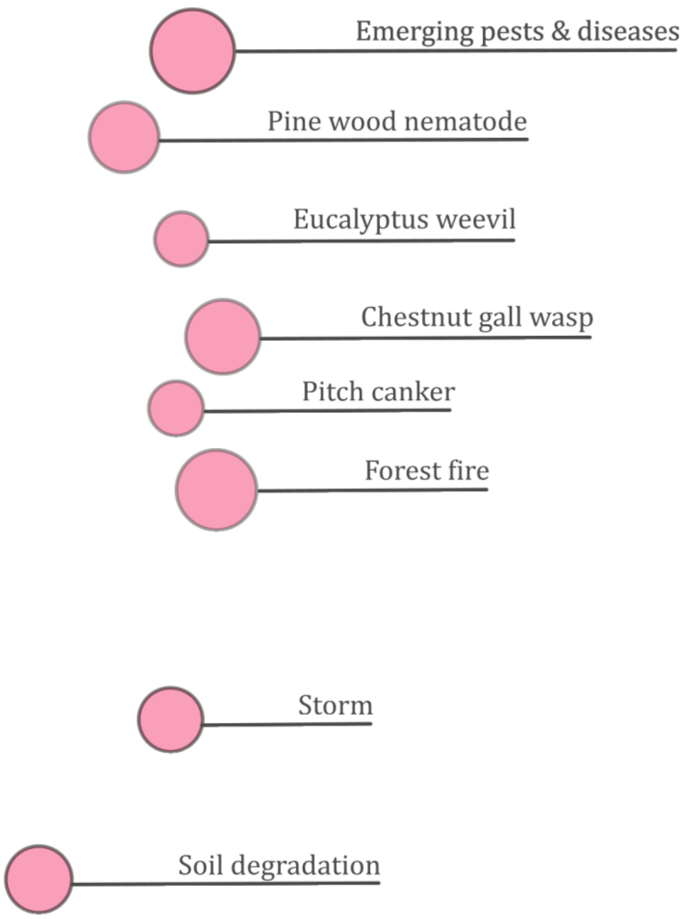
Minutes of the emerging pests and diseases workshop

Towards early warning detection methods



INIAV - Instituto Nacional de Investigação Agrária e Veterinária
Oeiras, Portugal
25 January 2018

Author of the minutes: Eduard Mauri (EFIATLANTIC)

Reviewer of the minutes: Manuela Branco (ISA)

Workshop organisers: Edmundo Sousa (INIAV), Manuela Branco (ISA)

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Agenda

PLURIFOR PROJECT
EMERGING PESTS AND DISEASES WORKSHOP:
TOWARDS EARLY WARNING DETECTION METHODS

THURSDAY **25 JANUARY 2018**	**Organisers:** Edmundo Saousa edmundo.sousa@iniav.pt (INIAV) & Manuela Branco mrbranco@isa.ulisboa.pt (ISA) **Language:** Portuguese - English - Spanish **Venue:** CAP Meeting room INIAV - Instituto Nacional de Investigação Agrária e Veterinária Av. da Republica, Nova Oeiras, 2780 Oeiras, Portugal

9:00	**Welcome and workshop objectives** Manuela BRANCO (ISA), Edmundo SOUSA (INIAV), Hervé JACTEL (INRA)
9:15	**Methods for detecting invasive forest pests and pathogens**
	09:15 Sentinel plantations and multilure traps. Dr Alain Roques (INRA) 10:00 Spore traps for pathogens. Dr Julio Diez (Castilla y Léon) 10:45 Smartphone application and EFI database on invasive forest pests. C. Orazio (EFI) *11:15 Coffee break* 11:45 PLURIFOR tool: case study on use of urban trees for early detection. Dr. M. Branco (ISA) and Dr. H. Jactel (INRA)
12:15	**Methods of eradication**
	12:15 Eradication of forest pests. Dr Manuela Branco (ISA) 12:45 An experience of control of fungal diseases in a *Pinus radiata* stand in Gipuzkoa, Basque Country (Spain). A. Cantero (HAZI)
13:00	**Lunch break**
14:00	**Methods of biological control against invasive pests**
	15:00 Classical biological control. Dr. M. Kenis (CABI) 15:45 Conservation biological control. Dr. H. Jactel (INRA)
16:30	Coffee break
17:00	Discussion with attendees about the potential of methods for invasive pest monitoring and management
18:00	End
20:00	Dinner (restaurant to be confirmed, at partners' own expense)

Requested participants: partners working on the emerging pests and diseases risks, PLURIFOR associated partners, and guests invited by the different teams.

Workshop registration before 19 January 2017. Limited places.

Emerging pests and diseases WP2 objectives

Emerging pests and diseases risk partners and associated partners

Region	Organisation	Contact person	Associated partners
Portugal	INIAV	Edmundo Sousa	Altri Florestal Instituto da Conservação da Naturesa e das Florestas RAIZ - Instituto de Investigação da Floresta e Papel
Euskadi	NEIKER	Amaia Ortiz	Gobierno Vasco - Departamento de Desarrollo Económico y Competitividad Diputaciones Forales de Bizkaia, Gipuzkoa and Álava
Castilla y Leáon	TRAGSATEC	Jorge Casado	Junta de Castilla y León Empresa de Transformación Agraria
Aquitaine	INRA	Hervé Jactel	Caisse de Prévoyance et de Protection des Forêts du Sud-Ouest Direction régionale de l'alimentation, de l'agriculture et de la forêt Association Régionale de Défense des Forêts Contre l'Incendie

Tools and risk management plans to be developed within PLURIFOR project

As decided by the PLURIFOR Technical committee n°2 meeting (25-26 January 2017 at NEIKER, Parque Tecnológico de Bizkaia, Parcela 812, calle Berreaga 1, Derio, Spain), the following tools and risk management plans will be developed by the emerging pests and diseases risk team in WP2:

- Investigate capacity of REINFFORCE arboreta network to detect the presence of invasive species;
- Test urban forest versus rural areas for early detection of new emerging species using box tree moth as a study case;
- Update the EFI web field guide for pests and diseases with information for new invasive species.

