Advances in the biocontrol of invasive non-native weeds

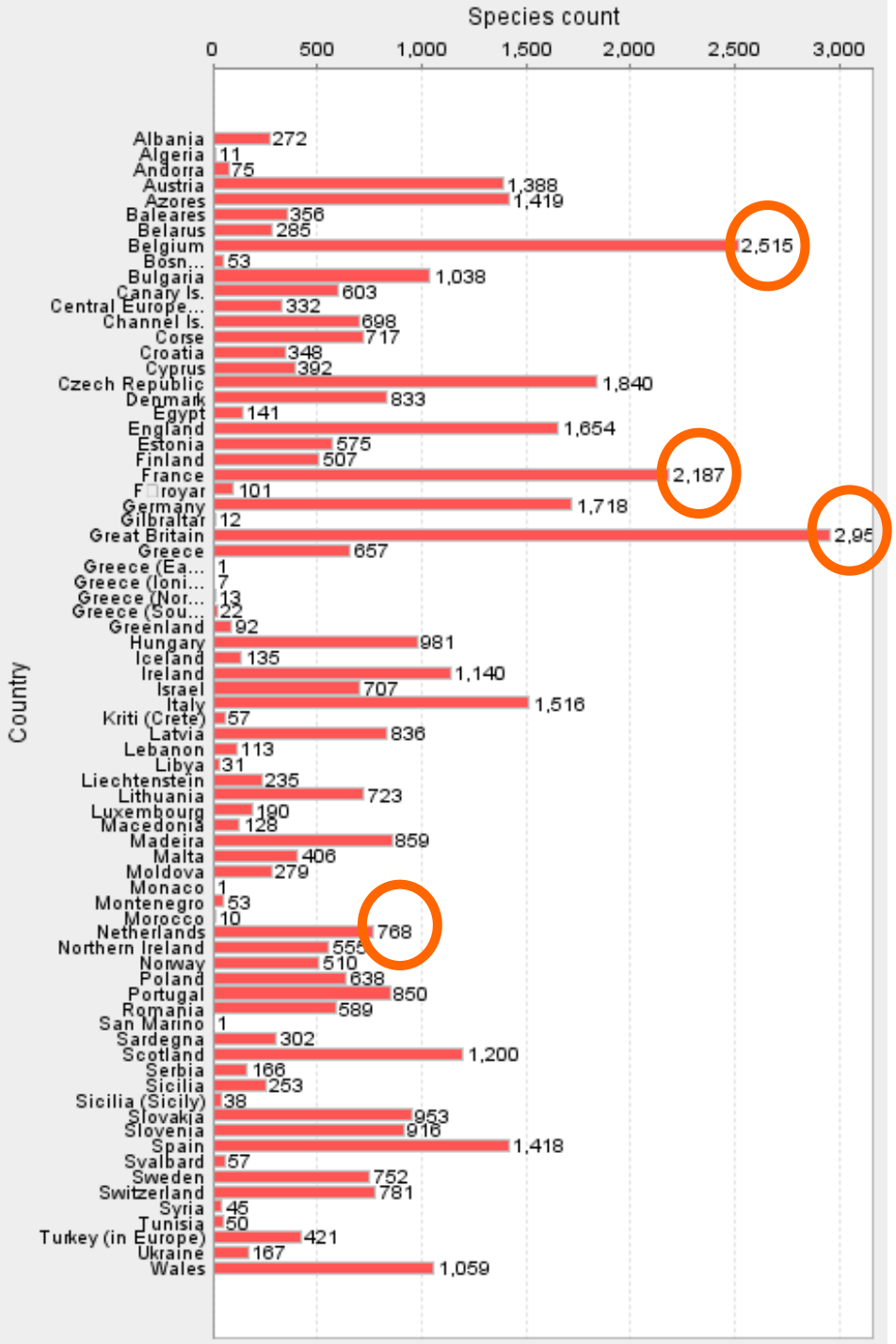
RINSE: Bridging the Gap, 23rd September 2014, Norwich

Corin Pratt, Suzy Wood & Dick Shaw

www.cabi.org
KNOWLEDGE FOR LIFE

CABI in brief

- Established in **1910**
- **Not-for-profit**
- Owned by **48 member countries**
- **9 centres worldwide**
- CABI provides scientific expertise and information about agriculture and the environment
- Activities include scientific publishing, development projects and research, and microbial services



