Forestry Commission

Pest Risk Analysis for *Hymenoscyphus pseudoalbidus* for the UK and the Republic of Ireland

Pest Risk Analysis for *Hymenoscyphus pseudoalbidus* (anamorph *Chalara fraxinea*) for the UK and the Republic of Ireland[1]

STAGE 1: PRA INITIATION

1. What is the name of the pest?

Hymenoscyphus pseudoalbidus (teleomorph – sexual stage). This was first described by Queloz *et al*. (2011) (published online March 2010).

Synonyms:

Chalara fraxinea, first described by Kowalski (2006), is the anamorph (asexual) stage of *H. pseudoalbidus*, and, until recently, this has been the name ascribed to the disease-causing organism. However, as described below, it has become clear that the teleomorph *H. pseudoalbidus* is the epidemiologically important stage of the fungus, producing the infective sexually-produced ascospores. *H. pseudoalbidus* should, therefore, be the name now used for the pathogen responsible for ash dieback. In this PRA, irrespective of whether C. fraxinea is the term used in cited publications many of which pre-date the description of *H. pseudoalbidus*, the pathogen is referred to as *H. pseudoalbidus* in addition to or as an alternative to *C. fraxinea.*

Common names of the pest:

The pest (also referred to as the fungus or the pathogen in this PRA) does not have a common name. The disease caused by the fungus is known as ash dieback, but it is not the same as the '*ash dieback'* syndrome which has previously been investigated in the UK (Hull and Gibbs, 1991). It is also commonly referred to as Chalara dieback.

Taxonomic position:

Kingdom - Fungi; Phylum - Ascomycota; Class - Leotiomycetes; Order - Helotiales; Family – Helotiaceae.

Special notes on nomenclature or taxonomy:

The anamorph *Chalara fraxinea* was first described as a new species of fungus, isolated from shoots and twigs of *Fraxinus excelsior* (European or common ash) exhibiting symptoms of dieback in Poland (Kowalski, 2006). Although not proven to be the cause of the disease at that time, it was suspected. No teleomorph stage was reported at that time. Subsequently, the fungus was found to be pathogenic to young ash trees when they were artificially inoculated under field conditions (Kowalski and Holdenrieder, 2009).

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In 2009, *C. fraxinea* was considered to be the anamorph (asexual stage) of *Hymenoscyphus albidus,* a species first described in 1850 (assigned then to *Peziza albida*) and considered to be non-pathogenic, native and widespread in Europe (Kowalski and Holdenrieder 2009a). Because of the disparity between the emergence of the disease in Europe (in Poland in the early 1990s without an identifiable cause at that time) and the apparent non-pathogenic status of the teleomorph, the authors commented that further investigation was needed in case the organism they described was a '*new mutant, a hybrid of* H. albidus *with an unknown introduced species or an exotic invasive species, which is indistinguishable morphologically from* H. albidus'.

Following on from this, molecular studies of Swiss isolates concluded that the teleomorph of *C. fraxinea* was not *H. albidus* but a new species, *Hymenoscyphus pseudoalbidus* (online paper March 2010, published as Queloz *et al.,* 2011; Husson *et al*., 2011), morphologically similar to but genetically distinct from *H. albidus*. Evidence from recent research (e.g. Gross *et al*., 2012; Bengtsson *et al*., 2012) supports the view that *H. pseudoalbidus* is the pathogen responsible for the current ash dieback epidemic in Europe including the recent findings in the UK and Ireland.

2. What is the pest's status in the EC Plant Health Directive (Council Directive 2000/29/EC) (Anon., 2000)?
H. pseudoalbidus/*C. fraxinea* is not listed in the EC Plant Health Directive. There is no emergency legislation in place in the EU. However, there is emergency legislation at the national level (Great Britain, Northern Ireland and Ireland – see 13. and Table 6) as well as for Jersey, Guernsey and the Isle of Man (see 6.).

3. What is the recommended quarantine status of the pest in the lists of the European and Mediterranean Plant Protection Organisation (EPPO)?
Chalara fraxinea was added to the EPPO Alert List in September 2007 (EPPO, 2007). It is still listed.

See: http://www.eppo.int/QUARANTINE/Alert_List/alert_list.htm

At the time of listing, although *C. fraxinea* was suspected to be the main cause of ash dieback in Europe, many other fungi had been isolated from diseased ash trees in European countries, and it was not known which abiotic factors (e.g. frost, drought) were involved in the disease. EPPO felt it appropriate to add the fungus to the Alert List because they were concerned that the disease might pose a threat to ash trees growing in European forests, parks, and nurseries.

EPPO (2007) considered that '*plants for planting and wood of* F. excelsior *could be pathways for spreading the disease over long distances'* and warned '*that there may be a risk in moving diseased* F. excelsior *plants across the region without any precaution*'. However, the fungus has never been moved to the lists of organisms recommended for regulation by EPPO. Such a recommendation has to be based on a PRA. By the time *H. pseudoalbidus* was eventually confirmed as the causal pathogen (online paper March 2010, published as Queloz *et al*., 2011) the disease was already quite widespread within the EPPO region.

4. What is the reason for the PRA?

At the request of the Forestry Commission (FC) this PRA was initiated in January 2013 to update the Rapid Assessment (RA) produced by Forest Research (FR) in August 2012 (Webber and Hendry, 2012). At the time of the RA there had been a low number of interceptions of ash saplings infected with the fungus in UK nurseries and in recent plantings. Since the RA was published, surveillance has shown that the disease is present in the wider environment in parts of Great Britain (GB). Northern Ireland (NI) and the Republic of Ireland (ROI) (not considered in the 2012 RA) have found infected material in nurseries and recent plantings (See 6. and 7.).

This PRA reflects the current status of the pathogen from surveillance in the PRA area. New findings of infected trees and nursery plants have been reported since the RA. Studies of the distribution and value of ash and the possible economic impact of the disease have been undertaken. Risk management activities have been carried out in the UK and the ROI. The PRA also examines additional pathways of entry (seeds, airborne ascospores) and all potential pathways (plants, wood, seeds, soil/growing media, airborne ascospores) are examined in depth. A more detailed consideration of pest risk management options has been undertaken. Suggestions for future controls and a list of uncertainties with associated research needs are provided.

5. What is the PRA area?

The PRA area is the UK and the Republic of Ireland (ROI). For the UK, the Crown Dependencies of Guernsey, Jersey and the Isle of Man are not included except with respect to comments on the status of the pest.

STAGE 2: PEST RISK ASSESSMENT

6. What is the pest's present geographical distribution?

H. pseudoalbidus/*C. fraxinea* is currently known to occur in at least 24 European countries outside of the UK and the ROI (see 7. for pest status). It has also been detected in imported material in the Crown Dependencies of Jersey and Guernsey. It has not been found on the Isle of Man. It is considered to be an exotic introduction in Europe, possibly from Asia where it has been reported from Japan (Zhao *et al*., 2012). More detail is given below.

Ash trees with symptoms of ash dieback were first observed in the early 1990s in Poland; however, the anamorph form of the causal organism of the disease was not named until 2006 (Kowalski, 2006). The fungus has spread across Europe since the early 1990s, and it was found causing disease, for the first time, in the UK and the ROI in 2012.

Nearly all European disease records have been attributed (some retrospectively) to the anamorph *C. fraxinea* but it is now known that these should be attributed to *H. pseudoalbidus.* Dates of publication of records do not necessarily reflect the date at which the pest entered the affected country. For early records this is partly because the cause of the disease was unknown. For all records, this is because the detection of symptoms at an early stage of introduction of the fungus is unlikely. Because of this, no attempt has been made to document a geographical pattern of perceived spread over the period since diseased trees were first observed in Europe in this PRA.

Table 1 below lists all known countries where the pest has been recorded. The EPPO Plant Quarantine Retrieval System (a database of pests of quarantine concern) confirms the status of '*No record*' for the Americas, the Caribbean and Oceania (EPPO, 2013). A record in Japan has recently been published (Zhao *et al*., 2012). Further commentary on the status of the pathogen in the UK and the ROI is given under 7.

Whilst not considered further in this PRA, Jersey, Guernsey and the Isle of Man have all undertaken surveys for the disease, followed-up by diagnostic tests on symptomatic material; this is ongoing.

Jersey began casual surveillance in 2011 with official surveillance of the whole island commencing in November 2012. To date they have checked all nurseries and garden centres and have started trace-back activities for imported material dating back to 2007. The fungus has been confirmed in a single tree in a planting of ten plants of *Fraxinus* imported from the UK all of which have been destroyed. *H. pseudoalbidus*/*C. fraxinea* is not considered to be established on Jersey at this time; rather it is considered to be *'transient, actionable and under eradication'* (see 7.) Jersey has introduced legislation to manage the disease/pathogen on the island and to reduce the risk posed by imports (S. Meadows, States of Jersey Department of Environment, Jersey, *personal communication*, 2013).

Guernsey began surveillance in September 2012 by checking selected sites with established trees and following-up trees planted in the past 2 years. In October 2012, Guernsey also confirmed ash dieback, in trees imported from a nursery in the UK and planted in February 2012. In the affected plantation, one standard tree had cankers on the stem and dieback was observed in 9 (out of 80) two-year-old trees. All of the consignment was destroyed and the only established ash tree in the vicinity was cut down. The stump was treated with herbicide. Only one other site had been supplied by the UK nursery and this was disease-free. Fifty nine sites had been inspected by February 2013 and no infection was found. Follow-up checks around the outbreak site and at selected sites will continue to be conducted. Guernsey banned the import of ash trees, seeds and logs in November 2012. The pest status in Guernsey was also declared to be *'transient, actionable and under eradication'*. EPPO (2012a) (N. Clarke, States of Guernsey Government Department, Guernsey, *personal communication*, 2013).

The Isle of Man (IoM) undertook surveillance in September 2012 and it has also introduced legislation (November 2012) following a request to importers of plants to voluntarily ban imports of material of *Fraxinus*. All plantings of imported stock dating back 5 years as well as nurseries and trees in the wider environment have been surveyed. By February 2013, there had been no evidence of ash dieback. Surveillance will continue (J. Walmsley, Forestry Department, IoM, *personal communication*, 2013).

In addition to the European records, a recent report (Zhao *et al*., 2012) indicates that *H. pseudoalbidus* has also been found in Japan, where it was previously assigned to *Lambertella albida.* The first report of *L. albida* in Japan was made in 1993, when it was isolated from samples of petioles[2] of *Fraxinus mandshurica,* a common species of ash in north-east Asia and an introduced ornamental in Europe (Hoyosa *et al*., 1993 in Zhao *et al*., 2012). This paper states that *H. pseudoalbidus* has not been reported to be pathogenic to indigenous ash in Japan. However, no details were available of the symptoms on *F. mandshurica* from the cited 1993 record. The species of ash from which it was originally isolated in Japan is only mildly affected by ash dieback in Europe (Drenkhan and Hanso, 2010). Although further studies are needed to determine the origin of *H. pseudoalbidus*, this paper and other studies on different aspects of the pathogen, host and non-host species of *Fraxinus* indicate that Asia is likely, possibly Japan.

[2] In this document, the term 'petiole' is used interchangeably with 'rachis'; a rachis is the stalk/petiole of a compound leaf. Ash has compound leaves.

Table 1. Distribution of *H. pseudoalbidus* (previously assigned to *C. fraxinea*)

Location	*Status*	*Reference*
North America	No record	EPPO (2013)
Central America	No record	EPPO (2013)
South America	No record	EPPO (2013)
Caribbean	No record	EPPO (2013)
Europe	Austria	Cech (2006), Halmschlager and Kirisits (2008), Kirisits *et al*. (2009)
	Belgium	Chandelier *et al.* (2011)
	Belarus	Timmermann et al. (2011)
	Croatia	Baric *et al*. (2012)
	Czech Republic	Jankovsky and Holdenrieder (2009)
	Denmark	Thomsen *et al.* (2007)
	Estonia	Drenkhan and Hanso, 2009, Rytkönen *et al.* (2010)
	Finland	Rytkönen *et al.* (2010)
	France	Ioos *et al.* (2009)
	Germany	Schumacher *et al*. (2007)
	Hungary	Szabo *et al.* (2008)
	Ireland	DAFM (2012)
	Italy	Ogris *et al.* (2010)
	Latvia	Rytkönen *et al.* (2010), Timmermann *et al*. 2011 and references therein
	Lithuania	Juodvalkis and Vasiliauskas (2002)
	Netherlands	EPPO (2010)
	Norway	Talgø *et al.* (2009)
	Poland	Kowalski (2006)
	Romania	Timmermann *et al*. 2011 and references therein
	Russia (Kalingrad)	Timmermann *et al*. 2011
	Slovakia	Kunca *et al.* (2011)
	Slovenia	Ogris *et al.* (2009)
	Sweden	Bakys *et al.* (2009)
	Switzerland	Engesser *et al.* (2009)
	Ukraine	Davydenko *et al.* (2012) and Matsiakh (2012)
	United Kingdom	See commentary and EPPO, 2012, 2012a.
Africa	No record	EPPO (2013)
Asia	Japan	Zhao *et al*. (2012)
Oceania	No record	EPPO (2013)

7. Is the pest established or transient in the PRA area? (Include information on interceptions and outbreaks here).

Establishment is defined as '*Perpetuation, for the foreseeable future, of a pest within an area after entry*' (FAO, 2012)

Transience is defined as '*Presence of a pest that is not expected to lead to establishment*' (FAO, 2012).

The pest is established in parts of the UK (see below). This could be formally designated as '*Present, only in some areas*' (FAO, 2011) but the status can change subject to ongoing surveys.

The pest is considered to be '*transient, actionable and under eradication*' in NI (S. Mayne, Department of Agriculture and Rural Development (DARD), NI, *personal communication*, 2013) as well as in the ROI (G. Cahalane, Department of Agriculture, Food and the Marine, (DAFM), ROI, *personal communication*, 2013; DAFM, 2012). This status is defined in FAO (2011) as '*The pest has been detected as an individual occurrence or an isolated population that may survive into the immediate future, but is not expected to establish. Appropriate phytosanitary measures, including surveillance, are being applied*'.

The history of detection and the current situation for the UK and the ROI are documented in more detail below.

<u>UK</u>
Prior to 2012, there had been no pest-specific surveillance for *C. fraxinea*/*H. pseudoalbidus* in the UK. Since 2009, the general condition of ash and other tree species in Great Britain has been monitored during National Forest Inventory (NFI) surveys (FC 2012a.). Fera, the Forestry Commission (FC), Scottish Government and DARD also conduct general '*pest and disease*' surveillance in their respective capacities for the UK Plant Health Service.

The general pest and disease surveillance resulted in the first finding of the pest in the UK in February 2012, during an inspection of symptomatic plants of *F. excelsior* undertaken by the Fera Plant Health and Seeds Inspectorate (PHSI) at a nursery in southern England. Symptoms were noted in a lot of 600 plants which had been imported from the Netherlands in November 2011. The presence of *C. fraxinea* was confirmed. The infected lot was destroyed (EPPO, 2012).

By August 2012, when the UK RA was published (Webber and Hendry, 2012), there had been four documented records of *C. fraxinea* affecting plants of *F. excelsior* within nurseries in England. Two were related to plants imported from the Netherlands (including that reported by EPPO (2012)), while the other two concerned plants supplied by a nursery in England that grew ash on site, but supplemented this production with stock imported from Germany. The latter cases were detected by tracing the origin of *ca*. 450 young ash trees planted in January 2012 around a car park in Leicestershire, of which 50% displayed symptoms of dieback by May 2012. These were confirmed as being infected by the pest in June 2012.

In Scotland, a case of dieback in ash planted in the spring of 2009 was investigated in July 2012 and the pest was confirmed in August 2012 (Webber and Hendry, 2012).

Since the publication of the RA, pest-specific surveillance of nurseries, new plantings and the wider environment has taken place in the UK conducted by several Government departments using a range of methodologies. This work has been systematic and extensive but has not been based on a statistically-randomised sampling design (FC, 2013).

Details of the responsibilities for surveillance and methodologies in the UK are summarised in italics below (J. Morgan, FC*, personal communication*, 2013):

Surveillance:

- *Nurseries in England and Wales = Fera, Scotland = Scottish Government, Northern Ireland = DARD*
- *Trace-forward/trace-back in England and Wales = Fera/FC, Scotland= FCS, Northern Ireland= DARD*
- *Wider environment in England and Wales = FC/Fera, Scotland= FCS, Scotland, Northern Ireland = DARD*

Methodology:

- *Many methodologies are employed*
- *Standard Operating Procedures (SOPs) apply to nurseries and trace-forward/trace-back sites in England and Wales, Scotland and Northern Ireland*
- *Some wider environment sites arose from a* 'rapid survey' *of up to 4 sample ash woods in each 10 km square in England, Wales and Scotland (SOP used)*
- *Others came from the FC National Forest Inventory plots (SOP used)*
- *Others were a follow-up of third party reports (SOP used for follow-up)*

SOPs have been shared between organisations. Certain categories of survey use the same methodology - for example the 'rapid survey' *of 10 km squares and any follow-up. This is also the case for the trace-forward work, of which approximately one third of all* 'known' *trace-forward sites have been investigated.*

Nurseries and recently-planted sites have been targeted for inspection based upon customer lists as part of the trace-back and trace-forward activities. Wider environment surveillance has mainly been in response to reports of suspected infected trees made by members of the public (R. McIntosh, Defra, *personal communication*, 2013).

Two additional investigations of the general health of ash trees in GB were made as a subset of the statistically-randomised design FC NFI Surveys (FC 2012a, FC 2013). These surveys are described in more detail under 10. NFI (2012a) presented the health status of ash trees prior to the FC '*rapid survey*' (for ash dieback) in November 2012. The information summarised findings from surveillance of *ca*. 7000 one hectare squares in GB from November 2009 to October 2012. This is a partial sample of the planned 15,000 squares to be sampled and for which the results will be presented in 2015. No statistical adjustment was made to the data in this report to account for geographical and other factors.

The key findings were that in woodlands $\geq$ 0.5ha, ash had 3.5% dead trees compared to 7.2% of broadleaves as a whole; 1.2% of ash trees exhibited crown dieback compared to 2% of broadleaves as a whole, and, that ash is the main contributor to the regeneration of young trees in broadleaved forests accounting for 40% of observed broadleaved seedlings/saplings[3].

FC (2013) also presented results from specific re-surveillance of a sub-sample of NFI survey sites for ash dieback. This subsample was of sites in October 2012 which had records of ash in woodland $\geq$ 0.5ha where symptoms had been recorded that were indicative of possible infection (crown dieback and higher than expected mortality levels). A later sample was done (in November and December 2012) of sites with apparently healthy ash when previously surveyed. Where symptoms were observed that were indicative of infection, samples were taken for diagnosis. The results showed that 2 of the 469 sites surveyed contained infected ash trees, 1 in England on '*older*' ash trees in the wider environment and 1 in Scotland on young ash trees. None were found in Wales. This is a '*snapshot*' of observable disease in the last quarter of 2012 in British woodlands containing ash and was intended to complement the other systematic surveillance for ash dieback, which found many more locations of the disease.

More detail of findings in the UK arising from the ongoing systematic surveillance is given below. The pest has been found in nurseries, recent

[3] The term seedling is used interchangeably with sapling in this document

plantings[4] and the wider environment. The situation in the UK in March 2013 is summarised in Table 2. A distribution map of findings in the UK and a summary of the situation can be seen on the Forestry Commission website: http://www.forestry.gov.uk/chalara

The NFI studies indicate that, overall, the levels of disease in woodlands >0.5ha in GB which have been subject to FC inspection is low. However, there are clearly hotspots, as indicated by the findings reported from systematic and targeted surveillance.

In October and early November 2012, infection was confirmed for the first time in the wider environment in England. This was after the RA (Webber and Hendry, 2012) was published. Findings were confirmed in long-established woodlands and hedgerows in East Anglia, Essex and Kent. The FC commented that the trees which are affected in East Anglia are in established woodland and do not appear to be associated with recent plantings of nursery-supplied plants. See press release: http://www.forestry.gov.uk/newsrele.nsf/AllByUNID/85414CC87C34610F80257AA1004C4FA2.

Northern Ireland (NI)

Within the UK, the pest status in NI is different (*transient, actionable under eradication*) to GB (established in parts – R. McIntosh, Defra, *personal communication*, 2013). Specific comments are made here.

DARD commenced surveys for ash dieback on nurseries and garden centres in August 2012, as well as on young plantings in October 2012, working with the Forest Service. The first findings of infected material were confirmed in NI in November 2012 at a recently-planted site. In response to this finding, a revised surveillance plan was initiated in November 2012. This focuses on recently-planted sites of ash in public and private woodland, roadside plantings, urban/amenity plantings, hedgerows/farm plantings, private gardens, established trees and hedgerows, as well as the ongoing surveillance of nurseries and garden centres mentioned above. Initially, the focus was on '*trees for planting*' and trees planted in the past 5 years. As of 25 March over 850 premises had been surveyed; 29 recently-planted sites and 3 nursery/retail/trade findings had been confirmed as having infected plants/trees, but there were no findings in the wider environment. On confirmation, affected ash and associated debris are destroyed and appropriate biosecurity measures are ongoing (S. Mayne, DARD, NI, *personal communication*, 2013).

[4] Recent plantings is defined as having been planted in the last 5 years; UK National Plant Protection Organisation, February 2013

All of the infected material in NI has been linked to imports from outside of NI and the ROI. The majority of the non-nursery sites were planted between 2010 and 2012; one site included material planted in 2009/2010 and 2010/2011 and it is unclear whether the earlier material was infected (J. Finlay, DARD, NI, *personal communication*, 2013).

See the DARD website for further detail and updates:
http://www.dardni.gov.uk/index/fisheries-farming-and-food/plant-health-for-northern-ireland-title-page/ash-dieback.htm

The overall situation in the UK on 25th March 2013 is shown in Table 2. The distribution of these sites is shown in Figures 1, 2 and 3 below.

Table 2. Number of findings of ash dieback in the UK (to 25th March 2013)

	Nursery	New Planting	Wider Environment	Total
Scotland	2	61	8	71
England	16	128	166	310
Wales	1	16	0	17
N Ireland	3	29	0	32
UK (total)	22	234	174	430

Of note is that, by the end of March 2013, there were no findings in the wider environment in Wales or Northern Ireland, with the majority of findings in all location types being made in England. Scotland has a relatively low number of findings in the wider environment.

Republic of Ireland (ROI)

The ROI targeted surveys and sampling for the pest from 2008 onwards in the following numbers of forest sites: 5 (2008), 28 (2009), 6 (2010) and 28 (2011) (DAFM, 2012).

Similarly to the UK, they also undertook ongoing general pest and disease surveys of a much higher number of forestry sites and forest nurseries.

The first findings of ash dieback were in October 2012, in a young forestry plantation in County Leitrim that had been planted with imported trees. The trees on this site and on the ten other sites planted with the same batch of trees were subsequently destroyed. See:
http://www.agriculture.gov.ie/forestservice/ashdiebackchalara/

Following this first finding, DAFM has undertaken a major survey of ash.

Table 3 outlines the current situation regarding confirmed findings in planted ash and nursery stock in the ROI. Surveillance and eradication action continues.

Table 3. Number of confirmed findings of ash dieback in the ROI (to 4 April 2013)

Location type	**Numbers of confirmed findings**
Forestry Plantations*	36
Horticultural Nurseries	15
Garden Centres	3
Private Gardens	2
Farm Landscaping Plantings/AEOS**	10
Roadside Landscaping Plantings	8

*Counties: Carlow, Cavan, Clare, Galway, Kildare, Kilkenny, Leitrim, Longford, Meath, Tipperary, Waterford
** Agri-Environment Options Scheme

It is thought that the initial affected plantations in the ROI were established from material imported from outside the ROI/NI and that these were planted in 2009 (J. Morgan, FC, UK, *personal communication*, 2013). However, there is some uncertainty regarding the dates of some findings and further investigations are underway to establish details (D. O'Leary, DAFM, ROI, *personal communication*, 2013).

In the ROI, the official pest status is currently considered to be '*transient, actionable and under eradication*' (G. Cahalane, DAFM, ROI, *personal communication*, 2013).

8. Is there any other reason to suspect that the pest is already established in the PRA area?
See the response to 7.

9. What are the pest's host plants? List natural and experimental hosts.
The RA (Webber and Hendry, 2012) listed natural hosts in a table, which is reproduced here but with some amendments (Table 4). The pest is only known to infect species of *Fraxinus* (ash). Koch's postulates have been completed for *Fraxinus excelsior* (Kowalski and Holdenrieder, 2009; Bakys *et al*., 2009), *Fraxinus angustifolia* (Kirisits *et al*., 2010) and *Fraxinus pennsylvanica* (T. Kirisits, IFFF, Austria, *personal communication*, 2013). Records on other species of *Fraxinus* are based on isolations of *C. fraxinea* from symptomatic plants/trees without completing Koch's postulates. *Fraxinus ornus* (Manna ash or south European flowering ash) was reported as a natural host in the RA (Webber and Hendry, 2012) but the record which was cited (Kirisits *et al*., 2009) referred to experimental susceptibility only; this is discussed below. The main hosts which have become affected in Europe are *F. excelsior* (common ash) and *F. angustifolia* (narrow-leaved ash).

Some less common species have also become affected. A small study of several Asian and American ash species planted in Estonia and *ca*. 40 years old showed that they were little or moderately affected, with the exception of black ash trees (*F. nigra*), which were badly affected. Green ash trees (*F. pennsylvanica*) were moderately affected (less evidence of dead shoots in the canopy). White and Manchurian ash trees (*F. americana* and *F. mandshurica*, respectively) were least affected (Drenkhan and Hanso, 2010).

Experimental susceptibility testing has mainly been limited to *Fraxinus* spp. As stated above, *F. ornus* has not been reported as a natural host, but it is experimentally-susceptible, although it seems to be less susceptible than other species. Kirisits *et al*. (2009a) wound-inoculated stems of one-year-old seedlings with *C. fraxinea*. This resulted in leaf wilting, dieback and necrotic stem lesions similar to those observed on *F. excelsior* in the same experiment. A repeat of the experiment resulted in no dieback and small necrotic lesions. The authors considered that *F. ornus* may be less susceptible than other species of *Fraxinus.* Kräutler and Kirisits (2012) showed that wound inoculation of leaves of seedlings of *Fraxinus* spp. with the fungus led to less leaf dropping on *F. ornus* compared to *F. excelsior* and *F. angustifolia.* They found similar amounts of necrosis and wilting to *F. angustifolia* but less than that exhibited by *F. excelsior*. Because of this and the fact that *F. ornus* has yet to be reported as a natural host the authors consider it may be immune/resistant to *H. pseudoalbidus*.

Table 4. Natural hosts of *Chalara fraxinea* (based on Webber and Hendry, 2012)

Host		**Family**	**Symptom/ location for detection**	**Location**	**Date sampled**	**Reference**
Scientific name	Common name					
Fraxinus excelsior	European or common ash	Oleaceae	Leaf wilting, shoot, twig, and branch dieback and bark lesions	Poland	1990s	Kowalski, 2006, Kowalski and Holdenrieder, 2009
Fraxinus excelsior Pendula	Weeping European ash	Oleaceae	Leaf wilting, shoot, twig, and branch dieback and bark lesions	Austria	2008	Kirisits *et al*., 2008, 2009
Fraxinus angustifolia	Narrow-leaved ash	Oleaceae	Shoot and twig dieback, necrotic lesions and bark cankers	Austria	2008	Kirisits *et al*., 2009a
Fraxinus angustifolia subsp. *danubialis*		Oleaceae	Shoot and twig dieback, necrotic lesions and bark cankers	Austria	2008	Kirisits *et al*., 2008
Fraxinus nigra	Black ash	Oleaceae	Wilting leaves, dieback and necrotic lesions of shoots and twigs, and canopy death	Estonia	2009	Drenkhan and Hanso, 2010
Fraxinus pennsylvanica	Green ash	Oleaceae	Wilting leaves, dieback, necrotic lesions of shoots and twigs, less twig dieback than black ash	Estonia	2009	Drenkhan and Hanso, 2010

Fraxinus americana	White ash	Oleaceae	Wilting leaves, minor shoot and twig dieback and bark necrosis	Estonia	2009	Drenkhan and Hanso, 2010
Fraxinus mandshurica	Manchurian ash	Oleaceae	Wilting leaves, minor shoot and twig dieback and bark necrosis	Estonia	2009	Drenkhan and Hanso, 2010

Reports of testing of other species are limited. For example, Kowalski and Holdenrieder (2009) investigated the pathogenicity of *C. fraxinea* to *F. excelsior* using artificial inoculation of stems under field conditions and included three stems of *Acer pseudoplatanus* (sycamore) and three branches of *Sambucus nigra* (elderberry). As with the ash controls, no lesions developed and the fungus could not be reisolated. Holdenrieder (Institute of Integrative Biology (IBZ), Switzerland, *personal communication*, 2013) advised that he had done a limited amount of unpublished work on stems of members of the Oleaceae (*Ligustrum vulgare* - privet, *Forysthia* sp. - forsythia, *Syringa vulgaris* - lilac, and *Olea europaea* - olive) and that these showed no necrotic lesions after stem inoculation.

