Photo: Tim Haye

Classical biological control by introduction against invasive insects

Marc Kenis, Brett Hurley, Ann Hajek et Matthew Cock

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Biological control

Definition :
Manipulation of living organisms (beneficials) to control other living organisms (pests).



Three categories of biological control methods:

1. Biological control by introduction

Introduction of a natural enemy of exotic origin to control a pest, usually also exotic, aiming at a permanent control of the pest

2. Biological control by augmentation

Augmentation of the density of natural enemies by regular releases. Releases can be inoculative (inoculation at the beginning of the season of a small number of BC agents that will reproduce), or inundative (mass releases for a single and immediate control)

3. Biological control by conservation

Methods favouring the efficiency of natural enemies already present in the system

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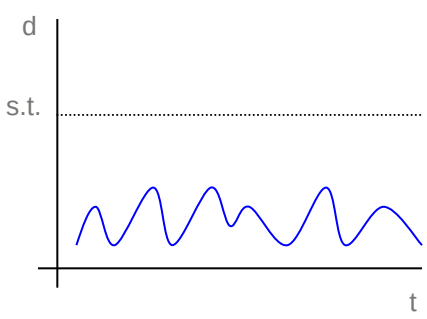
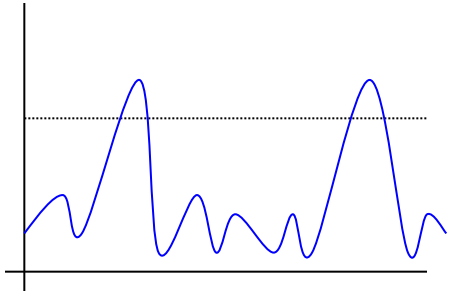
Plant-pest relationship

Situation at equilibrium:

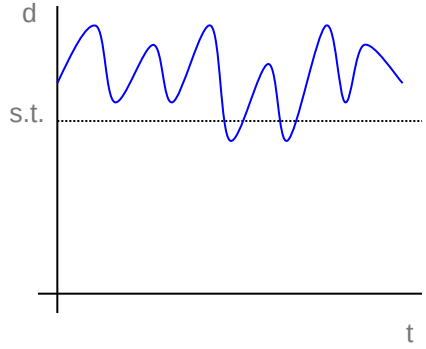
Pest populations are controlled by biotic and abiotic factors

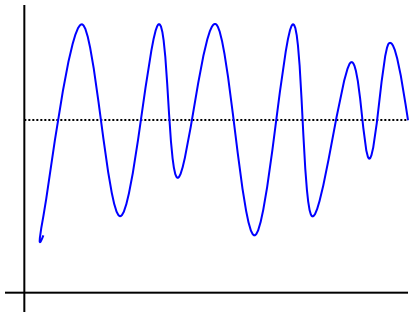




Equilibrium broken:

Outbreaks permanent or more frequent



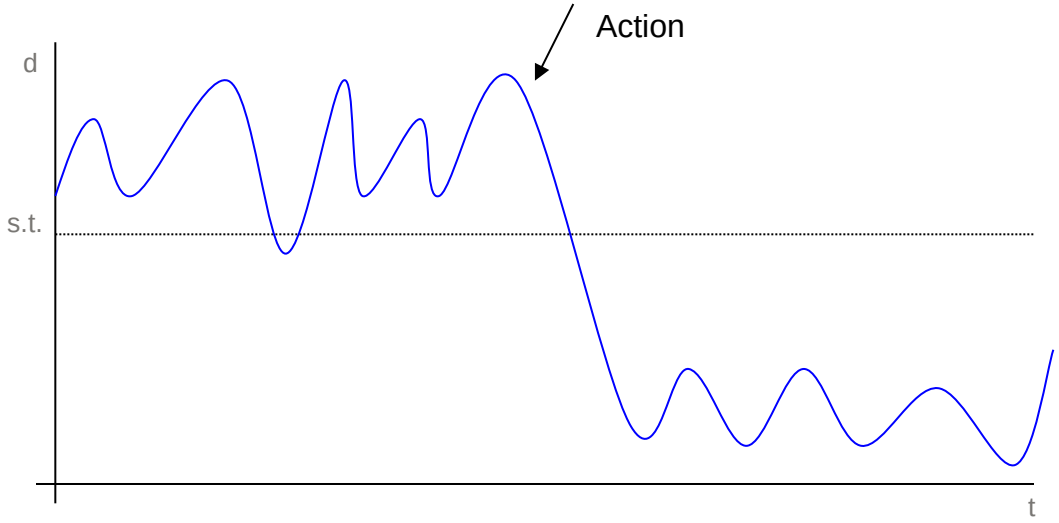


Causes of broken equilibrium:

- Host plant cultivated – artificial environment
- Pest introduced into a new environment
  - Without its natural enemies
  - On other host plants

Aim of classical biological control:

- Re-establish the plant-pest equilibrium and lower damages of the pest below a threshold that is economically or environmentally acceptable



How does CBC work ?

How does CBC work ?

- Evaluation of the problem, establishment of collaborations and literature survey

How does CBC work ?

- Choice of regions of investigation

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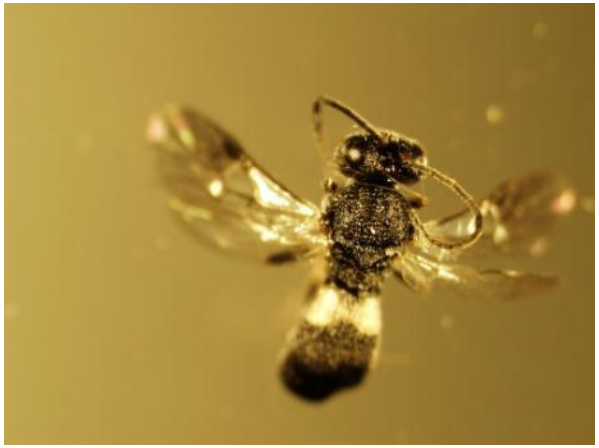
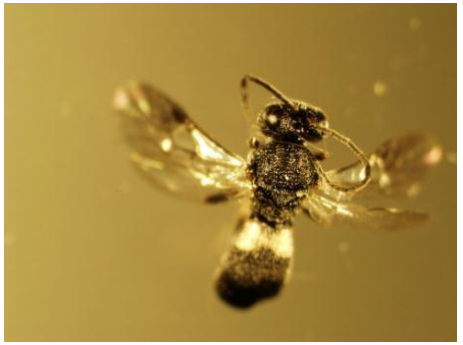
How does CBC work ?

- Inventory on natural enemies and study of their role as mortality factors in the region of origin



How does CBC work ?

- Study of the biology and ecology of the main species, especially their specificity
- Choice of species to introduce with priority list
- Petition & approval



How does CBC work ?

- Laboratory rearing
- Choice of release zones and releases

How does CBC work ?

- Verification of establishment
- Distribution of the biocontrol agent in the invaded zone
- Final evaluation of the project

Does CBC work?

Does CBC work?

