PEST RISK ANALYSIS FOR *PHYTOPHTHORA LATERALIS*

STAGE 1: INITIATION

1. What is the name of the pest?

Phytophthora lateralis Tucker & Milbrath

Taxonomic position:
Kingdom - Chromoalveolata; Phylum - Heterkontophyta; Class - Oomycota; Order - Peronosporales; Family - Pithiaceae; Genus – *Phytophthora*

Phytophthora lateralis has recently been found to exist as four phenotypically and genetically distinct lineages. Two are confined to Taiwan, one to the UK, and one to North America and western Europe (Brasier *et al.*, 2012).

2. What is the pest's status in the EC Plant Health Directive (Council Directive 2000/29/EC) and in the lists of EPPO?

Phytophthora lateralis has now been moved from the EPPO Alert List to the EPPO A2 list but is not listed in the Plant Health Directive (Anon., 2000). In the UK it is treated as a regulated organism under Article 16 (2) of the above directive which requires action on un-listed pests to prevent spread to other member states. Therefore outbreak sites are subject to Plant Health Statutory Notices which specify eradication and containment measures.

Since the first findings there have been various publicity actions to raise awareness about the pest in the UK. These include;
http://fera.co.uk/plantClinic/documents/factsheets/phytophthoraLateralis.pdf
http://www.forestry.gov.uk/pdf/LeafletPLateralisfactsheet.pdf/$FILE/LeafletPLateralisfactsheet.pdf
http://www.forestry.gov.uk/pdf/FCPH-PL-02-2014.PDF/$file/FCPH-PL-02-2014.PDF

3. What is the reason for the PRA?

A PRA for *P. lateralis* was undertaken in April 2006 following a single report of the pest in a nursery in the Netherlands. Since then there have been reports of several nursery outbreaks in the Netherlands in 2004, 2010 and 2011 (NVWA, 2013) and in Belgium in 2013 (NVWA, 2013). There have also been outbreaks in the wider environment in France since 2005 (Robin *et al*, 2011), and numerous confirmed wider environment outbreaks in the UK since 2010 (Green *et al*., 2013).

4. What is the PRA area?

The United Kingdom.

STAGE 2: PEST RISK ASSESSMENT

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

The distribution of *P. lateralis* by country, the situation and the date of the first records are given below in Table 1. The main region of distribution appears to be in forests in California and Oregon in the USA where the pathogen is considered to be an exotic introduction. Findings on nurseries occur in a number of locations in the USA and some of these may be misdiagnoses as indicated below. Recently the pathogen has been found in natural forest stands in Taiwan, where it was isolated from soil (Brasier *et al*., 2010) as well as from foliage of *Chamaecyparis obtusa* (Webber *et al*., 2012). South-East Asia is now thought to be the geographical origin of *P. lateralis* where the pathogen is not considered a threat to native *Chamaecyparis* spp.

Table 1: Distribution of *P. lateralis* by country/region

North America:	<u>Canada</u>: British Colombia (nursery, 1950s; Atkinson, 1965). <u>USA</u>: Washington (nursery, 1923) (Hansen *et al*., 2000); Oregon (forest, by 1940s) (Hansen *et al*., 2000); California (forest, by 1980s) (Kliejunas and Adams, 1981). States where published host records are the subject of debate are: Ohio (nursery, 1974) (Hoitink and Schmitthenner, 1974); Pennsylvania (nursery, 1974) (Hoitink and Schmitthenner, 1974); North Carolina (assumed to be nursery, 1990s) (Abad *et al*., 1994). There has been one published report in surface run-off water in Florida (2005) (Roberts *et al*., 2005).
Central America:	No record
South America:	No record
Caribbean:	No record
Europe:	Confirmed in the wider environment at numerous locations across the UK (2010 to current) (Green *et al*., 2013), and in Brittany, France (2005 to current) (Robin *et al*, 2011). Isolated reports from nurseries in the Netherlands in 2004, 2010 and 2011, and in Belgium in 2013 (NVWA, 2013).
Africa:	No record
Asia:	Found in Taiwan in soil (2008) and on foliage (2011) of native *Chamaecyparis* spp. (Brasier *et al*., 2010; Webber *et al*., 2012)
Oceania:	New Zealand (Roberson, 1982, Pennycook, 1989, Gadgil, 2005). These are all on kiwi fruit trees and may be misdiagnoses.