Invasive Species in Europe

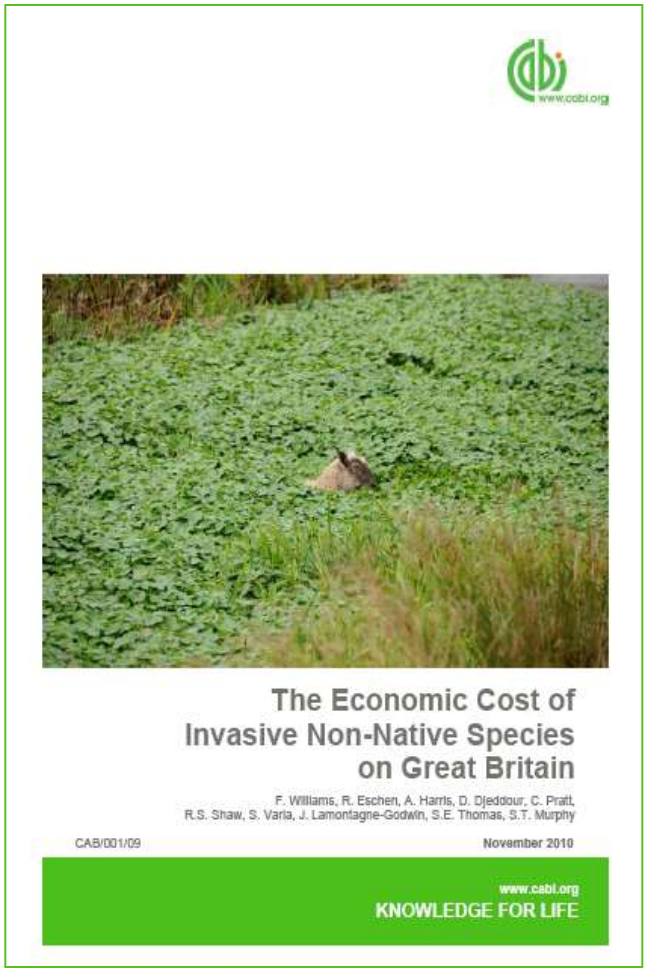
GB = nearly 3000

BE = ~2500

FR = ~2200

NL = ~770

Economic assessment for GB



Water Hyacinth in the Guadiana river, Spain

€23 million

Floating pennywort in Holly Bank Basin, Staffordshire, UK

£1800-£2000/km

Photo: T. Renals, Environment Agency

Recent legislation

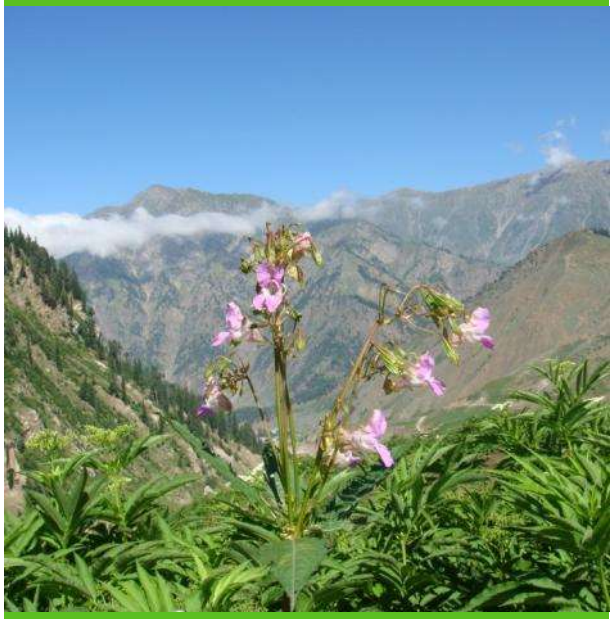
BANNED from sale in the UK (from April 2014):

1. Water fern (*Azolla filiculoides*)
2. Parrot's feather (*Myriophyllum aquaticum*)
3. Floating pennywort (*Hydrocotyle ranunculoides*)
4. Water primrose (*Ludwigia* spp.)
5. Australian swamp stonecrop (*Crassula helmsii*)

Aquatic ecosystems

- Are vulnerable and biodiverse
- More easily invaded
- Herbicide use is increasingly unacceptable in waterbodies
- **Water Framework Directive** – The presence of an invasive non-native species on or in a waterbody should seriously threaten “Good ecological status”
- Excellent targets for biocontrol

Unfair advantage



Impatiens glandulifera in the native range the foothills of the Himalayas Pakistan

- Non-native plant species arrived in the exotic range without the natural enemies that keep them in check in their native range – *enemy release hypothesis*
- Those natural enemies native to the introduced range which do attack invader do not cause enough damage for control
- Additionally, invasive weeds lacking damaging natural enemies may reduce allocation of resources to defence and more to competitive traits - *evolution of increased competitive ability hypothesis*
- Co-evolved insects and pathogens in the native range may be specific and damaging with potential for safe release as biocontrol agents

Biological control

Two *Listronotus elongatus* weevils on Floating pennywort

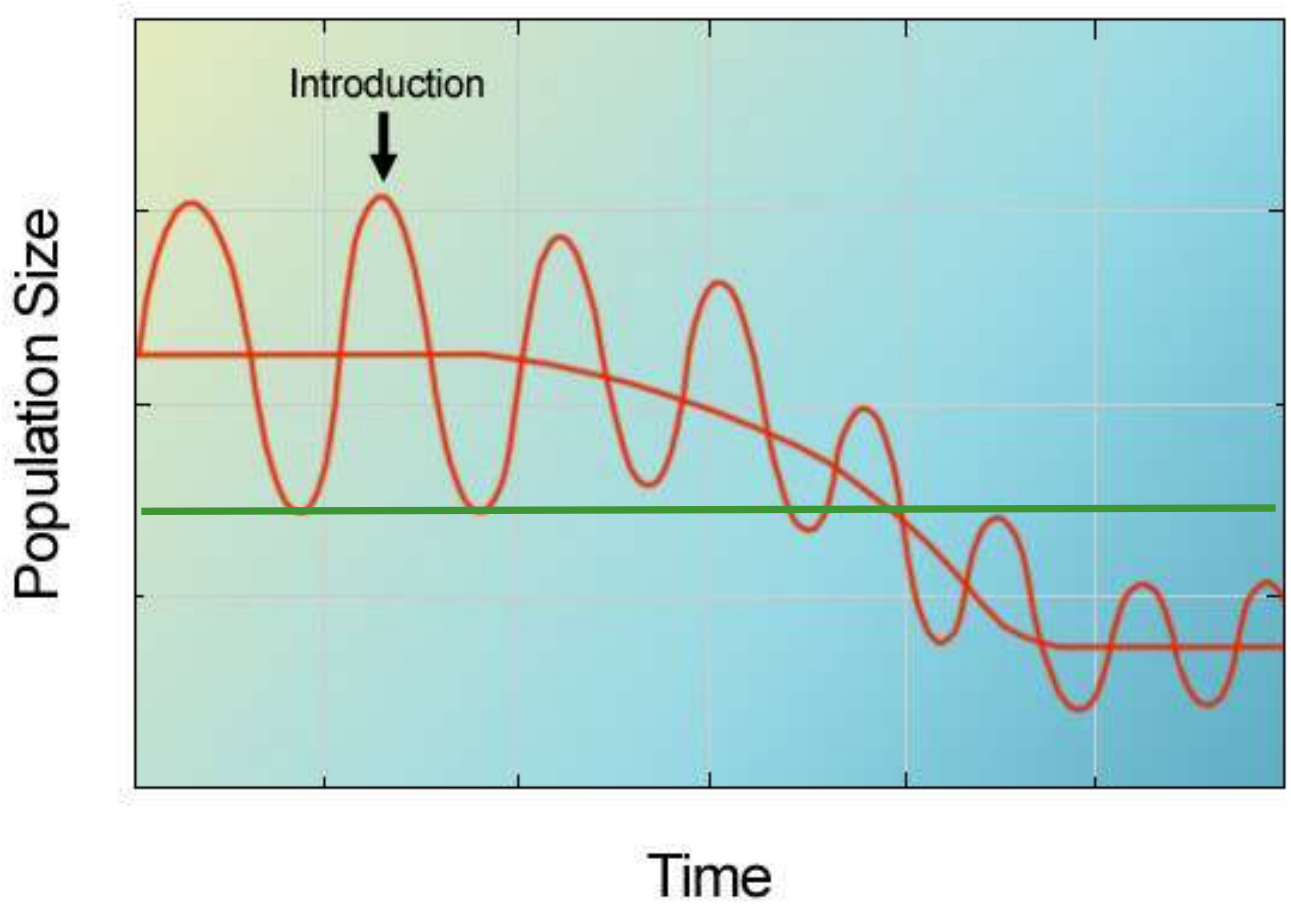
Three main types

Inundative - the mass production and periodic release of large numbers of biocontrol agents to control a pest

