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Pest pathways, phytosanitary legislation & regulation

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- BSc & MSc at University of Zagreb, Croatia
- PhD at University of Bern, Switzerland
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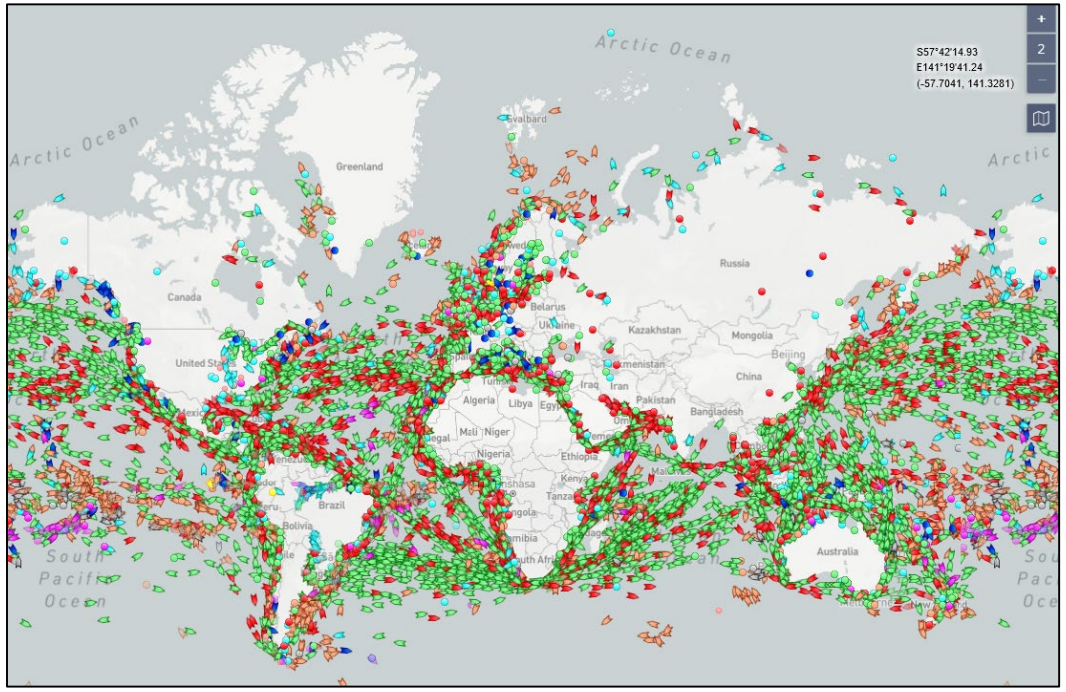
- Scientists in Phytopathology at WSL

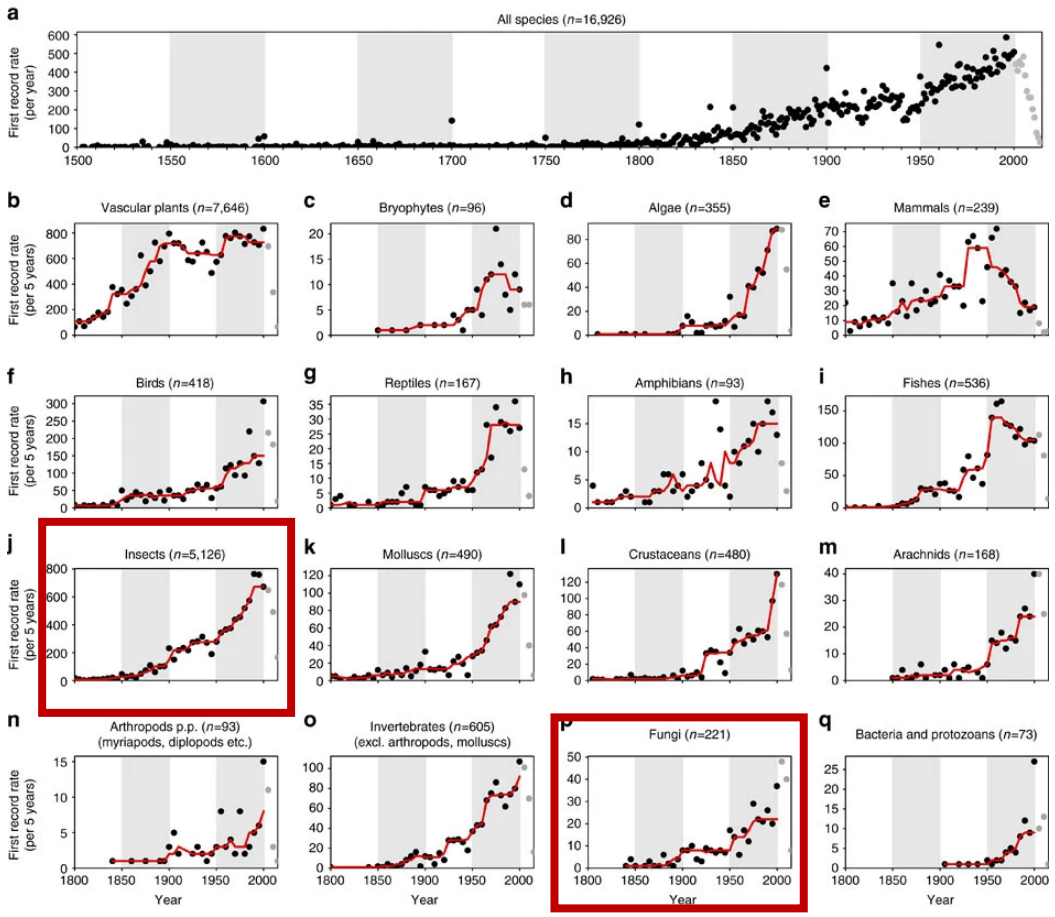
Trade is global, high in volume and increasing

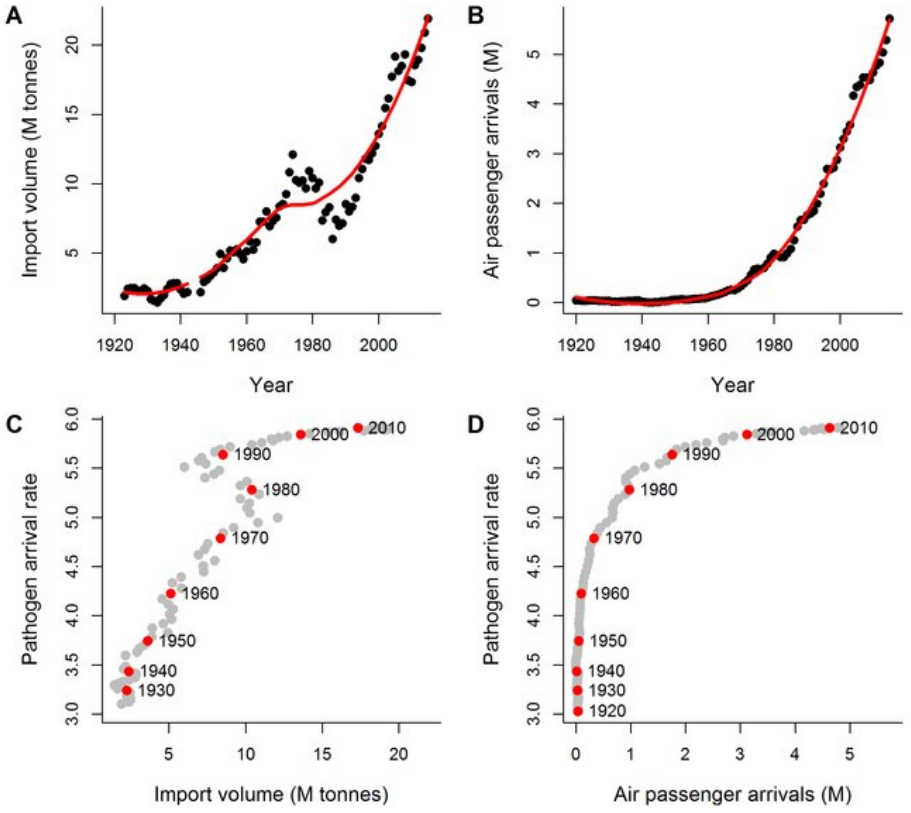


https://shiptracker.live/

https://www.flightradar24.com

As well as non-native insects and fungi





Seebens et al. 2017 Nature Communications

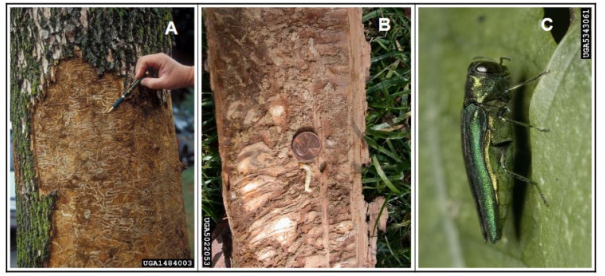
Sikes et al. 2018 Plos Biology

With devastating consequences for the environment

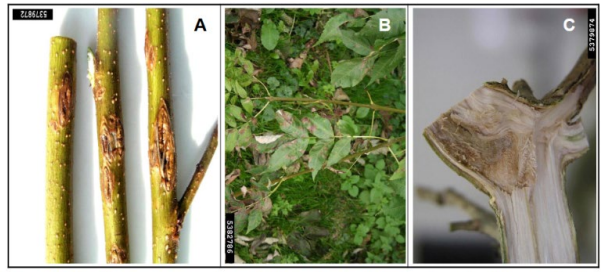
$10 billion over a decade in lost forest resources due to EAB (Kovacs et al. 2010 Ecological Economics)

Fraxinus excelsior
Photo: Matthieu Sontag, Wikimedia Commons

American ash spp.
Photo: Songlin Fei, Purdue University



Example 1. The emerald ash borer (**EAB**, *Agrilus planipennis*) is an invasive buprestid beetle native to Asia (Northeast China, Korea, Japan, and Far-east Russia).



Example 2. The fungus causing ash dieback was first described in 2006 as *Chalara fraxinea*. Four years later it was shown that *Chalara fraxinea* was the asexual (anamorphic) stage of a fungus that was subsequently named *Hymenoscyphus pseudoalbidus*.

* In 2014 the fungus was described as a new species, *H. fraxineus* (Baral et al., 2014).

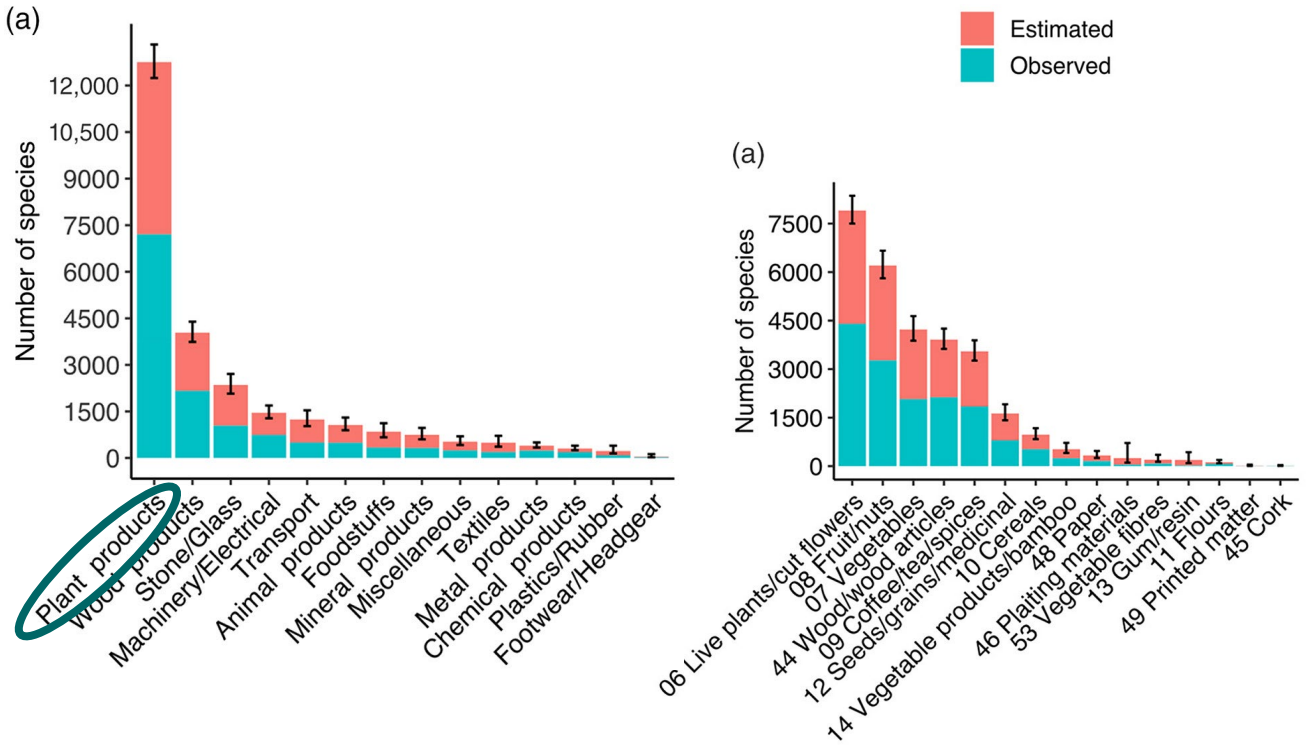
FAO 2014

- **Pest**
  - Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products.
  - Main groups of tree pests are insects and fungi (sometimes referred to as: insect pests and fungal pathogens or pests and diseases).
  - Native or non-native