The evidence of the behaviour of the pathogen in Europe indicates that the fungus is a highly virulent pathogen on *F. excelsior* and *F. angustifolia* and that it is pathogenic to some but not all other species of *Fraxinus*. Some species may be less susceptible than others. Among the European species, *F. ornus* is not currently known as a natural host of *H. pseudoalbidus*. There is no evidence of risk to other European woody plants.

There is some evidence of disease tolerance in the population of *Fraxinus* in Europe and this is discussed further within the PRA.

10. Which hosts are of economic and/or environmental importance in the PRA area?

The hosts which are of economic and/or environmental importance in the PRA area (UK and ROI) are species of *Fraxinus*, of which the most common species is *F. excelsior* (common/European ash). *F. excelsior* is native to the PRA area where it is of significant ecological importance (Peterken, 2013) and where it is also planted for landscaping or grown for timber. It is found in woodlands, scrub and hedgerows, occurring on moist soils but also on rock scars, cliffs and limestone pavement. In N. Scotland it is native on limestone and widely planted elsewhere (see weblink below). Its range is stable. Further details can be found at the Botanical Society of the British Isles (BSBI) website: http://www.brc.ac.uk/plantatlas/index.php?q=plant/fraxinus-excelsior

There are more than twenty other species of ash and numerous cultivars

(e.g. of *F. angustifolia*; *F. excelsior* 'Pendula') which are planted in the PRA area as ornamental species. However, their distribution is very limited compared with *F. excelsior* and they are mostly confined to landscaped environments and gardens. See the Royal Horticultural Society (RHS) website:
http://apps.rhs.org.uk/rhsplantfinder/plantfinder2.asp?crit=fraxinus&Genus=Fraxinus

Fraxinus excelsior: Maps
Maps of the distribution of *F. excelsior* from the recently-released NFI study of ash (FC, 2012b) are reproduced in this PRA, since these give a detailed illustration of ash prevalence; however this is only for GB (see Figures 2 and 3). For this reason, the BSBI tetrad map (used previously in the 2012 RA) has also been included to illustrate the prevalence of ash in NI and the ROI (see Figure 1).
http://www.brc.ac.uk/plantatlas/index.php?q=plant/fraxinus-excelsior

The BSBI map is incomplete for the ROI and does not reflect the full extent of the species distribution in the country as its completion is dependent upon the presence and activity of local BSBI recorders (D. O'Leary, DAFM, ROI, *personal communication*, 2013). More comprehensive ash distribution maps can be found in Section 10.

These host distribution maps are shown alongside the UK distribution maps of the confirmed findings of trees infected with the pest in recent plantings and the wider environment up to 25 March 2013. Updated maps combining both recent planting and wider environment sites are held at:
http://www.forestry.gov.uk/chalara#Distribution

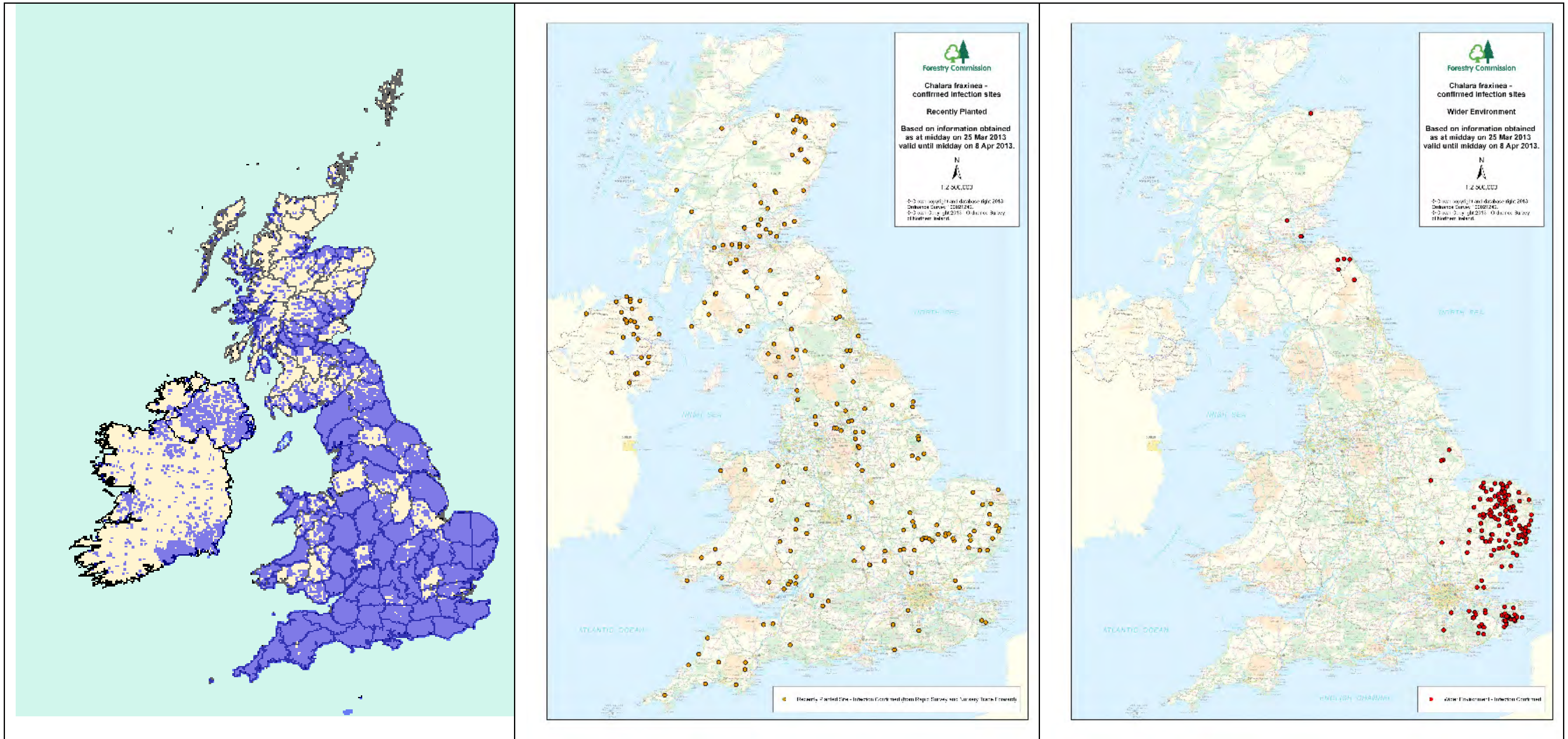

Figure 1. Left-hand side - BSBI Tetrad map (http://www.bsbi.org.uk/) - shaded areas indicate presence of *Fraxinus excelsior* in 10km squares over the UK as well as the ROI alongside the number of confirmed infected recently-planted sites in the middle and the number of confirmed wider environment sites on the right as of 25/03/2013

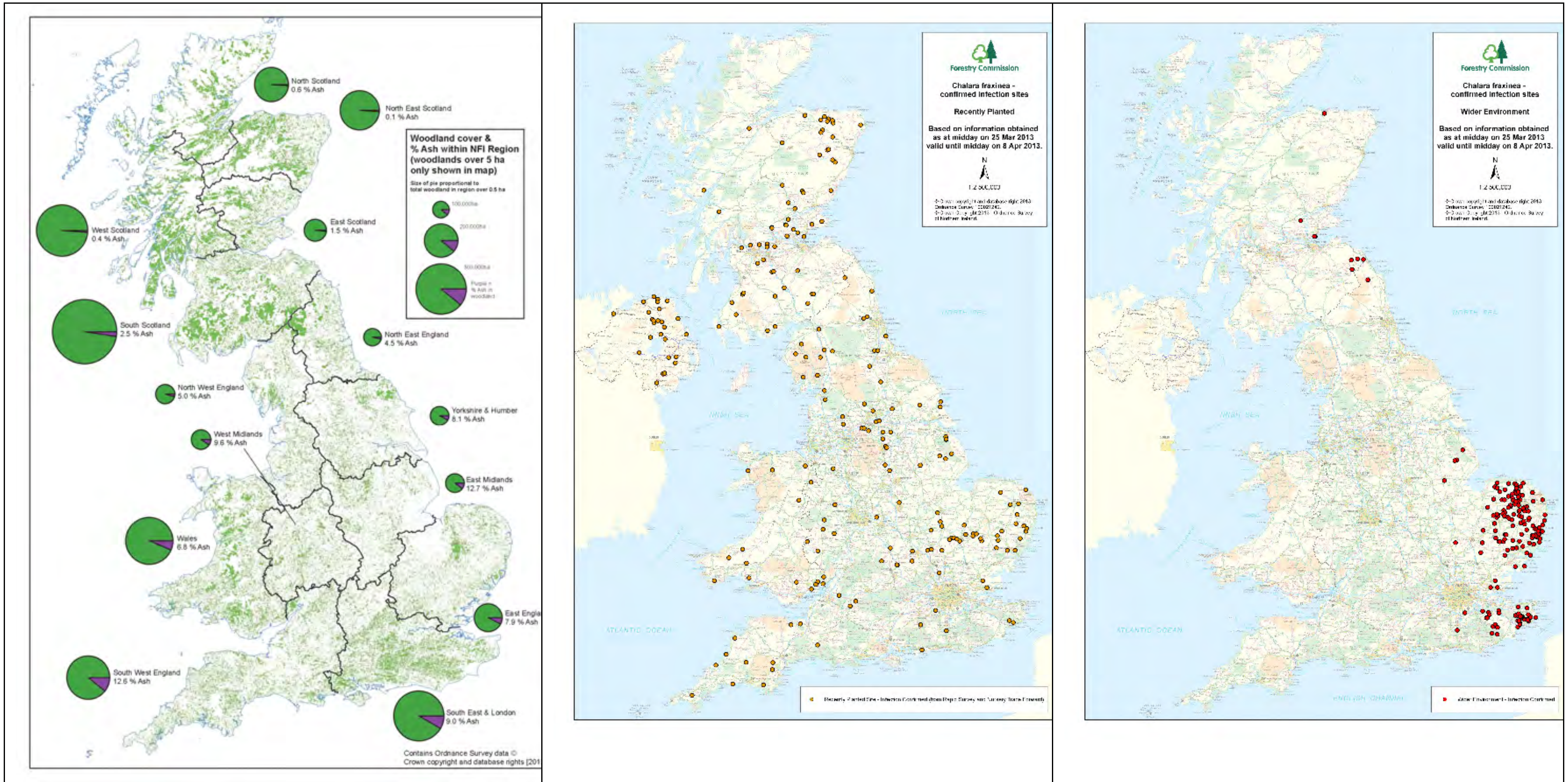

Figure 2. Left-hand side - Map 1, FC, 2012b - GB total woodland cover with proportion of ash by NFI region alongside the number of confirmed infected recently-planted sites in the middle and the number of confirmed wider environment sites on the right as of 25/03/2013

Figure 2 shows the proportion of ash found within all woodlands > 0.5ha within each NFI region of GB (FC, 2012b) in relation to the confirmed UK outbreak sites in recent plantings and the wider environment up to 25 March 2013.

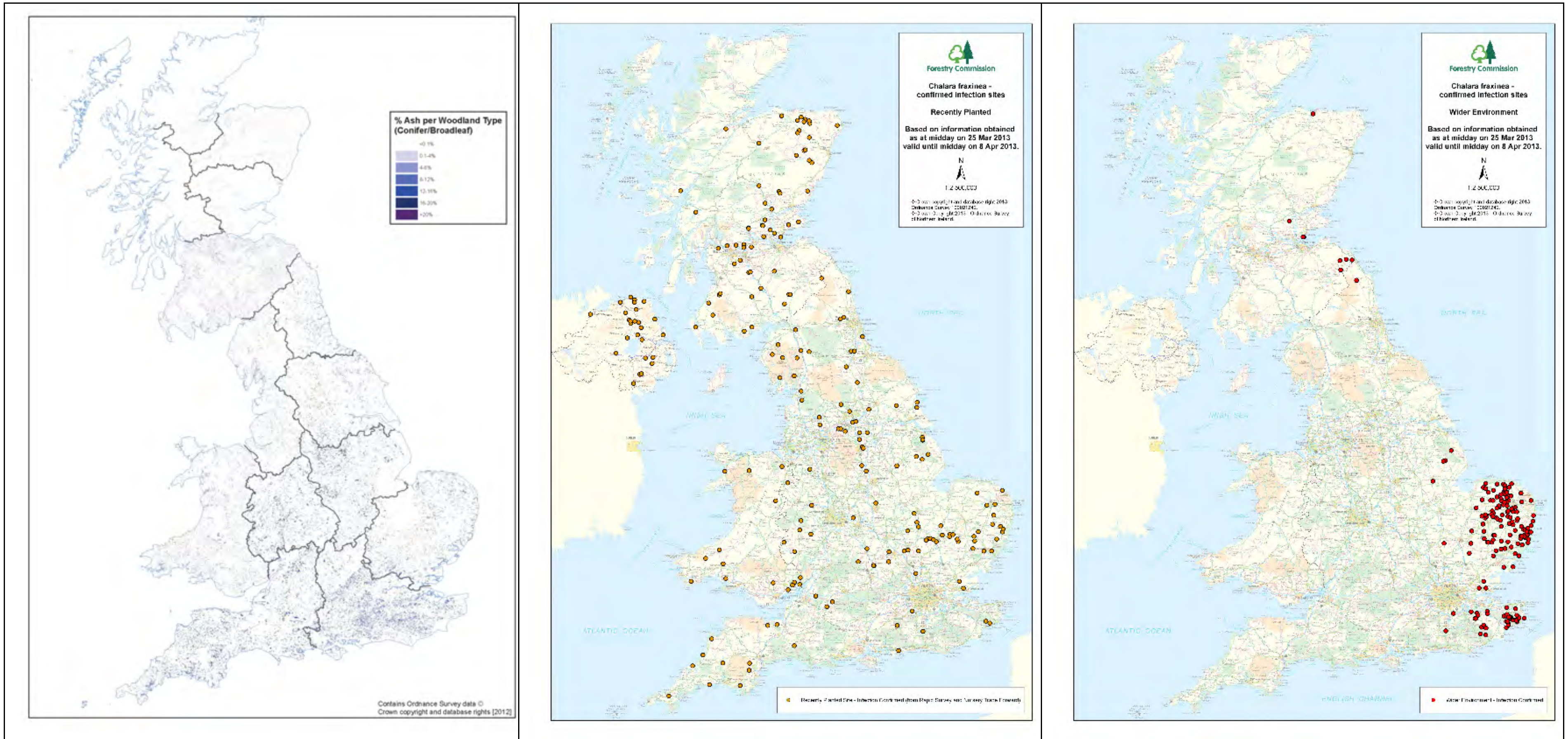

Figure 3. Left-hand side - Map 2, FC, 2012b - GB ash distribution (based upon % of ash per region by woodland type) alongside the number of confirmed infected recently-planted sites in the middle and the number of confirmed wider environment sites on the right as of

25/03/2013

Figure 3 shows the percentage of ash found within three woodland types $\geq$ 0.5ha identified within the NFI map for GB; broadleaved, conifer and young trees. (FC, 2012b) in relation to the confirmed UK outbreak sites in recent plantings and the wider environment up to 25 March 2013.

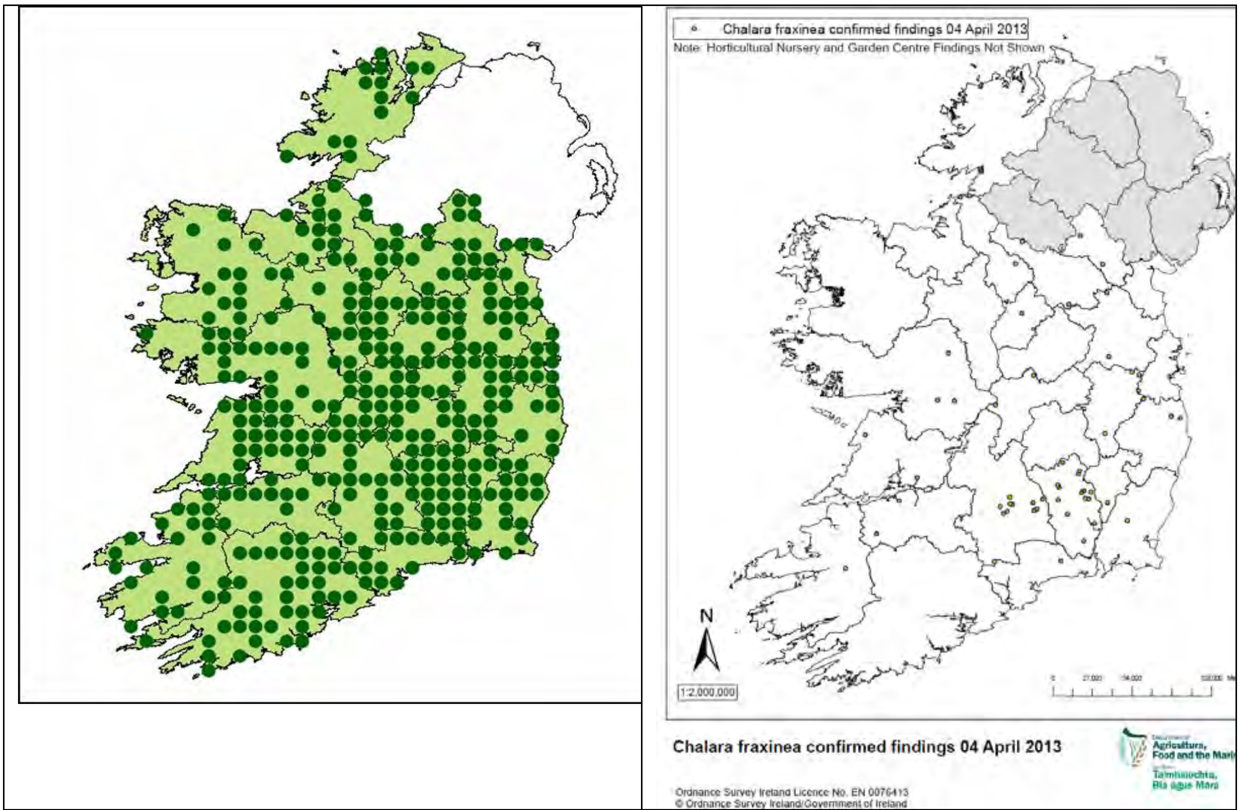

Figure 4. Distribution of ash dominated woodlands in the ROI on the left, distribution of confirmed findings (up to 4 April 2013) in recent forest plantations, roadside, farm and garden plantings on the right.

Figure 4 (D. O'Leary, DAFM, ROI, *personal communication*, 2013) shows the distribution of ash dominated woodlands in the ROI on the left (provided by J. Cross National Parks and Wildlife Service), alongside the confirmed findings of the pathogen in trees in forest plantations, roadside, farm and garden plantings, up to 4th April 2013.

Ash in Great Britain

Estimates of the stocked area, numbers of trees and standing timber volume of living ash (*F. excelsior*) trees in broadleaved forests and woodlands in GB as at 31 March 2011 as well as of the ash distribution were made in the NFI report (FC, 2012b). Forests and woodlands are defined in the report as: '*land predominately covered in trees with a minimum area of 0.5 hectares and minimum width of 20 metres'.* The report was produced based upon field surveys which (in this cycle of the NFI) started in 2009 and are intended to be completed in 2014. These data were intended to be published in 2013 but were published early because of the outbreaks of ash dieback. Thus, data are provisional. Ash represents 12% of broadleaved stocked area in England, 14% in Wales and 5% in Scotland. Within England, ash is considered to be most prevalent in the south-west, south and the Midlands. In Wales, it is more prevalent in the south than the north. Scotland has relatively low levels of ash north of the Forth and Clyde rivers; ash being more prevalent in the Scottish borders to the south. This reflects the natural range of ash, which is dependent upon the suitability of the site and environment. Land management practices can also have an influence, with ash being favoured on some sites but not others.

Estimates of quantities of ash in relation to all broadleaved species for England, Scotland and Wales, and individual regions within England and Scotland, each broken down by FC and private sector ownership, as well as individual age and size classes of the broadleaved and ash tree populations were also presented in this report (FC, 2012b).

The main findings were stated (paraphrased in italics) as:

- *The estimated stocked area of broadleaves within GB is 1.3 million hectares of which 142,000ha is ash (comprising 11% of all broadleaves and 5% of both conifer and broadleaves)*

- *There are* ca. *1.4 billion broadleaved trees in GB woodlands of over 0.5 hectares, of which ash trees are estimated as* ca. *126 million*

- *In addition, there are* ca. *4.2 billion broadleaved seedlings and saplings in GB private sector woodlands, of which ash constitutes* ca. *39% (1.6 billion)*

- *Total broadleaved standing volume in all woodlands of over 0.5 hectares in GB is ca. 240 million* m^3 *broken down as:*
    - *England - 182 million* m^3
    - *Scotland - 34 million* m^3
    - *Wales - 24 million* m^3

- *Total broadleaved standing volume on the private sector estate is* ca. *227 million* m^3 *and for the FC estate* ca. *13 million* m^3*.*

- *Ash accounts for approximately 14% of total broadleaved standing volume in GB*

- *Ash tends to be younger and slightly smaller than broadleaved species as a whole:*
    - *Ash trees aged between 20 and 100 years account for most broadleaved standing volume; very little ash is > 80 years old*
    - *Most broadleaved standing volume is contained in stands of trees ranging from 10-60 cm mean diameter at breast height*

(dbh); for ash standing volume is mostly found in stands with lower mean dbh

A separate report which is complementary to FC (2012b) and which was also produced in response to the findings of ash dieback in the UK provides estimates of the numbers of ash trees in woodlands in GB <0.5ha (Maskell *et al*., 2013) The main findings (also paraphrased in italics) are:

- *The area of ash in broadleaved woodlands of <0.5ha is* ca. *3,851,000 ha.*

- *Ash is found in fields, field boundaries, alongside rivers and streams and particularly in hedgerows*
- *Ash is the 2nd most abundant tree species in small woodland patches (<0.5ha) after oak, split as:*
    - *England - 321,000ha*
    - *Scotland - 44,000 ha*
    - *Wales - 199,000 ha*

- *There are* ca. *2.2 million individual ash trees (outside of woodland) in the countryside; ash is the second most common species of individual tree*

- *Most ash trees were in low to mid-range dbh categories i.e. >40% between 21 and 50cm dbh with very few veterans*

- *Ash is the most common hedgerow tree*

- *The estimated length of hedgerows and lines of trees composed of ash is 98.9 thousand km across GB, mostly being in England (86.1 thousand km)*

- *Ash trees increased in number of plots occupied on linear features (including hedgerows) between 1978 - 2007 and in the number of area (field) plots occupied between 1990 - 2007*

A draft report being prepared by Defra (Smith *et al.,* 2012, *unpublished draft*) in response to the ash dieback outbreaks provided the following preliminary information on the baseline value of ash, most of which relates to GB and some of which is only for England. This report is not yet complete, so the findings stated below are therefore provisional:

- The Gross Value Added of ash-specific commercial activity based on Office for National Statistics data is £22m p.a.

- Ash comprised 8% of all hardwood going to UK sawmills and 0.13% (in 2011) of all sawn wood (which is mainly softwood)
- Of 2.634 million ha of forest land, *ca*. 5% comprises ash; 70-80% of '*woodland ash*' is not managed for timber
- *ca.* Half of ash saplings/young trees planted in the UK are imported; the annual value to UK importers of trading young ash trees is tentatively estimated at up to £300,000
- Woodlands and trees provide a range of ecosystem services. The societal and environmental values of these are partially estimated at around £1.8bn p.a.; of which ash is estimated to contribute £150m p.a.
- Ash is a major component of 665 Sites of Special Scientific Interest (SSSIs) in England

A detailed report has also been compiled on the potential impact of ash dieback in Scotland (Worrell, 2013) and this also gives an account of the values of ash. The findings of the report are summarised under section 19. of this PRA.

The distribution of ecologically-important ash in GB was described in Annex B of the Defra Interim Control Plan for the disease (Defra, 2012). *'Important'* ash locations were described as '*significant and hard to replace or recreate semi-natural features with a strong role in ecosystem functioning'.* In addition to the 665 SSIs these locations included:

- Special Areas of Conservation (SACs)
- Ancient woodland (wooded continuously since 1600) with ash as a significant component
- Veteran ash trees
- Ash which supports exclusively or significantly-dependent species

A map of these important locations superimposed with the then known sites of infected trees is reproduced as Figure 5.

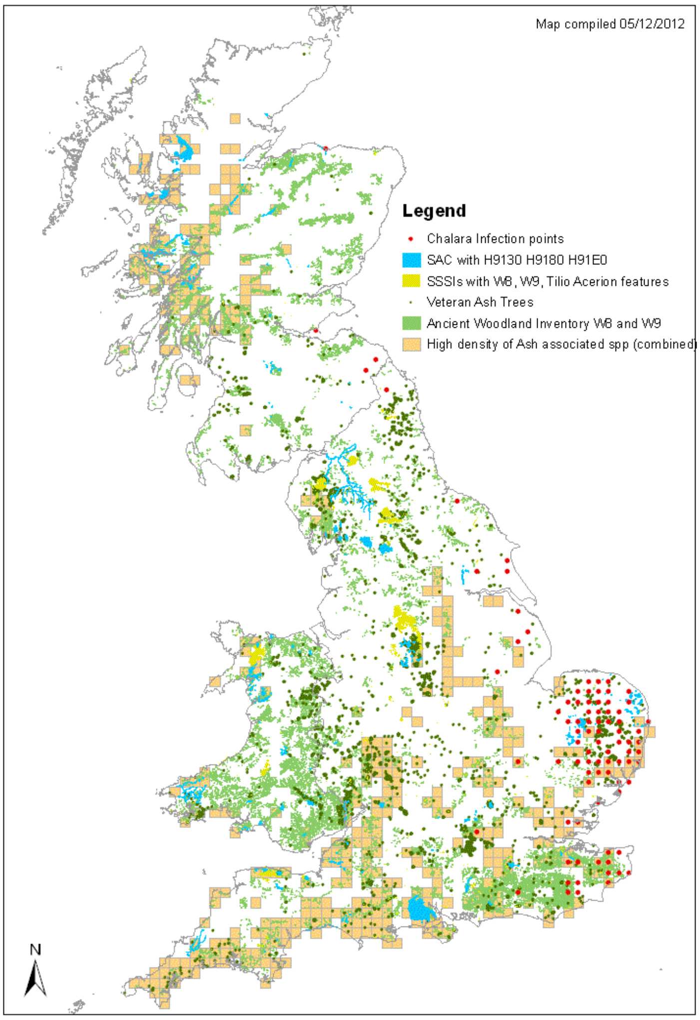

Figure 5. '*Proposed map of important ash locations*' with known outbreak sites at 5 December 2012. Reproduced from Defra (2012). http://www.defra.gov.uk/publications/files/pb13843-chalara-control-plan-121206.pdf [See report for further explanation]

The map (Figure 5) shows that '*important*' ash occurs across much of GB in a wide range of habitats. In Scotland, the distance between these locations is greater than in the rest of GB. These sites are ecologically-important and may become the focus of future management activities to try to protect them from *H. pseudoalbidus* where this is considered feasible.

