Using Natural Enemies against Exotic Weeds
An update on progress in the UK

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Country Director - UK

BCPC 2019

KNOWLEDGE FOR LIFE

CABI

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    - Floating Pennywort
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About CABI

- Established in **1910** ‘Commonwealth Agricultural Bureau’ now operates as simply ‘CABI’
- CABI is a **not-for-profit** science-based development and information organization
- Owned by **49** member countries
- CABI specialises in **agriculture** and the **environment**
- Activities and expertise include:
  - Scientific publishing
  - Research and project delivery
  - Consultancy and science communication

Invasive Species Management - UK

Staff 2018

- 13 scientists (3 registered PhD)
- 1 technical support (+1 casual)
- 1 emeritus fellow
- Students (MSc, internships etc)

Expertise in scientific fields of

- Entomology
- Plant Pathology/Mycology
- Ecology/Invasion Ecology
- Modelling/Data Analytics
- Socio-economy

Facilities

- 2 Defra licenced quarantine facilities
- Propagation greenhouse and polytunnels

Biocontrol projects

Invaders highlighted at Chelsea flower show

CBC

- Japanese knotweed (*F. japonica*) – UK, BC Canada
- Himalayan Balsam (*I. glandulifera*) – UK, BC Canada
- Australian swamp stonecrop (*C. helmsii*) – UK
- Floating pennywort (*H. ranunculoides*) - UK
- Yellow Himalayan raspberry/ Mysore raspberry (*R. ellipticus, R. niveus*) – US (Hawaii), Ecuador
- Flowering rush (*Butomus umbellatus*) - Northern US
- Kahili ginger (*H. gardnerianum*) - US (Hawaii), NZ
- Bellyache bush (*J. gossypiifolia*), Cat's claw creeper (*D. unguis-cati*)
- Lantana (*Lantana camara*) – Australia, NZ, SA
- Devil's claw (*C. madagascariensis*) - Brazil
- Old man's beard (*C. vitalba*), tutsan (*H. androsaemum*), common horsetail (*E. arvense*) - NZ
- European earwig (*F. auricularia*) - UKOT (Falklands)

Mycoherbicide/Augmentative

- Japanese knotweed (*F. japonica*) - UK, BC Canada
- Butterfly bush (*B. davidii*) - UK
- Water fern (*A. filiculoides*) - UK


DID YOU KNOW THAT…
100 million
Almost 70% of
women in Africa spend
hours
20 billion
weeding
per annum
70%
of
children miss school to help
with
weeding
on
family farms

What makes an invader

- There are many things that researchers look at to find the holy grail of predictive traits
- Fecundity, dispersal mechanisms, growth rate, generalists, allelopathy, plastic phenotypes etc
- However, given the massive range of INNS around the world this could be a fool's errand – always exceptions

- The best predictor is if it is a recidivist

- There is one factor that is always true though……..

Unfair Advantage

- They arrived in their new region without the **natural enemies** that keep them in check in their native range.
- Those native species which do attack them do not cause enough damage
- **Some** of the many insects and diseases in the area of origin may be safely released as classical agents

2 Categories of Control

Inundative - a.k.a the “Mycoherbicide Approach” using native pathogens for repeated application

Classical - Using Co-evolved (highly specific) NEs from the area of origin of the plant to provide self-sustaining control after a single release.

The Inundative Approach

- Used in high value horticulture, agriculture, golf courses to reduce chemical input/ combat resistance
- Or where conflicts of interest would exclude classical natural control

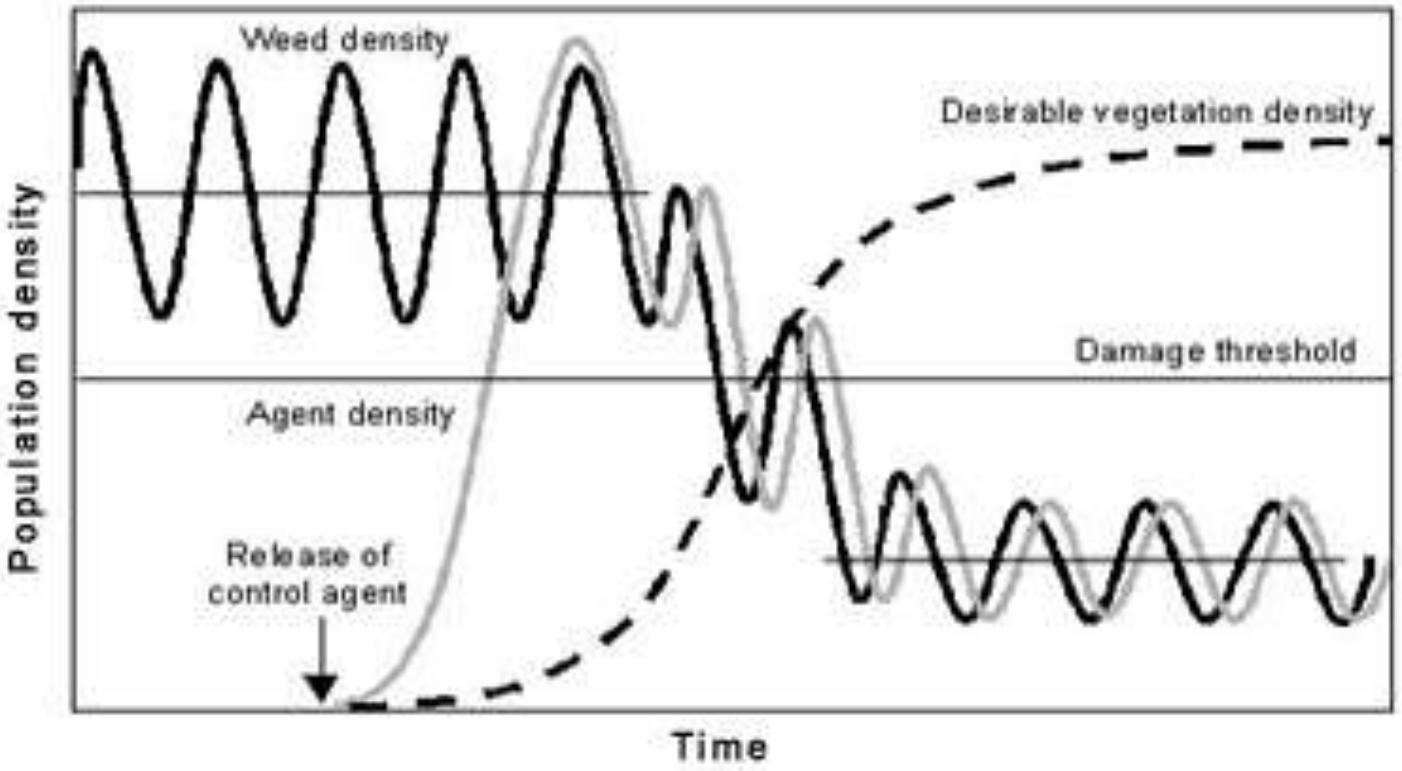
Better described as **COMMERCIAL** as applied like a chemical product from a bottle with a **label** and a user and is formulated.

Classical Biological Control (CBC)

Uses co-evolved, and highly specific natural enemies from the area of origin of the plant to provide self-sustaining control. Often after a single release.