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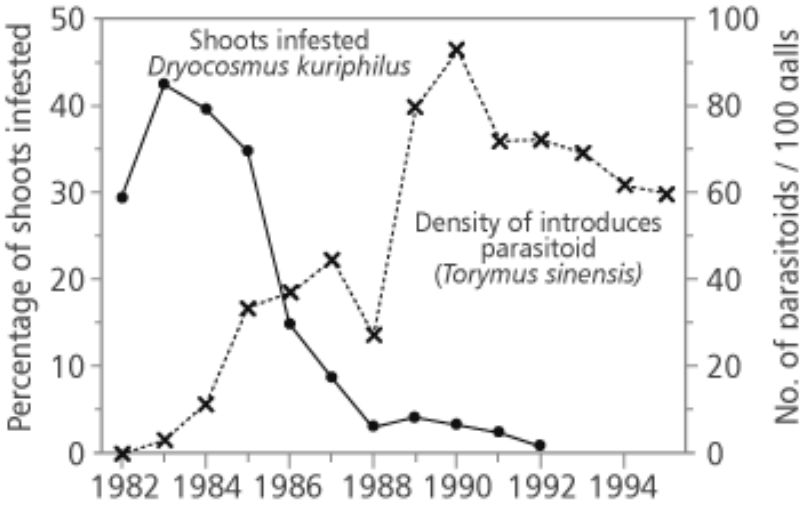
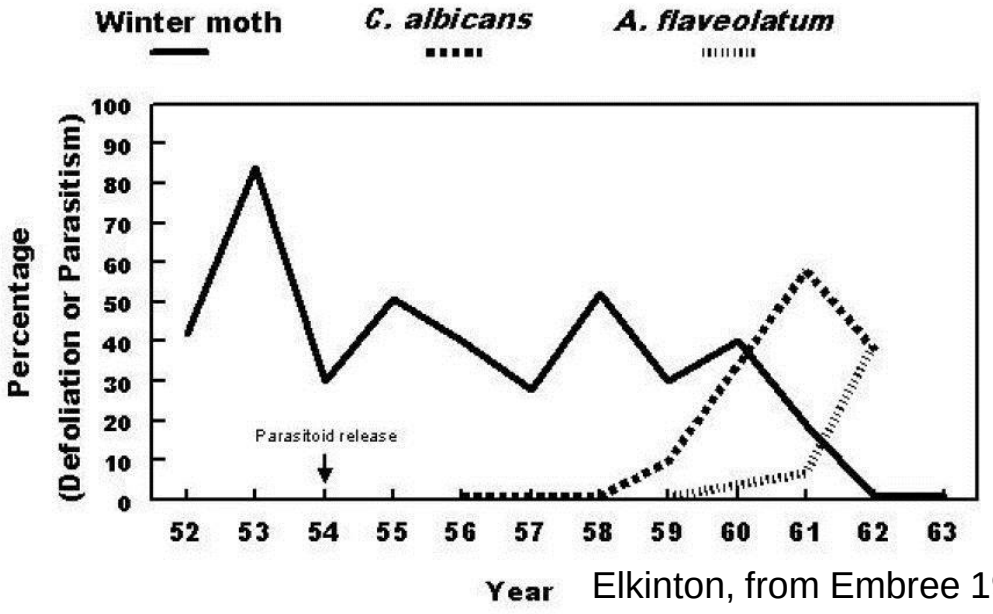
Does CBC work?



Moryia et al 1989



Elkinton, from Embree 1965

Does CBC work?

Since the success of the first biological control project in 1889:

- 6164 introductions of insect agents against 692 insect pests
- 37% led to establishment
- 10% contributed to success
- 27% of the insects controlled

Source: Biocat

Does it work better in forests and other perennial ecosystems?

(Pschorn-Walcher, Annu Rev Entomol 1977)

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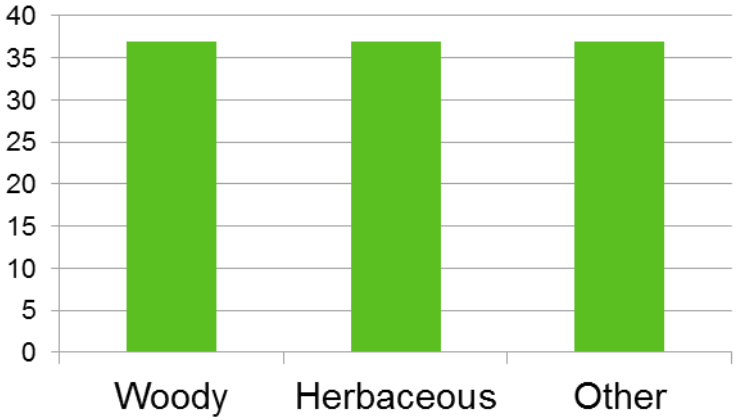
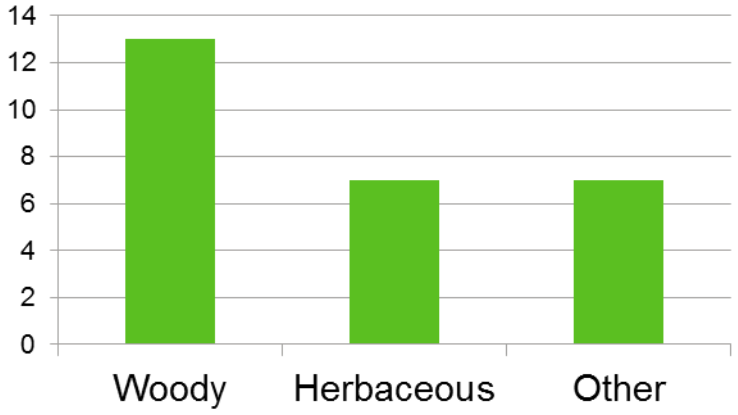
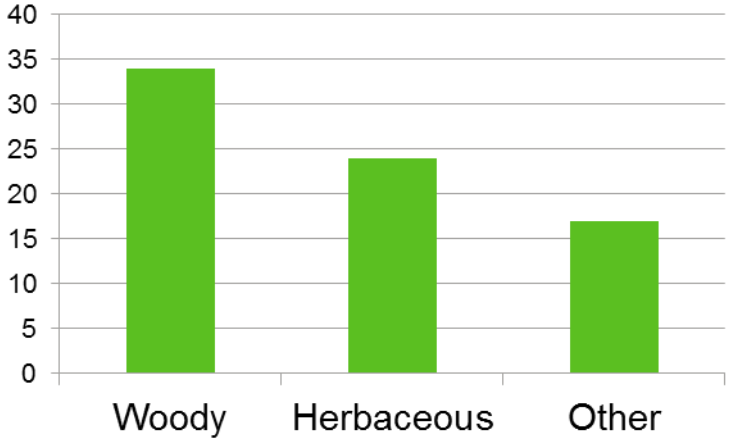