In Europe there are current outbreaks in the wider environment across the UK (Green *et al*., 2013) and in Brittany, France (Robin *et al*., 2011). Nursery outbreaks have been reported in the Netherlands in 2004, 2010 and 2011, and in Belgium in 2013 (NVWA, 2013). In December 2013, the National Plant Protection Organisation of The Netherlands made a decision to cease all physosanitary measures for *P. lateralis* since they consider the pathogen to be widely distributed across Europe and eradication is unlikely to be successful (NPPO, 2013).

6. Is the pest established or transient, or suspected to be established/transient in the UK?

The pest is present in the UK but subject to official control. There have been more than 20 outbreaks of *P. lateralis* reported in Scotland, England, Wales and Northern Ireland between 2010-14 (Green *et al*., 2013). It has also been established that there are two genetically and morphologically distinct lineages of the pathogen present in the UK; one which has colonised the Pacific northwest of the USA (known as the Pacific northwest lineage) and is now present in parts of Europe and the other (known as the UK lineage) which has, to date, only been found in Scotland (Brasier *et al*., 2012).

In early 2015 the Aboriculture Association invited their members to assist in the completion of a survey aimed at identifying locations of trees affected with *P. lateralis*, with the survey remaining open until mid-March 2015:
http://www.trees.org.uk/Phytophthora-lateralis-survey. At the time of writing, this survey has yet to be completed and no results are available.

7. What are the pest's natural and experimental host plants; of these, which are of economic and/or environmental importance in the UK?

Table 2 summarises the information on natural hosts published in the literature.
The main host with which the pathogen is associated is *Chamaecyparis lawsoniana* (Lawson cypress or Port Orford cedar) and numerous reports confirm this. Other natural hosts include *Taxus brevifolia* (Pacific yew) (DeNitto and Kliejunas, 1991), *Thuja occidentalis* (Schlenzig *et al*., 2011) and *T. plicata* (A. Schlenzig, unpublished record 2014). *Chamaecyparis formosensis* is listed as a host (CABI, 2006) but no further details are available for this report. Tucker and Milbrath (1942) and Webber *et al*. (2012) reported infections of *Chamaecyparis obtusa* (Hinoki cypress). In 2013 *P. lateralis* was isolated from infected *Chamaecyparis pisifera* in Scotland (A. Schlenzig, unpublished). *Chamaecyparis* and *Thuja* belong to the family Cupressaceae and *T. brevifolia* to the family Taxaceae. In 2014, *P. lateralis* was confirmed on *Juniperus sabina* at a nursery in North Yorkshire (Fera unpublished record, 2014).

According to Hansen (E. Hansen, Oregon, USA, 2006, *personal communication*) published reports on hosts other than those in the Cupressaceae and Taxaceae (eg *Actinidia chinensis* and rhododendron**)** are considered to be misidentifications. A range of explanations for this has been given but the most common appears to have been misidentification of another *Phytophthora* species, namely, *Phytophthora gonapodyides.*

These reports are nevertheless included in this Pest Risk Analysis for completeness.