Attendees

Attendees

Participants

First name	Last name	Organisation
Alda	Antunes	ICNF-DCNFLVT
Ana	Fernandes	ICNF
Ana Julia	Francisco	Câmara Municipal de Lisboa
Ana Margarida	Fontes	INIAV
Ana Paula	Ramos	ISA, Universidade de Lisboa
Ana Sofia	Domingues	ICNF, I.P.
António	Borges	ICNF
Bruno	Ferreira	Instituto Superior de Agronomia
Carlos	Borges	ICNF
Dina	Ribeiro	ICNF
Eduard	Mauri	EFIATLANTIC
Edurne	Lacalle	USSE
Elsa	Borges da Silva	CEF/ISA
Emmanuel	Kersaudy	DRAAF
Filipa	Maia	LPVVA-ISA
Filomena	Nobrega	INIAV
Gaëlle	Burlot	Caisse Phyto Forêt
Helena	Marques	ICNF
Helena	Vicente	INIAV
Ilidio	Loução	ICNF
Jean-Charles	Samalens	Telespazio
João	Silva	ICNF
Jorge	Casado Alvarez	TRAGSATEC
José António	Gomes	Câmara Municipal de Lisboa
Laura	Luquero Ramos	TRAGSA
Leire	Salaberria	USSE
Luís	Caparica	ICNF
Luís Felipe	Bonifácio	INIAV, IP
Margarida	Ferreira	Câmara Municipal de Lisboa
Maria do Rosário	Amaral	ICNF

First name	Last name	Organisation
Maria Helena	Bragança	INIAV
María José	Checa	Tragsatec (Grupo Tragsa)
Maria Lurdes	Inacio	INIAV
Marta	Rocha	Instituto Superior de Agronomia
Miguel	Pintos	INIAV
Olga Verónica	González	ASFOSA
Pedro	Marques	Individual
Stefano	Nones	INIAV
Susana	Pérez	EFIATLANTIC
Tatiana	Valada	LPVVA, ISA
Thierry	Bélouard	Département santé des forêts
Vasco	Oliveira	ICNF/DCNFLVT

Speakers

First name	Last name	Organisation
Alain	Roques	INRA URZF
Alejandro	Cantero	HAZI
Christophe	Orazio	EFIATLANTIC
Hervé	Jactel	INRA
Manuela	Branco	ISA
Marc	Kenis	CABI

Organisers

First name	Last name	Organisation
Edmundo	Sousa	INIAV
Manuela	Branco	ISA

Apologies

First name	Last name	Organisation
Amaia	Ortiz	NEIKER
Ander	Arias	NEIKER
Nahia	Gartzia	NEIKER

Absent

First name	Last name	Organisation
António	Nora	Floresta Atlântica
Diogo Neves	Proenca	University of Coimbra
Filomena	Caetano	CGA
Jorge	Simões	Companhia Das Lezírias
Julio	Diez	Universidad de Valladolid
Maria	Inacio	INIAV, IP
Paula	Morais	University of Coimbra
Pedro	Naves	INIAV
Rui	Tujeira	Soluções Tecnicas em Fitossanidade Unipessoal, Lda
Rui	Alves	Companhia Das Lezírias
Sónia	Duarte	National Laboratory for Civil Engineering
Susana	Carneiro	Centro PINUS
Susana	Brigido	2bforest
Teresa	Vasconcelos	ESAC

Introduction

By Hervé Jactel, INRA

Introductions of non-native forest insect species in Europe, North America and New Zealand have exponentially increased during the 20th and 21st centuries due to the increase of worldwide trade. There is no sign that this trend will reverse, as China is increasing its exports. The establishment of phytophagous insects in Europe is eased by the fact that many woody plants genera exist in Europe and in China.

The invasion process can be described in four steps: transport, introduction (or arrival), establishment (from casual stage to naturalisation), and spread (including population growth and dispersal). Between each step different tools exists to deal with the hazard that invasive species pose. Between transport and introduction, prevention and detection tools exist. Between introduction and establishment, surveillance and delimitation tools are available. Eradication tools must be employed when the invasive species has already been established but before it spreads. Finally, when the invasive species is already spread, eradication is nearly impossible and control tools to reduce the damage to acceptable levels are the only option. New technologies offer us the possibility to adapt these tools to new species and situations.

Methods for detecting invasive forest pests and pathogens

Sentinel plantations and mutilure traps

By Alain Roques, INRA

First part: Sentinel plantations and sentinel nurseries set over continents are very useful tools to detect potential invaders before they arrive

Global homogenisation, but no saturation, at world level in the establishment rate of alien species. However, differences in taxa as well as in regions exist.

If we consider the new arrivals, most of them correspond to "emerging species": those that have never been observed as introduced in a continent other than the native. All species that have arrived in Europe, most of them are new and some even some were new for science (not know in their area of origin). If we focus on terrestrial arthropods in Europe, globalization is exponentially accelerating establishment of exotic species. There is an increasing rate of new alien species arrivals due to phytophagous species, while the other groups' arrivals decrease. In average, 11.5 new phytophagous emerging species are detected every year in Europe since 2000; and the most important number of them are species associated to woody plants. The arrival of emerging species associated to crops and herbs are decreasing. Until 2016, 512 exotic arthropods related to woody plants had been established in Europe, most of them after 1975.