ISPM 5 Glossary of phytosanitary terms FAO 2018

Living plants are the main pathway for non-native pests

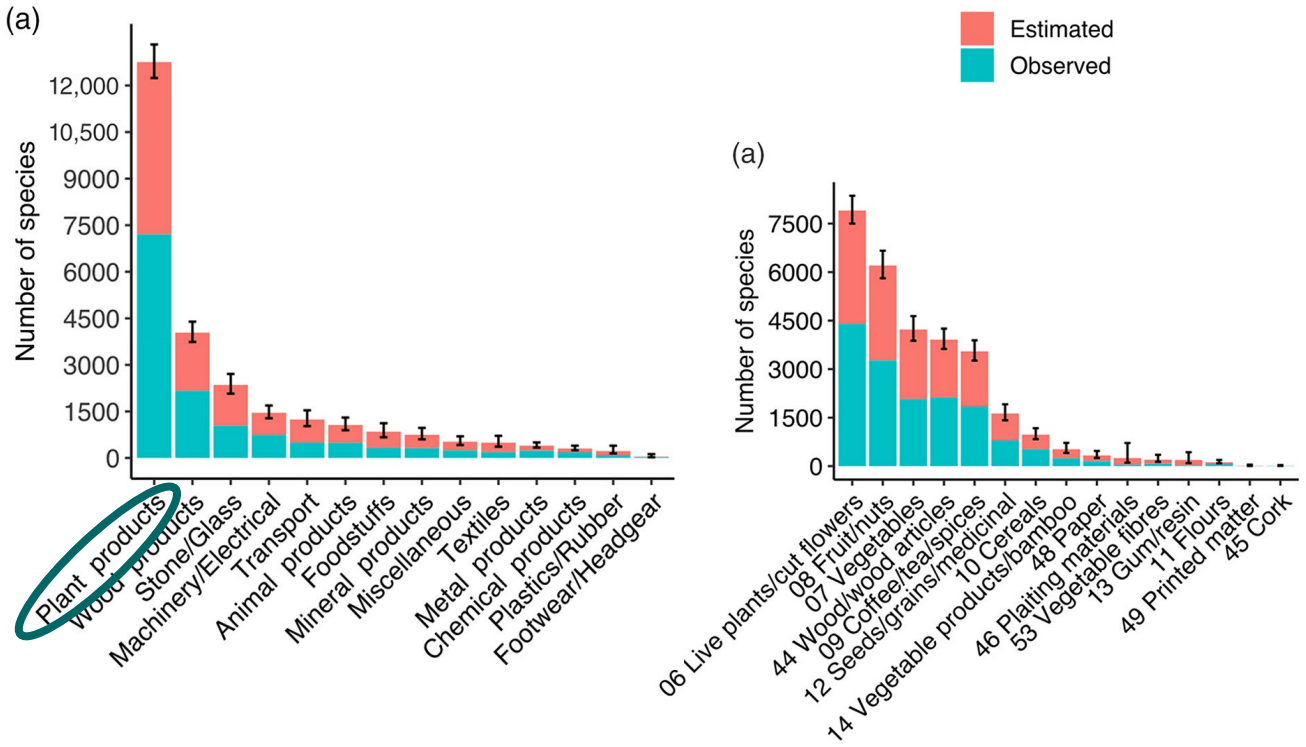
INSECTS



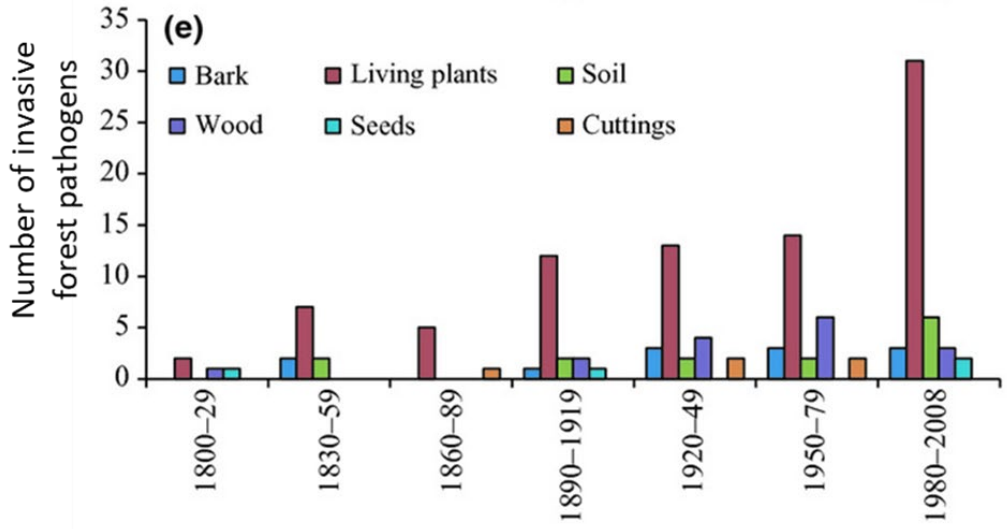
Fenn-Moltu et al. 2022 Ecological Applications

Living plants are the main pathway for non-native pests

INSECTS



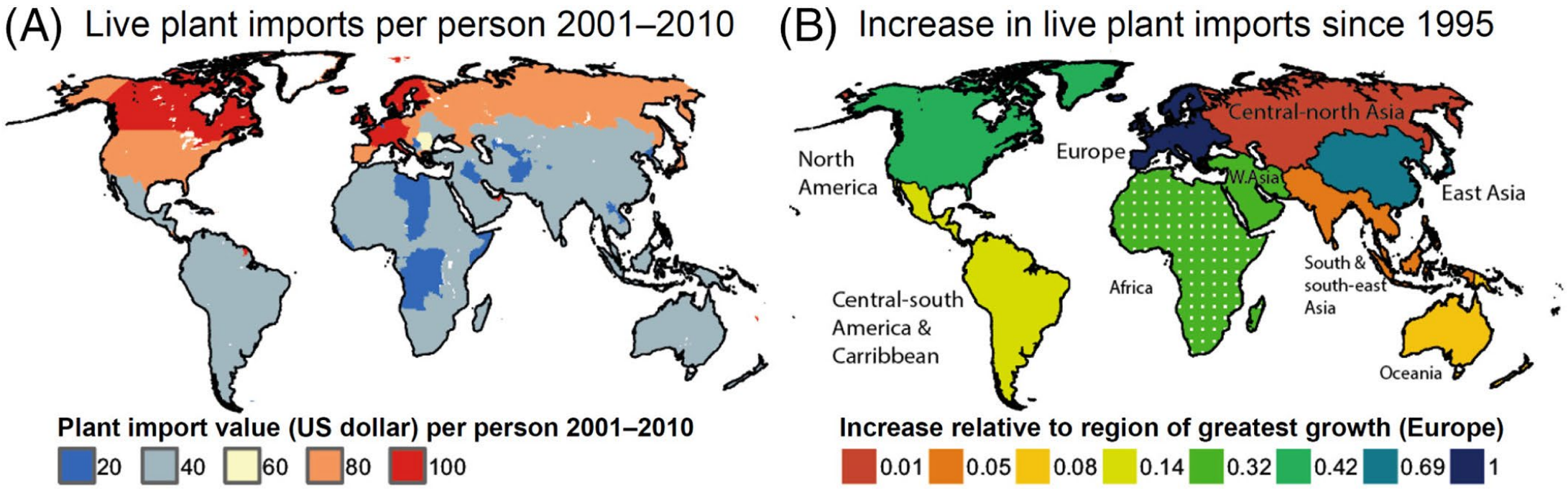
FUNGI



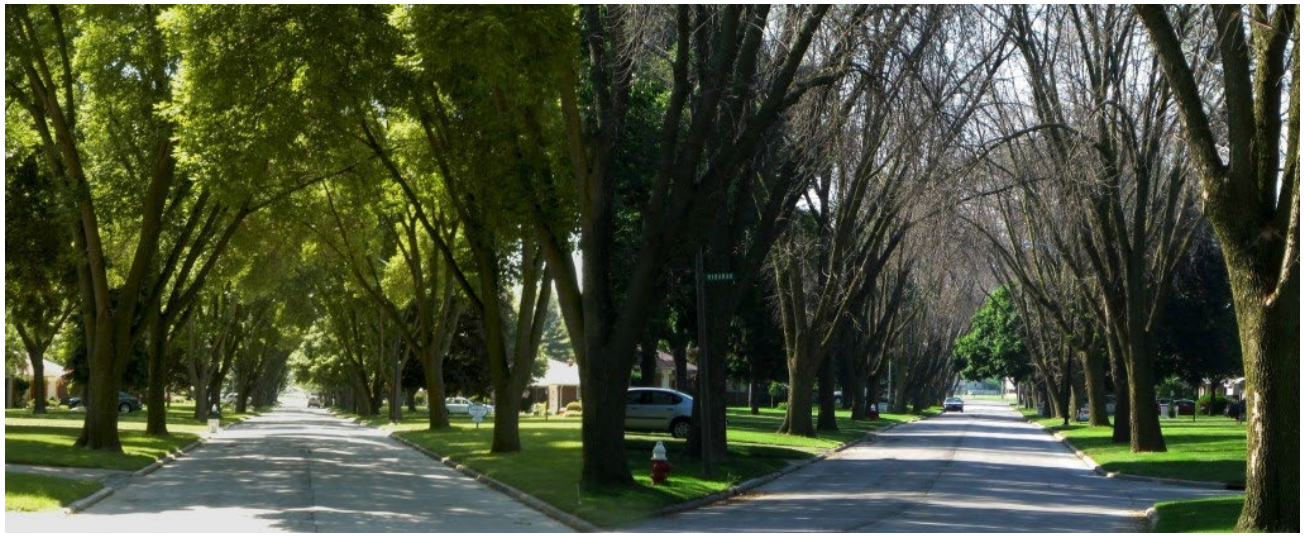
Fenn-Moltu et al. 2022 Ecological Applications