% of introductions leading to establishment



% of introductions leading to success

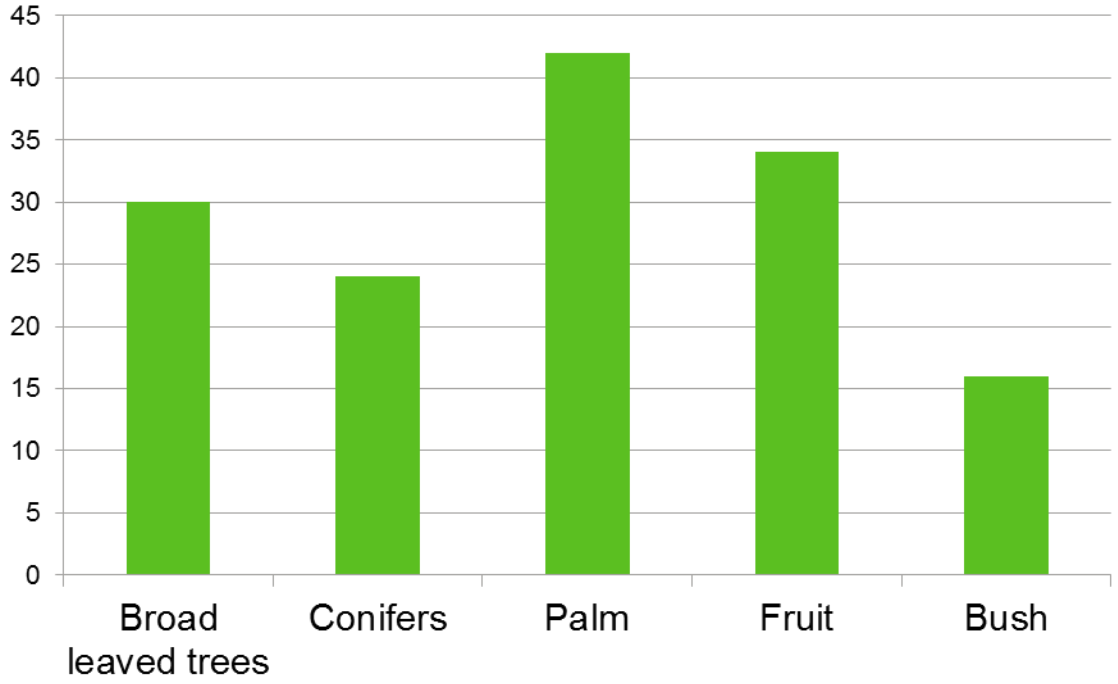


% species successfully controlled

Source: Biocat

Does it work better in forests and other perennial ecosystems?

(Pschorn-Walcher, Annu Rev Entomol 1977)



% species successfully controlled on different woody plants species

Source: Biocat

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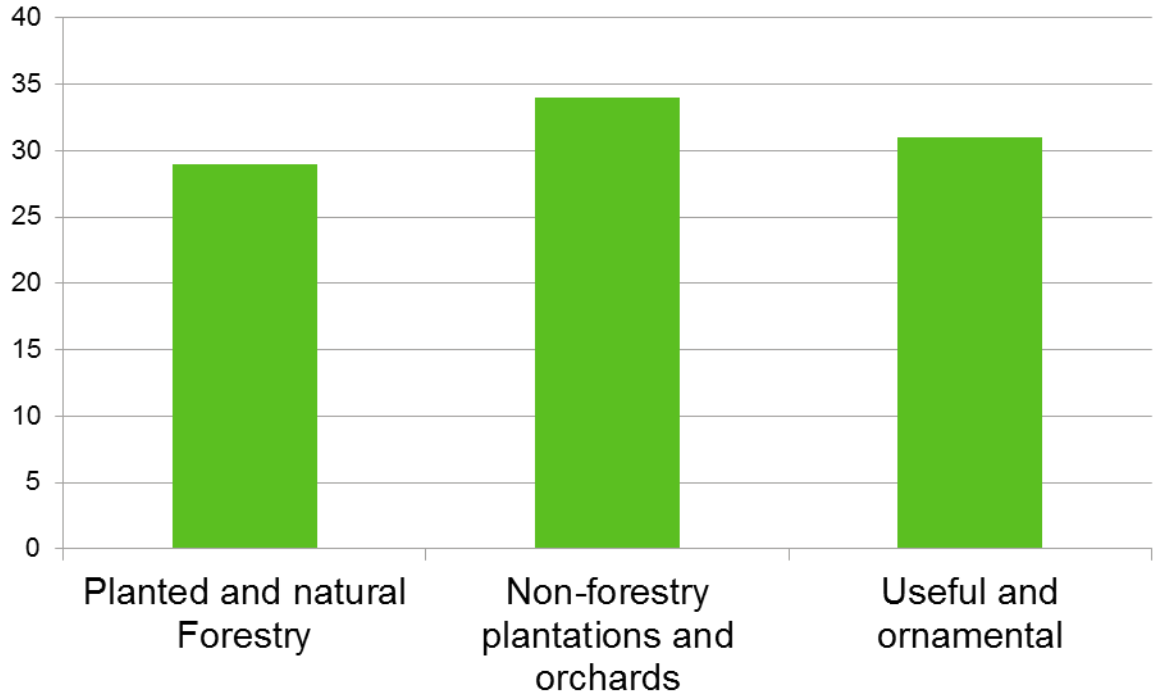

% species successfully controlled on woody species in different systems

Source: Biocat

What can be the expected economic benefits?

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CBC provides permanent control, leading to huge benefits

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CBC provides permanent control, leading to huge benefits

In Australia:

Cost:benefit ratio for biological control projects was **1:10.6** (1:2.5 for chemical control)
Some CBC projects exceeded **1:100** (Tisdell, 1990)

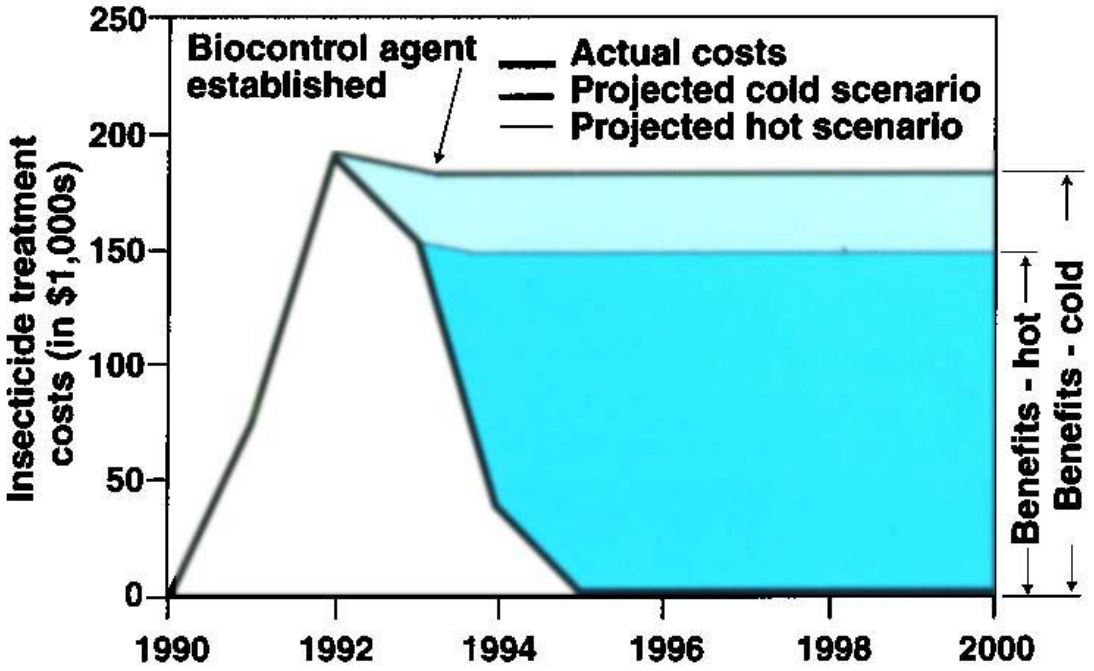
What can be the expected economic benefits?

Very few examples of calculations for tree pests

In California:

Blue gum psyllid
(Ctenarytaina eucalypti)
&
Psyllaephagus pilosus

Cost:benefit ratio
between **1:9** and **1:24**
(pesticides only)
(Dahlsten et al. 1998)



What can be the expected economic benefits?

Many examples in agriculture

In Africa:

Cassava mealy bug
(Phenacoccus manihoti)
&
Epidinocarsis lopezi

Cost:benefit ratio
between **1:200** and
1:500

Can there be also environmental benefits?

Can there be also environmental benefits?

Orthezia insignis

- Polyphagous South American scale insect introduced in St Helena, where it was threatening the endemic gumwood *Commidendrum robustum.*
- A specific ladybird, *Hyperaspis pantherina,* was introduced from South America in 1993-94.
- Scale populations strongly declined after the introduction of the ladybird and the tree is now considered as saved.