Table 2: Hosts reported* to be naturally infected by *Phytophthora lateralis*

Name	Common Name(s)	Family	Disease	Reference
Actinidia chinensis	Kiwi	Actinidaceae	Associated with root, crown and collar rot	Robertson, 1982**
Actinidia deliciosa	Kiwi	Actinidaceae	-	Pennycook, 1989**, Gadgil, 2005**
Catharanthus roseus	Madagascar periwinkle	Apocynaceae	Root rot	Abad *et al*., 1994
Chamaecyparis formosensis	Formosan cypress	Cupressaceae	-	CABI, 2006
Chamaecyparis lawsoniana	Lawson cypress, Port Orford cedar	Cupressaceae	Root and crown rot, also foliar infection	Tucker and Milbrath, 1942
Chamaecyparis obtusa	Hinoki cypress	Cupressaceae	Root and crown rot, foliage necrosis	Tucker and Milbrath, 1942 Webber *et al*., 2012
Chamaecyparis pisifera	Sawara cypress	Cupressaceae	Isolated from the crown	Schlenzig *et al.*, 2014
Juniperus horizontalis	Creeping juniper	Cupressaceae	Root rot	Abad *et al*., 1994
Juniperus sabina	Savin juniper	Cupressaceae	-	Fera unpublished record, 2014
Kalmia latifolia	Mountain laurel	Ericaceae	Root rot	Abad *et al*., 1994
Photinia x fraseri	Fraser photinia	Rosaceae	Root rot	Abad *et al*., 1994
Rhododendron sp.	Rhododendron	Ericaceae	Isolated from the crown	Hoitink and Schmitthenner, 1974**
Rhododendron sp. *(Azalea)*	Azalea	Ericaceae	Root rot	Abad *et al*., 1994**
Platycladus orientalis (syn. Thuja orientalis)	Oriental arborvitae Chinese thuja	Cupressaceae	-	Hall, 1991
Thuja occidentalis	Eastern white cedar	Cupressaceae	Isolated from the crown	Schlenzig *et al*., 2011
Thuja plicata	Western red cedar	Cupressaceae	Foliage	Schlenzig, unpublished
Taxus brevifolia	Pacific yew	Taxaceae	Crown	DeNitto and Kliejunas, 1991

*Several records are cited in Farr *et al*., 2006. These records may be based on Roberson (1982). Table also includes more recent reports of natural hosts.

** The reports are now thought to be misdiagnoses, that can be attributed to other *Phytophthora* species.

There are few published reports on the experimental susceptibility of plants and trees to *P. lateralis.* Those that exist are presented in Table 3.

Table 3: Plants tested and found to be susceptible to *Phytophthora lateralis* by experimentation

Host	Common name	Family	Disease	Reference
Rhododendron sp.	Rhododendron hybrid Purple Splendour	Ericaceae	Slight root damage	Hoitink and Schmitthenner, 1974
Pseudotsuga menziesii	Douglas fir	Pinaceae	Root infection of seedlings	Pratt *et al*., 1976
Cupressus nootkatensis	Alaskan Cedar	Cupressaceae	Seedling infection	Reviewed by Kliejunas, 1994

It is considered likely that the experimental inoculation of rhododendron by Hoitink and Schmitthenner (1974) may have been with a species of *Phytophthora* other than *P. lateralis* (E. Hansen, Oregon, USA, 2006, *personal communication*).

The two tree species (Table 3) that were tested were found to be susceptible to *P. lateralis* but only as seedlings.

Naturally susceptible economically important hosts are present within the PRA area including *C. lawsoniana* and *Thuja plicata*. *Chamaecyparis lawsoniana* is regarded as the principal host of the pathogen due to the extensive tree mortality the pathogen has caused in the Pacific states of the USA. This species is not a significant forestry species in the UK. It is estimated that there are *ca*. 20 members of the Association of British Conifer Growers (ABCG), many of whom grow *C. lawsoniana*. (J. Tate, ABCG, 2006, *personal communication*). The Royal Horticultural Society Plant Finder Website (RHS, 2014) lists over 200 suppliers of the plant. It was referred to as a common species in the “Trees in Towns II” report (Brtt & Johnston, 2008), suggesting that it is commonly used throughout England.

The other most frequently affected host, *T. brevifolia*, is known to have a variety of uses including wood, hedges and as an amenity and ornamental tree (CABI, 2006). However, it is not grown as a forestry species in the UK and is not widely used as an ornamental plant either.

Thuja occidentalis and *C. pisifera* are grown as ornamental species in the UK but are not used in commercial forestry. In contrast, *Thuja plicata* is used as a minor commercial forestry species, but only a single record of the pathogen affecting the foliage of this species is known.