Urban trees are also important, for example:

- There are 9,450 ash trees in the London Borough of Hackney; 3,500 in the Borough of Islington http://www.hackneygazette.co.uk/news/thousands_of_ash_trees_at_risk_fromnew_disease_in_hackney_1_1735033
- The London Borough of Lambeth has more than 1,500 ash trees http://tradescant.blogspot.co.uk/2012/11/ash-dieback-in-lambeth.html

UK trade information

To inform discussion on ash dieback the Horticultural Trades Association (HTA) conducted a survey of nurseries which both grow and trade in ash trees (HTA, 2012, *unpublished*). A summary of the findings can be found on the HTA website at:
http://www.the-hta.org.uk/page.php?pageid=1025

The survey did not include landscape/construction businesses, which may import ash trees directly. The HTA estimated that there are 60-80 UK businesses which grow ash commercially. Most of the production is done by a few large businesses. Sixty-two per cent of ash-growing businesses have a turnover of <£2.5 million. They estimated that the value of ash trees held on UK nurseries at the time of the survey was £2.5 million (survey identified £2.1 million) representing 2.5 million trees with most (2.1 million) being 1-2 year seedlings. The HTA estimated that 1.5 million ash trees had been imported by the nursery trade over the previous 12 months and 4 million since January 2009. Again this does not include imports made directly by contractors, and it is estimated that this would add an additional 2 million trees per year. Therefore, imported ash could represent as much as 3.5 million trees per year, which could be as high as 60% of the market for nursery trees.

Northern Ireland: NI

Information on the importance of ash in NI was provided by DARD (S. Mayne, DARD, NI, *personal communication*, 2013):

'Ash is a common component of many native woods and makes an important contribution to biodiversity and wildlife habitat. It is popular for landscaping urban facilities such as car parks. It is grown commercially for its dense, strong but elastic, easily worked hardwood, which was traditionally and commonly used for making tool handles and furniture and sports goods. Usage has declined in these markets due to the scarcity of supply and advent of other materials, but the good-quality timber is still sought after for flooring and high-end, bespoke uses, although most ash timber is imported. It also makes excellent firewood, smoking wood and barbecue charcoal'.

Republic of Ireland: ROI

Information on the importance of ash in the ROI was provided by DAFM (G. Cahalane) and the National Parks and Wildlife Service (J. Cross); ROI, *personal communications*, 2013:

'*Ash (*Fraxinus excelsior*) is one of the most important tree species in Ireland. It is probably the most widespread tree, occurring in almost every 10 km grid square (Preston* et al*. 2002). In a recently completed survey (Perrin* et al *2009) it was recorded in 91% of native woodlands. As a result of its relatively open canopy, ash dominated woodlands have a rich shrub and herb flora and are the most species-rich of all Irish woodland types in terms of their associated vascular plants. Woodlands in which ash is dominant or co-dominant constitute about 30% of our native woodlands. These woodlands occur throughout the country, although they are concentrated on the base-rich, low-lying soils in the midlands and south. However, ash is also an important constituent of other woodland types, e.g. alongside streams in sessile oak woodlands, in alluvial woodlands, which also cover considerable areas. At a European level, ash-dominated woodlands have a highly restricted distribution, having their headquarters in Ireland and Britain with outliers in Northern Spain/SW France and locally on the coast of Norway (Cross 2003). They are therefore extremely important in a European context*'.

Additional information has been provided by D. O'Leary (DAFM, ROI, *personal communication*):

Figures from the National Forest Inventory (NFI, 2007) report ash accounting for 3.1% of the national forest estate on an area basis or 4.6% of the total number of trees. Indications from the current National Forest Inventory (data yet to be published) are that ash remains the dominant broadleaf species, comprising over 21,000 ha or 3.4% of the total forest estate. Figure 6 below shows the total areas of ash in forests by county on the left and proportion of ash by total forest area by county on the right.

In recent years, the species has represented 10% of all planting under Forest Service granted aided afforestation schemes (DAFM, 2012). Table 5 below shows the area of ash planted with afforestation grant assistance from 1990 to 2012. In today's terms, the equivalent establishment costs for this area would exceed €60 million and represent €123 million in premium payments to landowners over a twenty year period.

Table 5. Area of ash planted under granted aided afforestation schemes (1990-2012)

Period	1990-1999	2000-2009	2010	2011	2012	Total
Area (ha)	5,026	5,772	834	746	483	12861

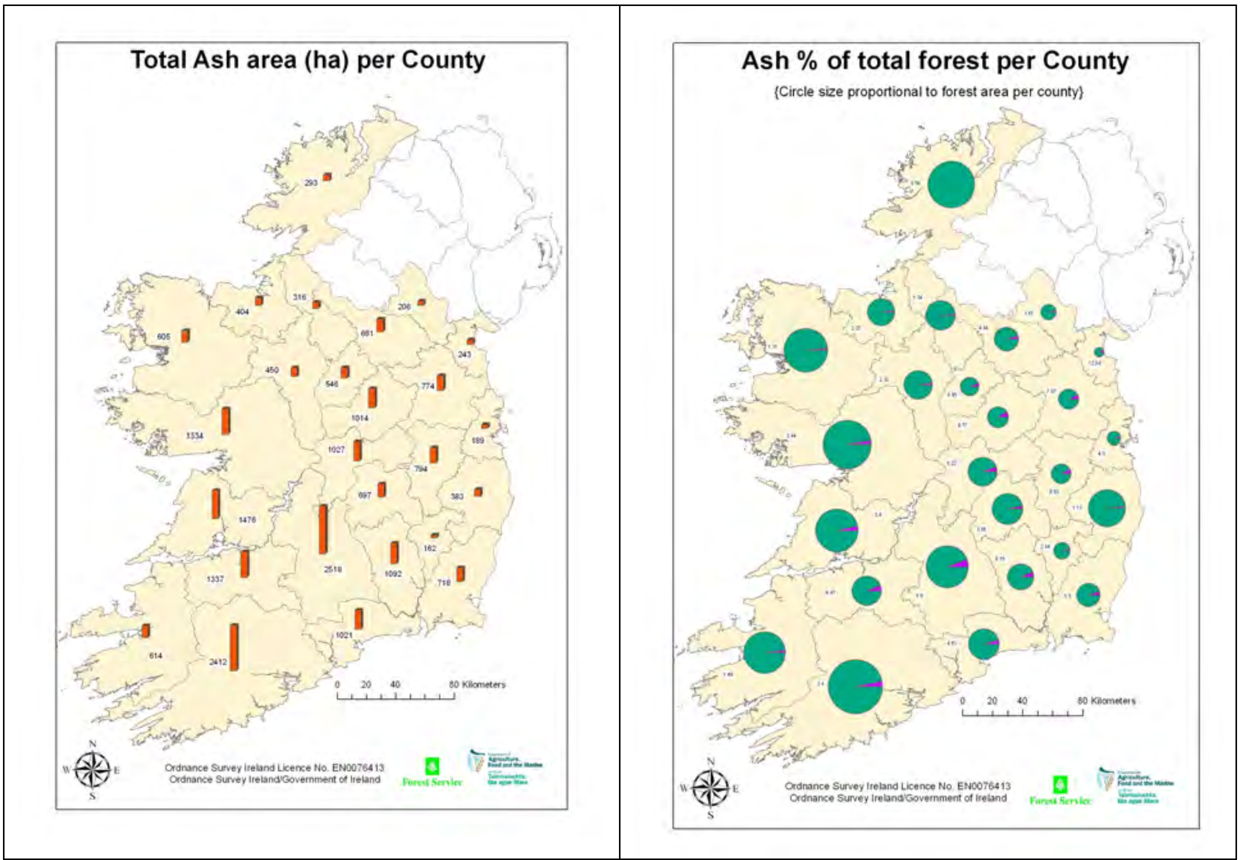

Figure 6. Total areas of ash in forests by county on the left and proportion of ash by total forest area by county on right based on National Forestry Inventory data.

The geographical distribution of these afforestation sites with areas of ≥ 0.5 ha of ash along with sub compartments containing ≥ 0.5 ha of the species in publicly owned forests managed by the State Forestry Company (Coillte) are shown in Figure 7 below. Details on an additional 5460 ha of non-grant aided ash forests in private ownership identified in the 2007 National Forest Inventory are not shown due to incomplete spatial data.

Ash is also a key species in Ireland's extensive network of hedgerows. Hedgerow surveys from 13 counties distributed across the country found ash to be the most commonly occurring tree species with ca. 50% occurrence average. This represents a very significant area of ash outside of forests, as hedgerows make up 3.9% of the land area of the country.

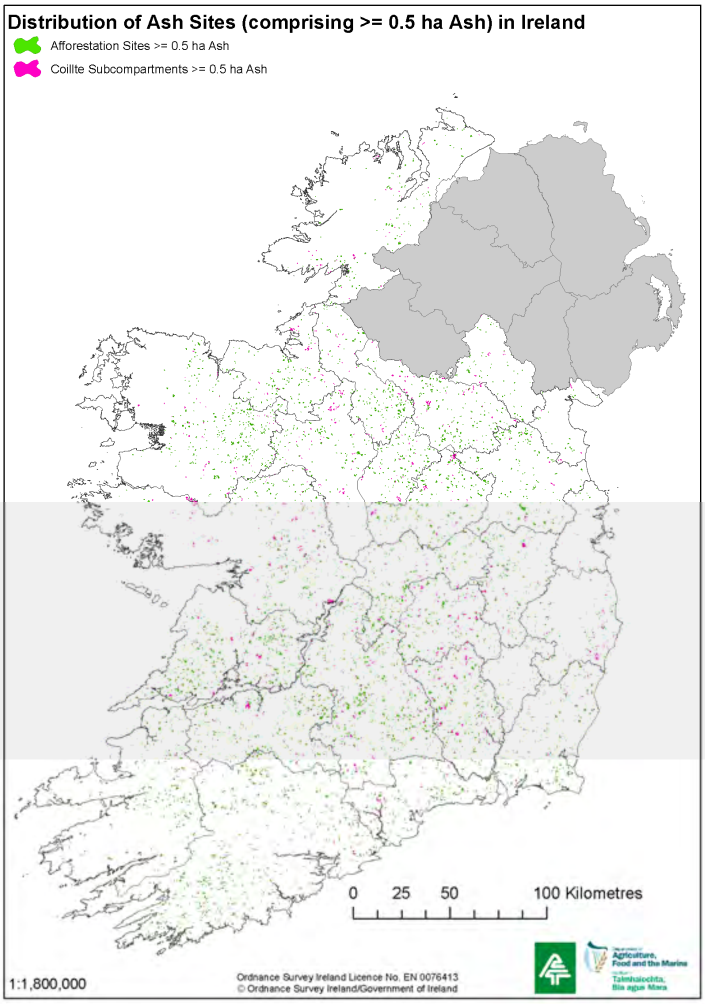

Figure 7. Geographical distribution of areas containing ≥ 0.5 ha of ash planted under afforestation schemes (1990-2012) and sub compartments in public forests managed by Coillte

Further information has been provided on the socioeconomic value of forestry to the ROI (D. O'Leary, DAFM, *personal communication*, 2013):

'Ash also confers a socioeconomic benefit as a component of the national forest estate. Forests contribute to the national well-being by providing recreational outlets (COFORD, 2006). They are the most important outdoor recreational facility in Ireland (COFORD, 2009). As tourism infrastructure they also contribute significantly to the economic output of the country (Fáilte Ireland, 2003). Fitzpatrick and Associates (2005) estimated 18 million visits were made to Irish forests generating €97 million in non-market benefits in 2005. The same study estimated the direct economic impact of forest recreation by Irish residents to be €268 million. Visitors to Ireland also make use of forest, with hiking/cross country walking the most popular activity taken by overseas visitors in 2011 (Fáilte Ireland, 2012), with over a half of all way marked walking routes on forest lands (COFORD, 2009). Forests are also used for

educational purposes, with educational trails and interpretative information available at many forests, helping to increase awareness of the physical and natural environment (COFORD, 2006)'.

NI and ROI

In Ireland, there is a long and strong association with the ash tree. D. O'Leary (*personal communication*, DAFM, ROI, 2013) stated that:

'*Historically, as outlined by MacCoitir (2003) the species played a significant role in the islands ancient folklore and cultural past. Today that link remains through the unique and specialist use of ash in the national sport of hurling, a sport with its origins dating back over 2000 years. The sport is a 15-a-side team game played with hurleys manufactured from the wood of ash trees with the term "the clash of the ash" associated with the sport. Participation in the sport contributes a significant socioeconomic benefit. For example, hurling remains one of the most popular sporting activities in the ROI (The Irish Sports Council, 2011) with approximately 23 % of spectator attendances to sporting events associated with the sport (The Irish Sports Council, 2008). Camogie, the female version of hurling, is also very popular and jointly shares the highest sporting participation rates among females in the ROI (Cumann Camógaíochta na Gael, 2010*)'.

According to a newspaper article (O' Riordan, 2012) around 350,000 hurleys are manufactured in Ireland every year, about 65 per cent of which are made from imported ash (see 12. and 13. below). Synthetic material can be used but ash is preferred. O' Riordan (2012) commented that the Gaelic Athletic Association hope to be self-sufficient in ash by 2017 (i.e. rely on domestic production). An earlier publication produced by the Irish State body Teagasc (Culleton, 2006) has more detail on the importance of ash for hurley production. The wood of ash is preferred, since it is strong and flexible with good shock absorbency. Although three-quarters of the ash timber used for hurley production was imported (from European countries – see 12. and 13.), Irish ash was preferred due to its particular properties, which are attributed to the mild and damp climate. Ash used for hurley production can be harvested from thinning operations whilst retaining the final timber crop to maturity. At the time of writing, ash supply was forecast to increase with increased demand for wooden hurleys and grants and premiums available for growing ash as a timber crop. This 2006 report also states that wooden hurley production was estimated at *ca.* 350,000 with the 2012 report implying little change in demand. Estimated return to the grower from cutting 500 hurley butts per hectare through thinning was €10,000 leaving the main timber crop still standing. Harvesting in fast-growing plantations was feasible 20 years after planting from straight and branch-free ash.

<u>Environmental importance of ash</u>
In addition to the direct economic importance of ash as a timber species, it is a highly important species in the environment. A draft review of the potential implications of ash dieback on biodiversity and conservation (Broome *et al*., 2012 *unpublished draft*), a similar report by Kirby (2012) and recent articles by Edwards (2013), Bosanquet (2013) and Stubbs (2013) give more detail. A forthcoming JNCC report (Mitchell et al. 2013) will provide an update on the impacts to other species and the ecological importance of ash.

The key points from these reports are:

Broome et al. (2012):
This report listed UK '*priority species*' whose survival is highly dependent upon ash:

Lower plants (mosses, lichens and liverworts*)*
- 130 lower plants are associated with ash woodland in GB,
- 60 out of the130 use ash trees as a habitat; bark is the substrate
- 40 of these 60 species require old trees with rough bark
- <10 of the 60 species colonise alternative substrates such as rock
- 15 of the 60 have only 1 other host species listed for GB, mainly oak or hazel
- 45 of the 60 use more than 2 tree species
- 3 species only use ash trees which are mainly growing in the open

Invertebrates
- 6 species are specifically dependent upon ash
- 3 species are strongly associated with ash wood as a habitat but are not ash-dependent

Fungi
- 2 species are specifically associated with ash trees, one of which uses dead wood and so it can use other trees as a substrate

Vascular plants
- 20 vascular plants are associated with broadleaved woodlands containing ash

Birds, mammals, reptiles and amphibians
- None are dependent on ash, but some species use ash, e.g. bats using cavities for roosting

Kirby (2012):
This report gives details of ash distribution and woodland types as well as the organisms which are dependent or associated with ash. Ash is important in many respects, not least because it produces abundant seed and can establish under a wide range of conditions. Consequently, it has filled gaps left by tree losses incurred through major events (e.g. Dutch elm disease and the devastating storm which occurred in the autumn of 1987). Kirby reported that at least 536 species of lichen grow on ash trees along with a '*suite of bryophytes*'. The mixed ash woods in northern and western Britain and non-woodland veteran trees are of particular importance in hosting lichens. At least 27 species of invertebrates were reported to use ash as a sole food plant. These figures are significantly higher than those quoted by Broome *et al*. (2012, *unpublished draft*). However both indicate that ash supports a high level of invertebrate biodiversity.

Edwards (2013):
Analysing data from the British Lichen Society based on records where the host information was given, he found:

- 536 lichens are recorded from *Fraxinus excelsior*
- 78 of the lichens are of conservation concern, either Red Listed Critically Endangered or Near Threatened
- For 10 species, ash is the principal host
- 2 species appear to be restricted to ash in Britain

Bosanquet (2013):
This paper states that "*a relatively small number of mosses and liverworts - three epiphytes and six species of Ash-dominated habitats with one overlapping these categories - are particularly vulnerable to ash dieback as currently understood*". He points out the "*significant potential for a reduction in epiphyte diversity and biomass in ecosystems where Ash currently supports abundant epiphytes*".

Stubbs (2013):
Reports that:

- Living *Fraxinus excelsior* is the sole food plant for 34 species of invertebrates (4 gall mites and 30 insects)
- A further 16 species have very few other food plants
- Thirty three species in the saproxylic fauna (of dead wood) are strongly associated with ash, 2 of which are seemingly dependent

Although the numbers given in the different reports vary depending on the data sources and criteria used by the authors, all indicate the high level of biodiversity supported by ash.

11. If the pest needs a vector, is it present in the PRA area?
The pest does not need a vector. *H. pseudoalbidus* spreads naturally via wind-blown ascospores which are released from fruiting bodies known as apothecia. With respect to the anamorph stage (*C. fraxinea*), there are other *Chalara* species which are known to have insect vectors, but these are unrelated to *Hymenoscyphus* species. Furthermore, there are currently no reports of an insect vector for *C. fraxinea* (Webber and Hendry, 2012). The conidia produced by *C. fraxinea* are not thought to play a role in dispersal (see 12.).

12. Describe the pathway(s) considered by this PRA[5].
There are four main potential trade pathways of (further) entry of the pest into the UK and the ROI, which are considered in this PRA. These are: a) Plants for planting, b) wood, c) seeds of *Fraxinus* spp. and d) contaminated soil/growing media as a commodity *or* with associated host and non-host plants, from countries where the pest is known to occur. These countries are listed under 6. Other than the UK and the ROI, the fungus is reported from at least 24 European countries (Austria, Belgium, Belarus, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Romania, Russia (Kaliningrad), Slovakia, Slovenia, Sweden, Switzerland, Ukraine) as well as from Japan. Movement of airborne ascospores from mainland Europe is also considered.

To understand the rationale for selecting these pathways (and to inform subsequent sections of this PRA), a description of what is known about the lifecycle/disease cycle is given below, followed by a summary of the main reasons why these pathways have been selected. The likelihood of entry is considered further for each pathway under section 13., with more detail of the evidence for the ratings.

Lifecycle/disease cycle of *H. pseudoalbidus/C. fraxinea*
Although the biology of the pest is not fully understood, the current understanding of the life/disease cycle deduced from the literature can be described as follows:

Wind-blown ascospores produced by the fruiting bodies of *H. pseudoalbidus* (Queloz *et al*., 2011) are considered to be the infectious spores (see e.g. Gross *et al*., 2012). These spores are released within diseased ash stands predominantly in the early morning, from summer to early autumn (Timmermann *et al*., 2011).

[5] A pathway description typically identifies a geographic origin, a host plant or plants and the intended use of the host. Other pathways including entry on other commodities or by natural means should be considered.

The small fruiting bodies, from which ascospores are released are known as apothecia; these are white to brown (depending on age) with a flat disc (1.5-3mm in diameter), being borne on a short narrow stipe (0.4-2mm long; 0.2-0.5mm wide). Apothecia are commonly found on blackened, pseudosclerotial ash leaf petioles from previous years in the leaf litter. They can also be formed on the shoots of 1-3-year old dead ash seedlings (Kowalski and Holdenrieder, 2009a), developing on dead ligneous (woody) parts of stems of nursery-grown plants (Kirisits *et al*., 2012). The apothecia usually occur at the stem base or at the root collar of the seedlings, but can also be present on dead, broken shoots and twigs in contact with the ground (Kirisits *et al*., 2012).

Most infections are thought to occur through leaves and leaf petioles/rachises, eventually causing dieback of shoots, twigs and branches on trees of all ages. However, symptoms of leaf infection can be inconspicuous on some ash species. For example, only limited leaf damage in the form of small necrotic lesions has been observed on naturally infected *F. angustifolia.*

Kräutler and Kirisits (2012) hypothesise that while the leaves are still attached to the tree, the normal course of leaf infection is for the mycelium to grow into the vascular tissue of the shoot causing necrosis in the phloem and subsequent discolouration of the wood. They suggest that only a small proportion of leaf infections might lead to shoot infection, since leaves are commonly shed before the mycelium has reached the xylem and phloem tissues.

The development of leaf symptoms following infection via ascospores has been proposed to take several weeks under field conditions (Kirisits and Freinschlag, 2012). Laboratory studies of the process of ascospore infection of leaves and petioles of 2-year-old '*seedlings*' of *F. excelsior* using light and electron microscopy showed that the spores germinate on these parts of the host to produce a single germ tube. An appressorium (germ tube swelling for attachment to the host) forms with mucilage thought to aid in adhesion. Penetration of the epidermis ensued. Hyphae were also observed extending into natural openings (e.g. leaf stomata). Putative conidia were also observed from terminal hyphae forming long chains. Hyphae were observed in the xylem, phloem, fibre and axial parenchyma cells. This is the first published observation of the infection process through the use of ascospores under laboratory conditions (Cleary *et al*., 2013).

Early leaf shedding following infection has been proposed as a means to escape further disease development, with clones of *F. excelsior* showing leaf senescence later in the autumn exhibiting higher levels of dieback (McKinney *et al*., 2011 in Kirisits and Freinschlag, 2012).

There is little evidence for infection paths other than via leaves. Husson et al. (2012), however, described infection of the collar and aerial roots of standing ash trees and suggested that ascospores may be able to infect trees directly via the bark. Whilst not considered to be a typical, systematically spreading vascular fungus (i.e. no linkages have been found in vessels between collar, branch and trunk lesions on mature logs), Husson *et al*. (2012) did detect the pest within the wood of logs, with trunk lesions mainly in the vicinity of infected sprouts or wounds. They consider that multiple infection events led to the pattern of infection which they observed.

Schumacher *et al*. (2010) studied the course of the disease on naturally-infected 3-year-old nursery saplings, detecting the pest within roots, but only when stem infection was detected (i.e. not in isolation from above-ground infections). They considered that hyphae can spread in all directions within the stem of young plants, from the point of infection; longitudinally in the pith and vessels and radially within the parenchyma. Infected tissue becomes necrotic and secondary fungi may colonise these parts of the host.

Cleary *et al*. (2012) detected DNA of *C. fraxinea* (*H. pseudoalbidus*) in ash seeds, but the route by which infection occurred is currently unknown and requires further investigation.

Symptoms of ash dieback are many and varied and include wilting of leaves (that may dry and remain on the shoots) and young shoots, shoot dieback, premature leaf fall, crown dieback and necrotic bark lesions of various colours but lacking exudates. Following infection, young trees die within a few years whereas in older trees the disease becomes '*chronic*', leading to secondary infection and colonisation by other organisms. Symptoms vary with the time of year. Damage caused by the pathogen may in part be related to its ability to produce secondary metabolites. Andersson (2012) detected 9 steroidal compounds in liquid cultures of the fungus, only 3 of which were known (viridiol, viridin and demethoxyviridiol) and 6 were previously unreported. Viridiol was shown to be damaging to seedlings of *F. excelsior* with higher levels of damage being recorded on seedlings of clones classed as susceptible to *H. pseudoalbidus*. For further details of symptoms see the Forestry Commission website: http://www.forestry.gov.uk/chalara

With respect to completion of the lifecycle, the blackening of infected petioles (rachises) is attributed to the production of melanised pseudosclerotia following infection by ascospores. Formation of the pseudosclerotia occurs during the winter period. The apothecia, which discharge the infectious ascospores, arise from the pseudosclerotia. Studies have shown that under field conditions the production of apothecia on pseudosclerotia can be delayed for at least 1 year, with air-dried pseudosclerotia surviving up to 3 months (Gross and Holdenrieder, 2013). Although the fungus does not produce an intact hardy resting spore (discrete from the host), natural survival as pseudosclerotia is postulated to be at least 2 years (Gross and Holdenrieder, 2013). The length of time that the fungus can survive in UK conditions in this form is unknown and requires investigation. However, this form of the fungus would allow it to persist between seasons, and, to delay further spread when conditions for fructification, dispersal and infection might be unfavourable, such as during a dry summer. Inoculum can therefore build up in the leaf litter, which can contain sclerotised rachises for a few years. Movement of fallen infected petioles or other material with associated pseudosclerotia/apothecia thus poses a risk of spread.

H. pseudoalbidus is heterothallic (outcrossing) requiring opposite mating types for sexual reproduction; these can arise on a single petiole (Gross *et al*., 2012).

The asexual spores produced by *C. fraxinea* are known as conidia; these are extruded in chains or more commonly in slimy droplets (Kowalski, 2006). They are not commonly observed in the field and appear to have no vector (Kowalski and Holdenrieder, 2009a). Gross *et al.* (2012) discuss their role in the disease cycle based upon other publications, stating that they are observed on leaf petioles in the autumn but also occasionally on infected sapwood, and, on necrotic lesions on ash twigs and stems. They state that it is unclear whether they have a dispersal role or whether they act as spermatia (male gametes) but the latter appears to be at least part of their role. Gross *et al*. (2012) showed that a single ash petiole can be colonised by many genotypes of *H. pseudoalbidus* resulting from multiple infections by ascospores. The ensuing production of a pseudosclerotial plate allows the pest to overwinter inside the infected petiole, with fertilisation of opposite mating types mediated by conidia (acting as spermatia) which are produced on the petiole in the autumn at low temperatures. The production of apothecia the following spring/summer (or if delayed in adverse summer conditions, 2 years on) completes the cycle.

<u>*Rationale for pathway selection*</u>

Prior to the RA being published and prior to the first findings of diseased plants and trees in the PRA area, various authors cautioned that plants of ash (and related material) originating in areas where the pest occurs posed the main risk of entry into geographically-isolated areas where it was then considered to be absent (i.e. the PRA area):

Queloz et al. (2011) stated that: '*We assume that the ash dieback pathogen is transmitted by airborne ascospores at the continental scale. In addition susceptible* Fraxinus *species have a very large and continuous distribution area in Europe. Therefore we do not believe that costly phytosanitary campaigns can stop the epidemic on the European mainland. However, long-distance dispersal, e.g. with* ***infected plant material****, to yet disease-free countries which are clearly separated from epidemic regions by natural barriers, might be prevented by quarantine measures*'.

Van Opstal (2011) wrote that '*Although data is still lacking on the exact role of* C. fraxinea *in ash dieback, EPPO member countries have increasingly become aware that ash dieback is emerging in Europe and that there may be a risk in moving* ***diseased*** **F. excelsior** ***plants*** *across the region without any precaution'.* Also that *"Although questions regarding spread mechanisms still remain, it is likely that natural spread is the most important factor on the continent. However, for endangered areas which are not yet infested, its introduction (GB, IE) or spread can be slowed down by preventing spread associated with plants for planting.* ***Plants for planting*** *which are produced in nurseries outside infested areas from* ***disinfested seeds*** *and traded in spring (to avoid trade of asymptomatic plants) pose a lower risk'.*

Kirisits *et al.* (2012) wrote: '*Plant quarantine measures for* ***nursery seedlings*** *(import bans, imports from confirmed disease-free areas only, plant inspections, plant passports and certifications) may be effective to avoid or delay the movement of the ash dieback pathogen to geographically isolated parts of Europe such as the British Isles and to other continents. However, the long incubation period in the disease cycle of ash dieback makes inspection of ash plants extremely difficult. Import bans for nursery seedlings and possibly other commodities (for example* ***ash logs*** *and* ***timber****) and thus closing potentially dangerous pathways would be the most effective measures to avoid the movement of* H. pseudoalbidus*, but are difficult to enforce politically'.*

Timmermann *et al*. (2011) wrote: '*As the ash dieback epidemic is associated with a high density of the pathogen, and the epidemic expanded rather quickly to neighbouring regions in Europe, it is likely that the* ***airborne ascospores*** *predominantly facilitate the long-range dispersal of* H. pseudoalbidus*, rather than the conidia embedded in mucilage-like droplets. It is likely that trade with* ***diseased nursery seedlings*** *also accelerated the spread of the ash dieback pathogen.*

Shoots of diseased ash seedlings can occasionally carry apothecia of H. pseudoalbidus. *In addition,* ***infected ash petioles may be transferred together with bare-root and container-grown seedlings****. Although the importance of infected ash seedlings and petioles as pathways to introduce the pathogen into new areas is difficult to assess, it is probable that they played some role, particularly in creating new disease foci, large distances away from natural infection sources'.*

Selection of pathways is thus based upon the prevailing consensus in the literature prior to the first findings in the PRA area that plants of *Fraxinus* spp. and other infected plant material of *Fraxinus* spp., as well as contamination (e.g. with infected leaf rachises) of traded planting material, are the primary routes of entry of the fungus to what was then deemed a pest-free area (the PRA area). The addition of ascospores entering from the continent of Europe (as opposed to it spreading across the continent) as a potential pathway arose following new views expressed in the autumn of 2012 and more recently that the pathogen has or is entering the PRA area via this route (see Wentworth, 2012; Defra, 2013).