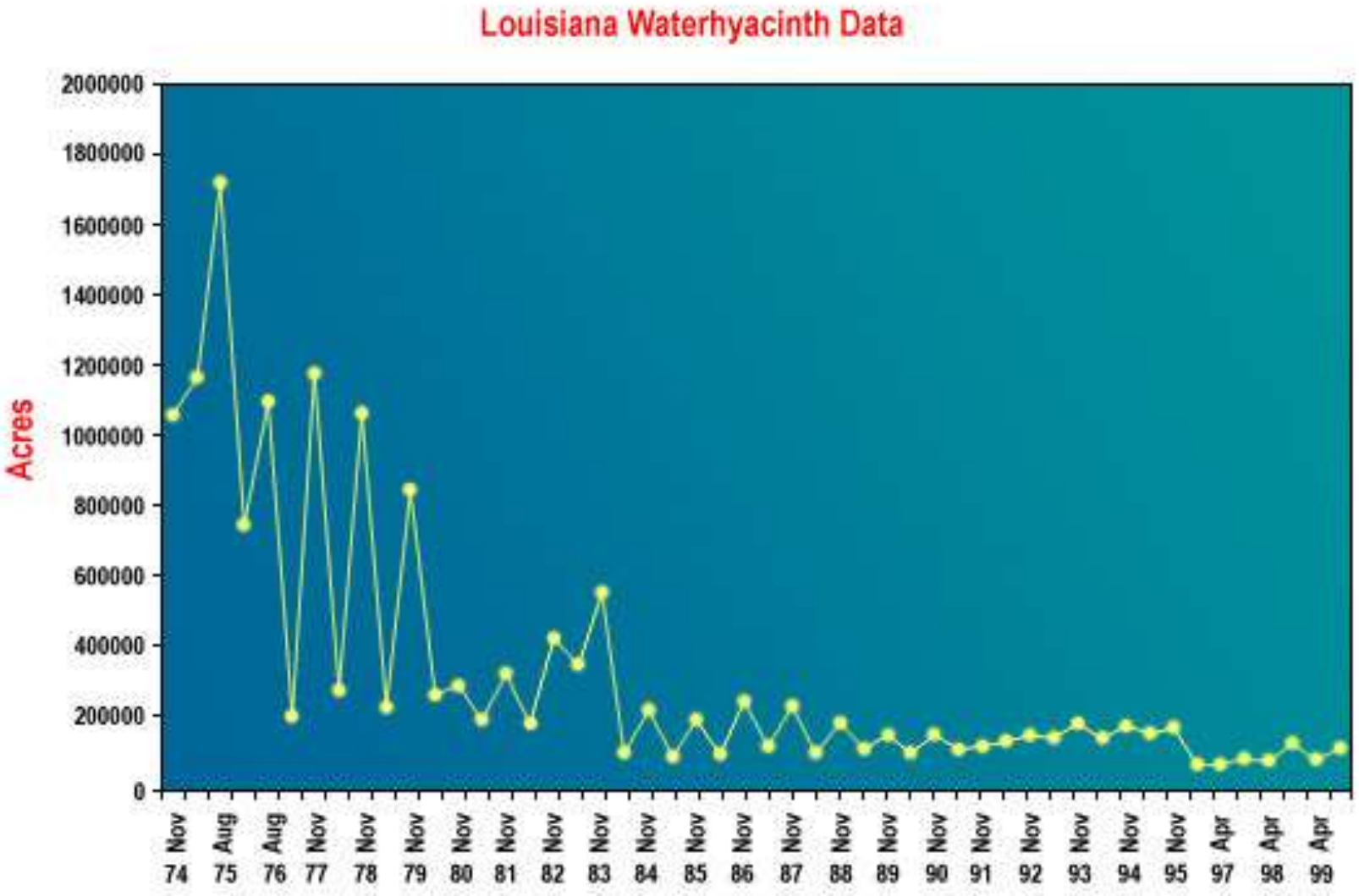
7,108 introductions of about 2,685 species of biological control agents have been made.