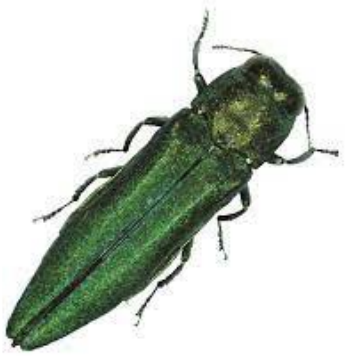
Santini et al. 2013 New Phytologist

Live plant imports are increasing

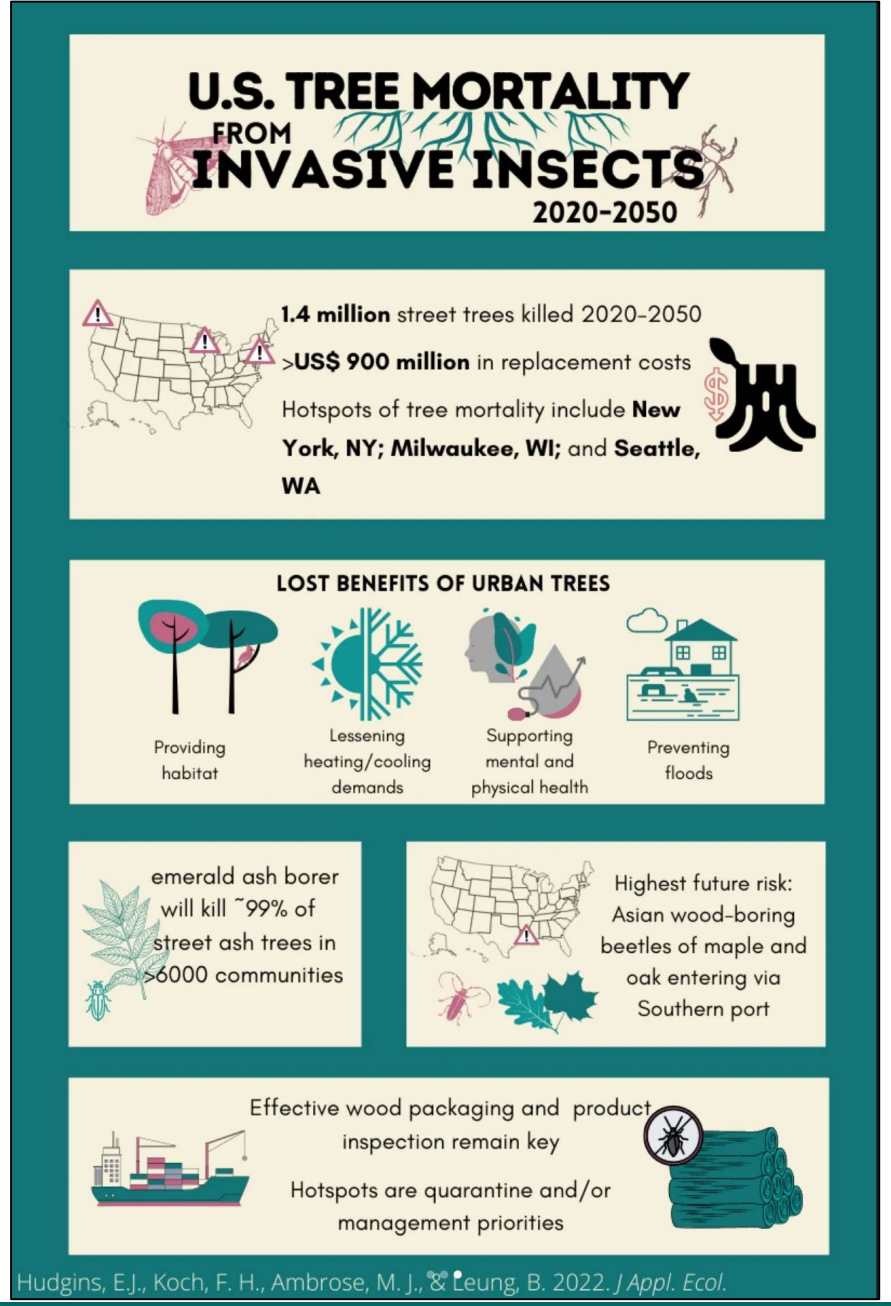


van Kleunen et al. 2018 Biological Reviews



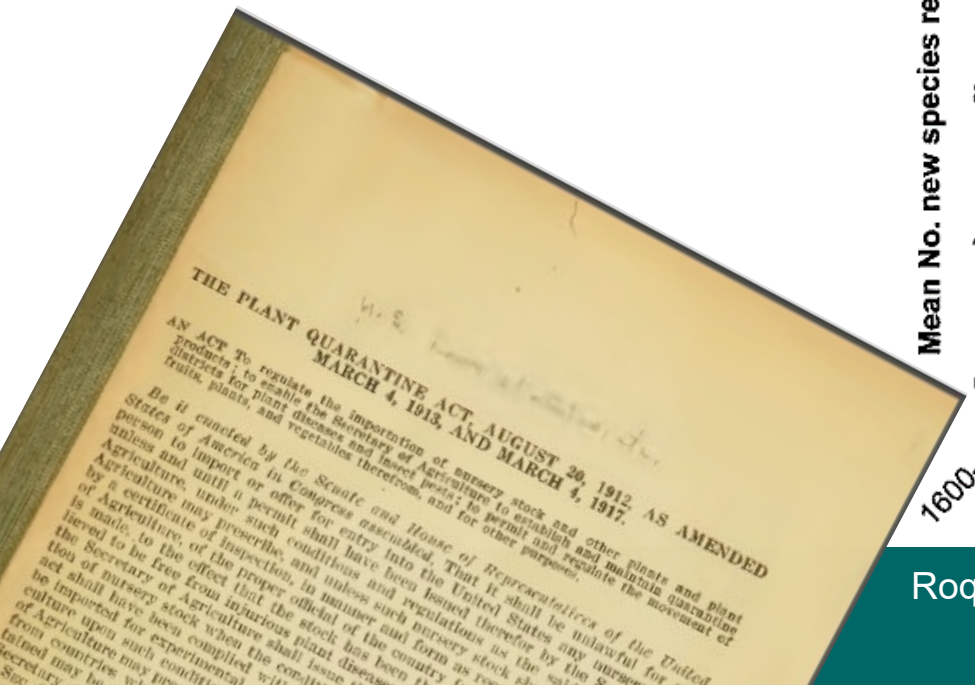


Left: Before EAB June 2006 | Right: Peak EAB June 2009
Photo: Dan Hermes, The Ohio State University



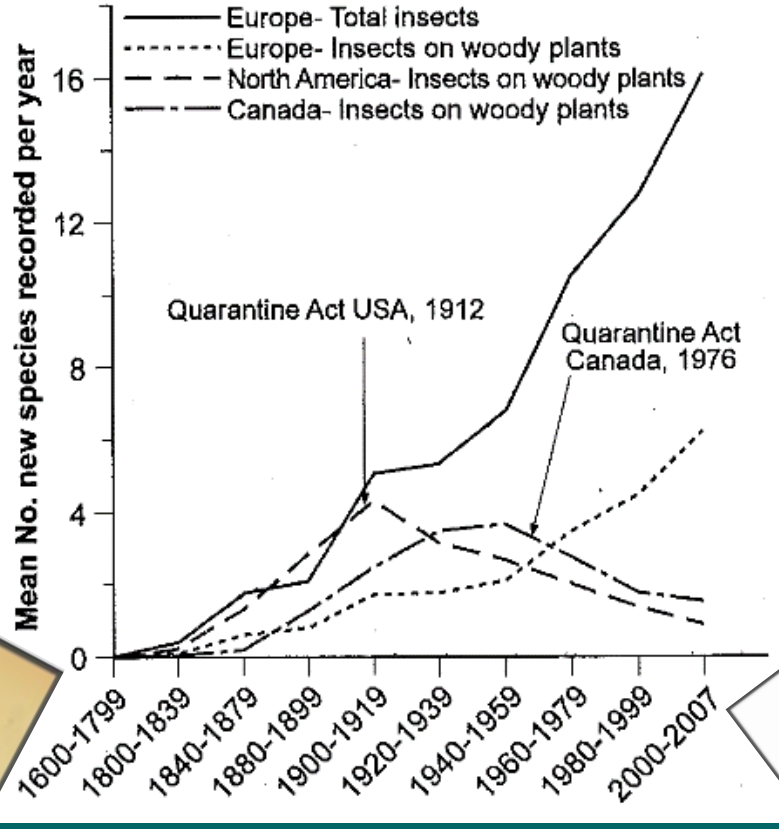
[Hudgins et al. 2022 Journal of Applied Ecology]

Legislation can reduce pest establishment rates


THE PLANT QUARANTINE ACT, AUGUST 20, 1912, AS AMENDED
MARCH 4, 1913, AND MARCH 4, 1917.

AN ACT To regulate the importation of nursery stock and other plants and plant products; to enable the Secretary of Agriculture to establish and maintain quarantine districts for plant diseases and insect pests; to permit and regulate the movement of fruits, plants, and vegetables therefrom, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That it shall be unlawful for any person to import or offer for entry into the United States any nursery stock or other plant, root, bulb, seed, fruit, or vegetable, unless and until it shall have been issued thereafter by the Secretary of Agriculture, under such conditions and regulations as he may prescribe, and unless such nursery stock or other plant, root, bulb, seed, fruit, or vegetable is accompanied by a certificate of inspection, in manner and form as required by the Secretary of Agriculture, of the proper official of the country in which the same was grown, certifying to the effect that the stock has been inspected and is believed to be free from injurious plant diseases and insect pests: Provided, That the Secretary of Agriculture may admit nursery stock when the conditions of this act shall have been complied with as far as practicable: Provided further, That any nursery stock may be imported for experimental purposes under such conditions as may be prescribed by the Secretary of Agriculture upon such permit: And provided further, That the Secretary of Agriculture may prohibit the importation of nursery stock or other plants, roots, bulbs, seeds, fruits, and vegetables from countries where he shall find that plant diseases exist and may be introduced by importation of such articles, and may make such rules and regulations as may be necessary to prevent the introduction of such diseases into the United States, and may modify or withdraw the same when in his judgment the public interests will not be endangered thereby.



Roques et al. 2010


CANADA

CODIFICATION

Loi sur la quarantain

CONSOLIDATION

Quarantine Act

Legal framework for phytosanitary regulation – global level

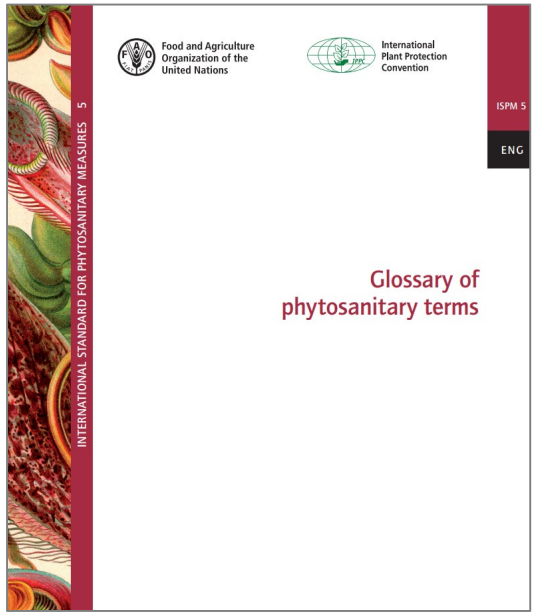
- International treaties and conventions set the standards for phytosanitary regulation of trade on a global level

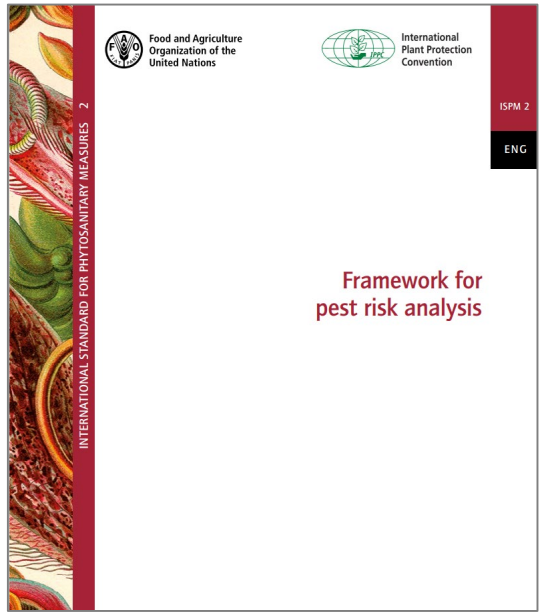
- **International Plant Protection Convention** (IPPC; 1951)
  - Aims at preventing the introduction, and spread of pests of plants and plant products, and to promote appropriate measures for their control

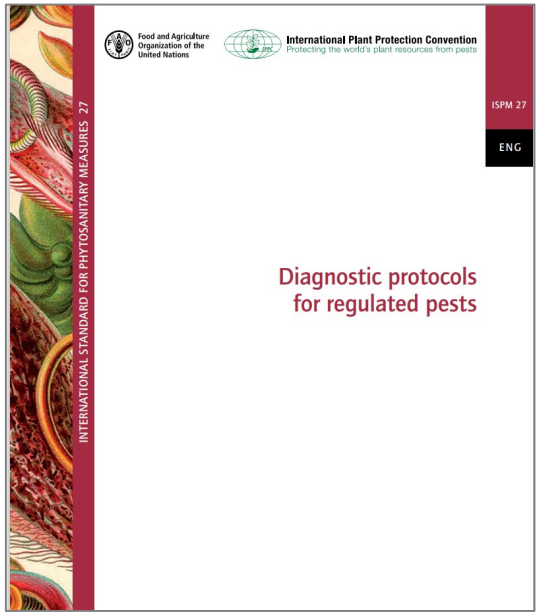
- The WTO **Agreement on the Application of Sanitary and Phytosanitary Measures** (SPS Agreement; 1995)
  - Sets constraints on member-states' policies relating to food safety, animal and plant health

Legal framework for phytosanitary regulation – global level

– International Standards for Phytosanitary Measures (ISPMs)







Legal framework for phytosanitary regulation – regional level

– Regional Plant Protection Organisations (RPPOs)

- Asia and Pacific Plant Protection Commission (APPPC)
- Caribbean Agricultural Health and Food Safety Agency (CAHFSA)
- Comunidad Andina (CAN)
- Comite de Sanidad Vegetal del Cono Sur (COSAVE)
- European and Mediterranean Plant Protection Organization (EPPO)
- Inter-African Phytosanitary Council (IAPSC)
- Near East Plant Protection Organization (NEPPO)
- North American Plant Protection Organization (NAPPO)
- Organismo Internacional Regional de Sanidad Agropecuaria (OIRSA)
- Pacific Plant Protection Organization (PPPO)

Asia & Pacific Plant Protection Commission

NAPPO
North American Plant Protection Organization
Organización Norteamericana de Protección a las Plantas

Legal framework for phytosanitary regulation – regional level – Europe

- 1951: EPPO (first RPPO) – 15 European countries working on the development of international standards
- 1977: Plant Health Directive (77/73/EEC) with harmonized list of quarantine pests of 9 countries (BE, FR, DE, IT, LU, NL, DK, IR, UK)
- 2000: EU harmonized Plant Health Law (EU/2000/29)
- 2006: EFSA Plant Health Panel – advisory body of EU Commission
- 2016: complete revision of EU Plant Health Law (EU/2016/2031)

efsa

European Commission

Legal framework for phytosanitary regulation – national level

– Regulatory frameworks (phytosanitary legislations, regulations and procedures) and National Plant Protection Organisations (NPPOs)

Germany

IPPC Official Contact Point

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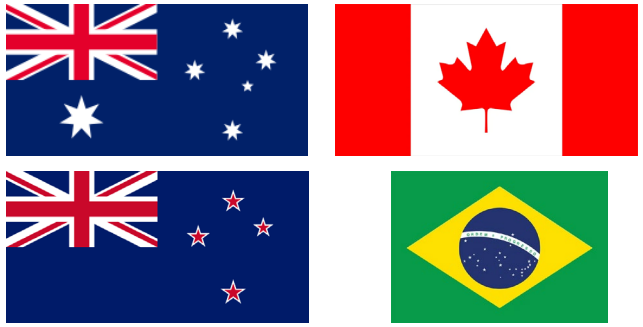
Preferred languages: English
Date contact registration: 01 Feb 2005


Contracting Parties 184
North America 2
Latin America and the Caraibbean 33
Europe 46
Africa 50
Asia 25
Near East 15
South West Pacific 13
IPPC Secretariat
RPPOs 10

Closed vs opened biosecurity approach

Closed countries

- Ban on import of the commodity, unless it has been proven to be safe
- **Commodity Risk Assessment** → Import permits