The pathways selected for assessment are described below:

a. Infected plants of *Fraxinus* spp. intended for planting are considered to be the main pathway of entry to the PRA area. EPPO considered this to be the main pathway of movement when they added *C. fraxinea* to the EPPO Alert List in 2007 (EPPO, 2007). All of the initial findings of infected plants/trees in NI/ROI along with (at least) the first findings in the UK were all linked to imported planting material. In December 2012 at least 136 of the 291 affected sites in the UK were considered to have resulted from the importation of infected trees (see http://www.parliament.uk/mps-lords-and-offices/offices/bicameral/post/post-news/chalara-fraxineae21/).

b. EPPO (2007) included wood as a possible pathway of movement in the information supporting the addition of *C. fraxinea* to the Alert List. Wood harvested from symptomatic infected *F. excelsior* has been shown to contain *H. pseudoalbidus* (detectable by PCR) (Husson *et al*., 2012).

c. Seeds of *Fraxinus* spp. are a potential pathway of entry of the pathogen to the PRA area. DNA of *C. fraxinea* could be detected in seeds of *F. excelsior* harvested from symptomatic infected trees (Clearly *et al*., 2012). There have been no studies to date as to whether infected seed can serve as a means of dispersal.

d. Soil/growing media containing leaf litter or other material of infected *F. excelsior* has the potential to harbour long-lived pseudosclerotia (Gross and Holdenrieder, 2013). Movement (importation) from areas where the pest is known to occur of contaminated soil/growing media as a commodity, *or* in association with plants for planting of host or non-host plants, poses a risk of movement of the pathogen.

e. Subsequent to the RA being published in August 2012 (Webber and Hendry, 2012), entry from continental Europe via wind-borne ascospores has been postulated to be a potential route of entry to the UK. Wentworth (2012) referred to the model developed by the University of Cambridge which has been used to support this hypothesis. The revised Defra '*Chalara management plan*' (Defra, 2013) refers to elements of the modelling work (University of Cambridge, 2013) and advises that more detail will be published at: http://www.plantsci.cam.ac.uk/research/chrisgilligan.html.

   Defra (2013) cite the University of Cambridge (2013) stating that '*The modelling work to-date indicates that: meteorological models strongly support the likelihood of airborne incursion - that is that the pathogen was carried by the wind across the Channel from Europe. Furthermore, the whole of the UK continues to be at risk from future airborne incursions either from continental or domestic sources of infection'.*

   In an unpublished paper (Castle and Cox 2013) the authors from the University of Cambridge provided further evidence to support the hypothesis for airborne incursion as a potential route for entry to the UK.

13. How likely is the pest to enter the PRA area[6]?

The pest has already entered the PRA area. Because of this, in recent months, the UK and the ROI have put national emergency legislation in place to try to limit (further) entry. This legislation is summarised in Table 6.

Although there are no specific phytosanitary requirements for *H. pseudoalbidus/C. fraxinea* in the EC Plant Health Directive (Anon., 2000) the ratings for likelihood of (further entry) on the first three of the trade pathways (plants, wood and seeds) described above are made with and without the <u>current</u> emergency legislation, in the latter instance accounting for other requirements for *Fraxinus* spp. that are already in

[6] Pest entry includes an assessment of the likelihood of transfer to a suitable host (ISPM No. 11, FAO, Rome)

place in the EC Plant Health Directive (Anon., 2000). These requirements principally refer to countries where an invertebrate pest, the Emerald Ash Borer (*Agrilus planipennis*) occurs. This includes Japan but does not include Europe. Such requirements are described under each pathway.

For plants (excluding seeds) the ratings given for the risk of entry with the current controls depend upon whether the requirements for importation (effectively a pest-free area (PFA) in the country of export) are declared as having being met and whether trade is facilitated because of this. Where imports are allowed from a PFA then the probability of entry will depend upon how effectively the PFA is implemented and so a range of probabilities is given for this scenario. In a Memorandum from the French Authorities to the European Commission in 2012 the following statement was made: '*The status of* Chalara fraxinea *as defined by NIMP No. 8 is: Present except in specified pest free areas. Based on the investigation under way since 2009, an area consisting in the 40 départements listed is to be considered free from* Chalara fraxinea*. The 40 départements cover 45% of the area of France*' (*personal communication* from Maria-Rosaria MANNINO, Vice Chief of Ministry of Agriculture, Agro-Food and Forestry, General Directorate for Food, Sub-directorate for Plant Quality and Protection, to R. McIntosh, Defra, UK; April 2013).

For wood, only part of the PRA area (NI and the ROI) has specific requirements for imports of wood of *Fraxinus*, which complicates the assessment of the risk of entry into the PRA area. However, quality requirements for wood entering GB equate to one of the options for phytosanitary requirements for wood entering NI and the ROI. The ratings assigned to this pathway are described in more detail below.

Table 6. Current legislative requirements for imported material of *Fraxinus* spp.

Item	Requirement for imports from the EU and third countries where the pest occurs	Part of PRA area	Statutory Instrument no./reference		Effective date
Forestry* and non-forestry plants of *Fraxinus* spp. for planting including seed	Must originate in pest-free area (PFA) for *C. fraxinea/H. pseudoalbidus*	Great Britain*	2707	Anon., 2012c	29/10/12
		England	2922	Anon., 2012b	14/12/12
		Scotland	326	Anon., 2012d	14/01/13
		Northern Ireland	392	Anon., 2012a	26/10/12
		Republic of Ireland	431	Anon., 2012	06/11/12
Wood of *Fraxinus* spp/	Must originate in pest-free area (PFA) for *C. fraxinea/H. pseudoalbidus* **OR** • Be squared so as to remove entirely the rounded surface OR • Be bark-free and <20% water content OR • If sawn (with/without bark) kiln-dried to <20% moisture content	Northern Ireland	400	Anon., 2012e	06/11/12
		Republic of Ireland	431	Anon., 2012	06/11/12

*GB Forestry order amendment covers non-forestry plants/seeds for Wales. It also has a requirement for parts of trees (branches/foliage but not wood) from 3rd countries to be accompanied by a phytosanitary certificate stating that the material originated in a pest-free area. If this trade exists, it is not documented. This pathway is not included in the PRA.

The rationale for the ratings and uncertainties applied to these pathways is explained in Appendix 1.

a. <u>Plants for planting of *Fraxinus* spp. excluding seeds from countries where *H. pseudoalbidus/C. fraxinea* occurs</u>

Ratings given are explained in the text below.

Likelihood of entry without current controls

Very unlikely		Unlikely		Moderately likely		Likely		Very likely	X

Likelihood of entry with current controls in place and no imports

Very unlikely	X	Unlikely		Moderately likely		Likely		Very likely	

Likelihood of entry with current controls in place and imports from a PFA

Very unlikely	X	Unlikely	X	Moderately likely	X	Likely		Very likely	

Infected plants for planting are recognised as the most likely route by which plant pests enter an area. This is because of their end-use which effectively introduces any organism that is present on the planting material into the location of planting. This is particularly important where the pest is not visible or not easily detected.

Imported planting material of *Fraxinus* spp. is destined for wholesale nurseries, garden centres and directly to those involved in landscape and amenity planting (Smith *et al*., 2012, *unpublished draft*).

In December 2012 it was thought that at least 136 of the 291 sites known to be affected in the UK resulted from the importation of infected trees: http://www.parliament.uk/mps-lords-and-offices/offices/bicameral/post/post-news/chalara-fraxineae21/

Without controls, the pest is very likely (with *low uncertainty*) to be present on plants for planting of *Fraxinus* spp. originating in countries where the pest is known to occur. This is because there are no phytosanitary requirements in the EC Plant Health Directive for *Fraxinus* spp., other than for plants originating from countries where Emerald Ash Borer (EAB; *A. planipennis*) occurs, to have come from a PFA or pest-free place of production. Such a requirement would not necessarily detect *H. pseudoalbidus/C. fraxinea* unless the plants were symptomatic when inspected for EAB. This may slightly reduce the risk of entry of plants of *Fraxinus* spp. from Japan in the absence of phytosanitary controls.

With the current controls, the emergency legislation has reduced the risks associated with the import of plants for planting of *Fraxinus* spp. to the PRA area, whilst only one country (France) is understood to have declared a number of areas free of *H. pseudoalbidus/C. fraxinea*. Whilst this requirement is in place and no imports take place, the pest is very unlikely to enter on plants for planting of *Fraxinus* spp. (with *low* *uncertainty*). Until recently it was possible that individuals who are travelling may bring small quantities of *Fraxinus* plants into the PRA area in their hand luggage, since the rules imply that, although this is controlled material, this would be allowed, provided the plants are free of symptoms of infection. There was a small risk that this could facilitate the entry of the pest (see Defra, 2009). The legislation has been amended to prohibit this exemption.

When a country where the pest occurs declares a PFA and imports are allowed, then the likelihood of entry will depend upon how effectively the PFA is implemented (see earlier comments cited from Kirisits *et al*., 2012 and van Opstal, 2011).

Where imports occur in the future, the likelihood of entry with the current phytosanitary controls could vary from being very unlikely to being moderately likely (with *medium uncertainty*).

As described below, although infection of plants of *Fraxinus* spp. can be symptomatic (which will help with inspections), it can also be asymptomatic:

Symptomatic plants and presence of the pathogen
Schumacher *et al*. (2010) studied naturally-infected 3-year-old containerised *F. excelsior,* isolating *C. fraxinea* (*H. pseudoalbidus*) from three hundred 3-year-old saplings with external symptoms described as: bark necrosis, death of terminal buds, and development of twin leaders. *C. fraxinea* (*H. pseudoalbidus*) was found in sapwood more than in roots (this was only seen when stems were infected) and occasionally in bark. Hyphae were detected in a range of tissues (parenchyma, pith and vessels – edge of discoloured xylem and phloem). The pathogen was not detected in asymptomatic tissue. Dal Maso *et al*. (2012) studied the presence of the pathogen in artificially-inoculated (with *C. fraxinea* (*H. pseudoalbidus*) mycelial plugs) 3-year-old containerised *F. excelsior* after they developed symptoms. They found hyphal colonisation in the phloem, paratracheal parenchyma and parenchymatic rays and to a lesser extent in the xylem.

Asymptomatic plants and presence of the pathogen
Kirisits *et al*. (2012) observed three-year-old '*seedlings*' of *F. excelsior* obtained from a forest nursery in Austria. In November 2010, these were considered to be '*disease-free*' based upon external inspection. These seedlings were potted-up and kept outside at the research institute. In late April 2011, 42% (196 of 464 seedlings) of the apparently '*healthy*' seedlings were symptomatic. Forty-one of the symptomatic seedlings were tested and *C. fraxinea* was isolated from all of them. As the

infectious ascospores of *H. pseudoalbidus* are not known to be released over the winter period, the authors concluded that the seedlings were already infected when potted-up. They commented that this was consistent with reports made by forest nursery managers who had selected healthy-looking ash seedlings in the autumn for sale in the following year, finding that they were diseased when inspected in the following spring. Thus, it seems that the fungus can develop within the host tissue over the winter months. Pseudosclerotia were shown to form on dead woody (ligneous) tissue of stems, shoots and twigs of *F. excelsior* in this study and produced apothecia of *H. pseudoalbidus* when incubated. Thus, the movement of healthy-looking material from areas where *H. pseudoalbidus* occurs to new areas could lead to the introduction of the pest.

Kirisits (T. Kirisits, IFFF, Austria, *personal communication*, 2013) commented that ligneous (woody) tissues bearing apothecia of *H. pseudoalbidus* always have black pseudosclerotia present (as happens with petioles/rachises) and these could be spotted by a trained inspector. He also commented that these structures have been observed on collars of dead '*seedlings*'[7] (and occasionally '*higher*' up the stem) around one to two years after the seedling has died.

Thus, the risk of entry is not from seedlings with pseudosclerotia present at the place of production, as these should be visibly dead when inspected. The risk arises from seedlings which have been recently infected when inspected and declared pest-free, and are subsequently moved to a new area.

He also explained the timing from infection to apothecial production as:

A seedling is infected in the spring or summer of year 1

- Visible symptoms (necrotic lesions) are seen either in the same year (late summer or autumn) or in the spring of the next year (year 2)
- Some of the '*seedlings*' may die in year 2, *H. pseudoalbidus* can grow down the root collar and in the roots; pseudosclerotia may develop on a low, but consistent portion of the seedlings
- Apothecia may develop on '*seedlings*' with pseudosclerotia in year 3; sporulation may continue on a portion of the '*seedlings*' with pseudosclerotia in year 4.

Kirisits commented that apothecia may develop in the second season after infection but that this would be rare.

[7] *'Seedlings'* is the term used by the correspondent

His observations support there being a risk of entry associated with asymptomatic planting material.

In terms of imports of plants for planting, during the period 2003-2011 when the pest was present in at least some of the exporting EU Member States, some 5.2 million bare-rooted ash plants were imported into the UK (see Table 7) (recorded as *F. excelsior for forestry purposes*).

Table 7. Number of UK imported ash plants (bare-rooted) from EU Member States registered on the Forest Reproductive Material database (updated* from Webber and Hendry, 2012)

Exporting country	**Year**									**Total**
	2003	2004	2005	2006	2007	2008	2009	2010	2011	
Belgium	30,000	7,800	11,000	400	0	15,000	47,200	32,500	136,000	279,900
France	155,125	7,000	400	22,200	0	0	700	0	1,000	186,425
Germany*	553,600	500,700	81,000	196,500	374,500	396,750	0	400,400	250,750	2,754,200
Hungary	0	0	0	0	0	0	4,625	0	0	4,625
Ireland	0	0	0	27,000	180,600	98,600	162,825	500	0	469,525
Netherlands	0	0	196,500	323,300	205,050	461,607	141,100	50,100	172,375	1,550,032
Total	**738,725**	**515,500**	**288,900**	**569,400**	**760,150**	**971,957**	**356,450**	**483,500**	**560,125**	**5,244,707**
% from affected countries	**75**	**97**	**28**	**35**	**49**	**41**	**1**	**100**	**100**	**60**

Grey shading in the table refers to the year *C, fraxinea* (*H. pseudoalbidus*) was first reported and then subsequently regarded as present in the exporting country. In most cases, symptoms were apparent on ash in the countryside before formal confirmation was made. *For Germany, ash dieback symptoms were first observed in 2002 but *C, fraxinea* (*H. pseudoalbidus*) *was* not confirmed until late 2006 (Schumacher *et al*., 2007).

The data in Table 7 show that the highest proportion ash plants imported between 2003 and 2011 were from Germany; a country which has been affected by the pathogen since at least 2002. Over the period, 60% of the plants imported originated in countries where the fungus is known to have been present. Although there has been considerable fluctuation in the overall percentage of plants imported from these countries, in 2010 and 2011 these represented 100% of imports. This planting material would not have been subject to specific inspection or testing for *H. pseudoalbidus*. The first known findings of the pathogen in the UK were in 2012 on plants imported from the Netherlands, another country where the pathogen is present (since at least 2010). This is likely to have been a major pathway of entry for the pathogen until the recent emergency legislation (see Table 6 and section 13.).

A HTA survey of UK growers conducted in November 2012 (HTA, 2012, *unpublished*) concentrated on imports from Europe (not specified as to whether this is EU only) and the responses indicated that imported ash could represent as much as 3.5m trees per year. This is significantly higher than the figures quoted in Table 7 but includes imports for purposes other than forestry, and, species of *Fraxinus* other than *Fraxinus excelsior.*

Separately, Smith *et al*. (2012, *unpublished draft*) estimated that between 2003 and 2011 approximately half of the ash saplings and young trees planted in the UK were imported, with an average of 580,000 plants per annum.

In terms of imports of plants for planting, for the ROI, between 2010 and 2012 the number of imported (bare-rooted) ash plants from EU Member States amounted to 650,000 based upon documents received by the authorities (D. O'Leary, DAFM, ROI, *personal communication*, 2013).

Table 8. Number of ROI imported ash plants (bare rooted) from EU Member States registered on the Forest Reproductive Material database

Exporting country	**Year**			**Total**
	2010	2011	2012	
Belgium	0	41,700	3,700	45,400
France	0	27,700	0	27,700
Germany	0	125,000	0	125,000
Netherlands	158,850	136,125	110,950	405,925
UK	0	54,304	0	54,304
Total	**158,850**	**384,829**	**114,650**	**658,329**

Grey shading in the table refers to the year *C. fraxinea* (*H. pseudoalbidus*) was first reported and then subsequently regarded as present in the exporting country

It is not known whether *Fraxinus* plants for planting are imported from 3rd countries such as Japan as this is not documented; so there are no figures. However, the requirement for a PFA also applies.

Irrespective of the variation in import data for plants for planting of ash, all sources show that there have been high volumes of ash imports which are currently subject to the emergency phytosanitary requirements. Trade poses a risk of further entry. France has declared some PFAs and these and any future PFAs in countries where the pest occurs will have to be established in a strictly-controlled manner if further entry is to be prevented. This is discussed in the Pest Risk Management section of this PRA.

b. <u>Wood of *Fraxinus* spp. with and without bark from countries where *H. pseudoalbidus/C. fraxinea* occurs</u>

The ratings given are explained in the text below.

Likelihood of entry without controls

Very unlikely		Unlikely	X	Moderately likely	X	Likely		Very likely	

Likelihood of entry with current controls

Very unlikely		Unlikely	X	Moderately likely	X	Likely		Very likely	

Imported wood of *Fraxinus* is destined for sawmills (for round wood – 20% of all hardwood is imported), as well as joiners and manufacturers (sawn wood, UK imports 80% of total consumption).

Separately, and not considered further as a pathway, '*woodfuel*' is imported for use as biomass in wood fuel generators and '*other*' fuel use. (Smith *et al*., 2012, *unpublished draft*). Biomass and other wood products appear to be a very low risk pathway of entry as indicated by the following correspondence (G. Hogan, FR, UK; *personal communication* to J. Morgan, FC, UK, 2013):

- Importers of woodfuel identified a single import of one container of ash from the Ukraine with no future planned imports; half of the container remains unsold due to public concerns about biosecurity
- Consensus between firewood importers is that they only import kiln dried material
- '*Large users*' of wood for biofuel ('*GW scale*' power stations) import wood pellets by the ship-load rather than chips or timber
- Almost all the wood chips being imported seem destined for barbeques and are non-ash species
- Some companies import sawdust and pellets for animal bedding

Wood waste which is chipped for mulching is not usually transported for long distances so this hasn't been considered as a potential pathway for entry into the PRA area. There is, however, a risk that this material could be a factor involved in the local spread of the disease within the PRA area (see 16).

Only Northern Ireland and the ROI have specific phytosanitary requirements for imports of wood of *Fraxinus* from areas where the pest occurs (see Table 6). These are for the wood to be accompanied by a plant passport or official statement stating that it originates from a PFA or the wood be squared to remove entirely the rounded surface, or be bark free with the water content < 20%, or if sawn (with/without bark) be kiln dried to below 20% moisture content.

Squaring-off will remove the bark, some of the sapwood and any twigs or leaves, this would remove the fungus at the surface of the wood but it could still be present within the wood (see comments below). There are no studies of the impact of kiln-drying on the fungus, but it is likely to be deleterious depending upon the process. Kiln drying is not an uncommon phytosanitary treatment option in the EU Plant Health Directive (Anon., 2000) where for example it is one of the options available for imports of oak from the USA against *Ceratocystis fagacearum* (synonym *Chalara quercina*) or for maple wood against *Ceratocystis virescens*. Kiln-drying is not a statutory requirement for wood (including firewood) entering GB from the EU, but the industry does kiln-dry timber and firewood for quality purposes and leaves and twigs will be removed during processing (J. Morgan, FC, UK, *personal communication,* 2013). There are requirements for wood of ash entering GB from third countries where EAB (*A. planipennis*) occurs; this would affect ash wood originating in Japan. Such wood must originate in a PFA for EAB (which would not affect the presence of *H. pseudoalbidus*/*C. fraxinea* unless symptoms were spotted during inspection), or it must be squared-off. Contamination with leaves and/or twigs is prohibited for ash material derived from third countries (such as Japan) (EFRA, 2013). There is currently no evidence of imports of wood entering GB from Japan but this does not mean it couldn't occur in future. The likelihood of entry on wood with and without controls is estimated as unlikely to moderately likely (with *high uncertainty*) because only part of the PRA area has implemented statutory requirements for wood and there are no published studies on the effect of kiln-drying of infected wood.

The detailed evidence for the presence of the pest in wood is given below:

Husson *et al.* (2012) investigated the presence of *H. pseudoalbidus* on samples of heart- and sapwood taken from the collar, trunk and branches (lower and upper crown) of ten symptomatic, mature, felled trees of *F. excelsior* in France.

Using a PCR test, *H. pseudoalbidus* was considered to be present in wood of all ten trees, but this was symptom-dependent and not found in all samples. The authors summarised their findings thus:

- It was not detected in discoloration located only in heart or sapwood
- It was detected in small bark lesions on trunks where they were linked to infected sprouts or associated with wounds

- It was also found in large bark lesions on the collar
- Separately, it was detected in the sapwood and heartwood of major roots on trees that exhibited collar lesions
- It was not detected in samples from healthy sapwood/heartwood

Table 2 of Husson *et al*. (2012) indicates that the positive samples came from sapwood with bark lesions on the collar (38% of 21 samples), trunk (44% of 3 samples), and the lower and upper branches (33% of 3 samples/64% of 22 samples respectively).

In the same study, sapwood pieces from PCR-positive necrotic wood discs from the collar (four) and root (one) of *F. excelsior* were incubated for 5-7 days in a humid chamber. Microscopic examination of the discs revealed phialides (conidial-bearing structures) typical of *C. fraxinea* on two of the collar discs and the single root disc. Isolations made from the three positive discs were confirmed positive for the fungus by PCR.

Husson *et al*. (2012) discussed their findings and commented that *H. pseudoalbidus* is not a vascular pathogen, since there was no connection between collar or branch lesions and trunk lesions and the organism was not detected in symptomless heartwood or sapwood. Also, the trunk lesions were mainly seen near infected sprouts or wounds. They also commented that conidia have not been observed to germinate *in vivo* or *in vitro* to date. Because of this they suggested that, although *H. pseudoalbidus* might be transported in infected ash logs, they did not consider that the data supported controls of ash logs as a quarantine measure; rather '*trimming the lower infected parts*' would reduce any possible risk. This may be of use for imports of ash wood for hurley production which use the lower part of the tree (see below). It is uncertain as to whether the pest would be able to survive kiln-drying of infected wood or if it could be liberated into new areas through the movement of kiln-dried or non-kiln-dried wood, since this would rely on the production of apothecia on the wood. Asexual conidia (which were observed in this study on wood discs) are considered to act as spermatia and there is a requirement for opposite mating types to be present for mating to occur before apothecia can be produced. This is theoretically possible on the same piece of wood but there are no published studies of the likelihood of completion of the lifecycle through this route.

In terms of the amount of ash wood that is imported into the PRA area there is limited information available because until the implementation of emergency measures in NI/ROI it has not been regulated. EFRA (2013) reported that there are a number of firewood merchants which import ash wood into the UK from other EU Member States. Volumes were considered to be fairly small, with one of the largest companies importing only around 1,500 tonnes per year. There are no records of ash firewood currently being imported from third countries. Regarding timber imported from Europe there is no evidence of trade in ash logs for sawmilling. Smith *et al*. (2012, *unpublished draft*) stated that between 2008 and 2011, the UK imported 15,000 to 20,000m^3 of sawn ash wood and exported 500m^3.

Imports of ash wood have been made into Ireland and NI for the manufacture of hurleys, used in the national sport of hurling, as well as ash for firewood (see DAFM, 2012). The imported wood comes in two forms: roundwood log '*butts*' and sawnwood. In either form, the material has to derive from the bottom 1.5m of the tree and include buttresses so as to capture the necessary curved wood grain pattern required for a hurley stick. Normally, the term '*roundwood*' would encompass the full main tree stem, but for hurley production it is the bottom section or '*butt*' which is of use. Due to the straight wood grain pattern, the upper portion of the main stem is not suitable for this purpose. Up to now, ca. 65% of the ash wood required for the production of *ca*. 350,000 hurleys a year has been imported. In 2006, all of the countries of origin for the imported timber were European, including some countries where the pathogen is known to be established: Romania, Poland, Czech Republic, '*other Eastern European countries*', Germany, and Britain (Culleton, 2006). Under the new regulations introduced under emergency legislation, the trade in certain ash wood products such as firewood and cut ash boards for hurley production has continued where they successfully meet the requirements. However, for some products such as roundwood log butts of ash, the new requirements have had more of an impact (D. O'Leary, DAFM, ROI, *personal communication*, 2013). The potential risk posed by this trade should be reduced by the emergency measures.

c. Seed of *Fraxinus* spp. from countries where *H. pseudoalbidus*/*C. fraxinea* occurs

Ratings given are explained in the text below.

Likelihood of entry without current controls

Very unlikely		Unlikely		Moderately likely	X	Likely		Very likely	

Likelihood of entry with current controls in place and no imports

Very	X	Unlikely		Moderately		Likely		Very	

unlikely				likely				likely	

Likelihood of entry with current controls in place and imports from a PFA

Very unlikely		Unlikely	X	Moderately likely		Likely		Very likely	

To date, there is one published study which suggests that there may be a risk of entry of the pest on seed harvested from infected trees of *F. excelsior*. Cleary *et al*. (2012) harvested seeds from the current and previous year from trees with branch and stem dieback in Latvia and Sweden. Samaras (ash keys) were surface-sterilised before they were opened and the seeds were cut into pieces for testing for the presence of DNA of fungal species including *C. fraxinea* (*H. pseudoalbidus*) using nested-PCR. Thirty different fungal taxa, ten of which were identified to species level, were detected overall. *C. fraxinea* (*H. pseudoalbidus*) was found in 8.3% of all* of the current year's seeds but only from the Latvian site. *(NB: 24 seeds from one Latvian tree, 24 from one Swedish tree). No isolations were performed, so the viability of the organisms that were detected is not known, although work is ongoing for *C. fraxinea* (*H. pseudoalbidus*). Seed viability was also not tested. It is not known whether the pest could be transmitted through to seedlings or whether it could successfully establish from infested seed in any other way. Despite these uncertainties the presence of the DNA of *C. fraxinea* in a low percentage of seed from one symptomatic tree suggests there is a <u>moderate</u> risk of seed posing a risk of entry without controls (with *high uncertainty*). With the current controls and no imports it is <u>very unlikely</u> to enter (with *low uncertainty*). However, if a PFA was declared and imports took place there would normally be a requirement for seed originating in a PFA to be tested and to be found free of the pest. In these circumstances, provided the sampling and testing protocol is robust, it is <u>unlikely</u> to enter with *low uncertainty.*

In terms of imports, seed of *F. excelsior* has been imported from European countries where the pest occurs. Germany has been the main source of seeds, but France has also sent seed. The data in Table 9 were provided by J. Morgan (FC, UK, *personal communication*, 2013). Imported seed is considered to be '*low volume*' and is destined for wholesale nurseries where plants are raised directly from seed (Smith *et al.*, 2012, *unpublished draft*).

Table 9. *Fraxinus excelsior* seed export notifications from EU Member States - kg seed (source Forestry Commission).

Country of origin	2003	2004	2005	2006	2007	2008	2009	2010	2011
Germany	0.1[1.]	0.1[1.]	25[2.]	10[3.]	nd	20[4.]	70[5.]	--	--
France	--	--	--	--	nd	--	--	--	2.5[6.]