And we should not forget:

CBC is much safer for human and animal health than chemical control

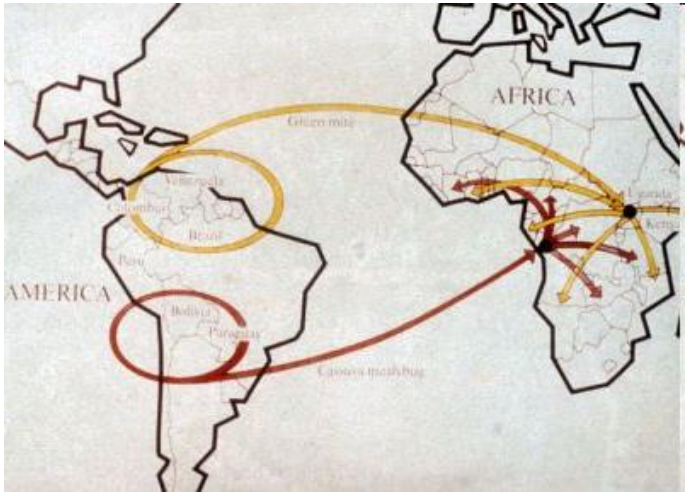
What are the risks of CBC?

What are the risks of CBC?

A CBC programme may take a long time before being successful

e.g. nearly 20 years for the biological control of cassava mealybug in Africa

Issue: finding the area of origin of the mealybug



What are the risks of CBC?

Risk of negative non-target effects

Negative effects can occur on:

- native biodiversity
- ecosystem services
- species of economic importance
- **Gained in importance since the 1980s**

What are the risks of CBC?

Risk of negative non-target effects

Some “infamous” classical biological control examples:

Mongoose (*Herpestes javanicus*)

Cane toad (*Rhinella marina*)

Predatory snail *Euglandina rosae*

What are the risks of CBC?

Compsilura concinata, parasitoid of *Lymantria dispar*

- *Lymantria dispar*, polyphagous defoliator introduced in North America in the 19th century
- CBC in the early 20th century, more than 60 spp. introduced, 12-13 established
- *Compsilura concinnata*, parasitic fly, polyphagous, causes the decline of rare saturniids.

What are the risks of CBC?

Harmonia axyridis

- Used as biological control agent worldwide in the 20th century
- Established on most continents
- Aggregates in buildings in autumn
- Feeds on grapes and gives a bad taste to wine
- Outcompetes and displaces native ladybirds

Harmonia axyridis larvae eating *Coccin*

Can CBC erradicate a pest or a non-target species?

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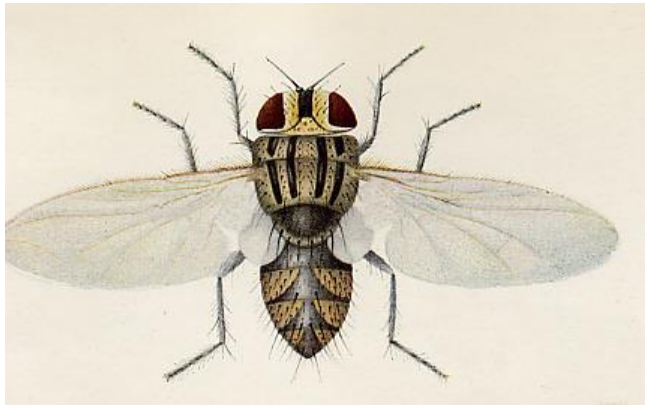
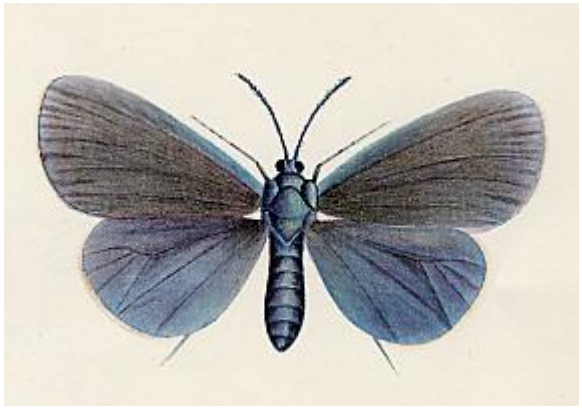
Bessa remota, parasitoid of *Levuana iridescens*



•Released in Fidji in the 1920s against the coconut moth *L. iridescens*.

•Suspected to have caused its eradication, but also that of a non-target native moth Heteropan dolens



How can the risks be mitigated?

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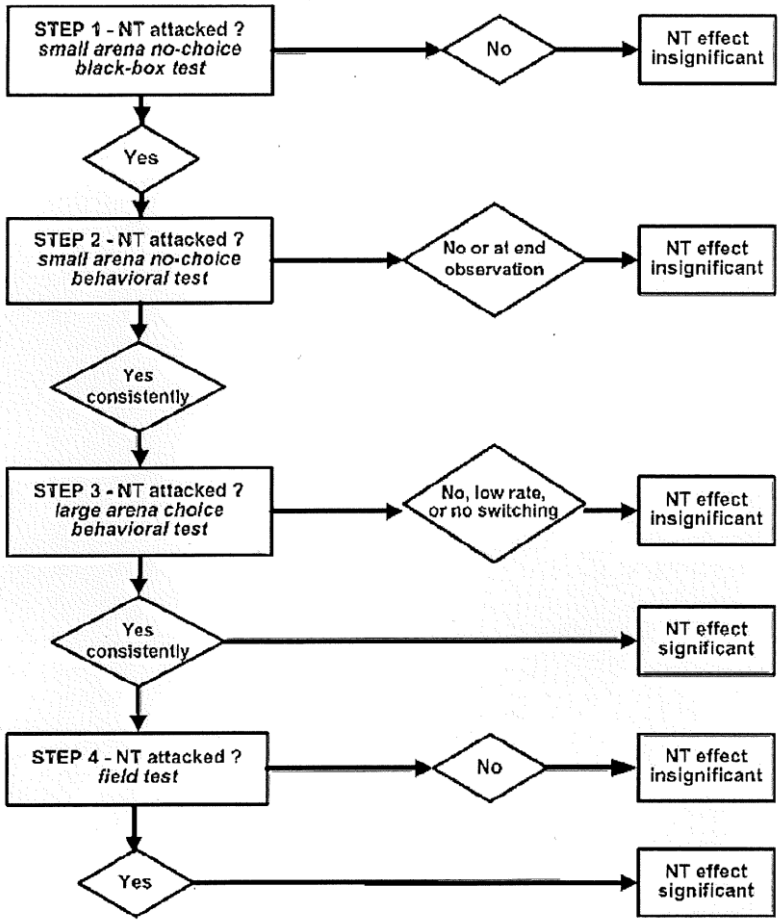
Procedures for assessing non-target effects are now well established (e.g. Van Driesche and Reardon, 2004; Bigler et al., 2006; Van Lenteren et al., 2008).

They are widely applied in weed biocontrol but not yet systematically in arthropod biocontrol



Does CBC work equally well against all insect orders?

