European and Mediterranean Plant Protection Organisation
Organisation Européenne et Méditerranéenne pour la Protection des Plantes
11-16987 (11-16902, 11-16726, 10-16415)

Pest Risk Analysis for *Agrilus anxius*

A preliminary draft has been prepared by the EPPO Secretariat. This document has been reviewed by an Expert Working Group that met in the EPPO Headquarters in Paris on 2010-09-13/16. This EWG was composed of:

Dr Christiane Fassotte - Walloon Agricultural Research Centre - Gembloux (Belgium)
Dr Robert Haack - US Forest Service- - Northern research Station- East Lansing, Michigan (USA)
Dr Dan Herms - Ohio State University – Wooster (USA)
Dr Daegan Inward - Centre for Forestry and Climate Change - Forest Research- Farnham (UK)
Dr Claire Sansford (Core member) - Food and Environment Research Agency- York (UK)

<u>Secretariat</u>
Ms Muriel Suffert – EPPO Secretariat
Dr Andrei Orlinski in charge of the Panel on Quarantine pests for forestry- EPPO Secretariat
Ms Fabienne Grousset – Consultant for EPPO who has prepared the draft PRA.

In addition, input was received from Dr Seppo Neuvonen, Finnish Forest Research Institute - Joensuu (FI)

The PRA was reviewed by the core members and the Panel on Quarantine pests for forestry in January-February 2011. The risk management part was reviewed by the Panel on phytosanitary measures on 2011-04-07 and by the Working Party on Phytosanitary Regulations on 2011-06-23.

Content

Stage 1: Initiation

1 - Give the reason for performing the PRA

Identification of a single pest

Comments:

Agrilus anxius was added to the EPPO Alert List in February 2010 (EPPO, 2010). The EPPO Panel on Phytosanitary Measures in February 2010 decided that a PRA should be performed.

A. anxius originates from North America where it is considered to be a serious pest of birch trees (*Betula* spp.) grown as amenity and forest trees. European species of birch (e.g. *Betula pendula* and *B. pubescens*) planted in North America are more susceptible than North American hosts. In the EPPO region, these birch species are widespread and important as amenity and forest trees. Concerns were raised regarding the increasing trade of wood for bioenergy (e.g. wood chips) from North America, which might constitute an additional pathway for the entry of *A. anxius* into the EPPO region. The Panel on Phytosanitary Measures recommended that a PRA be performed.

2a - Enter the name of the pest

Pest name

Agrilus anxius Gory (1841)

Common names: bronze birch borer (English); agrile du bouleau (French); Bronzefarbener Birken-Bohrer (German).

2b - Indicate the type of the pest

arthropod

Comments:

The pest is an insect (a wood-boring buprestid beetle).

Note on the biology of the pest and terms used in this PRA

The naming of life stages of *A. anxius* is sometimes variable in the literature. The present PRA uses specific terms and biological facts summarized below [*a datasheet will be prepared and include the necessary references*]. More details are given in the text where relevant.

Life stages: A. anxius has four larval instars. Eggs are laid in cracks/crevices on the bark of stems or branches. Larvae bore into the bark after hatching and feed by making galleries in the phloem and scarring the outer xylem (note: in the USA, larvae have not been reported to colonize trees with main stems below 2 cm diameter, but have been observed to bore from larger stems and branches into branches as small as 1 cm diameter (Herms, pers. obs.; Nielsen, pers. obs.)). Most 4th larval instars bore into the outer sapwood to construct individual pupal chambers (to a depth assumed to be in general 1 cm, but assumed here to be never deeper than 2.5 cm based on data obtained for *A. planipennis*). Each 4th instar larva also bores a short gallery into the outer bark that the future adult will use to exit the tree. The larva fills this gallery in the outer bark with frass. The 4th larval instar overwinters inside the pupal chamber and is often referred to as a prepupa at this time. Due to their mostly hidden life habit, late larval stages, ie. 4th instar larvae, including prepupae and pupae are likely to survive in wood even if bark is removed. When prepupae have been submitted to a suitable cold period, development starts again, and pupae form in the pupal chamber. Once the appropriate degree-days have accumulated, pupation ends and adults emerge. Adult emergence generally occurs over a 10-week period during late spring and early summer. Adults have a short life span (approximately 23 days) and require continuous feeding on foliage, including a 7-10 period of maturation feeding prior to becoming reproductively mature. They have a short survival period in the absence of food (4 to 7 days).

Life cycle. The pest has a 1- or 2-year life cycle. In vigorous (i.e. non stressed) hosts and in colder climates, the pest has a 2-year life cycle. Dates of emergence, ending of larval feeding, etc. depend on the local climate and other conditions. This varies widely across its North American distribution in association with the distribution of *Betula*.

Detection. No long range pheromones have been identified for any *Agrilus* species despite extensive research. Therefore no effective tools for trapping adults have been developed.

2d - Indicate the taxonomic position

Domain: Eukaryota

Kingdom: Metazoa
Phylum: Arthropoda
Class: Insecta
Order: Coleoptera
Family: Buprestidae
Genus: *Agrilus*
Species: *anxius*

3 - Clearly define the PRA area

The PRA area is the EPPO region (see www.eppo.org for map and list of member countries).

4 - Does a relevant earlier PRA exist?

No

Comments:

The PRA is not performed from a previous PRA. There is no indication of the existence of a previous PRA for *A. anxius*. However, the information in the EPPO Alert List for *A. anxius* provides the key points on the potential risk posed by this pest to the EPPO region (EPPO, 2010).

In addition, the present PRA makes many references to the related species *Agrilus planipennis* (emerald ash borer), an Asian wood-boring buprestid of ash that is now also present in North America and Moscow, Russia. A PRA was done by EPPO in 2003 and *A. planipennis* was included in the EPPO A1 List based on this PRA (EPPO, 2003a, 2003b). *A. planipennis* pest has a similar biology and ecology to *A. anxius* with respect to the general timing of major life-history events and it has been introduced outside of its natural range with substantial impact (e.g. in USA and Canada; see Loerch & Cameron, 1983b; Haack *et al*., 2002; Cappaert *et al.*, 2005; Petrice & Haack 2006, 2007; Poland & McCullough 2006; USDA–APHIS, 2009). The expert working group considered that, for many aspects of the PRA, *A. planipennis* is a good model of what would happen if *A. anxius* was introduced in the PRA area, and the experience with this pest is very relevant for the present PRA.

6 - Specify all host plant species (for pests directly affecting plants) or suitable habitats (for non parasitic plants). Indicate the ones which are present in the PRA area.

Comments:

In North America, *Betula* spp. are hosts of *A. anxius* at all stages of development. *B. nigra* does not appear to be a host (Nielsen *et al.*, 2011). *B. nana* has never been documented as a host, but this could be related to thermal constraints and small stem size. *Betula* spp. are widespread in the PRA area, as forest or ornamental trees, some of the species identified as natural hosts in North America are present in the PRA area. See 14 and Section B – risk of establishment.

Host species

Betula spp. (birch), including *Betula alleghaniensis* (yellow birch), *B. davurica* (black birch), *B. jacquemontii* (white-barked Himalayan birch), *B. lenta* (sweet birch), *B. maximowicziana* (monarch birch), *B. occidentalis* (water birch), *B. papyrifera* (paper birch), *B. pendula* (silver or European birch), *B. platyphylla* (Manchurian birch), *B. populifolia* (gray birch), *B. pubescens* (downy birch), *B. utilis* (Himalayan birch). *B. albosinensis* var *septentrionalis* and *B. ermanii* have been reported as rarely attacked by *A. anxius. A. anxius* is known to attack many native and introduced birch species (and their numerous crosses) in North America. Susceptibility varies between birch species, with European and Asian birch species being much more susceptible than North American birch species (Miller *et al.*, 1991; Nielsen *et al.*, 2011). *A. anxius* has been recognized as a pest of both ornamental/landscape/urban birch and forest birch (Anderson 1944; Ball & Simmons, 1980). *A. anxius* is considered to be a secondary pest of highly stressed North American hosts in North America (Haack, 1996; Santamour, 1990a); however, stress does not appear to be necessary for colonization of European and Asian species (Nielsen *et al.*, 2011; Hale & Herms, unpublished data).

The available literature does not provide information on the host status of some North American birch species (e.g. *B. pumila* – although this is not known to be present in the PRA area) or species that are also widely distributed in the PRA area (e.g. *B. nana*). In the latter case, it might be that the stems or branches are too small in diameter or that climatic conditions are not suitable. In Scandinavia (in the moutain region) *Agrilus paludicola* Krogerus 1922 reproduce in *B. nana*. The size of this Agrilus species (about 6mm) is much smaller than *A. anxius* (10-12mm).

Notes on other plants recorded as hosts:
There is no indication that *A. anxius* adults breed on other woody plants besides *Betula* spp. in the wild, and there are no published records of *A. anxius* emerging from any hosts other than *Betula* spp. There are however a few records of other host plants, which can be explained as follows:

- There were early records of *A. anxius* on beech (*Fagus* spp.) and aspen (*Populus* spp.), in addition to birch (*Betula* spp.) (e.g. in Anderson, 1944). However, Barter & Brown (1949) and MacAloney (1968) note that evidence has shown that the species attacking aspen is the closely-related *A. liragus* Barter and Brown (bronze poplar borer) and Johnson & Lyon (1976) note that *A. liragus* is very similar to *A. anxius* in its life history and morphology, and that the identity of the adults of these species are often confused.
- Some later articles also report feeding by *A. anxius* adults on other plant species, without egg laying on these species, nor of larval development. The studies concerned were conducted in cages or laboratories:
    - Cage experiments in the field on willow (*Salix elaeagnos*), poplar (*Populus deltoides*) (Akers & Nielsen, 1990; Johnson & Lyon, 1976).
    - Cage or laboratory experiments on cottonwood (*Populus deltoides*), *P. generosa*, aspen (*P. tremuloides*), *Acer saccharinum* (soft maple), *Quercus palustris* (pin oak) (Barter, 1957; Akers & Nielsen, 1990). These are probably the source of records of maple and oak as hosts (CABI, 2005).

7 - Specify the pest distribution

Comments:

EPPO region: Absent.

North America:
Canada: Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario, Quebec, Saskatchewan (Bousquet, 1991; Bright, 1987), Prince Edward Island (Department of Agriculture of Prince Edward Island). NRC (2010) specifies that *A. anxius* occurs throughout the range of birch in Canada.

USA

Alaska	Bousquet (1991)	Arkansas	Hopkins (ed.) (undated)
California	Dreistadt *et al.* (2004)	Colorado	Crawnshaw *et al.* (2000)
Connecticut	Douglas & Cowles (ed.) (2006)	Delaware	Caron (2004)
Georgia	Nelson *et al.* (1996)	Idaho	Solomon (1995), Johnson & Lyon (1976), Shetlar (2000)
Illinois	Appleby *et al.* (1973)	Indiana	Gibb & Sadof (2007)
Iowa	Iles & Vold (2003)	Kansas	Bauernfeind (2006)
Kentucky	Johnson & Lyon (1976)	Maine	Katovich *et al.* (2005)
Maryland	Katovich *et al.* (2005)	Massachusetts	Arnett (2000)
Michigan	Jones *et al.* (1993)	Minnesota	Wawrzynski *et al.* (2009)
Missouri	Solomon (1995)	Montana	Denke *et al.* (2008)
Nebraska	Keith *et al.* (2003)	Nevada	Carlos *et al.* (2002), Wescott (1990)
New Jersey	Johnson & Lyon (1976)	New Hampshire	Swier (2003)
New York	Arnett (2000)	New Mexico	Anonymous (undated, a)
North Dakota	Zeleznik *et al.* (2005)	Ohio	Johnson & Lyon (1976)
Oregon	Katovich *et al.* (2005), Nelson *et al.* (2004)	Pennsylvania	Hoover (2002)
South Dakota	SDDA (2009), Barter & Brown (1949)	Tennessee	Johnson & Lyon (1976)
Utah	Karren & Roe (2000)	Vermont	Hanson & Walker (1996)
Washington	Katovich *et al.* (2005)	West Virginia	Johnson & Lyon (1976), Shetlar (2000)
Wisconsin	WIDNR (2008)	Wyoming	WSFD (undated)
Washington DC	Santamour (1999)		

There are statements in the literature that *A. anxius* is present throughout the range of birch in the USA (Johnson & Lyon, 1976; Katovich *et al.*, 2005). In the absence of documented records, there is some uncertainty on the presence of *A. anxius* in the extreme southern USA where birch is present at least as an ornamental tree. *A. anxius* is also sometimes mentioned "in passing" in extension brochures as a parameter in the selection of ornamental birch species, but it is not specifically listed as a serious pest, presumably because birch is present as an ornamental tree and is not very adapted to the climate there. For example,

- reported as "uncommon in Texas because of the lack of host trees" (Drees *et al.*, 1994), but specific pesticides for its control are mentioned.
- reported as a factor to be taken into account for storm-damaged trees in Oklahoma by Smith *et al.*, 2008.
- *Betula papyrifera* and *B. pendula* are on a list of prohibited plants in South Carolina upstate region (Tourkow, 2009) with, among others, the reasons that they are susceptible to *A. anxius*, and intolerant to urban stress.

However *A. anxius* is likely to be present wherever birch is used, as forest or ornamental, as it has widely extended its range to locations where non native birch species have been introduced as ornamentals (references in tables above).

Stage 2: Pest Risk Assessment - Section A: Pest categorization

8 - Does the name you have given for the organism correspond to a single taxonomic entity which can be adequately distinguished from other entities of the same rank?

Yes

Comments:

It is a single taxonomic entity.

Agrilus liragus has been confused with *A. anxius* until Barter and Brown distinguished this species specifically (Barter & Brown, 1949). They can be distinguished on the bases of colour, male genitalia, and food-plants.

10 - Is the organism in its area of current distribution a known pest (or vector of a pest) of plants or plant products?

Yes (the organism is considered to be a pest)

Comments:

Agrilus anxius is considered to be a major pest of forest and amenity birch (landscape, private gardens, parks) in Canada and in the USA (e.g. NRC, 2010; Katovich *et al.*, 2005; Miller *et al.*, 1991, Ball & Simmons, 1980). It has been shown to attack many birch species.

12 - Does the pest occur in the PRA area?

No. The pest has not been recorded in the PRA area.

14 - Does at least one host-plant species (for pests directly affecting plants) occur in the PRA area (outdoors, in protected cultivation or both)?

Yes

Comments:

Birch, *Betula* spp., are widely distributed in the PRA area, both as forest and amenity trees (landscape, parks, private gardens, bonsais). Several species of birch reported as being attacked by *A. anxius* are widespread in the PRA area as forest or amenity trees, including *B. pendula* and *B. pubescens.* Some *Betula* species in the PRA area are not grown in North America, and their host status is therefore unknown. However, *A. anxius* has been shown to attack many native and introduced birch species there. European and Asian species show greater susceptibility to *A. anxius* and are generally killed by infestation.

See details on *Betula* spp. in the PRA area under 1.16.

15a - Is transmission by a vector the only means by which the pest can spread naturally?

No *A. anxius* is a free-living organism.

16 - Does the known area of current distribution of the pest include ecoclimatic conditions comparable with those of the PRA area or sufficiently similar for the pest to survive and thrive (consider also protected conditions)?

Yes

Comments:

The present distribution of *A.anxius* in North America matches the North American distribution of birch (Johnson & Lyon, 1976; Katovich *et al*., 2005) and this suggests that the pest will survive in areas of birch presence in Europe. The climate classification of Köppen-Geiger indicates that the pest is present in very different types of climates, which are present in the EPPO region (see Appendix 1).

Note about Arctic areas: the available literature does not mention the host status of *B. nana,* which is the main birch species growing in Arctic areas in North America and which is present in the PRA area in a wider range of ecoclimatic conditions. Collection records for *A. anxius* from Canada and Alaska are only from the boreal forest where birch exists as trees (rather than shrubs). It has not been reported from the tundra where birch only exists in the form of a shrub (e.g. *B. nana*) (Bright, 1987)

17 - With specific reference to the plant(s) or habitats which occur(s) in the PRA area, and the damage or loss caused by the pest in its area of current distribution, could the pest by itself, or acting as a vector, cause significant damage or loss to plants or other negative economic impacts (on the environment, on society, on export markets) through the effect on plant health in the PRA area?

Yes

Comments:

Birch is widely grown in the PRA area, both as forest and amenity trees. Direct effects on plant health occur in North America and it is possible that *A. anxius* could have similar effects in the PRA area. These are as follows:

- larval damage expected to lead to death of European and Asian birch species.
- potential for loss of export markets of birch products, especially wood and wood chips: *A. anxius* is not present for example in Asia where several countries import birch commodities from the PRA area.
- environmental impact. Birch is important as a primary or secondary species in some forests, and damage or death of birch would have a considerable effect on forest ecosystems. *A. anxius* is considered to be an important agent of disturbance in forests during outbreaks in North America.
- loss of amenity trees and subsequent changes to landscapes including in public and private gardens, need to replace damaged or dead trees.
- social damage: loss of aesthetic value of damaged trees or death of trees in amenity areas and private gardens.

See answers to questions 2.1, 2.6 and 2.8 for details and references.

18 - Summarize the main elements leading to this conclusion.

- *Agrilus anxius* is a known pest of birch wherever host trees are present in North America.
- Species of birch that have been shown to be hosts are widespread in the PRA area, as well as other species of birch whose host status is unknown.
- European and Asian birch species are much more susceptible to *A. anxius* than the North American species and are most likely to be killed by *A. anxius*.
- The range of eco-climatic conditions in North America where the pest occurs includes conditions that are present in the PRA area.

Stage 2: Pest Risk Assessment - Section B: Probability of entry of a pest

1.1 - Consider all relevant pathways and list them

1- Wood chips originating from where the pest occurs in Canada and in the USA

2- Plants for planting of *Betula* spp. originating from where the pest occurs in Canada and in the USA

3- Wood with or without bark of *Betula* spp. originating from where the pest occurs in Canada and in the USA

Possible pathways:

1. Wood chips containing *Betula* spp. originating from where the pest occurs in Canada and in the USA

This pathway was the main pathway of concern when adding this pest to the EPPO Alert List. Hardwood wood chips are a commodity class. Birch might be used alone or in mixture with other species for producing wood chips. Wood chips might be imported for pulpmills, energy production or fiberboard production. Wood chips might also be used as mulch, but it is not known if some wood chips imported from North America would be used as mulch.

Wood chips might be produced from lower quality wood that might be infested. A small percentage of larvae of the related species emerald ash borer *A. planipennis* have been shown to survive the chipping process (McCullough *et al*., 2007). To date, neither *A. anxius* nor *A. planipennis* have been intercepted in wood chips.

Wood chunks are another commodity used in wood industry but not mentioned in custom codes for trade. They are often referred to as "biomass chunks" and are usually not screened and are much bigger in size (e.g. cubes that are 5 cm or 10 cm on a side). The EWG was not aware of this type of commodity as the time of the PRA, but similar measures should be considered as for wood chips. The risk would be at least as high as for chips (as probability of survival of larvae and pupae in chunks is more likely than in chips).

2. Plants for planting of *Betula* spp. originating from where the pest occurs in Canada and in the USA

This pathway considers birch plants for planting traded as nursery plants for forest or amenity uses. There might be trade of such plants for nurseries wishing to use specific varieties or hybrids in the PRA area, especially as ornamentals. Bonsais are also considered, as some practical bonsai websites mention *A. anxius* as a pest problem (e.g. Caine, 2000; Anonymous, undated, b).

A. anxius is not likely to be associated with plants with a stem diameter below 2 cm (Herms, personal observations, 2010; Nielsen pers. obs., 2010). However, larvae may move from larger wood into branches as small as 1 cm. Scion stems bigger than 1cm diameter are therefore included.

3. Wood with or without bark of *Betula* spp. originating from where the pest occurs in Canada and in the USA

This includes round wood, wood with bark, wood without bark, and firewood. There is a trade of birch wood from North America (see Appendix 2). Birch wood has many uses, such as furniture, boxes, crates, doors, plywood, pulpwood, fuel wood, toothpicks, etc. (Alden, 1995). UNECE (2009) also reports an increasing trade of small diameter logs for energy production. Firewood might also be a pathway, and birch is listed as a species used and traded for firewood in Canada (CFIA, 2010) and the USA (Haack *et al*., 2010).

North American *Betula* spp. are the main species for this pathway, as they are grown as forest trees and used to produce wood. European and Asian *Betula* spp. are grown as ornamentals in North America.

4. Furniture and other objects made of untreated birch wood originating from where the pest occurs in Canada and in the USA

The expert working group considered that there could be a risk of presence of fourth instars, prepupae and pupae if untreated/air dried/bark-covered sapwood was used. This is often the case in rustic birch furniture where whole logs with intact bark are used to construct table legs, bed frames, etc. The expert working group considered that the risk of entry from this pathway would be similar to that for wood with bark. This pathway was not studied in detail because it was not possible to retrieve trade data for this commodity.

Pathways not studied further as considered less likely:

5. Wood packaging material (including dunnage) containing *Betula* spp.

Wood packaging material mostly accompanies other commodities. Since the adoption of ISPM 15 (FAO, 2009), all wood packaging material moved in international trade should be debarked and then heat treated or fumigated with

methyl bromide and stamped or branded, with a mark of compliance.
Birch is used for the production of wood packaging material, including dunnage. Wood packaging material is suspected to be the source for the introduction of other *Agrilus* species into North America: *A. planipennis* and *A. sulcicollis* (first recorded, respectively, in 2002 and 1995; Haack, 2006; Haack *et al*., 2002, 2009; Jendek & Grebennikov, 2009) and as the source of several interceptions of *Agrilus* spp. there (Haack *et al.*, 2002, 2009), but these records date from before the implementation of ISPM 15 (FAO, 2009).

In theory, treatments applied to wood packaging material if undertaken according to ISPM 15 *Regulation of Wood Packaging Material in International Trade* (FAO, 2009) should destroy the pest (methyl bromide fumigation or heat treatment at 56° C for 30 minutes throughout the entire profile of the wood including the core). For this reason, the EWG did not continue the assessment of this pathway. However, some concerns were raised about the efficacy of heat treatment against *A. planipennis*: some recent studies indicate that ISPM 15 heat treatment might not be 100% effective (Goebel *et al*., 2010), but treatments in this study measured temperature at a depth of 2.5 cm into the wood rather that at the core. Additional consideration of the results above is needed in terms of the risk management options for pathways 1 and 3[1].

6. Cut branches of *Betula* spp. originating from where the pest occurs in Canada and in the USA
Data are not available for imports on this pathway into the PRA area. Cut branches of birch are harvested (e.g. State of Alaska, 2008; Centre for Non-Timber Resources, 2006) and sold in North America as decorations around Christmas time, without leaves, but no evidence of export/import was found. In any case, such cut branches are very likely to have a small diameter, and it is thought that branches would probably have to be at least 1 cm in diameter to support bronze birch borer (Herms, pers. comm., 2010; Nielsen pers. comm., 2010).

7. Natural spread
Intercontinental spread from North America to the PRA area is very unlikely. However, this pathway would become a likely pathway of movement within the PRA area following an introduction.

8. Hitchhiking
Adults have a short life span (average 23 days) and have a limited survival time (4-7 days) without feeding on a host (Barter, 1957). Maturation feeding on host foliage is also necessary to allow oviposition (Akers & Nielsen, 1990). Adults also have a high affinity with host plants and are not likely to be on non-host material. However, this pathway would become a likely pathway of movement within the PRA area following an introduction.

9. Bark and objects made of bark
Birch bark is traditionally used for arts and handicrafts (State of Alaska, 2008; Centre for Non-Timber Resources, 2006). Only larvae might be present at the interface between the bark and the wood, but if they were removed with the bark, they would dry-out and not survive.

10. Birch processed wood material and commodities made of this (plywood, etc.), wood pellets
The degree of processing would not allow survival of larvae or pupae in the wood.

11. Individual live insects moved by amateur entomologists
A. anxius is a beautiful insect and might be sent to hobbyist entomologists. This pathway is difficult to regulate as such but could be covered once the pest is regulated.

[1] Since the meeting of the EWG, the *International Forestry Quarantine Research Group* discussed this issue (Lisbon, 2010-09-27/10-01) on the basis of recent research. The IFQRG concluded that the current schedule of 56°C for 30 minutes was adequate for *A. planipennis*. Later, in 2011, the treatment requirement was reduced to 60°C for 60 minutes (USDA APHIS, 2011).

1.3 - Pathway:

1- Wood chips originating from where the pest occurs in Canada and in the USA

1.3a - Is this pathway a commodity pathway?

Yes (see answer to question 1.1)

1.3b - How likely is the pest to be associated with the pathway at origin taking into account factors such as the occurrence of suitable life stages of the pest, the period of the year?

Moderately likely

Level of uncertainty: low

A. anxius is associated with birch in forests throughout the distribution of its native host species in North America (see answer to question 7). Imported wood chips might be used for paper, energy production, fibreboard production or as mulch (UNECE, 2009; Kopinga *et al*., 2010). They might be composed purely of birch or mixed with other hardwood species. Mixed hardwood wood chips might contain a limited amount of birch wood, which would lower the likelihood of association with the pathway. Wood chips are often produced from lower quality trees, which increases the probability of infestation.
Due to the life cycle of the pest, larvae might be present in the wood at any time of the year. As the life cycle of *A. anxius* is similar to that of *A. planipennis,* it would be possible to have living *A. anxius* fourth larval instars, prepupae, or pupae in wood chips greater than 2.5 cm in each dimension (McCullough *et al.*, 2007; Roberts & Kuchera, 2006). The EWG considered that earlier larval instars will not be able to complete their development in the chips.

1.4 - How likely is the concentration of the pest on the pathway at origin to be high, taking into account factors like cultivation practices, treatment of consignments?

Unlikely

Level of uncertainty: low

Concentration will depend on the population dynamics. *A. anxius* is present typically at low density, although in this situation some trees might still be heavily infested. Concentration is likely to be high in forests only during outbreaks. Outbreaks are infrequent in space and time (Jones *et al*., 1993; Haack & Petrice, unpublished data). Wood chips are typically made of low quality wood. Trees used to produce wood chips are more likely to have a high concentration of *A. anxius* than trees used to produce logs. There are no cultivation practices in forests that would limit the association of *A. anxius* with this pathway. However, the process of wood chipping is likely to reduce the concentration: wood chips are processed through grinding or chipping, which cut the wood into pieces and expose large amounts of the wood surface to drying. This is likely to kill actively feeding larvae, but survival of prepupal larvae and pupae would be possible in wood chips greater than e.g. 2.5 cm in each dimension.

Wood chips have been shown to carry viable prepupae of the related species *A. planipennis*, depending on the process and treatments applied, and in particular depending upon the size of the resulting chips (McCullough *et al*., 2007). As *A. planipennis* and *A. anxius* larvae and pupae are of similar width and length, it can be extrapolated that *A. anxius* larvae and pupae may also survive the chipping process. It should be stressed that not much research has been performed up to now and it is therefore not possible to give a definitive minimal size for the chips to support survival of the pest.

Furthermore, there is a wide variation in the size of wood chips, which can be quite large. A screen with a maximum size of 2.5 cm will guarantee this length only in 2 dimensions, while the third dimension can vary (e.g. 2.5 x 2.5 x 10 cm). For example, McCullough *et al*. (2007) reported a maximum chip size of 14 x 4 x 2.5 cm when a 10-cm square screen was used, and 12 x 2.5 x 1 cm when a 2.5-cm square screen was used. Similarly, in a survey of a boat load of hardwood wood chips imported to Norway in 2010 for a wood pellet production factory, chips from 1.6 to 22.9 cm (measured along their maximum length) were found (Økland, Norwegian Forest and Landscape Institute, pers. comm., 2010). In the Netherlands the common maximum chip size is 200 mm, which accounts for either of the dimensions, although chips are normally flake-shaped (Kopinga *et al*., 2010). According to Kopinga *et al*. (2010), there are no data on the average size of chips that are sold to power plants, nor on the probability that chips exceed certain sizes (e.g. 2.5 cm long). After visiting several wood chip factories in the US, Roberts & Kuchera (2006) found that none of the chip piles consistently contained only chips of one inch (2.5 cm) or smaller. Some chips were observed to carry live adult *A. planipennis* (Several trees were given a primary grinding, which resulted in many small wood chips, one inch or less, but which also resulted in a few larger chips, for example, 1 inch by 6 inches (2.5 by 15 cm). Approximately 4.5 kg of bark chips were collected and dissected for evidence of surviving beetles and three intact live adult beetles were found.).