The remaining published reports of natural hosts listed in Table 2 deal mainly with ornamental species.

There is significant doubt as to whether *P. lateralis* can infect rhododendron species which are important in the ornamental nursery trade and in some managed landscapes such as parkland. RHS (2014) lists numerous retail suppliers for *Rhododendron* and *Azalea*.

RHS (2014) also lists numerous retail suppliers for *Juniperus horizontalis, Juniperus sabina, Thuja occidentalis, Kalmia latifolia, Photinia x fraseri, Platycladus orientalis* and some suppliers for *Catharanthus roseus*. *Cupressus nootkatensis*, an experimentally susceptible species (as seedlings) is not listed in RHS (2014) but can found on various specialist conifer grower websites and is therefore assumed to be grown as an ornamental plant in the UK.

Pseudotsuga menziesii is experimentally susceptible and is therefore a potential host. It is an important forestry tree in the UK and Europe. It is present in plantations and its uses include timber, erosion control, shelterbelts and as an amenity tree. As a specimen tree it is present in parks and gardens (Preston *et al.*, 2002). However, only seedlings of *Pseudotsuga menziesii* have been successfully infected in experiments (Pratt *et al.*, 1976).

Environmentally significant hosts
C. lawsoniana is the main species in the natural environment affected by *P. lateralis* in its current range. It is not a species native to the UK and does not form part of any natural ecosystem. However, it is used in hedgerows, windbreaks and parks and is becoming increasingly widespread, particularly in the south. *Thuja plicata* is a commercial forestry species, but again is not a species native to the UK.

Thuja occidentalis and *C. pisifera* are present predominantly in ornamental plantings in the UK and rarely feature in natural landscapes. The two known *Juniperus* hosts are also ornamental species in the UK, although *J. sabina* is native to mountains of central and southern Europe (http://www.missouribotanicalgarden.org/PlantFinder).

The experimentally susceptible host *P. menziesii* is also not native to the UK and is also not part of any natural ecosystem. (Preston *et al.*, 2002).

Although the record of *P. lateralis* on rhododendron is thought to be a misdiagnosis it is common in the UK and is often present as an understory plant in woodland (Preston *et al.*, 2002).

8. If the pest needs a vector, is the vector present in the PRA area?

No vector is needed.

9. Could the pest enter the PRA area, what are the pathways on which it is likely to move and how likely is the pest to enter the UK?

The pest has entered the PRA area, and the main pathway for movement appears to be plants for planting. *Thuja occidentalis* imported from France into Scotland was found to be infected with *P. lateralis* (Schlenzig *et al.*, 2011). A batch of *C. lawsoniana* imported from The Netherlands was confirmed infected with *P. lateralis* at a garden centre in Scotland in 2011, and in 2014 the pest was also confirmed on *J. sabina* at a North Yorkshire nursery. Thus the trade in live plants, Cuppressaceae in particular, represents a significant pathway of entry and spread. However, plants of all natural tree hosts within the Cupressaceae are prohibited from entry into the UK (and the EU) from countries outside of the EU (Anon., 2000) which should prevent entry of the pathogen.

There have been outbreaks in four EU countries (UK, France, The Netherlands and Belgium), which, assuming compliance with the prohibition on imports of *Chamaecyparis* species from outside Europe, either arose from an introduction on another plant species or as a contaminant of soil (possibly as resilient chlamydospores which are thought to be long-lived), or via growing media associated with non-host plants, or from host plants infected from somewhere in the EU. It was suggested that the original 1923 Seattle outbreak originated from the pathogen's introduction on non-host plants from France (Roth *et al.*, 1972; as cited by Kliejunas and Adams, 1981 and Erwin and Ribeiro, 1996) but this is not supported by available information from France or the USA (Hansen *et al*., 2000). Sinclair *et al.* (1987) speculated that the pest was of Asian origin, and the centre of origin for *P. lateralis* is now known to be almost certainly south-east Asia following findings in Taiwan (Brasier *et al*., 2010, Webber *et al*, 2012). Therefore plants imported from North America and Asia pose a risk of entry, as do plants from EU Member States where *P. lateralis* has been found. It is possible that the pest could be imported with symptomless host plants as it is suspected that some chemical treatments can suppress symptoms.