However, there is no relationship between the establishment of alien species and their interception at borders. Consequently, inspections at borders are not efficient. Phytosanitary inspections only target species in the EPPO list, so no new ones are targeted.

The problem to be solved it: how can we detect emerging species at arrival? How to forecast the potential species that can invade? A number of EU projects aimed at developing novel strategies:

Preventive warning:

- Lists based on the pests known in the native range… but most newly-arrived species were not considered as pests in the native range … or unknowns;
- Sentinel plantings of European plants in exotic countries;
- Sentinel nurseries of exotic plants in exotic countries;
- Survey of arboreta and botanical gardens with European plants.

Early detection at arrivals:

- Test of multiplex traps and lures with generic attractants in ports of entry.

The objective is to have preventive actions, and preventively warn people. However, can we rely on lists of pests in their native country? If there is a pest in China, has Europe to be aware of its potential? The answer is no, because most of them are not even pests in China! Possible solutions are:

1. **Install sentinel plantations of European trees in China**

Two sentinel nurseries were installed, and designed for statistical analyses. Seven European tree species were planted. In some cases, even Chinese experts did not know the species of pests attacking these plants; 105 insect species colonised the plants. Three years were enough to get full recruitment for leave bores and root feeders, no xylophagous species were detected. In total, 39 potential invasive insects can threat European trees. *Quercus petreae* and *Carpinus betulae* were the most attacked tree species by number of different insects, with attacks of more than 15 different species. They can in fact complete their biological cycle on European tree species. Then, it is needed to check if they can survive transport and can be introduced into Europe. If this is possible, they will be specifically monitored at borders in France.

This methodology is also efficient for pathogens. The problem is that some of the pathogens found in China we do not know if they are from China of from Europe. NGS sequencing would be needed to detect the origin. Conclusion: we need analyses at the beginning to know if pathogens come from Europe.

2. **Install sentinel nurseries of ornamental plants in exotic countries, without phytosanitary control (European plants produced in China for export to Europe).**

Tree and shrub ornamental species are the most abundantly exported plants to Europe. Sentinel nurseries hosted 105 insect species; 90% were not found in previous Chinese literature. Nearly 80% of these insect-plant associations were not found in *a posteriori* literature survey. *Buxus* moth could have been detected prior to introduce in Europe if this experiment had been done before, as all *Buxus* sp. planted in China were destroyed by this pest.

Taxonomic identification is a big problem. Morphological keys are impossible to use because most of the detections are in larval form. All larvae were genetically analysed (DNA barcoding plus nuclear ITSs). Tentative match with genetic databases (GeneBanks and other) allowed identifying more than 10 species. It is necessary to develop more these databases to get better matches.

Five and six years after plantation, in 2016 and 2017, it was detected significant increase in the number of associated species belonging to new guilds: they were gall insects and xylophagous insects (no leave or root insects).

A complementary method is to survey arboreta in Europe, with European plants. However, no statistical tests are possible, as not all species plants are present. But, they can be used to detect native and non-native species and the potential host range. Arboreta can be used for early warning. The pathway can be the manager of the gardens/arboreta.

- It's necessary to standardise the methods allowing a quick identification of the damaging agents where still missing. A publication under COST action has been published for free online that aims to:
- Surveys in sentinel designs will often face the presence of organisms and symptoms that have never been observed before by the people in charge.
- The guide is aimed at aiding staff of sentinel/ arboreta and phytosanitary inspectors to characterize the observed damage in situations where most damaging agents are unknown

- The guide combines the description of symptoms of animal (insects, mites, nematodes, mammals, birds) damage, pathogen (fungi, Oomycetes, bacteria, viruses, phytoplasma) damage, and abiotic damage
- The guide only allows a tentative identification of a broad group of potential agents but NOT a definitive identification of the causal agent.
- The guide explains how to collect, how to preserve the samples, and how to proceed to get the most probable identification of the causal agent.

Second part: Longhorn beetles and bark beetles multilure blends traps can allow detecting wood boring insects at arrival ports of entry

Early detection at arrival is a major challenge. Phytosanitary inspection cannot rely on what inspectors can see or not: more automated tools are needed. Two options are multiple traps with a single lure, or few traps with multicomponent lure. This second option is less costly and can trap unknown species, but it implies to check possible repellence effects between components of the multilures through tests in forests, statistical analyses being not possible in ports-of-entry.

At first, only longhorn beetles (*Cerambycidae*) were considered. Progresses in pheromone identification revealed well-conserved sex- and aggregation-sex compounds among subfamilies and tribes at world level, and thus makes possible to use generic attractants for trapping non-natives at arrival.

In France, tests on multilures were first done in forests and then in ports-of-entry. Two blends, with four compounds each were tested in cross-vane traps coated with Teflon and a grid for water at collector's bottom and insecticide bag (to keep insects dry for further DNA barcoding). In ports-of-entry, they were located within and around (woody areas in 1 km radius) and whenever possible near wood waste deposit areas.

Some questions that this study wants to answer are:

- Do multilure blends provide a convenient genericity for detecting exotic species of longhorn beetles at arrival?
- Are some taxa not trapped at all?
- If yes, how can attractants can be improved?
- Has the colour of the trap an influence on captures?

Results are under publication.

Trapping using the same blends of attractants on other continents would be important to check their genericity, and a progress towards a worldwide database of the species potentially trapped with such lures. However, this is only an additional tool: the probability that insects arrive at the adult stage or near adult stage in ports-of-entry is low! Settling traps in wood waste deposit areas where larvae may have time to turn to adults may increase detection success.