Common sizes of wood chips that are being moved around the world are as follows (Zak, Canada Wood, pers. comm., 2011): Thickness: 4-8 mm / Length: 40-45 mm /Width: 15-20 mm. Importers will allow the chips to exceed these size ranges by 10% but beyond they may refuse the shipment.
Considering the above chip sizes and a *A. anxius* pupa or larva during the winter time (when it is doubled-over on itself like a letter V), then it is possible for *A. anxius* to fit inside a chip that is of the following dimensions: Thickness: 8 mm / Length: 40 mm / Width: 20 mm. If the chip is thinner, the individual would likely be exposed or cut, and die.

1.5 - How large is the volume of the movement along the pathway?
Major
Level of uncertainty: medium. Reason: proportion of birch in hardwood birch chips imports.
There are no specific data on imports of birch as wood chips, i.e. pure versus mixed, proportion of birch in mixed wood chips. However, the import of hardwood wood chips from North America to certain countries of the PRA area is rapidly increasing (see USA and Canada export statistics in Appendix 2). Analysis anticipates that this increase will continue to allow EU countries to meet the targets of the EU energy policy to 2020, although North America is not the only source of hardwood chips and supply of chips from other continents (e.g. South America) is also growing (UNECE, 2009).

Canada is recorded as a principal provider of wood chips for Europe (together with Germany, France, Latvia, Czech Republic, Russia, Uruguay, and Brazil). Non- coniferous wood chips would be expected to include large proportions of birch because there are extensive birch forests in Canada. Europe became a net importer of wood chips in 2008 with 29.8 million m^3 of wood chips and wood pellets (and there is an increasing demand for small diameter pulp wood for energy purposes, to complete the requirement for wood chips and wood pellets). Some new wood-fired power plants have been established in Europe and these will require massive quantities of wood fibre in coming years.

In Norway (Økland, pers. comm., 2010) a new wood pellet factory (second largest in the world) started operating in 2010 and it is importing nonconiferous wood from North America. Wood includes *B. papyrifera* and *B. alleghanensis* from Canada, and samples taken in the first shipment showed chips sizes of 1.6 to 22.9 cm in length. The content of birch in these shipments was about 30%.

1.6 - How frequent is the movement along the pathway?
Often
Level of uncertainty: medium. Reason: data of monthly exports do not detail how frequently consignments of birch wood would reach the PRA area
Wood chips are imported throughout the year, at least once a month.

1.7 - How likely is the pest to survive during transport /storage?
Moderately likely
Level of uncertainty: low
There are no data on how long late larval stages would survive in wood chips (i.e. whether they would survive the duration of transport). Nevertheless, it is assumed that actively feeding larvae would not survive as they would be exposed to desiccation and suffer from a lack of fresh phloem (inner bark). Only 4^{th} instars that have completed feeding, prepupae and pupae would survive, if not injured during chipping.

1.8 - How likely is the pest to multiply/increase in prevalence during transport /storage?
Impossible/very unlikely
Level of uncertainty: low
There is no data on temperature during transport/storage. Adults may emerge from pupae if temperature is sufficiently high (e.g. about 20-25°C). Even if adults are associated with the wood chips or did emerge during transport, they would not find food (i.e. host foliage) which is necessary to become reproductively mature, and thus would not reproduce (as they have a limited survival time without food) (Barter, 1957). Mating and reproduction is therefore impossible/very unlikely.

1.9 - How likely is the pest to survive or remain undetected during existing management procedures (including phytosanitary measures)?

Very likely

Level of uncertainty: low

In the EU countries, there are no phytosanitary measures targeting wood chips or other management procedures, and no phytosanitary certificate is required. The commodity would not be submitted to inspection.
An EU standard for quality of wood chips is being developed (CEN prEN 14961-1 2008.4 solid biofuel cited in Kopinga *et al*., 2010) which is to replace all other national legislation. This standard will describe the requirements for fraction size, moisture content, ash content and density of the wood chips.

Even if inspection was carried out, it is unlikely to detect the pest, as:
- wood chips might contain several tree species
- signs of presence of the pest in wood (e.g. galleries) would not be easy to observe.

Sampling rates for a possible detection of such pests in wood chips have not been defined but large samples would be needed to be confident that *A. anxius* is not present.

In Israel (Israel, 2009a) wood chip importation does not require an import permit but it does require a phytosanitary certificate. The consignment must meet the following requirements: (1) The woodchips do not include bark; (2) The consignment has undergone a vapour treatment with methyl bromide in accordance with the requirements detailed in the treatment manual (exposure for 16 hours, at 48g/m^3 at 21°C or more, or at 80g/m^3 at 10-20°C) (Israel, 2009b).
In Turkey (Turkey, 2007), requirements for imported woodchips of broadleaved (hardwood) trees are that they should be produced from wood that has been fumigated or stripped of its bark, or has been dried to below 20% moisture content, expressed as a percentage of dry matter.
In Russia, an import permit is required.

No requirements are specified for Tunisia or Morocco (according to the EPPO collection of phytosanitary regulations).

1.10 - How widely is the commodity to be distributed throughout the PRA area?

Moderately widely

Level of uncertainty: high - No data on distribution of wood chips made of birch in the PRA area. No data whether wood chips will be moved further between EU countries

There is a large and increasing demand for wood chips throughout most of the PRA area, but there are no specific data for wood chips from birch. Following importation, consignments might be further moved between countries, especially EU countries to satisfy demand, although this would be expensive for such a low value commodity.

UNECE (2009) indicate that the largest importers of wood chips (all types) into Europe in 2008 were Finland, Germany, Sweden, Turkey and Italy (energy, fibreboard and pulpmills). Other countries are listed in Appendix 2.

1.11 - Do consignments arrive at a suitable time of year for pest establishment?

Yes

Level of uncertainty: low

Consignments arrive all year round. There is a risk of presence of 4th instar larvae, prepupae or pupae at any time of the year, which can survive until conditions are favourable if wood chips are not used immediately.

1.12 - How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?

Moderately likely

Level of uncertainty: low

Wood chips might be stored in areas where birch is present as forest or amenity trees. Birch grows also along roads, railroads, abandoned industry ground, etc. Large quantities of wood chips are likely to be stored in the open. Some of the main importers are also countries where birch is widespread (e.g. Finland, Norway, Germany, Sweden). In Norway, the new wood pellet factory (see 1.5, pathway 3) mentioned earlier is storing wood chips in the open, and is located in the vicinity of birch forests (Økland, pers. comm., 2010).

1.13 - How likely is the intended use of the commodity (e.g. processing, consumption, planting, disposal of waste, by-products) to aid transfer to a suitable host or habitat?

Unlikely

Level of uncertainty: medium. Reason: it depends whether wood chips are stored (where, duration of storage, when during the year, etc.); whether imported wood chips are used as mulch.

Wood chips are imported to be fully burned for energy production, transformed into fibreboard or used in pulpmills (UNECE, 2009). All these processes are fully destructive and would not allow survival of the pest. Storage before use would increase the likelihood of pest transfer, if wood chips are stored long enough to allow *A. anxius* adult emergence prior to being used.

Use of wood chips as mulch would increase the risk of transfer.

1.3 - Pathway:

1- Plants for planting of *Betula* spp. originating from where the pest occurs in Canada and in the USA

1.3a - Is this pathway a commodity pathway?

Yes

1.3b - How likely is the pest to be associated with the pathway at origin taking into account factors such as the occurrence of suitable life stages of the pest, the period of the year?

Likely

> **North American species of birch: moderately likely**
> **European and Asian species of birch: likely**

Level of uncertainty: low

A. anxius is recorded throughout the area of birch presence in North America (see answer to question 7). It is considered to be a serious pest in nurseries (Lanthier, 2008). The likelihood would be less for nurseries growing North American species of *Betula* spp. (as trees from these species are less likely to be attacked by *A. anxius*), than for those growing European and Asian birch species. Due to its long life cycle (1-2 years) and depending on temperatures (Barter, 1957), larvae and pupae might be present in the trees throughout the year, and over long periods. However, prepupae must be exposed to below-freezing temperatures before pupation will occur (Bright, 1987), which synchronizes adult emergence over about a 10-week period from late spring to mid-summer (early May – early August depending on location). Oviposition begins within 7-10 days after adult emergence, and eggs hatch in about 2 weeks. Consequently, viable eggs are only present during summer and would not be present on dormant plants.

A. anxius is not likely to be associated with plants with a stem diameter below 2 cm (Herms, pers. comm., 2010) as it seems too small for the larvae to develop and eggs will not be present at the time of import.

Bonsais might reach such diameters and are therefore not excluded from this pathway.

1.4 - How likely is the concentration of the pest on the pathway at origin to be high, taking into account factors like cultivation practices, treatment of consignments?

Moderately likely

Level of uncertainty: medium. Reason: concentration in nursery plants for export in North America, whether North American or European/Asian species are imported, size of the plants being traded

Plants for planting would originate from nurseries. Pesticides are available to lower the population pressure, and nurseries with a history of *A. anxius* infestation might apply treatments (see 2.3). However, treatments are not always applied and are not fully effective.

1.5 - How large is the volume of the movement along the pathway?

Minimal

Level of uncertainty: high. Reason: no detailed data on volume of trade and on birch species traded.

Few data were found because the import of *Betula* plants for planting is not associated with a specific custom code. It is assumed that this pathway would be quite small, and would most likely be North American birch species used as ornamentals (as countries in the PRA area also have numerous sources of plants for planting that are of European or Asian origin). In weight, import of all species of ornamental plants for planting coming from the USA and Canada represent about 2% of the worldwide import of such plants into the EU (Eurostat, 2009). It is common that new hybrids of birch are developed, and these might be submitted to trade. Some nurseries in the PRA area that have websites report the origin of their plants being in North America, but do not specify from which country/state the plant material was obtained.

Data were found to date only from a few countries in the EPPO region.

- in the Netherlands from the USA (source: Dutch NPPO, 2010):

Year	**Number of plants**
2005	525
2006	433
2007	475
2008	1460

2009	3024
2010 (until the end of September)	2598

According to phytosanitary inspectors (van der Gaag, comm. pers., 2011), a majority of imported birch trees has a stem diameter less than 2 cm. One consignment of 10 trees was known to have a stem circumference of 12-14 cm (i.e. a diameter of 3.8-4.5 cm). Species were not recorded.

In Belgium (Fassotte, pers. comm., 2010): Since 1995 there have been no direct or indirect imports of *Betula* species for forestry from North America. Ornamental birch trees are usually imported from other EU countries. Occasional importation may occur (e.g. between 2004 to 2009 there were imports during winter of one-year old *Betula* plants (with “red leaves”) from Oregon but now this cultivar (unspecified) is available in Europe; therefore imports were stopped. Imports of some large trees of *Betula* from North America have also occurred over the past 5 years but the financial cost was too high and therefore imports were stopped.

In Finland, North American birch are not used as forest trees (Hynynen *et al.*, 2010; Neuvonen, pers. comm., 2010). However, very small numbers of some North American birch species may be used for decorative purposes, but in these cases the cultivated seedlings come from seeds collected in North America (Loukonen & Juhanoja, 2007), i.e. ‘plants for planting’ are not imported into Finland.

In England and Wales there are some data describing the number of plants, or kilograms or containers of *Betula* imported from the USA which are inspected on importers premises by the Plant Health and Seeds Inspectors (PHSI). The PHSI are part of the UK NPPO (source R. Hindley, PHSI, Fera, 2010 pers. comm. to C. Sansford, Fera, 2010). These data are shown below. The data do not include any inspections recorded via a separate imports system so they may be an under estimate. In addition to these figures, in 2007 there is a record of ‘1 container’ being inspected.

Year	**Number of plants**
2006	3060
2007	2235
2008	200
2009	150
2010	2220*

**This figure may be 1720 as one of the local inspectors (S. Lacey, PHSI, Fera) advised separately that the figure for the importer for whom she is responsible was 500 plants rather than the 1000 included in the data from which these figures were compiled.*

No data were found for other countries.

1.6 - How frequent is the movement along the pathway?

Rarely

Level of uncertainty: high. Reason: lack of detailed data on import

Data is lacking on this pathway except for England and Wales. The inspections that are referred to in 1.5 at the premises that imported *Betula* spp. from the USA were carried-out as follows:

2006: February (twice), March, April
2007: January (twice), February (twice), April, November
2008: February (twice), October
2009: March, November
2010 (information up until early October): February, March

This is in keeping with the EU requirement for these plants to be dormant when imported (EU, 2000).

No useful references were found in other countries' export or import statistics.

1.7 - How likely is the pest to survive during transport /storage?

Very likely

Level of uncertainty: low

Larvae, prepupae and pupae could survive in living plants for planting. Development of larvae can extend in unfavorable conditions (e.g. vigorous hosts or when temperatures are cool) (Barter, 1957). They therefore would be very likely to survive in plants even if these were transported in conditions unfavorable to adult emergence.

1.8 - How likely is the pest to multiply/increase in prevalence during transport /storage?

Impossible/very unlikely

Level of uncertainty: low

It is very unlikely that multiplication occurs during transport and storage. Larvae and pupae might be present in trunks or branches, and might continue their development. However, at least in the EU, the imported plants would be dormant (due to the EU phytosanitary requirements; EU, 2000; see 1.9). Even if adults emerge, they would not find the right conditions for maturation feeding (i.e. foliage of host plants) that is required for successful oviposition.

1.9 - How likely is the pest to survive or remain undetected during existing management procedures (including phytosanitary measures)?

Very likely

Level of uncertainty: low (although requirements for all EPPO countries could not be checked)

The presence of the pest is not easy to detect, in particular the signs of early infestation. It is likely that nursery plants would be subjected to a certain degree of inspection and surveillance, which might allow detection of some signs of presence of *A. anxius* (exit holes, galleries under the bark, ridges on the bark surface), although the presence of the pest is very difficult to detect without destructive sampling and larvae often do not produce signs or symptoms that are externally visible. Bronze birch borer has been observed to infest live nursery stock in the USA (Herms, pers. comm., 2010), and external signs and symptoms are often not visible until after adults have emerged.

There are some phytosanitary requirements for the importation of live plants in the EU, although not directly targeting *Betula* spp. The kind of inspection required in the general requirements below and in relation to the associated phytosanitary certificate (PC) for plants for planting and bonsais might allow detection of some signs of *A. anxius*, but these signs are difficult to detect especially at early stages of infestation, as indicated above. These requirements are not considered sufficient to detect and destroy the pest, even for bonsais where requirements are more restrictive (but not targeting specifically *A. anxius*).

EU requirements

Plants for planting with soil:

In the EU (EU Directive 2000/29/EC - consolidated) - Annex A, section I. points 39 and 40 (EU, 2000)

- “A phytosanitary certificate would be required for "Trees and shrubs/Deciduous trees and shrubs, intended for planting, other than seeds and plants in tissue culture, originating in third countries other than European and Mediterranean countries"
- Associated phytosanitary requirements:

Annex IV, Part A, section 1, point 39: ...where appropriate, official statement that the plants:

— are clean (i.e. free from plant debris) and free from flowers and fruits,

— have been grown in nurseries,

— have been inspected at appropriate times and prior to export and found free from symptoms of harmful bacteria, viruses and virus-like organisms, and either found free from signs or symptoms of harmful nematodes, insects, mites and fungi, or have been subjected to appropriate treatment to eliminate such organisms.

Annex IV Part A Section 1 point 40:where appropriate, official statement that the plants are dormant and free from leaves.”

Bonsais

“A PC is required for "Naturally or artificially dwarfed plants intended for planting other than seeds, originating in non-European countries"

Some of the specific requirements of Annex IV, Part A, Section I, point 43 might be helpful in relation to *A. anxius* (not all requirements of this point are listed below), especially:

(a) the plants, including those collected directly from natural habitats, shall have been grown, held and trained for at least two consecutive years prior to dispatch in officially registered nurseries, which are subject to an officially supervised control regime,

(b) the plants on the nurseries referred to in (a)

shall:

(aa) at least during the period referred to in (a):

... [2 requirements omitted]
— have been officially inspected at least six times a year at appropriate intervals for the presence of harmful organisms of concern, which are those in the Annexes to the Directive. These inspections, which shall also be carried out on plants in the immediate vicinity of the nurseries referred to in (a), shall be carried out at least by visual examination of each row in the field or nursery and by visual examination of all parts of the plant above the growing medium, using a random sample of at least 300 plants from a given genus where the number of plants of that genus is not more than 3 000 plants, or 10 % of the plants if there are more than 3 000 plants from that genus,
— have been found free, in these inspections, from the relevant harmful organisms of concern as specified in the previous indent. Infested plants shall be removed. The remaining plants, where appropriate, shall be effectively treated, and in addition shall be held for an appropriate period and inspected to ensure freedom from such harmful organisms of concern,
[3 requirements omitted]
or
[1 requirement omitted]
(bb) ....”

In Russia and countries of the Commonwealth of Independent States, plants for planting require an import permit. There are no specific requirements for *Betula* species.

1.10 - How widely is the commodity to be distributed throughout the PRA area?
moderatelywidely
Level of uncertainty: high. Reason: lack of data on distribution throughout the PRA area
No data were available to answer this question. However, birch is used widely in the PRA area, as an ornamental and as forest trees, and could be imported, especially as ornamentals, to all countries where birch is present. Nursery plants could be further distributed within the PRA area, especially within the EU.

1.11 - Do consignments arrive at a suitable time of year for pest establishment?
Yes
Level of uncertainty: low
No precise data were available but plants would arrive at a suitable time to be planted. In the EU, a requirement is that plants would be dormant (Annex IV.A.1.40) (EU, 2000), so they would arrive in late autumn-winter-early spring. There might be larvae at different stages of development in the trees at that stage, including prepupae close to emergence, which could then emerge if conditions were appropriate. Larvae can also remain in the trees for one more year to complete their development if conditions are not suitable.

1.12 - How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?
Likely
Level of uncertainty: low
If conditions are suitable for emergence, adults are likely to be able to fly to hosts in the vicinity. Adults are good flyers. Birch is widespread in the PRA area and it is present in a variety of environments, e.g. garden/landscape/forests. Birch plants for planting for nurseries are likely to be imported in birch-growing areas, where there would be birch in the vicinity.

Transfer might be less likely if the plants are in protected conditions or imported into areas of the PRA area where birch is not used as an outdoor tree (i.e. likely to be bonsais in both cases).

1.13 - How likely is the intended use of the commodity (e.g. processing, consumption, planting, disposal of waste, by-products) to aid transfer to a suitable host or habitat?
very likely
Level of uncertainty: low
Plants for planting of birch would be used in favorable environments, outdoors in nurseries, private gardens, amenity areas, forests. The pest would then be close to other birch in gardens, landscapes and forests.

1.3 - Pathway:

2- Wood with or without bark of *Betula* spp. originating from where the pest occurs in Canada and in the USA

1.3a - Is this pathway a commodity pathway?

Yes (see answer to question 1.1)

1.3b - How likely is the pest to be associated with the pathway at origin taking into account factors such as the occurrence of suitable life stages of the pest, the period of the year?

Moderately likely

Level of uncertainty: low. The association of the pest with the pathway is linked to the frequency of outbreaks (which is variable).

A. anxius is endemic throughout the range of its native birch hosts in North America (see answer to question 7). Native birch is most likely to be harvested for wood. Larvae, prepupae, and pupae might be present in birch trees (and therefore in wood) at any time of the year (Barter, 1957; MacAloney, 1968; Bright, 1987). Neonates bore through the outer bark into phloem tissue, so they may be found also in wood without bark.

Outbreaks are infrequent in space and time (Jones *et al*., 1993; Haack & Petrice, unpublished data) so the pest may not be associated with the pathway every year. Birch species native to North America have a high level of resistance (Herms, 2002; Nielsen *et al*., 2011).

1.4 - How likely is the concentration of the pest on the pathway at origin to be high, taking into account factors like cultivation practices, treatment of consignments?

Unlikely

Moderately likely for firewood and wood for bio-energy uses

Level of uncertainty: medium. Reason: the concentration of the pest with the pathway is linked to the intensity of outbreaks (which is variable), and whether infested wood would end up in exported consignments

Concentration will depend on the population dynamics. *A. anxius* is present typically at low density, although in this situation some trees might still be heavily infested. Concentration is likely to be high in forests only during outbreaks. Outbreaks are infrequent in space and time (Jones *et al*., 1993; Haack & Petrice, unpublished data).

Some observations were made on the concentration of the pest in a limited number of birch trees. Anderson (1944) recorded 0.61 prepupae and adults per square foot of bark (about 6.5 per m^2) in felled *B. papyrifera*, a native North American species. Akers & Nielsen (1990) noted that an average of 184 exit holes could be observed on recently killed *B. pendula* (a European species), with significantly less exit holes in the upper part of the trunk, and in the branches than in the trunk. Appleby *et al.* (1973) reported emergence of 45 adults from boles of *B. alba* (=*B. pendula*) showing evidence of borer attack.

Birch forests in North America are mostly not subject to cultivation practices. The only treatment likely to be applied post-harvest is air-drying of the wood, which is likely to have an impact on the concentration of the pest by affecting early larval instars, but this is likely to have much less effect on late instars, prepupae, and pupae.

Wood might be subjected to other processing procedures such as removal of bark or squaring. Removal of bark or squaring will lower the concentration of the pest (see also 3.17- for this pathway).

The concentration is expected to be higher in wood for bio-energy use, as wood of poor quality is usually used for this purpose and no treatment is applied afterwards.

On the contrary furniture and other birch wood objects are expected to have a lower concentration than other round wood as they will be made from high quality wood, and will be subject to air-drying.

1.5 - How large is the volume of the movement along the pathway?

Moderate

Level of uncertainty: medium. Reason: importance of this pathway, proportion of birch in hardwood imports from North America, *proportion of birch in firewood import.*

There is movement of birch logs from North America to some European countries (see Appendix 2). The different uses of birch are detailed in Alden (1995). UNECE (2009) also reports on an increasing trade of small diameter logs for energy generation, to complement supplies of wood chips and wood pellets.

Regarding firewood, birch is listed as one of the species on which Canada is taking measures to prevent the entry to Canada of quarantine pests (CFIA, 2010). The USA regulates firewood of all hardwood species within its territory (USDA–APHIS, 2009). There is trade of firewood within North America, and there is some trade of firewood from North America to the PRA area (about 2200 tonnes in 2007 – Eurostat, 2009). As no specific custom code exists to distinguish tree species that are present in wood consignments, it is not possible to know the volume of birch wood in this trade, but the EWG estimated it as 'moderate' because there are extensive birch forests in Canada and USA. Firewood could be a pathway for further spread within the PRA area, once the pest is introduced.

1.6 - How frequent is the movement along the pathway?

Occasionally

Level of uncertainty: medium. Reason: data of monthly exports do not detail how frequently consignments of birch wood would reach the PRA area.

Exports seem to be all year round, at least once a month (from online trade databases of USA and Canada - Global Agricultural Trade System USA, and Statistics Canada respectively).

1.7 - How likely is the pest to survive during transport /storage?

Likely

Level of uncertainty: low

Late larval stages or pupae are likely to survive in logs (Akers & Nielsen, 1986), and they are likely to have a higher survival in wood with bark than in wood without bark.

The related species *A. planipennis* is documented to have been transported long distance in firewood within North America (Haack *et al*., 2010; Robertson & Andow, 2009; USDA-APHIS, 2009).

1.8 - How likely is the pest to multiply/increase in prevalence during transport /storage?

Impossible/very unlikely

Level of uncertainty: low

Even if adults are associated with the wood or did emerge during transport, they would not find food (i.e. host foliage) which is necessary for reproductive maturity, and thus would not survive (as they have a limited survival time without food) (Barter, 1957). Mating and reproduction is therefore impossible/very unlikely.

1.9 - How likely is the pest to survive or remain undetected during existing management procedures (including phytosanitary measures)?

Likely

Level of uncertainty: low

In at least the EU, there are no specific phytosanitary requirements for birch wood. The consignments would not be accompanied by a PC and not submitted to inspection. For wood without bark, survival is likely to be lower, and detection higher (i.e. galleries occur below the bark).

1.10 - How widely is the commodity to be distributed throughout the PRA area?

Limited

Level of uncertainty: high. Reason: lack of details

Birch wood is imported by a few countries within the EU (see Appendix 2B). It could also be further moved between countries in the PRA area, especially within the EU.

1.11 - Do consignments arrive at a suitable time of year for pest establishment?

Yes

Level of uncertainty: low

Consignments arrive all year round. There is a risk of presence of late larval stages and prepupae at any time of the year, and they can survive until conditions are favourable if consignments are not used immediately.

1.12 - How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?

Likely

Level of uncertainty: low

Logs might be stored outdoors or further processing might produce by-products that are then stored or used outside containing larvae or pupae. Emerging adults could then fly to birch trees, which are widely grown in the PRA area.

The survival of early instar larvae might decrease with time in storage as logs continue drying out. This might prevent larvae from continuing development and thus prevent emergence. However, prepupal overwintering larvae are present in the wood for many months. A proportion is likely to survive storage conditions.

1.13 - How likely is the intended use of the commodity (e.g. processing, consumption, planting, disposal of waste, by-products) to aid transfer to a suitable host or habitat?

Moderately likely

Level of uncertainty: medium. Reason: no data on the end-use of the wood.

The primary uses of wood (sawn wood, pulpwood, energy production) are unlikely to aid transfer. Depending on how the logs are processed, there might be by-products (e.g. slabs, mulch) and waste, which could contain viable pests and these could aid transfer.

Storage prior to use in the country of destination would increase the likelihood of transfer, though survival of early instar larvae might decrease with time in storage as logs continuously dry out.

1.14c - The overall probability of entry should be described and risks presented by different pathways should be identified

- wood chips originating from where the pest occurs in Canada and in the USA - probability of entry is low to medium with medium uncertainty.

Even if the likelihood of association or concentration on the pathway is not high, the probability of entry would be increased by the volume of the commodity traded. There are constraints for entry on this pathway, i.e. only 4th instars that have completed feeding, prepupae and pupae could survive on this pathway, they would first need to survive the chipping process, and then emerge after import and before the intended use (i.e. destructive processes and transfer most likely only if the commodity is stored). However, if wood chips are used as a mulch transfer will be more likely.

Uncertainties:

- whether imported wood chips originate from trees killed by the beetle (i.e. low quality wood with potentially high concentration of pest)

- proportion of birch in hardwood chips imports

- data on pathway: volume, frequency of import (per month) in the PRA area, timing of imports, distribution throughout the PRA area

- whether chips would be stored for some time on arrival and in which conditions

- whether imported wood chips are used as mulch.

- plants for planting of *Betula* spp. originating from where the pest occurs in Canada and in the USA - probability of entry is low with medium uncertainty.

This pathway would most favour the successful entry of *A. anxius* (in particular transfer) to a suitable host given its biology, the intended use, and that live plants could carry most *A. anxius* life stages if the stem diameter is greater than 2 cm. If one consignment is infested, the risk of transfer to host plants would be very high. The related species *A. planipennis* is documented to have been transported long distance in nursery stock within North America (USDA–APHIS, 2009). However, there are constraints for entry on this pathway: moderate probability of association with the pathway given the high relative resistance of North American birch species, although European and Asian birch species are still grown in North America and could be imported; but total birch imports are presumed to be a very low volume.

