Final Report

Project title
Preparedness in biological control of priority biosecurity threats

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Contents

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2. Short project report

2.1. Executive summary

Recent years have seen a substantial increase in invasive insect species invading countries worldwide. Many of these insect species (e.g., brown marmorated stink bug, spotted lanternfly, spotted wing drosophila) are highly polyphagous and are considered as high-risk biosecurity threats to valued plant systems in many countries and can result in multi-billion dollar losses to agriculture and horticulture industries. Classical biological control (CBC) i.e. the release of an exotic natural enemy for permanent establishment to control an exotic invasive pest, is frequently considered for sustainable management of invasive arthropod pests and has often proved highly cost effective. However, the severity and imminent nature of some new high-risk insect threats means that it would be highly advantageous if we could avoid waiting for a pest to arrive before adopting CBC strategies. Traditionally there is a delay of several years before a biological control agent (BCA) can be introduced while research and biosafety testing is conducted during which time the invasive pest becomes established and spreads. Therefore, there is a need for a pre-emptive approach to develop CBC for invasive insect pests prior to their arrival and establishment into new environments.

Pre-emptive biocontrol is a novel approach that has the potential to increase effective preparedness for a potential invasion of insect pest species. This could, for example, accelerate response to invasive pests in urban areas before they spread to agricultural areas. Natural enemies can potentially be selected, screened and pre-approved for release before an anticipated pest invasion meaning that a natural enemy could be released against a target pest at a much earlier point in the emerging management programme. This could result in significantly reduced pest densities and rates of spread, reducing the economic or environmental damage associated with the pest. However, such an approach may not always be feasible. Therefore, we need to define the fundamental prerequisites, principles and objectives of best-practice pre-emptive biocontrol risk assessment, in order to assess the feasibility of conducting pre-emptive biocontrol for high-risk pests and to develop robust guidelines.

In this project we 1) reviewed a number of high-risk priority pests and their potential for pre-emptive biological control options, 2) produced a standard guideline and framework to assess feasibility to conduct pre-emptive risk assessment for the introduction of BCAs, and 3) established a network and repository for the exchange of information on biocontrol. We conclude that all work conducted in this project was highly valuable to all participant countries, and that the developed standard guidelines and framework are suitable to be used by researchers, from any country, and are recommended to be used to assess feasibility to conduct pre-emptive risk assessment against high-risk pests. We hope this project provided with important contribution for the successful implementation of the novel pre-emptive biological control approach for the benefit of the biocontrol community.

2.2. Project aims

Non-native invasive species threaten global biodiversity and food security resulting in substantial economic costs reported to be in excess of US$100 billion annually. Although practices are in place for the prevention and early detection of invasive species, management, usually eradication, tends to be reactive once the pest arrives and an outbreak is discovered. However, if the invasive pest establishes, long-term management is usually adopted for population suppression and slowing the rate of spread.

Identifying future risks and preparing to manage those risks are becoming increasingly important to help mitigate the impact that invasive species have on ecosystems in a new environment. Classical biological control, the introduction of a non-indigenous biological control agent (BCA), is recognised as a key strategy to manage invasive insect pest populations. However, the deliberate introduction of an exotic BCA is subject to regulatory measures which may take years before approval is granted, giving additional time for an invasive pest to establish, build up population density and spread.

A pre-emptive classical biocontrol programme has resulted in the New Zealand Environmental Protection Authority approving the conditional release of a parasitic wasp *Trissolcus japonicus* for the control of the brown marmorated stink bug (BMSB), *Halyomorpha halys*, in the event of the incursion and establishment of this pest. Pre-emptive biocontrol is a novel approach that has the potential to enhance effective preparedness for a potential invasion of pest species. Natural enemies can be selected, screened and pre-approved in the eventuality of a pest invasion so that release can be much earlier which may significantly reduce pest densities and slow rates of spread, reducing the economic or environmental damage associated with the pest. Preparedness for a pest incursion is a management strategy that could be widely adopted.