[1.] Non-commercial lots; [2.] Seed stand material: Stand number 811 02 North Germany
[3.] Seed stand material: Stand number 811 07 South Germany; [4.] Seed stand material: Stand number 811 02 North Germany
[5.] Seed stand material: Stand number 811 02 North Germany; [6.] Seed stand material: Stand number 901
nd = no data

d. Contaminated soil or growing media as a commodity or with associated plants for planting (hosts/non-hosts) from countries where *H. pseudoalbidus/C. fraxinea* occurs

Likelihood of entry

Very unlikely		Unlikely		Moderately likely	X	Likely		Very likely	

H. pseudoalbidus/C. fraxinea is moderately likely to enter the PRA area on this pathway (with *medium uncertainty*). This is because *H. pseudoalbidus* produces pseudosclerotia on infected petioles of ash which will facilitate survival of the fungus in the leaf litter. This material could contaminate soil or growing media originating in areas where the fungus occurs. Contaminated soil or growing media as a commodity or associated with non-host plants could enter the PRA area, since there are only limited, non-specific measures in place that regulate only elements of this pathway as described below.

Soil/growing media as a commodity
The introduction of soil and growing media as a commodity is prohibited from third countries (Article IIIA 14; Anon., 2000). These measures are entirely effective for preventing the entry of *H. pseudoalbidus/C. fraxinea* in material of this type from Japan (as it is prohibited), but not from Europe where the pest occurs. However, there is uncertainty as to the volume of trade, as there are no data on the importation of soil/growing media as a commodity from Europe (Sansford *et al*., 2009).

Soil/growing media attached to plants for planting
If imported planting material of hosts or non-hosts has contaminated soil or growing media attached to it there is a risk of introduction of the fungus. Plants for planting of ash have to originate in a PFA and if this is effectively controlled then the risk should be minimal. Non-host plants are not subject to regulation for *H. pseudoalbidus* and if they originate in

an area where the pest occurs the soil or growing media could become contaminated with infected leaf litter.

Annex IV AI article 34 (Anon., 2000) has a list of requirements for soil and growing medium attached to or associated with plants originating in third countries such as Japan where the pest occurs, but not for plants originating in Europe. Some of these requirements (e.g. the option for fumigation) may have some efficacy against the pest but this remains unproven.

There are some (similar) phytosanitary requirements to try to prevent the entry of other pests such as nematodes with soil/growing media attached to some plant species (other than *Fraxinus*) originating in Europe, but only for a few species. Again the efficacy of these requirements against *H. pseudoalbidus* is not known.

Non-host plants for planting other than those grown as protected crops, with associated soil or growing media produced on nurseries in affected areas, currently pose the highest risk of entry. Provided they are free of leaf litter of ash, host plants originating in a PFA should pose a reduced risk on this pathway if this trade occurs.

e. Natural entry by airborne ascospores of *H. pseudoalbidus* from countries in continental Europe where the pathogen occurs

Likelihood of entry

Very unlikely		Unlikely		Moderately likely	X	Likely		Very likely	

The overall rating assigned to this pathway (originating in continental Europe) is moderately likely with medium uncertainty. The reasons are set out below.

Background and assessment of the pathway

Subsequent to the publication of the RA (Webber and Hendry, 2012), this pathway has been postulated to be a route of entry from continental Europe into east and south-east England. This was most recently referred to by the University of Cambridge (2013) in Defra (2013). The model used to support this hypothesis has been partly described by Castle and Cox (2013, *unpublished*). It is based on NAME; the UK Met. Office's '*Numerical Atmospheric-dispersion Modelling Environment*'. The Met. Office developed this tool to model a wide range of atmospheric dispersion events:

http://www.metoffice.gov.uk/research/modelling-systems/dispersion-model

In order to assess the likelihood of entry on this pathway the route by which the pathogen spreads naturally within an affected area is described in the context of potential movement across the English Channel and/or the North Sea into the PRA area:

i. Ascospores of *H. pseudoalbidus* are liberated from apothecia produced on infected leaf debris and dead twigs/shoots in the litter layer on the ground at an infested site in Europe
ii. They are lifted from the ground into the wind which carries some of them out of the infested site (proportion escaping from the canopy)
iii. The portion which escapes the canopy travels on the wind blowing in the direction of and passing over the UK, including over an area of ash trees
iv. The spores at step iii) survive extremes of temperature, relative humidity, UV light etc. for the period of time it would take them to travel
v. The surviving spores remain in sufficient concentration to allow them to arrive and be deposited in an area where susceptible plants/trees of *Fraxinus* spp. are present
vi. These spores are present in sufficient numbers to infect their host
vii. Conditions for infection and disease development are favourable at their destination

In addition to this series of steps, for successful establishment of the fungus, infections by two compatible mating types of *H. pseudoalbidus* would need to occur in sufficient proximity (same individual tree, leaf or individual trees in close proximity) to complete the disease cycle.

Taking each step in turn, some elements are likely to occur, whilst others are less likely and/or uncertain.

i) Release of ascospores at an infested site(s) in continental Europe

The apothecia which release the ascospores have been observed in the field between May and October in continental Europe, occurring mainly on fallen ash petioles/rachises in the fallen litter layer from the previous year, but also occasionally on fallen ash shoots and other plant parts. Dead saplings on nurseries have occasionally been observed with apothecia on ligneous stem tissue.

The evidence to date shows that ascospores produced by the teleomorph stage of the pathogen (*H. pseudoalbidus*) are wind-dispersed and have been trapped in high numbers from the air within stands of diseased ash (Timmermann *et al*., 2011).

ii) Proportion of ascospores escaping from an infested site(s)
Whilst it is clear that very high numbers of ascospores are likely to be present in infested tree stands there appears to have been no studies on the numbers/proportion of spores that escape the canopy and that will then be potentially subject to longer distance transport by turbulent winds.

Timmerman *et al*. (2011) showed that ascospores of *H. pseudoalbidus* were mainly released in ash stands in Norway between 6am and 8am, peaking at 7am. They suggested that the maturation of ascospores takes place mainly at night when air humidity is high; discharge of spores in the presence of morning dew was presumed to prevent spore desiccation, thus facilitating germination and infection. The wind tends to be less strong at this time of day but this will not always be the case.

Savage *et al.* (2012) employed a mathematical model to simulate the dispersal of wind-borne fungal spores (generic, not specific to any fungal species) to determine the proportion of fungal spores undergoing long distance dispersal during June and September, at various times throughout the day in Western Australia. They commented that fungal spores released during the hottest part of the day are more likely to undergo long-distance dispersal than those released at other times. They found that for spores which are released at sunrise <1% travelled 10km in either month of the simulation.

In addition to the timing of spore release, there are other factors that will determine the proportion of ascospores escaping from the canopy at an infested site. These include the height at which they are released, and the density of the vegetation surrounding the apothecia from which the spores are released. The fruiting bodies of *H. pseudoalbidus* mainly occur in the leaf litter, on ash petioles/rachises, twigs and sometimes on saplings, low down on stems close to the ground. Aylor (1986) describes factors that influence escape of fungal spores from a hypothetical tobacco crop canopy in which they are produced with escape being hindered where spores are produced near to the bottom.

iii) Distance travelled by the proportion of escaping ascospores
The distance over which ascospores of *H. pseudoalbidus* can be dispersed has not been studied. There are however several observations of the spread of this disease within continental Europe that suggest a stepwise pattern of spread (Timmerman *et al.* 2011; Pautasso *et al*. 2013).

Monitoring of the disease front within an area of Norway showed that symptoms of ash dieback appeared between 20 and 30km further afield each year over two years (Solheim *et al*., 2011). Whilst not providing clear evidence that ascospores can travel 20-30km the authors postulated that this was possible. There are also other explanations. The publication does not indicate whether there is a possibility that the pest may have been introduced to new areas via the movement of infected plants, leaf litter, etc. Correspondence indicates that in Norway (i) up to March 2012, spore trapping had only been undertaken within affected stands of ash, (ii) that the first finding of disease was on plants imported from Sweden and (iii) fast spread during the first year was considered to be from nursery plants (H. Solheim, *personal communication*, Norwegian Forest and Landscape Institute, Norway, 2012/13).

Luchi *et al*. (2012) found (*C. fraxinea*) *H. pseudoalbidus* in 2009 along the Italo-Slovenian border with subsequent detection westward *ca*. 50-60 km /year; by November 2012 it was present north of the Po river, in the whole of north-eastern Italy, but not south of the river (although declining ash is present).

Rytkönen *et al*. (2010) surmise that in Finland, the pathogen has dispersed first to the Åland archipelago, probably from Sweden or Estonia over the Baltic Sea, and then to mainland Finland. The authors did not explain this hypothesis further. The distances involved between infected sites are not mentioned. However, Fasta Åland, for example, is separated from the coast of Sweden by 38 kilometres of open water to the west.

In the early 2000's the disease emerged in Gotland, a Swedish island in the Baltic Sea, with the closest distance to land (another island, Öland) being about 70 km (R. Vasaitis Swedish University of Agricultural Sciences, Sweden, personal communication, 2013. At about the same time the disease emerged in the Åland islands of Finland, thus much earlier than it was detected in mainland Finland. R. Vasaitis considers that the disease came from mainland Sweden, situated about 40 km east because it is very unlikely that there was any import of ash plant material to those islands from the mainland.

In France, ascospores can be detected at least 400m from ash trees, with longer distances being studied. Data on spread from plantations are only circumstantial (estimated as 50-100km per year). France was not considered to have been initially infected by airborne spores from neighbouring countries since the disease focus in northern France was not at the border with Germany and it involved a plantation initiated in the mid-1990s, far away from any other source of infection. Imported planting material in the area had been brought in from Poland (B. Marcais, INRA, France, *personal communication*, 2012/13).

Pautasso *et al*. (2013) mapped the rapid increase in infected stands of ash in Switzerland between 2008 (20 records) and 2011 (117 records).

Austria witnessed "*a surprising and an amazingly rapid emergence of ash dieback, resulting in its occurrence across almost all of Austria within just a few years after symptoms were first observed*" (Thomas Kirisits, personal communication, 2013).

While none of the above reports provide direct evidence of long-distance travel of ascospores, there are a few cases of plant pathogens which are considered to have moved long distances (between continents) by wind-blown spores leading to successful establishment. Brown and Hovmøller (2002) reviewed the literature and concluded that these are primarily rust fungi dispersing by wind-blown pigmented uredospores. For fungal pathogens with relatively fragile spores (e.g. hyaline (colourless) ascospores), long-distance dispersal between countries or continents leading to successful establishment usually occurs by human movement of infected planting material (and sometimes, infected/contaminated plant products). A brief review of the literature did not reveal any firm evidence that ascomycetes producing hyaline or pigmented ascospores liberated from apothecia have been successfully introduced to new areas.

Castle and Cox (2013) state that: '*the distance over which airborne particles can disperse, once they have escaped the canopy layer, is a function of air currents, physical properties of the spores, e.g. their mass, and precipitation, which can curtail the dispersal through washout. One of the conclusions that is drawn from the NAME output simulations is that wind directions and strengths in Europe are capable of transporting spores over sufficient distances from Continental locations to UK sites*'.

Aylor (1986) gives examples from the literature of trapping a range of spore types above the English Channel and other expanses of water but cautioned that the viability of these spores was not tested.

iv) <u>Survival of ascospores on the pathway</u>

With respect to the likelihood of ascospores surviving in the atmosphere across the sea for the duration of travel, Castle and Cox (2013) state that: '*the key difference between the probability of local and long distance dispersal is* (therefore) *the length of time spores can survive for whilst being carried i.e. whether the spores are still viable when they arrive at their destination. This is included in the NAME model; the model only tracks viable spores*'.

There are no published data on the period of time, for which ascospores of *H. pseudoalbidus* remain viable in the absence of a host, and none on the factors which affect their survival. These spores are not melanised at the time of release, but before germination they melanise quickly in wet conditions. (*O. Holdenrieder, personal communication, 2013).* This makes them potentially vulnerable to environmental factors such as extremes of temperature, relative humidity and ultraviolet light. There are a number of studies in the literature that show that these factors negatively influence the survival of ascospores of ascomycetes in particular, *Sclerotinia sclerotiorum*. For brevity, the findings are not repeated here but see, e.g. Caesar and Pearson (1983) and Clarkson *et al*. (2003).

Castle and Cox (2013) state that '*Aylor (1986) claims that most spores will be transported within the mixed layer of the atmosphere and as a consequence should not experience lethal temperatures or humidities*'.

Within this comprehensive paper, Aylor (1986) provided a long and detailed account on the likelihood of spore survival whilst airborne. He considered that factors that need to be accounted for include:

- Ultraviolet (UV) light component of solar radiation (SR) (considered most lethal)
- Temperature
- Relative humidity

The combination of temperature, relative humidity and UV was considered to be particularly lethal to spores. Other factors that may influence their survival in travelling across sea water include sea aerosols/salt and ozone. There are no published data on the effect of these factors on ascospores of *H. pseudoalbidus*.

Castle and Cox (2013) recognise that: '*The key aspect of survival in relation to long distance aerial dispersal is widely recognised as being the UV tolerance of the spores. Here, hyaline spores are recognised as being less tolerant than pigmented spores*'. Citing Caesar and Pearson (1983) and tabulating the survival of a range of fungal spores including *S. sclerotiorum* ascospores, they indicated that strong solar irradiation (SI) led to 95% mortality of these spores in 3.05hrs; weak SI such as that experienced under heavy overcast cloud cover led to 95% mortality in 39.2hrs and moderate SI such as that experienced under light cloud led to 95% mortality in 6.1hrs. There are no equivalent data for ascospores of *H. pseudoalbidus*. However, to put this in context, Castle and Cox (2013) state that::

"Unpublished data from O. Holdenrieder suggests that the 95% mortality time (i.e. the time it takes for 95% of the ascospores to become unviable) is approximately 6 days. The spores were protected from UV and the daylight was *very diffuse*. *These limited results indicate likely survival of over two days of flight time in weak Solar Irradiance conditions, which is sufficient time for spore deposition from continental sources to reach the UK (M. Castle, University of Cambridge, personal communication. 2013). Furthermore, sensitivity analyses using NAME have shown that 12 hour*

survival times are sufficient for spores to reach the UK, and so any sequence of even slightly cloudy days is likely to allow spores to survive for long enough to reach the UK from continental sources".

v) Concentration of surviving spores arriving in an area of ash trees in the PRA area

Matt Castle (University of Cambridge, *personal communication*, 2013) stated that: "*Spores travelling in air blown by the wind are subject to very significant dilution before being deposited. However the key factor here is that a very small proportion of a very large number can still be very large. The initial spore numbers are not known. The Cambridge model explicitly does not model the actual number of spores that will land on the UK. Instead it considers where any spores that did manage to escape the canopy in continental Europe would be deposited in the UK. The deposition maps produced show relative spore density rather than absolute spore density, and it is this relative density that correlates strikingly well (in fact it is statistically significant) with the distribution of wider environment infection)*".

vi) and vii). Concentration of deposited viable spores is sufficient and conditions are favourable for infection and disease development at the end of the pathway

There are no published data on the concentration of ascospores which might be needed for infection to occur. Citing Timmermann *et al*. (2011), Defra (2013) states that '*trees are likely to need a high dose of spores to become infected*' but this paper does not deal with this aspect of infection biology.

In theory, one spore could lead to infection. There is however the requirement for infections by two compatible mating types of *H. pseudoalbidus* to occur in sufficient proximity for sexual reproduction so as to enable the fungus to complete the disease cycle, To date, this has only been demonstrated for infections by ascospores on the same petiole. If this is the case, then, for disease perpetuation, a relatively high concentration of ascospores would be required.

Observational information from infected wider environment sites has been provided by the Forestry Commission in the final drafting of this PRA.

Some of the findings in the wider environment sites in the east of England cannot be easily explained, since they are apparently remote from recently-planted sites (B. Jones, Forestry Commission, *personal communication* to J. Webber, *Forest Research*; 2012). It is these in particular which are assumed to have resulted from windblown ascospores arriving from Europe.

In Kent, observations from tree experts indicate that, unlike in East Anglia, there seem to be many locations where the age of the infections on young trees are very similar. The intensity of symptom expression in Kent is lower than in established woodlands in East Anglia.

These observations would fit a simultaneous and later infection event occurring in Kent rather than the gradual, but inevitably slow build up of disease from infected, recently planted trees.

'Observations from infected established woodlands in Kent have reported that there is lower intensity of symptom expression than in established woodlands in East Anglia. Symptom progression and distribution is generally uniform across sites with coppice and natural regeneration appearing to be most susceptible, these observations have generally been made in the area of higher ground north of Folkestone and Dover. The majority of these sites do not have any association with introduced planting material'. (J. Morgan and B. Jones, FC, UK, *personal communication*, 2013):

Investigations of ash trees in woodlands have been made by Forest Research at two wider environment sites in East Anglia to attempt to determine the timing of infection.

One wood in Suffolk had been planted-up from the late 1980s to the early 2000s (species not stated). Ash planted in 2004 is known to be infected. This site is close to major ports of entry and not far from the A12. One other (additional) route of entry to these sites for consideration is movement of vehicles from the continent with infected leaves (although this remains unproven). A wood in Norfolk, south-east of Norwich has not been planted-up at all (but the proximity to other planting sites is not stated). Confirmation of infection at both sites only dates back to 2010. However, evidence of changes in growth in affected ash trees along with lesions on coppice stems at the Norfolk site indicates that the pathogen has been present there since 2008. Stephen Hendry (Forest Research, *personal communication*, 2013) stated:

'Chalara fraxinea *was established to be, or have been, present in 15 of the 17 non-girdling lesions sampled from coppice shoots at* [the Norfolk site]. *In all cases, the initial development of such lesions had occurred in the period between cessation of radial growth in one growing season and its resumption in the following year. Occasional evidence of bark killing during the course of the growing season was detected and perennation of established cankers was observed in 2 cases. The majority of lesions* *which were examined had been initiated during 2010 / 2011 with a single lesion formed during late 2008 or early 2009'*.

Although the reasons for the decline in tree health at this site cannot be determined retrospectively, the report author considered that it was possible that this was related to increasing levels of foliar infection by *H. pseudoalbidus* over the period in question since severe premature defoliation of mature trees during the development of ash dieback epidemics has been noted in other countries (Hendry, 2013, *unpublished)*.

The presence of the pathogen in this area for at least 5 years (based upon Hendry, 2013, *unpublished)* may have led to infections of the wider environment sites in this area.

It is evident that there are still many uncertainties involved in the biology and the observational evidence associated with natural entry into uninfected areas. The organism is already established within parts of the PRA area so the rate of natural spread will now be epidemiologically more important than the potential for natural entry from outside of the PRA area.

14. How likely is the pest to establish outdoors in the PRA area?

Very unlikely		Unlikely		Moderately likely		Likely		Very likely	X

PRA area

As noted in section 7, the fungus has already established in parts of GB. The pest is very likely (with *low uncertainty*) to establish outdoors in other areas of GB. In NI/ROI, its status is "transient, actionable under eradication", but, irrespective of the success of the measures being taken, the potential for establishment is also very high since the hosts are widespread and the climate is very similar to the parts of GB where it is already established.

There is considerable potential for establishment in NI and the ROI beyond the recently-planted infected sites but the pattern of invasion will depend on the survival and reproduction of the fungus, whether or not it has already been moved to new areas and the movement of infected plants, seed and timber. For the ROI, imports of certain ash wood products such as a significant trade in kiln dried firewood and cut ash hurley boards are still taking place (in compliance with the new emergency regulations) and there is potential to import plants from a PFA. Although, there are uncertainties surrounding the risks associated with imports of regulated material and potential future establishment, there is very limited movement of ash plants within the ROI and this will help limit the risk of further establishment though traded material.

Great Britain
As evidenced by the number of outbreaks in the wider environment and the development of the disease in recent plantings, the climate in GB is favourable for completion of the life/disease cycle of *H. pseudoalbidus*. The host distribution is wide and frequent (largely contiguous) although there are some regional differences which will influence the rate of spread and further establishment (see 16). Host availability is not a limiting factor.

The current distribution of infected trees in the '*wider environment'* sites in GB is along the south-eastern seaboard, with a small number further north and west.
http://www.forestry.gov.uk/chalara#Distribution

This distribution may be related to an incursion of ascospores from the continent. It is not known when *H. pseudoalbidus* first entered the PRA area but recent investigations by Forest Research suggests it may have been here since at least 2008 (Hendry, 2013, *unpublished*). However, once an introduced plant pathogen has been in an area for some time it is almost impossible to determine where it first came in. This will influence the observed pattern of distribution.

Disentangling the reasons for the current distribution is not easy to achieve. Other factors to consider include:

- *Climate*
  The distribution of the wider environment sites in GB may reflect climatic conditions being more favourable for infection and disease development in these areas. Although this is not well understood at present, there are reports in the literature which give an indication of climatic influences. Bengtsson *et al.* (undated; citing others) state that the fungus appears to be suited to a colder climate, since cankers that are formed as a result of infection seem to grow more in the winter. The lower temperature limit for the fungus in culture was estimated to be 0.5°C (Bengtsson, 2013). A study of three-year-old nursery saplings also shows that the fungus can develop within the plants over the winter (see section 13. and Kirisits *et al.,* 2012). Extremes of soil water (drought or waterlogging) seem to favour the disease although this may be related to stress on the vascular system of infected trees resulting from internal infection. Koltay *et al*. (2012) described the disease in Hungary being more frequent on sites with frost-hollows, deep soil and ample water but also on forest sites which are drier than

average and exposed to extreme cold. Keßler *et al*. (2012) described the disease in monitoring plots in Austria. They found considerable variation in disease intensity between plots and found lower levels of disease in plots in eastern Austria compared to western Austria, commenting that the incidence of ash is lower in the east but also that the sites are usually drier.

Reviewing the literature as part of a study on the effect of heat treatment of saplings, Hauptman *et al* (2013) commented that the severity of the disease in Slovenia appears to be higher in sites with higher relative air humidity, relatively lower temperatures and little direct sun exposure. They indicated that the optimal temperature for colony growth of the fungus is around 20°C, whilst the production of conidia in the autumn at low temperature and the ability to induce necrosis in host tissues during the winter indicate that the fungus is cold-tolerant. Another cited study as well as their experimental results indicated that the fungus is intolerant of temperatures ≥30°C. They felt that hot dry summers would limit disease development.

The exceptionally wet summer of 2012 (between June and August it was the wettest since 1912) is likely to have favoured apothecial production. This is likely to have multiplied the inoculum levels increasing the risk of further establishment although rainfall may have limited dispersal.
See: http://www.metoffice.gov.uk/climate/uk/2012/annual.html

With respect to the recently-planted sites that have been confirmed as infected in GB (planted within the last five years), these are scattered throughout the mainland. As traceback/traceforward activities are not yet complete it is uncertain how many of these were directly-related to imports of infected material and how many became infected after planting. However, at least some have import connections (see http://www.parliament.uk/mps-lords-and-offices/offices/bicameral/post/post-news/chalara-fraxineae21/; which at the time – December 2012 - stated that at least 136 of the 291 affected sites in the UK resulted from the importation of infected trees).

Overall, the climate in GB has allowed symptoms to develop on infected trees in the wider environment as well as in recent plantings so it is not limiting establishment but might influence the severity of future disease levels.

Imported material

Traceback of sites planted with ash has been limited to those which were planted with material only up to five years ago; however, high volumes of planting material have been entering the PRA area over a longer period from affected countries when the fungus is likely to have been present. The destinations of this imported material are not available. However, if planted in the area where there is a higher incidence of sites in the wider environment this may have favoured the apparent concentration of these sites in the east of GB. In December 2012 it was thought that at least 136 of the 291 affected sites in the UK resulted from the importation of infected trees (see http://www.parliament.uk/mps-lords-and-offices/offices/bicameral/post/post-news/chalara-fraxineae21/).

Movement of infected ash debris

The fungus is known to survive in leaf litter. It is possible that movement of infected material may play a role in the introduction to the east of GB either within GB or possibly on vehicles entering GB from the continent (Channel Tunnel, ferry terminals etc). Some of the wider environment sites in Kent which appear not to have any association with newly-planted sites (planted in the last 5 years) are on higher ground north of the ports of Folkestone and Dover (J. Morgan and B. Jones, FC, UK, *personal communication*, April 22nd, 2013). One of the affected woods in Norfolk with infection thought to date back to at least 2008 (Hendry, 2013, *unpublished*) is close to major ports of entry and not far from the A12.

Surveillance

The findings in the wider environment stem from surveillance reports from a variety of sources (see sections 7 and 10). Follow-up wider-environment surveillance in the infected regions of the east and south east of Great Britain were better-targeted and more intensive than elsewhere in GB. As this would increase the apparent concentration of the infected wider environment sites, the findings from the NFI survey and the FC 'rapid survey' are a better quantitative measure of the relative distribution of infected sites (FC 2013).

Phytosanitary measures are currently limiting the import and movement of plants and seeds of *Fraxinus* spp. With respect to findings on nurseries, recently-planted sites and the wider environment, a summary of the action that has been taken to date was provided by Defra (R. McIntosh, Defra, UK, *personal communication*, 2013):

In 2012, eradication action was required at nurseries and recently-planted sites and containment was pursued on sites with infected mature trees. More recently (2013), the focus has been on continuing to trace infected sites (nurseries and recently planted sites) but eradication notices have mostly been served on nurseries. However, the emergency legislation prohibits movement of *Fraxinus* planting material from these sites thus helping to facilitate containment. Voluntary measures have been adopted on some infected wider environment sites where mature infected trees remain *in situ* and these will help restrict movement of leaf litter and wood from these sites. Since the pathogen is considered to be established in some parts of GB, in future such restrictions are likely to be replaced by non-statutory guidance (best practice to reduce the risk of spread and further establishment). Because planting material is not allowed to be moved, if disposed of carefully it should not pose a risk of further spread if it is infected.

In Scotland, an option to have a '*sheltered area'* approach for the north west of country, where statutory action will be taken on infected, recently planted sites (all host material) is proposed. A '*buffer area*' to the east of the sheltered area where statutory action to remove only symptomatic host material is also proposed. In both areas statutory action will also be considered if limited infections in the wider environment are detected. (J. Morgan, FC, UK, *personal communication*, 2013); Defra, 2013). This, along with the lower incidence of ash growing in the area could help to limit further establishment for the time being.

See:
http://www.forestry.gov.uk/pdf/FCSCHALARAACTIONPLANSCOTLAND.pdf/$file/FCSCHALARAACTIONPLANSCOTLAND.pdf

The risk of further establishment in GB overall is not limited by external factors and as such this is rated as very likely with *low uncertainty*.

Northern Ireland/Republic of Ireland
In NI/ROI findings so far have been associated with imported ash trees dating back to 2009 at the earliest (as far as is known), planted in forests, horticultural nurseries, private gardens and amenity landscape planting. Notifications and surveys of older established trees in hedgerows and woodlands have to date not led to disease confirmation. The plant health authorities consider the pest to be transient and are hopeful that they can eradicate it.

In NI, whenever ash dieback is confirmed, plants are not allowed to be moved from the site and no further planting of ash is allowed. Destruction of the affected ash plants and associated plant debris is required. As far as possible, leaf litter is being actively collected on affected sites and is destroyed by burial at an approved landfill site or by incineration. Ash trees in the vicinity of eradication sites will be monitored in a buffer zone surrounding the site. Infected plants on nurseries have also been destroyed (A. McMahon, DARD, NI, *personal communication*, 2013). Similar measures are being taken in the ROI.

If imports of host material on the main trade pathways continue to be regulated into this part of the PRA area and if surveillance continues then the pest status can be verified. Because the fungus produces long-lived pseudosclerotia which can be present in leaf litter following the removal of infected/suspected infected plants it is possible that it might survive in an area after clearance of infected host material. Longer-term survival studies of the fungus on infected material under field conditions would be needed to verify this. Ash remains present in the wider environment and surveillance in the spring of 2013 when winter dormancy of ash trees is broken will also provide information as to whether the fungus has progressed into the wider environment.

Since the hosts are widespread and the climate is similar to that in the pathogen's current area of distribution, the risk of potential establishment in NI and the ROI is rated as very likely with *low uncertainty*.

15. How likely is the pest to establish in protected environments in the PRA area?

Very unlikely	X	Unlikely		Moderately likely		Likely		Very likely	

Nursery-grown *Fraxinus* spp. is not normally grown entirely under protected conditions. *H. pseudoalbidus/C. fraxinea* is therefore very unlikely to establish under protected environments. If any part of the production process is undertaken in protected environments the pest could establish under those conditions.

16. How quickly could the pest spread[8] within the PRA area?

The ratings are explained in the text.