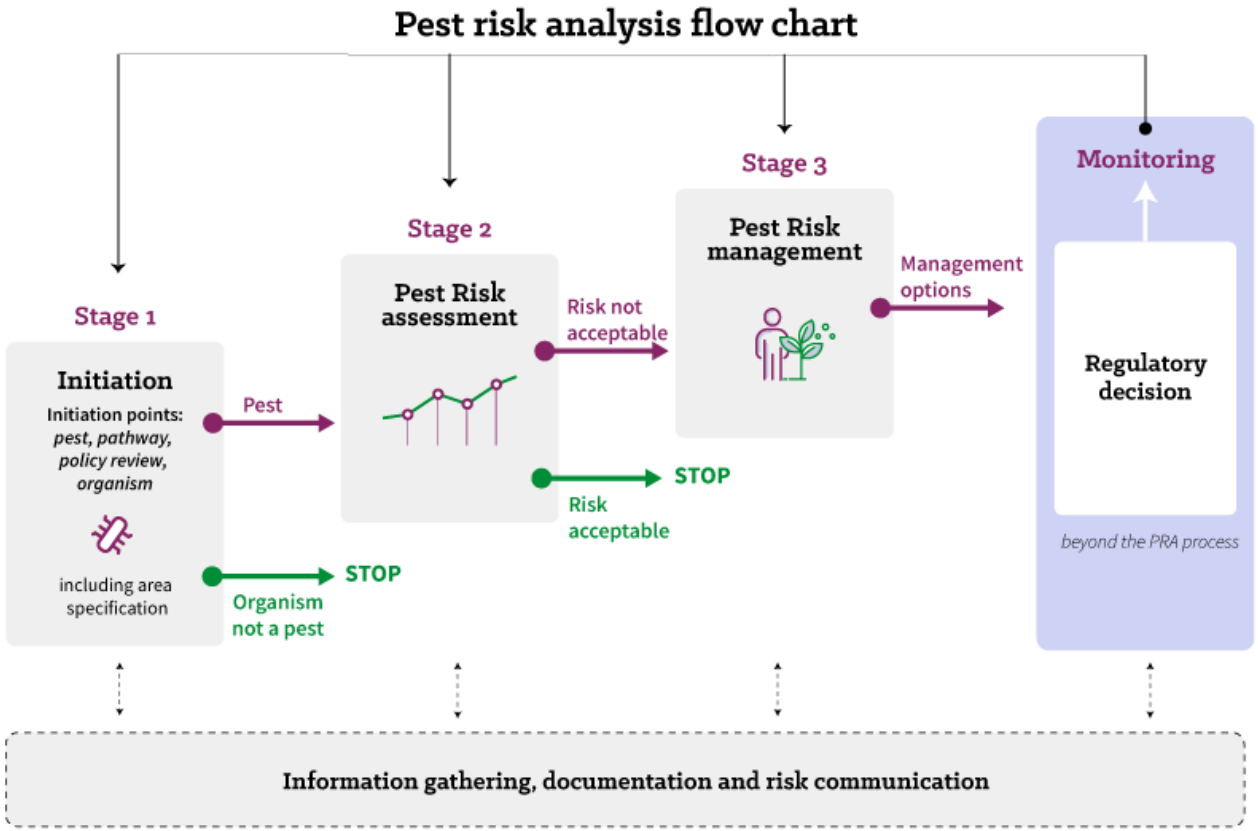


Opened countries

- Import allowed if there is no evidence of risk
- **Pest Risk Assessment** → Requirements for Pathways

Pest Risk Analysis

- PRA is the process of evaluating biological or other scientific and economic **evidence** to determine
  - whether an organism is a **pest**
  - whether it should be **regulated**
  - the strength of any **phytosanitary measures** to be taken against it.



FAO. Pest Risk Analysis

Pest Risk Assessment

Section 1. The organism
Section 2. Biological characteristics of the pest
Section 3. Geographical distribution of the pest
Section 4. Host plants of the pest
Section 5. Potential of the pest for establishment in PRA area
Section 6. Control of the pest
Section 7. Transport of the pest
Section 8. Economic impact of the pest

Uncertainties

Regulated pests

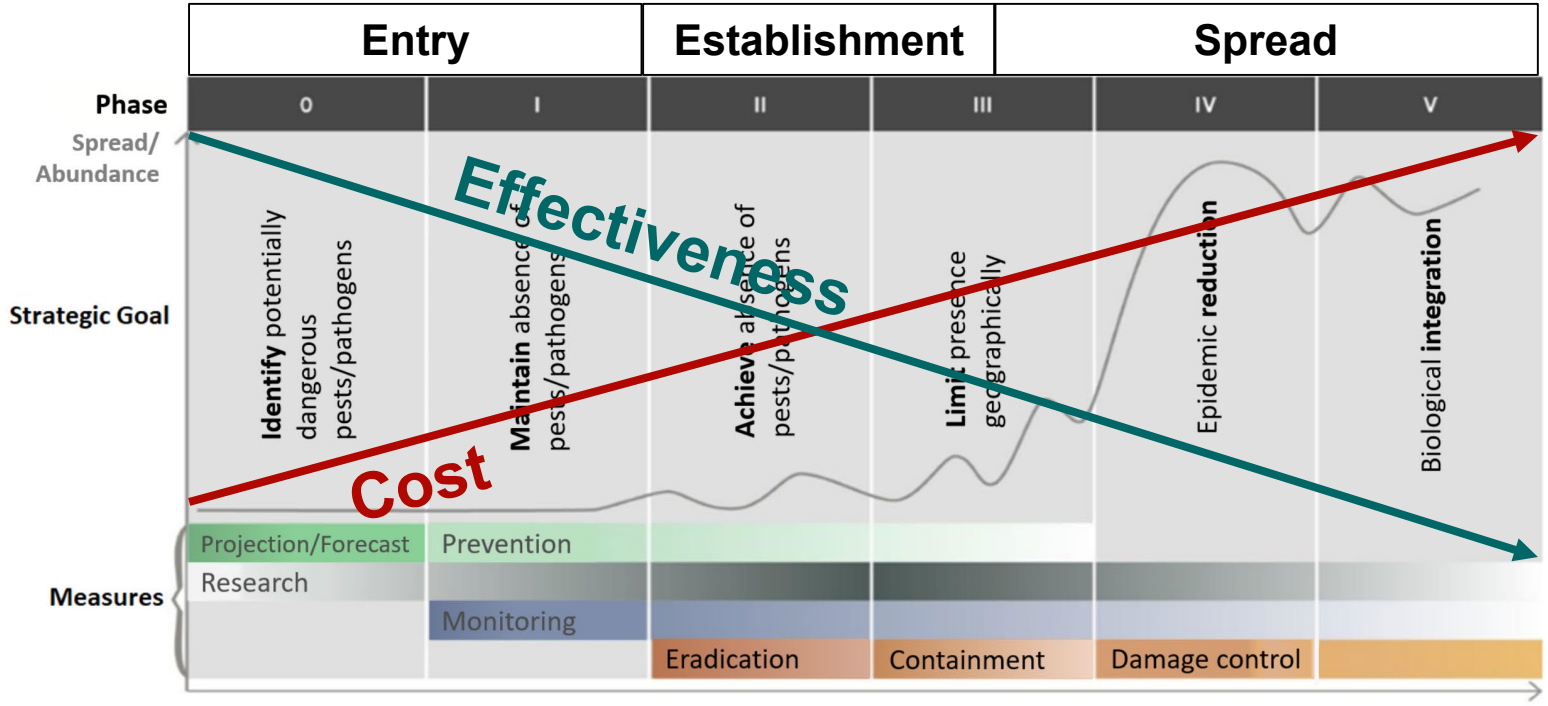
EPPO A1 and A2 list of pests recommended for regulation as quarantine pests

EPPO started to elaborate its A1 and A2 Lists in the early 1970s, the first lists were approved in 1975. The EPPO A1 List contains pests that are absent in the EPPO region, the EPPO A2 List contains pests that are not widely distributed in the EPPO region. In these early days, additions of pests to the A1 or A2 List were proposed by EPPO member countries and made on the basis of scientific documentation and expert judgement. Since the 1990s, additions to the EPPO A1 and A2 lists have been made on the basis of PRAs.

> ***EPPO A1 List*** *(online with links to pest-specific information)* **Quarantine pests**
> ***EPPO A2 List*** *(online with links to pest-specific information)* **Non-quarantine pests**
> ***EPPO A1 and A2 Lists*** *(PDF version)*
> ***List of pests recently added to the EPPO A1 and A2 Lists*** *(or of urgent phytosanitary concern)*

Pest Risk Management

– The identification of **phytosanitary measures** that (alone or in combination) reduce the risk to an acceptable level.



Phytosanitary measures

Table 2 – Summary of the measures stated in regulations, arranged by country. That a measure is required for all live plants imports is indicated with + and measures that are not required at all are indicated with –. Hash signs (#) indicate that additional measures are required for specific genus–origin combinations. In Europe, pathway risk analyses are carried out in exceptional cases, by the European and Mediterranean Plant Protection Organisation.

	New Zealand	Australia	USA	Canada	India	China	Brazil	Kenya	South Africa	EU
Phytosanitary certificate	+	+	+	+	+	+	+	+	+	+
Import permit	+	+	+	+	+	+	+	+	+	–
Import inspections	+	+	+	+	+	+	+	+	+	+
Pathway risk analysis	+	+	#	+	+	+	+	#	#	–
No contaminants/soil	#	#	#	+	#	+	+	+	#	#
Pre-export treatments	+	+	#	#	#	#	+	#	#	#
Pest free area	#	#	#	#	#	#	#	#	#	#
Pest free production site	#	#	#	#	#	#	#	#	#	#
Shipping in specific season	#	+	#	#	–	–	–	–	–	#
Post-entry quarantine	+	+	#	#	#	#	+	#	#	#

Eschen et al. 2015 Environmental Science & Policy

Phytosanitary certificate/ Plant passport

– Guaranties that certain plants, plant products, and other objects entering the EU are:
  - properly inspected;
  - free from quarantine pests, within the requirements for regulated non-quarantine pests and practically free from other pests;
  - in line with the plant health requirements of the EU, laid down in Regulation (EU) 2019/2072.

- Top left: The EU flag (in color, black and white, or reverse / negative)
- Top right: The word Plant Passport in the national language and in English.
- A: Botanical name of the plant
- B: Country code and 9-digit registration number
- C: Traceability code
- D: Country of origin (e.g. NL, US, etc.)

Import inspections

- Large volumes of traded plants and limited number of inspectors.
- Visual inspections – pests are often imported on their native hosts (no visible damage).

ISPM 15: treatment of wood packaging material

– Wood packaging materials must be debarked prior to:

- Being heat treated until its core reaches 56°C for at least 30 minutes.
- Being fumigated (Methyl Bromide).

Monitoring - early detection, rapid response

E.g., periurban areas

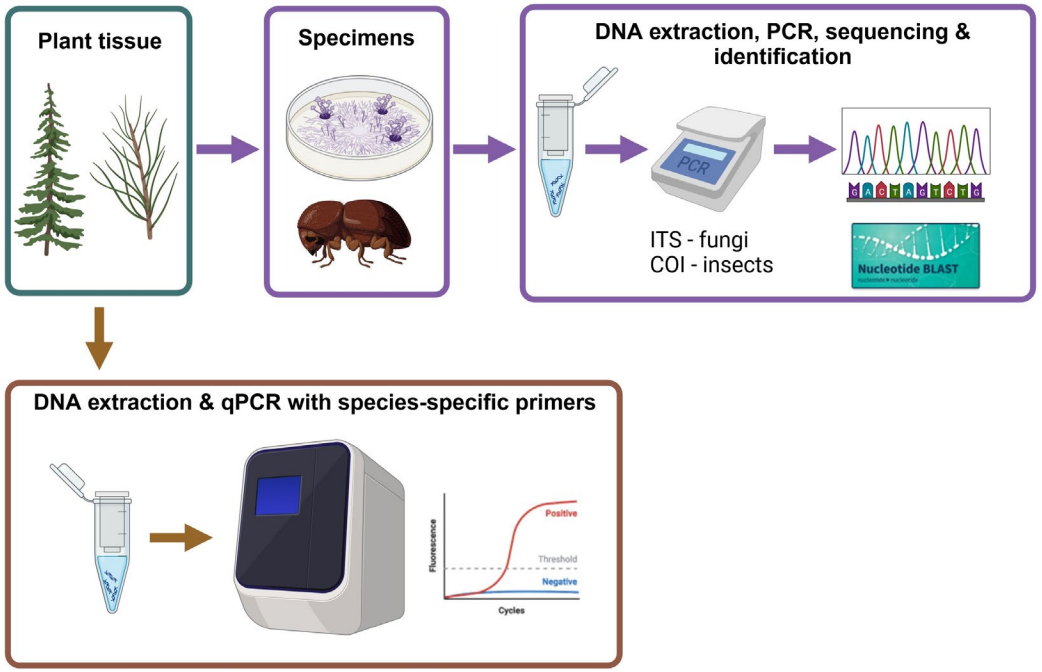
Abb. 1. Eingesetzte Fallentypen. vlnr: Deltafalle, grüne Trichterfalle, schwarze Trichterfalle, Sporenfalle. Fotos: WSS

In the nurseries

– Traps for collection of specimens and/or examination or sampling of symptomatic/asymptomatic plants.

Diagnostics

– Sampling and laboratory methods based on ISPMs.



ISPM 27
Diagnostic protocols for regulated pests

DP 22: *Fusarium circinatum*

Adopted 2017; published 2017

CONTENTS

Eradication

- Small affected areas, quick response, and efficient implementation of quarantine restrictions → high probability of eradication success.

- Expensive, disruptive and visible → likely to lead to opposition from the public and industry.