This project aimed to establish a biological control network to share knowledge and information on priority biosecurity threats and potential BCAs to increase preparedness for incursions of invasive invertebrate species. This will be achieved through:

- Reviewing priority pests and the potential for pre-emptive biological control options.
- Establishing a network and repository for the exchange of information.
- Producing a standard to assess feasibility to conduct pre-emptive risk assessment for the introduction of BCAs.

2.3. Description of the main activities

2.3.1. Project meetings

Regular (3-monthly) on-line project meetings were held throughout the project period. A hybrid meeting was held at Agroscope, Zurich in February 2023.

i. Kick-off meeting

Two KO meetings were held, Friday 11th and 18th June 2021 to enable all partners to attend.

ii. project meetings

- 22nd September 2021
- 8th December 2021
- 9th March 2022
- 8th June 2022
- 7th September 2022
- 7th December 2022
- 7th – 8th February 2023 (Agroscope, Zurich, in-person and on-line)
- 5th April 2023
- 28th June 2023 (final project meeting)

2.3.2. Priority biosecurity threats and biological control agents

The key priority non-native invasive pests that present biosecurity threats to partner countries were identified through national and international pest risk registers and tools (e.g., EPPO Reporting Service, Defra's UK Plant Health Risk Register, CABI's Plantwise Knowledge Bank) as well as using species and population distribution.
These pests were catalogued and categorised according to risk and partner country interest.
Fact sheets for 30 high-risk pest species, describing current classical biological control (CBC) efforts and suitable natural enemies for CBC, were jointly drafted by project partners.
The fact sheets were used to identify the most promising biological control agents (IBCAs) that could serve as suitable candidates for CBC in partner countries.

2.3.3. Guidelines to assess feasibility of pre-emptive risk assessment

The introduction of an exotic BCA is subject to regulatory measures including a risk assessment of the environmental effects of such introductions.
A general guideline to assess the feasibility to conduct pre-emptive biocontrol risk assessment and a decision framework, suitable for all partner countries, was developed. Current risk assessment protocols for exotic BCA introductions from partner countries, as well as the EPPO decision support scheme were reviewed and evaluated during the development of the guidelines and framework, so that the characteristics and prerequisites that need to be met for pre-emptive biocontrol risk assessment to be feasible could be agreed. From this guidelines for assessing feasibility of pre-emptive risk assessment were drafted and submitted to a pre-emptive biocontrol Special Issue in *Biological Control* (see below for details). The final guidelines and decision framework were used to conduct a number of case studies with different high-risk pest species, where the feasibility to conduct pre-emptive risk assessment for each pest species was assessed.

2.3.4. Biocontrol network and dissemination

2.3.4.1. Website

To develop a biocontrol network the Institute for Plant & Food Research (PFR) of New Zealand are hosting a biocontrol website (https://biologicalcontrol.eu/). This website will be used as a repository for the open access sharing of project documents (fact sheets, pre-emptive biocontrol standard protocol, pre-emptive risk assessments) and facilitate a wider network of stakeholders with interests in biological control. The website will also be used to provide all information about this Euphresco project (i.e., rationale, aims and objectives) as well as basic information about the institutions of partner countries and the researchers that were part of this project.

2.3.4.2. Presentations

Project outputs have been or will be disseminated through conference/workshop presentations and publications in peer review journal.

2.3.4.3. Publications

Dr. Gonzalo Avila was invited to put together and be guest editor for a special issue in *Biological Control* entitled “Pre-emptive classical biological control: a novel approach to increase preparedness for potential biosecurity threats”. The guidelines and decision framework developed in this project as well as some of the risk assessments and or factsheets are expected to be published in the special issue.

2.4. Main results

2.4.1. Priority biosecurity threats and biological control agents

A list of 73 priority pests was compiled using priority lists provided by each partner for their respective region. A final list of 30 priority pests with interest from two or more partner countries were selected (Table 1).

Table 1. Species names of selected priority pests categorised by order and family.