Discussion

Alain Roques (AR): We have to be very careful where the traps are set to avoid them being destroyed by machinery.

AR: France considers installing traps in ports of entry for stones, tiles, sand, earth, etc., not only for timber. In Austria they have done it. And also near Amazon warehouse.

AR: Chinese test could not test European pine species because there are local pine pests that they did not want to spread, and because they wanted to prevent any potential introduction of invasive species on pines from Europe.

AR: Traps with several colours on them could be testes: e.g. one half green and one half black. It is impossible to put traps at high heights in airports because of aviation regulations.

AR: REINFFORCE project arboreta could be used as sentinels to detect new invasive species.

Spore traps for pathogens

By Julio Diez, Universidad de Valladolid

Presentation cancelled due to the absence of the speaker.

Smartphone application and EFI database on forest pests and diseases

By Christophe Orazio, EFI

First part: Smartphone application on forest damage

The PLURIFOR project is developing a smartphone application from which citizens will be able to report damage to forest. Their report, generated in less than five minutes, will provide: type of damage, images, location, date, tree species, location of the damage within the tree and extent. These reports will be validated by regional authorities and they will ultimately identify the causing agent of the damage, along other relevant information. Final users of this database of reports will be regional forest services, as prevention or monitoring tool to map forest problems and prioritise actions, and researchers, to do spatiotemporal trend analyses.

Beta version test should start by end of April or beginning of May 2018. Contacts are needed from authorities who will validate the reports and use the data generated. Beta version will not be open to public, but final version, delivered on January 2018, may be if it is decided by project partners.

HOMED project being accepted, artificial intelligence will be tested in order to automatically identify the causing agent of the damage.

Second part: EFI database forest pests and diseases

The database on forest pests and diseases, host at EFI website, is an online guide for biotic risks. It wants to provide an up to date list of existing risks in Europe. It can be consulted as a list or by filtering different options to narrow the selection and arrive to a list of pests or diseases that respect all the selection criteria. Finally, users can open the descriptive card of each causing agent and access to information about host trees, identification, caused damage, biology, risk factor, distribution, pest management (monitoring, preventive measures and curative control), and climate change related issues. They are all in Portuguese, French, Spanish and English.

EFI wants to improve and increase the data base, as it must be updated with new species when detected in the territory. Christophe Orazio asks to attendees to help to keep this database up to date by sending mission information to EFI.

Discussion: proposals from the attendees on the smartphone application

- Create the figure of “reporter of the month” to stimulate people to participate.
- Provide feedback to users. For example, alerts like “be aware, this pest has been detected in your area”.

PLURIFOR tool: case study on use of urban trees for early detection

By Manuela Branco, ISA, and Hervé Jactel, INRA

Why urban forests are important to detect emerging pests and diseases:

- Cities receive more arrivals:
    - as they are close to ports-of-entry (airports, harbours, railway stations, etc.);
    - as there is more human population, more trade, more imported wood products, packaging or plants for planting (vectors of pests and diseases).
- In urban areas there is higher chance of establishment:
    - higher tree species diversity in parks and botanical gardens, this increasing the chances of finding a suitable host;
    - better climatic conditions for the survival of insect species from warm countries (urban heat island).

If the probability of exotic forest pest establishment is higher in urban areas, then it is worth concentrating detection efforts in urban forests.

Method

A bibliographic search was performed about first detections of emerging pests in Europe. From these publications, relevant information has been retrieved to describe the arrival and first detection of the pest. Additional information has been added about the feeding guild and to describe the location of the first detection. This tool focused only for pests, not on diseases.

Preliminary results

There were found 443 records. Urban areas habitat accounted for about 45% of first detections, while forest habitat came to second place, with less than 30% of the first detections. Half of the first detections took place in a radius of less than 10 km from a city, and most of the first detections were located less than 30 km from an airport or from a seaport. Consequently, so it is clever to put detections efforts around these locations.

Most of the emerging insects were sap feeders, followed by wood bores, then defoliators and gall makers. A very low proportion of insects were fruit suckers.

Next steps are to increase the bibliographic search, include more variables to characterise the urban areas and the landscapes and perform statistical analyses using countries as replicates. This task is a deliverable of the PLURIFOR project. Results will be presented in June 2018 PLURIFOR annual meeting.

Discussion

Alain Roques finds it interesting the idea of a network of European cities for detection. The weak point would be that urban trees diversity, which may be unbalanced. Therefore, statistical analyses would be difficult.

Manuela Branco: This is the case when the species are already established (in urban trees). Urban areas are really a starting point for the establishment.

Hervé Jactel: Citizens could use the PLURIFOR smartphone application in the cities with urban trees.

Methods of eradication

Eradication of forest pests

By Manuela Branco, ISA

The eradication of an invasive species is possible. It might be costly, but there are many successful cases with a high positive benefit-cost. We need to keep developing new tools to make this action more efficient.

- **Is eradication feasible?**

Yes. Out of 672 arthropod eradication programs, 59% were considered to be successful. Yet three species L. dispar, C. capitata, and B. dorsalis, collectively accounted for 169 programs. Whereas in some eradication has been a success (e.g. eradication of the Asian longhorned beetle Anoplophora chinensis in 2006 in France, three years after its detection), in others cases eradication has been a failure (e.g. the emerald ash borer, Agrilus planipennis, introduced in the 1990s in US, despite many quarantines and eradication attempts, continued spreading to other states and Canada).

- **Which are the reasons of failure or success?**

Quickness: time elapsed since establishment, relative detectability of the species, and the available methods of detection.

Confinement: size of the infested area, and time elapsed since establishment. Eradication campaigns were more successful in man-made habitats, e.g. greenhouses

Target species traits: rate of reproduction, easy detection at low population density (e.g. via visual identification or traps), host range, and dispersal ability.