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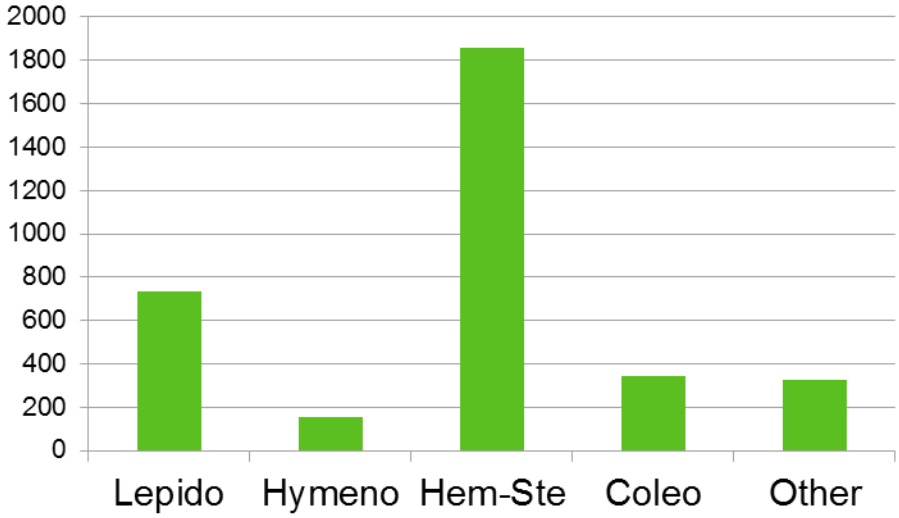
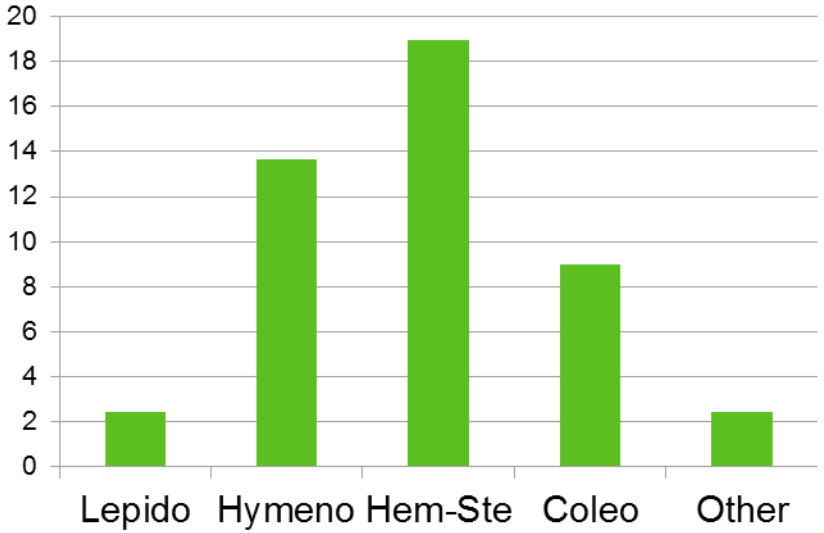


No. of CBC introductions against different insect orders on woody plants



% of introductions leading to successes . against different insect orders on woody plants

Source: Biocat

Do parasitoids and predators work equally well?

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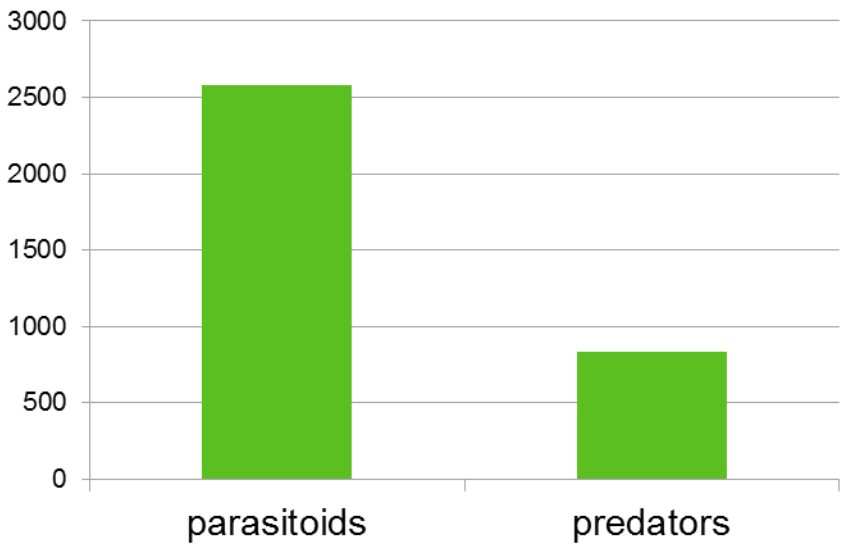
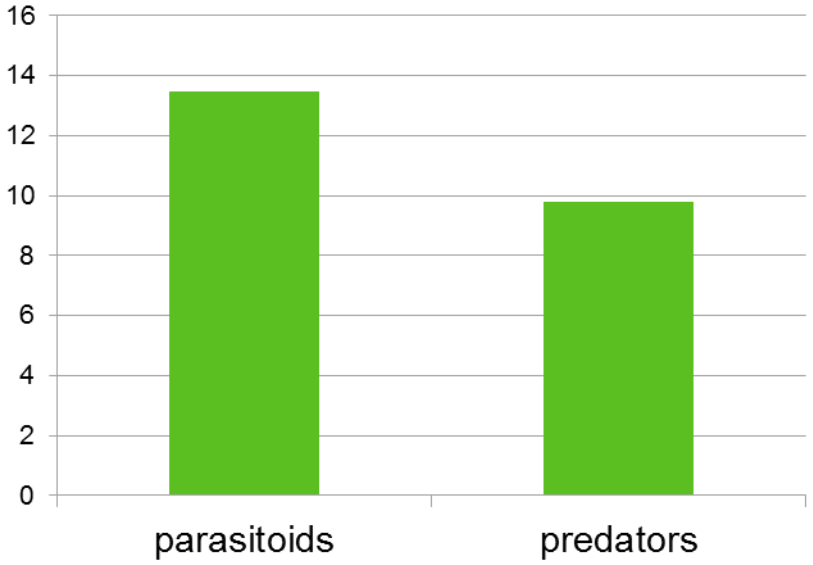


No. of parasitoid and predator introductions against insects on woody plants



%. of parasitoid and predator introductions involved in success

Source: Biocat

Has CBC declined since the rise of concerns for environmental impacts?

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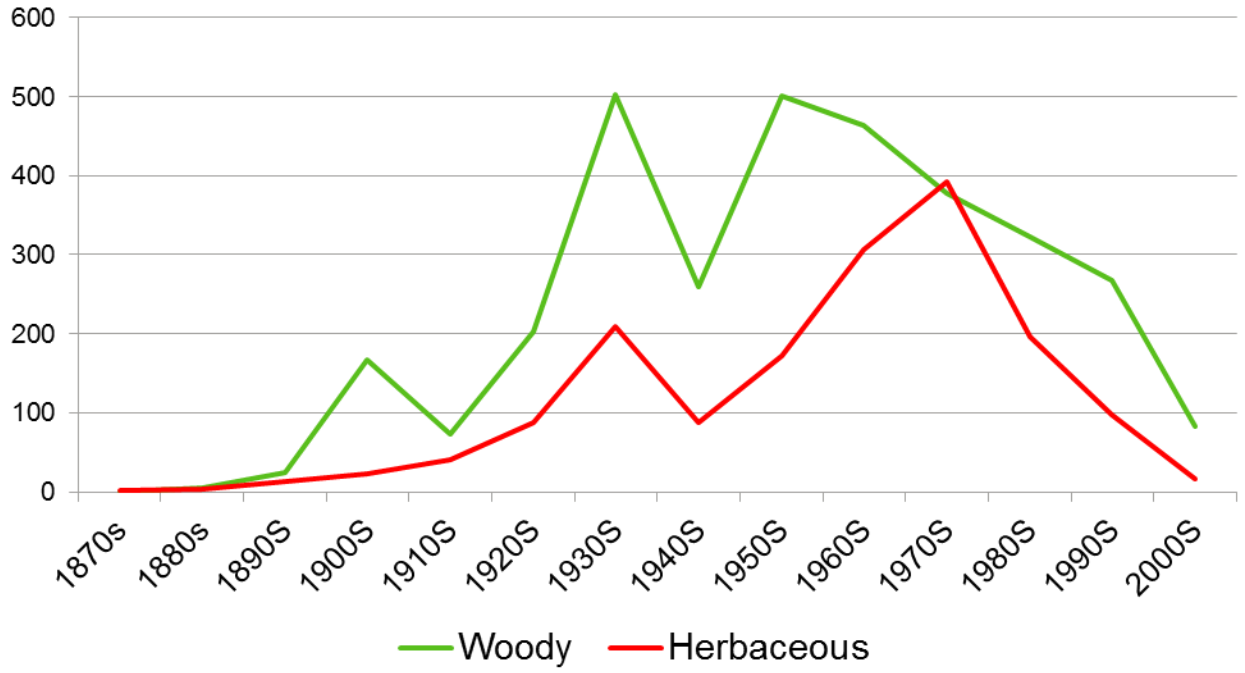