Conservation - modification of the environment or existing practices to protect and enhance specific natural enemies or other organisms to reduce the effects of pests

Classical (CBC) - the utilisation of co-evolved natural enemies in the regulation of host populations

The theoretical process

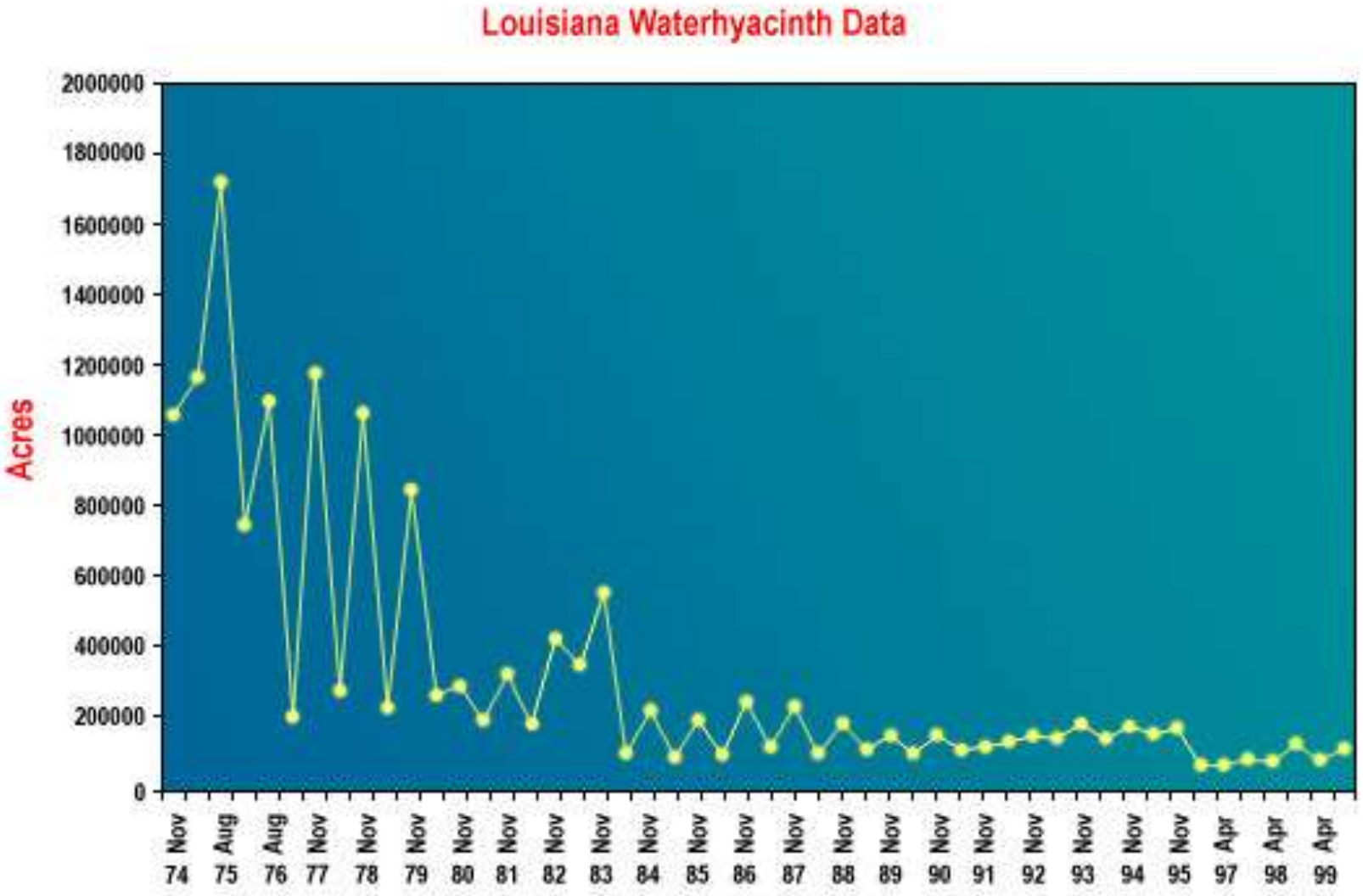


Graph courtesy of APIS

Eichhornia crassipes - Water Hyacinth

Neochetina eichhorniae

The real sequence of events



Graph courtesy of APIS

Salvinia molesta

Cyrtobagous salviniae

Photo-CRC

Salvinia weed

Before

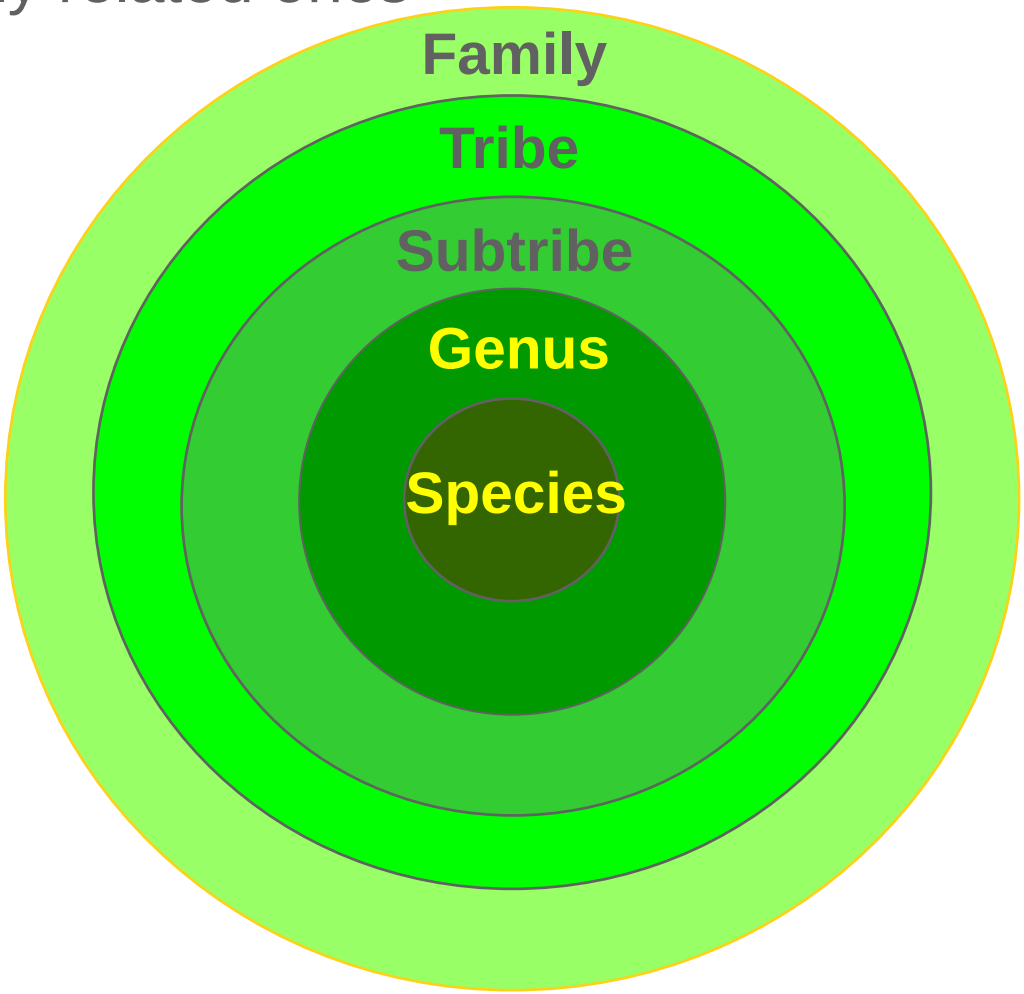
After

Biocontrol of *Salvinia molesta* in Sri Lanka

Host range testing

Phylogenetic centrifugal method (devised by Wapshere, 1974)

Closely related species are more likely to be attacked than more distantly related ones



Is Weed Biocontrol Safe?

- Over 1,300 releases of biocontrol agents around the world
- Over 400 agents against 150 target weeds
- A century of research
- Any non-target effects are predictable by the vigorous safety testing
- An International code of conduct
- Less than 5% have ever been found feeding on non-target plants (almost all were predicted or predictable the science applied today)
- A review of cost:benefit ratios from over 30 weed biocontrol projects showed a range from 1:2.3 to 1:4000 with an average of around 1:200 (Culliney, 2005)

Is It Effective?

Clewley et al (2012) - The effectiveness of classical biological control of invasive plants

- Meta-analyses of 61 published studies (2000-2011)
- Biocontrol agents significantly reduced:

  plant size (28 ± 4%),

  plant mass (37 ± 4%),

  flower and seed production (35 ± 13% and 42 ± 9%, respectively) and

  target plant density (56 ± 7%).
- Non-target plant diversity significantly increased by 88 ± 31%
- Beetles are best

Regulatory Drivers for Biocontrol

Instrument	Classical Biological Control
