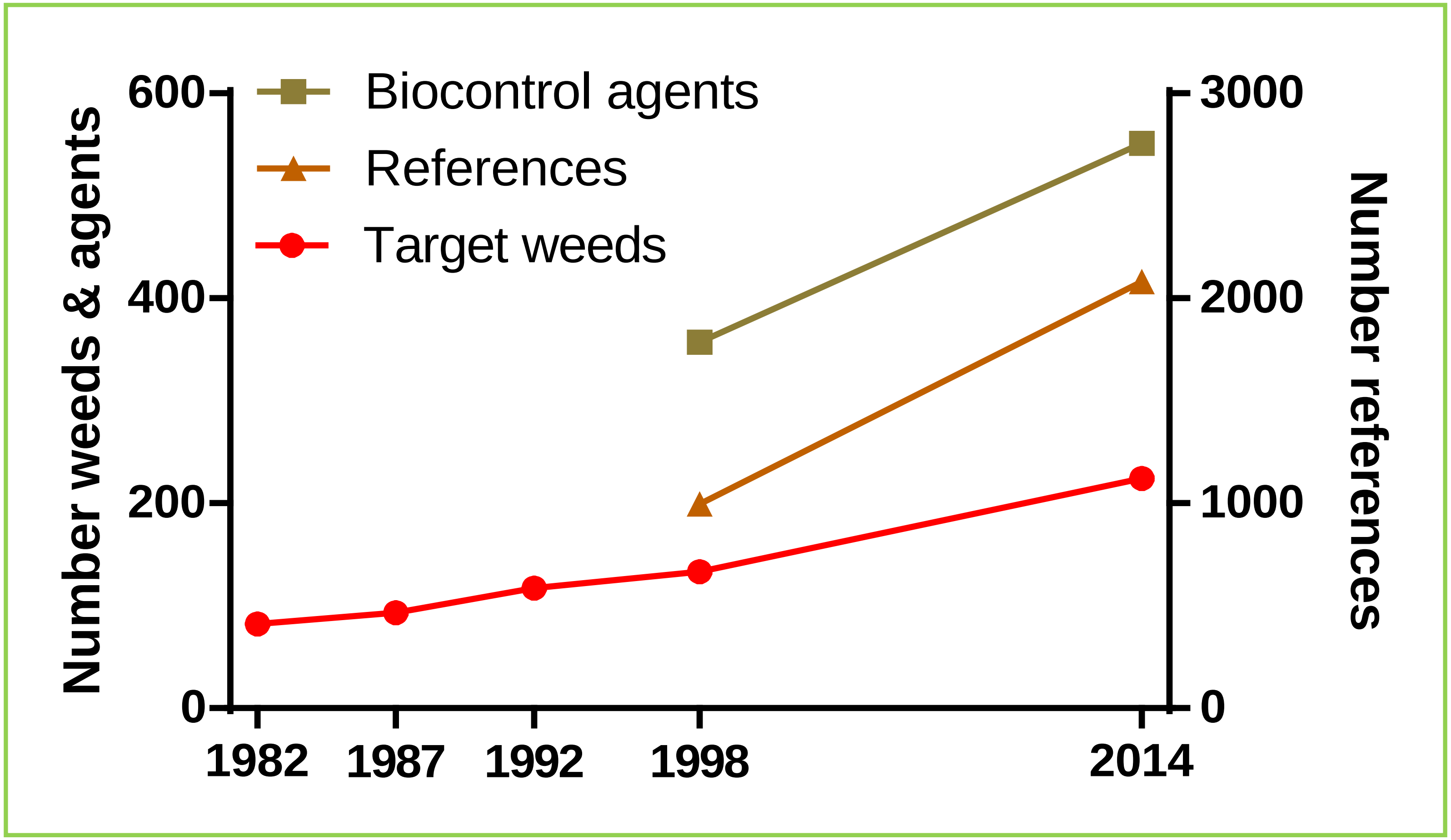
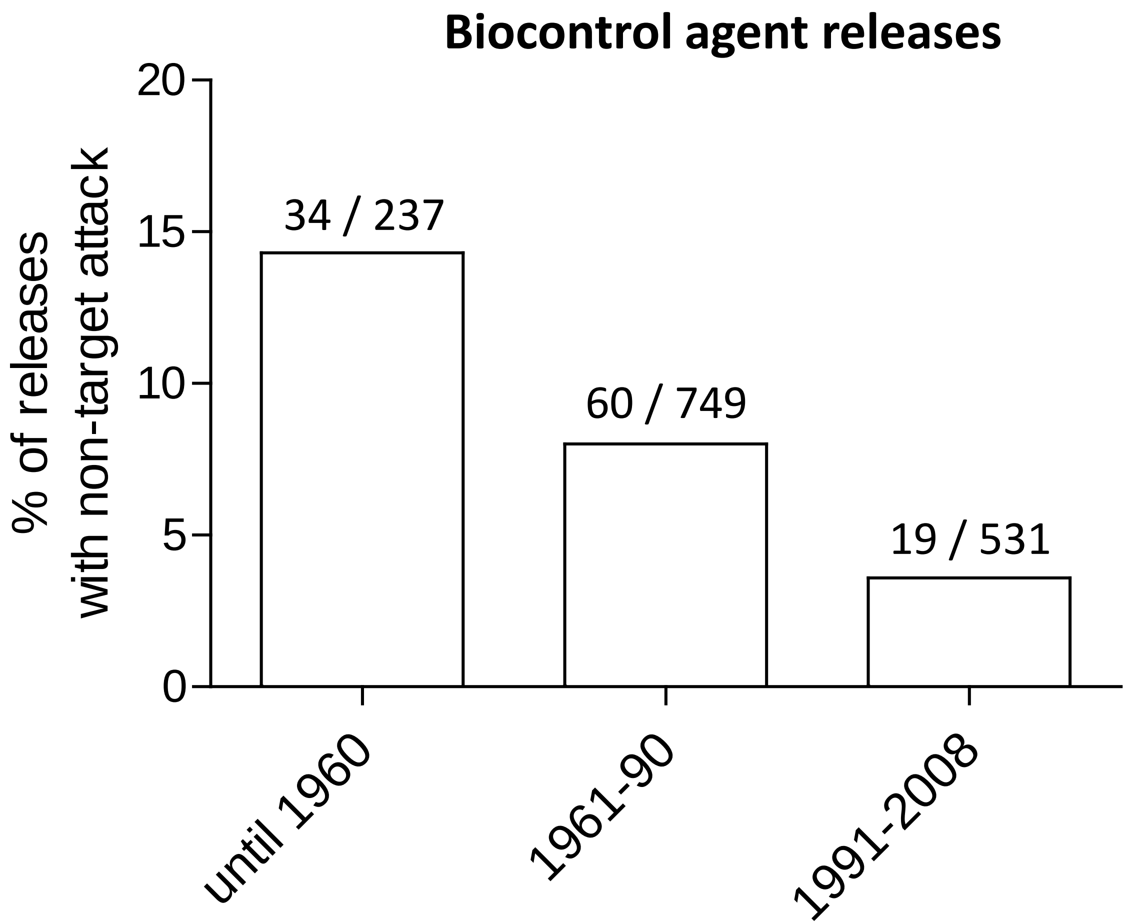