Uncertainties:

- association of the pest in North American nurseries for plants for export

- data on trade, i.e. volume, birch species traded (as the pest is more likely to be associated with susceptible European and Asian Betula *species), frequency of movement, lack of data on distribution of imported plants for planting throughout the PRA area, size of plants.*

- wood with or without bark of *Betula* spp. originating from where the pest occurs in Canada and in the USA - probability of entry is low to medium (wood without bark) and medium (wood with bark including firewood) with medium uncertainty.

The likelihood of entry would be tempered by the seemingly relatively low volume of trade on this pathway (note: this could change if trade of birch logs for large-scale energy production increased). There are further constraints for entry on this pathway, i.e. the pest needs to survive cutting and other processes applied to wood. In any case, only late instar larvae, prepupae and pupae are expected to survive. The related species *A. planipennis* is documented to have been transported long distance in firewood within North America (Robertson & Andow, 2009, Haack *et al*., 2010).

Uncertainties:

- frequency of outbreaks (the pest is most likely to be associated with the pathway during outbreaks in North America)

- data on pathway: volume, proportion of birch in hardwood imports from Canada, frequency of import (per month) in the PRA area, timing of imports, distribution of the commodity throughout the PRA area, end-use of the wood.

The expert group considered that the overall probability of entry is low to medium with medium uncertainty. But over a long time horizon (e.g. 20 years) and if the volume of wood chips/wood for bioenergy uses does increase dramatically, the risk of entry may increase.

In addition, the expert group raised questions relating to the efficacy of ISPM 15 (FAO, 2009) heat treatment for wood packaging material in providing 100% control of pests (see question 1.1, point 4), but this issue cannot be considered or solved in this PRA.

Stage 2: Pest Risk Assessment - Section B: Probability of establishment

1.15 - Estimate the number of host plant species or suitable habitats in the PRA area.

few

Level of uncertainty: medium. Reason: host status of some birch species present in the PRA area

A. anxius has been shown to attack many native and introduced birch species in North America. The list under section 6 includes 14 *Betula* species, which are also present in the PRA area, as ornamental or forest trees. More than 40 other *Betula* species not present/not used in North America are mentioned in answer to question 1.16, with an unknown host status, but these are still considered since the pest has adapted to most species introduced into North America.

Note on the susceptibility of birch species to *A. anxius*

It has been observed that susceptibility of birch species to *A. anxius* varies considerably (see table below), and the literature is inconsistent regarding variation among species. For example, *B. jacquemontii*, *B. pubescens* and *B. pendula* (which are widely planted in North America) have been considered to be highly susceptible; *B. alleghaniensis, B. lenta, B. platyphylla, B. populifolia, B. davurica, B. maximowicziana,* moderately susceptible; *B. nigra* (river birch), *B. albosinensis* var *septentrionalis* and *B. ermanii* have been reported as much less susceptible or rarely attacked by *A. anxius.* References in relation to birch species and their susceptibility are the following: Miller *et al.* (1991), Katovich *et al.,* (2005), Santamour (1999).
There is however some uncertainty about the susceptibility of the different species, with different authors reaching different conclusions (Nielsen *et al.*, 2011). Miller *et al.* (1991), Nielsen *et al.* (2011) and Herms (2002) note contradictions in the literature between observations of resistance to *A. anxius*, noting that some conclusions were based on anecdotal observations of isolated amenity birch or in arboreta. For example, depending on authors, *B. papyrifera* has been considered either more or less susceptible than European species. A large block experiment conducted over 20 years with different birch species in Ohio revealed 100% mortality for European and Asian birch species, including *B. pendula, B. pubescens, B. maximowicziana,* and *B. szechuanica*, all of which were heavily infested by *A. anxius* (Herms 2002; Nielsen *et al*., 2011). Survival of *B. papyrifera* and *B. populifolia* was much higher, although all trees were infested to some degree. *B. nigra* showed no evidence of colonization. The latter three species are all indigenous to North America, and the authors noted that the pattern of variation corresponded with coevolutionary history, with the North American species being much more resistant to *A. anxius* compared to the European and Asian species which lack a coevolutionary history (Herms, 2002; Nielsen *et al.*, 2011). A similar pattern has been observed regarding ash (*Fraxinus* spp.) resistance to emerald ash borer (*A. planipennis*); an Asian host (*Fraxinus mandshurica*) that shares an evolutionary history with emerald ash borer is much more resistant than naive/native North American hosts (Rebek *et al*., 2008). Other studies carried out in Michigan have also shown that *B. pendula* was particularly susceptible to *A. anxius*. Observations in nurseries (Santamour, 1990a) for some *B. pendula* and *B. pubescens* individuals indicated that they did not have high susceptibility, although these represent anecdotal observations rather than results of replicated trials. In any case, the climatic conditions play an important role in the degree of susceptibility of the different North American species. Ball & Simmons (1980) also mention that European birch (*B. pendula*) is the principal host in urban landscape plantings in North America.

Summary table of some *Betula* species susceptibility

Betula species	Origin	Susceptibility according to Miller *et al.* (1991), Katovich *et al.*, (2005), Santamour (1999), Nielsen *et al.* (2011) and Herms (2002)
B. jacquemontii	Asia	Highly susceptible
B. pubescens	Europe	Highly susceptible (low uncertainty)
B. pendula	Europe	Highly susceptible (low uncertainty)
B. maximowicziana	Asia	Highly susceptible (low uncertainty)
B. szechuanica	Asia	Highly susceptible (low uncertainty)
B. alleghaniensis	North America	Moderately susceptible if stressed (low uncertainty)
B. lenta	North America	Moderately susceptible if stressed (low uncertainty)
B. papyrifera	North America	Moderately susceptible if stressed (low uncertainty)
B. populifolia	North America	Moderately susceptible if stressed (low uncertainty)
B. platyphylla	Asia	Highly susceptible (medium uncertainty)
B. davurica	Asia	Highly susceptible (medium uncertainty)
B. nigra	North America	Rarely attacked (low uncertainty)

1.16 - How widespread are the host plants or suitable habitats in the PRA area?
very widely
Level of uncertainty: low
Birch is widespread in the PRA area, both as forest and amenity trees (landscape, amenity areas, parks, private gardens). Some species are also used as bonsais. Birch as stand-forming tree species are especially common in northern Europe and Russia, but also throughout western and central Europe. Birch is mostly not present in the warmest Mediterranean areas, although there are some birch forests in Mediterranean mountainous habitats, e.g. Turkey, Spain, Italy (including Sicily), France (including the Pyrénées and Corsica). See Appendix 3 for distribution maps of the main birch species. European and Asian birch species grown in North America have been shown to be more susceptible than North American birch species (see 1.15).

Note: the taxonomy of birch is complicated. There are numerous birch species recorded throughout the world, although whether they are all valid species or synonyms is sometimes unclear, and possible synonyms are indicated below.

Forests and woodlands
In northern European countries, birch constitutes a large proportion of the forest tree volume, ranging from 11 % in Sweden to 28 % in Latvia (Hynynen *et al*., 2010). In Scandinavian forests, the dominance of birch increases with latitude and altitude. Birch is also a very important commercial tree species in Russia and in Belarus.

The main species of birch in the western part of the PRA area in forests are *B. pendula* and *B. pube*scens, with also *B. humilis* from central Europe to the eastern part of the PRA area (see distribution maps in Appendix 3). A number of Asian or American species that have been shown to be attacked by *A. anxius* in North America (e.g. *B. davurica, B. ermanii, B. maximowicziana, B. platyphylla, B. occidentalis, B. papyriferae, B. populifolia*), are present in the PRA area.

EEA (2006) gives details on the presence of birch in forests in western Europe. In European forests and woodlands, *B. pendula* and *B. pubescens* are the most common species. They are present either in pure stands or as secondary species in mixed stands. Examples mentioned include:
- boreal and hemiboreal forests: with spruce or pine as dominant species, or as secondary birch forests colonising clear-cuts in spruce forests
- mixed forests with oak, ash, beech, pine, chestnut in various parts of Europe, including in lowlands and mountain forests
- swamp and wetland forests
- dominant species in mountain birch forests in the boreal zone, swamp and wetland birch-dominant forests. In mountains, birch often makes the transition between the conifer and alpine vegetation zones.

The same publication reports other birch species in western Europe:
- *Betula nana* in spruce-dominated boreal forests (see also map in Appendix 3)
- *Betula celtiberica* in upper mountainous and supra-Mediterranean Iberia (syn. of *B. pubescens* according to some authors)
- *Betula aetnensis* on Mount Etna lavas (Sicily) (synonym of *B. pendula* according to some authors)
- *Betula odorata, Betula carpatica* (both synonyms of *B. pubescens* according to some authors) in woods beyond and above the present range of oak woods in Scotland and northern England.

Betula species not present in North America with an unknown host status for *A. anxius*
A. anxius has been shown to attack nearly all native and introduced birch species in North America. Many native birch species occur in the EPPO region, but not in North America, and their host status is therefore unknown. They include
- in the western part of the PRA area: *B. celtiberica* and *B. carpatica* (both synonyms of *B. pubescens* according to some authors), *B. aetnensis*, *B. odorata* (synonyms of *B. pendula* according to some authors),
- in the eastern part of the PRA area, including Turkey, Caucasus, Russian Federation or Central Asia: e.g. *B. alajica, B. baicalensis, B. cajanderi, B. costata, B. demetrii , B. divaricata, B. exilis, B. extremi-orientalis, B. forrestii, B. fruticosa, B. fusca, , B. humilis, B. kelleriana, , B. korshinskyi, B. krylovii, B. lanata, B. litwinowii, B. mandshurica, B. medwediewii, B. megrelica, B. neoalaskana, B. pamirika, B. ovalifolia, B. procurva, B. prochorowii, B. raddeana, B. rezniczenkoana, B. rotundifolia, B. saposhnikovii, B. schmidtii, B. schugnanica, B. sukatsczewii, B. tortuosa, B. turkestanica, B. ulmifolia, B. x irkutensis , B. x montana* , and some species considered

as rare or threatened in central Asia such as *Betula jarmolenkoana*, *B. khirghisorum*, *B. tianshanica* (EPPO, 2000; USDA-ARS, 2010; Eastwood *et al*., 2009)

In addition, *B. nana* is widespread in Europe, from Scotland to Nordic countries down to the Alps in the south. In North America, this species seems to be present only at arctic/subartic latitudes of Canada and Alaska, and is not reported as a host.

Birch as an amenity tree

- Many birch species are used as ornamentals in Europe in gardens, parks, the urban environment, landscapes, etc., including European, Asian and North American species, such as *B. pendula*, *B. nigra*, *B. utilis*, *B. davurica*, *B. pubescens*, *B. albosinensis*, *B. ermanii*, *B. alleghaniensis*, *B. costata*, *B. maximowicziana*, *B. papyrifera* (most of these birch species are listed as hosts of *A. anxius* – see above).
- *B. pendula* is reported as being widely used for field shelterbelts in Siberia (Prairie Farm Rehabilitation Administration Shelterbelt Centre, Agriculture and Agri-Food Canada (PFRA Shelterbelt Centre, undated).

Bonsais

Bonsai birch are produced from several birch species, including *B. nana*, *B. pubescens*, *B. pendula* (see e.g. Caine, 2000).

1.18a - Specify the area where host plants are present (cf. QQ 1.15-1.17).
This is the area for which the environment is to be assessed in this section. If this area is much smaller than the PRA area, this fact will be used in defining the endangered area.

The whole of the PRA area, except North Africa, Israel, Malta, Cyprus, South of Turkey (based on distribution data of *Betula* spp.) (see Appendix 3).

1.18b - How similar are the climatic conditions that would affect pest establishment, in the PRA area and in the current area of distribution?

Largely similar

Level of uncertainty: low

Note: considering the Climatic mapping decision support scheme developed with the EU project PRATIQUE, it was decided that no mapping was necessary for the following reasons:

- *there is low uncertainty that the climate in the area suitable for establishment is completely or largely similar to the climate where the pest is currently present (as the pest occurs in Canada and USA in the different Koppen-Geiger zones present in the PRA area where birch occurs, see Appendix 1) and the presence of A. anxius seems to be restricted more by the presence of birch than by the climate.*
- *the pest spends a large part of its life cycle protected from climatic conditions as measured at weather stations (i.e inside the trunk)*

The pest is present in North America in a wide range of climatic conditions, including lowlands and mountains, and in all areas where birch is growing. From its biology, *A. anxius* is likely to survive in all areas where the birch is grown in the PRA area. The available literature indicates a gradation of damage with latitude. For example, in Canada, *A. anxius* is reported as being more common in the southern portion of Canada (Katovich *et al*., 2005). In nurseries, Lanthier (2008) mentions *A. anxius* as a serious pest of nurseries in British Columbia (interior) and Southern Alberta (both regions having high temperatures with minimal precipitations in summer, and below 0°C with rain/snow during winter).

However, collection records show the distribution of *A. anxius* to extend far north into Canada and Alaska, corresponding with the northern limits of the boreal forest (Bright, 1987). Considering the degree-days accumulation in base 10°C (see Appendix 1, Fig 2a and 2b), and the northern limit of collection localities noted by Bright, 1987, it appears that *A. anxius* cannot develop in zones where degree-day accumulation is between 0 and 250. If we apply this to the EPPO region, then *A. anxius* may not develop in most of Norway (except the southern Coast) and Northern Sweden and Finland (see Fig 2b in Appendix 1). It is interesting to note that this limit correspond more of less to the limit of distribution of *B. pendula* according to the map provided by EUFORGEN (see Appendix 3).

In both the USA and Canada, birch is generally recorded to be more susceptible to the pest in southern areas, where birch is also subject to additional stresses, in particular climatic stress (Jones *et al*., 1993; Haack, 1996). This could mean that birch is more at risk from *A. anxius* in the warmer climates within the PRA area, although northern areas would be at risk due to the density of birch.

A. anxius larvae are present in the wood of trees and can withstand long periods of freezing in winter. Infestations of North American hosts are favoured by climatic stress on trees, especially drought. Stress does not appear necessary for the colonization of the more susceptible European and Asian hosts (Nielsen *et al.*, 2011; Miller *et al.* 1991, Ball & Simmons, 1980; Ball & Simmons, 1986). The pest has a 1-2 year life cycle, depending on host vigour, date of oviposition, geographic location of the host, and climatic conditions.

In the current range of the pest, adults are reported to begin emerging around late April in the southern part of the range to the end of June in the north (Barter, 1957) and the period of emergence lasts for approximately 10 weeks. Temperatures needed for oviposition seem relatively high: Barter (1957) did not record oviposition below 70°F (approximately 21°C), with optimal temperature of 85°F (around 30°C).

1.19 - How similar are other abiotic factors that would affect pest establishment, in the PRA area and in the current area of distribution?

No judgement

Level of uncertainty: low

No other abiotic factors are expected to affect the establishment of *A. anxius* in the PRA area.

In North America *A. anxius* is considered in the literature to attack native birch only if subject to stress. Predisposing stress factors in North America are drought and high soil temperature; air pollution, ozone. Overall stress is not a factor that will influence the susceptibility of European and Asian birch trees in the PRA area because they are highly susceptible even when healthy.

1.20 - If protected cultivation is important in the PRA area, how often has the pest been recorded on crops in protected cultivation elsewhere?

N/A

Level of uncertainty: low

No data are available on the production of birch bonsais in North America, and if they are grown in protected conditions and attacked by *A. anxius*. Nursery trees would be produced outdoors.

1.21 - How likely is it that establishment will occur despite competition from existing species in the PRA area, and/or despite natural enemies already present in the PRA area?

Very likely

Level of uncertainty: low

Competition from other wood boring insect species is not important in North America. In the PRA area, there is only one known European *Agrilus* species restricted to birch (*A. betuleti*) and this is unlikely to compete for larval development on larger diameter stems and branches. Other European species (e.g. *A. viridis, A. paludicola*) may utilize birch, but this is only expected to provide limited competition.

The effects of natural enemies on population dynamics of the bronze birch borer have not been studied. Some natural enemies have been recorded in North America, but European birch trees planted in North America are commonly killed even in the presence of the range of *A. anxius* natural enemies (Nielsen *et al.*, 2011; Miller *et al.* 1991, Ball & Simmons, 1980). Natural enemies have not prevented the spread or establishment of the pest to the west of the Cascade Mountains in Oregon in 2003 (Nelson *et al.*, 2004) and in the San Francisco Bay area in 1992. Natural enemies are not thought to play a vital role in the pest dynamics (Katovich *et al.*, 2005). Woodpeckers are reported as being the main common predator of *A. anxius* larvae, but have not prevented establishment of the pest. Woodpeckers usually feed during the winter months after the larvae have done their feeding damage to the tree. Loerch & Cameron (1983a) recorded wood pecker predation of larvae mortality of 27% to 89% in a small number of trees. Woodpeckers (although different species than in North America) are widespread throughout the PRA area. They might control *A. anxius* to a certain extent, but presumably not fully. Parasitism does not seem to provide good control, although a number of parasites of eggs (*Ooencyrtus* sp., *Avetianella* sp.) and larvae (*Tetrastichus* sp., *Eurytoma* sp., *Phasgonophora sulcata* and *Atanycolus charus*) of *A. anxius* were identified, which contribute to a lesser extent to control the pest (Loerch & Cameron, 1983a). Natural enemies of *A. anxius* are being studied as part of a project currently being conducted (Rutledge, 2007). Association of expansive outbreaks with wide-scale episodes of stress events supports the view that the primary factor in the population dynamics of *A. anxius* in North America is host resistance, and suggests that natural enemies are incapable of preventing outbreaks when host resistance is compromised on a large scale. This would be the situation in the PRA area because of the low inherent resistance of European and Asian birch species.

It is expected that natural enemies will not prevent establishment in the PRA area. Larvae feed under the bark and they fill galleries with frass, which may reduce their exposure to some predators.

1.22 - To what extent is the managed environment in the PRA area favourable for establishment?

Highly favourable

Level of uncertainty: low

Birch might be present in managed environments: nurseries for ornamental or forest trees; ornamental species in gardens and amenity areas; forestry areas.

Nurseries

The level of management of nurseries varies across the EPPO region, from no intervention against pests to management practices such as grafting, pruning, thinning, weed control and fertilization. Few data have been found on nursery practices for birch in the PRA area (see 1.23), but it is presumed that trees would be grown outdoors and not protected from adult *A. anxius*. Other management practices would not specifically target *A. anxius.*

Forests

The level of management of forest birch also varies across the EPPO region, from no intervention to management practices such as pruning, thinning and fertilization (Hynynen *et al*., 2010).

B. pendula and *B. pubescens* are highly susceptible to *A. anxius* and are dominant birch species in European forests.

Stress will not be required for establishment. Stressed trees might be preferred, but the pest will readily attack healthy trees (see details in 2.1). Green-tree retention is common practice in some areas (e.g. Sweden), as a part of forest management: in such case some birch trees will be left on clearcut areas as a tool for maintaining soil biodiversity and functioning. These trees may be very suitable as host trees for *A. anxius*.

1.23 - How likely is it that existing pest management practice will fail to prevent establishment of the pest?

Very likely

Level of uncertainty: medium Reason: question how widely treatments are used, would they be effective against A. anxius?

There are practically no management practices that would prevent establishment of the pest in forests, in forestry nurseries, and in amenity areas.

In some nurseries for the production of ornamental birch, insecticides are applied to control the tenthredinid leaf miner *Fenusa* spp. and aphids (e.g. *Euceraphis punctipennis).* Active substances mentioned to control these pests in Belgium are thiacloprid against *Fenusa pumila;* the range of active substances used against aphids is larger*:* nicotinoids (acetamiprid, thiacloprid, imidacloprid), pyrethroids (cyfluthrin, cypermethrin, deltamethrin, lambda-cyhalothrine), organophosphate (dimethoate), carbamate (pirimicarb), flonicamid, pymetrozine. These cover sprays to trunk, branches and foliage are recommended between April and August (Fassotte *et al.*, 2010a and b). Among the active substances used in these birch nurseries, thiacloprid and lambda-cyhalothrine have been shown to be very effective against *Agrilus sinuatus* (the pear tree borer) as cover treatments (see question 2.3) to trunk, branches and foliage of young pear trees, in insecticide trials conducted in 2008-2009 by the Walloon Agricultural Research Centre (Fassotte, pers. comm., 2010) and thus these two insecticides would probably control the similar pest *A. anxius* if used during its flight period. It is yet difficult to evaluate whether current applications against other birch pests would cover the entire flight period of *A. anxius* in the PRA area. No other data were found on insecticide treatments in ornamental nurseries in other EPPO countries.

In North America experience with these other pests showed that the timing of application was not appropriate to control *A. anxius*. In addition, application rates labelled for use in nurseries in the USA, are too low to provide systemic control of *A. anxius*.

It can therefore be concluded that the insecticides already applied in ornamental nurseries against other pests in the PRA area will possibly partially control *A. anxius* populations but it is unlikely to prevent establishment of the pest.

Some management practices are mentioned in the literature for North America, but these are not likely to prevent establishment of the pest in the PRA area because European and Asian birch species have high susceptibility to the pest and stress is not necessary for colonization. They are:

Proper planting and maintenance of birch, improving tree health

- selection of tree species (Bauernfeind, 2006; Carlos *et al*,. 2002; Gibb & Sadof, 2007; Katovich *et al.*, 2005; Wawrzynski *et al*., 2009).
- appropriate location: birch needs cool moist soil (Wawrzynski *et al*., 2009; Katovich *et al*., 2005) and lawn conditions are often not favourable to birch (Gibb & Sadof, 2007).
- appropriate watering, mulching and fertilizing (Ball & Simmons, 1980; Bauernfeind, 2006; Crawnshaw *et al*., 2000; Hoover, 2002; Katovich *et al*., 2005). Santamour (1990a) notes that watering should not be excessive and that it might not be possible to maintain the continuity of adequate water supply as trees grow.
- control of other pest problems likely to affect the tree (Ball & Simmons, 1980).
- avoiding damage to trunk and branches (Carlos *et al*., 2002).
- avoiding stresses of urban landscape sites, soil compaction, de-icing salts, lawncare herbicides (Santamour, 1990a).

Sanitation/area management

- removal and proper destruction of infested trees (KSU, 2009).

1.24 - Based on its biological characteristics, how likely is it that the pest could survive eradication programmes in the PRA area?

Very likely

Level of uncertainty: low

Due to its 1- or 2-year life cycle and its mostly hidden life stages (eggs, larvae, prepupae, pupae), the pest might not be detected before a population is already well-established. There are no effective monitoring tools for *Agrilus* species and so delimiting an outbreak would be difficult. It might be easier to detect an outbreak in a nursery, but by the time an outbreak is detected, the pest might already have had a chance to spread to other birch trees. If birch is present, it is likely to be present in several types of habitats in the same area, e.g. forests, amenity areas, gardens, nurseries, which might be difficult to subject to an eradication programme.

The pest would be hard to eradicate. Eradication could be attempted by destroying infested trees and other host trees in a certain (unspecified) area around the outbreak, but the pest is a strong flier (see question 1.30), which would imply that a large quarantine area would be required to contain it (e.g. over 35 km radius). The pest might be easier to eradicate if it enters an area of low presence of birch, where there are not too many birch trees around and establishing a quarantine area might be easier. Aggressive eradication programmes against the related species *A. planipennis* have not been successful in Canada and in the USA (GAO, 2006).

1.25 - How likely is the reproductive strategy of the pest and the duration of its life cycle to aid establishment?

Moderately likely

Level of uncertainty: low

- The life cycle of the pest varies from 2 years in the north of its current distribution, to one year further south. *A. anxius* can stay at the prepupal stage (tolerant to desiccation) until sufficient degree days have accumulated for emergence of adults (Barter, 1957; Akers & Nielsen, 1984).
- Females deposit at least 25-50 eggs, and the level of survival is expected to be high, based on experience with *A. planipennis*. Eggs are laid individually or in groups at suitable sites on the bark along birch trunks and branches. The diversity of oviposition sites might also favour establishment.

1.26 - How likely are relatively small populations to become established?

Likely

Level of uncertainty: low

There is no information on the number of individuals necessary to start a population, but females lay at least 25-50 eggs (Barter, 1957; Akers & Nielsen, 1990).

There is little knowledge of the sources of introduction of other *Agrilus* spp., but they are generally first observed years after they have become established and spread (Haack *et al*., 2002, 2009, 2010; Jendek & Grebennikov, 2009). Small populations of related species have already established in North America. Low density populations of *A. anxius* persist in the endemic range and the pest successfully expanded its range as its hosts expanded their range in the western and southern USA with the introduction of ornamental birch species into these areas (see answer to Stage 1, question 7) (Johnson & Lyon, 1976).

1.27 - How adaptable is the pest? Adaptability is:

Moderate

Level of uncertainty: low

Agrilus anxius is adapted to a broad range of eco-climatic conditions: it is present throughout the range of birch in North America, which encompasses many eco-climatic conditions. It is highly pre-adapted to many European and Asian birch species introduced to North America as ornamentals which have no natural resistance to the pest. The pest does not have a diversity of host genera, as larvae are only found on *Betula* spp.

Some *Agrilus* spp. considered to be secondary pests attacking stressed or dying hosts in their native range have sometimes become severe pests once introduced in other areas (e.g. *A. planipennis*) (Liu *et al*., 2003).

1.28 - How often has the pest been introduced into new areas outside its original area of distribution? Specify the instances if possible in the comment box.

Occasionally

Level of uncertainty: low

The original area of distribution was northern USA and Canada coincident with the natural distribution of its host plants. *A. anxius* was first described in 1841 by Gory. *A. anxius* has then spread to cover nearly all areas where birch has been planted as an ornamental, for example it was first detected in western Oregon in 2003 (Nelson *et al.*, 2004) and the San Francisco Bay area in 1992. It is considered to be an invasive species in Wyoming (WSFD, undated.

No record of intercontinental spread of *A. anxius* has been found, and there are no records of *A. anxius* interceptions in Europe (EPPO Reporting Service). Some *Agrilus* spp. have been intercepted in other places: e.g. in New Zealand, *A. biguttatus* and *A. elongatus* (Bain, 1972, 1977). Thirty-eight *Agrilus* spp. and 41 buprestids not identified below family level were among 245 interceptions of Buprestidae in the USA in 1985-2000 (Haack *et al*, 2002, 2009). However, it should be noted that the genus *Agrilus* has nearly 3000 species.

There are records of international spread of several *Agrilus* spp. as plant pests, such as *A. planipennis* (from Asia to North America). Jendek & Grebennikov (2009) report *Agrilus* introductions to North America, and mention 10 species, including 4 first reported after 2000: *A. planipennis*, *A. sulcicollis* (from Europe/Russia to North America), *A. coxalis* (from Mexico to USA), and *A. prionurus* (from Mexico to USA) (see also Baez, 2009; Haack *et al.*, 2002, 2009, 2010; Haack, 2006).

1.29a - Do you consider that the establishment of the pest is very unlikely?

No

Once the pest has entered the PRA area, it is likely that it would find hosts and conditions suitable for its establishment, and existing host management practices in the PRA area would not prevent its establishment.

1.29c - The overall probability of establishment should be described.

The overall probability of establishment is considered as to be "very high".

Birch is widespread in the PRA area. The pest in its current distribution occupies a wide range of ecological and climatic conditions, that are also present in the PRA area. *A. anxius* would be difficult to eradicate. If introduced, it would most likely not be controlled by any natural enemies that might occur in the PRA area, nor by treatments. It is also highly pre-adapted to the hosts in the PRA area (i.e. European and Asian birch species are much more susceptible than native North American species).

Uncertainties: host status of some birch species present in the PRA area (further hosts would increase the probability of establishment), how widely treatments are used in nurseries in the PRA area against birch pests.

Stage 2: Pest Risk Assessment - Section B: Probability of spread

1.30- How likely is the pest to spread rapidly in the PRA area by natural means?