Sustainable Use Directive promotes alternative approaches or techniques such as non-chemical alternatives to pesticides.	Provides a non-chemical tool which can often be integrated with chemical/manual approaches

Weed CBC activity in Europe

Country	Recipient	Source
Austria	0	48
Finland	0	5
France	0	111
Germany	0	46
Greece	0	29
Italy	0	71
Portugal	0	18
Spain	0	9
Sweden	0	3
UK	2	41
Total	2	381

Classical Biological Control (CBC) in Europe

First weed CBC release in European Union (EU) made in 2010 by CABI:

Target: Japanese knotweed, *Fallopia japonica*

Agent: Psyllid, *Aphalara itadori*

More recently, a rust fungus was released in the UK against Himalayan balsam, *Impatiens glandulifera* (more later)

However, these are not the only examples of weed CBC in the EU…

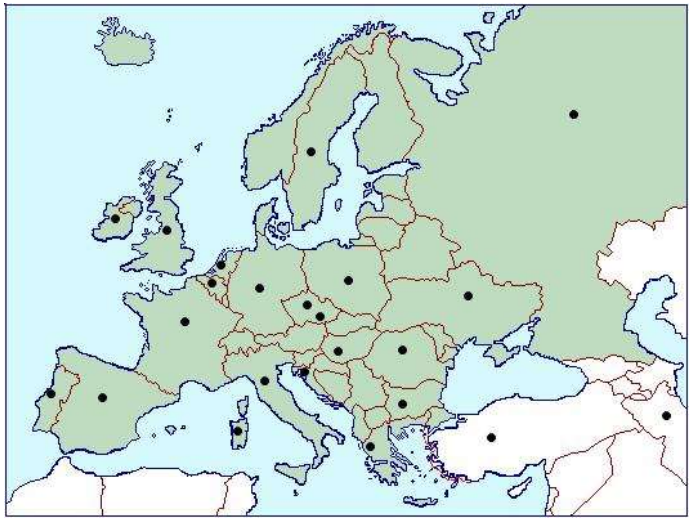
Introducing *Azolla*

Azolla filiculoides
- Daniel J Layton

Azolla filiculoides – a floating invader

- Native to the subtropical and temperate Americas
- First introduced to Europe in the mid-19th Century as an ornamental (and repeatedly since)
- Floating freshwater weed that forms dense mats
- Rapid colonisation via vegetative propagation; spore production late in the season
- Slow moving water – canals, ponds, lakes, irrigation channels, rivers

Azolla distribution and impacts



- Well established in the RINSE regions of the UK, the Netherlands, Belgium and France along with much of mainland Europe

Impacts of *Azolla*:

- Blocks out light and reduces oxygen available to plants, fish and invertebrates
- Blocks pumps and filters and can lead to flooding
- Can be mistaken for land covered by grass, leading to cattle deaths
- Affects recreation, e.g. fishing, boating

30 August 2011 Last updated at 15:20

Invasive plant carpets River Ray in Islip

The River Ray in Islip has been carpeted with Azolla since May when the watercourse was clear

Environment Agency officials have pledged action over an invasive water plant that has covered a stretch of a river in an Oxfordshire village.