The normal sequence of events



Eichornia crassipes – Water Hyacinth

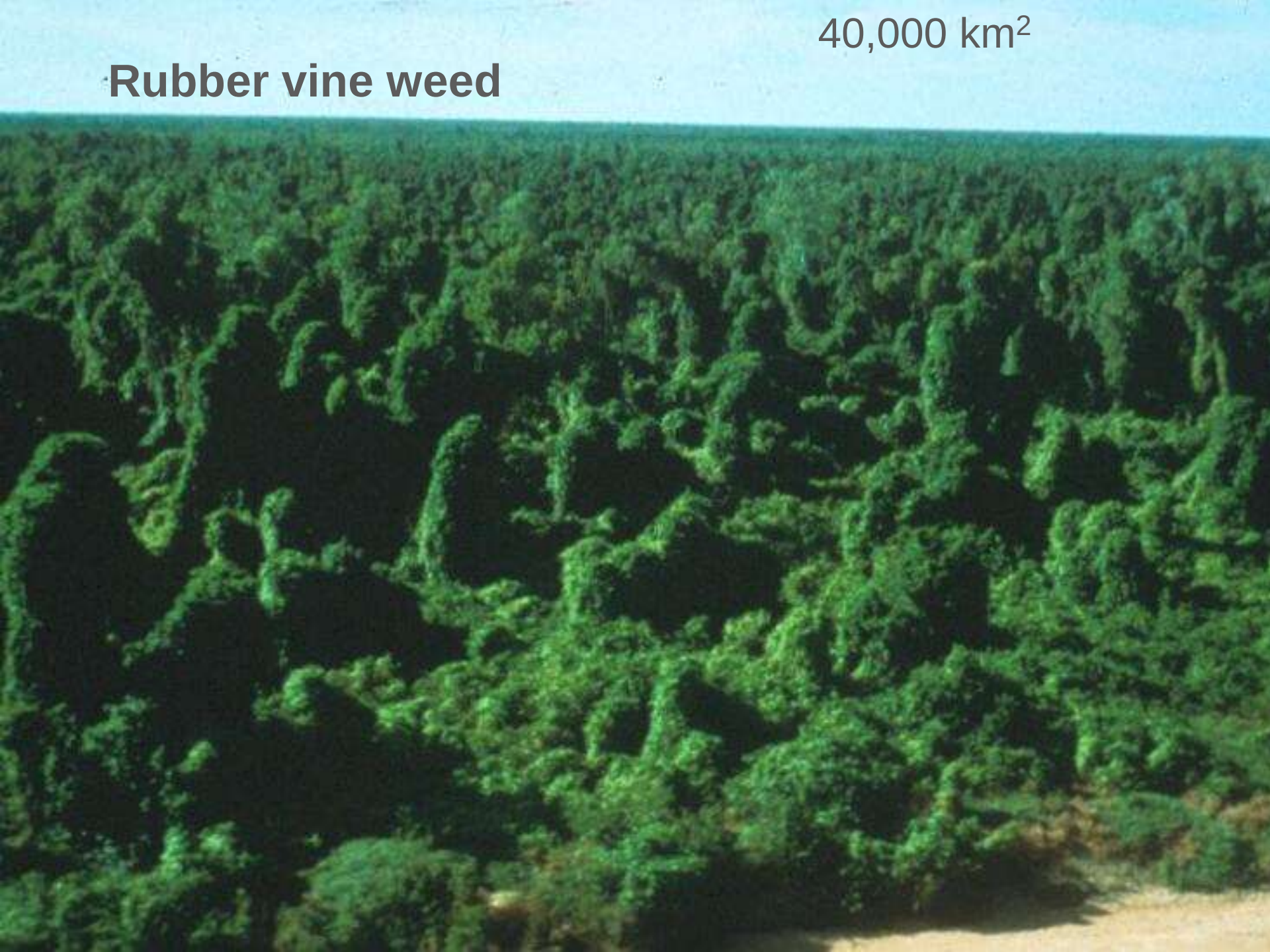
The real sequence of events



Graph courtesy of APHIS

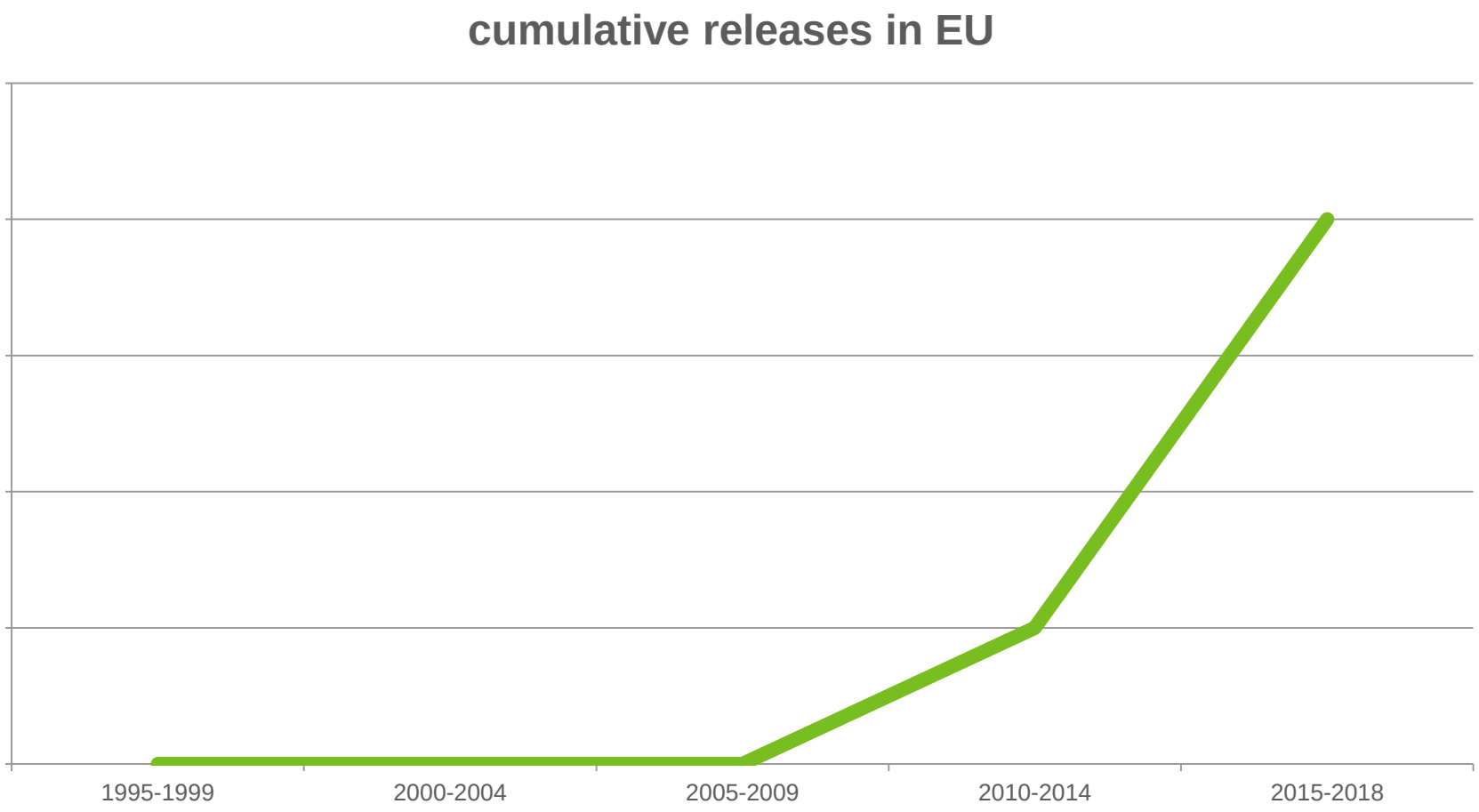
40,000 km^2

Rubber vine weed

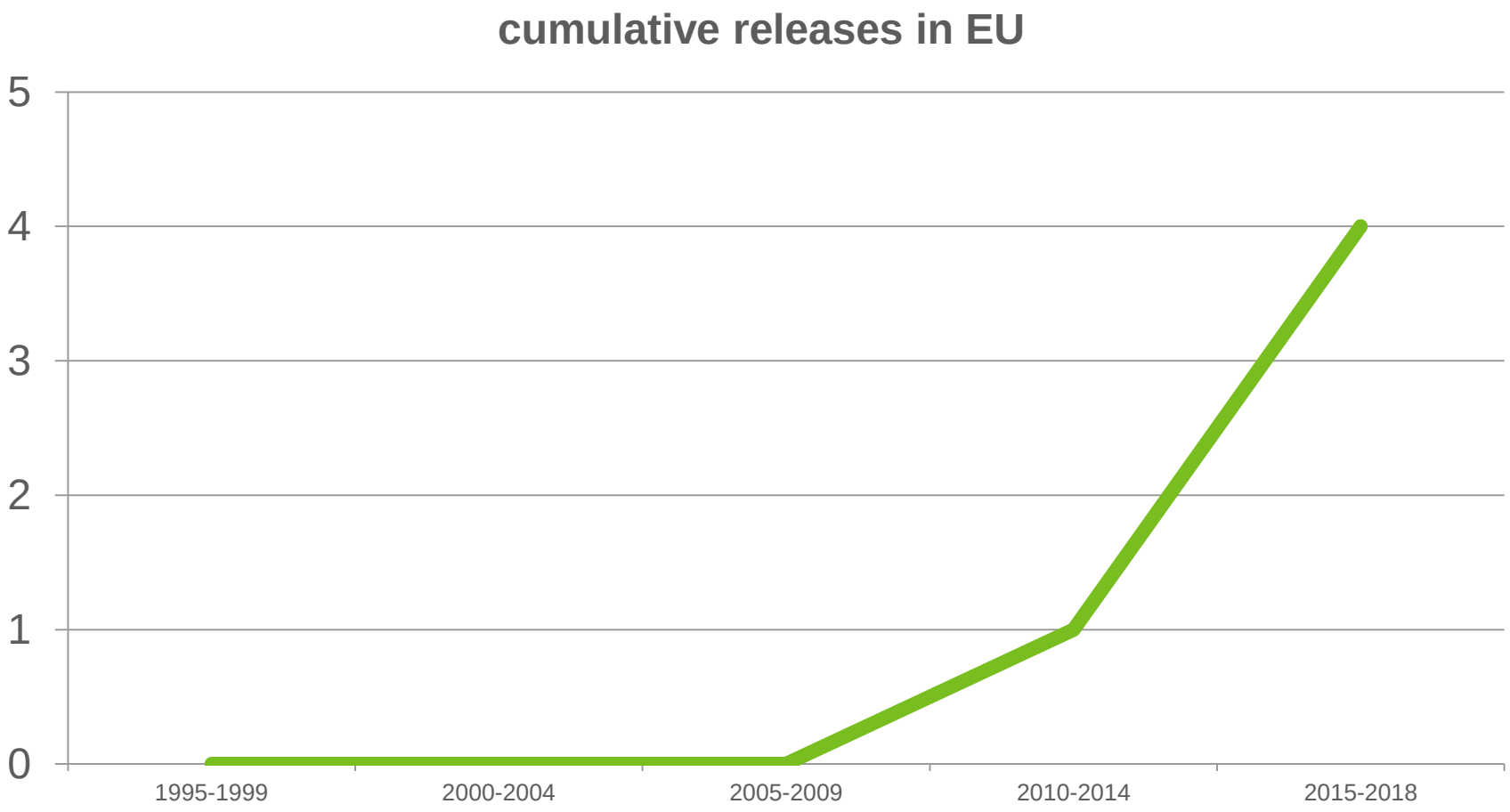


Rubber Vine with *Maravalia cryptostegiae* Australia

Exponential growth in weed biocontrol in Europe



Exponential growth in weed biocontrol in Europe



CBC activity in Europe

cf Insect BCA history

- In Europe there have been more than 300 releases of 176 predators and parasitoids against insects
- Many with very little regulation / Pest Risk Assessment

EU opportunities

Sheppard, Shaw & Sforza (2006) *Weed Research ;* Gassmann *et al.* (2006) *Hydrobiologia*

Species	Form	Origin	EU distribution	Genus native?	Conflict	BC history
Buddleja davidii	Ph	China	Temperate	No[b]	O	Yes
Fallopia japonica	Ge	Japan	Temperate	Yes	No	Yes
Acacia dealbata	Ph	Australia	Mediterranean	No[b]	O	Yes[d]
Azolla filiculoides	Hy	N America	Temp/Med	No[b]	No	Yes[d]
Ailanthus altissima	Ph	China	Temp/Med	No[b]	No	Yes
Impatiens glandulifera	He	India	Temperate	Yes	O	No
Rhododendron ponticum	Ph	S Europe	Temp/Med	Yes	O	Yes
Robinia pseudoacacia	Ph	N America	Temperate	No	F	No
Senecio inaequidens	He	S Africa	Temp/Med	Yes	No	Yes
Ambrosia artemisiifolia	Th	C America	Temp/Med	Yes	No	Yes[d]
Carpobrotus edulis	Ch	S Africa	Temp/Med	No[b]	No	No
Heracleum mantegazzianum	He	W Asia	Temperate	Yes	No	Yes
Solanum elaeagnifolium	He	S America	Tem/Med	Yes	No	Yes[d]
Baccharis halimifolia	Ph	N America	Mediterranean	No	No	Yes[d]
Hydrocotyle ranunculoides	Hy	N America	Temp/Med	Yes	No	Yes
Ludwigia peploides	He	S America	Temp/Med	Yes	No	Yes
Crassula helmsii	Hy	Australasia	Temperate	Yes	No	No
Elodea canadensis	Hy	N America	Temperate	No	No	No
Myriophyllum aquaticum	Hy	S America	Temp/Med	Yes	No	Yes
Solidago canadensis	Ge	N America	Temperate	Yes	No	No

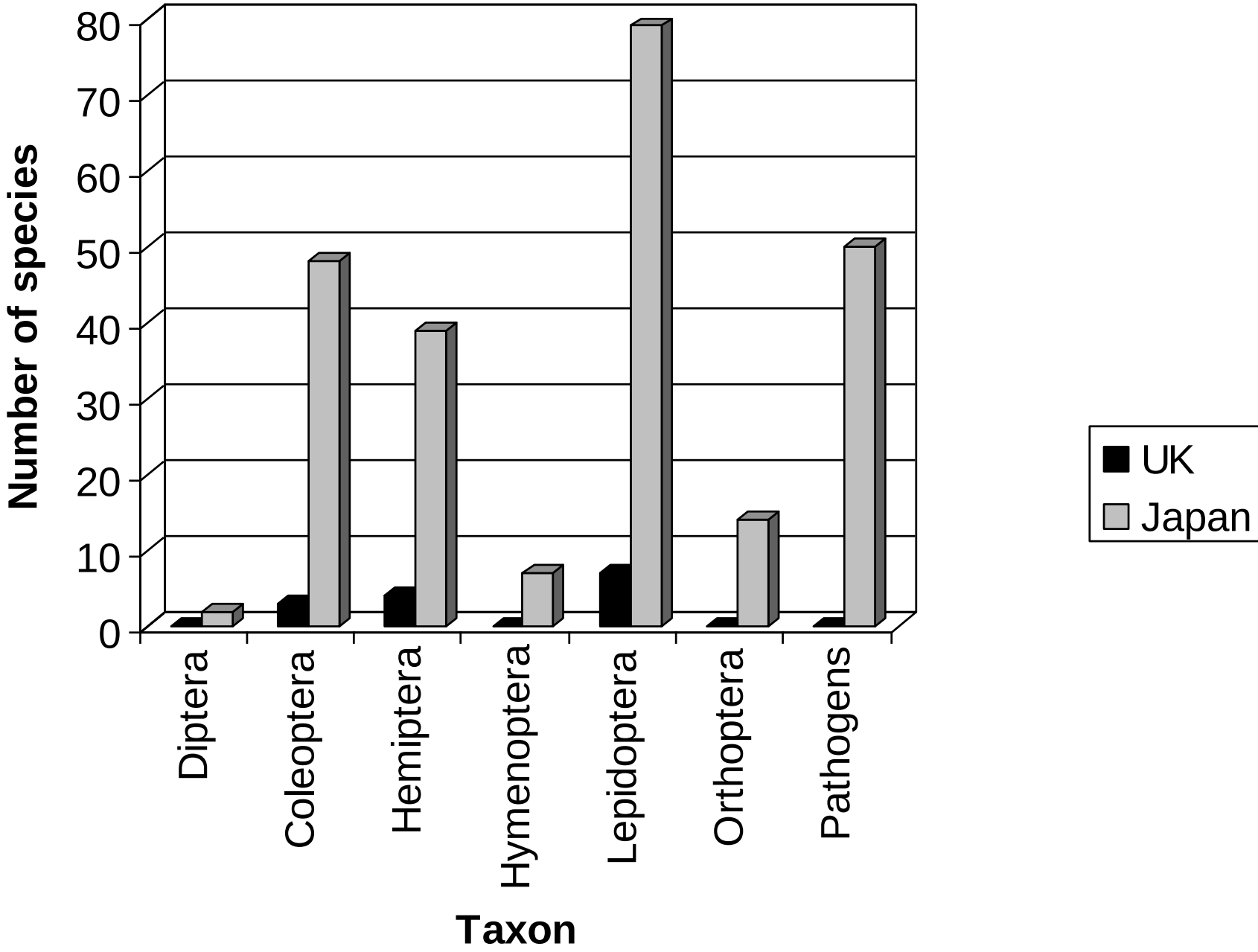
A lucky start to weed biocontrol in the EU