Branco et al. 2023 Neobiota

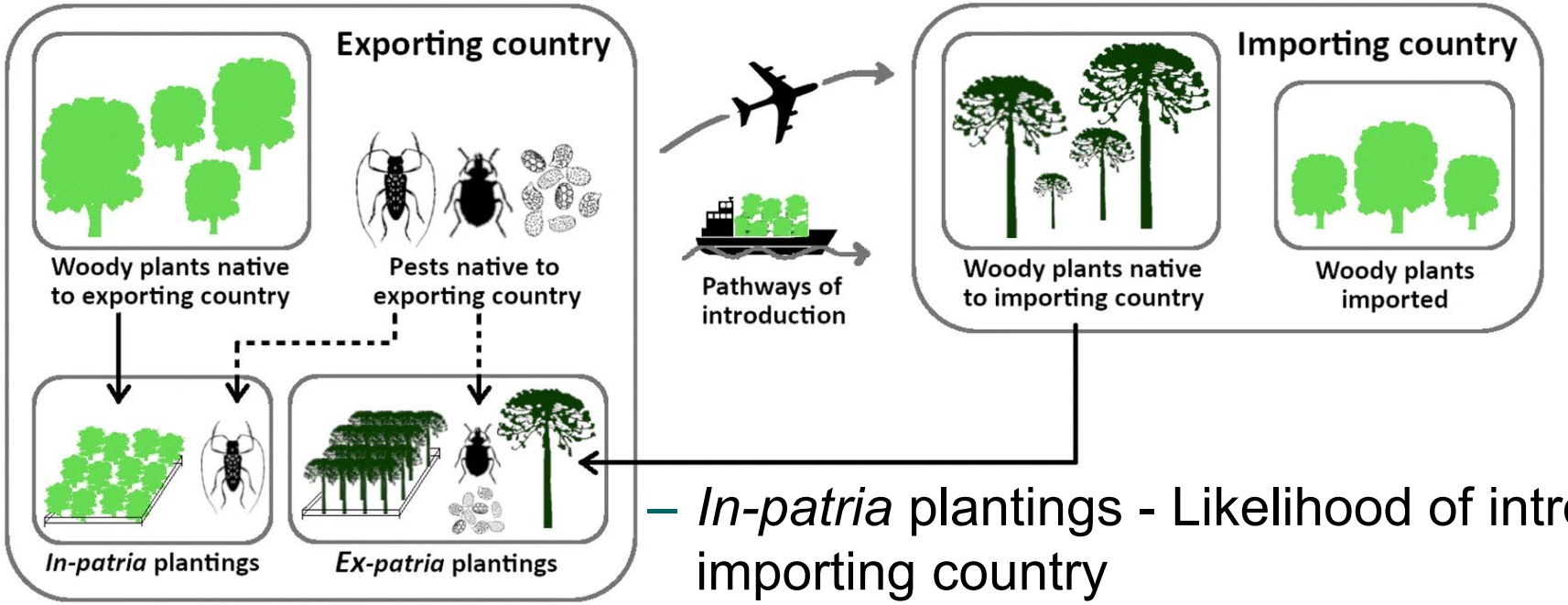
Phytosanitary measures in EU target known, risky pests

– The majority of non-native forest pests were **not known as harmful** before the introduction and were thus not regulated.

Emerald ash borer (*Agrilus planipennis*).
Photo by Debbie Miller, USDA Forest Service, Bugwood.org

Ash dieback fungus (*Hymenoscyphus fraxineus*).
Photo by Amadey Trnkoczy, mushroomobserver.org

Detection before introduction – sentinel plantings



- *In-patria* plantings - Likelihood of introduction to importing country
- *Ex-patria* plantings - Potential impacts if introduced
- Additional info for PRA (e.g., pest-host associations)

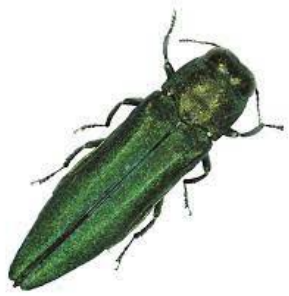
Eschen et al. 2019 Journal of Pest Science

New efforts are being made

- Shift to **pathway/commodity risk analysis**
  - Several tree genera are now listed as **high-risk plants** and their import into the EU territory is prohibited until a proper risk assessment is done.
- **Priority pests**
  - Information campaigns to the public if present in the country, annual surveys, contingency plans, simulation exercises, and action plans for eradication.







Summary

- Prevention is better than cure.
- Pest Risk Analysis – many uncertainties; doesn't deal with unknown pests.
- Import inspections – large volumes of traded plants and limited number of inspectors and methodological tools.
- Good news – EU is switching to pathway/commodity risk analysis.
- https://youtu.be/MXtQ9zVUqI0

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Phytosanitary safety of tree seed trade

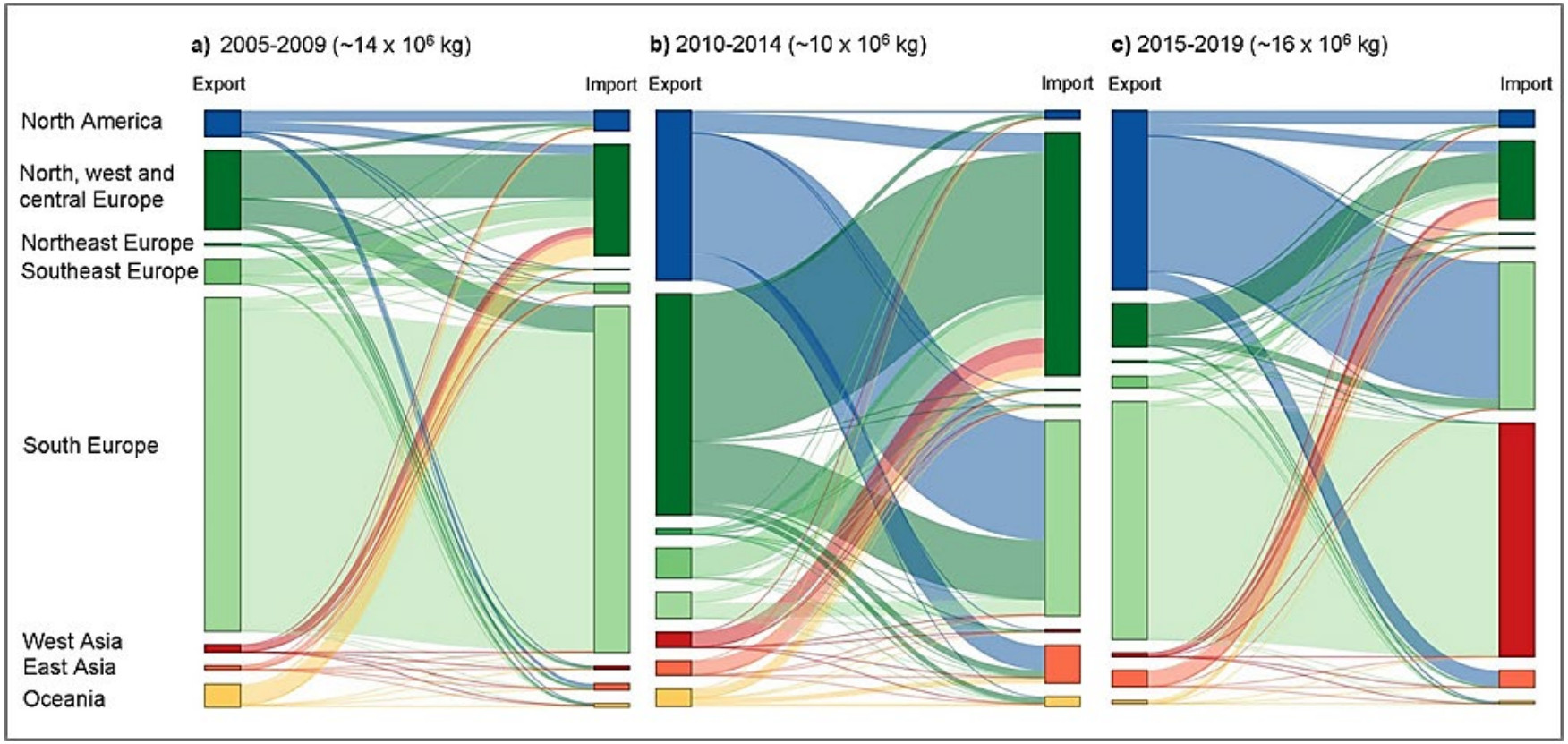
Iva Franić (iva.franic@wsl.ch)

Few restrictions target tree seed exchange in Europe

- All tree seed needs **phytosanitary certification**.
- Specific **phytosanitary requirements** for the movement of *Pinus* spp. and *Pseudotsuga menziensii* seed.
- *Fusarium circinatum* is the only quarantine forest pest that is known as **seed-borne**.

Intercontinental tree seed exchange is increasing

~ 25 million kg of tree seeds traded annually worldwide



Franić et al. Under review in Current Forestry Reports

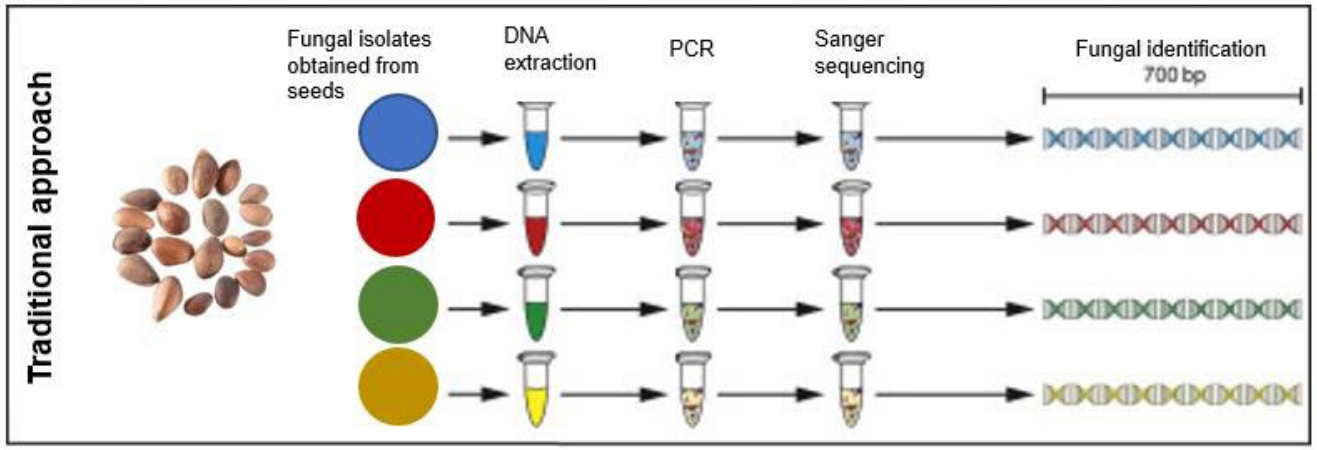
Ecological Applications, 29(7), 2019, e01971

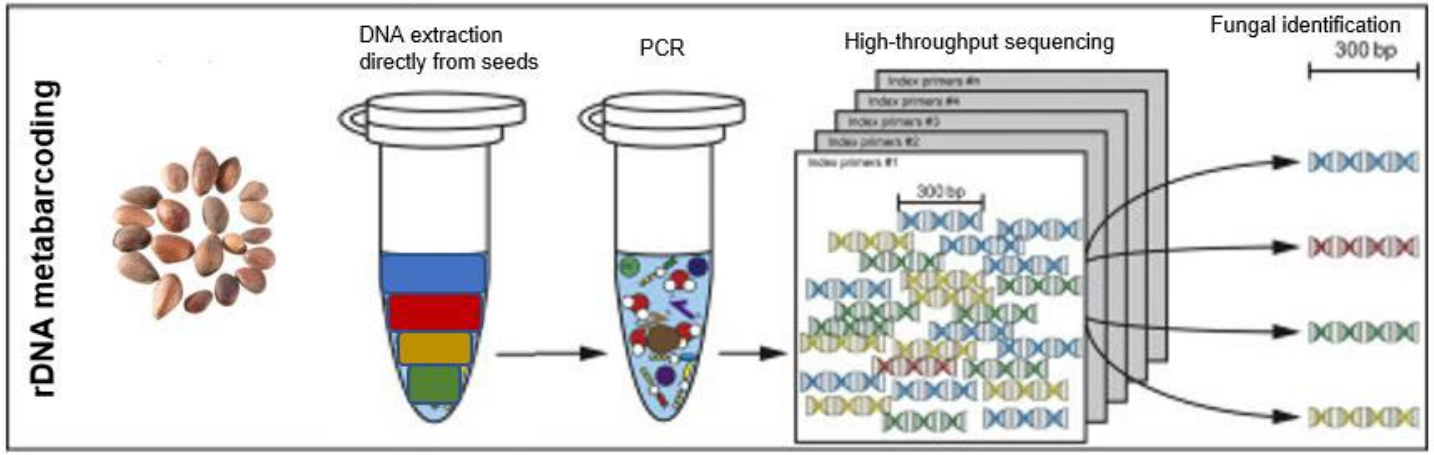
Are traded forest tree seeds a potential source of nonnative pests?