Coleoptera	
Buprestidae	*Agrilus planipennis, Agrilus anxius, Agrilus bilineatus*
Cerambycidae	*Anoplophora glabripennis, Anoplophora chinensis, Aromia bungii, Saperda candida*
Chrysomelidae	*Epitrix* spp.
Curculionidae	*Conotrachelus nenuphar*, *Anthonomus eugenii*, *Ips* spp.
Diptera	
Agromyzidae	*Liriomyza sativae*
Drosophilidae	*Drosophila suzukii*
Tephritidae	*Bactrocera dorsalis*, *Rhagoletis pomonella*, *Anastrepha ludens*, *Bactrocera zonata*
Hemiptera	
Cicadellidae	*Homalodisca vitripennis*
Fulgoridae	*Lycorma delicatula*
Liviidae	*Diaphorina citri*
Pentatomidae	*Halyomorpha halys*
Triozidae	*Bactericera cockerelli*
Lepidoptera	
Erebidae	*Lymantria dispar*, *Lymantria monacha*
Lasiocampidae	*Dendrolimus sibiricus*
Noctuidae	*Spodoptera frugiperda*, *Spodoptera littoralis*
Notodontidae	*Thaumetopoea pityocampa*, *Thaumetopoea processionea*
Tortricidae	*Thaumatotibia leucotreta*

Fact sheets describing the pest problem, history of classical biological control against each pest and most promising natural enemies for classical biological control were produced for the selected pests. An example of a fact sheet is shown in appendix 1. All facts sheets will be made available via the project website (https://biologicalcontrol.eu/).
Potential classical biological control agents against the selected priority pests were identified from the fact sheets and used to test the decision flowchart from the standard protocol for pre-emptive risk assessment (see below for details).

2.4.2. Guidelines to assess feasibility of pre-emptive risk assessment

Guidelines and decision framework to assess the feasibility of starting pre-emptive risk assessments of classical biological control agents were produced. The contents of this document are shown in Figure 1. Both the guidelines and decision framework were recently submitted for publication in the up-coming Biological Control special issue on pre-emptive classical biological control.