1) Non-target attack (NTA)

Proportion of biocontrol releases causing NTA has been declining in recent decades



- Total of **113** biocontrol agent releases with NTA (N = 1517)
- Proportion of releases with NTA: **7.4%**
- **47%** attack 1-2, **33%** attack 3-6, **20%** attack ≥7 non-target plant species

(Hinz et al., unpubl.)

NTA predictability

About half of the releases with NTA were predicted or predictable based on pre-release host-specificity data

- In **55** of the **59** 'not predicted' cases (93%), the non-target plant species had not been tested pre-release!
- Only **4** cases that were 'not predicted', where non-target plant species **had** been tested pre-release:
  - *Zygogramma bicolorata* on *Helianthus annuus*
  - *Bruchidius villosus* on *Chamaecytisus palmensis*
  - *Cydia succedana* on 3 exotic plant species
  - *Trichilogaster acaciaelongifoliae* on the exotic but economically used *Acacia melanoxylon*

→

(Hinz et al., unpubl.)

40 years of host-specificity testing – lessons learned

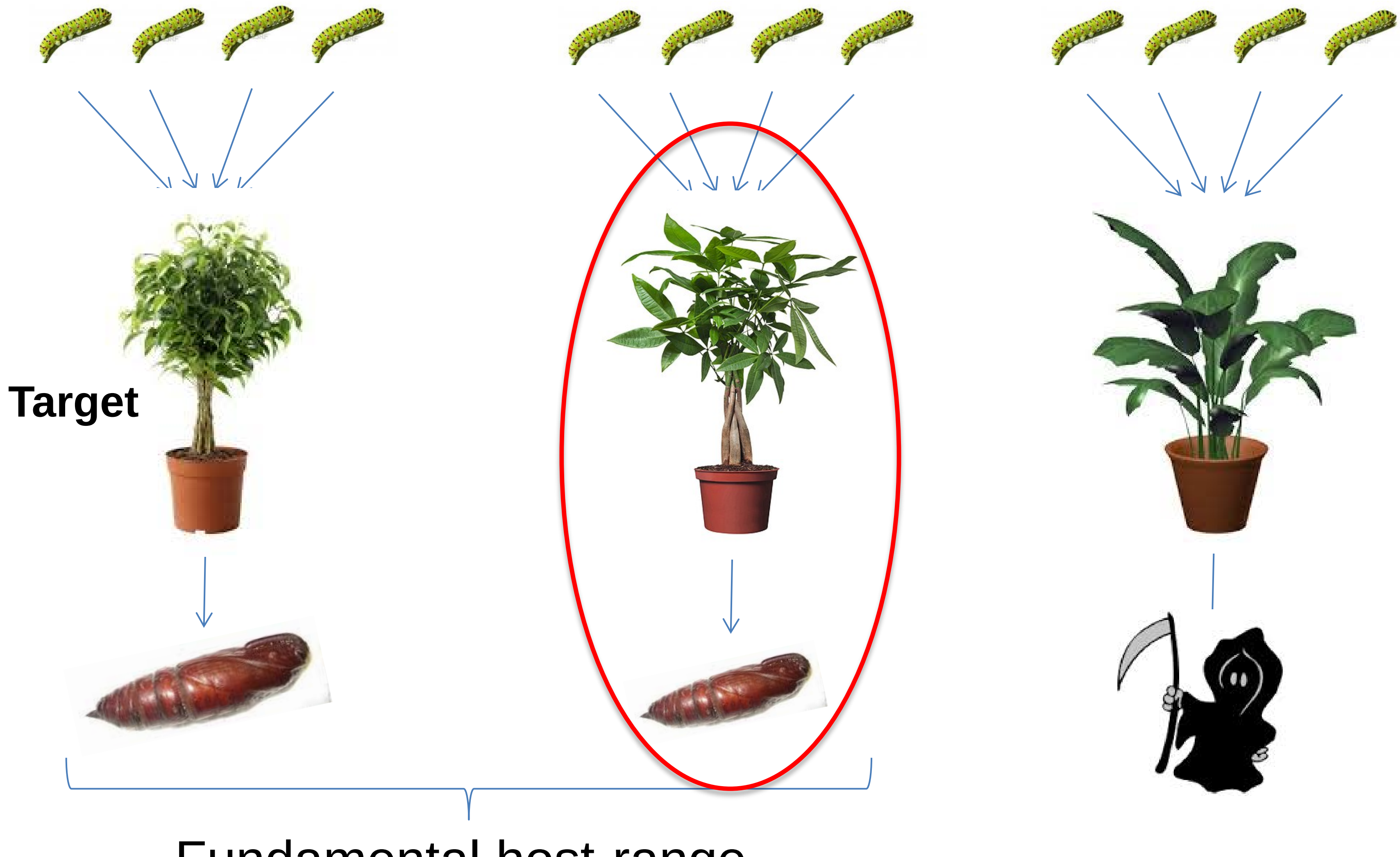
- Fundamental host-range relatively easy to assess

- Reported non-target effects almost always on plant species of the same phylogenetic clade as known host-plants (Pemberton 2001, Oecologia)

  > No evidence for change in fundamental host-range

- Level of attack of suitable non-target plants after release into the new range is more difficult to predict (realized host-range)

Assessing the realized host-range



(Recent) developments in weed biological control

- Make use of natural genetic variation occurring in the native range
- Assess the prospects of deliberate intra-specific hybridization using individuals from well-studied populations
- Assess the evolvability of traits of biocontrol agents

Making use of genetic variation in the native range

- In the past: collection and release of individuals from different parts of the native range > goal: founding population with high genetic variation

- From the 1980s: release of individuals from a single population that was tested for host specificity and impact