Chamaecyparis species could be imported under derogations from the requirements of Council Directive 2000/29 from Japan and Korea as naturally or artificially dwarfed plants (bonsai trees) (Anon., 2000). These derogations state that the plants *should be free from harmful organisms not known to occur in the community*. This would provide little protection as this pathogen is generally associated with the roots and it would not be detected by visual inspection until infection was advanced. However, the risks from this pathway would be small compared to entry on other host plants or on non-host plants in the soil or growing media. This is due to the considerable requirements for their entry, including the implementation of additional phytosanitary measures.

Host plants for planting:	Very unlikely		Unlikely		Moderately likely		Likely	**X**	Very likely	
Soil	Very unlikely		Unlikely		Moderately likely	**X**	Likely		Very likely	

10. How likely is the pest to establish outdoors or under protection in the PRA area?

Cultivation under protected conditions possibly only occurs at the beginning of the production process for *Chamaecyparis* spp. raised from cuttings. Summer temperatures of such environments if not well-ventilated may not be conducive to the pathogen as its growth is entirely inhibited above 30ºC (Tucker and Milbrath, 1942).

Outdoors, *P. lateralis* is now present in the UK but subject to official control, mainly in amenity plantings but with some commercial forest areas affected in Northern Ireland. The pathogen's temperature growth range of 3 to 25ºC (Hall, 1991) and ability to survive at low levels in frozen organic matter for at least 16 weeks (Ostrofsky *et al*., 1977) indicates that the UK climate is suitable for the establishment of the organism. Although vegetative growth of the pathogen is inhibited above 30ºC (Tucker and Milbrath, 1942), and such high summer temperatures occur occasionally in the UK, chlamydospores of *P. lateralis* would facilitate survival at these temperatures. Suitable humidity and/or moisture conditions for sporulation and zoospore production also occur in the UK. Aerial infections of *C. lawsoniana* have also been reported in Brittany, France (Robin *et al*., 2011), and in Scotland (Green *et al*., 2013). It is thought that windy, rainy conditions such as occur frequently in the UK and north-west France might aid in aerial dissemination of *P. lateralis*.

P. lateralis is considered a poor saprophyte and currently appears to have a relatively narrow host range. A limitation to the spread of *P. lateralis* is the restricted distribution of the principal host, *C. lawsoniana*, though it is found commonly in urban areas it is not a major forestry species, though it is becoming increasingly widespread and is sometimes recommended for under planting in plantations (Preston *et al*., 2002). But the fact it is currently largely absent from the wider environment (non-urban locations) means natural spread is limited between urban areas.

In addition to the current and previous outbreaks in the wider environment in the UK, there is a continued risk of the pathogen establishing in new locations outdoors on ornamentals produced in the nursery trade, either on *C. lawsoniana*, on other species of *Chamaecyparis*, on *T. brevifolia* or on *Thuja* species.

Because of a recent suggestion that some plant species listed as hosts in Table 2 may be misdiagnoses and because there are few published reports of the experimental susceptibility of other plant species it is not known whether *P. lateralis* has the potential to establish on a wide range of host species in the outdoor environment. However, infection of *C. lawsoniana* is sufficient to justify the maximum establishment score.

Outdoors:	Very Unlikely		Unlikely		Moderately likely		Likely		Very likely	**X**
Under protection:	Very Unlikely		Unlikely	**X**	Moderately likely		Likely		Very likely	

11. How quickly could the pest spread within the PRA area?

Chamaecyparis species are common in the ornamental nursery plant trade in the UK. It is possible that the pathogen could be spread on other known host species or as a contaminant of associated soil or growing media. Therefore the pathogen could be distributed relatively quickly throughout the UK via the horticultural trade, or via the transfer of contaminated soil on tools and equipment that have come into contact with infected sites. Since the pest is now established in the UK and in France, with an unknown but possibly wider distribution across Europe, intra-EU trade could see further introductions within Europe. Although foliage infections of nursery plants do occur (eg *Thuja occidentalis*), it can be difficult to check visually for the presence of the pathogen since it is most commonly associated with root infection and there is potential for symptom suppression with fungicide use.