Natural spread

Great Britain

Very slowly		Slowly		Moderate pace		Quickly		Very quickly	
									X

NI/ROI

Very slowly		Slowly		Moderate pace		Quickly		Very quickly	
					X				

In trade

Great Britain/NI/ROI

Very slowly		Slowly		Moderate pace		Quickly		Very quickly	
			X				X		

Natural spread

The pathogen is established in the wider environment in parts of the PRA area (at least parts of GB) as well as being present on sites that have been planted up to 5 years ago. In GB, phytosanitary action has changed with an evolving situation and is currently limited to containment of planting material of *Fraxinus* spp. on infected recently-planted sites and nurseries based upon the emergency legislation. Further natural spread of *H. pseudoalbidus* in GB is very likely to be quick via the movement of windblown ascospores potentially released from May to October (period to be defined) alighting on and infecting the most commonly-occurring host, *F. excelsior*, whose distribution is wide and frequent. Whilst apothecia have not been observed in limited surveillance within the PRA area, ascospores have been detected in pollen filters sampled at 4 sites in England between 2010 and 2012 within the period of expected sporulation (May to August – not all months) (J. Turner, Fera, UK, *personal communication*, 2013). Although the distance that ascospores are likely to disperse is not known, the risk rating of moderately likely with medium uncertainty for entry to the PRA area (see section 13e)

[8] ISPM No 5. defines spread as the expansion of the geographic distribution of a pest within an area. Note that just because an organism can move or be transported quickly, does not mean that it will spread quickly, i.e. it also has to establish.

suggests that ascospores can potentially be blown throughout the PRA area and that the Irish Sea may not provide a barrier to spread. The exceptionally wet summer of 2012 is likely to have favoured apothecial production although heavy rain may have limited aerial dispersal through '*downing*' of ascospores. Any new successful infections should be detected in the spring and summer of 2013. The rate of spread will be influenced by host availability and the local climate but, as described under 15., these are not factors that should limit infection and disease development in GB. Although host availability is not a limiting factor, the distribution of ash will influence the potential rate of spread with areas of high prevalence of ash (south, southwest England and the Midlands) suffering a more rapid rate of spread than elsewhere. The major sources of inoculum in GB are the outbreaks in the wider environment which are currently concentrated along the south-eastern seaboard of GB, with others further north and west. These outbreaks pose a threat to ash in the immediate vicinity (distance yet to be determined) with further natural spread to these areas likely in 2013. The probability of further spread is rated as very quickly in GB (with *low uncertainty*).

In NI/ROI although eradication and containment action is being taken there is still uncertainty as to whether the fungus is surviving and reproducing on recently-planted sites and whether it is present in the wider environment but has not been detected. Survival of *H. pseudoalbidus* could be facilitated by the production of pseudosclerotia. If these structures have formed, and if there has been any physical movement of infected material (leaf litter, twigs etc.) from the affected sites, the fungus may have spread already. If this has occurred and apothecia are produced in the summer, either on site or in new areas, and if ash is present, then this could result in further infection and disease development. Because of this, the likelihood of natural spread is rated as being at a moderate pace with *high uncertainty*.

Ongoing surveillance for at least the next 2 years (the potential minimum longevity of the pseudosclerotia) will help determine whether or not spread has occurred. As with GB, the wet summer of 2012 may have already facilitated the production of apothecia and led to new infections which may be detected in the spring and summer of 2013. Host availability is also not a limiting factor but the distribution of ash will influence the potential rate of spread should this occur, with areas of high prevalence suffering a more rapid rate of spread than elsewhere.

Windblown movement of leaves is likely to result in spread of the fungus to new areas in the locality. The distance that infected leaves could spread is not known and remains an area of uncertainty for future investigation.

Although there is potential for inadvertent spread by wild animals (e.g. birds, insects, mammals etc.) this is not assessed here since it is has not been studied. Whilst not strictly deemed '*natural*', spread of the fungus is also possible through human activity where infected leaf litter may become attached to, e.g. footwear, dog's paws, mountain bikes, and vehicles.

Spread in trade

The emergency legislation which has recently been enacted limits movement of planting material (plants and seed) of *Fraxinus* spp. (into and) within the PRA area until such times as a PFA can be or is declared. France has recently declared a number of areas that are considered to be free of the pest although the organism is not subject to statutory control. There is limited movement of ash plants within the ROI.

In GB the movement of wood of *Fraxinus* spp. is not regulated; in ROI/NI it is subject to regulation. Infected mature trees harvested for wood felled for timber are likely to be symptomatic. A requirement for inspection for symptoms on wood moved in trade would limit spread in this way. There is uncertainty over the risk associated with infected wood or wood originating from infected areas, and whether kiln-drying (a quality treatment for timber moving from affected areas into and within GB and one of the options for phytosanitary requirements for wood moving into and within NI/ROI) is effective against the fungus. The efficacy of the other options for phytosanitary treatment for wood imported into NI/ROI from affected areas (bark-free with <20% moisture content, or square-sawn to remove the rounded surface) is unknown and requires investigation, but all treatments are likely to reduce levels of infection. There is significant trade in ash wood into the ROI including kiln-dried firewood and ash for hurley production.

Given the current measures, lack of imports and limited movement of planting material. and quality treatments for wood in GB, the rate of spread in all trade is rated as slowly with *medium uncertainty*.

On the declaration of a PFA, with plants for planting, the rate of movement could be '*quickly*' (rapid) (with *medium uncertainty)* since infected plants can be asymptomatic. The requirements of, and methods by which, a PFA is determined will influence the rate of movement in trade. Spread in trade *of Fraxinus* plants is likely to be quick if a PFA for planting material is at risk from further incursion of ascospores or where phytosanitary requirements associated with the declaration of a PFA prove ineffective; this is particularly important for plants for planting which can be asymptomatic.

The movement of infected/contaminated seed from a PFA is more likely to result in minimal (*slow*) spread since it is possible to test seed for the presence of DNA of *C. fraxinea* (*H. pseudoalbidus*) (Cleary *et al*., 2012). Provided a protocol for seed testing is developed which has a high probability of detection of the fungus and this becomes a specific requirement for seed being moved in trade, then this should minimise spread in trade through this route.

The rate of spread in trade is therefore likely to be slow under the current phytosanitary regime which is limiting trade in all host material except timber moving within GB but which is facilitating trade in ash wood and potentially some ash plants into the ROI. If measures remain in place and a PFA is declared with imports of planting material occurring, plants pose a significantly higher risk than seed. Timber poses the least risk.

Whilst not possible to rate, non-host containerised plants produced in areas where the fungus is present have the potential to become contaminated with infected leaf litter and this may result in spread of *H. pseudoalbidus* in trade. Similarly soil/growing media may become contaminated with infected leaf litter and movement as a commodity or in association with non-host plants could also result in spread in trade.

17. Which part of the PRA area is the endangered area?[9]
The endangered area is all areas of GB, NI and the ROI where *F. excelsior* is planted or is growing as natural vegetation in the wider environment. These include woods planted for timber, urban trees, SSSIs and SACs. Areas where ornamental species of ash are planted are also endangered although it is possible that *F. ornus* may remain uninfected.

The maps of ash (*F. excelsior*) distribution in GB from the NFI report (FC, 2012b) presented as Figures 2 and 3 in this PRA show that there is a relatively high prevalence of ash in woodlands in the southern part of GB, with high concentrations in the south of England, and also a strong belt of ash running through the English midlands. Ash is also present, but in lower concentrations, in Wales and in east England. It becomes less prevalent as a component of woodlands in the more northern part of GB declining still further into and through Scotland, becoming only a very small component of woodland in North Scotland.

Maps of ash distribution in the ROI are shown in Figures 4 and 6.

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[9] An **area** where ecological factors favour the **establishment** of a **pest** whose presence in the **area** will result in economically important loss (see Glossary Supplement No. 2) [FAO, 1995]

18. What is the pest's economic, environmental or social impact within its existing distribution?

Very small		Small		Medium		Large		Very large	X

Outside of the PRA area

Ash trees (*F. excelsior* and *F. angustifolia*) suffering with ash dieback now known to be caused by *H. pseudoalbidus* have been found in 22 European countries outside of the PRA area. The first observation of mass tree death was reported in Poland in the early 1990s (this is repeatedly reported in the literature) and retrospectively this has been attributed to the pathogen. Trees have become infected in all environments (woods, forests, hedgerows, landscape planting, planted ornamentals in gardens, nursery plants etc.). Overall, young trees succumb to the disease more quickly than mature trees but there are many factors that influence disease progress. Apart from tree mortality and the associated major economic, environmental and social impacts, wood quality is also directly affected (Olrik, 2012). The degradation of timber caused by infection has not been studied in detail but the Defra Interim Control Plan for the disease (Defra, 2012) suggested that degradation takes *ca*. 4 years from the time of infection. The overall impact has not been quantified but there are individual reports which indicate that the severity of the disease in affected areas and the overall impact within the existing distribution of the pest in Europe is considered to be very large with *low uncertainty*.

In Japan where *H. pseudoalbidus* is now considered to occur there are no published reports of damage attributable to the pathogen (so the impact here may be very small). It has been hypothesised (e.g. Queloz *et al*., 2011) that the origin of *H. pseudoalbidus* may be Asia where, as a native organism, it has coexisted with *Fraxinus* spp. causing no obvious damage. In Europe it is considered to be an exotic introduction where it has been highly successful in infecting two important species of *Fraxinus* and others, and where it has spread rapidly.

A Forestry Commission survey of the situation in EU Member States was conducted in late 2012 (FC, 2012). Examples of the impact derived from this report vary between countries. Poland reported that the disease occurs across Poland in all age classes of ash stands but that it is most severe in the '*first*' age class (youngest). Sweden reported that in 2009 and 2010, ash trees exhibiting defoliation were found in all areas where ash occurs. More than 50% of ash trees with a diameter >10cm were significantly defoliated and 30% had '*serious injuries*' or were dead. In contrast Austria reported that ash only represents 1% of the overall tree composition and of these 20% was affected.

Examples from the literature include a report from Hungary (Koltay *et al*., 2012) where symptoms of ash dieback were first reported in 2008 and where it was considered to be present across the whole of the country in 2008-2009. The disease affected trees of all ages but was most frequent in 2 to 10-year-old forests. The worst case of infection was detected in 2009 in a 10-year-old stand of *F. excelsior* of 0.5ha all of which were symptomatic, with 37% mortality in the surveyed area and 20-90% of infected stems in the living trees. They commented that the death of older trees takes longer than those of 2 to 10 year olds.

In Austria Keßler *et al*. (2012) reported that the disease was first recorded in 2005 and that it has become the most damaging disease of hardwood trees in the country. Permanent monitoring plots of ash were observed from 2008-2010. In Lower Austria disease development was slow on mature trees with mean dieback intensity in 2008 ranging from 1 to 34% on 14 plots (mean 11%). In 2010 the intensity varied from 2 to 38% (mean 16%) between plots. Disease intensity was higher on most plots in the mountainous and more humid western part of Lower Austria compared to those in the drier east. Factors influencing the variation in intensity were postulated to be related to the biology of the pathogen and external factors such as stand characteristics, the amount of ash in the vicinity and site-dependent humidity during the infection period. The authors stated that during the study period Eastern Lower Austria was not only drier than the west but also had a lower incidence of ash. In addition individual trees on plots which remained uninfected were thought to have some form of resistance to *H. pseudoalbidus*. Whilst ash dieback was slow to damage mature ash trees, field observations in Austria suggested that the disease was more severe and mortality higher on nursery seedlings, in afforestations, on natural regeneration as well as in thicket-sized and pole-sized stands. They conclude that the disease is problematic for establishing young ash stands with mature trees able to endure infection for a relatively long time.

In Denmark the disease was first noted in 2002 and in 2005 it has become common throughout the country. Some clones of *F. excelsior* were considered to have some form of genetic resistance to infection. (Nielsen *et al*., 2012). Kjaer *et al* (2012) also report this. Whilst reports in the press (e.g. Coghlan, 2012) indicate 90% mortality in Denmark, other reports indicate that this may in fact be the percentage of affected forest stands (e.g. slide 12, Thomsen, 2010).

In Sweden the disease was first observed in 2001/2002 on the island of Öland and has spread quickly since then. Surveys to study the effect of the disease on veteran trees in south-west Sweden showed that 63% of the observed trees were affected in 2009 and 76% were affected in 2011, with 3% dying between surveys. In 2011 ash trees with a larger girth were less affected but this was not observed in 2009. Trees in the east were more seriously affected than those in the west. The effect of pollarding varied between years with trees that had been pollarded less than 20 years previously being more affected in 2011 compared to 2009 (Bengtsson, undated). In discussing their results and the literature, the authors considered that the impact of the disease was higher on trees of smaller girth and that few trees older than 20 years of age die from ash dieback. Rather, they are weakened making them more vulnerable to honey fungus or another secondary cause.

There are many factors that have influenced the impact of ash dieback in its area of distribution outside of the PRA area but overall it is considered to be very large.

Within the PRA area

H. pseudoalbidus is present and established in parts of GB and '*transient, actionable and under eradication'* in NI and the ROI. Because of this it is already having a damaging effect within the PRA area. This has not been quantified to date.

In addition to the direct effects of the fungus (tree death, associated loss of biodiversity, loss of infected nursery stock) there are impacts arising from the phytosanitary measures which were introduced in the autumn of 2012. In response to the outbreaks and the measures, in November 2012 the UK Horticultural Trades Association reported on a survey of their members (HTA, 2012, *unpublished*) that of the £2.5 million valued stock of ash held on UK nurseries at the time of writing:

- *13% of nurseries had already destroyed ash stock in response to the disease (either due to destruction notice or market failure)*
- *95% of businesses state that the current situation will have a negative effect on their business with 58% predicting cash flow problems over the winter period and 87% expecting reduced business profitability.*
- *8% of those surveyed believe they may go out of business without financial support.*

Also that:

The immediate business challenges being faced by tree nurseries are as follows:

- *Cost of destruction of diseased stock*
- *Loss of earnings from ash stock that now cannot be sold*
- *Threat of legal action from customers that have purchased trees that have subsequently been confirmed with* Chalara

With respect to loss of earnings from ash stock that cannot be sold in the ROI, forest nurseries have ca. 3 million ash plants for sale in the 2012/2013 growing season. These are normally grown on a 2-year cycle so there will be an equivalent number in production for the 2013/2014 cycle. Coillte Seed Centre will also have stocks of collected ash seed. Three forest nurseries have being permitted to sell their ash stock under the new emergency measures introduced last winter as they were inspected, sampled and found to be disease free. In the case of horticultural nurseries because there has been a significant number of findings of the disease (linked to stock originally imported) and as these trees are more difficult to inspect due to their size (e.g. half standards, standard etc.) a temporary hold has being put in place until inspectors get a better opportunity to inspect them over the summer. Regarding demand for forestry ash plants, it has significantly fallen for several reasons including the temporary suspension of grant aiding the species under the Departments afforestation schemes and the reluctance of people to plant the species given the uncertainty around the disease. What exactly nurseries will do with their stocks of ash trees is difficult to say. Similarly what those nurseries with stocks of ash seed will do is also currently unclear. (D. O'Leary, DAFM, ROI, *personal communication*, 2013).

19. What is the pest's potential to cause economic, environmental or social impacts in the PRA area?

Great Britain

Very small		Small		Medium		Large		Very large	
									X

NI/ROI

Very small		Small		Medium		Large		Very large	
					X		X		X

H. pseudoalbidus is already present and established in parts of GB and is considered to be transient in NI and the ROI. The first observations of symptomatic trees in the PRA area were made in 2012. Given the rapid spread which has occurred in mainland Europe and the ensuing impacts described under 18., this organism has the potential overall to cause very large economic, environmental and social impacts in all parts of the PRA area where ash is present. Some of these result from the phytosanitary measures, others to the direct effect of the disease and costs of non-statutory disease management. Importantly, the impact of the organism will not be seen immediately since disease development can take years in established trees, with mature trees being able to survive pending secondary attack by other pests and pathogens. In GB where action is not aimed at eradication and where diseased trees have already been found in the wider environment, the short-term impacts which are directly attributable to the disease are likely to be greater than in NI/ROI. However, if outbreaks are found in the wider environment in NI/ROI in the summer of 2013 then these impacts will increase. The overall impacts depend upon the rate of spread of the organism, the rate of disease development and any interventions which are made at a local, regional and national scale.

Some elements to consider in predicting future impacts are described below:

Forestry and wood products
In the timber industry ash is not considered to be a major component of production. However, timber quality is affected by *H. pseudoalbidus* through staining of the timber (Olrik, 2012). The future impact in this sector is likely to be small but it will be significant to local businesses. Smaller merchants and specialist craftspeople that use ash may be affected (Marren, 2013). An example of this is the specialist market in NI/ROI for the use of ash for the production of hurleys. The use of wood as a biofuel for energy production is just starting-up in the PRA area. Long-term supply to fuel boilers may be affected where ash woodlands were forecast to be a main fuel source. However, this could be supplemented long-term through planting of other species and through imports (Defra, 2012).

In GB, some woodland owners who receive grant payments to support the establishment of new woodlands may be affected where full establishment is affected by ash dieback. In December 2012, repayment of such funding was provisionally assessed as not being required (Defra, 2012).

The position is similar in the ROI, where landowners would have received grant payments for planting ash, with a temporary suspension of grant-aiding new ash plantations now in place. There will also be additional costs with the provision of a '*Chalara reconstitution scheme*' the purpose of which is to support the reconstitution of ash plantations which have been affected or associated with ash dieback. (D. O'Leary, DAFM, ROI, *personal communication*, 2013).

Nursery and horticulture sectors
The impacts estimated by the HTA (2012, *unpublished*) will be influenced by future policy on all aspects of the management of *H. pseudoalbidus* including imports, movement and planting of ash. Other factors include

changes in demand for other species and this has already occurred. Specialist producers will have to adapt to production of different species until such times as a resilient and reliable form of *Fraxinus* is identified or bred.

There could also be an impact on trade in horticultural commodities other than ash such as imports of suspect soil, mulch, compost and other growing media from affected areas.

Ecology and biodiversity

Ash is of high ecological significance. In GB, because most infected standing mature trees are being left *in situ,* as they take time to succumb to infection, they will retain their value to the wider ecological community. Over the long-term, when these trees die, felling (where necessary to avoid danger to the public) will have an impact on the local ecology and on biodiversity. Organisms which rely directly on living ash for food, reproduction and habitat will be directly affected unless they have alternative species available. Conversely, leaving felled trees in place will provide habitats for a range of other organisms. Younger trees are likely to succumb to infection more quickly and their loss will leave gaps in woodlands where the disease is prevalent. There may be benefits from this in opening up the understorey, but as with other impacts this has not been estimated. Peterken (2013) considers that, where ash is in a minority, other species will fill the space vacated. The greatest impacts are likely to be where ash is dominant: secondary lowland woods, ash-wych elm stands of the uplands and Borderlands following disease in wych elm and landscapes where ash remains as a prominent farmland tree.

Broome *et al.* (2012, *unpublished draft*) reviewed the biodiversity and conservation implications of ash dieback in the UK. Impacts will vary between woodlands and will depend on various factors including ash prevalence, site location, the age of the woodland and management of the disease. In recently-planted woodlands where plant and animal communities have not developed significantly, the impact is likely to be small. Planted ash can be replaced with another species. In mature broadleaved woodlands the impact will depend upon ash prevalence and management responses. In woods such as these, young ash trees are tolerant of shade relative to other species and the ability to seed and regenerate in a wide range of situations means that it is important in natural succession. Loss of such trees will result in a range of consequences some of which will be negative. The impact of management measures within woodland e.g. using heavy machinery to clear dead or dying trees may have more negative consequences. Impacts on the priority species (referred to by Broome *et al*., see 10.) whose survival is highly dependent upon ash will vary depending upon whether they are dependent on living or deadwood. For example, living ash is the only host for *Atethmia centrago* (Centre-barred Sallow), a moth whose larvae feed on buds and flowers of mature ash trees. This insect is present throughout the UK. Populations of four invertebrate species whose larvae inhabit wood/deadwood of ash would be negatively affected by the removal of dead trees.

Although *F. excelsior* supports fewer phytophagous insects than several other trees (only 68 species of phytophagous insects are associated with *F. excelsior* compared to over 400 for *Quercus* species (Kennedy and Southwood, 1984), it allows more light to penetrate its canopy than many other woodland trees and two of the 18 national woodland vegetation classifications (W8 and W9) are based on *F. excelsior*. These are widespread and very important constituents of woodland on calcareous soils in Great Britain (Rodwell *et al*., 1991; Hall *et al.*, 2004).

Kirby (2012) reviewed the conservation implications of ash dieback in GB. He commented that lack of management in some woodlands has led to an increase in shade. Thus, some loss of trees to ash dieback may benefit ground flora and other species including birds and butterflies, by increasing the amount of available light within woodland. An increase in deadwood may be beneficial provided it is left *in situ*. However, increased levels of tree death opening up affected woodlands could result in over-dominance by more competitive woodland flora. Outside of woodlands, the individual contribution of mature and veteran trees in providing cover and value to wildlife is relatively greater than individual trees in woodlands. Where death of such trees occurs this may have significant ecological effects.

In recognition of the threat to ash, the species composition for the Forest Service Native Woodland Establishment Scheme in Ireland has been revised. The scheme is developed in partnership with Woodlands of Ireland, National Parks & Wildlife Service, Inland Fisheries Ireland and the Heritage Council. (D. O'Leary, DAFM, ROI, *personal communication*, 2013).

Smith *et al*. (2012, *unpublished draft*) have started estimating the likely economic, environmental and social risks and impacts of ash dieback as part of the planning of future controls in parts of the PRA area (Defra, 2012 and future iterations including the recently-published plan – Defra, 2013). They consider the impacts of 3 main options: doing nothing, slowing the spread of the pathogen, and encouraging adaptation to the disease. As this work is not complete the comments made in this PRA based upon their draft are only provisional. Most of the evidence they used related to GB but some is only for England. As is normal for plant diseases which are subject to official control, they also recognise that the impacts will depend upon future control strategies, where these are deployed, the rate of spread of the pathogen (and the level of ensuing disease development) as well as the uncertainty which has been expressed in relation to the scientific evidence. In particular, the rate of spread is uncertain although in this report it has been presumed to be 20-30km per year, rising up to 60-70km per year. This is yet to be substantiated.

The rationale of the work was based around the Defra Interim Control Plan for the disease (Defra, 2012) whose objectives were stated as:

- *Reduce the rate of spread of the disease*
- *Develop resistance to the disease in the native ash tree population*
- *Encourage landowner, citizen and industry engagement in surveillance, monitoring and action in tackling the problem*
- *Build economic and environmental resilience in woodlands and in associated industries.*

If the pathogen is allowed to spread Smith *et al*. (2012, *unpublished draft*) estimated losses of '*non-market benefits*' (e.g. recreation, amenity and biodiversity values) over a 25-year period are expected to be £40-£400 million – i.e. £1-16 million on an annual average basis. Risks and costs from unmanaged spread will be regional depending upon the prevalence of ash and the rate of spread. They include:

- Inspection, maintenance and removal of large infected trees along road and rail routes (Highways Agency estimates *ca*. 3 million ash trees on the road network; no estimates for the railways) – aim to remove infected stock <7 years of age (1-5% in this age category) on roads
- Tree management/disposal costs to landowners
- Short-term costs to nurseries and those planting nursery stock resulting from a collapse in demand
- '*Downtrading*' of timber to firewood (for woodland owners)
- Substitution of ash with alternative species for planting and trading
- Ecological impacts
- Possible changes in visitor numbers to woodlands/woodland-based tourism etc.

Benefits of taking action to slow the spread of the pathogen are dependent upon the effectiveness of any measures taken to try to implement this, especially in areas where non-market values are relatively high. For illustrative purposes, Smith *et al*. (2012, *unpublished draft*) estimate that slowing the annual rate of spread by 1% over 25 years could generate public welfare benefits of £40-£90 million over the period. They caution that these are '*broad-brush*' estimates and that they will be regionalised. It is unclear what benefits there might be to industry from taking action aimed at reducing spread since currently there are ongoing restrictions and a reduction in demand for ash. Nurseries will only wish to resume trading if there is a continuing demand for ash. Setting up '*pest-free zones*' (=PFAs), and opening trade between them may give modest short to medium-term benefits. However, within GB this is likely to prove very difficult to implement as commented on previously. Costs of tree inspection and management may be reduced by giving clear advice and, where disease spread is slowed, road and rail authorities would benefit from this.

The costs of taking action to slow the spread of the pathogen are yet to be estimated. Uncertainty is high depending on various factors:

- Costs of removal and disposal of a yet unknown number of young trees (vs. no action)
- Ongoing costs of restrictions on imports and movement (likely to decline over time) but currently HTA estimate a value of £300,000 per annum to the horticulture sector (HTA, 2012, *unpublished*)
- Landowner costs associated with mandatory tree removal
- Surveillance costs in relation to spread
- Environmental costs/risks of taking action
- Treatment and disposal costs for local authorities

The spread of the pathogen is dependent upon host prevalence and climatic factors and this will result in regional differences. Smith *et al*. (2012, *unpublished draft*) commented that England will suffer relatively higher losses from ash dieback compared to GB as a whole because of a higher proportion of ash trees and disproportionately high recreational and landscape values. Overall, the costs of taking action will be short-term, with longer-term benefits from slowing spread which are difficult to estimate. In terms of addressing the objectives of the Defra Interim Control Plan for the disease (Defra, 2012), the authors commented that there is a case for taking action if control options are effective and cost-effective; but this is difficult to determine. A broad-brush national approach is compared to a targeted regional approach which is considered more appropriate, albeit challenging. Eradication is unfeasible at least in GB, whichever measures are undertaken. This is because of the mode of natural dispersal mainly through windblown spores. Regions with a higher incidence of diseased trees pose a threat to unaffected or less affected regions. Those with a higher incidence of ash (if not already affected), are likely to become affected more quickly.

The new '*Chalara Management Plan*' (Defra, 2013) presents some of the predictions from the modelling work undertaken by Cambridge University. They predict that '*by 2017 there will continue to be regional differences in* *both the probability of disease presence and the extent of infection across the UK. The east and the south-east of England are predicted to experience the highest levels of infection with lower disease presence predicted in other regions'*. Thus the impacts will also be regional. Advice on the cost-effectiveness of intervention based upon the modelling work was based upon the hazard posed by different types of location to other locations and this has been used to inform the management plan. (See Defra, 2013 for details).

A detailed report has also been compiled on the potential impact of ash dieback in Scotland (see Worrell, 2013). This is publically available and because of the status of the pathogen in GB overall being '*established*' in parts, no further detail is given in this PRA other than the summary of the findings which is quoted below:

The Disease – Likely Spread and Damage

1. *The disease could spread to most or all of Scotland within 5 years (confidence rating - moderate).*
2. *Young trees and regeneration will die quickly once infection is present. Polestage trees will die, beginning 3-5 years after infection. Mature trees will show progressive crown dieback over a period of many years and will then start to die due to the combined effects of* Chalara *and other pathogens/pests. A proportion of both polestage and mature trees will remain alive for many years (confidence rating – high); however loss of foliage and other systemic damage will render them increasingly vulnerable to other pathogens, pests and climatic damage. It is possible that a high proportion of trees will be badly damaged or dead throughout Scotland within 10-15 years (confidence rating – moderate). The current population of ash will be killed in the long term (confidence rating – moderate). A very small proportion of trees will survive with few or no symptoms and some of these may be genetically resistant* (NB: no confidence rating assigned in the summary)

Summary of impacts

A categorisation of the ecological, economic and landscape and social impacts identified in the report is given in table 15, according

to severity (low to very high) and duration (short-long term). The

highest impacts are anticipated to be:

1. *Potential loss of ash in general woodland management and silviculture, especially as a timber tree, component of native woodlands, a specialist species in gap replacement and in riparian woodlands.*

2. *Biodiversity: in relation to lichens, mosses/liverworts, fungi and invertebrates; damage to designated sites, veteran trees and wood pasture.*

3. *Economic activity: costs to woodland owners of cutting diseased trees and replanting including compliance with Statutory Plant Health Notices; felling individual trees for health and safety reasons, and short term losses in the nursery industry.*

4. *Landscape and Social: loss of individual trees along roadsides and field margins, in woods heavily used by the public and in urban situations.*

Impacts will generally develop fairly slowly as the disease progresses from killing twigs and branches, to more extensive dieback, followed in the longer term with tree death. The most immediate impacts will be the damage to young planted woodlands.

This report concurs with those already cited.