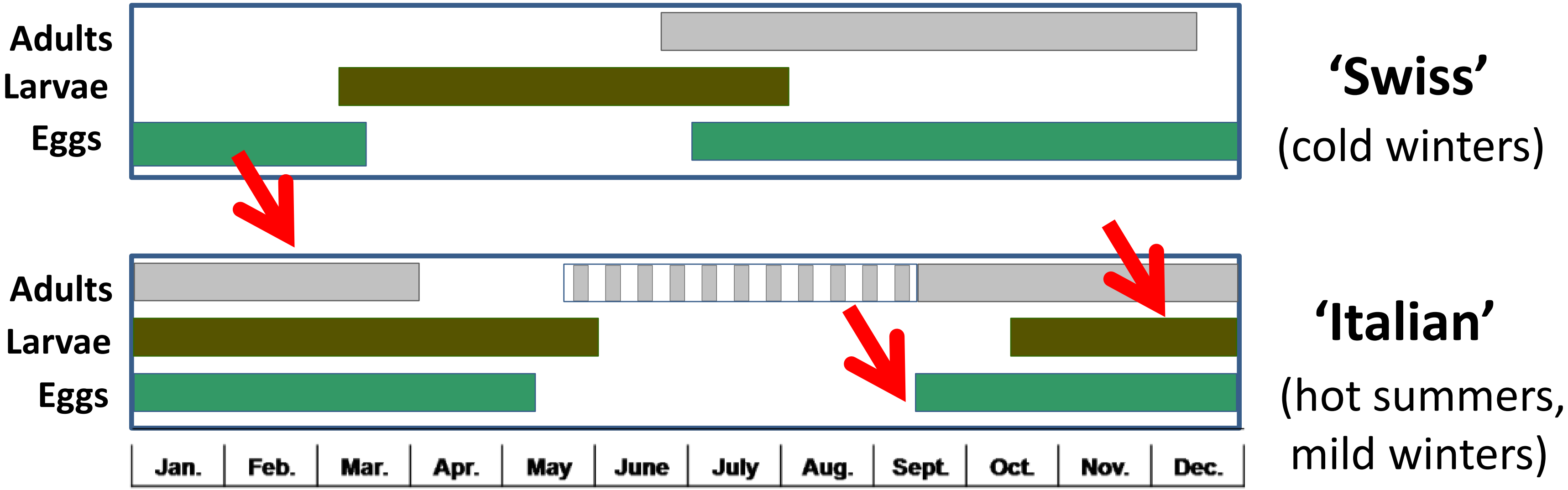
- Sometimes release of individuals from ≥ 2 tested populations of the same species with distinct phenotypic traits

Biological control of tansy ragwort, *Jacobaea vulgaris*

- Invasive in different regions of the world
- First records in North America in the late 19th century
- Highly toxic
- Invasive in rangelands in the USA and Canada
- Successful biological control, mainly due to the flea beetle *Longitarsus jacobaeae*

Longitarsus jacobaeae

- Univoltine
- Specialist on tansy ragwort
- Adults feed on leaves, larvae inside the roots
- Different 'biotypes' in Europe, morphologically identical