Islip residents met agency officials on Tuesday to discuss how to control the floating water fern azolla filiculoides in the River Ray.

A spokesman for the agency said it would conduct a fisheries survey and if necessary remove the weed.

The aquatic plant, from North and South America, can damage local ecosystems.

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Warning on water weed 'invaders'

Weed-eating weevils go into canal

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Most Popular

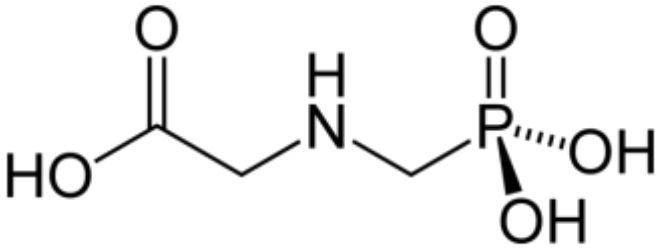
Controlling *Azolla*

Manual *Azolla* clearance
– Danny Depypere,
Nature Management, Belgium

- Azolla is difficult to control using traditional methods:

Chemical

Manual



Time consuming and ineffective…

Biological control?

Stenopelmus rufinasus
– Rob Reeder, CABI

Biological Control of *Azolla*

- *Azolla* biological control research undertaken in South Africa – extensive host range testing
- Weevil, *Stenopelmus rufinasus* found to be an *Azolla* specialist and released in 1997
- Hugely successful biological control agent
- Benefit-cost ratio of *Azolla* biocontrol programme in South Africa 15:1 by 2010

Azolla biocontrol in Europe?

S. rufinasus distribution in Europe based on DAISIE data

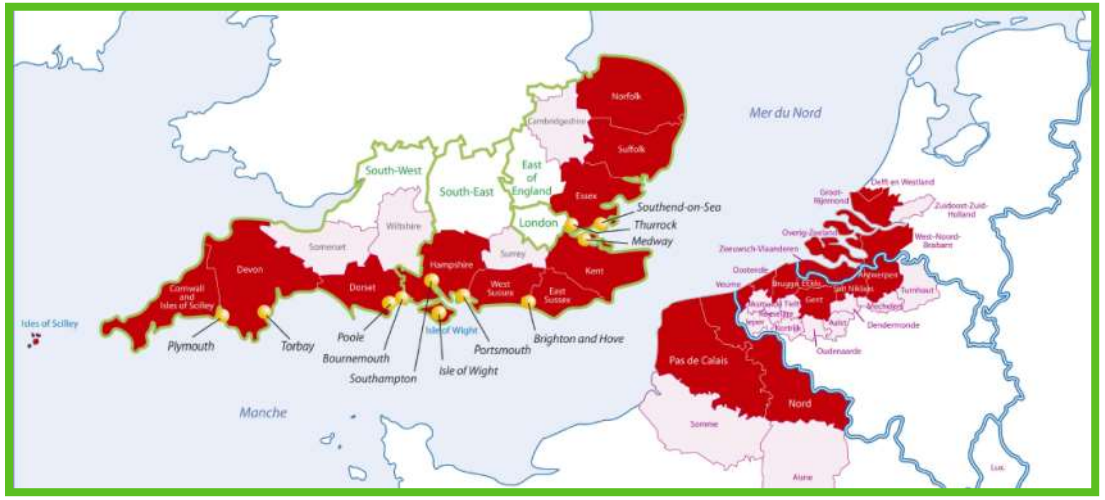
- The weevil is already present in a number of European countries including France (1901), the Netherlands (1922), Belgium and the UK (1921)
- Introduced as a stowaway on *Azolla,* now naturalised
- Potential for countries in western Europe to rear weevil populations for *Azolla* biocontrol

RINSE

RINSE - Reducing the Impact of Non-native Species in Europe

www.cabi.org

- European Union, Interreg IV 2 Seas Programme funding
- 9 partners from France, England, Belgium and the Netherlands



- Awareness and management of INNS
- CABI conducting demonstration trials with the *Azolla* weevil

RINSE

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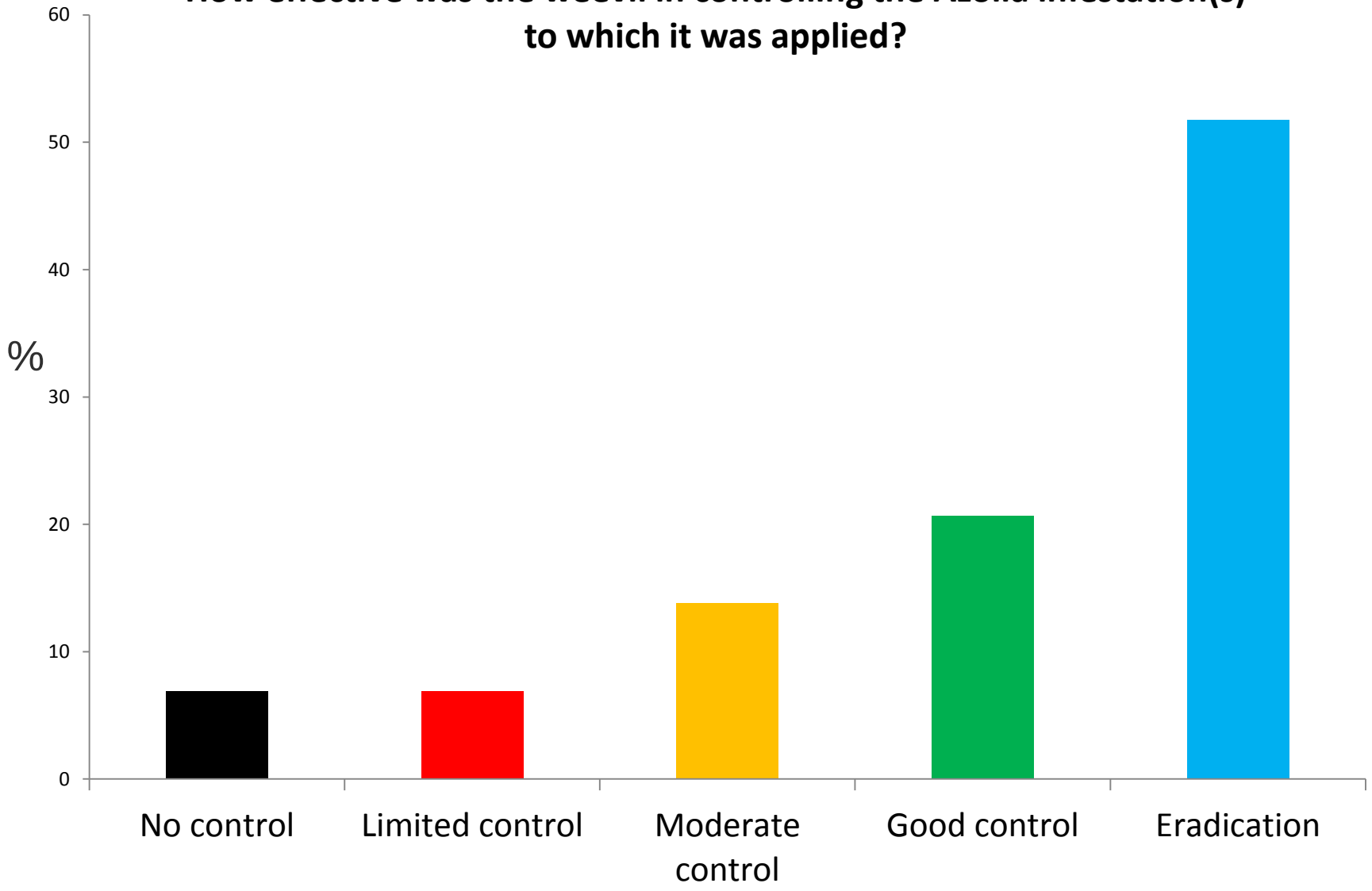
Azolla weevil workshop at CABI, Egham UK