Shaw et al, 2018 Weed biological control in the European Union: from serendipity to strategy, BioControl DOI 10.1007/s10526-017-9844-6

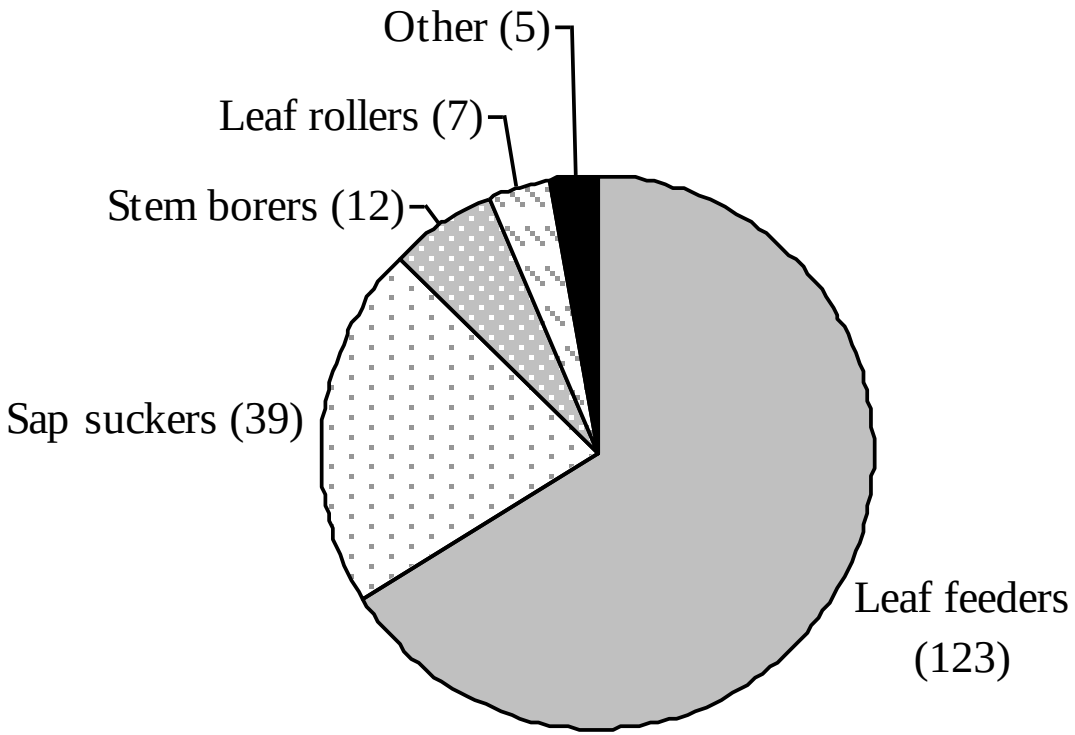
Stenopelmus rufinasus

After


PRIVATE ROAD
NO PARKING
NO THROUGH


Number of species
80
70
60
50
40
30
20
10
0
Diptera
Coleoptera
Hemiptera
Hymenoptera
Lepidoptera
Orthoptera
Pathogens
Taxon
UK
Japan

Many insects feeding on most parts



186 species of phytophagous arthropod recorded from Japanese knotweed in Japan.

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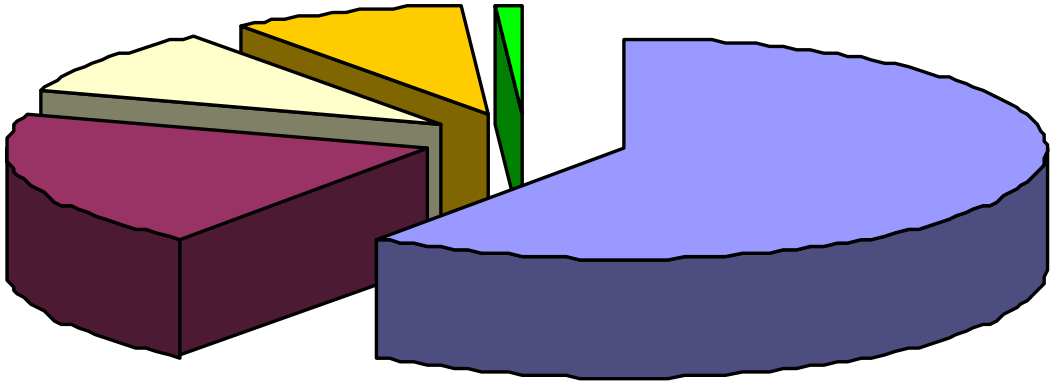
Nikon

A process of elimination



literature review

field observations

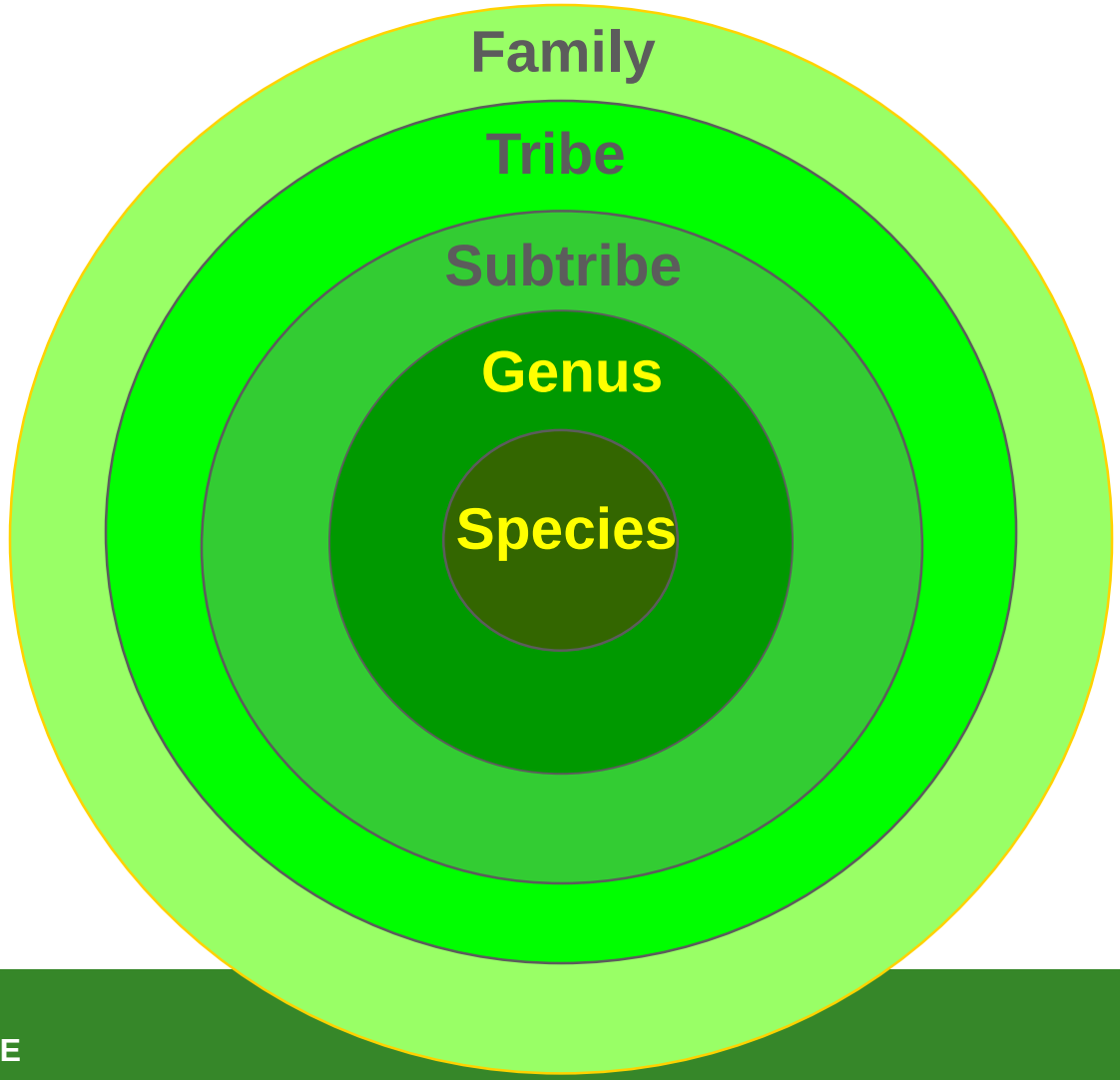
susceptibility studies

host range tests

suitable

Centrifugal phylogenetic method:

More closely related species more
likely to be attacked than more distantly related ones

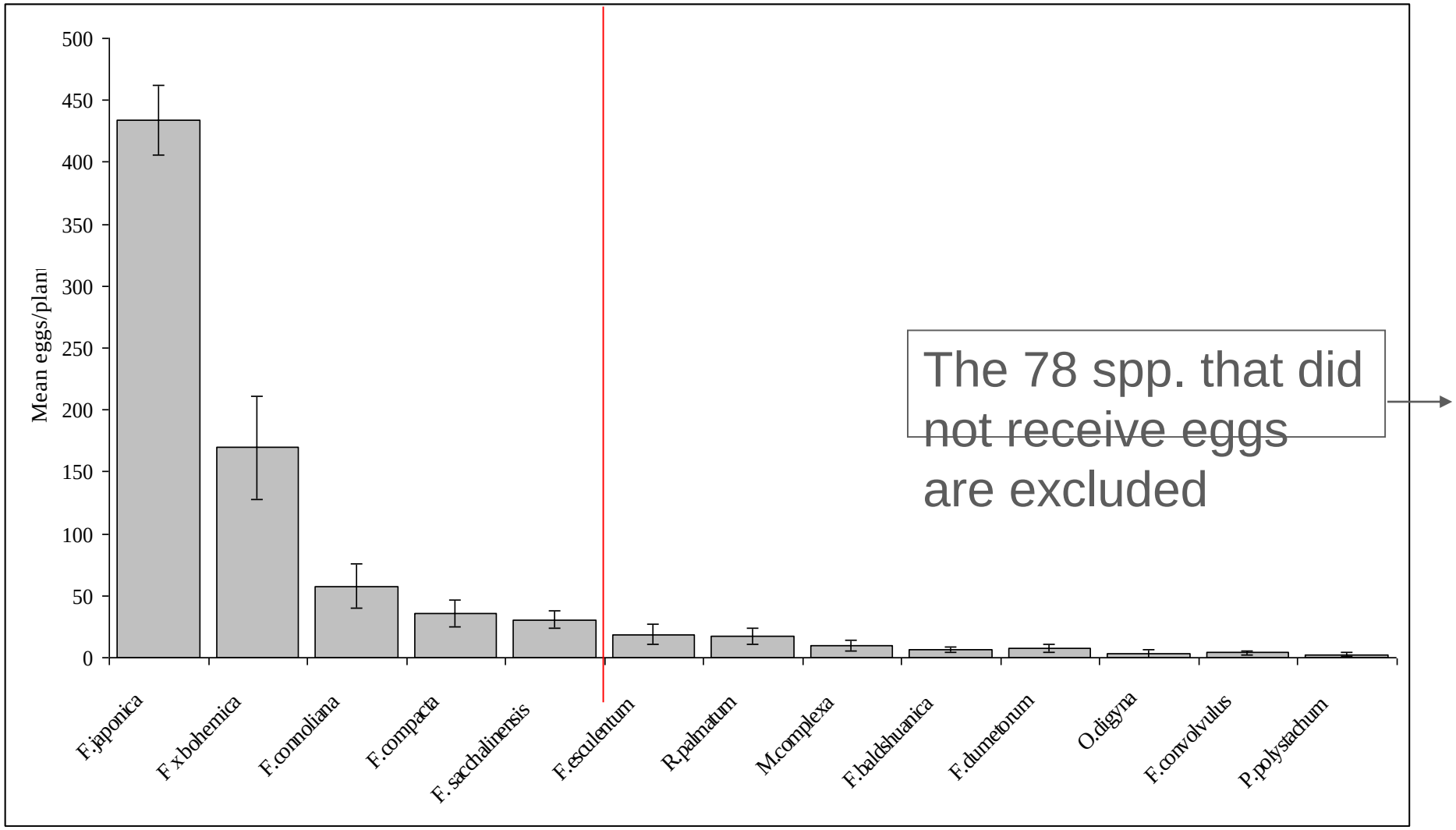


Aphalara itadori

Only 2mm as an adult

Eggs can just be seen with the naked eye

Host range testing



Bar chart showing mean egg count on those plants that did receive eggs in multiple choice oviposition tests. (+/- 1SE).

Development only successful to the left of red line

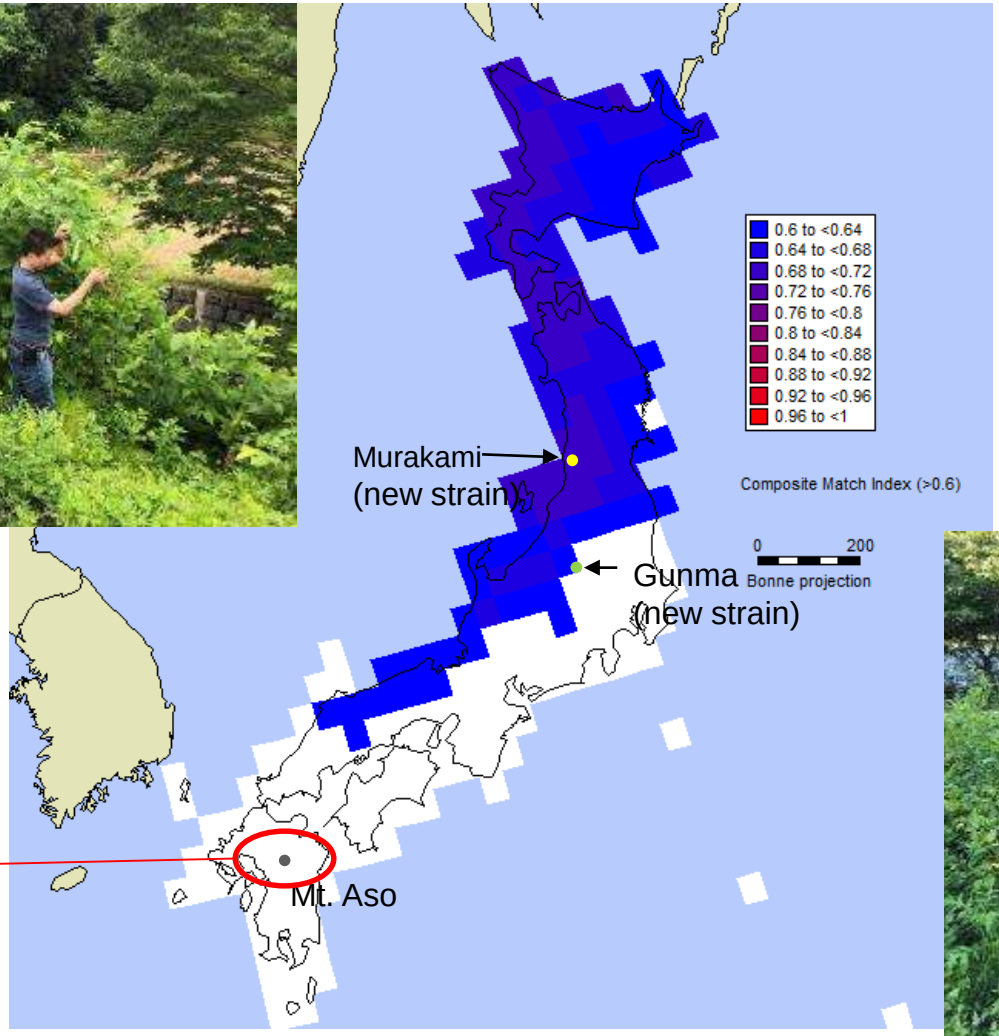
Fallopia japonica (Japanese knotweed) - psyllid