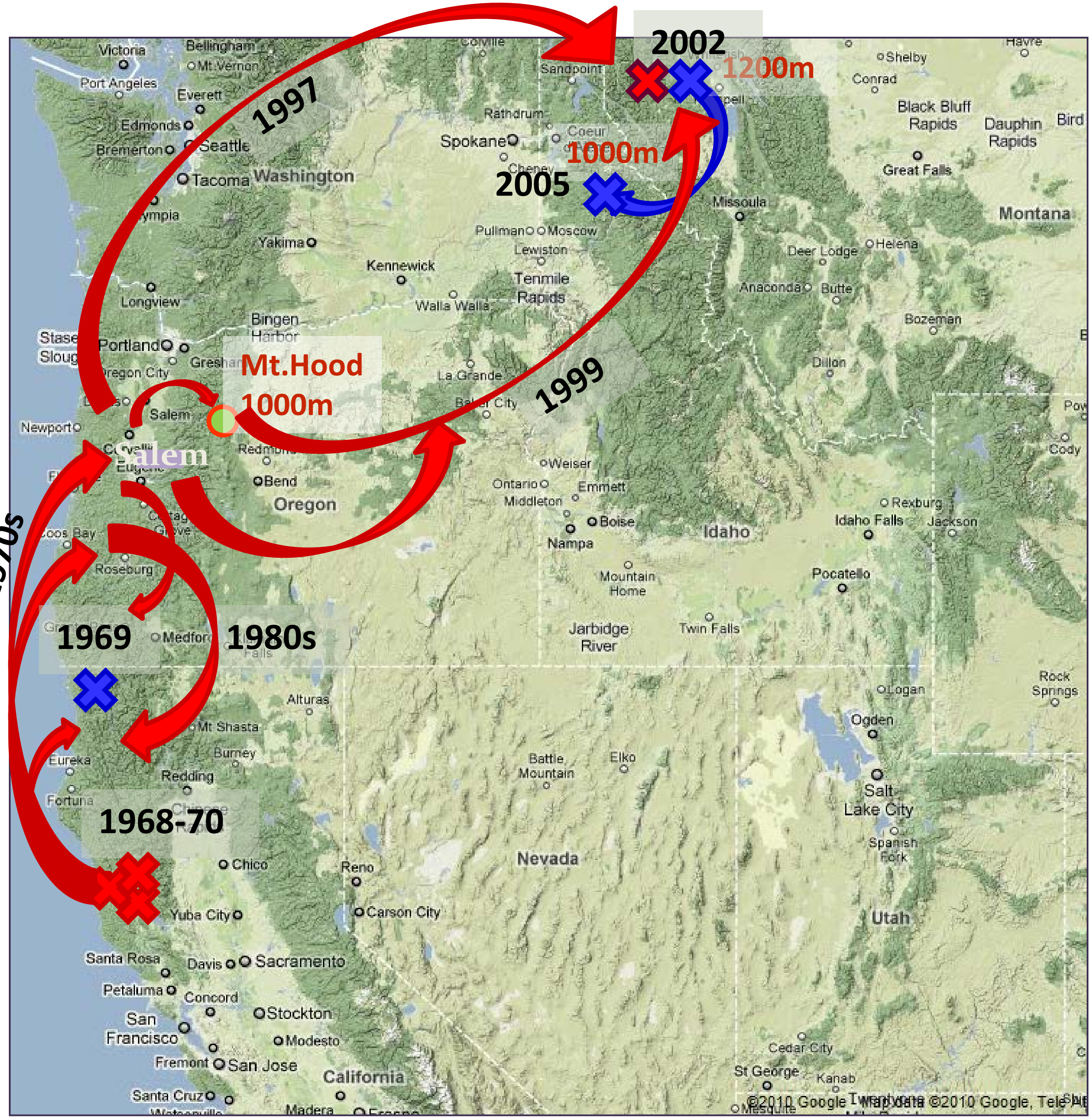
Release history of *L. jacobaea*

Italian biotype release site

Swiss biotype release site

Redistribution path of Italian biotype

Redistribution path of Swiss biotype