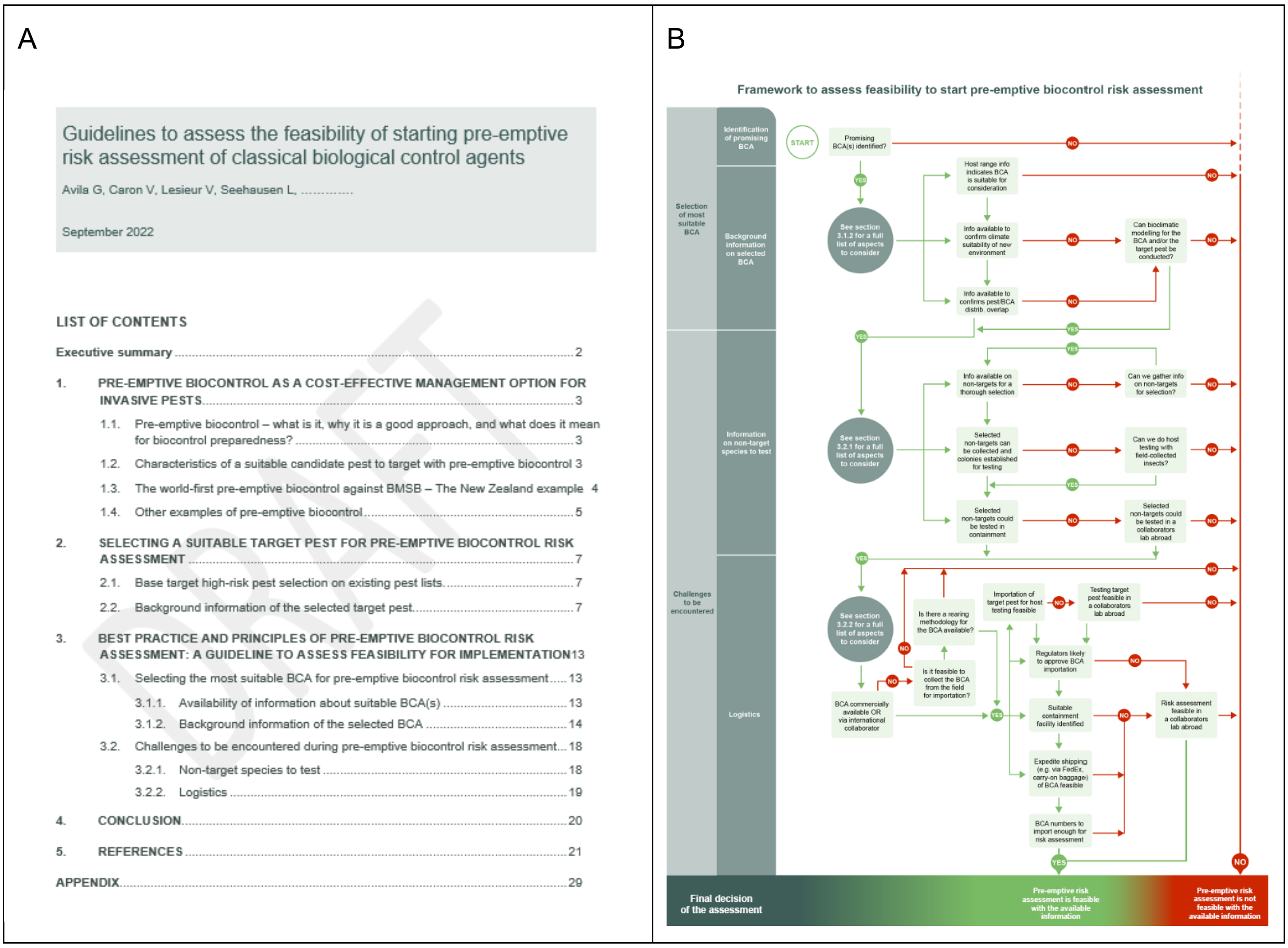

Figure 1. Table of contents of the standard guidelines for pre-emptive risk assessment of classical biological control agents (A) and the decision framework to assess its feasibility to be started (B).

The decision framework was tested for selected biological control agents by different partners resulting in both positive and negative outcomes (i.e., pre-emptive risk assessment either feasible or not feasible). Examples of the feasibility studies will be submitted for publication in the Biological Control special issue.

As an example, in a UK context, feasibility studies produced a positive outcome for *Tamarixia triozae* (Hymenoptera: Eulophidae) against the potato psyllid (*Bactericera cockerelli*), but recommended climatic modelling as part of the risk assessment. In contrast, a negative decision was the result of testing *Atanycolus charus* (Hymenoptera: Braconidae) against the bronze birch borer (*Agrilus anxius*). The reasons for this negative outcome were:

- Insufficient data for climatic modelling for the BCA.
- No clear evidence that *A. charus* can impact *A. anxius* populations, and only limited information available on rates of parasitism.

- Insufficient information available on the biology, reproductive potential and life cycle of the *A. charus*.
- The BCA is not commercially available and currently there are no collaborations in place that would allow for the provision of the BCA for pre-emptive risk assessment.

2.4.3. Biocontrol network and dissemination

2.4.3.1. Project website

A project website has been created (https://biologicalcontrol.eu/, Figure 2) which will host project documents including fact sheets, pre-emptive risk assessment feasibility studies and open access publications.