Aphalara itadori (psyllid) ex. Japan

- **Safety**: 12 year research programme - host range testing (87+ European plants), highly specific to Japanese knotweed, no effects on native invertebrates in cage and field
- **Impact**: Sap-sucking insect, reduced height and rhizome weight in lab and field cages
- **Releases**: 2010-2018 with Local Action Groups and Local Authorities collaboration in England and Wales. 5 year monitoring and contingency programme
- Successful overwintering 2016-17 at sites in Swansea, Surrey, Cornwall, County Durham
- Still working for consistent field establishment
- Survey to Japan in 2019 to source better climatically matched strain for the UK
- Project expanded to the NL

Field survey to collect psyllids in Japan

Murakami



Map with CLIMEX model

Gunma

New impact

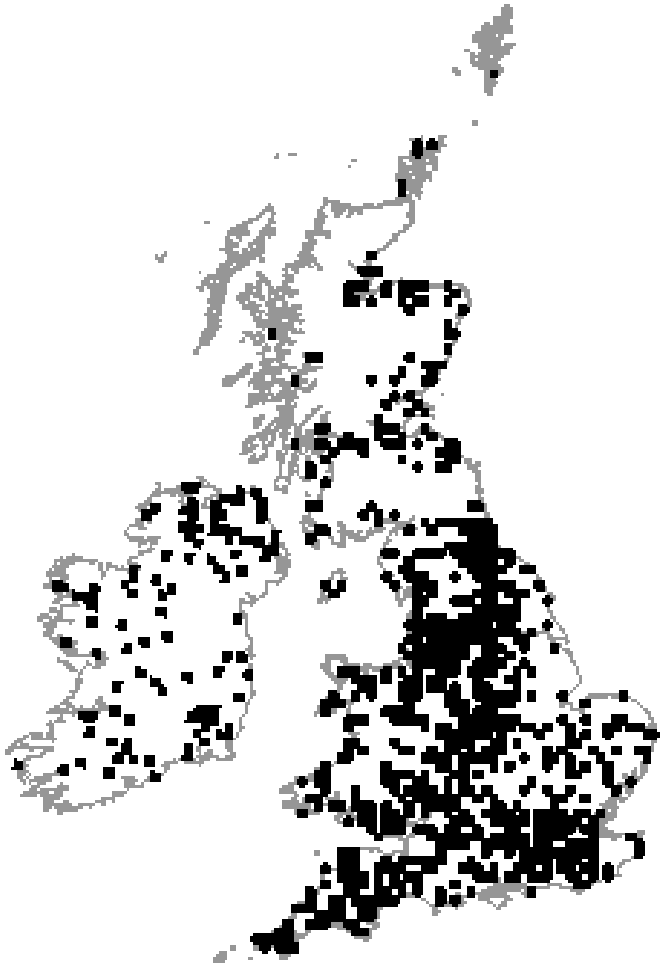

Knotweed leafspot

Knotweed mycoherbicide

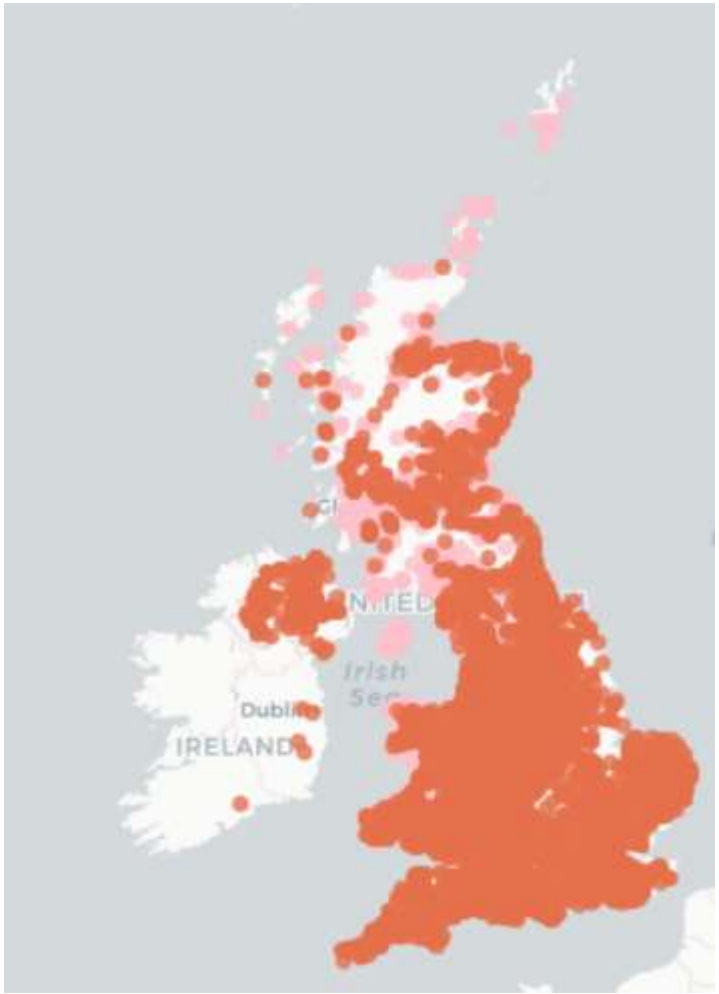
- In this case a mycelial preparation of a single mating type of Mycosphaerella for the control of Japanese knotweed
- UK and International Patent applied for in the name of Secretary of State
- UK Patent Application No. 1503510.8; https://www.ipo.gov.uk/p-ipsum/Case/ApplicationNumber/GB1503510.8
- European patent granted 2019!!
- Next Proof of Concept


Himalayan balsam
(Impatiens glandulifera)
Native to foothillls of Himalayas
First introduced into the UK in 1839
Tallest annual plant species in Europe