Iva Franić,[1,2,3,9] Simone Prospero,[2] Martin Hartmann,[4] Eric Allan,[3] Marie-Anne Auger-Rozenberg,[5] Niklaus J. Grünwald,[6] Marc Kenis,[1] Alain Roques,[5] Salome Schneider,[2] Richard Sniezko,[7] Wyatt Williams,[8] and René Eschen[1]

Tree species	Common names	Family	Group	Origin	No. seed lots
Acer macrophyllum Pursh	bigleaf maple, Oregon maple	Sapindaceae	Angiosperm	North America	6
Quercus garryana Douglas ex Hook	Garry oak, Oregon white oak, Oregon oak	Fagaceae	Angiosperm	North America	6
Pinus ponderosa Douglas ex C. Lawson	Ponderosa pine, bull pine, blackjack pine, western yellow-pine	Pinaceae	Gymnosperm	North America	8
Tsuga heterophylla (Raf.) Sarg.	western hemlock, western hemlock–spruce	Pinaceae	Gymnosperm	North America	7
Acer pseudoplatanus L.	sycamore	Sapindaceae	Angiosperm	Europe	3
Fagus sylvatica L.	common beech	Fagaceae	Angiosperm	Europe	6
Pinus sylvestris L.	Scots pine	Pinaceae	Gymnosperm	Europe	5
Picea abies (L.) H. Karst.	Norway spruce, European spruce	Pinaceae	Gymnosperm	Europe	5
Acer palmatum Thunb.	palmate maple, Japanese maple, smooth Japanese maple	Sapindaceae	Angiosperm	Asia	5
Pinus tabuliformis Carrière	Manchurian red pine, southern Chinese pine, Chinese red pine	Pinaceae	Gymnosperm	Asia	4
Larix gmelinii (Rupr.) Kuzen.	Dahurian larch	Pinaceae	Gymnosperm	Asia	3

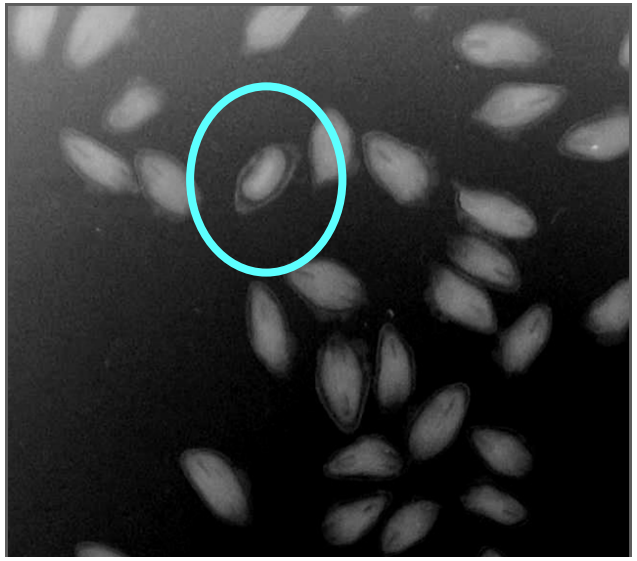
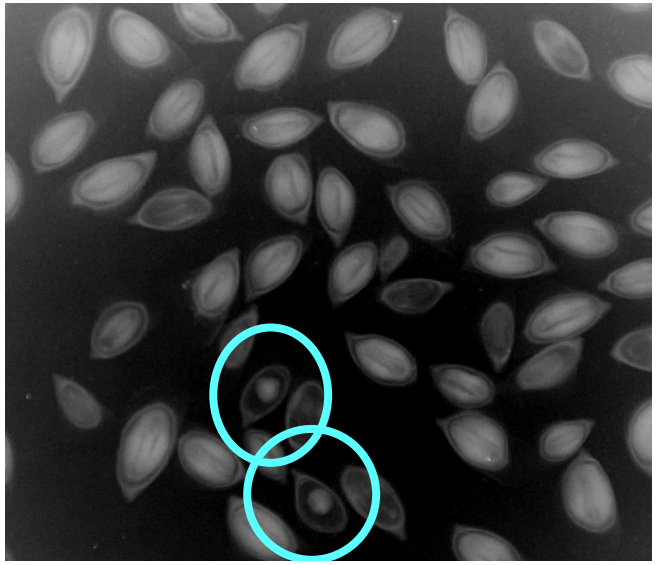
Methods



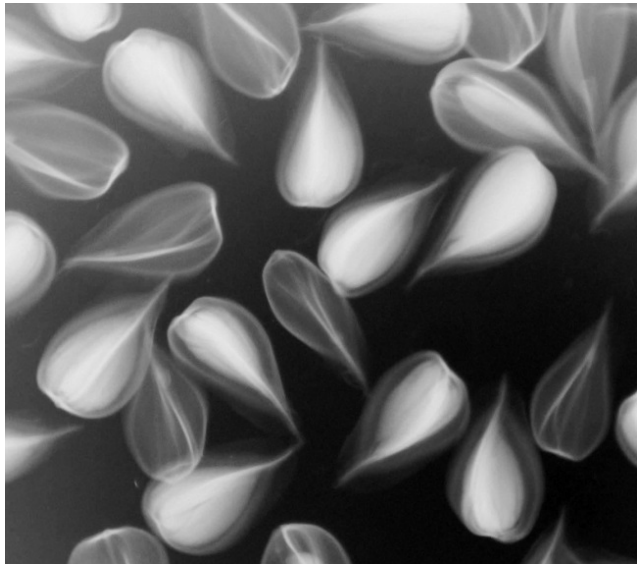
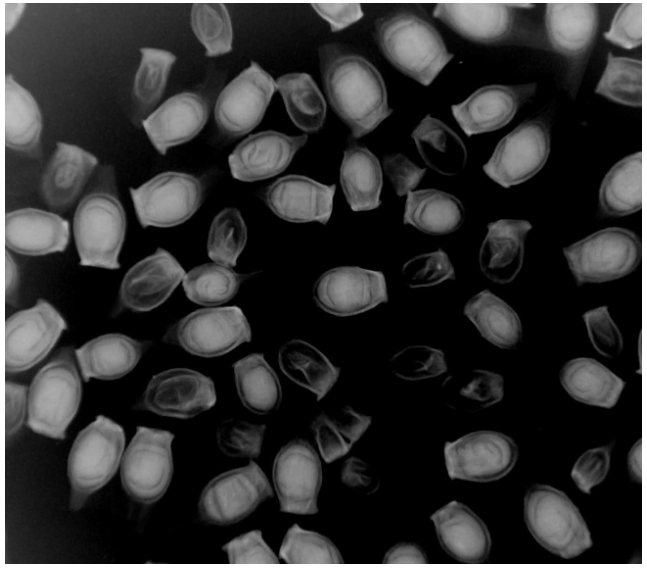


- Fungi were assessed using **traditional plating** and **rDNA metabarcoding.**
- **FUNGuild** used for parsing trophic modes and guilds.

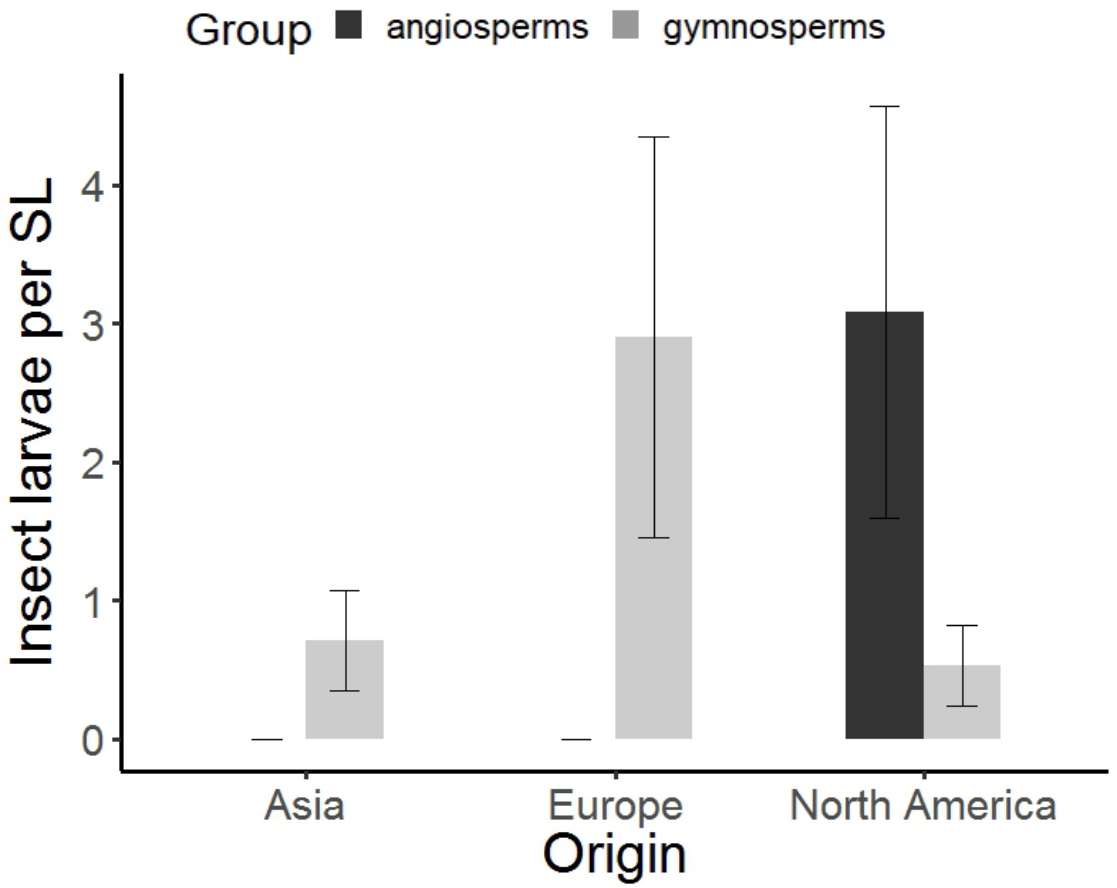
Adapted from Gill et al. 2016


X raying, dissecting → identification

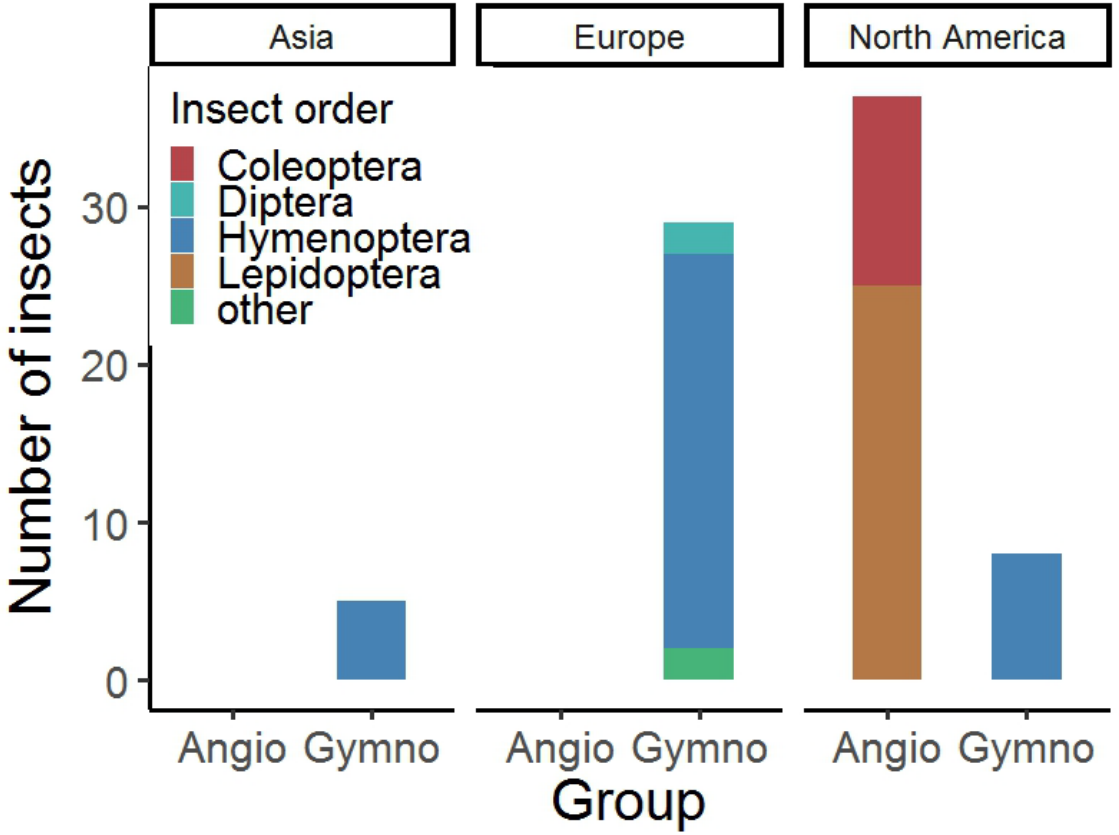




30% of SL infested with total of 79 insects



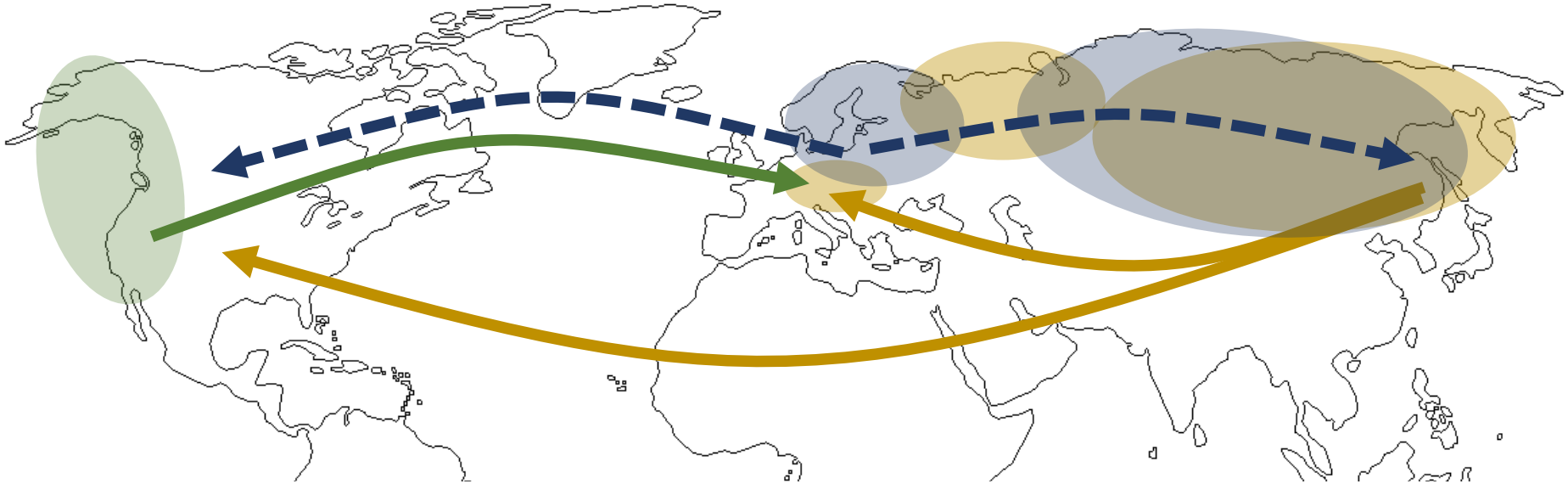
Dominant gymnosperm and angiosperm insects are different