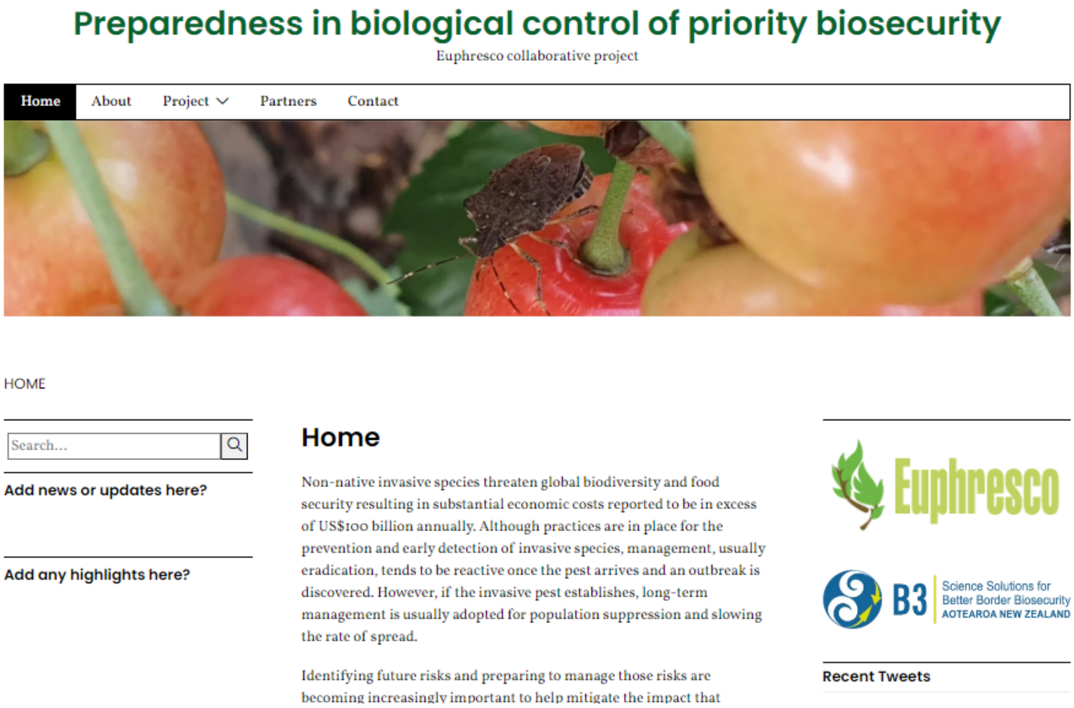

Figure 2. Home page of the biological control website.

The website will serve to establish a biological control network beyond the project partners for information sharing. Stakeholders will be able to register their interest and post comments.

2.4.3.2. Presentations

Project partners have or are planning presentations at a variety of meetings/conferences.

- 4th International Congress on Biological Invasions (ICBI) 2023 – Christchurch, New Zealand. Gonzalo Avila (PFR) presented an overview of the project during a talk about pre-emptive biological control
- EU Green Week (EU Green Week 2023 (europa.eu)). Neil Audsley (Fera) presented an overview of the project at a webinar during EU Green Week.
- The IOBC WPRS working group meeting on Benefits and Risks of Exotic Biological Control Agents, University of Aveiro, Portugal, September 2023. Neil Audsley (Fera) will present an overview of the project and pre-emptive biological control in the UK. Kiran Horrocks (Agroscope) will present an overview of applying the Euphresco decision framework using emerald ash borer as a case study.
- Third International Congress of Biological Control (ICBC3) (San José, Costa Rica - 24-27 June 2024). Gonzalo Avila (PFR) will propose a panel discussion on pre-emptive biocontrol for the ICBC3. He will give a talk about pre-emptive biocontrol, its status in NZ, and an overview of the project. Jana Collatz (Agroscope) will present on case studies using the

decision framework on parasitoids of emerald ash borer, Japanese beetle and red necked longhorn beetle.
- International Conference of Entomology (ICE) 2024 (Kyoto, Japan – 25-30 August 2024). Gonzalo Avila (PFR) will present presented an overview of the project and pre-emptive biocontrol in New Zealand during a talk about pre-emptive biological control.

2.5. Conclusions and recommendations to policy makers

- Recent years have seen a substantial increase in invasive insect species invading countries worldwide. Many of these insect species are considered serious high-risk biosecurity threats to valued plant systems in many countries.
- Pre-emptive biocontrol is a novel approach that has the potential to increase effective preparedness for a potential invasion of insect pest species.
- Pre-emptive biocontrol provides an opportunity to develop classical biological control (CBC) for invasive pests prior to their arrival into a new country, where natural enemies can be selected, screened in containment or overseas, and potentially pre-approved prior to pest establishment, thus, improving CBC efficiency.
- However, such an approach may not always be feasible and may also depend on authorization processes in various countries.
- In this collaborative project we developed a standard set of guidelines and a decision framework to assess the feasibility of starting pre-emptive biological control risk assessment. We also produced a number of factsheets of high-risk pests and their most promising natural enemies. The developed guidelines and framework were tested by conducting a series of feasibility studies for pre-emptive risk assessments for potential BCAs of high-risk pests. Such risk assessments were conducted in collaboration with all project partners, to ensure that results are appropriate for each participating country.
- We concluded that all work conducted in this project was highly valuable to all participant countries, and that the developed standard guidelines and framework are suitable to be used by researchers, from any country, and are recommended to be used to assess feasibility to conduct pre-emptive risk assessments for potential BCAs of high-risk pests.
- It is highly important to identify high-risk biosecurity threats and future pest risks and to prepare for managing those risks to help mitigate the impact that the establishment of an invasive species has on native ecosystems.
- Pre-emptive classical biological control should be considered as part of any action plan to be effectively prepared for invasive species so that candidate biological control agents can be pre-approved before a non-native pest incursion.
- Instigating classical biological control as soon as an invasive pest is detected will help mitigate the risk by preventing its growth and spread thereby reducing costs for control, compared to traditional classical biological control programmes which are initiated for long-term management once a pest has established.
- The guidelines developed in this project should be used to determine the feasibility of pre-emptive biological control as part of a management strategy for high-risk non-native species.