Very likely

Level of uncertainty: low

Adults are strong fliers and can disperse several kilometres. The US Federal Register (2003) states that *Agrilus anxius* is capable of a natural spread of 10 to 20 miles per year (16 to 32 km/year) and this was used as a possible estimate of *A. planipennis* spreading capability. Since then further studies were conducted and up to 20 km per day were recorded for mated females of *A. planipennis* subject to studies of tethered flights under laboratory conditions (Taylor *et al*., 2005; Taylor *et al*., 2007). This could be similar for *A. anxius* adults as their size and morphology are nearly identical, as are their behavioral tendencies.

One important factor for the speed of spread might be how easy it would be to find a host. Adults have found hosts even where birch exists at low density planted only as an amenity tree (Ball & Simmons, 1980).

1.31 - How likely is the pest to spread rapidly in the PRA area by human assistance?

Very likely

Level of uncertainty: low

The pest could be transported over long distance with plants for planting and wood with or without bark (including firewood, wood chips, logs, and mulch).

Consignments entering the PRA area might be further moved between countries, especially EU countries, to satisfy demand, although this would be relatively expensive for such a low value commodity (especially wood chips, wood for energy production).

Once the pest has entered the PRA area, infested wood from amenity trees killed by *A. anxius* might be transported to other areas. There are exchanges of all these commodities in the PRA area, but the probability of spread would be higher once introduced to one of the areas of high presence of birch. There is an important trade of hardwood wood chips and birch wood within the PRA area.

Movement of the related species *A. planipennis* in North America by human assistance is well documented (USDA–APHIS, 2009).

1.32 - Based on biological characteristics, how likely is it that the pest will not be contained within the PRA area?

Very likely

Level of uncertainty: low

Host plants are widely distributed and outbreaks would be difficult to contain if *A. anxius* were introduced to an area of high presence of birch in different habitats. In addition, introductions of new *Agrilus* spp. seem to be detected when the pest has already established a population (Haack *et al.*, 2002, 2009; Jendek & Grebennikov, 2009). The pest may remain undetected for some years, even when some signs and symptoms might be observed (e.g. exit holes, galleries under the bark, and later signs of dieback). There are no good monitoring tools for *A. anxius*.

Natural spread will also affect the ability to contain the pest. Considering that the pest can fly several kilometres, establishment of a buffer zone would be very difficult, and this has not been successful in the case of the related species *A. planipennis* in the USA and Canada.

The control measures available would not allow containment of the pest in forest environments. It would also be difficult to manage on birch planted as ornamentals. European and Asian hosts are highly susceptible, so management measures recommended for North American hosts (selection of resistant species as ornamentals, good conditions for trees, pruning of branches, removal of trees) (Katovich *et al.*, 2005), will not be sufficient to contain it. Pesticides are only practical for protecting individual high value trees. Movements of plants for planting, wood chips and wood might be possible to control, but not firewood or by-products. To contain the pest, host plants would have to be eliminated around the outbreak, which might be difficult in areas of high birch density and where birch is present in different habitats. There is no effective area-wide control for *A. anxius* in North America. Area-wide control has been attempted for *A. planipennis* in North America but has not been successful for containment (GAO, 2006; Poland & McCullough, 2010).

1.32c - The overall probability of spread should be described.
The probability of spread is considered to be "very high".

A. anxius will spread naturally as it is a strong flier, but it will also move with human activities (movement of plants, wood and wood products) because the wood boring habit and cryptic nature of the pest makes detection of infested material difficult. Spread is also likely to be facilitated because hosts are widely distributed in many different habitats (forests, amenity areas, urban areas, gardens) and European and Asian birch are highly pre-adapted (i.e. susceptible). Monitoring of *A. anxius* is difficult because of its cryptic nature and the lack of efficient monitoring tools (no lures and traps available) meaning that outbreaks cannot be easily delimited. Management measures to try to prevent spread are possible on a small- scale for individual amenity trees, but are more difficult to apply for forests, and they would not be sufficient to ensure containment.

Uncertainties: none identified.

Stage 2: Pest Risk Assessment - Section B: Conclusion of introduction and spread and identification of endangered areas

1.33a - Conclusion on the probability of introduction and spread.
The probability of entry was rated as low to medium with medium uncertainty; the probability of establishment and spread as very high with low uncertainty.

1.33b - Based on the answers to questions 1.15 to 1.32 identify the part of the PRA area where presence of host plants or suitable habitats and ecological factors favour the establishment and spread of the pest to define the endangered area.
All areas where birch is naturally present in the PRA area, i.e. northern Europe, from western Europe to Siberia to the East, and from Nordic countries to central France to the South. Distribution data (see Appendix 3) suggests that birch is rare or not present in North Africa, Israel, Malta, Cyprus, and southern Turkey.

Stage 2: Pest Risk Assessment - Section B: Assessment of potential economic consequences

2.1 - How great a negative effect does the pest have on crop yield and/or quality to cultivated plants or on control costs within its current area of distribution?

Major

Level of uncertainty: low

Birch is an ecologically and economically important tree in North America (Miller *et al.*, 1991). *A. anxius* was first mentioned as a pest of ornamental birch in the 1890s (Slingerland, 1906), and reported as a forest pest in 1918 (Akers & Nielsen, 1984, Katovich *et al.*, 2005). Outbreaks developed during the long period of widespread birch dieback in forests in Northern USA and Canada beginning in the early 1930's (MacAloney, 1968; Jones *et al.*, 1993). The pest is also considered to be one of the major contributing factors in the decline and death of amenity birch trees in North America (Ball & Simmons, 1980). It attacks and kills trees, which die in a few years if no remedial action is taken (Appleby *et al*., 1973). Johnson & Lyon (1976) mention it as a limiting factor to extending the range of white birch in the southern USA.

In landscape/urban environment/nurseries:

A. anxius is the most destructive pest of species with white-barked birch in the urban environment (Akers & Nielsen, 1984), and a major mortality factor in landscape birch (Ball & Simmons, 1980). Carlos *et al.* (2002) report that several thousands of mature birch trees were killed by the pest in urban areas in Nevada since the droughts in 1990s. *A. anxius* is a major pest and the most important limiting factor to the long-term cultivation of white-bark birch in landscape plantings (Santamour, 1990a, 1990b; Iles & Vold, 2003). European white birch is no longer recommended as suitable for use in landscape and other plantings due to its susceptibility to *A. anxius* attacks throughout North America.

In nurseries, Lanthier (2008) mentions *A. anxius* as a serious pest of nurseries in British Columbia (interior) and Southern Alberta (both regions having high temperatures with minimal precipitations in summer, and below 0°C with rain/snow during winter). There has been a shift by nursery producers from European and Asian birch to birch species that are endemic to North America because of their higher level of resistance to bronze birch borer. There are no data available on control costs in nurseries specific to *A. anxius*.

In forests

In North America *A. anxius* is considered in several publications to be a key factor contributing to birch mortality in forests during severe drought or during other stress events (e.g. Barter, 1957; Jones *et al*., 1993; Houston, 1987; Anderson, 1944; NRC, 2010; Katovich *et al*., 2005). Extensive damage is sometimes recorded in forests (e.g. WIDNR, 2008, Hodge *et al*., 2009, Scarr *et al*., 2010). There have been no control costs documented in North America for forests as the pest is not being managed (and no other high impact scolytids require management).

Relationship between damage by *A. anxius* and tree stress in North America

In North America *A. anxius* is considered in the literature to attack native birch only if subject to stress, whereas European and Asian birch are attacked even when healthy. A number of articles discuss the relationship between *A. anxius* and birch dieback, and whether *A. anxius* causes birch dieback, or is a factor associated with it due to weakened trees. There has been discussion on whether *A. anxius* is a minor pest, killing trees already predisposed to death by other factors, or if it is sufficient in itself to contribute significantly to birch dieback (Anderson, 1944; Barter, 1957).

Possible predisposing stress factors mentioned in the literature are (e.g. Balch & Prebble, 1940; Clark & Barter, 1958, Haack, 1996; Herms, 2002):

- drought and high soil temperature
- attacks by other insects, especially insect defoliation (e.g. forest tent caterpillar - WIDNR, 2008)
- air pollution, ozone
- climatic conditions (Jones *et al*. (1993) detail the links between birch dieback, *A. anxius* and climatic conditions).

Widespread mortality of birch associated with activity of *A. anxius* after several years of climatic stress is reported (Haack, 1996). It is noted that factors like frost, drought or warmer temperatures have been considered to be important stress factors. Paper birch (*Betula papyrifera*) is sensitive to temperature and moisture in the surface soil. Drought and extreme temperature were observed to favour attacks. Increases of temperature of 2°C and decrease of summer

precipitation of 15% have caused high mortality.
- localized stress, such as damage to branches or trunks due to other insects or cutting injuries (Santamour, 1990a), root injuries.
- old age (weaker defenses)
- specific stresses in urban environments (e.g. soil compaction, de-icing salts, lawncare herbicides).

Overall stress is not a factor that will greatly influence the susceptibility of European and Asian birch trees in the PRA area because they are highly susceptible even when healthy.

2.2 - How great a negative effect is the pest likely to have on crop yield and/or quality in the PRA area without any control measures?

Massive

Level of uncertainty: low

European and Asian birch grown in North America, especially *B. pendula*, *B. pubescens*, *B. platyphylla*, *B. maximowicziana*, (Nielsen *et al.*, 2011; Herms, 2002), *B. jacquemontii* (Katovitch *et al.*, 2005), are highly susceptible to *A. anxius* and healthy trees are attacked and killed in North America. The impact of the pest is likely to be high mortality of birch in the PRA area in landscapes, gardens, nurseries and forests. There are birch species in the PRA area that are not present in North America (see question 1.16), and their susceptibility is not known.

The high susceptibility of North American ash to *A. planipennis* when these were planted in China proved to be a good predictor of the impact that *A. planipennis* would have when it was introduced to North America (Liu *et al.*, 2003), where it is killing both healthy and stressed ash trees.

2.3 - How easily can the pest be controlled in the PRA area without phytosanitary measures?

With much difficulty

Level of uncertainty: low

A. anxius is not easy to control. The control measures applied in North America are applied mostly to amenity birch in urban/landscape/garden environments, and not in forests. It would be difficult to apply any control measures in forests in the PRA area, and amenity areas are also minimally managed. However, an insecticide regime targeted specifically at *A. anxius* could effectively control this insect in nurseries, should it be detected.

The pest management practices that are recommended in the area where *A. anxius* occurs are likely to provide adequate control only in defined situations, e.g. nurseries, but would not prevent damage. It might take several years before symptoms show, as some infested trees might not show symptoms quickly. The measures aim mostly at managing the populations of the pest and depend on the situation.

Ornamental birch

Because of the high susceptibility of European and Asian birch species, the only effective measure would be application of preventive insecticides on an ongoing basis to protect high value amenity trees.
Two approaches have been shown to be effective in the USA:

- Systemic insecticides applied to the soil or trunk targeting early instar larvae. Imidacloprid (soil or trunk), dimethoate* (soil only), dicrotophos* (trunk injections only) are currently recommended in the USA (Shetlar & Herms, 2003; Gibb & Sadof, 2007; KSU, 2009)
- Preventive cover sprays to trunk, branches and foliage targeting adults during their flight period and young larvae before they bore into the trees (e.g. Ball & Simmons, 1980; Bauernfeind, 2006; Carlos *et al.*, 2002; Crawnshaw *et al.*, 2000; Gibb & Sadof, 2007; Katovich *et al.*, 2005; KSU 2009). Example: 2-3 applications at 2-3 week intervals, beginning with first adult emergence. Insecticides mentioned in USA literature: chlorpyrifos, permethrin*, bifenthrin. The first emergence of adults in north central USA coincides with the blooming period of *Robinia pseudoacacia*, as calculated by day degree accumulation (average day degrees in Ohio is 550 from base temperature 50°F starting January 1, which is equivalent to 306 DD in base temperature 10°C) (Herms, 2003)

*Note: * indicates active substances that are not registered in the EU (EU Pesticides Database, 2010)*

A number of other control measures (maintain the health of the tree and area management) are applied in North America aiming at reducing the impact of the pest (see 1.23), but they are not expected to be effective in controlling the pest in the PRA area.

In forests
In USA the following good silvicultural practices limit the impact of outbreaks (Katovich *et al*., 2005), but they will not be sufficient in the PRA area to control *A. anxius* as the native birch species are highly susceptible:
- silvicultural practices that increase stand health and vigour
- avoid management practices that cause significant disturbance
- thinning done with care in birch stands
- enhance age class diversity (the pest is more likely to attack old trees and can better build populations in areas of old birch trees).

Biological control
There are natural enemies of *A. anxius* in North America (parasitoid wasps) but these do not protect European birch trees when planted in North America (see answer to 1.21). The parasitoids might be introduced with the pest. The control that would be provided by natural enemies and woodpeckers in the PRA area is not known, but it is expected from the North American experience with *A. anxius* and *A. planipennis* that they would not provide adequate control. Nevertheless in forests the use of introduced biological control agents seems to be the only realistic possibility to reduce populations of *A. anxius*.

2.4 - How great an increase in production costs (including control costs) is likely to be caused by the pest in the PRA area?
Moderate
Level of uncertainty: low
General costs: surveillance and monitoring, eradication/containment efforts.
In forests: additional costs would be incurred by pest surveillance, removal of infested trees and destruction/processing, and sanitation practices where applicable, and possible phytosanitary measures applied to wood for export specifically for *A. anxius*.
In nurseries: control operations (additional spray and associated surveillance/model to predict emergence, looking for damage, pruning), destruction of infested trees (in case of control failure), initial costs of shifting to producing alternative species.
In landscapes and gardens: additional costs of surveillance, removal of infested trees and destruction, cost of replacing trees.

2.5 - How great a reduction in consumer demand is the pest likely to cause in the PRA area?
Minimal
Level of uncertainty: medium. Reason: it is not known whether consumer demand would be affected, i.e. whether there will be a shift to other tree species or origins
Comments:
The pest is unlikely to affect the demand within the PRA area. Birch is popular as a plant for planting in gardens or landscapes (plant producers might choose to shift to more resistant species); its wood is also widely used.

2.6 - How important is environmental damage caused by the pest within its current area of distribution?
Minor
Level of uncertainty: low
Ayres & Lombardero (2000) and Houston (1987) mention *A. anxius* among the herbivores that are significant agents of biological disturbance in North American forests. Any impacts on the environment, such as biodiversity, have not been measured. Even in the case of outbreaks in forests, most trees are not killed and therefore birch is always available. Effects on biodiversity are most probably limited.

2.7 - How important is the environmental damage likely to be in the PRA area?
Major
Level of uncertainty: low
In the PRA area, birch grows in pure and mixed forest stands. As the most common broadleaved species in northern

Europe, birch is very important for the biodiversity of coniferous forests. In different phases of succession, a large number of species feed on or live together with birch, including mycorrhiza-forming fungi, herbivores, wood-decaying fungi and saproxylic insects (Hynynen *et al.*, 2010). Given the high susceptibility of European and Asian birch, the impact of *A. anxius* would be to dramatically change the ecological balance and composition of several forest types in the PRA area. It might affect sensitive ecosystems. Biodiversity and ecosystem processes are likely to be affected. The importance of dead wood is highlighted in Scandinavian forest management. If trees affected by *A.anxius* are cut and remowed out of the forest, this will reduce the amount of dead wood used by other species.
Birch is a dominant species in the boreal forest, and widespread mortality would affect carbon sequestration.

A. anxius might constitute an additional threat for several species of birch that are already threatened with extinction in Central Asia such as *Betula jarmolenkoana, B. khirghisorum, B. tianshanica* (Eastwood *et al*., 2009) or are restricted to limited areas in sensitive conditions (EEA, 2006).

2.8 - How important is social damage caused by the pest within its current area of distribution?

Minor

Level of uncertainty: low

Social damage has been principally aesthetic due to the loss of ornamental trees in the landscape. Historically in the USA, *A. anxius* had an important impact when European birch (*B. pendula*) was the dominant species in the nursery industry, but the impact is now minor as North American species dominate in nurseries. The pest is an important pest of non-native ornamental birch. This has resulted in many garden, city and landscape trees having to be cut down once infested, and in other control measures being applied to affected/susceptible trees.

2.9 - How important is the social damage likely to be in the PRA area?

Major

Level of uncertainty: low

Birch is the most common broadleaved species in northern Europe (Hynynen *et al*., 2010). In forests, establishment of *A. anxius* will result in potential loss of large areas of native birch forests as well as a potential loss of recreational areas. It may also affect livelihoods where birch forests are economically important, e.g. in Russia and Belarus (Hynynen *et al*., 2010).
Infested birch in gardens, cities and amenity areas will first affect the aesthetic value of amenity trees, and they might also have to be felled and replaced.

Birch has a large cultural significance in northern European countries. It is considered to be a national tree of Russia and Finland. Birch has spiritual importance in several religions, both modern and historical. Birch is associated with the Tír na nÓg, the land of the dead and the Sidhe, in Gaelic folklore, and as such birch frequently appears in Scottish, Irish, and English folksongs and ballads in association with death, or fairies, or returning from the grave (source Wikipedia).
Birch sap is a traditional beverage in Russia (Russian: Берёзовый сок), Latvia (Latvian: Bērzu sula), Estonia, Finland, Lithuania (Lithuanian: Beržų Sula), Belarus (Belarusian: Бярозавы сок), Poland (Polish: Sok z Brzozy) and Ukraine (Wikipedia, Tschirpke, 2006).

2.10 - How likely is the presence of the pest in the PRA area to cause losses in export markets?

Moderately likely

Level of uncertainty: medium. Reason: effect on export markets, whether Russia exports to Asia

Birch is mostly produced in North America and the PRA area (especially Russia). There has been no documented effect on export markets for North American birch and birch products. The expert working group was not aware of any existing phytosanitary regulation against *A. anxius*. There are data on exports of birch wood from the PRA area although it is not known to which countries such exports occur (UNECE, 2006).

Main exporters were as follows in 2004 (UNECE, 2006):

Country	**1000m3 of non-coniferous sawnwood exported (total)**	**1000m3 of birch sawnwood exported**	**Percentage (birch/total)**
Belarus	58	58	100
Denmark	36	7	19
Estonia	153	128	84
Finland	18	14	78

Latvia	556	78	14
Russian Federation	413	269	65

There is a high demand for birch as ornamental tree and as wood. Export markets might be affected by shifts to non-infested areas or other tree species. Importing countries may also impose phytosanitary requirements.

2.11 - How likely is it that natural enemies, already present in the PRA area, will not reduce populations of the pest below the economic threshold?

Very likely

Level of uncertainty: low

A. anxius is considered to be a pest in its current range despite the natural enemies that are present there (woodpeckers and some parasitoids, see 1.21). It is not likely that natural enemies or European woodpeckers would be more effective than the North American ones in bringing populations of *A. anxius* below an ecologically or economically-damaging threshold. The lack of natural enemies for the related species *A. planipennis* is thought to be a contributing factor for the spread of this pest in North America.

2.12 - How likely are control measures to disrupt existing biological or integrated systems for control of other pests or to have negative effects on the environment?

Unlikely

Level of uncertainty: medium. Not sure whether insecticides already in use or not in nurseries

In nurseries and for amenity/garden trees, chemical control is the most likely measure, but this is already in use against other pests in some countries. Where pesticides are not currently used or it results in increased pesticide use, this could disrupt biological systems and may have a negative effect on the environment where the pest is present.

In forests, possible measures (cutting-down trees or the use of biological control) might affect ecosystem functioning.

2.13 - How important would other costs resulting from introduction be?

Moderate

Level of uncertainty: medium. Costs will depend if actions are taken against the pest.

Costs would include research for biological control agents and pesticides, research on *A. anxius* host susceptibility, investigation of natural enemies, outreach and education, administration.

2.14 - How likely is it that genetic traits can be carried to other species, modifying their genetic nature and making them more serious plant pests?

Impossible/very unlikely

Level of uncertainty: low

No example of this has been found for *A. anxius* in the literature.

2.15 - How likely is the pest to cause a significant increase in the economic impact of other pests by acting as a vector or host for these pests?

Impossible/very unlikely

Level of uncertainty: low

There is no evidence of *A. anxius* being a vector or carrier for other pests in North America. Unlike the adult stage of bark and ambrosia beetles that vector mutualistic fungi, bronze birch borer adults (the mobile phase of the pest) do not enter the tree.

2.16 - Referring back to the conclusion on endangered area (1.33): Identify the parts of the PRA area where the pest can establish and which are economically most at risk.

All areas where birch is present in the PRA area. Northern Europe, from Western Europe to Siberia to the East, and from Nordic countries to Central France to the South.

Northern areas would be at risk because birch represents a high proportion of the forest trees; southern areas mainly because of the presence of susceptible ornamental species.

Distribution data suggest that birch is very rare or not present in North Africa, Israel, Malta, Cyprus, south of Turkey (see Appendix 3).

Stage 2: Pest Risk Assessment - Section B: Degree of uncertainty and Conclusion of the pest risk assessment

2.17 - Degree of uncertainty: list sources of uncertainty

Below each subheader the following medium or high uncertainties were noted during the assessment (overall uncertainty is given first):

Probability of entry on pathways originating from where the pest occurs in Canada and in the USA:

- **hardwood wood chips** (medium uncertainty overall)

- proportion of birch in hardwood chips imports
- data on pathway: volume, frequency of import (per month) in the PRA area, timing of imports, distribution throughout the PRA area
- whether chips would be stored for some time on arrival and in which conditions
- whether imported wood chips are used as mulch.

- **plants for planting of *Betula* spp.** (medium uncertainty overall)

- association of the pest in North American nurseries for plants for export
- data on trade, i.e. volume, birch species traded (as the pest is more likely to be associated with susceptible species), frequency of movement, lack of data on distribution of imported plants for planting throughout the PRA area, size of plants (the pest is associated with stems >2cm diameter).

- **wood with or without bark of *Betula* spp.** (medium uncertainty overall)

- frequency of outbreaks (the pest is most likely to be associated with the pathway during outbreaks in North America)
- data on pathway: volume, proportion of birch in hardwood imports from Canada, frequency of import (per month) in the PRA area, timing of imports, distribution of the commodity throughout the PRA area, end-use of the wood.

Probability of establishment (low uncertainty)

- susceptibility of some birch species (those present in the PRA area but not in North America; also *B. nana*; and some North American species)
- how widely treatments are used against other pests in nurseries, and would they be effective against *A. anxius*.

Probability of spread: No uncertainty identified.

Potential impact (low uncertainty overall)

- whether consumer demand would be affected, i.e. shift to other tree species or origins
- effect on export markets and whether Russia currently exports birch products to some Asian countries
- what would be done about the pest, i.e. there would be other costs resulting from introduction.

2.18 - Conclusion of the pest risk assessment

A. anxius **is a pest of birch, present throughout the range of its native host species in North America and in areas where birch has been planted as an amenity tree, but it has not been recorded in the PRA area. In North America, the pest causes damage to forests and ornamental birch. European and Asian species of birch are especially susceptible, particularly** ***B. pendula*** **and** ***B. pubescens*** **which are widespread in the PRA area. Whereas** ***A. anxius*** **attacks mostly weakened North American birch, it attacks healthy European and Asian birch, and has proved to be a limiting factor for the use of these species as ornamentals in North America.**

The expert group considered that the most likely pathways for its introduction would be hardwood wood chips, plants for planting of ***Betula*** **spp., and wood with or without bark of** ***Betula*** **spp. Detailed trade data were missing for these pathways as this pest is currently not subjected to phytosanitary requirements and** ***Betula*** **spp. are not recorded as a category in trade data included in Eurostat. The pathway analysis showed an overall low likelihood of entry. Details are given in the conclusion of the probability of entry.**

It should be noted that the pathways for plants for planting and wood are probably relatively minor, and presumably have existed for some years (at least 10), but ***A. anxius*** **is (yet) not known to have entered or established in the PRA area. It is not expected that there would be an increase in the trade of birch plants for planting or wood between North America and the PRA area (except possibly for small logs for energy production plants; this might increase in the future). Different wood commodities might present different risks depending on how they have been processed (i.e. wood with or without bark), their intended use (e.g. firewood for private consumption, energy production plants, pulpmills) and their by-products, the birch species, and whether wood is stored on arrival (or processed before the pest can emerge).**

On the other hand, the probability of entry on wood chips is moderate, and the volume of wood chips in general is expected to continue increasing to satisfy demands for energy production. However, the exact amount of birch in this trade is not known, as well as whether the trade would be from North America or other regions.

If ***A. anxius*** **entered the PRA area, the pest would have a very high probability of establishment wherever birch is present. It is adapted to a wide range of climatic conditions and would find susceptible hosts. Eradication or containment would be difficult due to the hidden life stages of the pest and the fact that it might not be detected before it has already established and caused damage. It is also very likely that it would spread (natural spread as it is a strong flier; human-assisted through movement of infested birch material). Due to the higher susceptibility of European and Asian birch species, it is expected that the pest would have major economic consequences where birch is present in the PRA area. On the whole, introduction would result in high mortality of birch throughout the PRA area, and major economic impacts (including major environmental impacts).**

It is considered that all areas where birch is present in the PRA area would be at risk, i.e. Northern Europe, from Western Europe to Siberia to the East, and from Nordic countries to Centre France to the South. Distribution data suggest that birch is not present in North Africa, Israel, Malta, Cyprus, southern Turkey (see Appendix 3).

Stage 3: Pest Risk Management

3.2a - Pathway:

3- Wood chips originating from where the pest occurs in Canada and in the USA

3.2 - Is the pathway that is being considered a commodity of plants and plant products?

Yes

See under 1.1., point 3.

3.12 - Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?

No

See question 1.9 for this pathway.

At least in the EU, there are no measures applied for this pathway.

It is worth noting that EU legislation for quality of wood chips is being developed (CEN prEN 14961-1 2008.4 solid biofuel) which is to replace all other national legislation. This standard will describe the requirements for fraction size, moisture content, ash content and density of the wood chips (Kopinga *et al*., 2010). It is not known when this standard will be finalized and how much it will address phytosanitary issues.

3.13 - Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?

No

The pest would be difficult to detect in wood chips.

3.14 - Can the pest be reliably detected by testing (e.g. for pest plant, seeds in a consignment)?

No

3.15 - Can the pest be reliably detected during post-entry quarantine?

No

Theoretically post-entry quarantine is a possible option [It should be long enough to allow time for adults to emerge as adults will not be able to reinfest chips (the pest only attack living trees). A 1-year storage will be sufficient for wood chips as only prepupae and pupae are likely to survive the chipping process. Transport and storage should be designed to prevent escape of any emerging beetles (i.e. under closed conditions).]

The Panel on Phytosanitary Measures agreed that in practice post-entry quarantine is not suitable for such material.

3.16 - Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?

Yes; Possible measure: specified treatment.

Chipping down to a certain size (with screen smaller than 2.5 cm) is considered effective against *A. planipennis* (McCullough *et al*., 2007, USDA-APHIS, 2009). The current EU requirement for wood chips against *Agrilus planipennis* is that the wood "has been processed into pieces of not more than 2.5 cm thickness and width" (EU, 2000). It may be considered that chips with a size smaller than 2.5 cm in either dimensions would probably be safe also for *A. anxius*. The typical chip size is: Thickness: 4 to 8 mm / Length: 40 to 45 mm / Width: 15 to 20 mm (see answer to 1.4 in the entry section for wood chips). Considering the above chip sizes and a *A. anxius* pupa or larva during the winter time (when it is doubled-over on itself like a letter V), then it is possible for *A. anxius* to fit inside a chip that is of the following dimensions: Thickness: 8 mm / Length: 40 mm / Width: 20 mm. If the chip is thinner than 8 mm, the individual would likely be exposed or cut, and die.