Megastigmus strobilobius larva in *Picea abies* seed.
Photo Iva Franic



Ernobius spp. larva in an acorn.
Photo: Stephen Katovich, USDA Forest Service, Bugwood.org

Cydia latiferreana larva in an acorn.
Photo: Iva Franic



Evidence for movement of insect pests

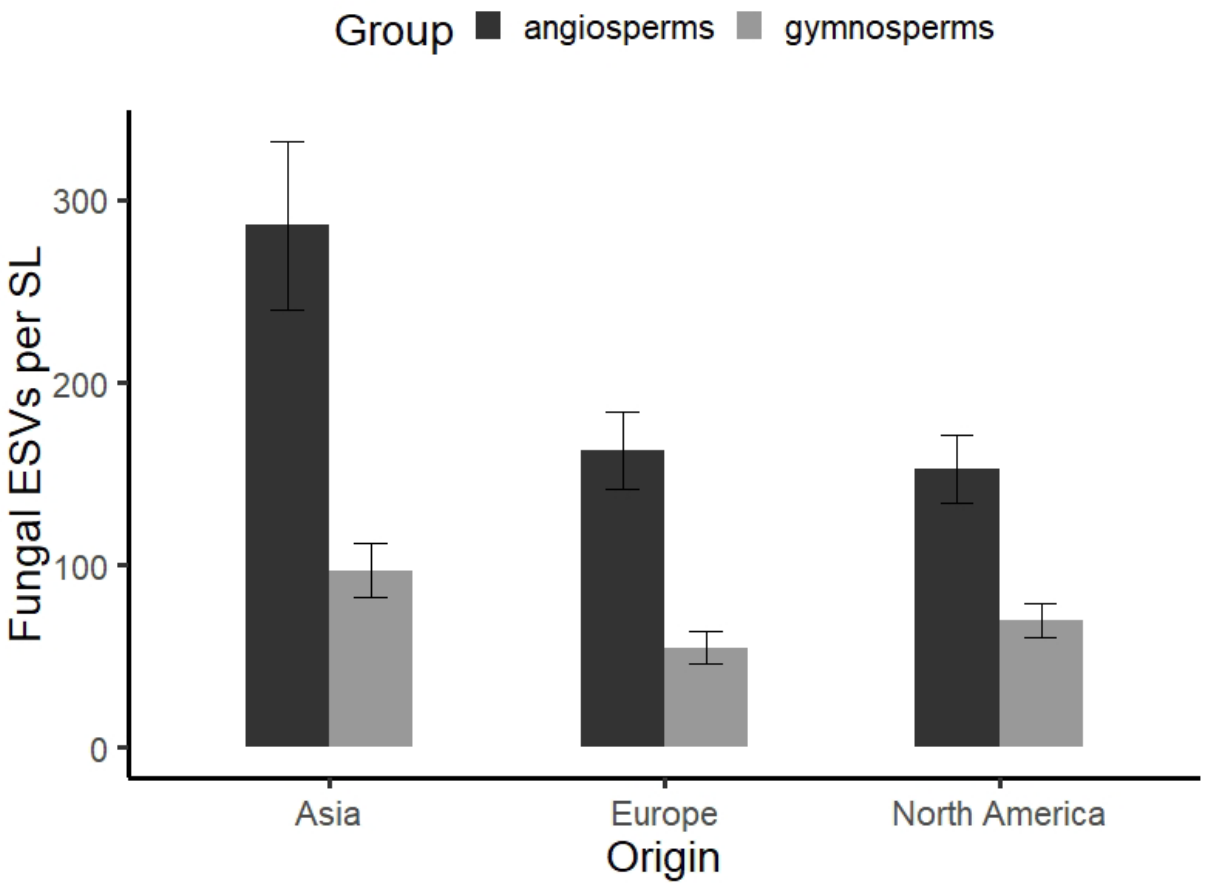
Megastigmus pictus – Eurasian *Larix* spp

Megastigmus tsugae – North American *Tsuga* spp

Megastigmus strobilobius – Eurasian *Picea* spp

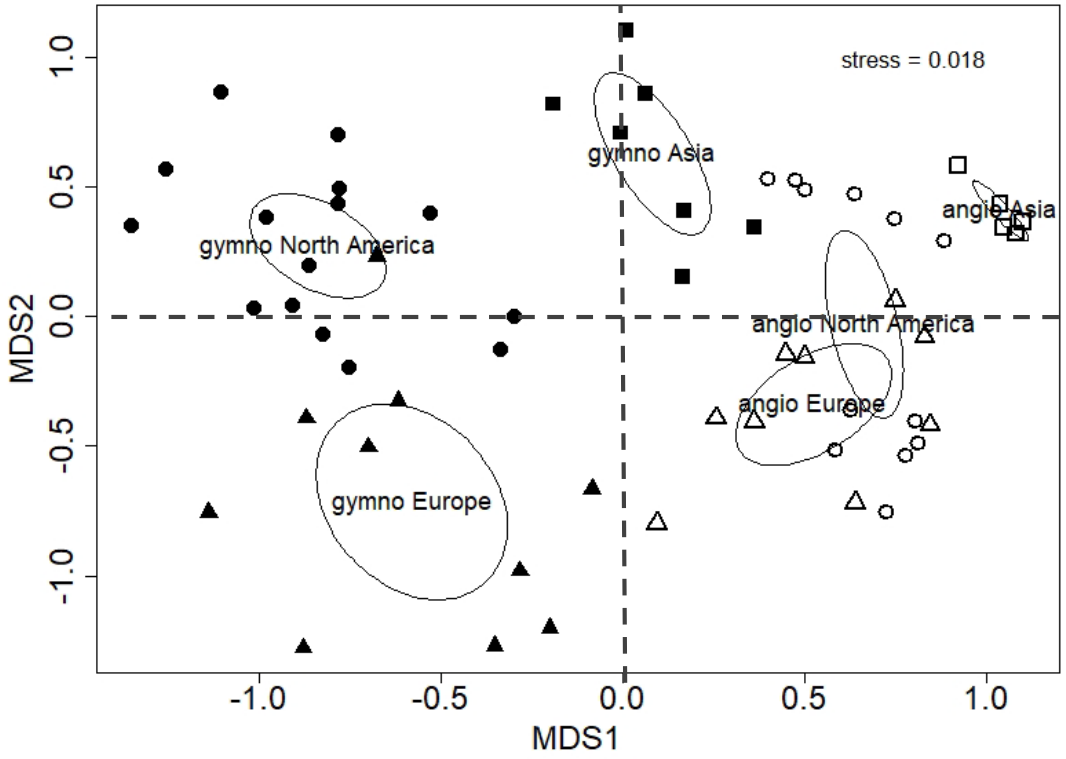
Megastigmus spp.
Photo by S. Boivin, INRAE,
DOI: 10.1007/s00114-004-0554-4

Fungal diversity is high, especially in angiosperm seeds and seeds from Asia



- All seed lots infected.
- 1905 ESVs belonging to 234 genera and 269 species.
- Large fraction of unidentified ESVs.

Seed fungi differ among seeds of different groups and continents



- 19% of ESVs shared between groups.
- 65% of ESVs unique for one of the continents.
- Europe and North America share 3 times more ESVs than each of them with Asia.

Identified plant pathogens

- 630 out of 1905 ESVs (33%) classified as plant pathogens based on their taxonomy (FUNGuild).
- Angiosperms have a higher fraction of plant pathogenic ESVs than gymnosperms.

	Number
Identified fungal species	269
Plant pathogenic fungal species	100
Woody plant pathogens not previously recorded in EU	7
Woody plant pathogens with limited distribution in EU	4

TABLE 5. Fungal species known to be potential pathogens of woody plants, found in traded seed lots from different continents.

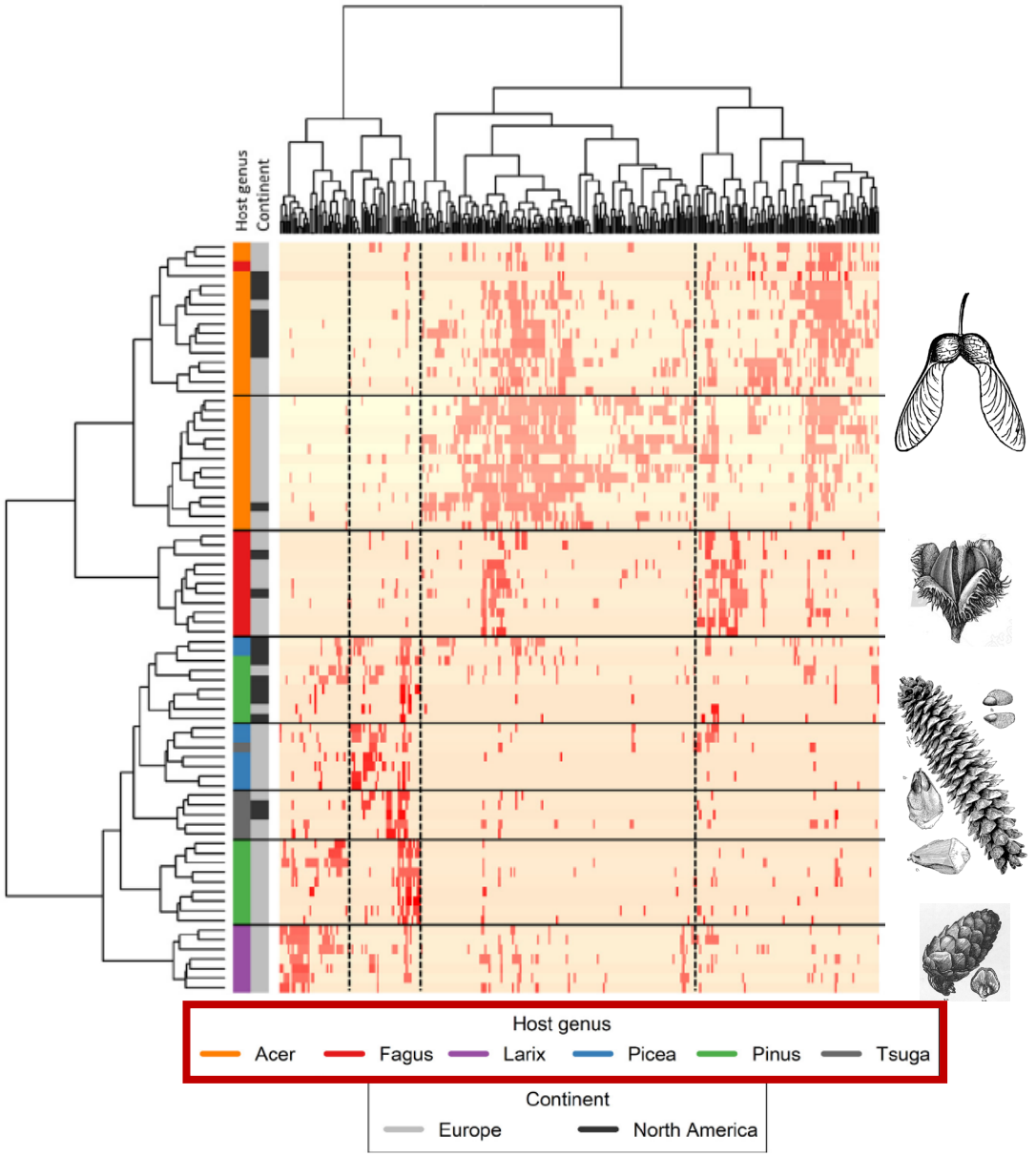
Plant pathogenic species	Corresponding ESV	Origin of seed lots		
		Europe	North America	Asia
Absent from Europe				
Alternaria rosae E.G. Simmons & C.F. Hill	ESV0248	**57, 73**	**11, 12, 50**	
Colletotrichum gigasporum Rakotonir. & Munaut	ESV2475			29, 75, 77
Diaporthe australafricana Crous & Van Niekerk	ESV0675	**57, 78**	5, 7, 10, 11, 14,15	
Diaporthe siamensis Udayanga, X. Z. Liu & K.D. Hyde	ESV1811			**77**
Lasiodiplodia crassispora T. Burgess & Barber	ESV0546			**27, 29, 74, 75, 76**
Phaeoacremonium roseum J.R. Úrbez-Torres, P. Haag & D.T. O'Gorman	ESV0482		16, 17, 20	**77**
Pseudocercospora sphaerellae-eugeniae (Rangel) Crous, Alfenas & R.W. Barreto	ESV0479 ESV0731 ESV0856 ESV1113 ESV1721 ESV2598			**75, 77**
Limited distribution in Europe				
Diplodia corticola A.J.L. Phillips, A. Alves & J. Luque	ESV2722		19	**75**
Neonectria major (Wollenw.) Castl. & Rossman	ESV0139	63		
Setomelanomma holmii M. Morelet	ESV0362	71, 73		**30**
Diaporthe alleghaniensis R.H. Arnold	ESV1258 ESV2757	73		**28, 30, 68, 74**

Notes: New records for species-continent combinations are identified by boldface type. Numbers indicate the seed lots (Appendix S1: Table S1) in which the species were found. ESV, exact sequence variant.