Public opinion

A UK golf course with an *Azolla* problem – Corin Pratt

- Questionnaire sent to 97 previous users of the Azolla weevil in the UK
- Requesting feedback on weevil impact, opinion and alternative control methods
- 30 responses
- Limitations: imperfect response rate; risk of responses from most displeased users (or happiest); no river feedback; application rate varies

  – but useful


How effective was the weevil in controlling the Azolla infestation(s) to which it was applied?
60
50
40
%
30
20
10
0
No control
Limited control
Moderate control
Good control
Eradication

Opinion of weevil for Azolla biocontrol

- Generally very positive; to be categorised for comparison
- Examples:

"Very very effective completely eradicated the growth with no sign of any regrowth at all."

"The weevil control was miraculous! From a dead pond to a wildlife sanctuary in a matter of weeks!!"

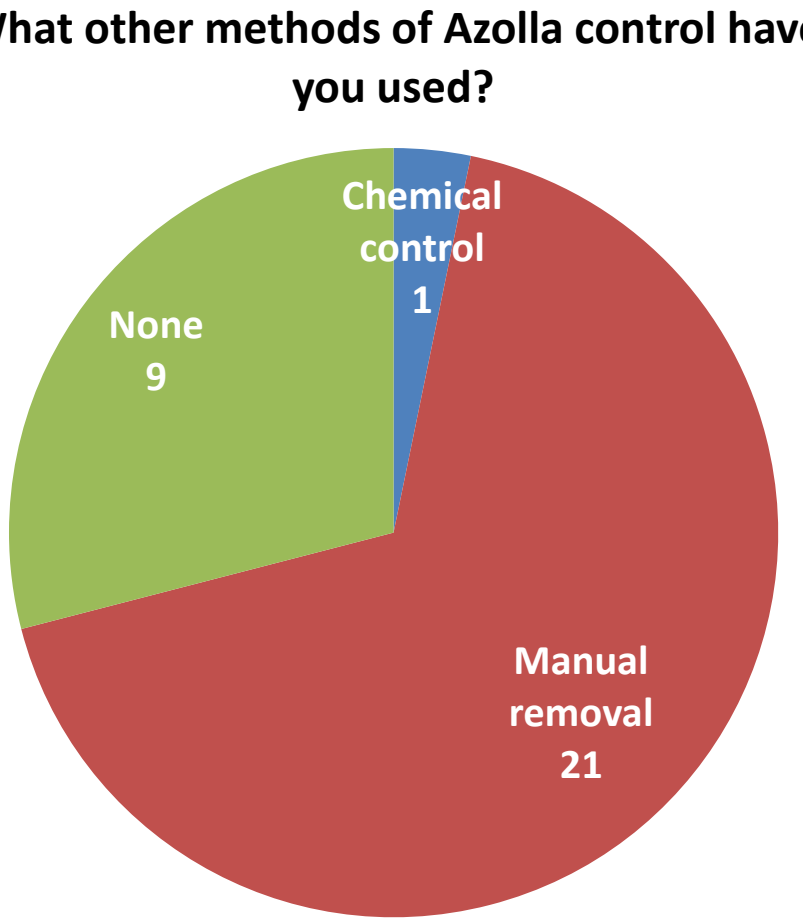
"If placed on Azolla at the right time of year it has proven to be effective."

"Has worked effectively at all the locations where we have deployed it in good time or it has over-wintered."

"Very effective in a short space of time."

"First attempt was not successful, introduced too late in the season. Second application complete success."

Other methods of Azolla control



- General feedback on traditional methods: **ineffective/short-term**
- Examples:

"Completely ineffective, the azolla grew back very quickly. It was a losing battle"