Dispersal capacity: the rate of spread of an organism affects the likelihood of delimitation. Dispersal can result in populations establishing at long distance from the main infestation.

Feeding guild and size of organism: among large groups, fungi have the lowest probability of eradication and bacteria the highest, insects are in the midway. Among insects, bark and wood borers seem to have the lowest rate of eradication success! Data may be biased by target groups for which more eradication programs were undertaken.

Availability of eradication tools: the availability of taxon-specific monitoring and control tools increases the probability of eradication success (e.g. pheromone traps). Surveillance tools are crucial for detecting and delimiting the presence of small newly founded populations. Eradication relies on the existence of efficient control tools with a minimum effect on non-target species.

Propagule pressure: eradication is difficult if there is a continuous introductions of new invaders. Repeated eradication may increase costs and reduce benefits.

- **What about eradication tools?**

Detection and surveillance tools: eradication relies on an efficient monitoring system: detection, delimitation, evaluation of treatments and confirmation of eradication. New **molecular tools** are relevant to identify the source of infestation, and allowing higher accuracy of correct species identification. New **technological tools** (e.g. drones, electronic nose) may bring new improvements to early detection. **Citizens science** reports by citizens facilitated may help to detect new cases.

Control tools: taxon-specific control tools increase the probability of eradication: release of sterile males (sterile insect technique), spraying with microbial insecticides (e.g. BT for tree defoliators), systemic insecticides (wood borers), bait attractants (mass trapping), host tree removal (e.g. wood borers, pathogenic fungi), mating disruption with sex pheromones, host traps (mass trapping), quarantine regulations.

Tools exploring Allee effect: eradication does not imply the seemingly impossible feat of eliminating every individual in a population! Control tools can be used to intensify Allee effects pushing populations to levels below Allee threshold and/or increase Allee thresholds altering cooperation, defense, reproduction or inbreeding depression (e.g. release of sterile males or mating disruption increase Allee effects related with reproduction). Many successful eradication programs have combined two or more tactics, particularly combining density-independent treatment (e.g. pesticides) with a density-dependent treatment (e.g. mating disruption).

- **Is eradication cost-effective?**

Decisions should be based on benefit-cost analyses, but there are only a few cost-benefit analyses studies and eradication programs tend to underestimate the costs and overestimate the benefits. Although the cost-benefit analysis is conceptually simple, conducting a rigorous analysis is extremely difficult because identifying and comparing the costs and benefits of all actions and inactions becomes increasingly unmanageable. Costs increase with area affected and when populations become low. Escalating costs for killing the last individuals: eliminating the last 1-10% of the population may demand equal expenditures of time, energy, and money to that required for the first 90-99% and therefore is more expensive per insect killed.

Benefits: avoidance of trade restrictions on potentially contaminated goods, yield losses, permanent treatments costs of established populations, societal implications (e.g. unemployment), ecological impacts (e.g. biodiversity conservation), land use land cover changes.

Costs: eradication costs, ecological impacts (non-target species), human health impacts (e.g. spraying insecticides), economic impacts of quarantine restrictions.

- **Is eradication relevant to involve citizens?**

Non acceptance of society of the eradication programs and the lack of consensus and participative collaboration may hinder eradication efforts, especially when suppressive measures collide with human safety, economical concerns, cultural values or welfare. Inversely, the collaboration of the society may be extremely important to guarantee successful results.

More fragmented landscapes with large number of ownerships imply more efforts on the engagement of variated stakeholders and citizens and pose more challenges. As land becomes increasingly subdivided, each manager assumes responsibility for a smaller portion of the total; the incentive to control invasive is therefore diminished. Coordination may be facilitated by top-down and middle-out approaches that promote education, regulation, incentives, and increased communication among all stakeholders.

- **What about when eradication is no longer a possibility?**

In principle, eradication should be carried out when long-term costs of damage and/or control exceed short-term costs of successful and permanent elimination. Ultimately, eradication is not necessarily more efficient than ongoing lower-level control efforts. Then, other strategies may be used.

Discussion

Question from an attendee (Q): Is utopic to think about eradication of fungi diseases?

Manuela Branco (MB): Fungi are the worst cases for eradication because they can be anywhere (air, soil, vegetation, etc.). Confinement is important. Confinement in tree nurseries is easier; in forests it is very complicated!

Q: What about national/EU rules? What about fungi in forests? We cannot cut all host trees species for preventive measures in the forest.

MB: First reaction of EU is eradications, and first measure is to cut trees. We have to be able to propose other tools than just cut trees: more smarts and effective tools. It is also tricky when there is also scientific disagreement. In some cases, this led to stop some eradication tools and therefore the failure of eradication, maybe. Eradication is more successful in islands than in main land countries.

An experience of control of fungal diseases in a *Pinus radiata* stand in Gipuzkoa, Basque Country (Spain)

By Alejandro Cantero, HAZI

The cryptogamic red is a set of defoliator fungi, present for many years in Basque forests. In recent years, for unknown reasons, the damage has spread. This disease does not usually kill the pines, but it causes their defoliation, it weakens the pines and their growth is very low. Many forest owners end up cutting the pine forest and replacing it with other species. Each spring, new needles are formed and, when infected, they fall during the summer, especially if it is warm and rainy.