No. of CBC introductions per decade against plant pests, on woody and herbaceous plants

Source: Biocat

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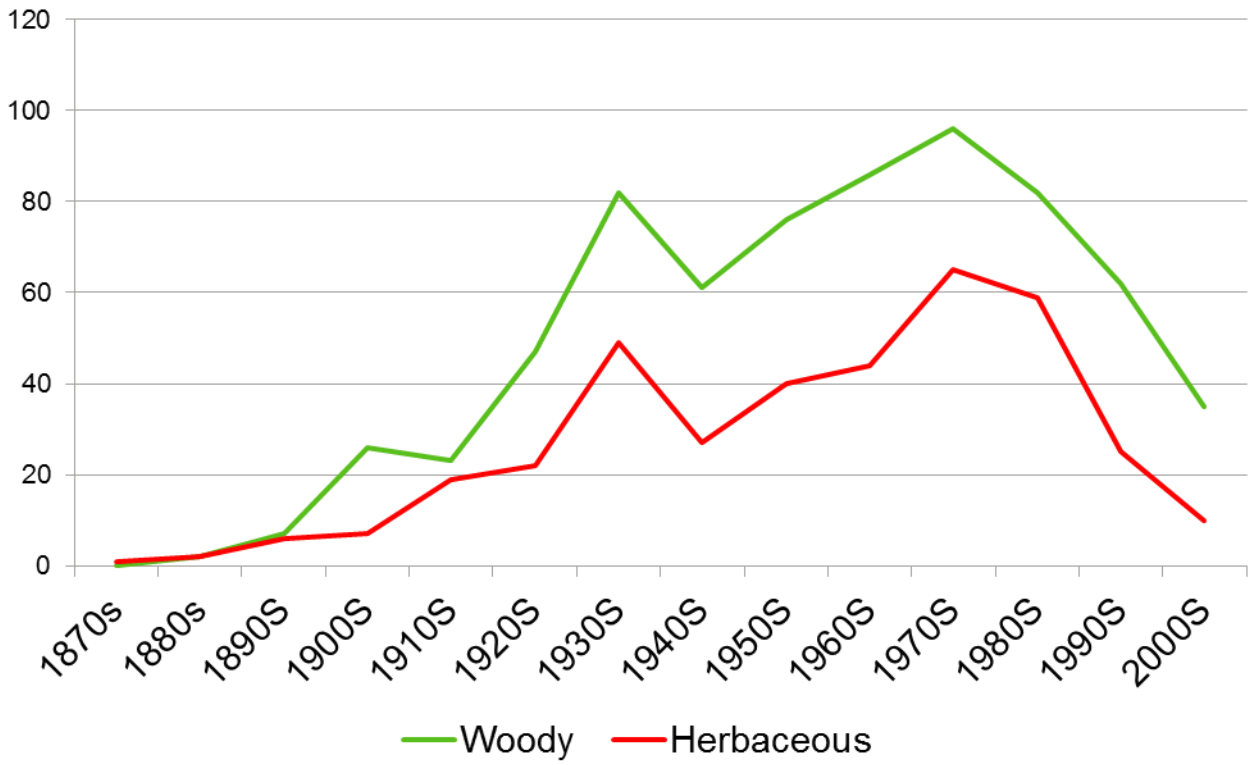

No. of plant pest species targets of CBC programmes per decade

Source: Biocat

Has CBC in forestry declined more compared to agriculture?

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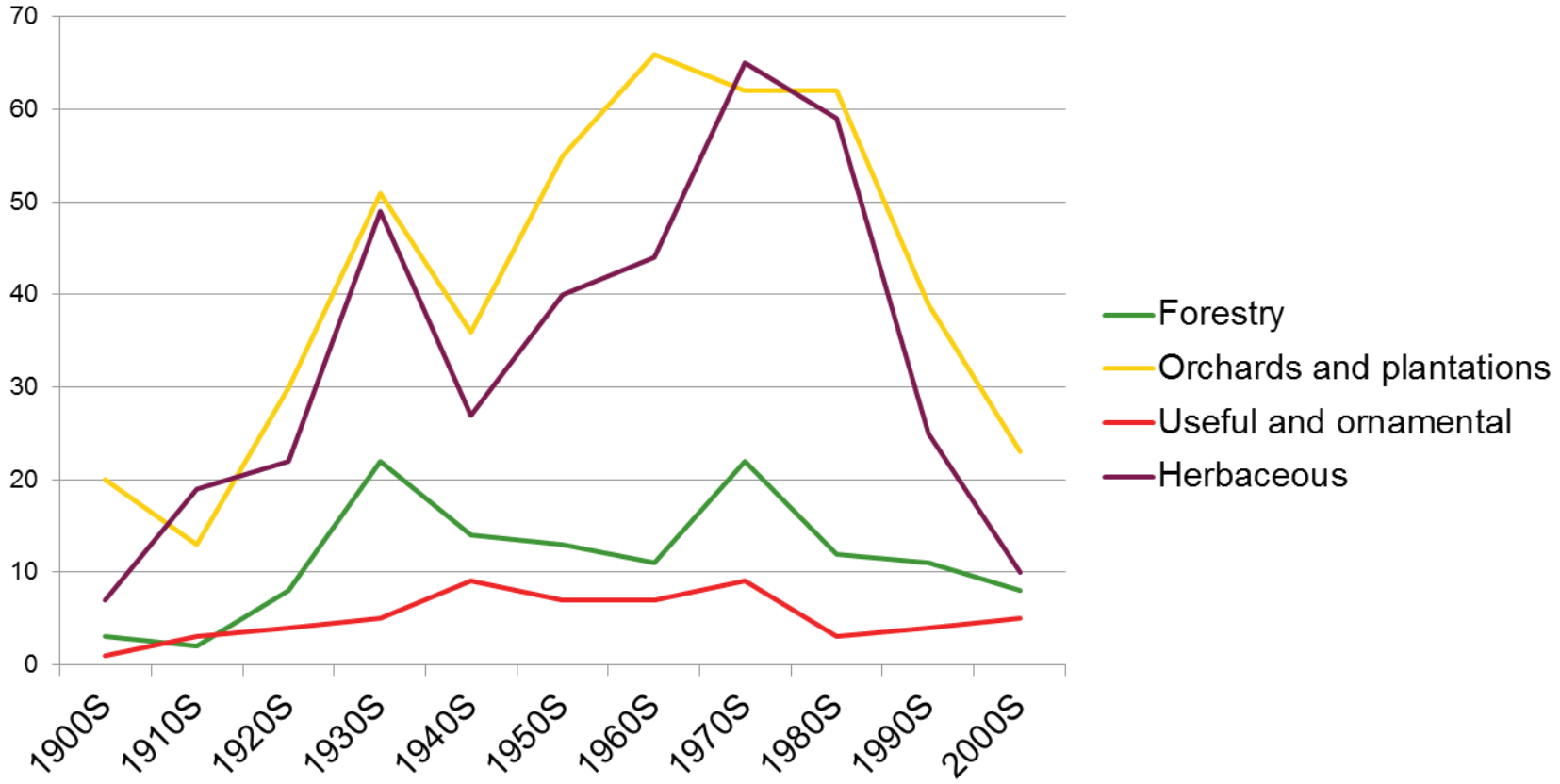

No. of plant pest species targets of CBC programmes per decade per crop system

Source: Biocat

Has CBC success rates increased with time?