Once established in the nursery trade, the pathogen is then capable of spreading into the wider environment and causing tree death amongst plantings of *C. lawsoniana* or other *Chamaecyparis* species. Three such events have likely already occurred in the UK, with infected mature *C. lawsoniana* being found adjacent to three garden centres, one of which was found to harbour young infected *C. lawsoniana* imports from The Netherlands among its commercial stock. Whilst *C. lawsoniana* is not an important forestry tree in Britain, it is a valued ornamental and is planted in situations conducive to disease spread (Hansen, 1985).

Spread of *P. lateralis* in the wider environment is likely to be slow due to the lack of large continuous plantings of *C. lawsoniana*. All outbreaks to date have been fairly isolated from each other geographically, with the exception of two outbreaks in Scotland which are only 10 km apart. It is likely that most outbreaks represent independent introductions of the pathogen via infested plants or soil. The disease is still recurring at a number of outbreak sites in Scotland containing large numbers of *C. lawsoniana*, and at two of these locations aerial infections of mature trees have been reported which may have implications for the rapidity of spread of the pathogen. There is also potential for spread to occur on urban trees through pruning and maintenance work, if tools used on infected hosts are not correctly cleaned or footwear carrying contaminated soil is not disinfected.

Natural spread:	Very slow		Slow	**X**	Moderate		Rapid		Very rapid	
In trade:	Very slow		Slow		Moderate		Rapid	**X**	Very rapid	

12. What is the area endangered by the pest?

The pest could potentially become established throughout the range of its known hosts in the UK, especially in western parts of the UK where climatic conditions could be most favourable for survival and spread (Green and Webber, 2012). The survival of the pathogen in sub-zero conditions suggest that the organism is well suited to the UK climate, particularly as it survives under similar conditions in parts of the USA and British Columbia in Canada.

13. What is the pest's potential to cause economic, environmental or societal impacts within its existing distribution?

Phytophthora lateralis has been present in Pacific Northwest of the USA for around 100 years. Impacts were first seen on ornamental cedars in the 1920s but by the 1950s the pathogen had established in forests. It is now present in all areas where *C. lawsoniana* grows as a native forest species (northern California and southwest Oregon) (Betlejewski *et al.* 2003). Disease caused by *P. lateralis* is devastating with many thousands of trees of *C. lawsoniana* killed by the pathogen. Where there are high inoculum levels and suitable conditions for disease transmission, death of *T. brevifolia* trees also occurs. *P. lateralis* has caused considerable economic losses in the forestry industry and causes moderate environmental damage by reducing species richness by one or possibly two species (Hansen *et al*., 2000). The introduction of the pathogen also caused the collapse of the *Chamaecyparis* nursery industry in west coast USA because the disease could not be controlled. Where it is present in British Columbia, Canada, there is considerable cost in replacing dead trees in parks and gardens (Utkhede *et al*., 1997). The high level of mortality of *C. lawsoniana* may be related to the geographical isolation of the trees from the likely origin of the pathogen as Asiatic species of *Chamaecyparis* exhibit resistance (Sinclair *et al.*, 1987).

The discovery of *P. lateralis* in an old growth *Chamaecyparis obtusa* forest in Taiwan (Brasier *et al*., 2010) suggests that this is the geographic centre of origin for the species and it is probably widespread in the native range of *C. obtusa*. In Taiwan, *P. lateralis* has been recovered from forest soils and also from minor symptoms of foliage necrosis on *C. obtusa* (Webber *et al.*, 2012) but there are no acute disease symptoms in the native forests so impacts are minimal.

Impacts are considered for North America alone, as in its likely native range in south east Asia there are no records of any environmental damage caused by the pathogen.