The traditional solution was copper products, so that the needles become resistant: Bordeaux mixture (Bordo Mix) is a mixture of copper(II) sulfate ($CuSO_4$) and slaked lime ($Ca(OH)_2$) used as a fungicide in vineyards, fruit-farms and gardens to prevent infestations of downy mildew, powdery mildew and other fungi. It is sprayed on plants as a preventive solution. In Spain, there are no authorized copper products for forestry applications

Experimentally, 300 ha of *P. radiata* forest in Gipuzkoa, 20 years old and affected for 10 years, where pruning infested branches provided no solution, were treated with two copper applications (derogation) in June:

1. Through endotherapy: Cuprosan and Bordeaux mixture injected into the sap. The doses are applied depending on the perimeter of the tree: One for every 30 cm. The amount applied

per dose is 10 cc in the case of Cuprosan and 15 cc in the case of Bordeaux mixture. The application is simpler with Bordeaux mixture, because Cuprosan seems to precipitate more easily.

2. Spraying application from truck along 1 km of forest road, reaching 20-25 m each site of the road. It is used Bordeaux mixture: 24 kg in two tanks with 1,000 litres of water each one. The ULV mean dose has been 1 l/m on each side of the road along 1 km of P. radiata stand. More or less, the product reaches 20-25 m from the truck. 5,5 kg/ha of Bordeaux mixture = 450 l/ha of application

Needles were collected on November 2017 from the study area. Treated trees had more copper in needles, and those that received endotherapy had more copper than those sprayed.

NDVI measured from drone images on December 2017 showed that pines in treated zones have better NDVI values. The pines treated from the road sprayer show better photosynthetic activity (higher NDVI index) than the untreated pines.

The experience should be replicated in another forest and this first experiment should be remeasured later. Endotherapy is very expensive. Curiously, in endotherapy plots, non-treated trees feature high copper content. As they are very close to treated trees, maybe some copper passed through roots from treated to non-treated trees. That would be a beneficial side-effect. I was also observed that the distribution of cooper was similar in all needle, regardless of their position in the trees.

Endoptheraty is very expensive: it is impossible to treat all forests. Spraying is the best solution, but if the forest road network is no dense enough, airborne spraying should be considered. Ultimately, can the legislation be changed to accept copper products in forest?

Methods of biological control against invasive pests

Classical biological control by introduction against invasive insects

By Marc Kenis, CABI

Biological control is the manipulation of living organisms (beneficial) to control other living organisms (pests). There are three categories of methods:

1. By introduction of enemies: introduction of a natural enemy of exotic origin to control a pest, usually also exotic, aiming at a permanent control of the pest.
2. By augmentation of already existing natural enemies: by regular releases. Releases can be inoculative (inoculation at the beginning of the season of a small number of agents that will reproduce), or inundative (mass releases for a single and immediate control).
3. By conservation: methods favouring the efficiency of natural enemies already present in the system.

Pest populations are controlled by biotic and abiotic factors. Irregular outbreaks occasionally occur. When the equilibrium is broken, outbreaks become much more frequent. Causes can be: the host plant cultivated artificially (so its amount increases and is found in a less diverse environment), or the pests is introduced into a new environment without enemies (without natural enemies or because the pests finds other host plants).

The aim of the biological control is to decrease the level of outbreaks to be economically, socially or environmentally acceptable by re-establishing the plant-pest equilibrium.

How does classical biological control work? Steps are:

1. Evaluate the problem if it is severe enough (collaboration with the region of origin and literature review).
2. Choose the regions of investigation (origin of the pest) with similar conditions to the newly infested area.
3. Go to the native areas, survey and study the role of native enemies and study their role as mortality factors in the region of origin. Study the specificities of the pest to avoid collateral damages. Choose the species to introduce with priority list.
4. Ask for approval of authorities.
5. Laboratory rearing.
6. Chose the release zones and the release methods.
7. Verify the establishment of the control agent, its distribution in the invaded zones.
8. Perform a final evaluation of the project. Why did it work or not?

Does classical biological control work?

Yes, including for forest pests. But many studies have not been done properly. First biological control was in 1889. Until 2010, 6,164 introductions have been done against 692 insect pests. Of these introductions, 37% led to the establishment of the biological enemy, 10% of them contributed to success of control, and 27% of the pest insects were controlled.

Does it work better in forests and other perennial ecosystems?

Introductions have equal establishment success for woody than for herbaceous ecosystems. However, introduction leading to success and the rate of species successfully controlled are more successful in forests than in herbaceous ecosystems and corps.

No difference of success is seen for biological control in plantations, orchards of ornamental plants and natural forests.

What can be the expected economic benefits?

Classical biological control provides permanent control, leading to huge benefits. Once established, the enemy should to the job forever, so benefits are cumulative for years. Cost-benefit in Australia has been calculated to be 1:10.6 (while 1:2.5 for chemical control). Some biological control campaigns exceeded the 1:100 ratio. But there are very few examples of cost-benefit analyses for forest trees; for agriculture it is better known, with ratios between 1:200 and 1:500.

Can there be also environmental benefits?

Yes, some examples exist. Biological control is safer for humans and animals than chemical control.

What are the risks?

A classical biological control programme may take a long time before being successful. It is a challenge to keep sponsors interested. Funding must be long-term minded.

There is the risk of negative non-targeted effects: native biodiversity, ecosystem services, and species of economic importance, gained in importance since 1980s and can be threatened.

Can classical biological control eradicate a pest or a non-target species?

No, in the vast majority of cases. In a few cases it is possible, especially on islands.

How can the risks be mitigated?

Procedures for assessing non target effect are now well established, and widely applied, but not yet systematically in arthropod biocontrol.

Does classical biological control work equally well against all insect orders?

No. But this does not mean not to try, because in some cases it works.

Do parasitoids and predators work equally well?

Parasitoids (four times more used than predators for biological control) have a success rate of 14%, while for predators it is 10%.

Has classical biological control declined since the rise of concerns for environmental impacts?