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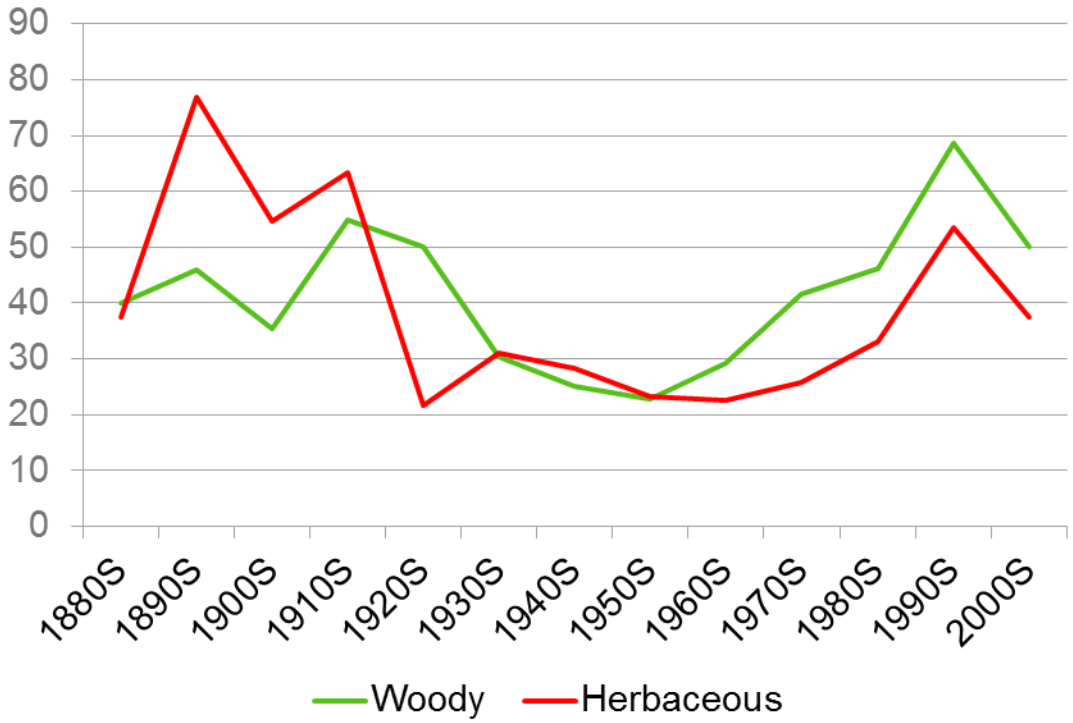
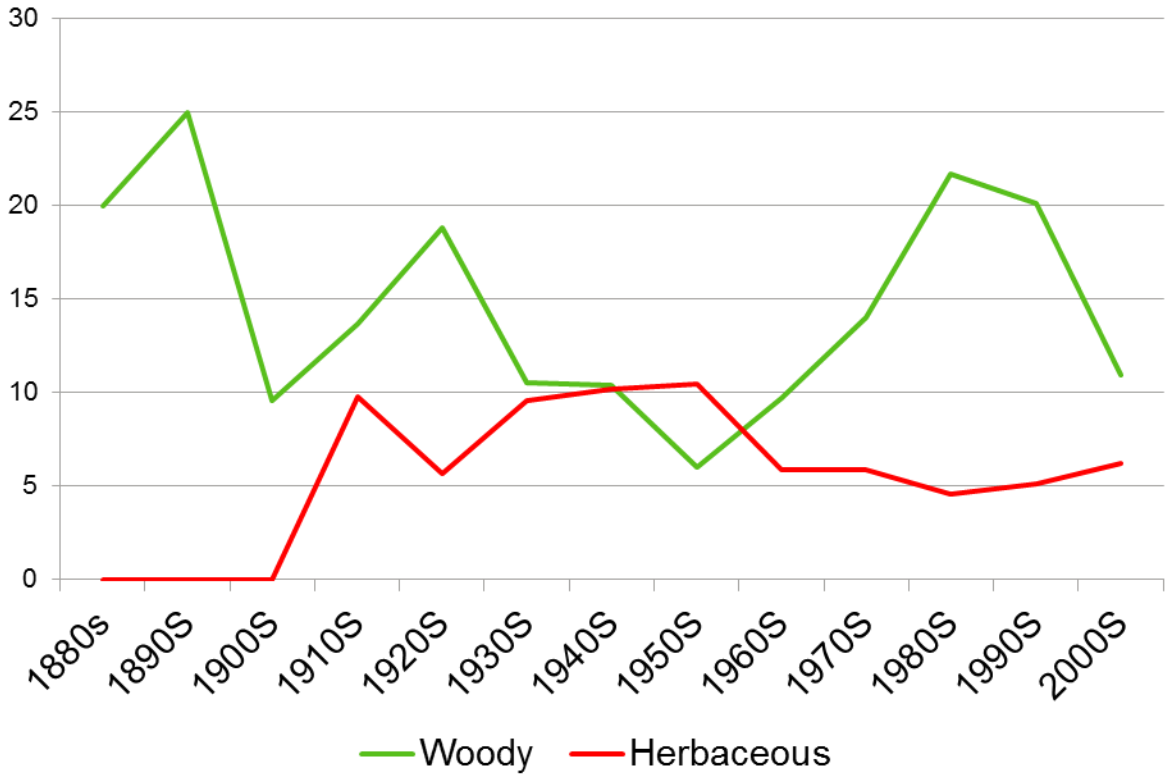


% of successful establishments per decade against plant pests, on woody and herbaceous plants

Source: Biocat

Has CBC success rates increased with time?



% of introductions of CBC agents leading to successful control per decade against plant pests, on woody and herbaceous plants

Source: Biocat

Can’t we wait until indigenous natural enemies are able to control the invasive pest?

Can't we wait until indigenous natural enemies are able to control the invasive pest?

Yes but it may happen fast, after a long time lag …. or never

The probability will be higher if:

1. The exotic insect belongs to a group of insects that are usually controlled by polyphagous natural enemies (e.g. leaf miners)
2. There are, in the region of introduction, insects that are taxonomically and ecologically closely related to the invader

Dilemma: wait or act fast?

Can’t we wait until indigenous natural enemies are able to control the invasive pest?

Ambermarked birch leaf miner

- Native of Europe, where it is very rare
- Introduced during the 20th century in Canada
- Caused very important damage on birch in urban areas
- A biological control project has been set up to find natural enemies in Europe
- Suddenly, an indigenous parasitoid, *Lathrolestes luteolator*, recruited *P. thomsoni* in Canada
- *L. luteolator* is parasitoid of *Profenusa alumna*, a closely-related oak leaf miner in North America
- Since then, this new association resulted in the total collapse of *P. thomsoni* populations in Canada

Can exotic natural enemies come by themselves (with the pest, or after)?