Roberts & Kuchera (2006) note that the cost of a secondary chip grinding in the marshalling yards, to reduce the chips to a smaller size (2.5 cm or less), can be prohibitive (three times as much as the primary grind). Therefore to be cost effective, chips should be ground to a small size on the first grind. It should also be noted that chipping with certain screen size produces a variety of chip sizes; a maximum is only guaranteed in 2 dimensions, while the third dimension can vary (e.g. 2.5 x 2.5 x 10 cm). See answer to question 1.4 concerning uncertainties related to chipping.

The Working Party on Phytosanitary Regulations considered that this management option should not be recommended for the time being. Further research should be considered to determine the safe size for wood chips in relation to *A. anxius* before allowing trade of such commodity. It should be also checked that chipping by commercial companies will produce only chips of the required size.

Other treatments could be effective but their practical implementation should be defined based on further research. New Zealand regulates wood chips, sawdust and wood for a number of pests, including *A. sexsignatus* (MAF, 2003). Wood pieces should be either no larger than 15 mm in length and 10 mm in cross-section, or no greater than 3 mm in cross-section if longer than 15 mm. Treatment options required for import in New Zealand are either heat treatment or fumigation as outlined below:
- heat treatment. It has been shown that heat treatment at 55°C for 120 minutes applied to wood chips does not destroy all prepupae (overwintering 4th larval stage) of the related species *A. planipennis* (McCullough *et al*., 2007). No prepupae survived exposure of 60°C for 120 minutes. In logs, it is considered that 60°C for 60 min is an efficient treatment[2] (see answer to 3.16 for wood). In New Zealand heat treatment of wood chips for at least 4 hours at a minimum core temperature of 70°C is required to destroy a range of wood boring pests including *A. sexsignatus*.
- fumigation. In New Zealand, requirements for wood chips against insects are methyl bromide or sulphuryl fluoride fumigation (80 g/m^3), in separate units no larger than 2 m^3, for more than 24 continuous hours at a minimum temperature of 10°C. In Israel (Israel, 2009b), methyl-bromide fumigation is required against internal and external pests for 16 hours at 80 g/m^3 at 10-20°C or at 48g/m^3 for 16 hours at 21°C or more (see question 1.9 for this pathway).
- irradiation. As irradiation is considered effective to destroy wood boring insects in wood (EPPO Standard PM 10/8, EPPO (2008c)), it might also be used for wood chips, although this might be difficult to apply in practice for large quantity of chips.

3.17 - Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment?
No

3.18 - Can infestation of the consignment be reliably prevented by handling and packing methods?
No handling and packing methods will not prevent infestation. A long storage before export would ensure that no live stage are present in the wood but this option is considered under see 3.22.

3.19 - Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?
Yes
possible measure: import under special licence/permit and specified restrictions
The wood chips for processing could be imported at a time of the year when adults could not emerge (winter, i.e. when temperature is less than 5 degrees) and be processed before the next flight period of *A. anxius*. This will vary dramatically depending on the origin, destination and storage conditions. Considering that in Ohio and Michigan, adult emergence has been shown to begin at about 305 cumulative degree days, using a base temperature of 10°C and a starting date of Jan. 1 (Herms 2004), processing the chips before 150 degree-days have accumulated should be safe. This might be possible for wood chips imported by specific plants for burning for energy production or for the production of fiberboards or paper. Chips must be covered during transport from the point of entry to the process plant (but using covered truck, containers and railcars). Additionally, chips should not be stored outside. This would be possible only if use can be guaranteed and verified.
The specifications of the requirements need to be done on a case by case basis depending on the origin and the country of destination.

3.20 - Can infestation of the commodity be reliably prevented by treatment of the crop?
No. Treatment is not possible in forests.

3.21 - Can infestation of the commodity be reliably prevented by growing resistant cultivars?
No
Wood chips are often produced from a mixture of woods and wood types. *B. nigra* is the only species that is known to be not susceptible to *A. anxius* and this species is only in mixed stands with other hardwood species (the natural range of *B. nigra* does not overlap with the natural range of susceptible *Betula* spp.). Nevertheless wood chips containing only *B. nigra* would be considered safe.

[2] However efficacy of this treatment is being considered by EFSA. A scientific opinion should be delivered in 2011 but was not available in 2011-06.

3.22 - Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?

Yes

Wood chips could be stored in the exporting country under the strict control of the NPPO for a sufficient period, i.e.1 year, since only prepupae and pupae would be likely to survive the chipping process and should have emerged as adults within this period of time.

3.23 - Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?

No

Larvae are less likely to be present at certain times of the year, but any stage (except adults) might be present all year round. In addition, this might be difficult to implement for the production of wood chips.

3.24 - Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

No. Not relevant.

3.25 - Has the pest a very low capacity for natural spread?

No

3.26 - Has the pest a low to medium capacity for natural spread?

No

3.27 - The pest has a medium to high capacity for natural spread

Yes

Possible measure: pest-free area.

Adults are strong fliers and can disperse several kilometres. See answer to question 1.30. Spread is limited only by distribution of hosts.

3.28 - Can pest freedom of the crop, place of production or an area be reliably guaranteed?

No

Possible measure identified in questions 3.25-3.27 would not be suitable.

The pest is present throughout the range of birch in North America (natural and planted) and it would be difficult to establish and maintain a PFA in areas climatically suitable for cultivation of birch.

3.29 - Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?

No

Surveillance might allow detection of the pest, but detection is likely to occur when the pest is already established. There are no effective monitoring tools for *A. anxius*, as for other buprestids.

3.30 - Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest?

Yes, see 3.31

3.31 - Does each of the individual measures identified reduce the risk to an acceptable level?

Yes

- treatment: heat treatment or fumigation;
- storage in country of export (1 year) under the strict supervision of the NPPO;
- import permit and specified restrictions: importing in winter and processing before the next flight period (*Requirements need to be specified on a case by case basis depending on the origin and the country of destination).*

3.34 - Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

The measures will interfere with international trade as there are currently no measures in place and the volume on this pathway is increasing. Some other countries (e.g. New Zealand, Israel) require measures for wood chips for phytosanitary purposes.

3.35 - Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

The measures create additional costs.
Importing countries would have costs of inspection related to the requirement for a PC, and of post-entry quarantine if this measure is used.
Exporting countries will have to apply measures. Exporters should have the necessary equipment to process wood chips to the specified size. However, stringent measures for wood chips are already applied by some countries (e.g. New Zealand), and treatments are equivalent to others for wood.
There would be a negative impact on the quality of wood chips in case of storage (particularly for the paper industry).
Treatments are expensive and might not be cost-effective (albeit the heat treatment requirements are not yet defined for this pest).

This pest would be difficult to eradicate if introduced, and the measures have lower cost than attempting eradication or bearing the costs of impact by *A. anxius* if it established.

3.36 - Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

Yes

- treatment: heat treatment (but the conditions required to destroy *A. anxius* are not clearly-defined and require research) or fumigation;
- storage in country of export (1 year) under the strict supervision of the NPPO;
- import permit and specified restrictions: importing at certain time and processing before the next flight period (*The specifications of the requirements need to be done on a case by case basis depending on the origin and the country of destination).*

3.1 - Is the risk identified in the Pest Risk Assessment stage for all pest/pathway combinations an acceptable risk?
No

3.2a - Pathway:
1- Plants for planting of *Betula* spp. originating from where the pest occurs in Canada and in the USA

3.2 - Is the pathway that is being considered a commodity of plants and plant products?
Yes

3.12 - Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?
No
See answer to question 1.9.
The EU currently has no specific measures for plants of planting of *Betula* spp. but it does have measures for trees and shrubs and bonsais in general (Annex IV.A.I.39, 40, 43 in EU, 2000). A PC is required and consignments would be inspected. However, the pest is hard to detect and these measures would not prevent introduction.

Russia and CIS countries require a PC and import permit for plants for planting. *(source for all countries: EPPO collection of phytosanitary regulations)*

No information for other EPPO countries.

3.13 - Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?
No
The pest is difficult to detect. Eggs are usually laid in crevices and under bark flaps, making them extremely difficult to spot. Some signs of larval presence might be observed in certain circumstances (galleries below the bark, leafless or dead branches, ridges caused by callus formation over galleries) as well as adult exit holes. Adults are highly mobile and strong fliers, and do not stay on the plants. It is unlikely to be detected by visual inspection.

3.14 - Can the pest be reliably detected by testing (e.g. for pest plant, seeds in a consignment)?
No
Development of acoustic detection systems and thermal imaging tools to detect the presence of boring insects in wood is underway but further development is necessary before practical tools are available. Experience in the USA with *A. planipennis* with such acoustic systems was found not to be practical for detection (Haack, pers. comm., 2010).

3.15 - Can the pest be reliably detected during post-entry quarantine?
No
Plants for planting could be kept in post-entry quarantine in conditions favorable to the insect until the emergence of the adults. The pest can have a 2-year cycle (over 3 calendar years) if conditions are not favourable (Barter, 1957), and the post-entry quarantine should be long enough (2 complete growing seasons) to ensure that all adults have emerged.

Note: Plants for planting need to be kept for "two complete growing seasons", which can be shorter or longer than 2 years. For example, if a live birch tree arrives in winter (e.g. December 2010), it should be held in quarantine for the next 2 flight seasons (2011 and 2012). It could then be released anytime starting in autumn 2012. If released in September 2012, then it would have been held 21 months.
Similarly, if a tree arrives in late summer (e.g. July 2010), it should be kept until at least Sept 2012, so about 27 months. A tree that arrives in July could have been exposed to ovipositing *A.anxius* adults in early summer 2010, so the 2010 summer does not count as the first growing season.

The Panel on Phytosanitary measures considered that post-entry quarantine should not be allowed as a sole phytosanitary measure. The risk to introduce potentially infested plants was not acceptable in general. Post-entry quarantine should only be considered within a systems approach (e.g. with pest-free areas).

3.16 - Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?
No

No practical treatment is available to control all stages of the pest, especially non-feeding stages such as prepupae and pupae. Larvae are difficult to detect, and also difficult to remove or target with specific treatments.

If presenting signs of damage, plants might be removed from the consignments, but this would not be sufficient to ensure that the pest is not present in the consignment.

Fumigation, irradiation and heat treatment are possible, but have not been evaluated. They will probably affect the viability of the plants.

Chemical treatment

Systemic insecticides as injections or drenches are mentioned in few publications (see also answer to 2.3), but they would not be effective against prepupal larvae that have completed feeding, or pupae. Insecticide sprays would not affect larvae that have already colonized the plants.

Treatment with fumigants is probably not effective since the larvae are protected inside woody stems and fumigants will probably not be able to enter the larval tunnels to kill the larvae. Treatment with methyl bromide under vacuum might kill the larvae inside the woody material (T201-a-2 in USDA Treatment Manual - USDA, 2009). Research will be needed to determine the efficacy of this method. This method cannot be recommended from an environmental point of view as the use of methyl bromide should be abandoned in the future due to negative effects of this substance on the ozone layer (Montreal Protocol).

Irradiation

Insects need an absorbed dosage of 1000 Gy. Effects on plants can be seen on a dosage of more than 1 Gy; 1000 Gy will lead to negative effects on the viability of the plants. Lower dosages may be sufficient to sterilize the larvae inside the plants. Experimental research will be needed to test that hypothesis. When it works, methods will have to be developed to be able to check that the treatment has been properly performed and larvae are innocuous.

Thermal treatment

Incubation of woody plants (dormant) in hot water might kill the larvae inside the stem. Larvae are present in the woody stem of the plant and plants need probably to stay in a hot water for a relatively long time to achieve lethal temperatures inside the wood that will kill the larvae. It is, therefore, expected that temperatures and exposure time needed to kill the larvae will negatively affect the viability of the plants. Heat treatment is accepted as a Phytosanitary procedure to kill larvae of *Anoplophora glabripennis* (another longhorned beetle) in wood packaging material. In that case the internal core of the material should reach a minimum of 56°C during 30 min. [EPPO Standard PM 10/6(1) *Heat treatment of wood to control insects and wood-borne nematodes*, EPPO (2008)]. Such a treatment will likely have negative effects on the viability of the young trees and will, therefore, not be a good option.

3.17 - Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment?

No

The larvae are present under the bark of main stem and branches (that are over 1 cm diameter).

3.18 - Can infestation of the consignment be reliably prevented by handling and packing methods?

No

Some pest stages (larvae, prepupae, pupae) would be in the plants before packing and handling.

3.19 - Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?

No

The end use is for planting, most of the PRA area is at risk from *A. anxius*, and the areas not at risk (i.e. areas where birch can not grow) would not be importing birch plants for planting.

3.20 - Can infestation of the commodity be reliably prevented by treatment of the crop?

No

No insecticide provides 100 % protection all the time.

Treatment is one of the control methods mentioned for the pest (see question 2.3), but is not sufficient for prevention of infestation of plants for planting. Stem injection with imidacloprid or emamectin benzoate for at least 1-2 years before being sold would probaly allow pest freedom, but this should be confirmed by specific testing. Combination with other measures may be considered in a systems approach (preventive treatment + produced in nurseries + absence of symptoms).

3.21 - Can infestation of the commodity be reliably prevented by growing resistant cultivars?

No

Only one species, *B. nigra*, is recognized as completely resistant (i.e. does not become infested) (Nielsen *et al.*, 2011; Herms, 2002). Some other species of birch are reported as less susceptible, but they are still attacked.

3.22 - Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?

Yes, in combination

Possible measure: specified growing conditions

Growing plants under insect-proof conditions (e.g. mesh houses, nets, greenhouses) during the period of adult flight is generally not considered practical but could be effective. These measures may be appropriate for high value commodities (e.g. bonsais).

Appropriate surveillance should be in place as well as forecasting for the flight period. The plants should be under protected conditions throughout the period of flight of adults. Adults are unlikely to be associated with the plants in consignments, especially for the EU where plants should be dormant and without leaves (EU, 2000).

3.23 - Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?

Yes

Possible measure: specified age of plant, growth stage or time of year of harvest

Larvae or pupae can be present in the wood throughout the year. However stems below 2 cm diameter, and scion below 1 cm, are very unlikely to be infested (Herms, pers. comm. 2010; Nielsen, pers. comm., 2011). Limiting the commodity to small seedlings would prevent infestation.

3.24 - Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

No

A certification programme could require some level of visual inspection for pests, including *A. an*xius. However visual inspection is not sufficient to detect *A. anxius* and there are no tests. Certification schemes are in place to address mostly plant pathogens, and are not considered to be a possible measure.

3.25 - Has the pest a very low capacity for natural spread?

No

3.26 - Has the pest a low to medium capacity for natural spread?

No

3.27 - The pest has a medium to high capacity for natural spread?

Yes

Possible measure: pest-free area.

Adults are strong fliers and can disperse several kilometres. See answer to question 1.30. Spread is limited only by distribution of hosts.

3.28 - Can pest freedom of the crop, place of production or an area be reliably guaranteed?

No

Possible measure identified in questions 3.25-3.27 would not be suitable.

The pest is present throughout the range of birch in North America (natural and planted) and the EWG considered that it would be unpractical to establish and maintain a PFA in areas climatically suitable for cultivation of birch.

3.29 - Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?

No

Surveillance might allow detection of the pest, but detection is likely to occur when the pest is already established. There are no effective monitoring tools for *A. anxius*, as for other buprestids.

Eradication could be envisaged only in specific situations (e.g. very small outbreak detected in a nursery) in areas of low presence of birch, if detection occurred early before emergence of the pest.

3.30 - Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest?

Yes

Larvae or pupae can be present in the wood throughout the year. However stems below 2 cm diameter, and scion below 1 cm, are very unlikely to be infested (Herms, pers. comm. 2010; Nielsen, pers. comm., 2011). Limiting the commodity to small seedlings would prevent infestation.

3.31 - Does each of the individual measures identified reduce the risk to an acceptable level?

No: Growing plants under specified conditions (insect-proof)

3.32 - For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

Yes

The plants should be grown under specified conditions (insect-proof) and for at least 2 years no signs of *A. anxius* have been observed during two official inspections per year carried out at appropriate times, including immediately prior to export.

3.34 - Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

The effect on trade would be limited because it is thought that the importation of birch plants for planting from North America is limited. There would be no disruption for trade of plants below 2 cm stem diameter. Other measures proposed would most likely end the trade of larger stemmed plants, except for high value bonsais.

3.35 - Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

Trade of plants below 2 cm stem diameter would not be affected.

Growing under insect proof conditions is unlikely to be cost effective as birch is a low value commodity, except for high value bonsais.

This pest would be difficult to eradicate if introduced, and the measures suggested above have lower cost than attempting eradication or bearing the costs of impact by *A. anxius* if it established.

3.36 - Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

Yes

There is little trade from areas where the pest is present and therefore measures will not interfere much with existing trade. Requiring plants for planting to have a stem diameter below 2 cm will interfere with trade, but not unduly.

3.2a - Pathway:

2- Wood with or without bark of *Betula* spp. originating from where the pest occurs in Canada and in the USA

3.2 - Is the pathway that is being considered a commodity of plants and plant products?

Yes

Birch wood is used for a variety of purposes (Alden, 1995; UNECE, 2009, see 1.1, point 2).

It is considered that some measures relevant for this pathway could be applied to the pathway "rustic furniture and other birch wood objects"

3.12 - Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?

No

Birch wood is not subjected to any phytosanitary measures at least in the EU countries.

In Russia, import of wood is submitted to an import permit and logs should be free of bark.

In Israel, imported wood should be debarked and the consignment should undergo vapour treatment, with either phosphine or methyl bromide (Israel, 2009a).

In Turkey (Turkey, 2007), imported industrial wood, logs and roots should be fumigated or should be stripped of their bark. Timber of non-coniferous species should have a) their bark stripped and they shall be free from harmful organisms; b) have undergone kiln-drying to below 20% moisture content, expressed as a percentage of dry matter, achieved through an appropriate time/temperature schedule *(source for all countries: EPPO collection of phytosanitary regulations)*

The fact that the wood is debarked or treated may help preventing the introduction of the pest (see question 3.13 and 3.16 respectively)

3.13 - Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?

No

Visual inspection might allow detection of some signs of infestation (e.g. galleries under the bark, exit holes), but would not be sufficient on its own. Mechanical debarking might obscure galleries, which would reduce reliability of visual inspection.

Only a percentage of consignments would be visually inspected.

3.14 - Can the pest be reliably detected by testing (e.g. for pest plant, seeds in a consignment)?

No

3.15 - Can the pest be reliably detected during post-entry quarantine?

No.

Theoretically post-entry quarantine is a possible option [It should be long enough to allow time for adults to emerge (2 years) as adults will not be able to reinfest logs (the pest only attack living trees). A 1-year storage will be sufficient for wood chips as only prepupae and pupae are likely to survive the chipping process. However, this may require transport and storage under closed conditions to prevent escape of any emerging beetles. The quality of the wood might decrease over time, and this might not be appropriate for some of the intended uses.]

The Panel on Phytosanitary Measures agreed that in practice post-entry quarantine is not suitable for such material.

3.16 - Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?

Yes, *Possible measure: specified treatment.*

EPPO recommends two treatments for wood with or without bark against wood-related insects (including Buprestidae):

- Irradiation: see EPPO Standard PM 10/8 *Disinfestation of wood with ionizing radiation*, EPPO (2008c)
- Heat treatment: until the core temperature reaches at least 56°C for at least 30 minutes (EPPO Standard PM 10/6 *Heat treatment of wood to control insects and wood-borne nematodes*, EPPO (2008a)). However, in the case of *A. planipennis*, some recent studies indicate that heat treatment at 56°C (or 60°C) for at least 30 minutes might not be 100% effective (Goebel *et al.*, 2010; Myers *et al.*, 2009), but treatments in this study measured temperature at 2.5 cm

into the firewood (i.e. where the pest is present) but not at the core. Based on Myers *et al.* (2009), experimental data for *A. planipennis*, internal temperature of the wood of 60°C for 60 minutes should be considered a minimum for a safe treatment to control *A. planipennis* in firewood.
In the USA, the APHIS treatment schedule for firewood against regulated wood articles, including *Fraxinus* (ash logs and firewood) and all hardwood from quarantine areas for *A. planipennis* was changed to 71.1°C for 75 minutes (treatment schedule T314-a, USDA 2009), based on McCullough *et al.* (2007).

Further research should be considered to identify the best temperature and duration of treatment for wood for the appropriate level of protection against *A. anxius*.
Note: Since the meeting of the EWG, the *International Forestry Quarantine Research Group* discussed this issue (Lisbon, 2010-09-27/10-01) on the basis of recent research. The IFQRG concluded that the current schedule of 56°C for 30 minutes was adequate for ash and *A. planipennis.* **In January 2011, treatment schedule T314-a was changed to 60°C core temperature for 60 minutes (USDA-APHIS, 2011, USDA, 2011).** However efficacy of this treatment to allow import of wood from USA is being considered by EFSA. A scientific opinion should be delivered in 2011 but was not yet available in 2011-06.

- Methyl bromide fumigation will be efficient but only if there is no bark, see EPPO Standard PM 10/7 *Methyl bromide fumigation of wood to control insects,* EPPO (2008b). The Panel on Phytosanitary Measures thought that this option was not suitable as this active substance is now forbidden in EU countries., and EPPO should not encourage methyl bromide fumigation for non-essential uses.

Treatments are expensive, and might be suitable only for high quality logs.

3.17 - Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment?
Yes, *Possible measure: removal of parts of plants from the consignment*
Early larval stages occur just below the bark, but removal of the bark would not affect stages in the outer sapwood (i.e. 4th instar larvae, prepupae, pupae).

Both bark and the outer sapwood would need to be removed to ensure that the pest is not present. This would affect the value of wood with bark. In the case of *A. planipennis*, the USDA requirement for transporting ash logs to mills outside the quarantine zone is removal of the bark and an additional 0.5 inch (1.27 cm) of sapwood (USDA–APHIS, 2009).

3.18 - Can infestation of the consignment be reliably prevented by handling and packing methods?
No handling and packing methods will present infestation. A long storage before export would ensure that no live stage are present in the wood but this option is considered under see 3.22.

3.19 - Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?
Yes, *Possible measure: import under special licence/permit and specified restrictions*
Wood for processing (e.g. furniture, pulpmills, fuel wood for energy production) could be imported during periods of the year outside of the flight period of *A. anxius* (ideally in winter when temperature is less than 5 degrees), this will vary dramatically depending on the origin, destination and storage conditions.,and imported material would need to be processed before the next flight period of the pest. Considering that in Ohio and Michigan, adult emergence has been shown to begin at about 305 cumulative degree days, using a base temperature of 10°C and a starting date of Jan. 1 (Herms 2004), processing the chips before 150 degree-days have accumulated should be safe. This would be possible only if use can be guaranteed and verified. It would not be possible for firewood used by individuals, which might be stored before use. Waste or by-products from this wood should also be managed before the next flight period in such a way as to prevent adult emergence.
The specifications of the requirements need to be done on a case by case basis depending on the origin and the country of destination.

3.20 - Can infestation of the commodity be reliably prevented by treatment of the crop?
No. Treatment is not possible in forests.

3.21 - Can infestation of the commodity be reliably prevented by growing resistant cultivars?
No.
B. nigra and its cultivars are reported not to be host of *A. anxius*. However, mixes of species might be present in some commodities e.g. firewood or energy wood.

3.22 - Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?
Yes.
Based on the experience with *A. planipennis*, it may be considered that no adults will emerge 2 years after cutting (Petrice & Haack, 2007; Petrice & Haack, 2006). The pest cannot reinfest cut wood.
If the wood is stored in suitable conditions before export for 2 years under the strict control of the NPPO, this would ensure that the pest emerges before export. Nevertheless, there might be an impact on the quality of the wood.

3.23 - Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?
No
Only late larval stages and pupae are likely to survive in cut wood. However, different stages of the pest might be present in the wood throughout the year. So, even at a time when most larvae would be in the early stages (e.g. early summer), there might be some mature larvae in the trees at harvest.

3.24 - Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?
No. Not relevant for forestry.

3.25 - Has the pest a very low capacity for natural spread?
No.

3.26 - Has the pest a low to medium capacity for natural spread?
No.

3.27 - The pest has a medium to high capacity for natural spread
Yes, ***Possible measure: pest-free area.***
Adults are strong fliers and can disperse several kilometres. See answer to question 1.30. Spread is limited only by distribution of hosts.

3.28 - Can pest freedom of the crop, place of production or an area be reliably guaranteed?
No.
Possible measure identified in questions 3.25-3.27 would not be suitable.
The pest is present throughout the range of birch in North America (natural and planted) and it would be difficult to establish and maintain a PFA in areas climatically suitable for cultivation of birch.

3.29 - Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?
No
Surveillance might allow detection of *A. anxius*, but detection is likely to occur when the pest is already established. As for other buprestids, there are no effective monitoring tools for this pest.

3.30 - Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest?

Yes, see 3.31

3.31 - Does each of the individual measures identified reduce the risk to an acceptable level?

Yes

For wood with or without bark:
- treatment (heat treatment, but noting that the temperature and time required is not clear, irradiation)
- removal of bark and outer sapwood (1.27 cm)
- storage for 2 years in country of export
- import permit and specified restrictions: import outside of flight period and processing before the next flight period (except firewood), but noting that it might be difficult for the NPPO to control that the wood is processed immediately. The requirement need to specified on a case by case basis depending on the origin and the country of destination.

For rustic furniture and other birch wood objects, treatments should be applied.

3.34 - Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

There are currently no measures on birch wood, so any measure would interfere with trade.
Measures that might affect the quality of the wood (e.g. long storage or debarking) and measures that require processing before the next flight period would have an impact on trade.

Trade in all birch wood seems quite small, so interference would not be major. It would become so if birch becomes an important component of the developing trade of small logs for energy generating purposes.

3.35 - Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

Similar measures are already imposed for other species, but the measures create additional costs.
Importing countries would have costs of inspection related to the requirement for a PC.
Exporting countries would have costs of issuing PCs.
Storage for 2 years, treatment for low quality wood, may not be cost-effective. Removal of outer sapwood would result in loss of some of the product.
This pest would very difficult to eradicate and possible probably only if it is detected within a few years after its introduction unless it is decided to remove large areas of birch. The measures suggested above have lower costs than attempting eradication or bearing the costs of the effect of *A. anxius* if it established.

3.36 - Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

Yes, see 3.31

3.41 - Consider the relative importance of the pathways identified in the conclusion to the entry section of the pest risk assessment

Despite the lack of detailed data, there are enough data to indicate that movement of the host (birch, *Betula* spp.) along the three pathways analyzed exists (though interceptions were not made in the EU/EPPO region), that the pathways present a risk of introduction of *A. anxius*, and that the consequences of introduction would be devastating given the high susceptibility of European and Asian host plants and the large and wide distribution of birch in the PRA area.

The expert working group concluded that *A. anxius* posed an unacceptable risk to the EPPO region and identified phytosanitary measures which could substantially reduce the risk. Specific details of heat treatments that would be required to destroy *A. anxius* in wood or wood chips have not been defined and require further investigation. Measures could interfere with trade, but costs of eradication or containment attempts would be high and introduction is likely to threaten birch on a continental scale because European and Asian birch species are extremely susceptible, resulting in major economic (including environmental) impact.

Data are lacking on imports for these pathways, specific to birch. It was thought that none of the pathways considered is regulated at the moment.

- Wood chips is a growing pathway (but the proportion/importance of birch in hardwood wood chips is unknown). The likelihood of the pest surviving the chipping process appears lower than for other two pathways. However as the volume of imported chips increases, so does the risk of introduction of *A. anxius* by this route.
- Plants for planting of *Betula* spp. is probably a small stable pathway. One infested consignment might introduce the pest as all stages could be associated with this pathway.
- Wood of *Betula* spp. is probably a small stable pathway at the moment. Its importance could increase if import of birch logs to be used in energy plants increases.

Note: if there is a risk of entry with wood chips, then a similar risk might exist for some other invertebrate wood pests.