Yes, but maybe because also nowadays we do not introduce any kind of vegetables without considering the risks. And now, introductions of biological control agents are less but more thought and more studied before introducing.

Has classical biological control in forestry declined more compared to agriculture?

In agriculture, classical biological control increased between the 40s and 70s and drastically declined. In forestry, the number of plant pest species that have been targets of classical biological control programmes per decade are more constant.

Has classical biological control success rates increased with time?

Success rates are very variable. On woody plants, percentages of successful agents establishments, per decade, against plant pests range from 25% to 70%; percentages of introductions of agents leading to successful control, per decade, against plant pests range from 5 to 25%. There are no clear trends.

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:

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

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

Yes, they can. It happened for eucalyptus: the red gum lerp psyllid, in several areas, it was "naturally" followed by its parasitoid *Psyllaephagus bliteus* that provided substantial control.

Can classical biological control work against native pests?

Traditionally, classical biological control has been used against exotic invasive pests. Occasionally, it has been used against native pests. In some cases, it worked quite well. The "new association" theory suggests that exotic enemies are more effective against native pests because no there has been no co-evolution of the pest with these new enemies.

Reasons of failure are usually because 1) enemies are too different from the targeted pest: they are either too specific or too polyphagous; 2) natural enemy complexes of closely related insects are very similar, so there is no empty ecological niche and possibility of competition with native natural enemies.

Does classical biological control against exotic (forest) pests still have a future?

Yes, because the rate of introduction of new exotics species is growing, and because chemical control measures are more and more banned.

What are the biggest threats to classical biological control in the future?

- A too stringent legislation for importation and releases of classical biological control agents and for access and benefit of the sharing principle.
- Image of classical biological control among some ecologists and part of the public because past bad examples due to some irresponsible biocontrol practitioners.

Conclusion: 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, including negative effects of pest vs potential negative effects of biological control agents, and economic effects vs ecological effects. It is not easy and it needs specific funding for this task.

Conservation biological control for the management of exotic forest pests

By Hervé Jactel, INRA

Pests can be biologically controlled by two ways:

1. By importing exotic natural enemies that destroy pests = classical biological control.
2. By conserving the native natural enemies of the pests that are already there or are readily available = conservation biological control.

Conservation biological control is conserving native natural enemies of the pests that are already there or are readily available. How?

By manipulating the habitat to enhance native natural enemies so that they are sufficiently abundant and locally present to effectively control new pests, providing:

- Alternate feeding resources: other prey (predators) or hosts (parasitoids);
- Complementary feeding resources: pollen, nectar, honeydew (for adult parasitoids);
- Shelter for protection against adverse weather conditions, super predators (spiders), hyper parasitoids, for egg-laying, overwintering.

A key condition is that native natural enemies need to be generalists enough to be able to shift onto the new (exotic) host or prey. This is more likely to occur when the new host or prey belongs to same family or feeding guild as the native hosts or prey.

In agriculture, flower strips, beetles banks (beetles shelter during winter), intercropping, hedgerows are methods for providing shelter for protection for natural enemies.

In forestry several questions are posed:

- Are monocultures more “invisible” than mixed forests?
- Does tree diversity drive resistance to forest pest invasions?

There are evidences that this works for native pests, but not with exotic or emerging pests. By knowing the mechanisms than make more diverse forests more resistant to native pests, we could make forests more resistant also to non-natives pests. It seems that:

- Diversity reduces abundance of host trees;
- Diversity reduces physical or chemical detectability of the host;
- Diversity enhances the activity of natural enemies of pests: more insect predators, parasitoids, insectivorous birds, etc. This has a cascading effect along the food chain.

In conclusion:

- There are promising results for conservation biological control of invasive forest pests with increased tree diversity.
- But we were lucky: similar hosts (two scale insects of the same genus, two gall makers of broadleaved trees) and presence of generalist enemies able to shift onto new prey (predatory bug) or new host (parasitoid wasp).
- There are more difficult cases, e.g. box tree moth, as there are no native box tree chewers.
- We need more research.

Discussion

Hervé Jactel: It is important to make people understand that biological control will not kill all the pest individuals: there will always remain some damage. This has to be understood especially by agricultural producers. The inconvenient of biological control against a new invasive pest is that it is not immediate. It takes many years to be efficient, but crops are harvested every year. During the first years biological control low results cause a decrease in crop yield.

Biological control agents, especially birds, can travel high distances. Therefore, it is importance to preserve biodiversity islands in the landscape to connect forest areas.

Conclusions

Discussion

Christophe Orazio: We can make a plan for monitoring emerging species, but a plan for species we do not know, how do we do it? What are the next steps?

Hervé Jactel: As soon as emerging species are detected, there is already a European regulation, unless it is a species completely new. Moreover, if it is found in a trap, it does not mean that it has been established.

Emmanuel Kersaudy and Marc Kenis: If an exotic insect species is trapped for the first time, a risk management plan cannot be done immediately. What should be done is to design a trapping strategy in order to continue its detection, investigate which are the tree spices that can be its host, and perform a risk analysis. It is also important to investigate if the insect can be a vector for other pests or diseases. This has to be taken into account for risk evaluation.

Once considered established, and eradication program cannot be delayed because the sooner we start eradication, the more chance we have for a successful eradication.

For non-regulated insects there are no European regulations. There should be an “alarm bell” to communicate to all countries and continue surveillance.

Hervé Jactel: Could a model plan to manage the first detection of emerging species be a PLURIFOR WP2 deliverable?

Christophe Orazio: Is it more efficient to monitor traps or affected trees? Which strategy would be used in plan to manage the first detection of emerging species?