2.6. Benefits from trans-national cooperation

- Collaboration with biocontrol experts from over 10 participating countries was highly beneficial, since this provided opportunity for an open debate and forum to discuss pre-emptive biocontrol, its benefits, and the best ways for its successful implementation.
- All outputs produced in this project (i.e., factsheets, guideline and framework for pre-emptive biocontrol risk assessment, case studies, and website) were possible because of a strong and committed collaborative team.
- The project allowed the development of a strong and cohesive network of biocontrol researchers, and we expect to keep in contact and develop more collaborative projects.

- The coordinated approach used and the website developed increased the visibility of pre-emptive biocontrol, which may promote the development of new collaborations outside the current group.
- Reciprocating knowledge and expertise from different countries and regions (e.g. between Europe and Australasia) on exotic pests and biological control agents.
- Since it involves the transfer of biocontrol agents from one region to the other, classical biological control can only be conducted through trans-national collaborations.
- So far, European countries do not have common legislations and practices regarding CBC whereas introduced agents don’t recognize borders. Thus, a trans-national collaboration within Europe is essential to ensure safe, efficient and cost-efficient CBC practices at continental scale.

3. Publications

3.1. Article(s) for publication in the EPPO Bulletin
None.

3.2. Article for publication in the EPPO Reporting Service
None.

3.3. Article(s) for publication in other journals

Dr. Gonzalo Avila will guest edit a special issue of *Biological Control* entitled "Pre-emptive classical biological control: a novel approach to increase preparedness for potential biosecurity threats".
Project related manuscripts include:

- Avila G. *et al*. (2023). Guidelines to assess the feasibility of starting pre-emptive risk assessments of classical biological control agents. *Biological Control* https://www.sciencedirect.com/science/article/pii/S1049964423002402.
- Horrocks *et al*. Assessment of parasitoids for emerald ash borer pre-emptive biocontrol.
- Horrocks/Seehausen *et al*. Modelling potential distribution of emerald ash borer parasitoids in Europe.
- Horrocks *et al*. Review on biology of *Aromia bungii.*
- Kenis *et al*. Potential for classical biological control of *Popillia japonica* in Europe.

4. Open Euphresco data

Priority pest fact sheets and feasibility studies for pre-emptive biological control risk assessments will be made available via the project web site: https://biologicalcontrol.eu/.

Appendices

Appendix 1 – Example fact sheet

Japanese beetle (*Popillia japonica* Newman)

Introduction

The Japanese beetle (JB), *Popillia japonica,* is native to Japan and the Russian Far East. It was accidentally introduced to eastern USA in the early 20th century, then into the Azores in the 1970s and, in 2014, it was found in Northern Italy, from where it is presently spreading (EPPO 2022). In eastern North America, it causes considerable damage to golf courses, lawns, pastures and herbaceous and woody landscape plants, and similar damage are now being observed in Italy, where JB population levels have become very high. The host range includes more than 300 different ornamental and agricultural plant hosts. Adults feed on foliage, flowers, and fruits, and larvae on grass roots (Potter and Held, 2002). Infestations of JB also have an indirect economic impact on nurseries because of the cost of applying the phytosanitary measures adopted to prevent the movement of plants with soil containing beetle larvae.