Can exotic natural enemies come by themselves (with the pest, or after)?

Red gum lerp psyllid
(*Glycaspis brimblecombei*)

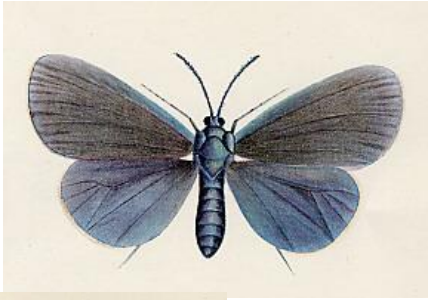
- Introduced in many parts of the world
- In several areas, it was «naturally» followed by its parasitoid *Psyllaephagus bliteus* that provided substratioal control

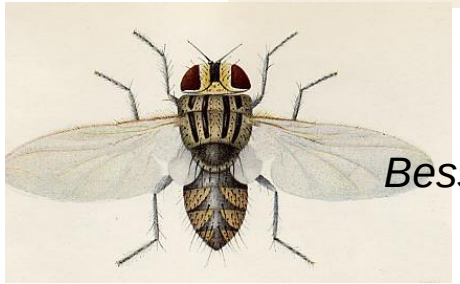
Can CBC work against native pests?

Can CBC work against native pests?

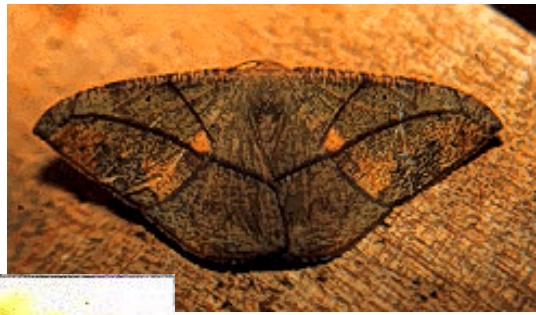
- Traditionally, CBC against exotic pests
- But, since a long time, occasionally carried out against native pests
- In the 1980's, debate re. the "*New Association*" theory suggesting that natural enemies that have never been in contact with a pest would perform better than natural enemies having co-evolved with the pest

Levuana iridescens





Bessa remota



Oxydia trychiata/

Telenomus alsophilae

Can CBC work against native pests?

In the 1980s and 1990s, CABI & CFS: 7 large biological control projects against native Canadian pests

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In the 1980s and 1990s, CABI & CFS: 7 large biological control projects against native Canadian pests

Results: 2 parasitoids introduced – no establishment.

Reason:

- Insects used are source of biological control agents are too different from target pest, resulting in parasitoids either too specific or too polyphagous (e.g. hemlock looper, bark beetles)
- Natural enemy complexes of closely related insects are very similar, no empty ecological niche and possibility of competition with native natural enemies (e.g. spruce budworm, spruce cone and seed insects)

Can CBC work when the cause of the invasive pest's success is due to the lack of resistance of new hosts rather than to enemy release?

Does CBC against exotic (forest) pests still have a future?

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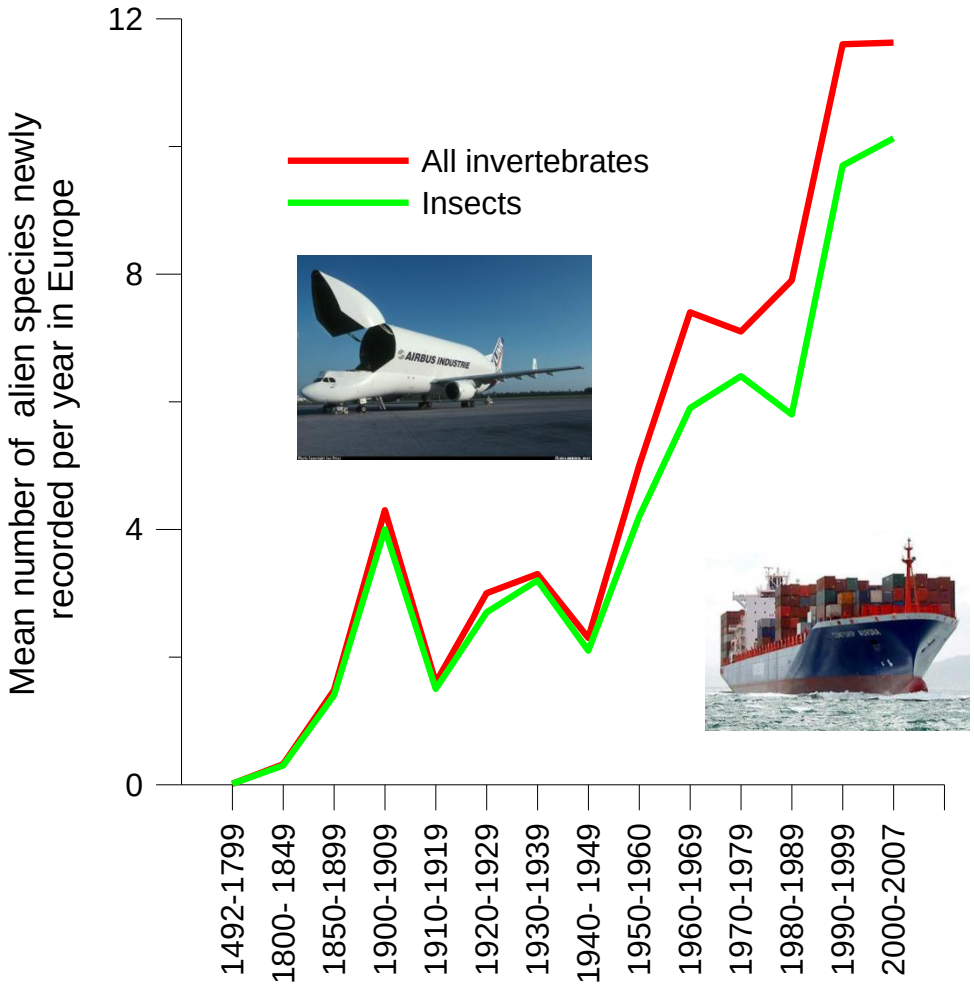

Source: Daisie project

What are the biggest threats to CBC in the future?

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- Too stringent legislations related:
  - Importation and releases of CBC agents
  - Access and benefit sharing principle (CBD)

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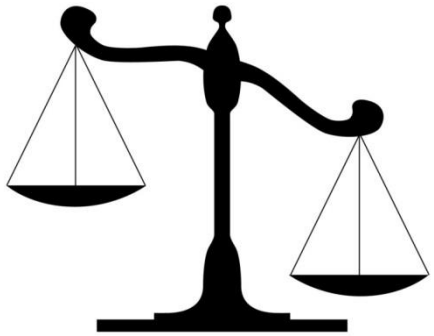
  - Access and benefit sharing principle (CBD)
- Image of CBC among some ecologists and part of the public

What are the biggest threats to CBC in the future?

- Too stringent legislations related to:
  - Importation and releases of CBC agents
  - Access and benefit sharing principles (CBD)
- Image of CBC among some ecologists and part of the public
- Irresponsable biocontrol practitioners

The risks and benefits need to be balanced

A risk assessment for alien biological control agents should also include cost/benefit analyses integrating economic, environmental and social considerations



- Negative effects of pest vs potential negative effects of BC agents
- Economic effects vs ecological effects

Thank you for your attention

Kenis, M., Hurley, B., Hajek, A., E. and Cock, M. (2017) Classical biological control of insect pests of trees - facts and figures. Biological Invasions, doi:10.1007/s10530-017-1414-4

And thanks to many websites for photos