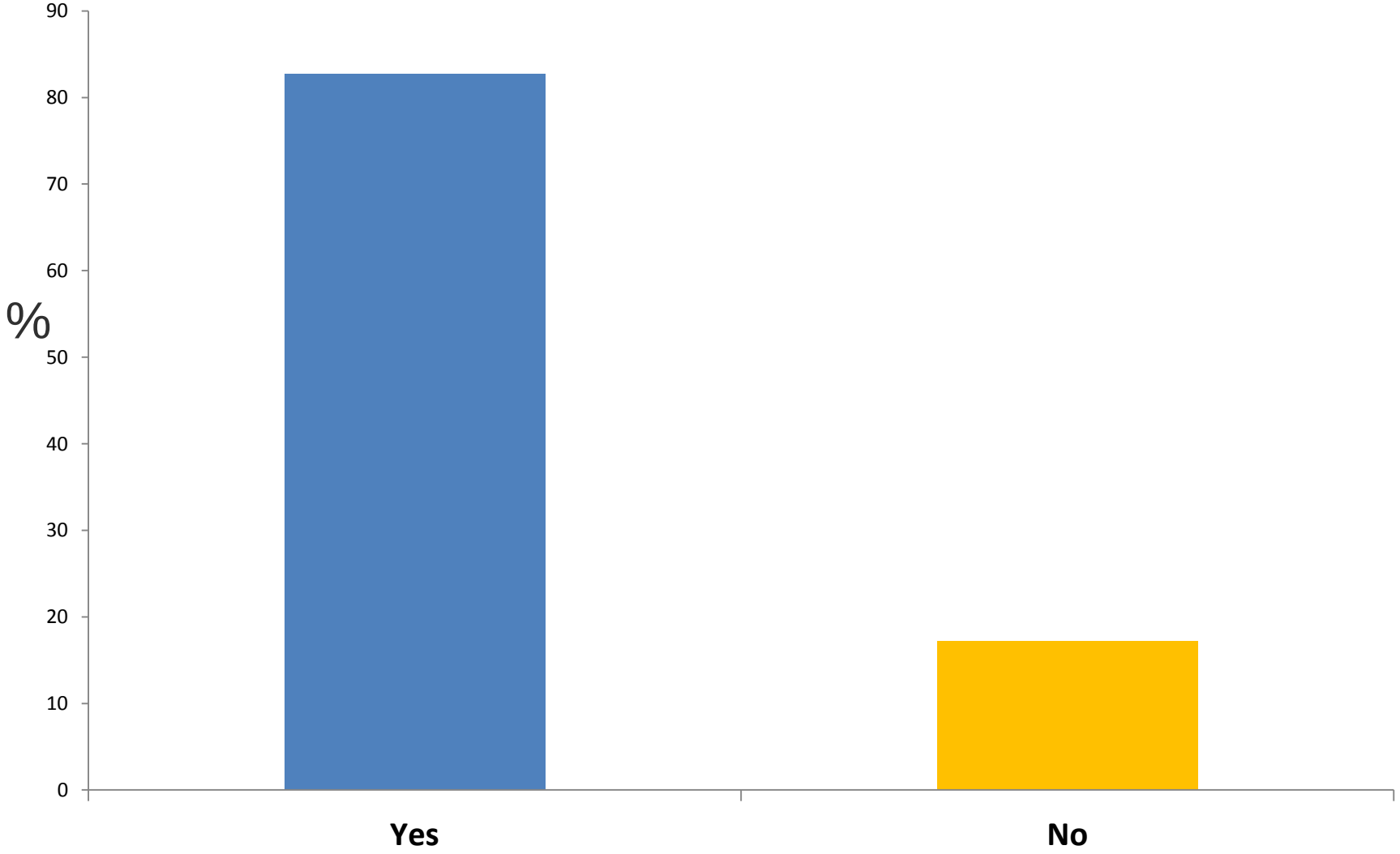
"Painful!"

"Visually an improvement but impossible to remove all the Azolla due to pond vegetation etc."

"Manual removal only gave temporary relief, within four or five days the pond was covered again."

"Manually removed bulk before introducing weevils to assist eradication."

Is the Azolla weevil now your preferred method for Azolla management?



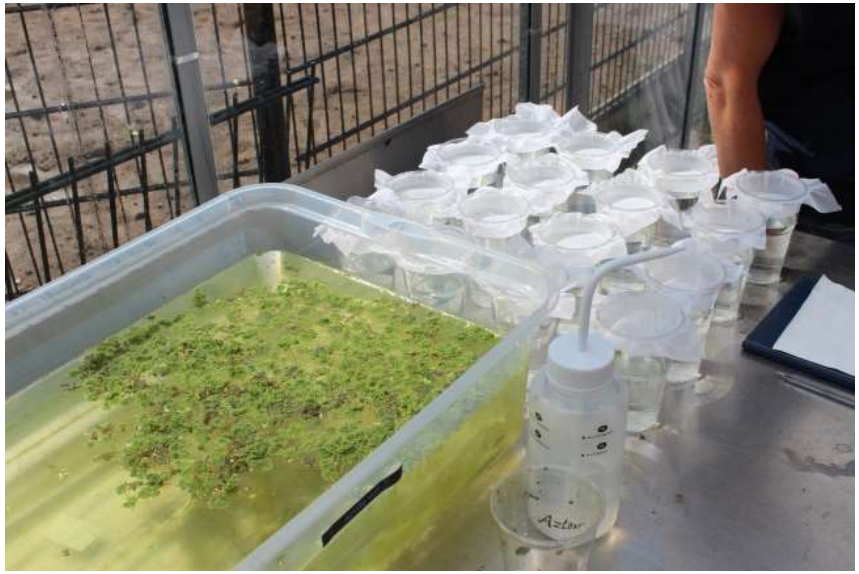
Differing requirements by country

UK	Netherlands	Belgium	France
"Ordinarily resident" Department for Environment, Food and Rural Affairs (Defra)	**Formal Risk Assessment required** Nederlandse Voedsel- en Warenautoriteit (NVWA) (Netherlands Plant Protection Organisation)	**"Naturally occurring"** Departement Leefmilieu, Natuur en Energie (LNE) (Department of Environment, Nature and Energy)	**Proof of residency required** Ministère de l'agriculture, de l'agroalimentaire et de la forêt (Ministry of Agriculture, Food and Forestry)
No restrictions to rearing and redistribution (England & Wales)	Pest Risk Assessment followed by water authority authorised trials with 'native' weevils	Rearing and redistribution of native stock to sites with permission of land managers/ local authorities	Collection and formal ID of weevils in France followed by rearing and regulated releases at limited sites


After


After

Netherlands



Hoogheemraadschap van Schieland en de Krimpenerwaard (HHSK) weevil rearing facility, Rotterdam

- Limited Azolla for trials within the district 2012-13
- Late trials 2013, ongoing trials 2014

France

- Weevils located on survey in June 2014
- Submitted for formal identification to Muséum national d'histoire naturelle (MNHN), Paris
- Release not possible in 2014, aim for future demonstrations

Belgium

Weevils harvested from Azolla on verge of collapse (Assebroek)

Relocated to sites with significant Azolla infestation

Gulke Putten nature reserve, Wingene

Belgium

De Zegge (Geel, Flanders), nature reserve of the Royal Antwerp Society for Zoology KMDA

Manual removal impacts rare natives such as *Hypericum elodes* and *Ludwigia palustris*