History of classical biological control against *Popillia japonica*

During 1920-1933, the USDA imported dozens of parasitoids of *P. japonica* and related scarabs from the orient and Oceania and released 14 species into infested areas in the USA (Fleming, 1968; Clausen 1978). Only five parasitoids became established. The most widely distributed are *Tiphia vernalis*, a wasp that parasitizes overwintering grubs in spring and *Istocheta aldrichi*, a tachinid fly that parasitizes adults. *Tiphia vernalis* is well established throughout the beetle-inhabiting areas in the USA but has not yet reached Canada. *Istocheta aldrichi* has long been restricted to the New England states, but has recently become established in North Carolina, Michigan, Minnesota and Missouri, USA (Jackson and Klein, 2006) and in Quebec, Canada (Gagnon and Giroux, 2019). In the USA, it is often considered that these parasitoids do not provide sufficient control (Potter and Held, 2002). However, parasitism by *I. aldrichi* seems to increase since the beetle has spread further north. Furthermore, in its area of origin in Japan, parasitism is much higher, and the beetle is considered a minor pest. Therefore, classical biological control should still be considered in newly invaded areas.

Most promising natural enemies for classical biological control

Tiphia vernalis Rohwer (Hymenoptera: Tiphiidae): the adult wasp locates third instar larvae by kairomones in spring. The wasp uncovers the subterranean larva, paralyzes it, and lays an egg on the exterior of the larva. The egg will later hatch and burrow into the host to feed (Rogers and Potter 2003). *Tiphia vernalis* is not abundant in Japan and was originally collected from other *Popillia* spp. in China and Korea (Fleming, 1968; Clausen 1978). It is known to attack at least one native species in the USA, *Anomala orientalis* (Reding and Klein 2001). *Tiphia vernalis* can parasitize up to 60% of JB larvae, but further studies show that preventative applications of imidacloprid insecticides during their flight period inhibit the wasps' ability to parasitize (Clausen, 1979; Rogers and Potter 2003).

Tiphia popilliavora Rohwer (Hymenoptera: Tiphiidae): this species was collected from JB in Japan and the other known hosts are other *Popillia* spp. in Asia. In contrast to *T. vernalis*, *T. popilliavora* attacks larvae in autumn and, in the USA, adults often fly too early to parasitize the last instar larvae of JB, which is their preferred stage. *Tiphia popilliavora* was first considered widely established in the USA but has become rarer, for unknown reasons.

Istocheta aldrichi Mesnil (Hymenoptera: Tachinidae): the adult fly lays eggs on the pronotum of the adult beetle, mostly on females. When the eggs hatch, the larvae burrow into the flight muscles and then into the abdomen of the adult beetle, where the fly pupae will overwinter. Death of the adult beetle usually occurs within six days (Clausen 1978). This parasitoid is native to Japan, where it is the dominant parasitoid of JB. In northern Japan, it parasitised up to 100% of females in years of low JB abundance and 30-35% in years of high beetle abundance (Clausen 1978). In North America, where it has been introduced, *I. aldrichi* has not completely synchronized with its host's life cycle and often emerges prior to the beetle. This lack of synchronization is most likely due to climatic differences between the area of origin and the area of introduction. Interestingly, while the beetle and its parasitoid migrate to colder areas in northern USA and Canada, which are climatically more similar to northern Japan, parasitism is increasing, reaching an average of 39% in Canada in 2019 (Vincent and Lasnier 2020).

Other natural enemies for classical biological control

During the extensive surveys by USDA in Japan in the early 20th century, many other parasitoids were found on JB. However, from the information provided by Fleming (1968), Clausen (1978) and references therein, no other parasitoid seems abundant and specific enough to be considered as suitable biological control agent for Europe.

Several entomopathogens can infect JB and are occasionally used or tested as biopesticides in invaded areas. A strain of the bacterium *Paenibacillus popilliae* not present in Europe which is apparently specific to JB could potentially be used for classical biological control.

The entomopathogenic bacterium *Paenibacillus popilliae,* which causes milky disease in insects, potentially could be used for classical biological control in countries where it is currently absent (CABI, 2022). A strain that infects JB is apparently specific (Ref, Potter and Held, 2002).

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