The overall impact in the PRA area is likely to very large, especially in GB (with *low uncertainty*) where eradication is not being attempted. In NI and the ROI the potential future impact depends upon the success of the eradication campaign and whether or not findings are made in the wider environment in 2013. This is rated as medium to very large with *high uncertainty*.

20. What is the pest's potential as a vector of plant pathogens?

The pest is a fungus, a plant pathogen itself, and it does not act as a vector of other plant pathogens.

STAGE 3: PEST RISK MANAGEMENT

21. What are the risk management options for the PRA area? (Consider exclusion, eradication, containment and non-statutory controls; under protection and/or outdoors)

This question has been answered under the four main headers underlined above.

Exclusion

H. pseudoalbidus has already entered the PRA area; further exclusion on traded material is considered in this section.

Exclusion from protected environments

Very likely	X	Likely		Moderately likely		Unlikely		Very unlikely	

Exclusion from outdoors: with current controls and no imports

Very likely	X	Likely		Moderately likely		Unlikely		Very unlikely	

Exclusion from outdoors (plants and seeds): with current controls not effectively-implemented and imports facilitated

Very likely		Likely		Moderately likely		Unlikely	X	Very unlikely	

Exclusion from outdoors (plants and seeds): with current controls effectively-implemented and imports facilitated

Very likely		Likely	X	Moderately likely		Unlikely		Very unlikely	

Exclusion from outdoors (timber): with current controls – all circumstances

Very likely		Likely	X	Moderately likely		Unlikely		Very unlikely	

The first findings in GB were made in 2012 on imported plants and since that time the pathogen and the disease it causes has been found in a range of locations including nurseries, recent plantings and the wider environment. Findings in recent-plantings in GB are thought to be largely linked to imported material, although the data are not easily extracted (J. Morgan, FC, *personal communication*, 2013).

The initial findings in NI and the ROI have also been linked to imported planted ash trees in forests, horticultural nurseries, private gardens and amenity landscaping planting with no confirmed findings in established native hedgerow or forest trees. Further investigations are ongoing and the situation is evolving.

Current restrictions on imports of plants and seed to the PRA area are very likely to exclude entry to outdoor environments (with *low uncertainty*), whilst imports are not taking place. When a PFA is declared and imports are facilitated, then the fungus is unlikely to be excluded (with *low uncertainty*) if the measures in the PFA are ineffective; effective measures are likely to prevent further entry (with *low uncertainty*). The risk posed by future imports of plants from PFA(s) depends upon the proximity of current findings to the PFAs and the type of inspections/testing that take place on the material intended for export.

Despite the absence of phytosanitary requirements for timber imported into GB, because of the quality treatments which equate to one of the options for phytosanitary requirements for timber entering NI and the ROI, the likelihood of exclusion is likely with *medium uncertainty* for imported timber in all circumstances

For both GB and NI/ROI it is very likely that the fungus will continue to be excluded from protected conditions (with *low uncertainty*) because host plants produced on nurseries are normally grown outdoors.

Eradication

Under protection	Very likely	X	Likely		Moderately likely		Unlikely		Very unlikely	

Great Britain

Outdoors	Very likely		Likely		Moderately likely		Unlikely		Very unlikely	X

ROI/NI

Outdoors	Very likely		Likely		Moderately likely	X	Unlikely		Very unlikely	

The pest has already entered the PRA area.

Under protection
Eradication under protection is very likely (with *low uncertainty*) in the event that nursery stock is produced entirely under protection (such production is considered very unlikely).

Outdoors: nurseries
All nursery findings in the PRA area have so far been subject to eradication. In GB the rationale has shifted to containment based upon the requirements of the emergency legislation, but this may result in the voluntary destruction of planting material of *Fraxinus* spp. onsite, as it is not allowed to be moved until a PFA is established. Eradication is feasible on nurseries growing containerised stock, where affected plants, their growing media and associated leaf litter and debris can be destroyed and disposed of safely (burning onsite where this is allowed or safe movement and deep burial). Onsite hygiene measures can be used to clean and sanitise the surfaces upon which containerised plants are raised (although the efficacy of these measures requires investigation).

Where nursery plants are raised directly in the ground there is a possibility that the fungus could persist in the soil as pseudosclerotia on infected material; in these situations, replanting with *Fraxinus* spp. would have to be prohibited to allow natural decline of the fungus in the absence of the host. The period over which replanting should not occur (based upon one published paper: Gross and Holdenrieder, 2013) is at least 2 years. Longer-term studies of the survival of pseudosclerotia in the absence of hosts are required to determine an endpoint. The effect of soil fumigation (chemical, steam treatment or solarisation) against these survival structures has not been tested. Where feasible (and in the case of chemicals, where these are allowed), these may be of use.

Outdoors: non-nursery (wider environment and recently-planted sites)
In countries outside of the PRA area where *H. pseudoalbidus* is known to occur, eradication has not been attempted in the wider environment.

In non-nursery situations, the pest is considered to be established in parts of GB where measures that are being taken are not aimed at eradication. For this reason the rating of very unlikely to be eradicated has been given for GB (with *low uncertainty*).

In NI and the ROI, *H. pseudoalbidus* is considered to be '*transient, actionable and under eradication*'. DARD is working with DAFM to produce a control strategy. (G. Cahalane, DAFM, ROI, *personal communication*, 2013). No further detail was available at the time of writing. DARD state that on detection of suspect symptoms, movement restrictions are imposed along with biosecurity measures preventing further planting at the affected sites; plants and associated plant debris is destroyed (see http://www.dardni.gov.uk/q-and-a-on-ash-dieback-v8.pdf). Surveys are ongoing.

In the ROI, DAFM (2012) gave details of the measures taken at the first findings of ash dieback at 11 of the recently-planted sites. Trees associated with the imported infected batch at the first confirmed site and those traced from the same batch to 10 other sites were subject to eradication measures. This included destruction of the plants by burning. Remaining stumps were treated with herbicide to prevent regrowth. In some instances, additional adjoining ash trees were destroyed as a precaution. The policy being implemented in relation to confirmed findings is in addition to destroying infected trees; all trees from the same batch will also be destroyed. Ash trees in the immediate and wider area will continue to be under surveillance for expression of symptoms.

In NI and the ROI importation of plants, seed and wood of *Fraxinus* spp. is regulated by the emergency legislation. Imports of wood are being facilitated and there was a proposal for imports of plants from PFAs in France into the ROI which did not take place. There may be a risk of further entry *of H. pseudoalbidus* to this part of the PRA area on plants which could influence the potential for eradication.

Ongoing surveillance in the wider environment will determine whether the fungus is present beyond the currently-confirmed plantings and nurseries.

The rating of '*moderately likely*' to be eradicated in the outdoors in NI/ROI has *high uncertainty*. The determination of the success of the current eradication strategy will depend upon whether or not there are further findings of ash dieback in recent plantings and if first findings in the wider environment are made in the summer of 2013 or later. The earliest recent plantings which have been found affected by ash dieback date back to imported material planted in 2009. However, there is some uncertainty regarding the dates of some findings and further investigations are underway to establish details (D. O'Leary, DAFM, ROI, *personal communication*, 2013). Although it is not known whether the earliest known imported material which has been detected as infected was already infected at the time of planting, if movement of infected leaf litter, twigs etc. to other sites where ash is present has occurred, there is a risk that *H. pseudoalbidus* may have been introduced to new locations.

If this is the case and the fungus has survived and successfully completed its lifecycle this will affect the current status of the pest. Ongoing monitoring during the summer months will help determine more accurately the status of the pest.

Management of waste

With respect to safe disposal of infected or contaminated material at all locations where outbreaks are confirmed, currently it is not known whether composting (or other degradation processes) of infected and contaminated material would destroy this pathogen since this has not been tested under controlled conditions. The fungus infects woody tissue as well as green leaves and shoots and is able to produce melanised pseudosclerotia on woody tissue; these can facilitate survival for at least 2 years. It is not advisable to use composting for management of material requiring disposal until efficacy of a controlled process is tested and proven. Under the most recent Defra-funded *Phytophthora* programme similar studies have been undertaken and can be built upon for developing a standard operating procedure (SOP) for *H. pseudoalbidus* in infected material.

Containment and non-statutory control

In March 2013, Defra published an update to their earlier control plan (Defra, 2012); the details of the new plan (Defra, 2013) are not reiterated here, but the objectives remain the same with controls focussing on reducing the rate of spread of the disease and development of '*resistance*' to the disease in the ash tree population. The implementation measures in the plan relate to England only with the Devolved Administrations of the UK basing implementation on their own policy and individual circumstances.

Eradication is not deemed possible for GB with Wales supporting the objectives of the plan for England.

NI and the ROI have developed an all-Ireland plan aimed at containment and eradication (DARD & DAFM, 2013).

Scotland has developed a plan which complements measures taken in GB. In this plan the authorities are seeking to delay the arrival of the disease in the north and west of Scotland which will be delineated as a '*sheltered area*' with a buffer zone. See: http://www.forestry.gov.uk/pdf/FCSCHALARAACTIONPLANSCOTLAND.pdf/$file/FCSCHALARAACTIONPLANSCOTLAND.pdf

Eradication measures will apply to recently planted trees with infection and action will be considered in areas of wider environment infection which are less than 0.5 ha. (See Defra, 2013).

Nurseries

Eradication is feasible on nurseries growing containerised stock, and with additional precautions, it may be possible on sites where plants are field-grown.

The establishment of PFAs on all nurseries may prove difficult in areas where *H. pseudoalbidus* is present in the wider environment or in recent plantings. This is because it will not be possible to prevent the entry of ascospores from infested areas in the vicinity of nurseries. Ascospores are likely to be liberated during the months from May to October (although this period has not been defined in the PRA area and will vary with the season). For nursery locations which are remote (not easy to define) from outbreak sites (wider environment, recent plantings) plants of *Fraxinus* spp. could be grown provided the nursery has been free from confirmed infected plants for at least 2 years. Inspections of the immediate vicinity should also be made to confirm that there have been no signs of infected ash trees for at least 2 years prior to production. Inspections should be made in the spring when symptoms are most likely to have developed on previously asymptomatic infected material. Following inspection, movement of healthy plants should take place preferably before leaves sprout and before any undetected source of infection in the vicinity has the opportunity to produce infective spores. Thus, movement would have to be before May at the latest.

Wider environment and recent plantings

In GB, the fungus is considered to be established in parts and eradication is not considered feasible. Containment in areas where *H. pseudoalbidus* is present in the wider environment is only being undertaken with respect to planting material of *Fraxinus* spp., which is not allowed to be moved should there be any onsite. Eradication measures are not being undertaken here mainly because of the mode of natural spread of the fungus which is via wind-blown ascospores. Reduction in ascospore inoculum might be facilitated by management of leaf litter (safe disposal or treatment aimed at degradation of host/fungal material) but the feasibility of this depends upon the extent of the affected area. Efficacy of leaf litter treatments (e.g. to aid decomposition) would require investigation. Management of leaf litter could reduce the rate of spread of the fungus.

The establishment of *cordon sanitaires* to protect currently unaffected ash stands which are of ecological importance in GB depends upon the proximity of outbreaks in the wider environment and in recent plantings and the distance over which ascospores can travel which requires investigation. Some protection of these stands could be provided by clear felling of ash beyond the important stand.

For NI and ROI, further exclusion from outdoor locations will depend upon whether there has been movement of infected plant debris from the known affected sites to other sites, and whether in the future, movement of planting material is facilitated from designated PFAs along with the method of verifying PFA status.

Wood

Currently there are no phytosanitary requirements for wood entering or moving within GB although the industry does implement quality measures which include kiln-drying. Although it was possible for the movement of wood arising from felling on outbreak sites to be prohibited where a GB site was under statutory control, this has not been implemented.

In NI/ROI there are specific phytosanitary requirements for wood entering from countries where the pest is known to occur including an option of kiln-drying to below 20 % moisture content (see Table 6). The efficacy of drying against internal infection of wood by the fungus is not known, however it is likely to be deleterious. It is one of the options available for phytosanitary treatment of imports of oak from the USA against *C. fagacearum* and for maple wood against *C. virescens* (Anon., 2000).

For most wood in trade, the removal of twigs and leaves is also undertaken (quality and phytosanitary treatment) and this will remove any such material which is infected. However, where bark is retained the fungus may still be present below the bark or within the wood. Whether the fungus can be transferred from infected wood to growing plants or trees is not known. Husson *et al.* (2012) observed conidial production on infected wood which are not thought to play a role in dispersal, but the successful completion of the lifecycle on infected wood through to apothecial production has not been observed. It is not known whether the fungus can complete its life cycle on wood and this would depend upon whether it has been previously infected by compatible mating types.

Non-statutory control

Options for non-statutory control could also be incorporated into requirements for phytosanitary measures where these are deemed appropriate. These fall into 3 main areas outlined below

Host resistance or tolerance

F. excelsior is the most widely-grown and native species of *Fraxinus* in the PRA area and it is highly susceptible to infection by *H. pseudoalbidus*. At least one species, *F. ornus,* which can be grown as an ornamental in the PRA area is not currently reported as a natural host.

There is some evidence that there may be individuals within a population of *Fraxinus* which exhibit a degree of tolerance to infection. Tolerance is defined as the ability of a plant to sustain the effects of a disease without dying or suffering serious injury. In addition to the studies mentioned in earlier parts of the PRA there are other publications. For example, Nielsen *et al.* (2012) studied clones of *F. excelsior* and provisionally identified a low frequency of family groups with '*significantly less symptoms*'. These results have been presented in other papers which have not been studied further but are cited here (McKinney *et al*., 2011; Kjaer *et al*., 2012). Stener (2012) also studied clones of *F. excelsior* in Sweden and reported that no clones were resistant but some appeared to have reduced susceptibility, retaining this under 6 years of heavy infection pressure. This paper cited other examples already mentioned, as well as Pliura *et al*. (2011) who found '*strong genetic effects*' in relation to the host and ash dieback in Lithuanian progeny trials. Stener *et al.* (2012) found that susceptible clones appeared to have a prolonged growing season. Discussion of this effect in the light of other publications implied that trees with a shorter growing period may escape infection by means of early leaf shedding. Kirisits and Freinschlag (2012) however, found no consistent relationship between leaf shedding and levels of dieback. Other work has indicated that healthier clones actively reduce the rate of growth of the fungus (McKinney *et al*., 2012). This author (along with others) felt that resistant (tolerant) trees in natural ash stands are quite rare. Kirisits and Freinschlag (2012) also provide evidence for tolerance/resistance to ash dieback within the population of *Fraxinus excelsior*.

Pautasso *et al.* (2013) reviewed the literature on host susceptibility. The authors cautioned against the planting of just a few ash clones exhibiting tolerance as they were concerned that further introductions of different genotypes of the pathogen might increase its genetic diversity within the population. This might increase the potential of *H. pseudoalbidus* to overcome host tolerance and this would be more likely if tolerance is based on a narrow genetic basis. Maintenance of host genetic diversity is also required to enable the genus to withstand other pathogens and climatic events. The authors felt that there was a need to conduct a major survey throughout the range of the pathogen to establish comprehensive germplasm collections and to breed for tolerance. In addition to monitoring the main species that are affected (*F. excelsior* and *F. angustifolia*), they suggested that it might be useful to monitor exotic ornamental species planted in the vicinity of disease outbreaks.

The likelihood of heritability of tolerance is not yet clear but at least some authors (e.g. Stener, 2012) are hopeful that there is scope for breeding programmes to produce material which may have low susceptibility to the disease caused by *H. pseudoalbidus*.

As part of the new management plan (Defra, 2013), 250,000 ash saplings will be bought by Government and planted in the east/south-east of England. Trees will be monitored to identify saplings which do not succumb or are least affected by the disease. Objective 2 of the new Chalara Management Plan (Defra, 2013) '*Developing resistance to the disease in the ash population*' describes this work and related work under the heading of '*Genomic Research*' see also:
http://www.defra.gov.uk/news/2013/03/26/chalara-resistant-ash-trees/

Chemical control
There are no known or approved chemical treatments which could be applied to control *H. pseudoalbidus* in the PRA area.

The survey of EU Member States (FC, 2012) provided some responses on investigations of potential controls in countries where the pathogen is established. The general view is that the use of fungicidal chemicals in woods and forests is impractical, expensive, and ecologically unacceptable. Nursery plants might be suitable candidates for treatment and a programme of fungicide sprays may afford protection against infection. However, there are risks of masking infections where chemicals suppress symptom development whilst not killing the fungus (fungistats). Belgium commented that treatment of nursery plants was not necessary because they would become infected as soon as they are planted-out. Slovenia has investigated the efficacy of a number of active ingredients against pure cultures of *C. fraxinea* as well as on leaf petioles with some showing activity against mycelial growth (unpublished work). In addition to nursery stock, individual trees which are deemed to have high value (ecological, environmental etc.) could be protected by stem injection with suitable products but these are yet to be investigated.

In March 2013, Fera announced a short-list of chemicals for investigation for disease control:
http://www.fera.defra.gov.uk/plants/plantHealth/pestsDiseases/documents/fungicideListForScreening20March2013.pdf

Those showing efficacy in laboratory screens will be tested for protectant activity in ash saplings under field conditions in the spring of 2013.

Cultural control
To slow the spread of *H. pseudoalbidus* measures which have already been taken on affected sites should be encouraged. These include:

- Avoiding replanting with ash in affected areas until a reliable source of tolerant ash is available (some years off)
- Encourage the use of alternative species for planting purposes
- Safe management of leaf litter in the autumn to avoid spread

- Possible establishment of *cordon sanitaires* to delimit healthy ash stands
- Sanitation (machinery, pruning tools etc.) to prevent cross-infection

One area of debate in the literature is whether or not to leave diseased trees *in situ.* The benefit of doing this would be to allow the identification of individuals capable of surviving the disease. Trees which are retained could be used to support future breeding and could allow the adaptive potential of populations to be expressed through natural regeneration (Kjær *et al*., 2011). There are also ecological benefits from leaving infected mature trees in place as discussed earlier. Thomsen and Skovsgaard (2012) made some recommendations:

Ash stands should be inspected for disease during the growing season when it is easier to identify. However, the crown may regenerate by the production of prolific epicormic shoots which can disguise the presence of disease. In these cases, winter inspection would identify diseased trees (although this may prove difficult – J. F. Webber, FR, UK, *personal communication*, 2013). Seemingly, at least two inspections are needed per year to identify trees with ash dieback.

Dependent upon the age of the stand and the level of disease Thomsen and Skovsgaard (2012) proposed that:

- Severely infected '*young'* (not defined) stands should be clear-cut and replanted - but presumably with an alternative species; leave surviving trees in place
- Young stands with a high % of healthy trees should be left; use paint to mark at least 200 trees per ha when healthy; thin among unmarked trees
- Older stands should be inspected in the growing season and in winter; all stands to be inspected at least once per year
- All older trees with epicormic shoots intended for timber harvesting should be felled to avoid wood staining
- Various recommendations were made for harvesting of timber dependent upon the level of death of the primary crown
- Trees with high vitality and only minor symptoms should be left as potential seed sources

The survey of EU Member States (FC, 2012) provided some responses on attempts at cultural control but most recognised that the biology of the pathogen has hindered progress in controlling the pathogen in non-nursery situations.

Slovenia has investigated hot water treatments for diseased saplings with some success. Their results have just been published (Hauptman *et al*., 2013) and could be used to develop future control strategies.

22. Conclusions and recommendations

H. pseudoalbidus, the cause of ash dieback, a lethal disease of *Fraxinus* spp. in at least 24 European countries and also now known to be present in Japan, has entered the PRA area where it was found to have caused disease, mainly on *F. excelsior*, in Great Britain (GB) in 2012. Evidence from an affected wood in Norfolk indicates that It may have here since at least 2008 (Hendry, 2013, *unpublished*). Plants on nurseries, recent plantings and trees in the wider environment have been found affected. In Wales, at the time of production of version 1.3 of this PRA, there were no wider environment sites affected. It has also been found in Northern Ireland (NI) and the Republic of Ireland (ROI) on nurseries and planted sites. GB is currently the most badly-affected part of the PRA area and the pest is considered to be established here, with a higher concentration of trees affected in wider environment sites in the east and south-east of England than elsewhere. NFI studies indicate that, overall, the levels of the disease in woodlands >0.5ha in GB which have been subject to FC inspection is low. However, there are clearly hotspots, as indicated by the findings reported from separate systematic and targeted surveillance studies. In NI and the ROI all of the findings are associated with imported planting material. The pest is considered to be transient in NI/ROI where it is subject to eradication measures. All parts of the PRA area continue to be subject to surveillance. The status of the pest in NI and the ROI will be better verified now that trees have broken dormancy since symptoms on trees may be more obvious at this time. Eradication is not being attempted in GB.

As a result of the 2012 findings, emergency phytosanitary legislation was implemented in late 2012. This has effectively prevented the unrestricted import and movement of planting material (seeds and plants) of *Fraxinus* spp. from countries where the pest is known to occur as well as regulating movement of such material in the PRA area. Additionally, in NI and the ROI, imports and movement of wood of *Fraxinus* from countries where the pest is known to occur are now regulated. This will help reduce the risk of further entry of the pest, as well as movement of the pest on planting material from affected sites in all of the PRA area, as well as on wood into NI/ROI.

A summary of the probabilities associated with further entry to the PRA area is given below in Table 10.

Table 10. Likelihood of further entry of *H. pseudoalbidus* into the PRA area.

Pathway originating in countries where the pest occurs outside of the PRA area	Controls	Part of PRA area			Uncertainty
		Great Britain	Northern Ireland	Republic of Ireland	
Plants for planting of *Fraxinus* spp.	Without controls	*Very likely*	*Very likely*	*Very likely*	Low
	With current controls but no imports	*Very unlikely*	*Very unlikely*	*Very unlikely*	Low
	With current controls and imports from PFA	*Moderately likely*	*Moderately likely*	*Moderately likely*	Medium (depends upon success of PFA protocol)
Wood of *Fraxinus* spp.	Without controls	*Unlikely to Moderately likely*	*Unlikely to Moderately likely*	*Unlikely to Moderately likely*	High (no data on efficacy of kiln-drying etc.; lifecycle in wood)
	With current controls and imports from PFA	*N/A (no controls on timber)*	*Unlikely to Moderately likely*	*Unlikely to Moderately likely*	
Seed of *Fraxinus* spp.	Without controls	*Moderately likely*	*Moderately likely*	*Moderately likely*	High (no data on viability of pathogen in seed or viability of infected seed)
	With current controls but no imports	*Very unlikely*	*Very unlikely*	*Very unlikely*	Low
	With current controls and imports from PFA	*Unlikely*	*Unlikely*	*Unlikely*	Low (with a robust PFA protocol)
Contaminated soil /growing media (commodity) **or** with plants (hosts/non-hosts)	No controls	*Moderately likely*	*Moderately likely*	*Moderately likely*	Medium (no data on imports of soil etc.; depends upon nursery hygiene for imported plants)
Airborne ascospores	No controls	*Moderately likely*	*Moderately likely*	*Moderately likely*	Medium

Imports of plants for planting of *Fraxinus* spp. pose the highest risk of further entry into the PRA area. Without controls in areas where the pest occurs it is very likely to enter the PRA area (with *low uncertainty*). With the current controls and no imports, it is very unlikely to enter (with *low uncertainty*). The only route by which the pest might have entered was in asymptomatic plants brought in via passenger baggage, but the emergency legislation for *H. pseudoalbidus*/*C. fraxinea* now prohibits this. If a PFA is established (as has happened in France) and imports occur, it is moderately likely (*with medium uncertainty*) that the pest could enter on asymptomatic material. For this reason the protocol for establishing a PFA should be precisely-defined and strictly controlled.

For imports of wood of *Fraxinus* spp. from areas where the pest occurs both with and without controls (which are not in place in GB), the pest is unlikely to moderately likely to enter (*with high uncertainty*). Although the fungus is known to infect wood and may be able to produce conidia on wood under humid conditions, these are not considered to play a role in dispersal. These spores are more likely to be produced on leaves, petioles etc. where they are thought to act as spermatia (male reproductive organs). Sexually-produced ascospores are the main route of natural dispersal. Until such times as these are known to be produced on wood it seems unlikely that the fungus could be disseminated through this route. Kiln-drying is normally applied to wood as a quality measure (J. Morgan, FC, UK, *personal communication*, 2013) and is one of the options for phytosanitary requirements for wood of *Fraxinus* spp. imported into NI/ROI from countries where the pest is known to occur. The efficacy of kiln-drying against the fungus has not been tested, but it is used as a phytosanitary treatment for other fungi that might be present in wood and is likely to be deleterious. Because this has not been tested the rating of entry on wood of *Fraxinus* spp. has high uncertainty.

Seed harvested from infected *F. excelsior* has been shown to contain DNA of the fungus, but the viability of the fungus and the infected seed has not been tested. Without controls, the pest is moderately likely to enter on seed of *Fraxinus* spp. (with *high uncertainty*). With controls and no imports it is very unlikely to enter on seed (with *low uncertainty*). Seed can be readily tested for the presence of fungal DNA and as such, should a PFA for the pest be declared, provided seed-testing is undertaken in a robust manner, as part of the requirements, the pest is unlikely to enter (with *low uncertainty*).

It is not known whether there are imports of soil or growing media from areas where the pest occurs. If there are, the fungus may be present as a contaminant if the commodity originates in an area of high prevalence for ash dieback. Containerised stock of non-host plants from nurseries where the pest occurs may have surface contamination with infected leaf litter. For those plant species where there are no phytosanitary controls in place (thus moving with limited inspection), there is a risk that the fungus could be present. The pest is moderately likely to enter through these pathways (with *medium uncertainty*). Host plants with (or without) associated soil/growing media are currently not being imported but could be from a PFA in the future. The same comments apply.

Ascospores are the natural mode of dispersal and spread of *H. pseudoalbidus* within and from an area of infected ash trees. These wind-blown spores are produced by ascomycete fungi from fruiting bodies known as apothecia (noting that other fruiting structures occur in the Ascomycota) and are generally considered to be relatively fragile compared to (for example) windblown spores of rust fungi . However, there are no published data on the factors affecting ascospore survival for *H. pseudoalbidus*. Nevertheless as with other ascomycetous fungi, they are likely to be adversely affected by extremes of temperature, relative humidity, UV light, aerosols emitted from the sea containing salt, should they enter this hostile atmosphere. In order to survive, these spores must alight on a host plant within a relatively short period of time (undefined for *H. pseudoalbidus*) in order to infect. There are no data on the dispersal distance for ascospores of *H. pseudoalbidus* but other ascomycetes such as *S. sclerotiorum* tend to be dispersed in the vicinity of their apothecia with longer dispersal distances of a few spores up to several hundred metres facilitated by wind. Movement of ascospores of *H. pseudoalbidus* from mainland Europe across the North Sea and the English Channel will be subject to dilution effects and conditions adverse to spore survival. Based upon the biology of other ascomycetes and all the factors that will influence this pathway (described under section 13) it is moderately likely that this is a pathway of further entry of *H. pseudoalbidus* to the PRA area (with *medium uncertainty*).

The likelihood of further establishment and spread in the PRA area is summarised in Tables 11 and 12 below.

Table 11. Likelihood of further establishment of *H. pseudoalbidus* in the PRA area.

Location	Part of PRA area			Uncertainty
	Great Britain	Northern Ireland	Republic of Ireland	
Outdoors	*Very likely*	*Very likely*	*Very likely*	Low
Under protection	*Very unlikely*	*Very unlikely*	*Very unlikely*	Low

Table 12. Likelihood of further spread of *H. pseudoalbidus* in the PRA area.