Appendix 1: **Climatic maps**

Fig 1. World Map of Köppen – Geiger Climate Classification

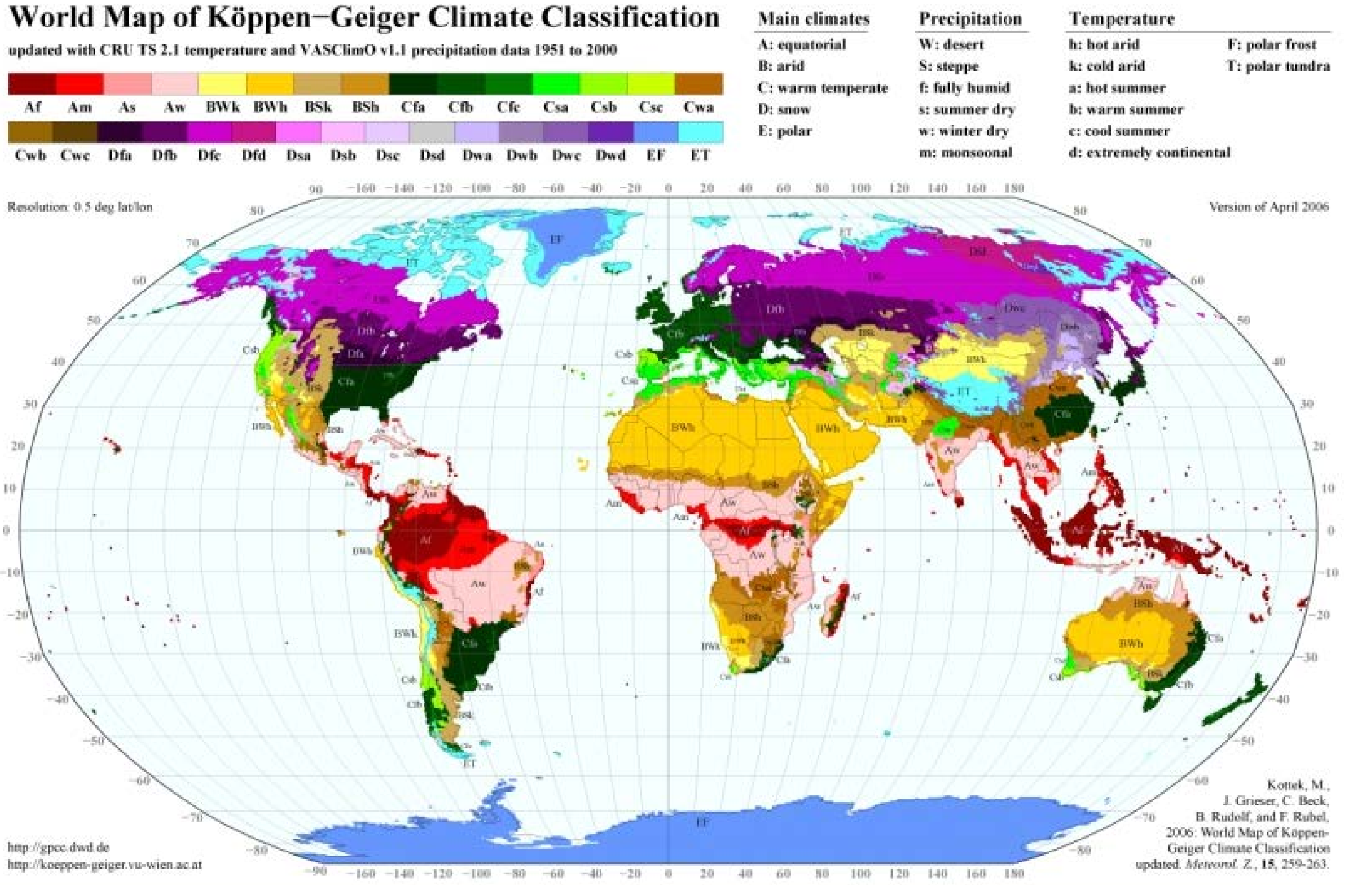


Fig 2a: European Map of Temperature Accumulation (Degree Days) based on a threshold of 10°C using 1861-90 monthly average maximum and minimum temperatures taken from the 10 minute latitude and longitude Climatic Research Unit database (New *et al.*, 2002).

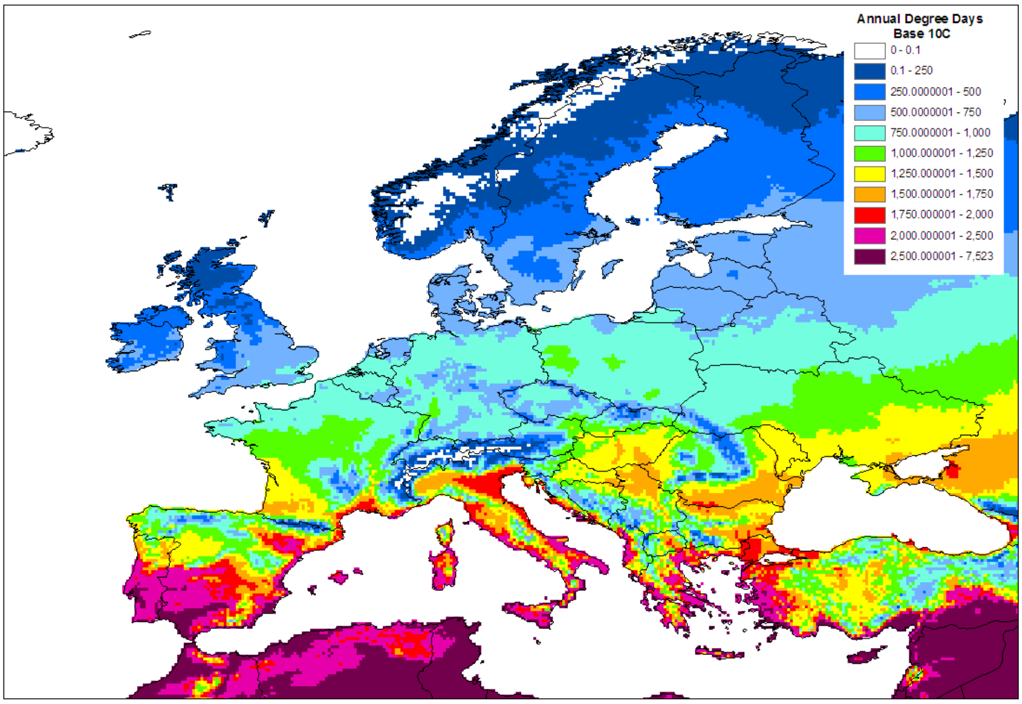
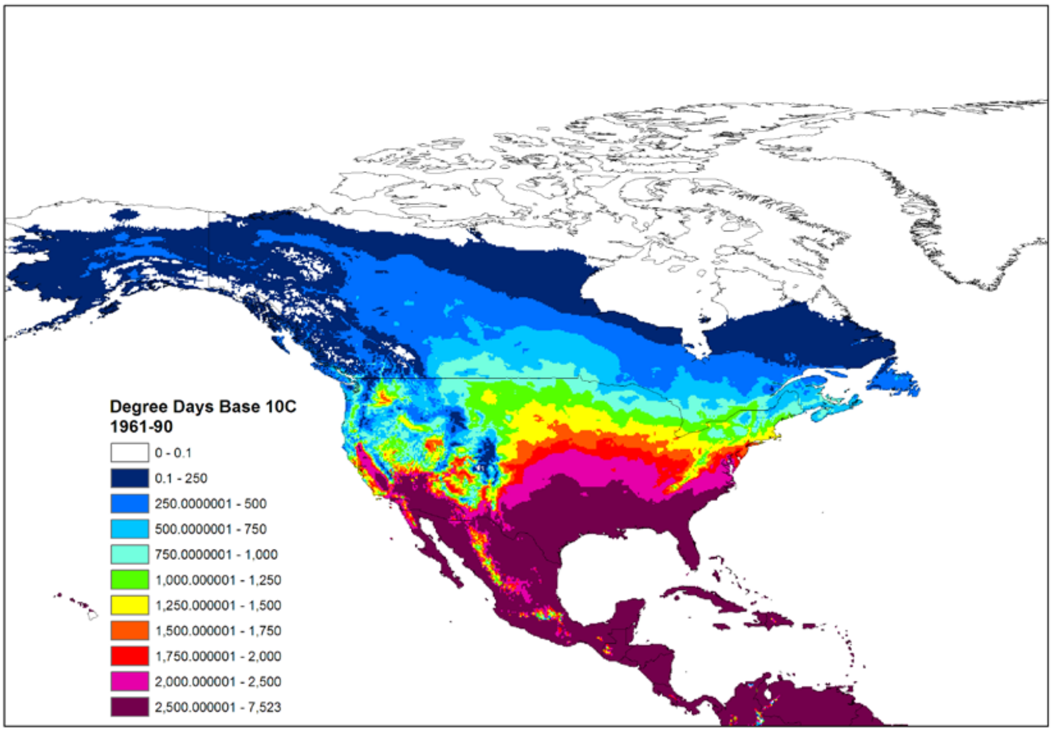


Fig 2b European Map of Temperature Accumulation (Degree Days) based on a threshold of 10°C using 1861-90 monthly average maximum and minimum temperatures taken from the 10 minute latitude and longitude Climatic Research Unit database (New *et al.*, 2002).



Appendix 2. **Data on Canada (A) and USA (B) exports to the PRA area**

A- CANADA (Statistics Canada, Canadian International Merchandise Trade Database

http://cansim2.statcan.gc.ca/cgi-win/CNSMCGI.PGM?Lang=E&CIMT_Action=Sections&ResultTemplate=CII_CIMT5)

Tables below:
1- wood in chips, non coniferous
2- wood in the rough, non-coniferous, and logs for pulping
3- lumber, non-coniferous, of thickness > 6 mm

1- Wood in chips, non-coniferous (among 12 top countries) (440122). Quantities in metric tons

	2010	2009	2008	2007	2006
Finland	98,563	118,307	57,709	28,500	0
Turkey	33.146	37,730	146,964	156,295	0
United Kingdom	0	2,039	881	253	0
Italy	-	22	0	7	112,247
Netherlands	16	3	0	21	0
Belgium	-	2	0	0	0
Norway	66,280	0	0	0	0

2- Wood in the rough, non-coniferous, and logs for pulping (440399). Quantities in m³

	2009	2008	2007	2006
Netherlands	1,210	346	3,207	227
Germany	839	595	755	630
Italy	1,047	767	1,148	1,537
Israel	66	80	45	0
France	61	71	30	131
Turkey	1	0	492	0

Includes birch, alder, cherry, ash, maple, poplar, walnut, other temperate

3- Lumber, non-coniferous, of thickness > 6 mm (440799). Quantities in m³ Includes birch, maple alder, cherry, poplar, ash, other temperate

	2009	2008	2007	2006
Germany[1]	3,260	5,091	6,619	23,407
United Kingdom	2,583	5,354	11,135	15,528
Netherlands	526	1,069	2,343	2,991
France	1,104	1,455	2,461	3,622
Italy	943	1,292	3,020	6,191
Ireland, Republic of (EIRE)	502	1,291	2,058	1,767
Poland	480	510	573	1,124
Sweden	373	835	1,197	3,615
Israel	298	926	66,600	4,769
Finland	204	998	835	1,413
Spain	271	782	2,164	5,503
Denmark	179	1,445	1,495	3,061
Belgium	213	695	1,538	3,242

Malaysia	179	567	737	2,140
Portugal	112	51	1,158	1,756
Lithuania	59	1,046	293	1,453
Austria	48	493	447	1,925
Estonia	103	1,254	379	0
Jordan	31	84	43	1,034
Russian Federation	32	2	277	0
Switzerland	27	112	69	757
Croatia	52	68	46	137
Turkey	62	312	44	307
Greece	25	132	348	470
Malta	24	32	495	490
Cyprus	14	85	18	207
Czech Republic	3	142	106	65

Appendix 2

B- USA (Global Agricultural Trade System USA http://www.fas.usda.gov/gats/default.aspx)

Tables below:

1- Harwood chips
2- Hardwood logs, birch
3, 4, 5- Lumber, birch
6- Hardwood logs and chips (all species)
7- Hardwood lumber (all species)

1 - HARDWOOD CHIPS (0440122000) in Metric tons

Partner	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Belarus	0	0	0	0	0	0	0	78	0	0
Belgium	0	0	58	0	0	14	9	0	664	0
Bulgaria	2	6	17	0	0	14	636	0	813	813
Czech Republic	0	0	0	0	0	0	0	0	65	0
Denmark	0	0	50.862	0	0	0	0	496	2.088	0
European Union-27	25.033	30.837	73.362	31.744	43.358	6.279	21.500	38.746	45.398	36.128
Finland	2.237	0	0	465	524	541	0	0	44	0
Former Soviet Union-12	0	151	0	0	0	0	0	78	473	0
France	1.559	769	77	19	8	103	7.100	12.578	15.341	10.075
Germany	0	42	428	1.040	90	340	3.666	5.360	3.309	3.470
Greece	30	865	3	11	0	4	0	0	0	0
Iceland	0	11	0	343	0	0	0	0	0	0
Ireland	66	3	0	0	0	0	0	0	0	0
Israel	10	3	22	0	6	465	491	2.228	1.319	2.181
Italy	19.916	28.059	21.840	30.048	39.892	4.292	6.103	8.594	8.318	13.364
Kazakhstan	0	151	0	0	0	0	0	0	0	0
Moldova	0	0	0	0	0	0	0	0	473	0
Morocco	0	2	5	258	5	1	0	0	0	0
Netherlands	0	0	0	10	5	1	164	893	5.642	2.745
Other Europe	0	11	0	343	0	0	270	0	0	476
Portugal	0	0	33	6	3	23	654	2.763	4.005	1.373
Slovenia	0	0	0	126	2.682	0	0	0	0	0
Spain	970	1.062	20	19	139	907	2.808	7.413	4.016	4.065
Sweden	0	0	0	0	0	0	0	421	965	0
Switzerland	0	0	0	0	0	0	270	0	0	476
Turkey	0	0	0	0	0	0	0	226	0	45
United Kingdom	253	31	24	0	15	40	360	228	128	223

2- HW LOGS, BIRCH 4403990030 in m^3

Partner	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Austria	41	0	0	0	0	0	0	0	0	0
Belgium	41	27	0	0	0	0	0	0	0	0
Denmark	0	0	0	0	28	0	0	0	0	0
Estonia	0	0	0	0	0	0	0	0	0	188
European Union-27	162	206	502	31	60	18	31	1.151	87	666
France	0	0	68	0	0	0	0	652	0	0
Germany	60	169	74	31	20	18	0	0	0	318
Italy	20	0	150	0	11	0	31	415	87	160
Norway	29	0	0	0	0	0	0	0	0	0
Other Europe	29	0	0	59	0	0	0	0	0	0
Portugal	0	0	210	0	0	0	0	0	0	0
Switzerland	0	0	0	59	0	0	0	0	0	0
United Kingdom	0	10	0	0	1	0	0	84	0	0

3. - LMBR,D, BIRCH (4407990051) in m^3

Partner	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
European Union-27	0	0	0	0	0	64	0	0	0	0
Germany	0	0	0	0	0	6	0	0	0	0
Ireland	0	0	0	0	0	58	0	0	0	0
Jordan	299	0	0	0	0	0	0	0	0	0

4- LMBR,R, BIRCH 4407990050 in m^3

Partner	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Austria	0	0	71	37	0	0	40	0	0	0
European Union-27	450	121	1.324	3.297	3.120	3.342	2.890	0	0	0
France	96	0	0	0	0	0	731	0	0	0
Germany	0	56	92	0	64	273	5	0	0	0
Ireland	0	0	0	0	0	2	5	0	0	0
Israel	55	0	0	35	0	0	0	0	0	0
Italy	0	31	1.091	3.231	3.019	3.067	2.109	0	0	0
Netherlands	29	0	0	0	0	0	0	0	0	0
Other Europe	0	0	60	0	0	0	0	0	0	0
Switzerland	0	0	60	0	0	0	0	0	0	0
United Kingdom	325	34	70	29	37	0	0	0	0	0

5. - LMBR, BIRCH (4407990110) in m^3

Partner	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
European Union-27	0	0	0	0	0	0	0	339	326	0
France	0	0	0	0	0	0	0	113	0	0
Germany	0	0	0	0	0	0	0	24	198	0
Italy	0	0	0	0	0	0	0	114	128	0
Spain	0	0	0	0	0	0	0	88	0	0

6- Logs and chips (all species) in m^3

Partner	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Albania	0	0	0	0	0	236	369	105	360	19
Algeria	0	0	0	0	0	0	0	0	117	166
Armenia	0	0	0	0	0	0	0	174	0	0
Austria	5.503	6.116	728	84	1.298	195	947	377	837	314
Azerbaijan	0	0	0	0	0	0	0	0	28	29
Belarus	0	0	0	0	0	0	0	0	33	29
Belgium	11.893	24.116	9.872	6.944	3.086	3.979	7.713	12.175	14.959	13.814
Bulgaria	0	0	0	153	0	18	0	28	28	0
Croatia	601	37	0	165	18	263	92	263	258	210
Cyprus	188	0	97	1.459	1.990	28	122	411	3.400	360
Czech Republic	0	0	1.335	4.398	911	1.761	621	1.884	549	421
Denmark	8.918	3.831	12.965	3.721	3.527	2.971	8.012	12.976	4.089	2.134
Estonia	0	0	0	0	70	0	32	2.763	3.565	3.769
European Union-27	323.551	335.230	262.107	303.378	335.081	256.827	298.217	533.356	489.556	340.285
Finland	663	58	704	967	987	1.216	667	3.502	4.373	2.378
Former Soviet Union-12	119	783	0	0	0	48	87	462	1.609	351
France	20.206	21.702	18.167	11.588	20.885	5.467	9.422	14.838	11.953	10.511
Georgia	70	534	0	0	0	0	0	0	0	0
Germany	91.771	106.131	65.557	65.020	54.770	49.309	54.026	90.731	93.544	58.887
Gibraltar	11	0	0	0	0	0	0	0	0	0
Greece	511	894	1.316	291	1.021	594	626	8.546	13.948	8.796
Greenland	0	0	0	0	0	0	0	0	0	0
Hungary	0	0	792	164	170	0	0	0	0	0
Iceland	558	0	86	83	127	19	626	980	1.415	672
Ireland	3.182	1.250	3.404	3.350	3.236	5.145	3.915	12.013	12.795	6.148

Partner	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Israel	2.671	3.288	796	1.668	1.138	1.322	2.602	7.426	5.866	6.062
Italy	104.018	92.271	77.490	93.014	97.147	94.185	100.741	151.513	121.834	91.531
Jordan	117	86	341	1.541	1.512	486	249	2.370	3.481	4.437
Kazakhstan	0	0	0	0	0	0	0	0	0	0
Latvia	87	0	0	0	0	0	139	1.862	399	33
Lithuania	0	0	30	424	481	153	143	168	732	126
Luxembourg	178	0	0	0	0	0	0	0	0	0
Malta	27	214	56	348	469	241	231	1.163	1.848	1.270
Moldova	49	141	0	0	0	0	0	0	29	0
Montenegro	0	0	0	0	0	0	0	0	1.268	0
Morocco	0	0	0	159	101	0	0	182	1.054	306
Netherlands	3.151	4.692	4.261	15.939	21.802	4.006	4.688	11.028	11.032	4.354
Norway	1.064	326	423	275	105	235	366	3.044	4.692	3.393
Other Europe	7.762	6.195	4.914	5.295	6.537	1.794	23.366	7.533	35.876	4.610
Poland	73	266	0	92	2.180	5.424	6.918	12.602	7.213	9.636
Portugal	16.312	18.039	13.720	17.088	19.359	17.665	20.242	34.947	27.666	20.597
Romania	666	0	34	20	27	37	0	180	785	29
Russia	0	0	0	0	0	48	87	288	1.492	293
Serbia and Kosovo	0	0	0	0	0	0	0	129	192	0
Serbia, Montenegro, and Kosovo	0	0	0	46	0	0	118	0	0	0
Slovenia	502	2.059	6.524	4.486	393	98	139	7.003	4.685	1.945
Spain	35.895	30.076	29.821	32.113	42.065	39.061	48.809	89.292	60.979	31.408
Sweden	4.538	1.684	2.298	6.902	9.102	1.332	2.168	7.030	7.357	7.047
Switzerland	5.528	5.832	4.405	4.726	6.287	1.041	21.795	3.012	27.691	316
Tunisia	0	30	30	112	315	75	100	0	1	98
Turkey	697	998	2.360	1.930	4.787	3.909	3.694	7.612	16.276	9.850
Ukraine	0	108	0	0	0	0	0	0	27	0
United Kingdom	15.269	21.831	12.936	34.813	50.105	23.942	27.896	56.324	80.986	64.777

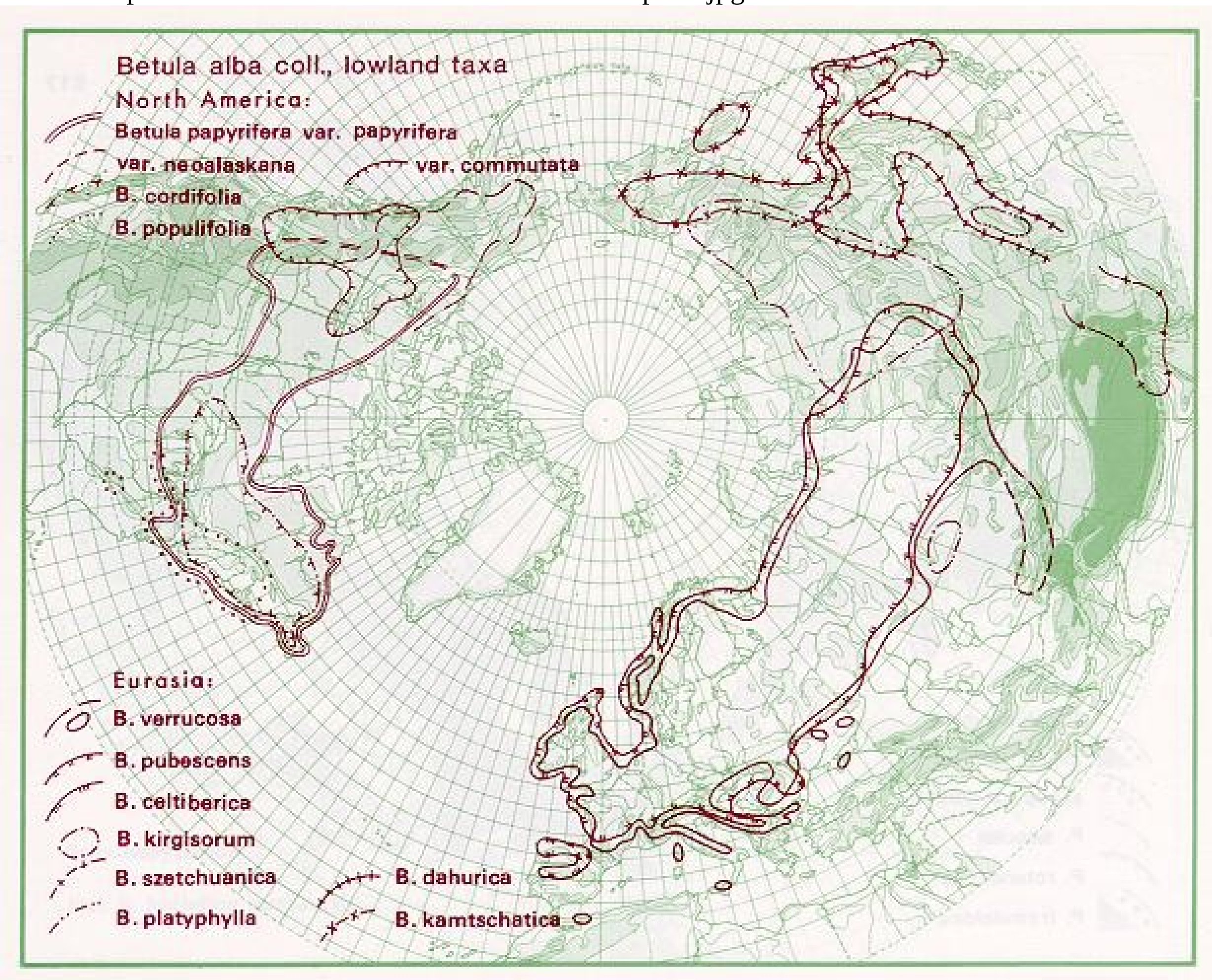
7- Hardwood Lumber (all species) in m^3

Partner	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Albania	0	0	0	0	28	230	83	96	94	128
Algeria	0	0	0	0	0	26	28	0	33	38
Armenia	0	0	0	0	0	0	27	0	0	0
Austria	1.408	500	556	334	679	252	1.035	1.217	355	270
Azerbaijan	0	0	26	0	0	60	22	0	0	0
Belarus	0	0	0	0	0	0	0	0	163	0
Belgium	52.393	51.409	35.436	30.108	27.710	25.823	23.057	20.059	21.720	10.184
Bosnia and Herzegovina	122	0	0	0	0	0	0	0	0	0
Bulgaria	0	93	0	69	5	2	0	155	307	283
Croatia	23	0	0	142	259	0	132	360	202	178
Cyprus	1.927	1.522	821	982	1.184	917	774	1.080	592	602
Czech Republic	825	598	441	804	678	777	696	504	192	678
Denmark	22.963	16.681	18.582	11.884	15.314	16.785	29.754	12.042	5.422	3.215
Estonia	606	558	936	1.103	1.478	1.755	2.509	2.568	3.038	2.963
European Union-27	845.362	726.687	678.701	649.063	685.316	684.929	723.560	646.774	452.577	353.693
Finland	5.917	5.746	5.751	5.041	5.641	4.630	5.795	3.606	2.610	1.906
Former Soviet Union-12	427	2.503	1.096	1.188	212	306	1.060	361	1.796	1.675
France	45.084	30.456	28.925	21.470	23.187	18.272	15.728	11.552	10.829	7.926
Georgia	82	0	0	30	30	0	413	27	134	83
Germany	77.141	47.065	32.635	40.323	48.623	54.440	56.720	47.859	33.323	36.246
Gibraltar	27	0	0	0	0	0	0	0	0	0
Greece	12.692	10.643	13.851	14.377	13.771	15.915	17.548	15.379	17.900	11.606
Greenland	0	0	0	0	0	0	0	0	28	0
Hungary	696	30	282	133	71	0	0	29	0	0

Iceland	769	993	318	307	412	621	295	510	400	284
Ireland	24.306	17.979	21.962	20.144	22.985	27.695	35.181	25.694	13.522	11.593
Israel	8.804	5.508	7.476	6.471	5.465	5.651	3.049	7.400	7.260	7.839
Italy	200.989	163.514	160.606	165.267	175.925	160.556	201.315	209.019	152.170	125.513
Jordan	2.231	2.286	2.061	2.030	2.467	1.936	2.876	2.328	3.726	3.139
Kazakhstan	0	0	0	0	18	0	18	117	64	0
Latvia	0	0	0	141	54	152	627	988	810	154
Lithuania	25	87	603	710	655	562	1.412	841	1.269	734
Luxembourg	66	34	0	26	0	0	0	0	0	0
Malta	3.640	3.490	3.521	3.353	3.644	2.799	3.141	2.914	1.761	1.781
Moldova	203	22	61	0	0	0	0	0	0	0
Morocco	470	0	345	255	453	281	177	765	278	610
Netherlands	31.750	23.187	17.863	14.140	15.249	15.016	17.506	13.515	12.367	7.146
Norway	11.378	11.062	8.347	8.705	8.494	8.829	9.672	9.270	6.949	4.982
Other Europe	15.592	15.344	11.455	9.504	10.174	12.779	12.342	10.532	8.355	5.731
Poland	253	452	294	153	1.113	3.683	1.269	669	1.878	1.452
Portugal	32.788	31.296	37.626	39.347	40.079	40.186	38.639	40.383	26.872	21.660
Romania	126	12	32	81	76	397	293	193	308	30
Russia	142	0	0	867	137	246	508	180	1.227	1.512
Serbia and Kosovo	0	0	0	0	0	0	0	28	32	0
Serbia, Montenegro, and Kosovo	0	13	0	0	0	0	24	0	0	0
Slovakia	0	0	0	0	181	0	66	0	0	9
Slovenia	267	233	388	386	2.210	8.327	930	1.393	1.248	52
Spain	181.532	179.325	173.196	171.145	172.494	163.349	139.661	124.861	64.053	39.415
Sweden	22.471	21.255	20.484	18.502	20.868	21.370	23.474	19.344	10.174	9.406
Switzerland	3.273	3.276	2.790	350	981	3.099	2.136	268	678	159
Tunisia	44	0	128	138	290	116	36	36	0	180
Turkey	362	1.104	414	427	1.665	2.472	3.708	1.822	3.243	4.353
Ukraine	0	2.481	1.009	291	27	0	72	37	208	52
United Kingdom	125.497	120.522	103.910	89.040	91.442	101.269	106.430	90.910	69.857	58.869
Uzbekistan, Republic of	0	0	0	0	0	0	0	0	0	28