Occurrence of Himalayan balsam in the UK



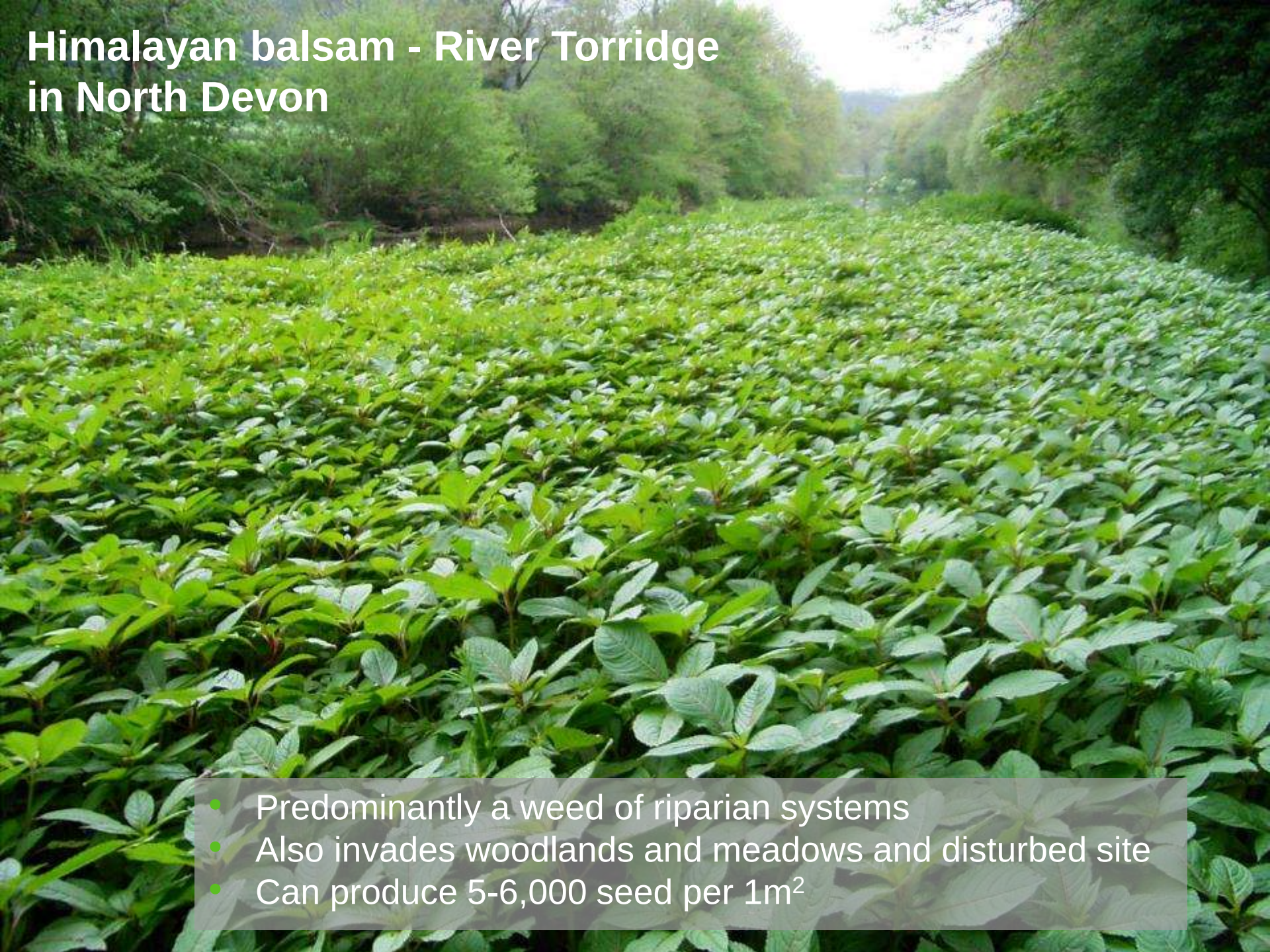
1950



2019

Data from NBN Gateway

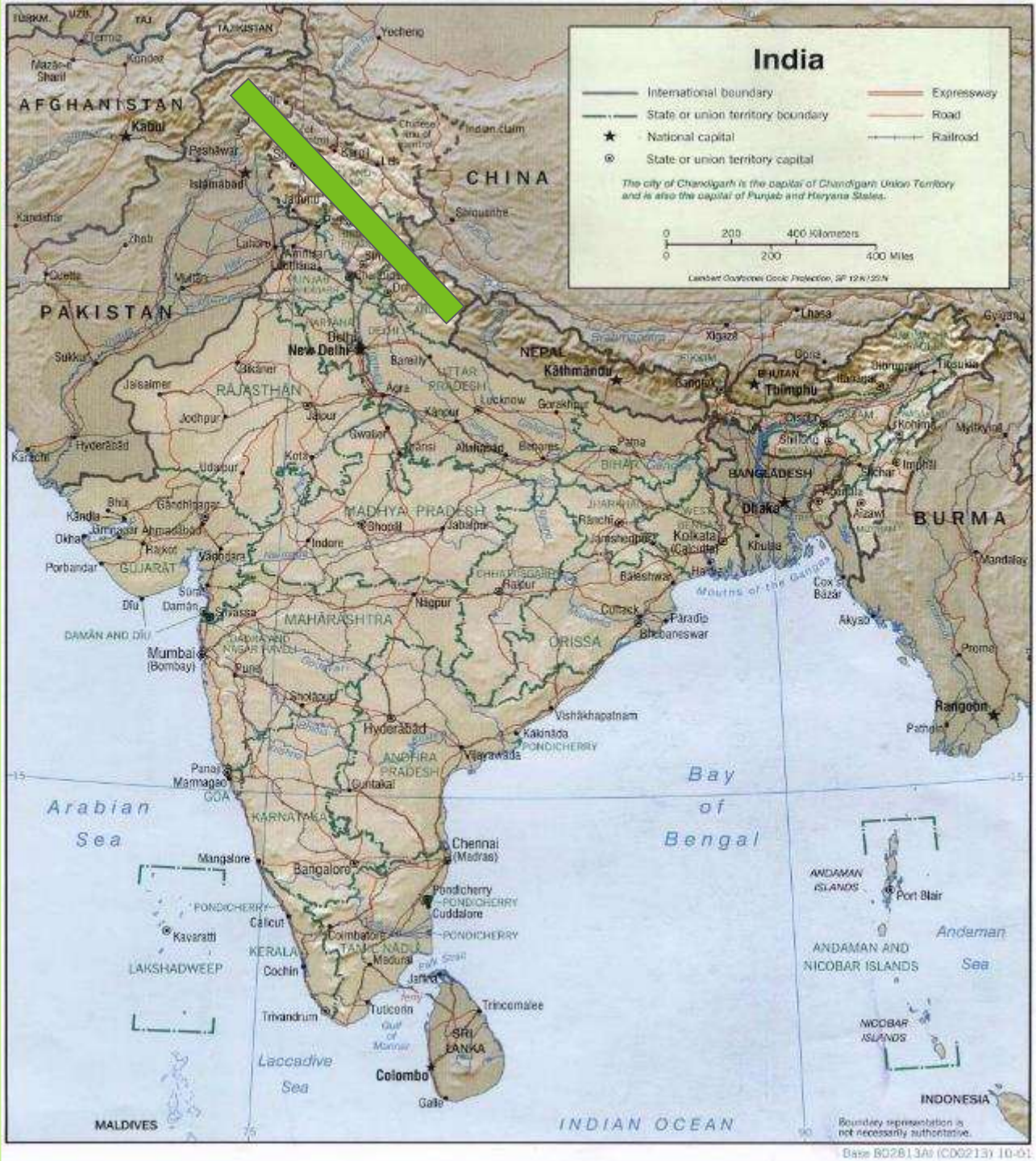
Himalayan balsam - River Torridge in North Devon



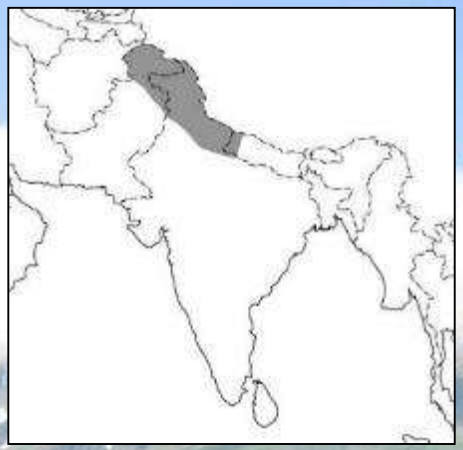
- Predominantly a weed of riparian systems
- Also invades woodlands and meadows and disturbed site
- Can produce 5-6,000 seed per $1m^2$

The survey

- Location
- Timing



Biological control of Himalayan balsam



- Programme commenced in 2006
- Native to foothills of Himalayas (from north-west Pakistan to Northern India)
- Surveys conducted and numerous natural enemies collected & identified
  - most rejected, not specific

Rust pathogens

- Rust diseases can be very damaging to their host:
  - restricting the area available for photosynthesis
  - distorting plant growth
- Many rust diseases are only able to infect one or a few plant species (coevolved biotrophs)
- Good history of use in biological control programmes around the world

- *Puccinia komarovii* var. *glanduliferae*

Rust releases

- Rust approved for release in August 2014
- Full release programme commenced in 2015

Initial results

- Good infection at some sites
- Poor symptoms at others (small pustule size)
- Limited spread of rust (5-10 m)
- Differing results could not be linked to environmental conditions

Solution?

- A strain of the rust from Pakistan retrieved from storage in liquid nitrogen

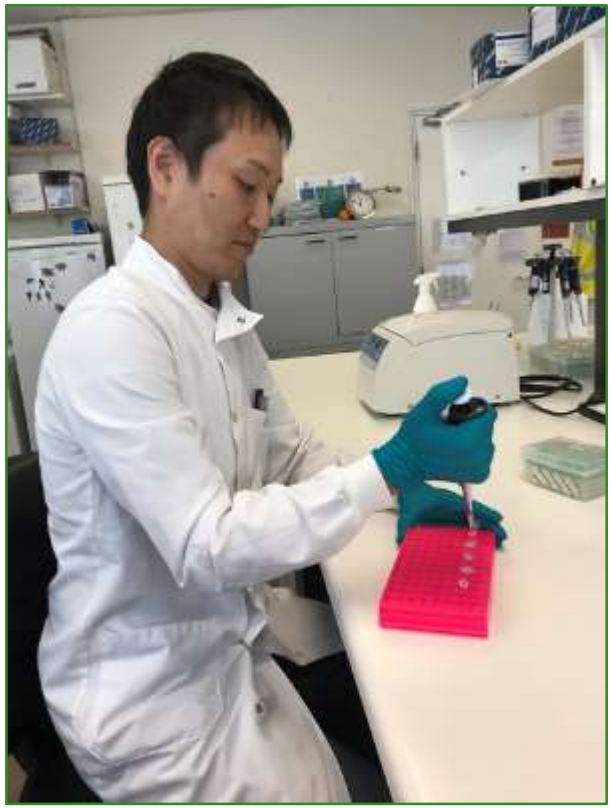
Variation in susceptibility of Himalayan balsam populations

Twizel Bridge, Tweed, Northumberland

Grogley, Bodmin, Cornwall

Working with LAGs 2017-2019

- Enabled rust to be released at sites across the country
- Release kit and monitoring protocol provided
- Rust supplied to LAGs and Local Authorities with training and supervision of first rust application
- Rust applied using spray bottle 3 times in season (June, July, August)
- Monitoring of infection recorded by LAGs, results sent to CABI



Molecular analysis of Himalayan balsam in the British Isles

- Aim: to identify number of different genotypes of Himalayan balsam in the UK and if possible, link these with genotypes in the native range

- Total of 93 leaf samples from 58 sites
  - 37 sites from introduced range
  - 21 from native range (India, Pakistan and Kashmir)

- Sequenced 7 mitochondrial DNA regions from each leaf sample and constructed a phylogenetic tree

Summary

- Rust release programme progressing well:
  - Optimised rust release protocol, rust production and site selection
  - Successful collaboration with LAGs
  - Rust successfully overwintered at 8 sites
  - Rust showing adaptation to UK field conditions and significant spread
- The two existing strains of the rust are not virulent towards all Himalayan balsam populations in the UK
- For biocontrol to be successful multiple strains of the rust are required for control in the UK
  - Molecular work identified region in Kashmir to survey for new strains
  - Survey conducted in India identified a new strain for assessment (currently stored in LN and awaiting permission for export)