Evidence for movement of fungal pathogens

Host identity is the key factor in shaping tree seed mycobiomes

Natural distribution range	Continent of seed collection	
	Europe	North America
Asia	**12**	**4**
Acer palmatum Thunb.	5 NN	4 NN
Larix gmelinii (Rupr.) Kuzen.	7 NN	0 NN
Europe	**34**	**8**
Acer pseudoplatanus L.	10 N	2 NN
Fagus sylvatica L.	10 N	2 NN
Picea abies (L.) H. Karst.	6 N	2 NN
Pinus sylvestris L.	8 N	2 NN
North America	**12**	**8**
Acer macrophyllum Pursh	5 NN	3 N
Pinus ponderosa Douglas ex Hook	3 NN	3 N
Tsuga heterophylla (Raf.) Sarg.	4 NN	2 N
Total	58	20



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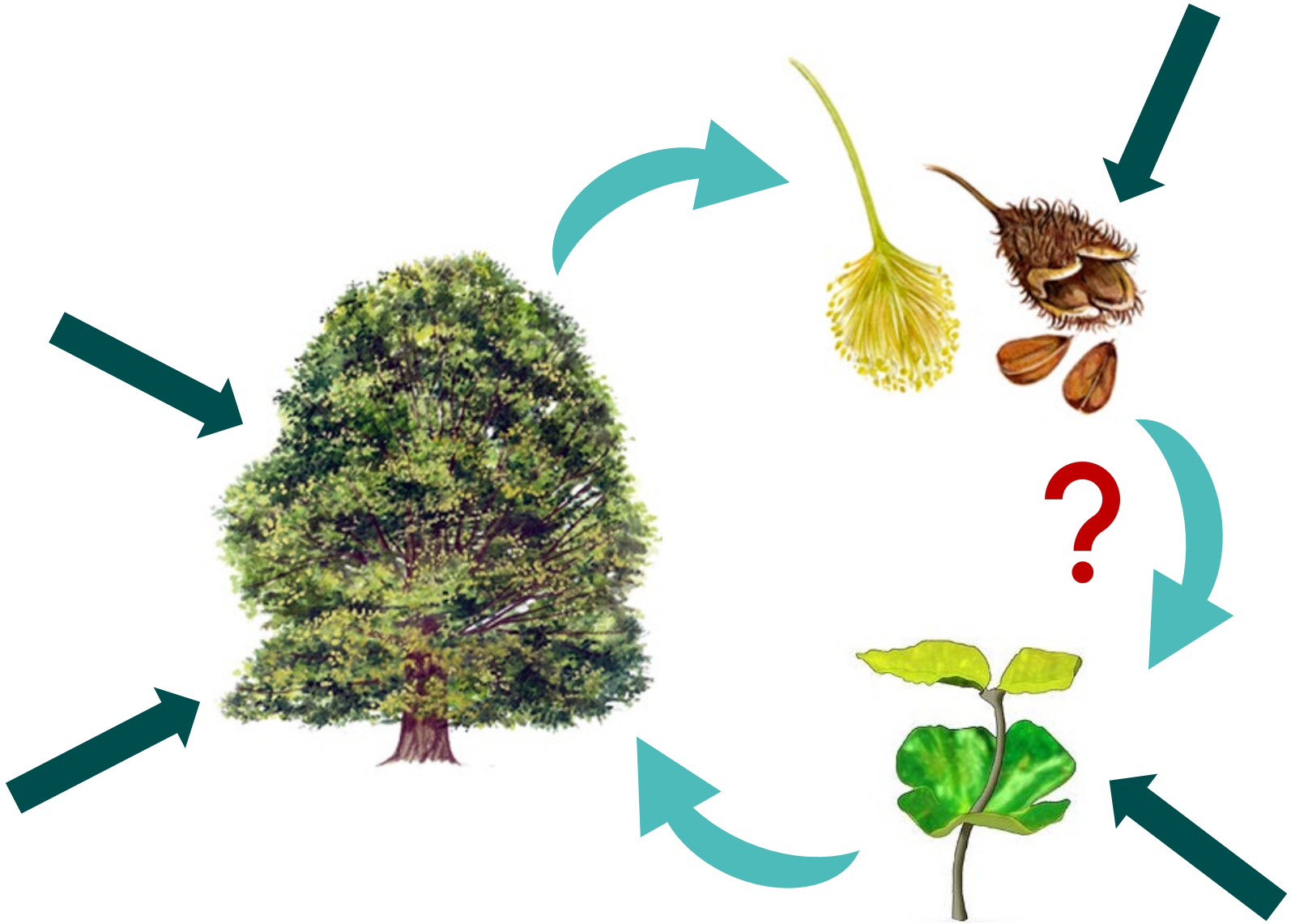
Vertical transmission

- Pollen and/or embryo

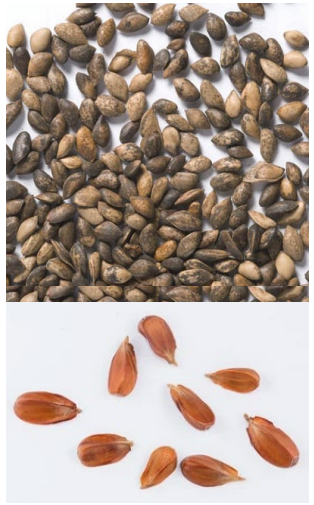
Horizontal transmission

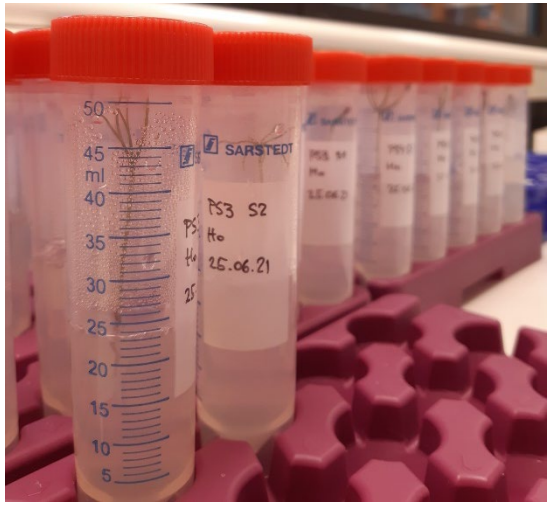
- Wind
- Rain
- Insects
- Soil



Methods

- We characterized **fungi associated with seeds and seedlings** grown in sterile environment of *Pinus sylvestris* and *Fagus sylvatica*, 5 SL each.
- Fungi were assessed directly from seeds and seedlings using **traditional plating** and **rDNA metabarcoding.**

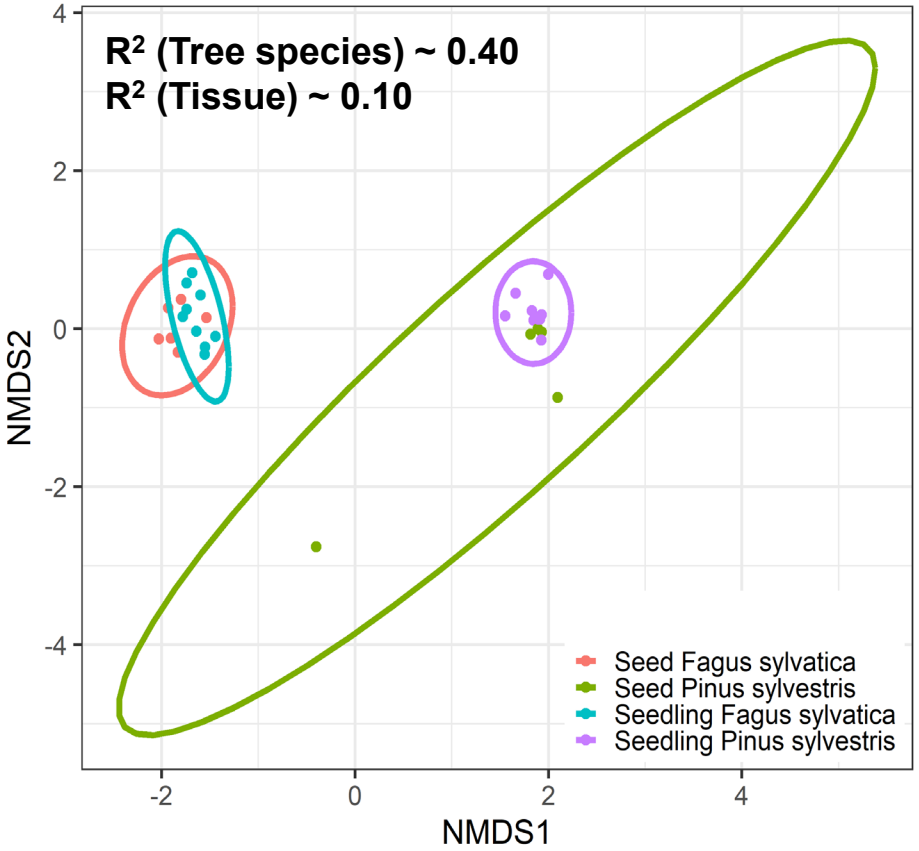




Species composition similar in seeds and seedlings

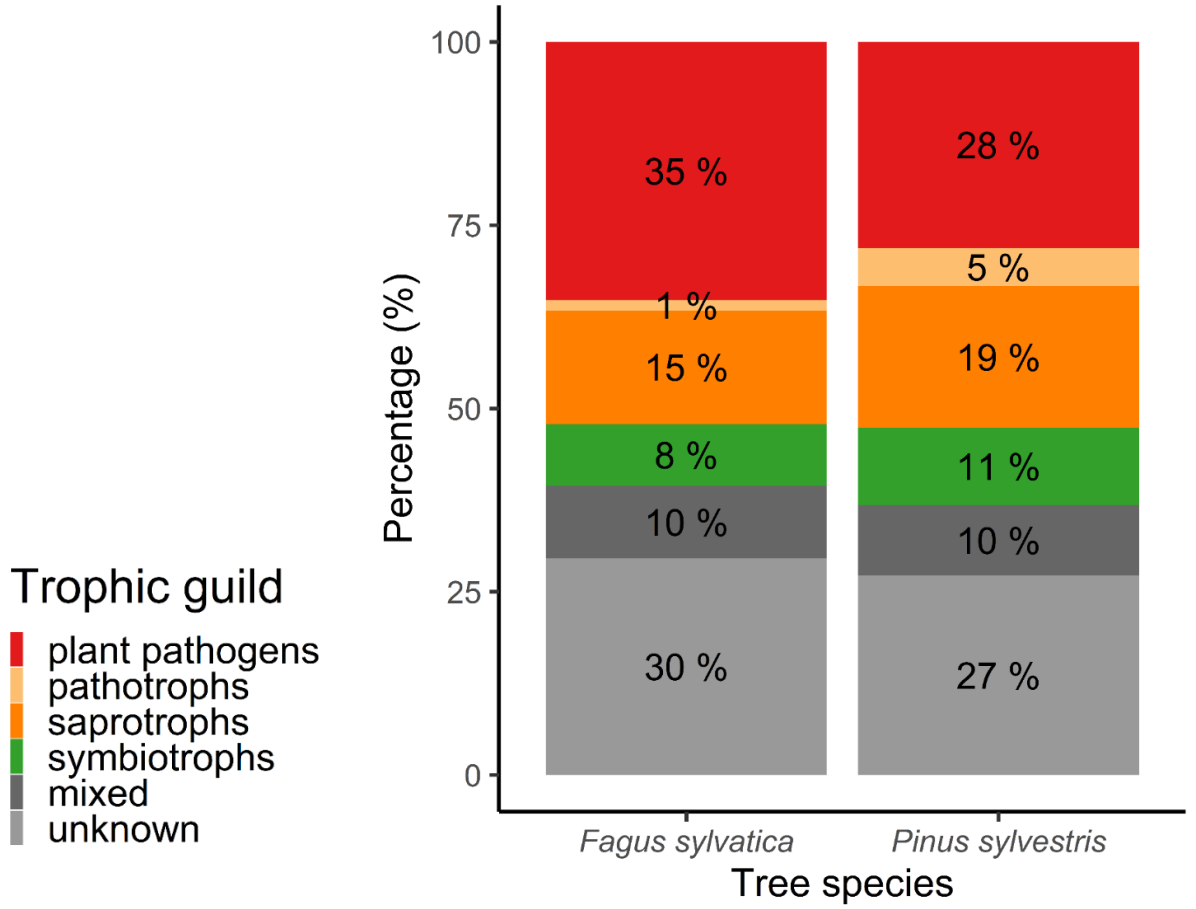
- ~70% of OTUs found in seeds were also present in seedlings.

  Fagus sylvatica: 71 out of 97 genera (73%)
  Pinus sylvestris: 114 out of 136 genera (84%)



High percentage of plant pathogenic fungal genera

- Large fraction of genera not assigned to trophic guild.
- One third of fungal genera are possible or probable plant pathogens.



Summary and conclusions

- Seed-borne fungal pathogens are **highly diverse** and can be **vertically transmitted** – risk of transport, introduction and establishment is high?
- Improved risk assessment requires additional information about seed-borne fungi: **viability**, **persistence** in seedlings over time, **reproduction, dispersal and damage**.