Intraspecific hybridization

Goal:

- To increase establishment success
- To increase population build-up, at least during the early phase of colonization

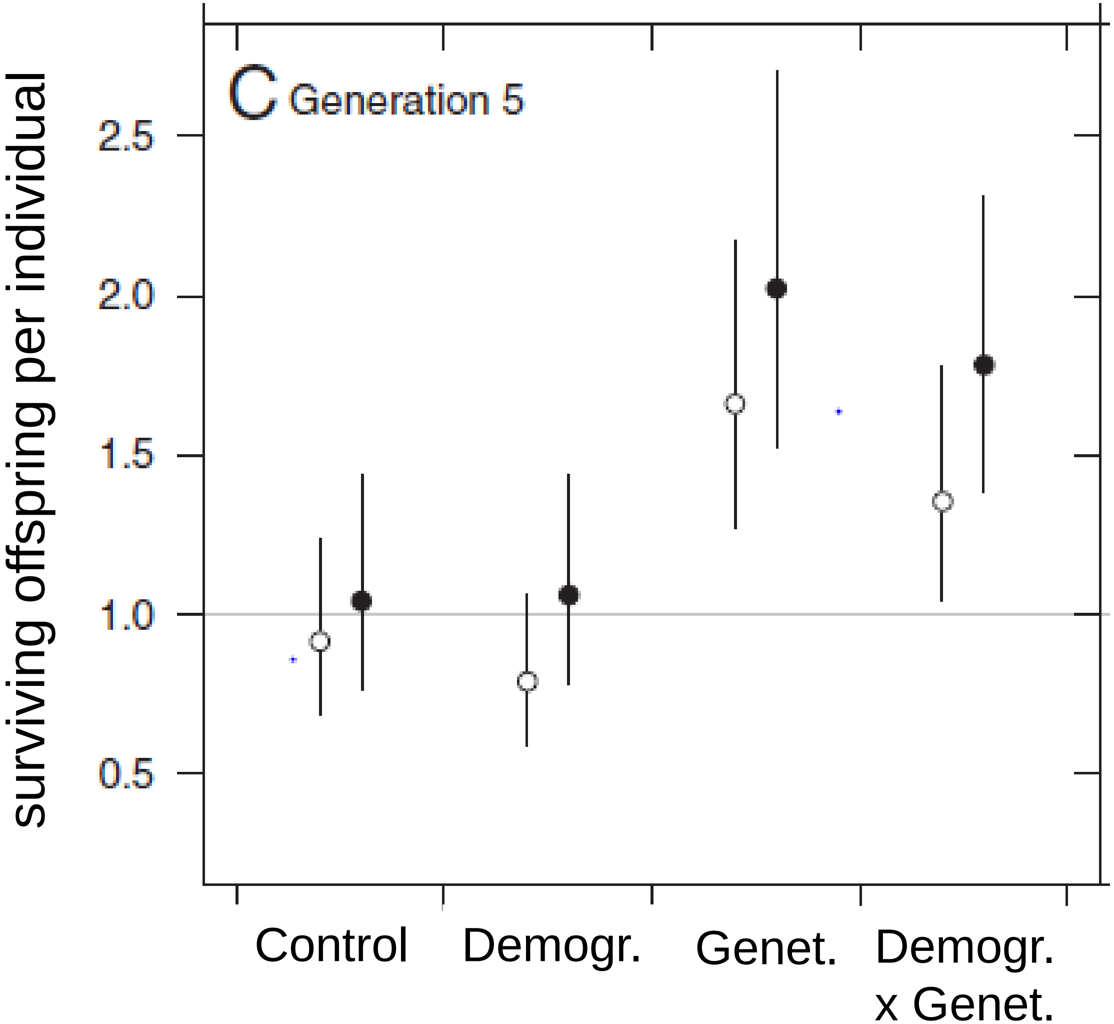
By:

- Increasing genetic variation
- Hybrid vigour
- phenotypic novelty, e.g. generating phenoyptes with transgressive characters

Risks:

- Outbreeding depression
- Change in traits related to host specificity

Proof of concept



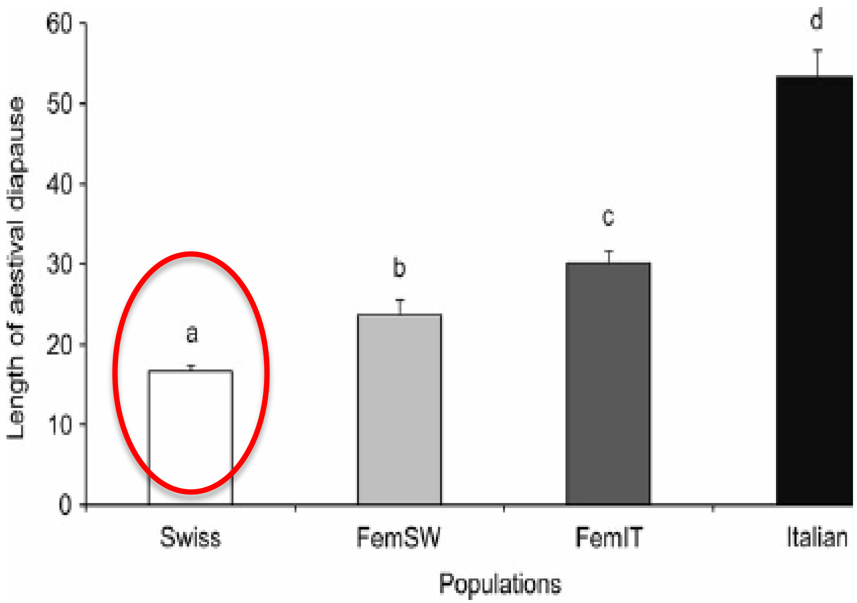
Model organism:
Tribolium castaneum

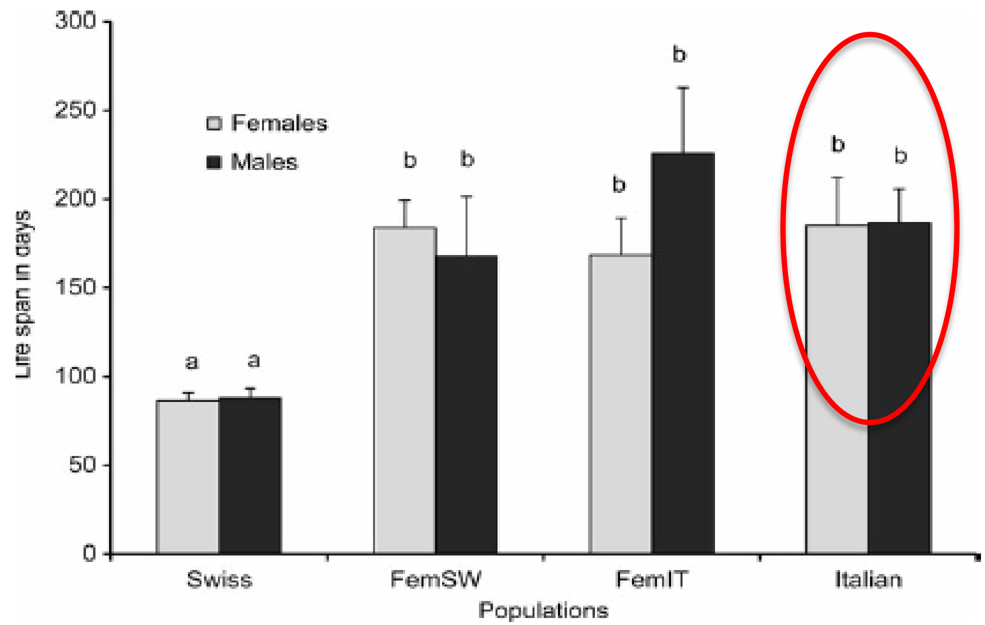