Summary of demonstrations

Country	Site location	Site type	Azolla area (m^2)	Weevil application date	Weevil application method	No. weevils applied	Outcome	Time taken
UK	Cornwall	Pond	6	Jul 2012	Mass rear and release	50	Eradication	10 weeks
UK	Hampshire	Pond	240	Aug 2012	Mass rear and release	3000	Good control	6 weeks
UK	West Sussex	Pond	200	Jul 2013	Mass rear and release	1000	Eradication	10 weeks
UK	Surrey	Pond	20,000	Weevils present Jul 2012	Natural infestation	N/A	Eradication	15 weeks estimated
BE	Assebroek	Pond	200	Weevils present Apr 2013	Natural infestation	N/A	Eradication	10 weeks estimated
BE	Kuurne	Pond	1,200	Weevils present Jul 2013	Natural infestation	N/A	Very good control	18 weeks estimated
BE	Kampveld	Pond	360	Weevils present Sept 2013	Natural infestation	N/A	Eradication	8 weeks estimated
BE	Wingene	Ditch	50	Weevils present June 2014	Natural infestation	N/A	Likely eradication (site flooded)	12 weeks estimated
BE	Wingene	Pond	500	Weevils present June 2014	Natural infestation	N/A	Approaching eradication	Ongoing
BE	Wingene	Pond	15	Weevils present June 2014	Natural infestation	N/A	N/A	Ongoing
BE	Wingene	Ditch	30	June 2014	Relocate and release	300	Likely eradication (site flooded)	12 weeks estimated
BE	Gistel	Pond and ditch	300	Weevils present June 2014	Natural infestation	N/A	N/A	Ongoing
BE	Geel	Pond	10,000	Weevils present June 2014	Natural infestation	N/A	Eradication	15 weeks estimated
NL	Glasshouse, Rotterdam	Tank	1	Ongoing 2012-2014	Mass rearing	N/A	Eradication	N/A
NL	Rotterdam	Waterway	500 estimate	Sept 2013	Mass rear and release	300	Intermediate control (interrupted by removal)	6 weeks

Achievements & Recommendations

- Azolla biocontrol demonstrations very successful
- Scalable, cost effective, environmentally benign approach
- Ecological, economic and social benefits
- Regulatory requirements for implementation in RINSE regions established
- Proposed “best-practice” control method
- Potential to be employed across much of Europe helping to achieve objectives of Water Framework Directive

Engaging stakeholders

- Use of weevils and biocontrol in general novel to many in Europe
- Through RINSE we have engaged directly with policy makers, land managers and the general public to describe and demonstrate effective Azolla management through biocontrol
- Publications, presentations, posters and blog to inform stakeholders of Azolla biocontrol demonstrations and RINSE project aims
- Informed stakeholders sharing knowledge more widely


Biological control of invasive non-native weeds: An opportunity not to be ignored

Cross-border collaboration

- Essential and extensive!
- Identifying and engaging with regulatory authorities
- Suggesting key contacts
- Identifying sites for demonstrations
- Assisting in the field
- Providing translations
- Numerous collaborators involved in each RINSE region
- RINSE partners invaluable!

Future work

S. rufinasus adult – Corin Pratt

- Generations per year in different regions
- Dispersal ability in relation to temperature; nutrient status; wing muscle development
- Willingness to fly in relation to sunlight/ temperature
- Further European studies? Augmentation through mass rearing in northern Europe. Introductions and monitoring in southern Europe?
- Molecular analysis of weevils across Europe. Genetically distinct populations? Original source?

Himalayan balsam

Impatiens glandulifera

- Highly invasive annual plant
- Introduced to Europe in the early 1800s
- Spread rapidly throughout riparian systems and damp woodlands
- Impacts on biodiversity, river networks and infrastructure
- Outcompetes native plants for pollinators
- For successful manual/chemical control, it must take place on a catchment scale

Biological Control?

- Programme commenced in 2006
- 9 surveys conducted to the plant's native range
- Numerous natural enemies collected and identified
- Based on field observations and laboratory studies most organisms have been rejected
- One organism showed considerable promise - a plant pathogen *Puccinia komarovii* var. *glanduliferae*
- The first fungal biocontrol agent released against a weed in Europe
- **Releases made in the UK in September 2014**

Release 2 weeks ago!

Biocontrol of Floating pennywort

Hydrocotyle ranunculoides

- Part of EU WFD project group funded by Defra
- Only 1 native *Hydrocotyle* sp. in Europe
- *Listronotus elongatus* weevil is most promising agent, no non target development

- Draft PRA should be submitted in 2015
- 2 other potential agents:

  Puccinia hydrocotyles rust

  Eugaurax sp. fly ex Argentina

- Opportunities for EU piggy-backing, esp. Netherlands, France and Belgium, Germany

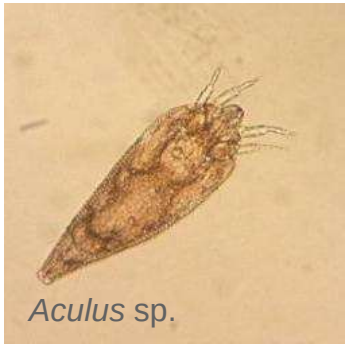
Crassula helmsii

Crassula helmsii in flower

Australian swamp stonecrop

- Semi aquatic plant, native to Australia and New Zealand – introduced to UK in 1911
- Forms dense mats, outcompeting native species and altering habitat for native species
- Difficult to control using conventional methods
- Project initiated in 2009/2010
- Test plant list produced – 41 species including natives, *Crassula aquatica* and *Crassula tillaea*

Hydrellia perplexa



Aculus sp.

Colletotrichum sp.

Future targets

Ludwigia in a canal in France

Ludwigia spp
Creeping water primrose

- Native to South America
- Complex taxonomy
- On-going eradication in UK, impossible in other regions, particularly France
- Very high management costs and ecological damage
- Known natural enemies

Take home message

- Classical biological control offers a sustainable solution to many weeds that are beyond eradication
- Proposed Invasive Species Directive will require better control methods for invasive weeds, with biological control being a key component of Integrated Management approaches
- Water weeds make excellent biocontrol targets
- CABI are currently working on biocontrol projects for a number of aquatic invasive weeds
- *Azolla* is a European weed with a proven biocontrol agent, a weevil whose potential has been demonstrated through the RINSE project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Many thanks

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Thank You

Dank U wel

Merci beaucoup