Hervé Jactel: First action is to identify the species at the country of origin and then decide how to monitor and track is: in traps, in trees or both. So, while we do not know this information, we need generic tools: surveillance using traps and trees.

Gaëlle Burlot: Would it be possible to have a decision-making tool, e.g. a flowchart, to help practitioners to choose the best method of control?

Hervé Jactel: Yes, it could be possible. Such a tool would use pest’s functional traits. It is crucial to react very quickly. Another issue is human resources: there are not so many forest entomologists working, consequently there is a lack of flexibility.

Christophe Orazio: DNA barcoding will be widely used in the future?

Hervé Jactel: Not for emerging species arriving to Europe, as no DNA database exists. It should be built. Identification lacks of resources. However, DNA barcoding will not solve the problem in the short term because we still need to build this database.

Alejandro Cantero: What about [fungal] diseases?

Hervé Jactel: French are aware of the importance of diseases, but there is a lack of efforts. Spore traps connected to DNA analyses is a method of surveillance already being tested.

Marc Kenis: Biological control against diseases exists, but methods are different from those for the pests. More research efforts are needed.

Attendee: It is a keystone to implicate political authorities quickly and transnationally. The EFI proposal for a European Forest Risk Facility would be very helpful.

Marc Kenis and Emmanuel Kersaudy: Alert lists of potential emerging species would be useful. It would allow a quick and quality reaction.

Hervé Jactel: The cases that worked were those where the species was already known to be dangerous elsewhere. But what if it is a new species? Do we have to go fast without knowing if it is dangerous, or wait for studies to find out before we start eradication and lose time of the first year or two?

Marc Kenis: Europe is much more open to imports, especially of plants. The most efficient is to avoid missing any opportunity to advocate the danger of importation of vegetal material, especially living plants. If we do not change this, with more restrictive legislation, we will continuously face arrival of more and more invasive alien species, as it is impossible to import disease-free plants. First restriction should be for ornamental plants.

Hervé Jactel: We need to open the flow of information: to be as transparent as possible.

Edmundo Sousa: Cooperation with Australia and New Zealand is important, as these countries have lots of experience with controlling invasive species.

General workshop evaluation questionnaire

Questions

Workshop content

	Statement	Strongly disagree	Partially disagree	Partially agree	Strongly agree	Not applicable	No opinion
1.	I was well informed about the objectives of this workshop and they were clear to me.		1	6	8		
2.	This workshop fulfilled my expectations.			11	4		
3.	The content is relevant to my job tasks concerning forest risks management.			9	5	1	
4.	The quality and depth of knowledge of this workshop were appropriate and represented state-of-the-art tools/technologies.			10	5		

Workshop design

	Statement	Strongly disagree	Partially disagree	Partially agree	Strongly agree	Not applicable	No opinion
5.	The workshop activities/case studies stimulated my learning.		1	7	7		
6.	The activities/case studies in this workshop gave me sufficient practice and feedback.		2	8	3	2	
7.	It was easy for me to understand the messages of the professionals/lecturers, they were good communicators.			9	6		
8.	The pace of this workshop was appropriate.		1	6	8		

Workshop instructor/facilitator/lecturer

	Statement	Strongly disagree	Partially disagree	Partially agree	Strongly agree	Not applicable	No opinion
9.	The instructor/facilitator/lecturer was well prepared.			5	10		
10.	The instructor/facilitator/lecturer was helpful.			4	10		1

Workshop results

		Strongly disagree	Partially disagree	Partially agree	Strongly agree	Not applicable	No opinion
11.	I accomplished the objectives of this workshop.		2	10	3		
12.	I would be able to use the tools that I learned in this workshop on my tasks concerning forest risks management.			10	3	2	
13.	The exchanges with other professionals/instructors/lecturers were fruitful and will be useful for accomplishing my tasks concerning forest risks management.			4	8	2	1

Self-paced delivery

		Strongly disagree	Partially disagree	Partially agree	Strongly agree	Not applicable	No opinion
14.	The workshop was a good way for me to learn its content.		1	5	9		

Improvements and values

How would you improve this workshop? (Check all that apply)

_6_Provide better information before the workshop.
_4_Clarify the workshop objectives.
_1_Reduce the content covered in the workshop.
___Increase the content covered in the workshop.
___Update the content covered in the workshop.
_3_Improve the instructional methods.
_4_Make workshop activities more stimulating.
_2_Improve workshop organization.
___Make the workshop less difficult.
___Make the workshop more difficult.
_1_Slow down the pace of the workshop.
_2_Speed up the pace of the workshop.
___Allot more time for the workshop.
_1_Shorten the time for the workshop.
_3_Improve the tests used in the workshop.
_5_Add (more) video to the workshop.

What other improvements would you recommend in this workshop? *The order of the answers is not relevant.*

It would have been good if communications had been more balanced, addressing diseases such as pests.

More interactive activities allowing more participation of the audience instead of only attending presentations.

It has not been a real workshop and there has been no material, only talks focused on insects, no diseases.

The venue: making it easier for attendees to arrive at their destination, choosing easily accessible destinations in order to achieve greater participation by members, avoiding wasting so much travel time.

Simultaneous translation.

What is least valuable about this workshop? *The order of the answers is not relevant.*

It was a pity that the fungi community of experts did not attend. Not enough contributions from the diseases' knowledge, risk and control in the forest.

The rhythm of the talks, some very long and repetitive.

Low participation of the attendees.

Missed information due to the different languages used.

What is most valuable about this workshop? *The order of the answers is not relevant.*

The subject is of paramount importance.

Presentation of methodologies and potential technologies.

Contact with professionals from other countries, and their different experiences was the most valuable.

Possible future tools (web and application).

The content.