○ = small populations

● = large populations

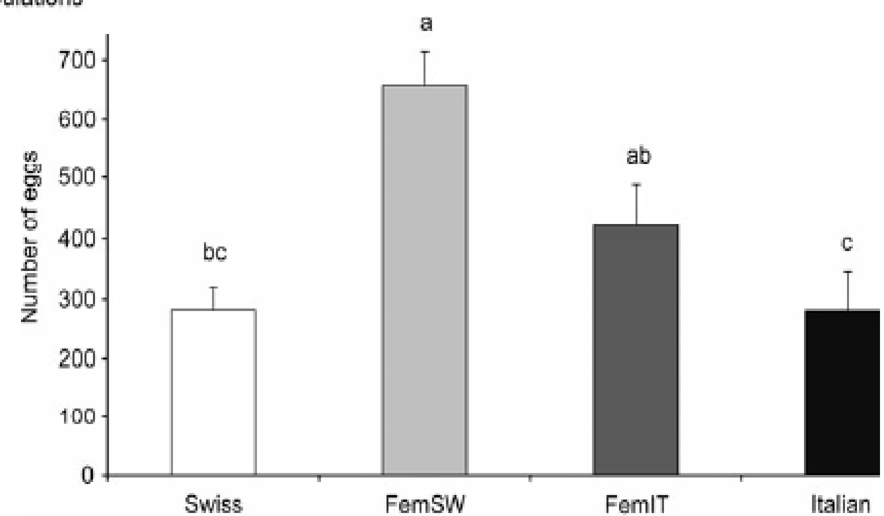
(Hufbauer et al. PNAS 2015)

Longitarsus jacobaeae –
intraspecific hybridization



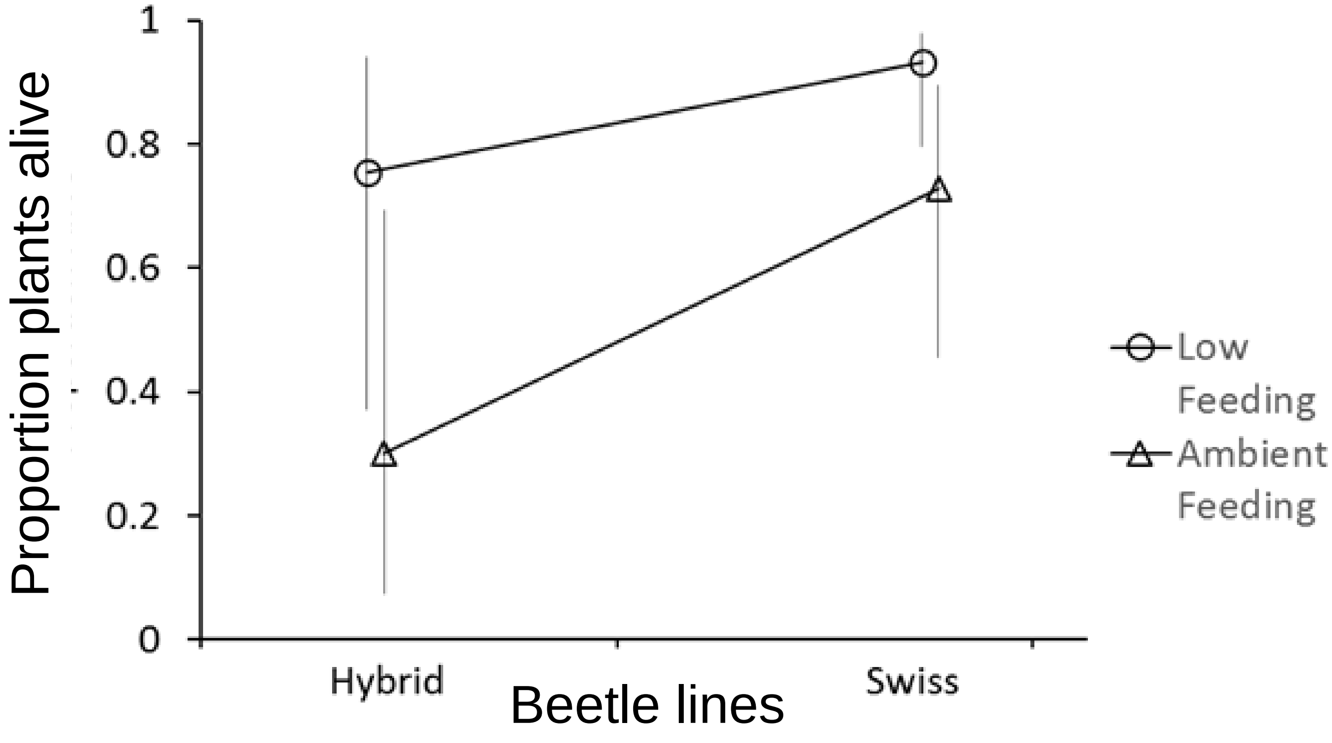


F2 hybrids



(Szucs et al., Evol. Appl. 2012a)

Intraspecific hybridization – impact on target weed



At field sites with hybrid beetles:

- Plant survival 50% reduced (Ancestry x Feeding $P = 0.02$)
- Larval densities 50% higher (Ancestry $P < 0.001$)

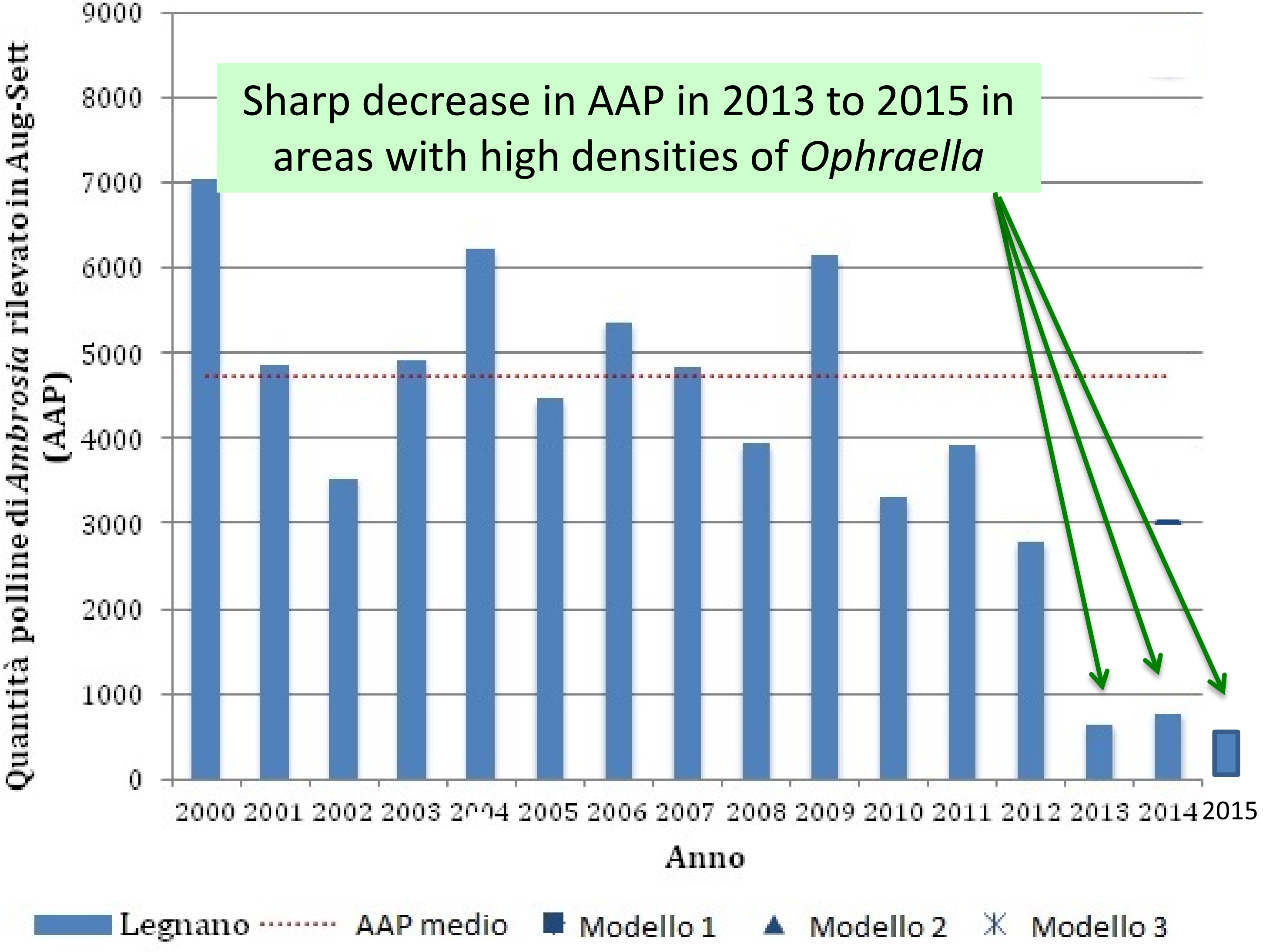
Assessing evolvability of weed biological control agents

- Pre-release studies desribe status quo
- New selection pressures in the introduced range
- Abiotic vs *biotic* selection pressures

Ophraella communa – a biocontrol agent against *Ambrosia artemisiifolia* in Europe

Ophraella has 3-4 generations in N-Italy and thus builds up high population densities

A. artemisiifolia pollen in Milano area



Bonini et al.
2015 Aerobiol

Assessing risks of non-target attack on sunflower

Australia did not release *O. communa* because larvae can complete development on sunflower under lab conditions; China uses this beetle as biocontrol agent and reports no/very little damage of sunflower

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... and you for your attention