Route of spread	Part of PRA area			Uncertainty
	Great Britain	Northern Ireland	Republic of Ireland	
Natural spread	*Very quickly*	*Moderate pace*	*Moderate pace*	Low for GB; high for NI/ROI (depends upon success of eradication)
In trade (varies with the commodity)	*Slowly or quickly*	*Slowly or quickly*	*Slowly or quickly*	Low for current slow spread and spread with seed; medium for quick spread (if trade is allowed this depends upon the success of the PFA protocol)

In outdoor situations, the pest is very likely to establish further in GB (with *low uncertainty*) as it is already established in the wider environment with a relatively high number of affected woodlands containing infected ash. Currently, measures in GB are containing the movement of planting material from affected sites, but the future control of wood and leaf litter (etc.) seems unlikely to be practical except in areas which are considered to pose a high risk to other unaffected sites. In GB, natural spread through the dispersal of windblown ascospores is likely to be very quickly (with *low uncertainty*) since eradication is not being attempted. Under favourable conditions (yet to be defined, but relatively cool and wet) the fungus is capable of producing high amounts of infective ascospores over a prolonged period (possibly May to October, also yet to be defined here). Affected wider environment sites are concentrated in the east/south-east of England, but there are recently-planted sites and other wider environment sites scattered across GB. The east/south-east poses a risk of dispersal of high amounts of infective inoculum across a (yet-to-be defined) dispersal area. Dispersal may occur from all other sites where outbreaks have occurred. The exceptionally wet summer of 2012 is likely to have resulted in production of high amounts of inoculum and new infections, which will be detected in the spring/summer of 2013. The prevalence of ash in GB is not limiting to the establishment and spread of the fungus, but there are areas of higher concentration of ash where spread may be quicker than elsewhere. In NI/ROI, although the pest is under eradication and there are no findings in the wider environment it is very likely to establish here (with *low uncertainty*) because the climate is similar to areas where the pest is present in GB and the host is widespread and common. This is dependent upon the findings of surveillance in the spring and summer 2013 (following a wet summer in 2012) as well as the success of the eradication measures will help clarify the situation. The recently-planted sites that are affected were planted with imported material, some of which may date back to 2009 (or possibly earlier). It is not known whether the earliest imported material was infected or at what time any of the material that was imported became infected (pre- or post-import). As the fungus produces survival structures known as pseudosclerotia which can survive for at least 2 years in adverse conditions, should material of *Fraxinus* (leaf litter, twigs) have been moved to new areas, it is possible that there may be as yet undetected locations to which it has been introduced. The apothecia of the fungus are produced on pseudosclerotia between May and October in Europe and these, therefore, have the potential to perpetuate the fungus. Spread is therefore rated as being at a moderate pace (with *high uncertainty*) dependent upon the findings of surveillance in the spring and summer and the efficacy of the eradication campaign.

The pest is very unlikely to become established under protected conditions (*low uncertainty*) because the host is not normally grown under protection.

Spread in trade is rated slowly currently (with *low uncertainty*) but slowly, or quickly (with *medium uncertainty*) if trade from a PFA is allowed in future, dependent upon the robustness of the protocol for determining a PFA.

The endangered area is all parts of the PRA area where ash (mainly *F. excelsior*) grows naturally or where it is planted. Some areas have a greater prevalence of ash than others and where these are currently unaffected but in close proximity to outbreak sites they are more likely to become affected quickly in GB, as eradication is not being undertaken. There are no limiting abiotic factors for the establishment of *H. pseudoalbidus* in the PRA area. There is potential for a low degree of tolerance to the effects of the disease in the natural population of *F. excelsior* so a small percentage of individuals may survive relatively unscathed if left *in situ*. Ornamental species vary in their susceptibility to infection and, whilst many *Fraxinus* species have not been tested or have had the disease recorded on them, currently only *F. ornus* is not considered to be a natural host. Exploitation of the gene pool of surviving individuals and ornamental species could be used for future breeding programmes for *Fraxinus,* but currently the heritability of tolerance to disease is uncertain.

The current and future impacts of *H. pseudoalbidus* in the PRA area and elsewhere are summarised in Table 13.

Table 13. Current and potential future impacts of *H. pseudoalbidus*

Impact	Location				Uncertainty
	EU	Japan	GB	NI/ROI	
Current impact	*Very large*	*Very small*	*Not estimated*	*Not estimated*	Low
Potential impact	*Very large*	*Very small*	*Very large*	*Medium to Very large*	Low for GB (and Japan); high for NI/ROI (depends upon success of eradication)

Although no values have been placed on the effects of ash dieback in Europe, it is clearly having a very large impact, given the high level of disease that has occurred over a relatively short period of time, since the disease was first noted in Poland in the early 1990s. There are no impacts reported from Japan and so this is rated as very small (with *low uncertainty*). The potential impact in GB is likely to be very large (with *low uncertainty*) since no attempt is being made to eradicate the fungus as it is not feasible. In NI/ROI impacts may be medium to very large (with *high uncertainty*) because of the uncertainty surrounding the success of eradication. Currently, the phytosanitary measures are affecting trade in plants, seeds and wood in all of the PRA area either directly or indirectly (in GB there are no restrictions on wood but it is presumed that demand has been affected). Although ash is not a *major* element of timber production in the PRA area it is used, and, it does have specialist markets such as the production of hurleys for the national sport of hurling in Ireland. Synthetic alternatives to ash are available for this purpose, but ash is preferred. Until 2012, imports of ash wood from Europe represented a high proportion of material being used for hurley production. This is still a permitted trade provided the requirements laid-out in Table 6 are complied with. Local production and movement of ash wood in Ireland will depend upon the future status of the pest in this country. Ash (*F. excelsior*) is native to the PRA area and has high ecological value. Mature ash trees are hosts and provide a habitat for a wide range of organisms. Following infection, young trees are likely to die more quickly than mature trees. Death of older trees can take some years; leaving them in place will perpetuate their environmental value since deadwood is beneficial to the ecology of woodlands.

Leaving dead trees in place in locations where they do not pose a hazard will have benefits. The ultimate death of mature ash poses a risk to a small number of species which rely on a living host. The horticultural trade is and will be significantly affected by current restrictions in trade in planting material. However, over a longer period of time, adapting to new markets (given that demand is likely to have declined) will help reduce these impacts.

Although the pest has already entered the PRA area, the likelihood of exclusion of *H. pseudoalbidus* is summarised in Table 14 and discussed below.

Table 14. Likelihood of further exclusion of *H. pseudoalbidus* in traded material

Imports originating in countries where the pest occurs	Location	Part of PRA area			Uncertainty
		Great Britain	Northern Ireland	Republic of Ireland	
With or without current controls	Under protection	*Very likely*	*Very likely*	*Very likely*	*Low*
With current controls and on imports	Outdoors	*Very likely*	*Very likely*	*Very likely*	*Low*
With current controls and imports of plants and seed allowed from PFAs in countries where the pest occurs – ineffective measures	Outdoors	*Unlikely*	*Unlikely*	*Unlikely*	*Low*
With current controls and imports of plants and seed allowed from PFAs in countries	Outdoors	*Likely*	*Likely*	*Likely*	*Low*

where the pest occurs – effective measures					
With current controls and imports of timber	Outdoors	*Likely*	*Likely*	*Likely*	*Medium*

Exclusion from protected environments is very likely (with *low uncertainty*) given that *Fraxinus* spp. are not normally grown under protection.

With the current controls in place, and no imports, further exclusion on traded material from outdoor locations is very likely (with *low uncertainty*).

With the current controls in place, and imports of plants and seed from a PFA, where measures are ineffective, further exclusion on traded material from outdoor locations is unlikely (with *low uncertainty*). Where imports of plants and seed occur and the measures are effective then the pest is likely to be excluded (with *low uncertainty*). Exclusion of the pest on imports of timber in all circumstances is likely (with *medium uncertainty*).

The likelihood of eradication of *H. pseudoalbidus* is summarised in Table 15.

Table 15. Likelihood of eradication of *H. pseudoalbidus*

Location	Part of PRA area			Uncertainty
	Great Britain	Northern Ireland	Republic of Ireland	
Under protection	*Very likely*	*Very likely*	*Very likely*	Low (no known production under protected conditions)
Outdoors	*Very unlikely*	*Moderately likely*	*Moderately likely*	Low for GB; high for NI/ROI (depends upon success of eradication and any pre-existing undetected spread)

Eradication under protection is rated as very likely (with *low uncertainty*) due to there being no known production of *Fraxinus* spp. under protected conditions.

Eradication outdoors has not been attempted in Europe and is not being undertaken in GB, so it is very unlikely (with *low uncertainty*) that *H. pseudoalbidus* will be eradicated here. In NI and the ROI measures aimed at eradication are being undertaken at affected sites. It is moderately likely (with *high uncertainty*) that the pest will be eradicated here because of the biology of the fungus, the level of infection per site detected and the extent to which the fungus has had an opportunity to spread to undetected areas. Surveillance in 2013 will help to more accurately determine the extent to which this will be successful before a final position can be established.

Where it is neither feasible, practical nor worthwhile to attempt eradication there are some options for containment and/or non-statutory controls. Movement of planting material of *Fraxinus* spp. should only be from areas known to be free of *H. pseudoalbidus.* Infected plants can be asymptomatic for an unknown amount of time following infection in the summer. The fungus continues to develop inside the plant over the winter with symptoms appearing in the spring. This may depend upon the age of the plant when it was infected. To avoid moving asymptomatic infected material, plants should be inspected before breaking dormancy in the spring to detect previously undetected infection on stems, and to avoid infection of new leaves arising from undetected sources of inoculum. The viability of infected seed is not known but it is possible to test seed for DNA of the fungus and this should be part of any protocol for determining sources of healthy seed. Wood may harbour fungal mycelium and, although the efficacy of kiln-drying or other treatments against the fungus is unknown, drying is likely to be deleterious. It is unknown whether the fungus could complete its life cycle on infected wood. Movement of wood from an area known to be free of the pest would help reduce any uncertainty over the risk associated with this material. Leaf litter (etc.) and soil from affected areas pose a risk of movement of the fungus to new areas and where control is required, attempting to clear litter from affected areas with safe disposal (incineration, deep burial etc.) will help reduce the level of inoculum in the area. Controlling movement of vehicles and machinery with associated contaminated soil will also help prevent movement. Non-host plants produced on nurseries in areas where the pest is prevalent may be contaminated with infected leaf litter etc. Good hygiene to remove any associated debris will reduce the risk of inadvertent movement on non-host (and host) planting material. It is not known whether soil/growing media from affected areas is moved in trade but there is a risk associated with this where it originates in an area of high pest prevalence. The practicality of attempting controls on this pathway is questionable.

There is some evidence of tolerance to the pathogen in a low percentage of the natural population of *Fraxinus* in Europe and there is also at least one species of *Fraxinus*, *F. ornus*, which is not known to be a natural host and may thus be grown as an ornamental in the PRA area. Exploitation of possible genetic sources of tolerance could be used two-fold. In the first instance where control is not being attempted and where infected trees do not pose a risk to currently unaffected areas, leaving infected trees *in situ* will help identify individuals capable of surviving infection. These individuals may facilitate natural regeneration of ash in affected areas. Selection of tolerant individuals along with the identification of the genes responsible for tolerance will inform future breeding programmes. The source of natural resistance of *F. ornus* could also be exploited in this way. The heritability of tolerance is as yet not completely understood and requires investigation in the PRA area to ensure that the pathogen is not able to overcome this in future plantings of so-called tolerant plants. A programme of research is already underway on this topic.

Where control is desirable, in areas of recent-plantings, young plants should be removed as they may already be infected or could become infected and will facilitate the production of infective inoculum on fallen leaves etc. When replanting, only non-ash alternatives should be used. Leaving mature trees *in situ* will benefit the local environment. Trees destined for timber production should be felled before the fungus has affected the quality of the wood.

Currently there are no known chemical controls for the fungus and should any come to light in the future (Fera is investigating this), the practicality of application is such that this is only likely to be worthwhile on valuable individuals, possibly by stem injection, which will need to be repeated to protect against infection. Nursery material should not be routinely treated with fungicides since such treatment may prevent symptom development whilst harbouring undetected infection. Hot water treatments of planting material are also not tried and tested (although there is one recently-published paper which may be of use). This may helpful for planting material in the future.

23. Given the information assembled within the time scale required, is statutory action considered appropriate / justified?

<u>Great Britain</u>

In GB, the pest is established in parts and eradication is not being attempted. Some parts have a higher prevalence of diseased trees than others (east/south-east England) and these pose a high risk of disseminating the fungus to new areas. Isolated wider environment sites that are known to be infected also pose a risk of spreading the fungus to currently unaffected areas, along with recently-planted sites (planted ≤5 years ago) which may harbour infected planting material.

Maintaining controls on the import and movement of planting material of *Fraxinus* spp. would limit the further entry and movement of *H. pseudoalbidus* into GB in trade. However, it would not prevent the natural spread of the fungus within GB by windblown ascospores, or via movement of infected leaf litter (etc.), contaminated soil, or timber (lower risk). The cost of taking statutory action needs to be weighed-up against the benefits since further spread and establishment across GB is inevitable and is likely to be relatively quick. Slowing spread will give more time to help policy makers and stakeholders develop a plan for managing woodlands, rural and urban landscapes given the inevitable decline of ash as a native and managed species. The nursery trade and other trades dependent upon ash have already had to make adjustments to using other species given the existing controls which are effectively prohibiting import and movement of planting material in GB.

The objectives of the Defra Interim Control Plan for the disease (Defra, 2012) were to:

- *Reduce the rate of spread of the disease;*
- *Develop resistance to the disease in the ash tree population;*
- *Encourage landowner, citizen and industry engagement and action in tackling the problem; and,*
- *Build economic and environmental resilience in woodlands (and other areas such as hedgerows, parkland etc.) and in associated industries.*

These are retained in the revised plan (Defra, 2013).

Any or all of the measures that have been described could be deployed to reduce the rate of spread of the fungus where this is deemed appropriate. Slowing the rate of spread from the worst-affected areas would help facilitate this, but may not be practical. Management of affected sites should be done on a case-by-case basis dependent upon whether a site poses a risk and on the prevalence of ash in the area. Targeting affected newly-planted areas in locations where the disease is not yet present in the wider environment would be beneficial. Affected isolated wider environment sites could also be targeted to prevent spread to unaffected areas in the locality. Thus, regionalisation of measures could be considered. Devolved Administrations may choose to take different approaches in such circumstances. For example, in Scotland there is a proposal to have a protected area approach for the north and west of the country where action will be taken on infected recently planted sites (all host material) (J. Morgan, FC, UK, *personal communication*, 2013; Defra, 2013). This, along with the lower incidence of ash growing in the area will help limit further establishment for the time being.

Controls on planted trees could be implemented on a voluntary basis through stakeholder engagement except in areas where protection is deemed vital and necessary to slow the spread of the fungus. Surveillance should be targeted at recently-planted sites to identify those that pose a risk and which therefore will require the enforcement of safe removal and disposal of planted material. It will only be possible to identify isolated wider environment sites that become infected in currently unaffected areas if surveillance is also targeted there.

In order to minimise the risk of further entry and spread of *H. pseudoalbidus* on planting material of *Fraxinus* spp., it will be necessary to retain emergency legislation in place whilst the necessary adjustments are made to EU controls. Any desire to trade in ash in the immediate future will need to be carefully managed by a legislative requirement for strict protocols pertaining to the establishment of pest-free areas (or pest-free places of production).

Northern Ireland/Republic of Ireland

In NI/ROI the pest is yet to be found in the wider environment and the authorities are attempting eradication. Surveillance in the spring and summer of 2013 will better determine the status of the pest since it was only detected in the autumn of 2012. It is not known whether it has spread to previously undetected locations. DARD has worked with DAFM to produce a joint all-Ireland control strategy (DARD & DAFM, 2013). Pending the outcome of future surveillance, it is advised that the authorities should keep existing controls in place to help prevent any potential for further introduction and spread. Consideration of future action is dependent upon the results of future surveillance. Comments regarding the situation in GB can be taken into account in determining future management of *H. pseudoalbidus*, should the pest status change from transient to established in parts.

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The Forestry Commission gratefully acknowledges the assistance of several individuals and institutions in producing this PRA. Following a rapid risk assessment written by Forest Research in August 2012, Dr. Claire Sansford (Independent Plant Health Consultant, York, UK) prepared a detailed PRA that took into account the recent events in the UK, included the latest information on the pathogen and extended the PRA to include the island of Ireland. This was subject to internal review by members of the Defra Plant Health Risk Management Workstream (RMW) and included input from the Devolved Administrations and the Republic of Ireland. An external review was also carried out by seven experts in March-April 2013: Rimvys Vasaitis (Swedish University of Agricultural Sciences, Sweden), John Mumford (Imperial College, UK), Gordon Murray (Charles Sturt University, Wagga Wagga, NSW, Australia), Mike Shaw (Reading University), Eric Allen (Pacific Forestry Centre, Victoria, Canada), Matt Castle (Department of Plant Sciences, University of Cambridge, UK) and Thomas Kirisits (Institute of Forest Entomology, Forest Pathology and Forest Protection, University of Life Sciences, Vienna, Austria). The PRA and the expert reviews were then discussed at the monthly RMW meeting on 25th April 2013. This final draft, coordinated by Fera with the assistance of Forest Research, takes into account the expert reviews, additional feedback from Claire Sansford and issues raised at the RMW meeting.

Further work that would help reduce uncertainties:
It is likely that some of this work is being investigated in Europe (at least). The UK is also commissioning new work under the Chalara Control Plan (Defra, 2013). The findings from this research will help reduce the levels of uncertainty in the PRA.

Area of PRA	Uncertainties	Further work that would reduce uncertainty
Taxonomy	None	N/A
Distribution	Official pest-status in NI/ROI Status in other countries including those where the pest has limited distribution or had not been reported in Europe, as well as status in other parts of Asia where it is thought to have originated	Ongoing surveillance in 2013 Surveillance
Hosts	Koch's postulates only undertaken for *F. excelsior*, *F. augustifolia* and *F. pennsylvanica* Full host-range of *Fraxinus* has not been tested Host susceptibility testing has not been undertaken using ascospores (difficult)	Koch's postulates for species known to be recorded as infected by the fungus Expand the list of species for testing (full literature review needed to determine which species are not currently affected) and select species for testing to include those of Asian origin as potential sources of tolerance/resistance Develop method of inoculation using ascospores *In vitro* screening using tissue cultures
Pathways	*Origins of all pathways depend upon distribution* PLANTS Risk of introduction of the fungus through apothecial production on the stems of young plants intended for planting	*Comments under 'distribution' apply* PLANTS Studies on the timing of the production of pseudosclerotia and apothecia on seedlings/saplings

	SEED Risk of introduction of the fungus through infected seed	SEED Studies on the viability of the fungus in infected seed Studies on the viability of seed infected with the fungus Studies on whether the fungus can develop in seedlings arising from infected seed Studies on whether the fungus can form pseudosclerotia and apothecia on infected seed
	WOOD Risk of introduction through infected wood	WOOD Studies on the efficacy of the different elements of kiln-drying (heat, moisture reduction) and other statutory or non-statutory treatments on the viability of the fungus in wood Clarify the extent of colonisation of wood (bark, sapwood, heartwood) Studies on whether the fungus can complete its lifecycle on infected wood
	SOIL/GROWING MEDIA Longevity of the fungus in soil/growing media	SOIL/GROWING MEDIA Survival studies of different types of infected tissue including material with pseudosclerotia Testing survival times of the pathogen in leaf petioles (including those bearing pseudosclerotia) and ligneous pieces (especially those bearing pseudosclerotia) under extreme environmental conditions (e.g. in dried petioles, shoots and twigs) in order to infer the risks posed by dry leaves, especially pseudosclerotia
	ASCOSPORES Factors affecting apothecial production and spore release Proportion that escape from infested sites Dispersal distances Survival Deposition rates	ASCOSPORES Determination of factors influencing sporulation Spore-trapping studies on land Spore-trapping studies/baiting at sea Influence of temperature, %RH, UV light, salt, ozone etc. on survival and germination in relation to conditions

	Inoculum threshold for infection Probability of presence of opposite mating types CONIDIA Whether they have a dispersal role	likely to be experienced at sea Spore-trapping at coastal locations containing ash (discrete from other locations) Development of ascospore inoculation techniques Determination of factors influencing infection Prevalence of mating types in coastal locations containing ash (discrete from other locations) Investigation of timing of melanisation of ascospores CONIDIA Investigation of conidial production on different plant parts and dispersal potential
Establishment	Timing of apothecial production in the PRA area Factors affecting ascospore survival Factors affecting the germination and infection process Factors affecting survival of the fungus in leaf litter and soil Number of ascospores needed to initiate infection	Surveillance of leaf litter of affected woodlands from May to November in different years See above: studies of abiotic factors affecting ascospore survival, germination and infection as well as factors affecting survival of different forms of the fungus (pseudosclerotia on infected leaves, twigs stems etc.). Host/pathogen studies using different levels of ascospore inoculum
Spread	Dispersal distance and survival of ascospores within an affected area and beyond Dispersal via other routes including the distances that infected leaves might spread by wind	Studies in and around isolated affected woodlands using spore trapping Viability of ascospores over time following dispersal Field-studies of tagged infested leaves
Impact	Monetary values associated with ash dieback (economic,	Study of the direct and indirect impact of the fungus in affected areas

	environmental, social) Costs of measures Full host-range within the genus *Fraxinus* Disease progression, especially in older trees	with assigned monetary vales along with costs of phytosanitary controls Cost-benefit analysis of costs of action of different levels versus no action Host-range susceptibility testing based upon literature review Investigation into mode of infection and spread of basal and other lesions in older trees. Monitoring the disease in ash stands of various age and growing under a wide variety of site and climatic conditions
Management	Basis of and heritability of host tolerance Transferability of natural resistance in known non-susceptible hosts Efficacy of composting or other degradation processes including anaerobic digestion against the pathogen Efficacy of chemical treatments to protect valuable trees	Identification of the genes responsible for tolerance in less-susceptible individuals Testing of a range of genotypes of the pathogen against '*tolerant*' individuals Planting of a range of tolerant individuals in affected areas and a study of the consequences (started in GB). Disease and phenology assessments in germplasm collections of ash species, provenances, families and clones (in botanical gardens, provenance and family plots, clonal archives and orchards). This work should be related to that done in Ireland. Leaf phenology assessments prior to and after the arrival of ash dieback would be particularly intriguing (as the pathogens alters leaf phenology, especially leaf shedding, substantially). Development of standard protocols to assess disease severity and resistance/tolerance in *Fraxinus* spp. Incorporation of non-host *Fraxinus* spp. including *F. ornus* in genetic studies and breeding programmes. Controlled experiments using a standard protocol for composting (etc.) against different forms of infected plant material (to include woody material, leaf litter and pseudosclerotia)

	Efficacy of heat treatments for planting material (one paper recently-published) Efficacy of current measures for wood Onsite treatment options for leaf litter Efficacy of hygiene measures used on nurseries Effectiveness of tool/machinery sanitation methods Survival time in absence of host Size of cordon sanitaries Possible variability in incubation period and appearance of symptoms Reliability of inspection Reliability of PFAs including survey methodologies	*In vitro* and *in vivo* studies of selected active ingredients including different methods of application methods (e.g. stem injection, foliar sprays) (started in GB) Further investigation of hot water treatment of young plants to eliminate infections Investigation of kiln-drying, square-sawing etc of infected wood Experiments on treatment options such as urea, slaked lime etc Experiments to investigate hygiene measures used on nurseries in areas where the pest occurs Investigation of efficacy of methods for sanitising tools and machinery used in ash production and disease management Pathogen survival studies in different forms (ascospores, petioles bearing pseudosclerotia, ligneous pieces) Distance over which ascospores can travel along with other modes of spread Inoculation and incubation of host tissues and timing of development of symptoms under different conditions. Disease inspections / symptom observations in the field (in situ). Marking visually healthy ash trees/seedlings and surveying/observing them for the presence of symptoms over time. As above Development of detailed protocols based upon experimental results including the determination of the required frequency, intensity, and which tissues to sample if inspection and testing is used in PFA protocols

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Appendix 1. Explanation of the ratings used to estimate the risk of entry of *H. pseudoalbidus* to the PRA area in Section 13 of this PRA

This Appendix has been written for the benefit of the reader. It is based upon the experience of the author (a former pest risk analyst with Fera), as well as existing pest risk analysts in Fera, whose input is incorporated in the text below (R. Baker and A. MacLeod, Fera, UK, *personal communication*, April 2013).

Background

It is normal practice when using the UK PRA scheme for the choice of risk rating and the uncertainty score to be based upon the evidence available to the risk analyst as well their experience, without detailed guidance being provided to the reader.

As there is much interest in the mode by which *H. pseudoalbidus* has entered and could continue to enter the UK and the Republic of Ireland, especially in relation to the potential for entry by windblown ascospores (which was specifically externally reviewed in the last iteration of this PRA), in response to a request from the Forestry Commission and the Defra Plant Health Evidence Team an exception has been made.

Section A and B below are an annotated summary (much of it *verbatim*) of a personal communication from two of the existing Fera risk analysts to the Forestry Commission made in April 2013. Section C summarises a dialogue between the author of this PRA and the Forestry Commission following the production of version 1.3 of this PRA which was initiated to try to explain the timescales used in section 13 of this PRA. This is unique to this PRA and not transferable to other PRAs.

A. Time and risk ratings used in UK, EU and EPPO PRA schemes

There is no current agreed guidance available for the PRA schemes used in the UK, EU or by EPPO. This is explained below:

1. In the current UK PRA scheme the choice of the risk rating and the uncertainty score are based on the evidence available as well as the experience of the risk analyst.

2. Risk ratings and uncertainty scores for the hundreds of PRAs produced throughout Europe over the last 30 years have all been done in this way. They are supported by documented evidence so the scores and ratings can be challenged, and, if appropriate, changed. Such challenges/changes occur before wider dissemination. In the UK Plant Health Service this occurs firstly within Fera and then at the monthly Risk Management Workstream

meetings currently chaired by Defra Plant Health Policymakers. This PRA has been subject to a high level of scrutiny and has been reviewed in the light of the comments received.

3. Recognising the problem of consistency between PRAs and risk analysts when rating risk and scoring uncertainty, considerable efforts were made within the EU-funded Project PRATIQUE and the EFSA-funded Project Prima phacie (both led by Fera pest risk analysts) to provide detailed guidance. However, this guidance was designed for the much more complex computerised version of the EPPO Scheme (CAPRA). See: http://capra.eppo.org/

4. Note that PRA includes pest risk assessment and pest risk management. 5. The extensive guidance developed by the EU projects named in 3. above cannot readily be transferred to the UK PRA scheme because the latter has far fewer questions than the CAPRA scheme. Research to enhance consistency in the UK PRA scheme is being undertaken.

6. Setting a time horizon for the assessment of entry (and also for impacts) has been discussed at length in EU and EPPO fora. However, no agreement has been reached (i) because risk assessors found a specific time horizon too difficult to take into account (ii) concerns that the choice of a time horizon would appear to provide additional unjustified credibility to the PRA and (iii) because risk managers were unable to agree on the appropriate length of time to be used by risk assessors.

B. Uncertainty

Alan MacLeod (Fera) has developed the table in this Appendix as part of the work in PRATIQUE and Prima phacie. It has been widely accepted though it has not been specifically included in the EPPO CAPRA PRA scheme. This was not used in this PRA but gives some indication of how judgements on uncertainty were made.

C. Summary of the timescales used only in Section 13 of this PRA

Noting the estimates of uncertainty assigned to each rating of likelihood, all assessments of OVERALL probability of entry for each of the pathways described in section 13 of this PRA only, have been made with the following timescales in mind:

Very unlikely: once a decade to once in a century

Unlikely: once every 5 years to once in 50 years.

Moderately likely: once per year

Likely: more than once per year

Very likely: many times per year

Appendix 1 (continued): Table to provide guidance regarding the use of the uncertainty rating within the EPPO PRA Scheme
Alan MacLeod 09/03/2011; revised 28/04/2011

Uncertainty	Interpretation / Meaning	Examples to justify the uncertainty rating	Certainty
Low	There is little doubt about the assessment and the risk rating The assessor is confident	There is direct relevant evidence to support the assessment. The situation can easily be predicted. There are reliable / good quality data sources (e.g. for pest records data provided by NPPOs/RPPOs). The interpretation of data/information is straight forward. Data/information are available from a peer reviewed journal article. Data/information are not controversial, contradictory Personal communication is from experts regarded as specialists on the question raised.	**High**
Medium	There is some doubt about the assessment and the risk rating The assessor has some confidence	There is some evidence to support the assessment. Some evidence for the prediction of the situation is available, but this prediction may be unreliable Some information is indirect, e.g. data from a other species has been used as supporting evidence, The interpretation of the data is to some extent ambiguous or contradictory.	**Medium**
High	There is considerable doubt about the assessment and the risk rating The assessor has little confidence	There is no direct evidence to support the assessment, e.g. only data from other species have been used as supporting evidence The situation cannot be readily predicted because the evidence is poor, and difficult to interpret, e.g. because it is strongly ambiguous. The information sources are considered to be of low quality or contain information that is unreliable, e.g., because it is strongly contradictory.	**Low**