Appendix 3. Maps of some *Betula* spp. in the PRA area (or parts of)

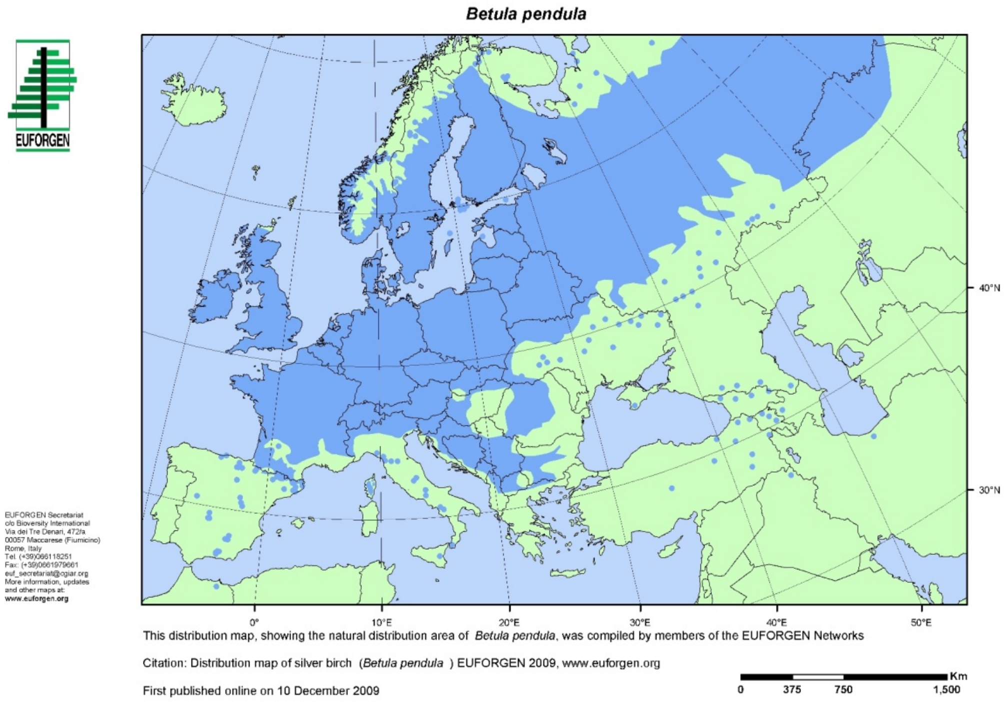
Distribution of B. verrucosa, B. pubescens, B. celtiberica, B. kirgisorum, B. szetchanica, B platyphylla, B. dahurica, and B. kamtschatica in Eurasia, and of B. papyrifera, B. cordifolia and B. populifolia in North America.
Source: http://linnaeus.nrm.se/flora/di/betula/betul/betupubv.jpg



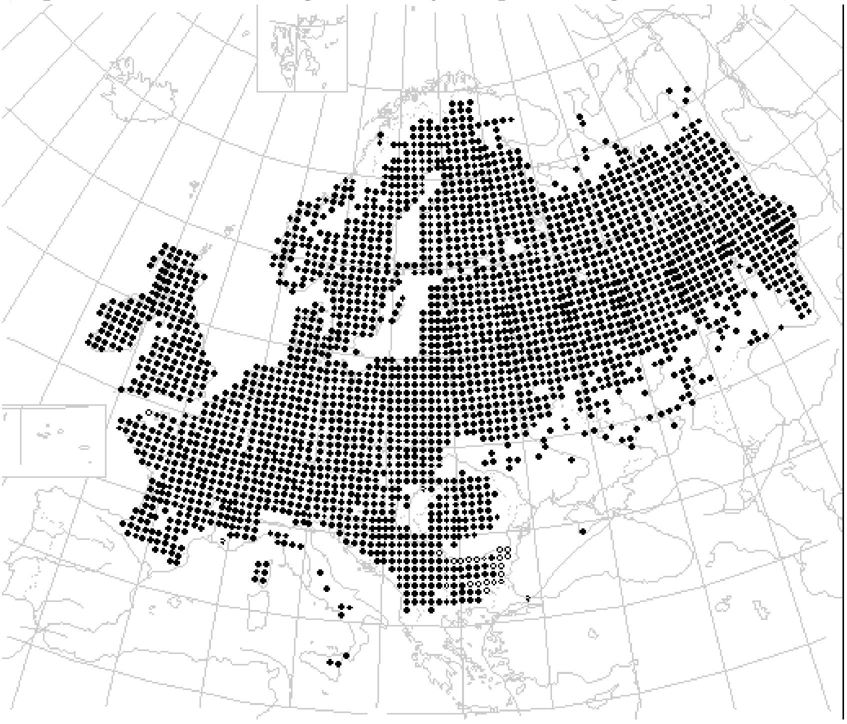
Betula pendula,

- source EUFORGEN (European Forest Genetic Resources Programme)

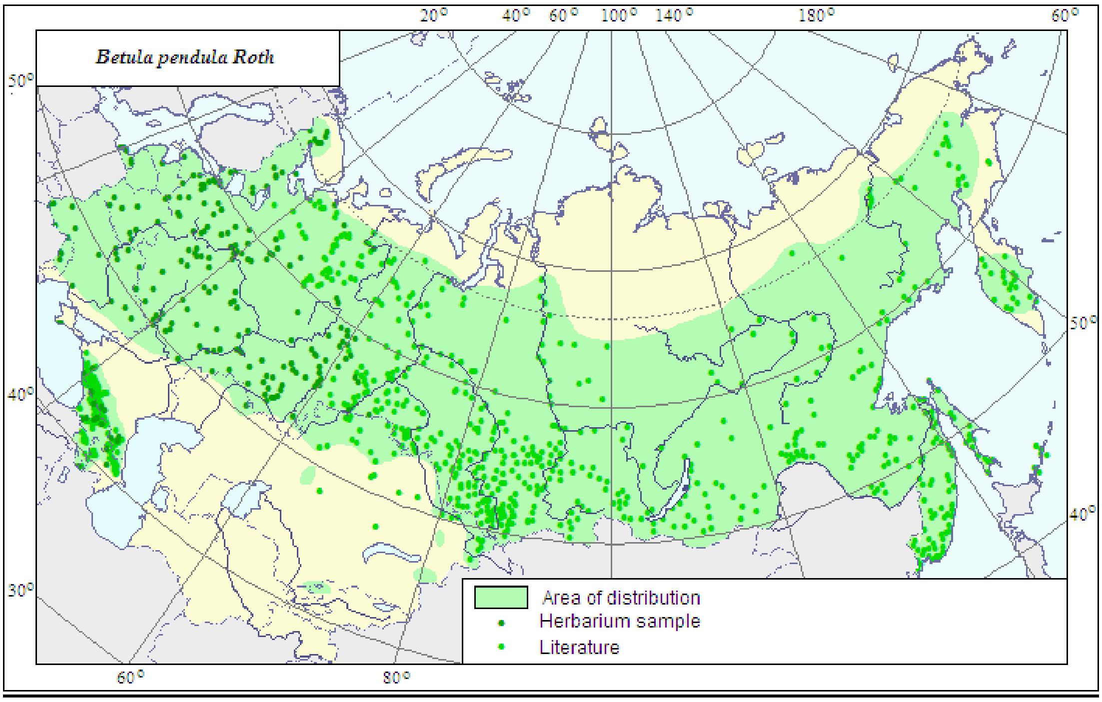
http://www.euforgen.org/distribution_maps.html



- Source Atlas Florae Europea (in Finnish Museum of Natural History) (http://www.luomus.fi/english/botany/afe/publishing/database.htm)

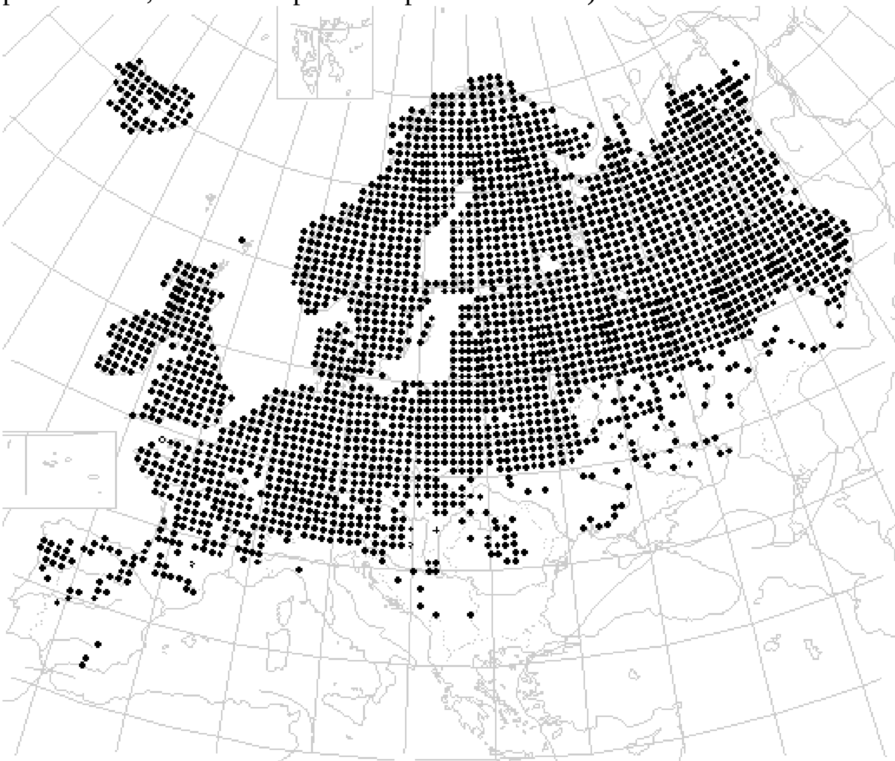


- *Betula pendula* in Russia. Source Afonin *et al*., 2008

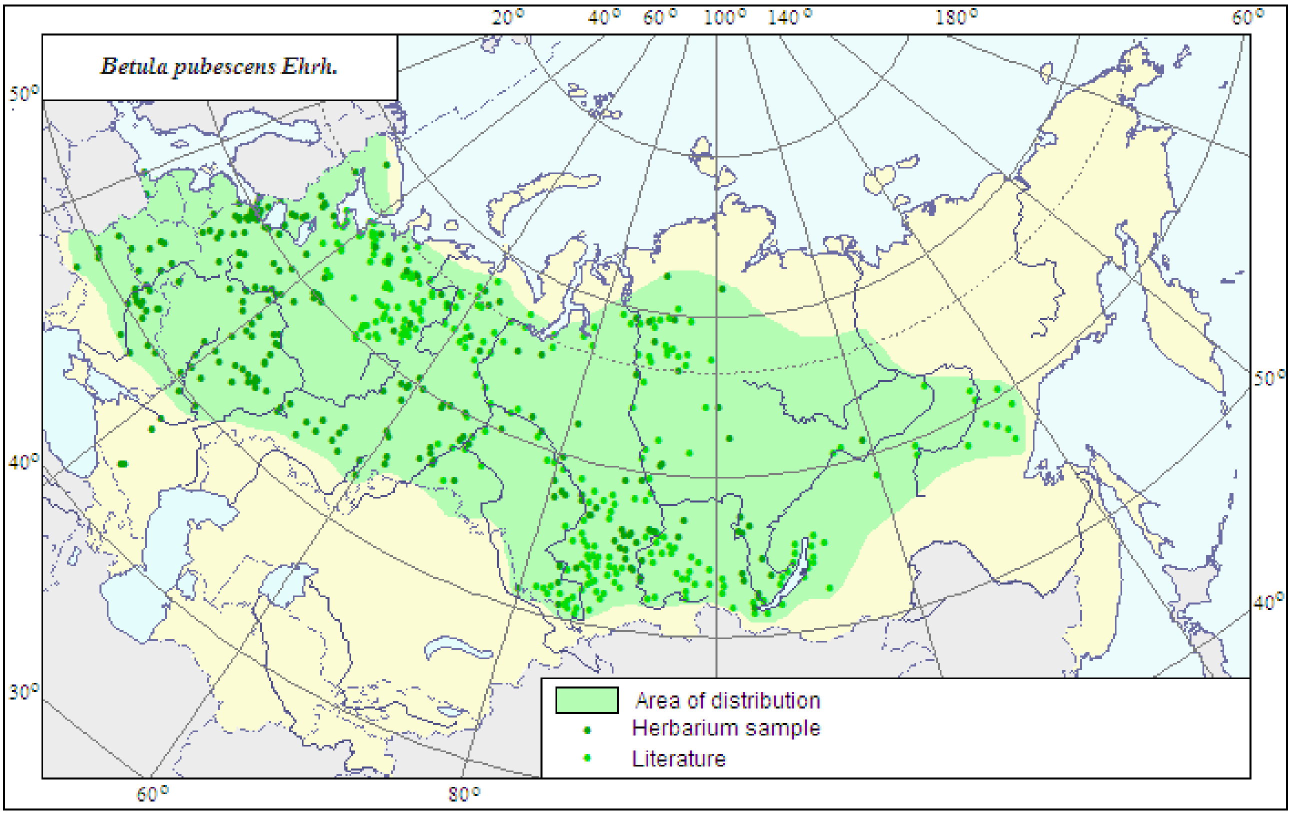


Betula pendula Roth
20°
40°
60°
100°
140°
180°
60°
50°
40°
30°
50°
40°
60°
80°
Area of distribution
Herbarium sample
Literature

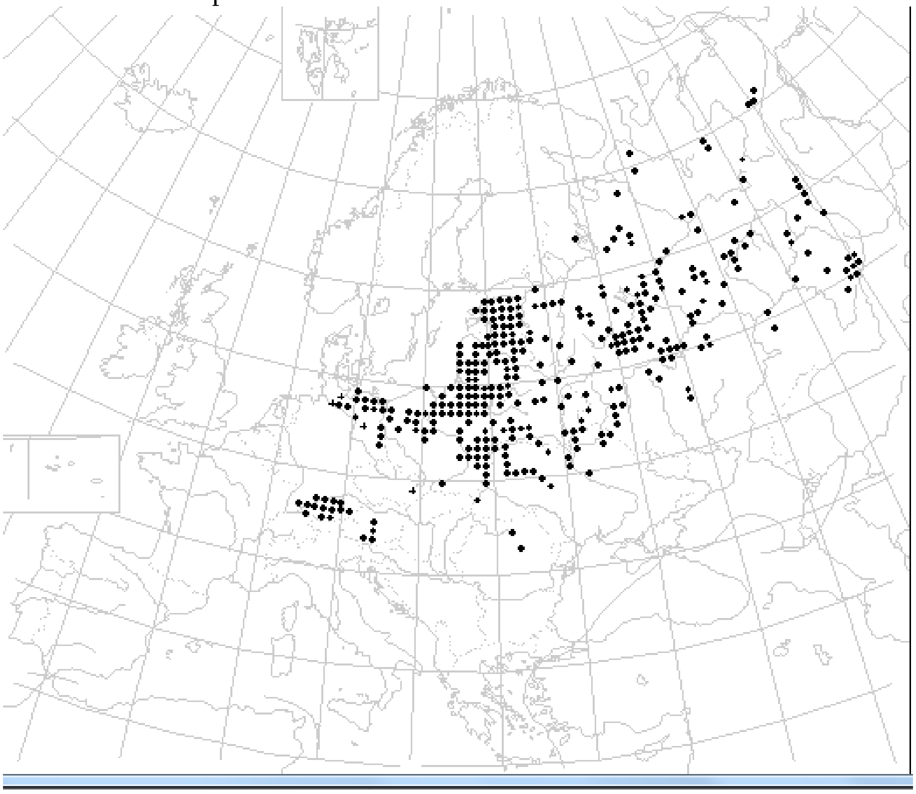
B. pubescens – Atlas Florae Europea (*Betula celtiberica* recognized as synonym of *B. pubescens* in some publications, and as independent species in others)



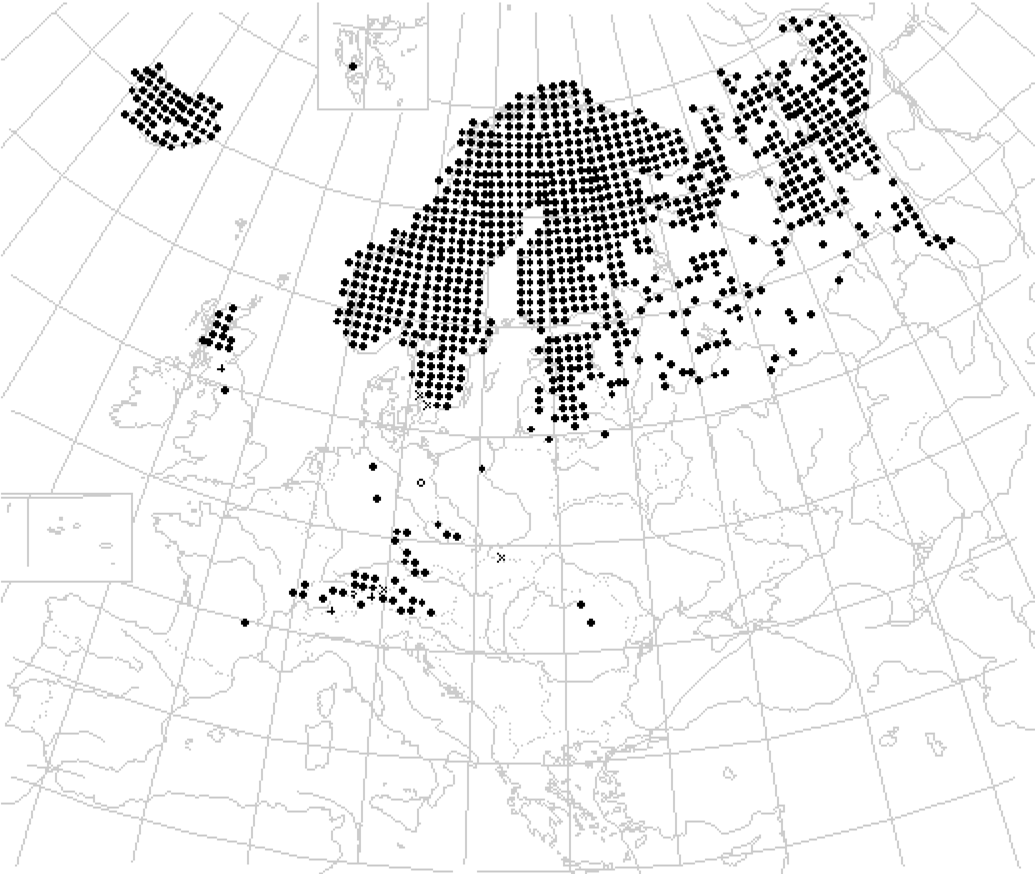
- *Betula pubescens* in Russia. Source Afonin *et al*., 2008

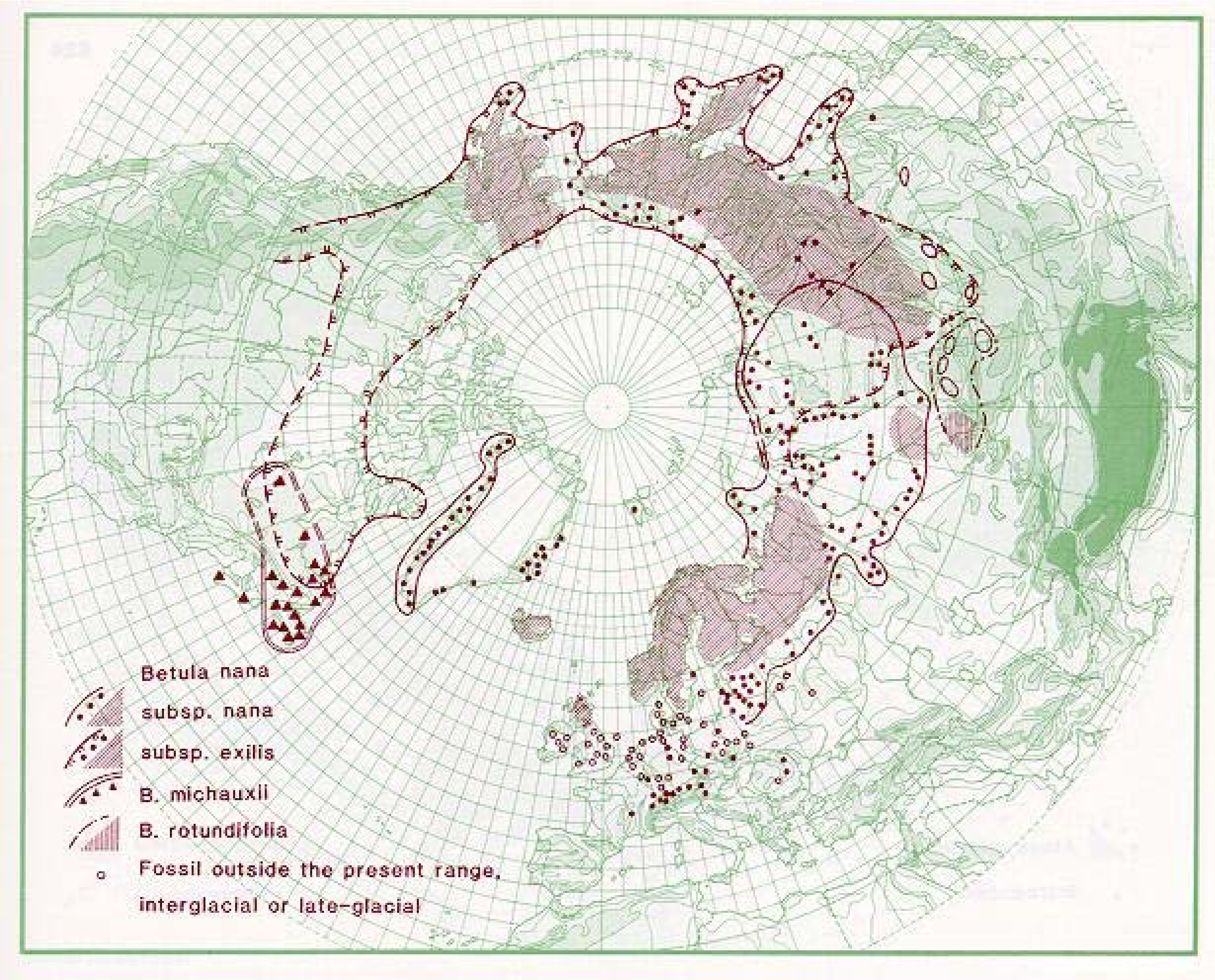


B. humilis
Atlas Florae Europea



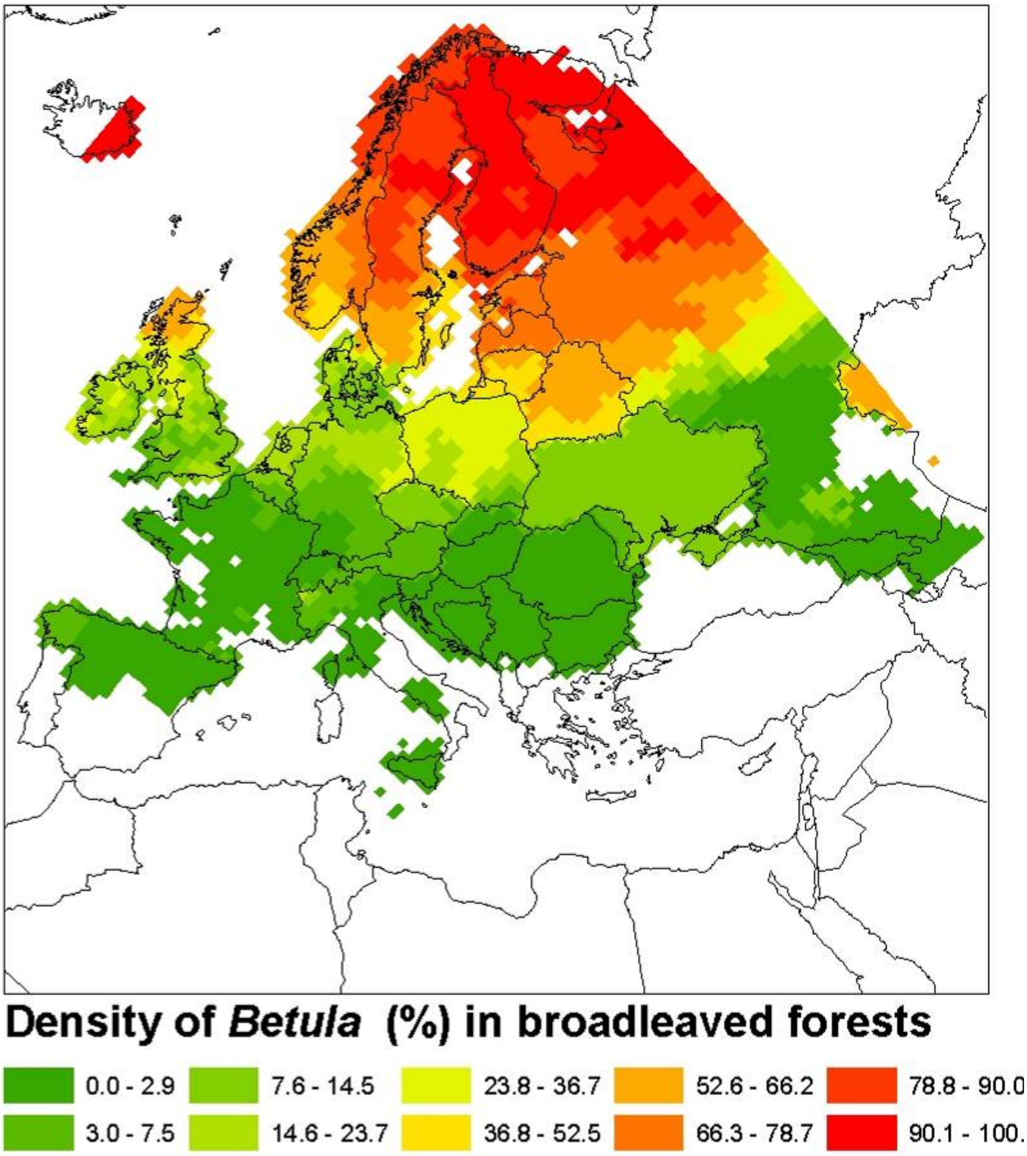
B. nana
Source: Atlas Florae Europea





Source http://linnaeus.nrm.se/flora/di/betula/betul/betunanv.jpg

National Environmental Research Institute, Aarhus University
Skjøth, C. A., Geels, C., Hvidberg, M., Hertel, O., Brandt, J., Frohn, L. M., Hansen, K. M., Hedegård, G. B., Christensen, J., and Moseholm, L., 2008, An inventory of tree species in Europe - An essential data input for air pollution modelling, Ecological Modelling 2008, doi:10.1016/j.ecolmodel.2008.06.023
http://www.dmu.dk/NR/rdonlyres/F9F81D76-A747-4640-901F-CE46A5A66031/0/Betula.jpg



Appendix 4: References

Afonin AN; Greene SL; Dzyubenko NI, & Frolov AN (eds.). 2008. Interactive Agricultural Ecological Atlas of Russia and Neighboring Countries. Economic Plants and their Diseases, Pests and Weeds [Online]. Available at: http://www.agroatlas.ru.