Biocontrol of *Crassula helmsii*

Aculus sp. (Eriophyidae)

- A species new to science
- Emergent/ terrestrial growth affected, not submerged form
- Life cycle: Mites feed and shelter in shoot tips. It can complete several generations in growing season
- Challenging species to work with due to its size
- Plants are significantly shorter and secondary shoot growth is significantly reduced when infested by mite.
- Released in late 2018, establishing in the field with successful overwintering outside this year

Impact

(Left lab, below field)

Biocontrol of Floating pennywort

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COLNE VALLEY FISHERIES CONSULTATIVE

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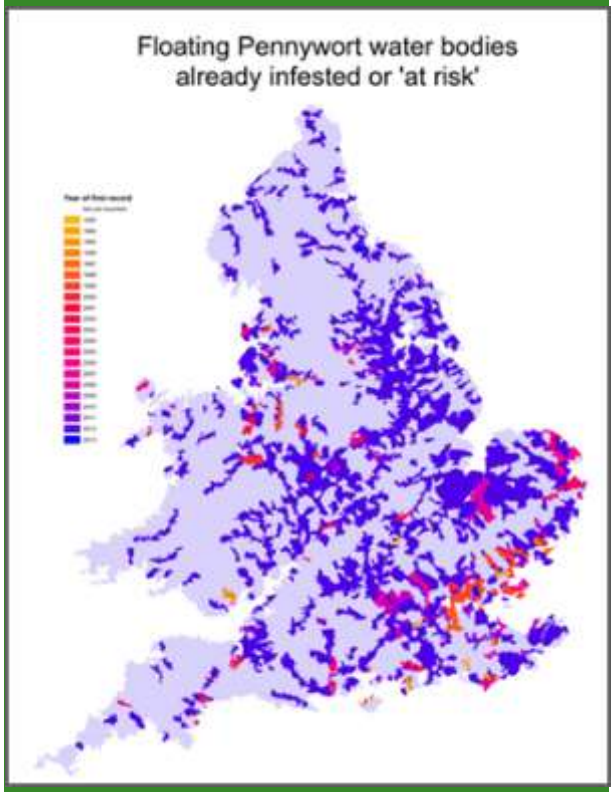
Problem



Distribution of *H. ranunculoides* in GB (NBN Gateway)

Projected spread and risk areas (EA)

- Ornamental aquatic trade import with origins in South/Central America
- Naturalised in the British Isles since 1990
- Widespread and well established in aquatic habitats, especially south and east of England - spreading rapidly north and westwards
- Very fast growing, free-floating, sometimes rooted, aquatic weed - can grow up to 20cm per day
- Very difficult to control due to ability to grow from tiny fragments
- Forms dense, impenetrable mats across water bodies
- Impacts on native species but also compromises flood defences, navigation and leisure activities

Costs the GB economy an estimated £25.5 million each year (management, disposal, flooding and indirect costs e.g to boating and angling) (2010 report)

Photo: T. Renals, Environment Agency

Potential Solution

Adult weevil ~ 6mm long

- Defra WFD project initiated in 2011
- Identified *Listronotus elongatus* weevil from Argentina as most promising candidate for biological control (pathogens and a fly dismissed after testing)
- Only ever found on *H. ranunculoides* in the native range. Heavy infestations cause plant death, mined petioles and stolons wilt and rot
- Adults feed on leaves, females lay eggs in the petioles and stolons, larvae mine and finally pupate in the submerged stolons
- Significant impact on mats. Egg to adult in ~50 days in UK quarantine (23^{o}C)

Listronotus elongatus

All stages can overwinter (even freezing) and has at least 3 generations/year in native range

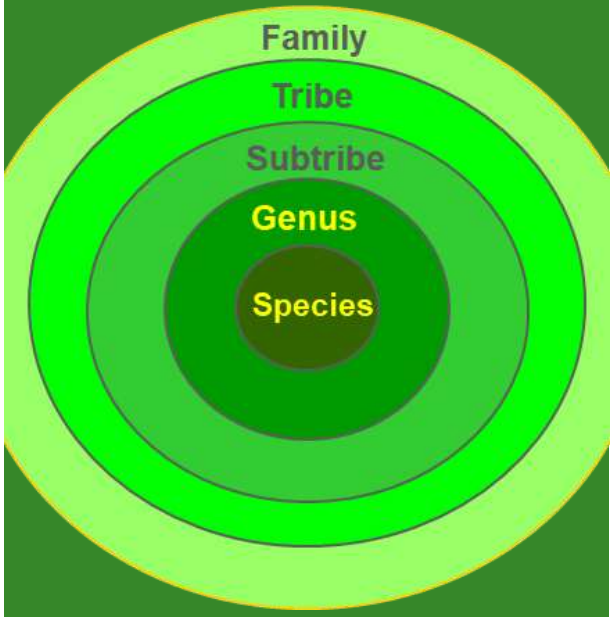
Adults feed on leaves - characteristic lesions on upper surface, sparing lower cuticle of leaf

~50 days at 23°C

Females lay eggs in small perforations in the petiole, often cramming 2-12 eggs in a row below the epidermis

Larvae mine down the petiole, into the submerged stolon, where they finally pupate inside the hollow pith of the plant

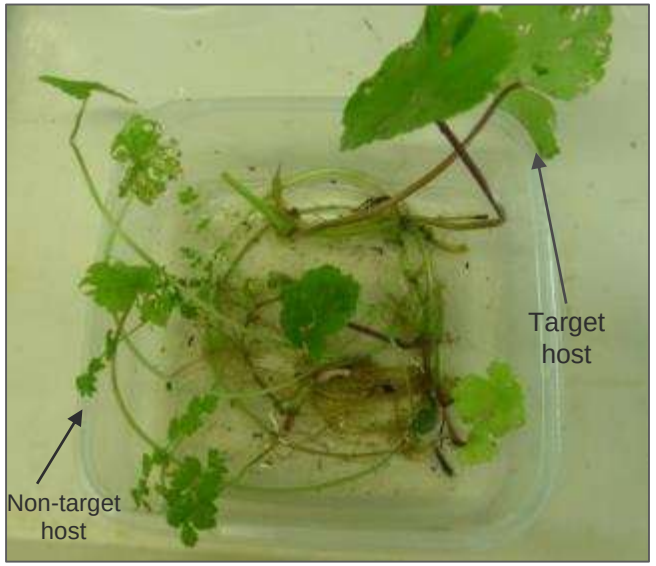
Host specificity testing



Feeding, oviposition and development

Cut leaf no choice

Functional plant, no choice with mating pairs



Functional plant, choice test with mating pairs

Summary and progress

- Tests in the lab are very precautionary (extreme, starvation tests) and intrinsically artificial (optimal conditions provided)

- Feeding damage, oviposition and development is recorded on non-targets alongside *H. ranunculoides* controls- highly significant preference for target **BUT** 2 natives are in the fundamental host range of the weevil (*H. vulgaris* and *Apium repens*). Oviposition on non targets is insignificant compared to controls and plant is highly unlikely to support development in the field

- Pest risk Assessment + ACRE application was submitted in May 2017 and feedback was received highlighting knowledge gaps to be addressed- Weevil could not be endorsed for release without further tests, but not ruled out

- Requested opportunity to consolidate data to address questions before PRA review + consultation process resumes-Plan to resubmit PRA in September

- Export negotiated for Paraguay strain of the weevil to finish off host testing of rare EU species and few other native UK species

Choice test

Apium repens (*Creeping marshwort*)

Set up with 10 mating pairs

Hydrocotyle vulgaris (*Marsh pennywort*)

After 2 weeks

The alternative?

With invasive species, doing nothing is NOT a low risk option

Not considering all the tools available can be an expensive option

Recent project vs Water Hyacinth in the Guadiana river in Spain

Would it have been wiser to spend 5% of that budget on finding a cold tolerant strain of the legendary Neochetina biocontrol agent so there is a back up plan when it comes back?

Conclusions

- Invasive weeds are serious issue for the environment and economies
- Classical biocontrol can provide a long term, safe solution but it is not a quick fix nor is it straightforward
- The technique is on the rise in Europe from a very slow start
- The UK is at the forefront of this field in Europe
- It is another way to see the world and meet interesting people!


Canal & River Trust
TWEED FORUM
BRISTOL CITY COUNCIL
North West Kent Countryside Partnership
wakefield council working for you
CORNWALL COUNCIL
defra Department for Environment Food and Rural Affairs
Environment Agency
BRITISH AIRWAYS
NERC SCIENCE OF THE ENVIRONMENT
Norfolk County Council
Network Rail
South West of England Regional Development Agency
Llywodraeth Cynulliad Cymru Welsh Assembly Government
The Scottish Government Riaghaltas na h-Alba
CAERPHILLY COUNTY BOROUGH COUNCIL CAERFFILI
CORNWALL COLLEGE
Thank You!
waterwaysnet
Bristol Zoo Gardens
Working for your Countryside MEDWAY VALLEY COUNTRYSIDE PARTNERSHIP
NATURAL ENGLAND
RIBBLE RIVERS TRUST
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