Akers RC & Nielsen DG (1984) Predicting *Agrilus anxius* Gory (Coleoptera: Buprestidae) adult emergence by heat unit accumulation. Journal of Economic Entomology, 77(6): 1459-1463.

Akers NC & Nielsen DG (1986) Influence of post-felling treatment of birch logs on emergence success of bronze birch borer, *Agrilus anxius*, adults (Coleoptera: Buprestidae). Journal of Entomological Science. 21(1): 63-67.

Akers RC & Nielsen DG (1990) Reproductive biology of the bronze birch borer (Coleoptera: Buprestidae) on selected trees. Journal of entomological science, 25:196-203.

Alden HA (1995) Hardwoods of North America. Gen. Tech. Rep. FPL–GTR–83. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 136 p. www.fpl.fs.fed.us/documnts/fplgtr/fplgtr83.pdf

Anderson RF (1944) The relation between host condition and attacks by the bronzed birch borer. Journal of Economic Entomology 37: 588-596.

Anonymous (undated) a http://cahedev.nmsu.edu/CES/yard/2005/100805.html

Anonymous (undated) b http://www.absolutebonsai.com/birch_bonsai

Appleby JE, Randell R & Rachesky S (1973) Chemical control of the bronze birch borer. Journal of Economic Entomology 66(1): 258-259.

Arnett RH Jr. (2000) American Insects: A Handbook of the Insects of America North of Mexico (2nd edition). CRC Press, New York (US), 1003 pp.

Atlas Florae Europaeae 1999 http://www.luomus.fi/english/botany/afe/publishing/database.htm

Ayres MP & Lombardero J (2000) Assessing the consequences of global change for forest disturbance from herbivores and pathogens. The Science of the Total Environment 262:263-286

Baez I (2009) *Agrilus coxalis* Waterhouse: Gold-spotted oak borer. New Pest Advisory Group (NPAG), Plant Epidemiology and Risk Analysis Laboratory, Center for Plant Health Science & Technology.

Bain J (1972) Forest entomology - timber inspection servicing. N.Z. FOR. SERV. REP. FOR. RES. INST.: 1972:56. http://www.bugz.org.nz

Bain J (1977) Overseas wood- and bark-boring insects intercepted at New Zealand ports. N.Z. FOR. SERV. FOR. RES. INST. TECH. PAP.: 63:1-28. http://www.bugz.org.nz

Balch RE & Prebble JS (1940) The bronze birch borer and its relation to the dying of birch in New Brunswick forests. Forestry Chronicle 16:179-201.

Ball JJ & Simmons GA (1980) The relationship between bronze birch borer and birch dieback. Journal of Arboriculture 6 (12) 309-314.

Ball JJ & Simmons GA (1986) The influence of host condition on post first instar development of the bronze birch borer, *Agrilus anxius* (Coleoptera: Buprestidae). Great Lakes Entomologist 19: 73-76.

Barter GW (1957) Studies of the bronze birch borer, *Agrilus anxius* Gory, in New Brunswick. The Canadian Entomologist 89: 12-36

Barter GW & Brown WJ (1949) On the identity of *Agrilus anxius* Gory and some allied species (Coleoptera: Buprestidae). The Canadian Entomologist 81: 245-249.

Bauernfeind R (2006) Borers. Common Kansas species. MF-2735. Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Bousquet Y (Ed.) (1991) Checklist of beetles of Canada and Alaska. Research Branch, Agriculture Canada. Publication 1861/E., Ottawa. 430pp

Bright DE (1987) The Insects and Arachnids of Canada, Part 15: The Metalic Wood-boring Beetles of Canada and Alaska, Coleoptera: Buprestidae. Research Branch, Agriculture Canada, Publication 1810, Canadian Government Publishing Centre, Ottawa, Canada. 335 pp.

CABI (2005) Data sheet for *Agrilus anxius*. Forestry Compendium. CAB International, Wallingford, UK.

Caine S (2000) Birch - *Betula* sp. Bonsais club International. http://www.bonsai-bci.com/species/birch.html

Carlos WJ, Johnson WS, Skelly JA & Knight J (2002) The bronze birch borer. Cooperative Extension Fact Sheet 02-38. University of Nevada.

Caron DM (2004) Birch leafminer and birch borer. University of Delaware Cooperative Extension. http://ag.udel.edu/extension/horticulture/pdf/ent/ent-16.pdf

Centre for Non-Timber Resources (2006) Market and Product Development for Birch Timber and Non-Timber Products: Current Status and Potential in British Columbia. Centre for Non-Timber Resources, Royal Roads University, Victoria, British Columbia (CA). http://cle.royalroads.ca/files-cntr/Market%20and%20Product%20Development%20for%20Birch%20Timber.pdf

CFIA (2010) Directive D-01-12: Phytosanitary Requirements for the Importation and Domestic Movement of Firewood (6 May 2010), 2nd revision. www.inspection.gc.ca/english/plaveg/protect/dir/d-01-12e.shtml, 6 May 2010

Clark J & Barter GW (1958) Growth and climate in relation to dieback of yellow birch. Forest Science 4: 343-364.

Crawnshaw W, Leatherman D & Kondratieff B (2000) Insects that feed on Colorado trees and shrubs. Bulletin 506A. Colorado State University Cooperative Extension. 176 pp

Department of Agriculture of Prince Edward Island (last accessed 2010-09) http://www.gov.pe.ca/agriculture/index.php3?number=69864

Denke P, Mettler M & Foley I (2008) Montana department of agriculture cooperative pest survey report 2008. Montana Department of Agriculture. http://agr.mt.gov/weedpest/caps/CAPS%2708_report/caps08-full.pdf

Douglas SM & Cowles RS (ed.) (2006) Plant pest handbook. http://vvv.caes.state.ct.us/PlantPestHandbookFiles/pphB/pphbirc.htm. The Connecticut Agricultural Experimental Station.

Drees BM, Jackman JA, & Merchant ME (1994) Wood-boring insects of trees and shrubs. Texas Agricultural Extension Service. The Texas A&M University System. http://insects.tamu.edu/extension/bulletins/b-5086.html

Dreistadt SH, Flint ML, & Clark JK (2004) Pests of landscape trees and shrubs: an integrated pest management guide. 501 pp.

Eastwood A, Lazkov G & Newton A (2009) The Red List of Trees of Central Asia. Fauna & Flora International, Cambridge, UK. http://www.globaltrees.org/downloads/RedListCentralAsia.pdf

EEA (2006) European forest types. Categories and types for sustainable forest management reporting and policy. Technical report No 9/2006. European Environment Agency

EPPO (2000) Distribution of the main forest trees and shrubs on the territory of the former USSR. Unpublished document, 00/7806

EPPO (2003a) Report of a Pest Risk Assessment for *Agrilus planipennis*. Document 04/10811. http://www.eppo.org/QUARANTINE/Pest_Risk_Analysis/PRA_documents.htm

EPPO (2003b) Report of a Pest Risk Management for *Agrilus planipennis*. Document 04/10812. http://www.eppo.org/QUARANTINE/Pest_Risk_Analysis/PRA_documents.htm

EPPO (2008a) Standard PM 10/6(1) Heat treatment of wood to control insects and wood-borne nematodes. Bulletin OEPP/EPPO Bulletin 39, 31

EPPO (2008b) EPPO Standard PM 10/7(1) Methyl bromide fumigation of wood to control insects. Bulletin OEPP/EPPO Bulletin 39, 32-33

EPPO (2008c) EPPO Standard PM 10/8(1) Disinfestation of wood with ionizing radiation. Bulletin OEPP/EPPO Bulletin 39, 34-35

EPPO (2010) *Agrilus anxius* (bronze birch borer): addition to the EPPO Alert List. EPPO Reporting Service 2010/030. archives.eppo.org/EPPOReporting/2010/Rse-1002.pdf

EU (2000) Council Directive 2000/29/EC on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community

EUFORGEN birch distribution maps www.euforgen.org

EU Pesticides Database (2010)

EUROSTAT http://epp.eurostat.ec.europa.eu

FAO (2009) ISPM 15 Regulation of Wood Packaging Material in International Trade. https://www.ippc.int/file_uploaded/1240490152156_ISPM_15_Revised_2009_E.pdf

Fassotte C *et al.* (2010a) Avertissement concernant la tenthrède mineuse du bouleau *Fenusa pumila* Leach. CRA-W, Gembloux, Avertissements Pépinières 2010/03 - 22.04.2010

Fassotte C *et al*. (2010b) Avertissement concernant le puceron du bouleau pubescent, *Euceraphis punctipennis* (Zetterstedt). CRA-W, Gembloux, Averissements Pépinières - 2010/01 - 06.04.2010

Federal Register (2003) Emerald Ash Borer; Quarantine Regulations, Interim Rule and Request for Comments. Animal and Plant Health Inspection Service. Vol. 68, No. 198. October 14, 2003. http://edocket.access.gpo.gov/2003/pdf/03-25881.pdf

GAO (2006) U.S. Government Accountability Office. Invasive Forest Pests: Lessons Learned from Three Recent Infestations May Aid in Managing Future Efforts. 125p. http://www.gao.gov/new.items/d06353.pdf

Gibb TJ & Sadof CS (2007) Bronze birch borer. Purdue extension E-50-W. Purdue University.

Global Agricultural Trade System USA http://www.fas.usda.gov/gats/default.aspx

Goebel PC, Bumgardner MS, Herms DA, & Sabula A (2010) Failure to Phytosanitize Ash Firewood Infested With Emerald Ash Borer in a Small Dry Kiln Using ISPM-15 Standards. Journal of Economic Entomology 103(3):597-602. www.nrs.fs.fed.us/pubs/jrnl/2010/nrs_2010_goebel_001.pdf

GRIN taxonomy for plants. USDA-ARS http://www.ars-grin.gov/cgi-bin/npgs/html/tax_search.pl

Haack RA (1996). Will global warming alter birch susceptibility to insect attack: a provenance study. Pages 234-247 in WJ Mattson, P. Niemela, M. Rousi (eds), Dynamics of Forest Herbivory: Quest for Pattern and Principle. USDA Forest. Service, North Central Forest Experiment Station, General Technical Report NC-183.

Haack RA. (2006) Exotic bark- and wood-boring Coleoptera in the United States: recent establishments and interceptions. Canadian Journal of Forest Research 36: 269-288.

Haack RA, Jendek E, Liu H, Marchant KR, Petrice TR, Poland TM, & Ye H (2002) The Emerald Ash Borer: A New Exotic Pest in North America. Newsletter of the Michigan. Entomological Society 47(3-4): 1-5.

Haack RA & Petrice TR (2009) Bark- and wood-borer colonization of logs and lumber after heat treatment to ISPM 15 specifications: the role of residual bark. Journal of Economic Entomology 102: 1075-1084.

Haack RA, Petrice TR, & Zablotny JE (2009) First report of the European oak borer, *Agrilus sulcicollis* (Coleoptera: Buprestidae), in the United States. Great Lakes Entomologist 42: 1-7.

Haack RA, Petrice TR, & Wiedenhoeft AC (2010) Incidence of bark- and wood-boring insects in firewood: a survey at Michigan's Mackinac Bridge. Journal of Economic Entomology 103: 1682-1692.

Hanson T & Walker EB (1996) Field guide to common insect pests of urban trees in the Northeast. Waterbury, VT: Department of Forests, Parks and Recreation. Vermont Department of Forests.

Herms DA (2002) Strategies for deployment of insect resistant ornamental plants. In: M.R. Wagner, K.M. Clancy, F. Lieutier, and T.D. Paine, eds. Mechanisms and Deployment of Resistance in Trees to Insects, pp. 217-237. Kluwer Academic Publishing, Dordrecht, The Netherlands. 332 pp.

Herms DA (2003) A biological calendar for predicting pest activity: six years of plant and insect phenology in Secrest Arboretum, pp.40-49. In: J.A. Chatfield, J.F. Boggs, E.A. Draper, and P.J. Bennett (eds.), Ornamental plants: annual reports and research reviews 2002. Ohio Agricultural Research Development Center and The Ohio State University Extension Special Circular 189. http://ohioline.osu.edu/sc189/sc189_29.html

Hodge P, Czerwinski E, Ingram W & Evans HJ (2009) Forest Health condition in Ontario 2007. Section 6 Southern region. www.mnr.gov.on.ca/en/stdprodconsume/groups/lr/@mnr/@forests/documents/document/274141.pdf

Hoover G (2002) Bronze birch borer. Entomological Notes. Pennsylvania State University. http://ento.psu.edu/extension/factsheets/pdf/bronzebirchborer.pdf

Hopkins JD (ed) (undated) Ornamental, Tree and Turf Pest Control. Training Manual. AG1158. Section "Cultural Management for Ornamental Plants University of Arkansas". http://www.aragriculture.org/pesticides/training/manuals/AG1158/Sec3Cultural.pdf

Houston DR (1987) Forest tree declines of past and present: current understanding. Canadian Journal of Plant Pathology 9: 349-360.

Hynynen J, Niemistö P, Viherä-Aarnio A, Brunner A, Hein S & Velling P (2010) Silviculture of birch (Betula pendula Roth and Betula pubescens Ehrh.) in northern Europe. *Forestry* 83 (1): 103-119

Iles JK & Vold AM (2003) Landscape tree cultivar preferences in Iowa, U.S. Journal of Arboriculture 29(6): 331-336

Israel (2009a) Ministry of Agriculture and Rural Development, Plant Protection and Inspection Services - Plant Protection Law – 1956. Plant Import Regulations February 2009

Israel (2009b) Treatments as required by the plant import regulations 2009. http://www.ppiseng.moag.gov.il/NR/rdonlyres/90BED4A9-EB14-41BD-99DD-10EF0C3C1B57/0/TreatmentRegulationsPPISImport2009.pdf

Jendek E & Grebennikov VV (2009) *Agrilus sulcicollis* (Coleoptera: Buprestidae), a new alien species in North America. Canadian Entomologist. 141:236-245

Johnson WT & Lyon HH (1976) Insects that feed on trees and shrubs. Comstock Publishing Associates, Cornell University Press, Ithaca and London. pp 464.

Jones EA, Reed DD, Mroz GD, Liechty HO & Cattelino PJ (1993) Climate stress as a precursor to forest decline: paper birch in northern Michigan, 1985-1990. Canadian Journal of Forest Research 23: 229-233.

Karren JB & Roe AH (2000) Bronze birch borer. Fact Sheet 24. Utah State University Cooperative Extension. http://extension.usu.edu/files/publications/factsheet/bronze-birch-borers00.pdf

Katovich SA, Munson AS, Ball J & McCullough D (2005) Bronze birch borer. Forest Insect & Disease Leaflet 111. US Department of Agriculture and Forest Service http://extension.usu.edu/forestry/UtahForests/Assets/FIDLs/BBB.PDF

Keith D, Baxendale F, & Carstens J (2003) Flatheaded borers. University of Nebraska-Lincoln. http://entomology.unl.edu/ornamentals/pestprofiles/flatheaded_borers.shtml

Kopinga J, Moraal LG, Verwer CC & Clerkx APPM (2010). Phytosanitary risks of wood chips. Alterra report 2059. Wageningen, NL. 80 pp. http://www.alterra.wur.nl/UK/publications/Alterra+Reports/

KSU (2009) Kansas state university. Problem: bronze birch borer - *Agrilus anxius*. Kansas State University. http://www.hfrr.ksu.edu/DesktopModules/ViewDocument.aspx?DocumentID=1594

Lanthier M (2008) Prospects for biological control of pest problems in outdoor nursery production in Western Canada. IOBC WPRS BULLETIN, 32:115-118.

Liu H, Bauer LS, Gao R, Zhao T, Petrice TR, and Haack RA (2003) Exploratory survey for the Emerald Ash Borer, *Agrilus planipennis* (Coleoptera: Buprestidae), and its natural enemies in China. Great Lakes Entomologist. 36: 191-204. http://nrs.fs.fed.us/pubs/jrnl/2003/nc_2003_liu_001.pdf

Loerch C & Cameron EA (1983a) Natural enemies of immature stages of the bronze birch borer, *Agrilus anxius* (Coleoptera: Buprestidae), in Pennsylvania. Environmental Entomology, 12(6)1798-1801.

Loerch C & Cameron EA (1983b) Determination of larval instars of the bronze birch borer, *Agrilus anxius* (Coleoptera: Buprestidae). Annals of the Entomological Society of America, 76(6): 948-952.

Loukonen S, Juhanoja S (2007) North American deciduous trees in Southern Finland. Harvest – Horticultural Research Results 2003-2005. MTT:n selvityksiä 139, pp. 92-93. http://www.mtt.fi/mtts/pdf/mtts139.pdf

MacAloney HC (1968) The bronze birch borer. Forest Pest Leaflet 111. US Department of Agriculture. Forest Service. http://na.fs.fed.us/spfo/pubs/fidls/br_bir_bor/bbbfidl.htm

MAF (2003) Import Health Standard Sawdust, Wood Chips, Wood Shavings, and Wood Wool from All Countries Pursuant to Section 22 of the Biosecurity Act (1993). Ministry of Agriculture and Forestry. Wellington, New Zealand. http://www.biosecurity.govt.nz/files/ihs/sawdust.pdf

McCullough DG, Poland TM, Cappaert D, Clark EL, Fraser I, Mastro V, Smith S & Pell C (2007) Effects of chipping, grinding, and heat on survival of emerald ash borer, Agrilus planipennis (Coleoptera, Buprestidae), in chips. Journal of Economic Entomology 100(4): 1304-1315

Miller RO, Bloese PD, Hanover JW & Haack, RA (1991) Paper birch and European white birch vary in growth and resistance to bronze birch borer. Journal of the American Society of Horticultural Science 116(3): 580-584.

Myers SW, Fraser I & Mastro VC (2009). Evaluation of heat treatment schedules for emerald ash borer (Coleoptera: Buprestidae). Journal of Economic Entomology 102 (6): 2048-2055.

Nelson A, Bridgwater D, Johnson J, Kanaskie A, McWilliams M, Overhulser D, Sprengel K (2004) Forest Health Highlights In Oregon – 2003. Oregon Department of Forestry - USDA Forest Service, Pacific Northwest Region. R6-NR-FID-TP-05-04. Portland, Oregon (US). http://www.fs.fed.us/r6/nr/fid/health/2003highlights-or.pdf

Nelson GH, Westcott RL & MacRae TC (1996) Miscellaneous notes on Buprestidae and Schizopodidae occurring in the United States and Canada, including descriptions of previously unknown sexes of six Agrilus Curtis (Coleoptera). The Coleopterists Bulletin 50(2):183-191.

Nielsen DG, Muilenburg VL, & Herms DA (2011) Interspecific variation in resistance of Asian, European, and North American birches (*Betula spp.*) to bronze birch borer (Coleoptera: Buprestidae). *Environmental Entomology* 40:648-653.

New M, Lister D, Hulme M. & Makin I (2002). A high resolution data set of surface climate over global land areas. Climate Research 21: 1-25.

NRC - Natural Resources Canada (2010) Insects and diseases of forests in Canada. Bronze birch borer. Www.nrcan-rncan.gc.ca

Petrice TR & Haack RA (2006) Effects of cutting date, outdoor storage conditions, and splitting on survival of *Agrilus planipennis* (Coleoptera: Buprestidae) in firewood logs. Journal of Economic Entomology 99: 790-796.

Petrice, TR & Haack RA (2007) Can emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae), emerge from logs two summers after infested trees are cut? Great lakes Entomologist 40: 92-95.

PFRA Shelterbelt Centre (undated) Improvement of Conservation trees and shrubs - *Betula pendula.* http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1192121852125&lang=eng

Poland TM & McCullough DG (2010) SLAM: a multi-agency pilot project to SL.ow A.sh M.ortality caused by emerald ash borer in outlier sites. Newsletter of the Michigan Entomological Society 55: 4-8. http://www.nrs.fs.fed.us/pubs/jrnl/2010/nrs_2010_poland_001.pdf

Rebek E, Smitley D & Herms D (2008) Interspecific variation in resistance to emerald ash borer (Coleoptera: Buprestidae) among North American and Asian ash (*Fraxinus* spp.) Environmental Entomology. 37(1): 242-246.

Roberts DL & Kuchera J (2006). The Survival of EAB in Wood Chips: Does Size Matter? The Landsculptor, 19-21. http://www.anr.msu.edu/robertsd/ash/Roberts_ash%20woodchips.pdf

Robertson DR & Andow DA (2009). Working paper: Human-mediated dispersal of emerald ash borer: Significance of the firewood pathway. (www.entomology.umn.edu/faculty/andow/EAB_Firewood.pdf)

Rutledge CE (2007) Research project: Host finding strategies, mating behavior and the natural enemies of wood-boring beetles in the families Buprestidae and Cerambycidae. http://www.reeis.usda.gov/web/crisprojectpages/212812.html

Santamour FS (1990a) Tree stress and the bronze birch borer. Journal of Arboriculture 16(11): 289-290.

Santamour FS (1990b) Rhododendrol and susceptibility to the bronze birch borer. Journal of Arboriculture 16(10): 260-263.

Santamour FS (1999) Progress in the development of borer-resistant white-barked birches. Journal of Arboriculture 25(3): 151-162.

Swier S (2003) Bronze birch beetle. University of New Hampshire. Cooperative extension. From http://extension.unh.edu/Forestry/cpestssub.cfm?sear=3

Scarr T, Ryall K & Thompson L (ed) (2010) Forest Health Conditions in Ontario, 2008. http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@forests/documents/document/289853.pdf

SDDA - South Dakota Department of Agriculture (2009) Broadleaf insects and mites. http://sdda.sd.gov/Forestry/programs-services/broadleaf-insects.aspx

Shetlar DJ (2000) Bronze birch borer management. Ohio State University Extension Fact Sheet HYG-2018-95. Ohio State University Extension. http://ohioline.osu.edu/hyg-fact/2000/2018.html

Shetlar DJ & Herms DA (2003) Ornamentals: information about insecticides and acaricides. http://www.entomology.umn.edu/cues/Web/287Ornamentals.pdf

Skjøth CA, Geels C, Hvidberg M, Hertel O, Brandt J, Frohn LM, Hansen KM, Hedegård GB, Christensen J & Moseholm L (2008) An inventory of tree species in Europe - An essential data input for air pollution modelling. Ecological Modelling 217: 292-304.

Slingerland MV (1906) The bronze birch borer: an insect destroying the white birch. Cornell University Agriculture Experiment Station Bulletin 234.

Smith DL, Rebek EJ, & Schnelle MA (2008) Managing Storm-Damaged Trees. EPP-7323, Oklahoma Cooperative Extension Service, 5 pp. www.hortla.okstate.edu/pdf/storm_damaged_trees.pdf

Solomon JD (1995) Guide to insect borers in North American broadleaf trees and shrubs. Agric. Handb. 706. USDA Forest Service, Washington, DC. 735 pp.

State of Alaska (2008) Non-Timber Forest Products Harvest Manual For Commercial Harvest on State-Owned Lands. Department of Natural Resources Division of Mining, Land and Water Alaska. http://dnr.alaska.gov/ag/PMCwebsite/PMCPublications/84HarvestManual2008.pdf

Statistics Canada, Canadian International Merchandise Trade Database http://cansim2.statcan.gc.ca/cgi-win/CNSMCGI.PGM?Lang=E&CIMT_Action=Sections&ResultTemplate=CII_CIMT5

Taylor RAJ, Bauer LS, Miller DL, & Haack RA (2005). Emerald ash borer flight potential, pp. 15-16. In Proceedings of the 2004 Emerald Ash Borer Research and Technology Development Meeting Romulus, Michigan. USDA Forest Service FHTET-2004-15. 92 p. http://www.invasive.org/eab/biologybehavior.cfm#2

Taylor RAJ, Poland TM, Bauer LS, Windell KN, & Kautz JL (2007) Emerald ash borer flight estimates revised. Pages 10-12 in V. Mastro, D. Lance, R. Reardon, & G. Parra, (eds.). Emerald ash borer and Asian longhorned beetle research and technology development meeting - 2006. United States Department of Agriculture, Forest Service / Animal and Plant Health Inspection Service, Cincinnati, Ohio. http://www.emeraldashborer.info/files/EAB_ALB_2006.pdf

Tourkow A (2009). Prohibited Plant List For the South Carolina Upstate Region. Appalachian Council of Governments. 7p. http://www.greenstepschools.com/greensteps/pdf/UPSTATE%20SC%20-%20Prohibited%20Plant%20List%20-%20FINAL%20Update%207-10-9.pdf

Tschirpke S. (2006) Horch, was die Birken flüstern. - Wald Holz 87, 4: 43-44. http://www.waldwissen.net/themen/holz_markt/forstliche_produkte/wsl_birkensaft_EN

Turkey (2007) Regulation on Agricultural Quarantine (2007-01-23). EPPO collectıon of phytosanıtary regulatıons. http://www.eppo.org/ABOUT_EPPO/EPPO_MEMBERS/countries/animation/turkey.htm

UNECE (2006). Timber Committee Forest Products Statistics. Trade by species (roundwood and sawnwood) 2000-2004. 30pp. http://www.unece.org/timber/database/species2000-2004.pdf

UNECE-FAO (2009) Forest Products Annual Market Review 2008-2009. Geneva Timber and Forest Study Paper 24. UNITED NATIONS. Available at: http://timber.unece.org/fileadmin/DAM/publications/Final_FPAMR2009.pdf New York and Geneva.

USDA (2009) Treatment Manual

USDA (2011) Treatment Manual http://www.aphis.usda.gov/import_export/plants/manuals/ports/treatment.shtml

USDA–APHIS (2009) Emerald Ash Borer Program Manual, *Agrilus planipennis* (Fairmaire) USDA–APHIS–PPQ–Emergency and Domestic Programs–Emergency Planning, Riverdale, Maryland (US).107p. http://www.aphis.usda.gov/import_export/plants/manuals/domestic/downloads/emerald_ash_borer_manual.pdf

USDA-APHIS (2011) Notice of decision to revise a heat treatment schedule for emerald ash borer. Federal Register, 19 January 2011, 76(12): 3077-3079.

USDA ARS (2010), National Genetic Resources Program. Germplasm Resources Information Network - (GRIN) [online database]. National Germplasm Resources Laboratory, Beltsville, Maryland. http://www.ars-grin.gov/cgi-bin/npgs/html/tax_search.pl (07 October 2010)

Wawrzynski RP, Krischik V & Katovich S (2009) The bronze birch borer and its management. University of Minnesota, extension service. http://www.extension.umn.edu/distribution/horticulture/DG1417.html

Wescott RL (1990) Distributional, biological and taxonomic notes on North American Buprestidae (Coleoptera). Insecta Mundi, 4(1-4):73-80.

WI DNR (2008) Wisconsin forest health highlights 2008. Wisconsin Department of Natural Resources, Division of Forestry, Madison. http://dnr.wi.gov/forestry/publications/FHH08.pdf

WSFD (undated) Invasive insects in Wyoming. Wyoming State Forestry Division. http://slf-web.state.wy.us/forestry/invasive.aspx

Zeleznik JD, Walla JA, Knodel JJ, Kangas M, Glogoza PA, &Ruby CL (2005) Insect and Disease Management Guide for Woody Plants in North Dakota. F-1192 (Revised). North Dakota State University Fargo, North Dakota 58105. http://www.ag.ndsu.edu/pubs/plantsci/trees/f1192w.htm

Personnal communications

Brian Zak, Canada Wood, Vancouver, BC, Canada. zak@allforestsolutions.com

Dave Nielsen, Ohio State University (USA)