Economic:	Very		Small		Medium		Large	X	Very large	

	small									
Environmental:	Very small		Small		Medium	X	Large		Very large	
Social:	Very small		Small		Medium		Large	X	Very large	

14. What is the pest's potential to cause economic, environmental or societal impacts within the UK?

The pest has the potential to cause severe economic losses for ornamental *Chamaecyparis* growers in the UK as the pathogen causes very high mortality rates. This may result in many growers abandoning production of *Chamaecyparis* altogether and seeking to produce other species. *Chamaecyparis lawsoniana* is commonly planted in amenity situations and is perhaps the most important conifer in the UK ornamental nursery plant trade; one estimate states that *C. lawsoniana* accounts for a '*significant portion*' of the £29 million garden centre sales of conifers per year, but precise figures are unknown are thus a source of uncertainty. This figure also includes imports**.**

Chamaecyparis lawsoniana is not native to the UK, is not an important forestry tree and is not present as large continuous areas of woodland, unlike the Pacific west coast of the USA. However, it is used in hedgerows, windbreaks and parks and is becoming increasingly widespread in the UK. Based on current knowledge concerning virulence to known natural hosts, it can be considered that the environmental impact of the pathogen in natural environments would be relatively low. Significant economic costs have been incurred however by a number of site owners in the UK because of the Plant Health requirement to fell and destroy infected *C. lawsoniana* trees in managed landscapes, parks and garden environments.

Taxus brevifolia, *Thuja occidentalis* and *C. pisifera* are not economically or environmentally important species in the UK and should they become infected in the UK the impact would be minor. *P. lateralis* is likely to cause losses of *T. brevifolia* only under favourable conditions including high levels of inoculum. *Thuja plicata* is a commercially grown forest tree, but the impacts of *P. lateralis* on this species are currently uncertain as only one tree of this species has been found affected, with the infection limited to foliage rather than the potentially lethal stem cankers that occur with *C. lawsoniana*. The only recorded *Juniperus* hosts are ornamental species, and again impacts are unclear as there are limited records. Because of the suggestion that published records on some other hosts are misdiagnoses, the impact on other plant and tree species is unknown.

Overall, economic costs associated with impacts on *Chamaecyparis* growers and costs of tree removal are assessed as medium, whilst environmental impacts are likely to be small as affected plants tend to be ornamental or non-native species. Environmental impacts are uncertain, because the potential host range could include native species. Social impacts could be higher because of the potential loss to widely used ornamental plants and impacts on parks and landscaped recreation areas.

Economic:	Very small		Small		Medium	X	Large		Very large	
Environmental:	Very small		Small	X	Medium		Large		Very large	

Social:	Very small		Small		Medium	X	Large		Very large	

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

Phytophthora lateralis is a plant pathogen with no capacity to act as a vector of other pathogens.

STAGE 3: PEST RISK MANAGEMENT

16. What are the prospects for eradication and/or management from the PRA area?

Phytophthora lateralis is present in the UK but subject to official control. Findings have been made throughout the PRA area, although its distribution is sporadic.

The prospects of eradicating the pathogen from non-nursery situations are poor unless comprehensive and widespread measures are taken. Hansen *et al*. (2000) states that once the pathogen has established in a forestry situation (i.e. *C. lawsoniana* woodland) it is virtually impossible to eradicate. Continued infections of *C. lawsoniana* at UK outbreak sites first reported in 2010/2011 also suggest that the pathogen will continue to remain active at these sites while its main host species is present.

The prospects for eradicating isolated outbreaks in nursery situations are good. The 2004, 2010 and 2011 Dutch nursery outbreaks were successfully eradicated (J. Meffert, Netherlands, 2006, *personal communication*; NVWA, 2013). An outbreak in a shelterbelt of *C. lawsoniana* around the perimeter of a nursery in south west England required destruction of all the trees, but the outbreak was successfully eradicated (P. Reed *personal communication*).

17. What options for control are available?

In North America, several chemicals (fungicides) have been reported to be successful as soil drenches against *P. lateralis* when growing *C. lawsoniana*. These include chloropicrin (Foster and MacSwan, 1954), mancozeb, nabam and zineb (Atkinson, 1970). Mancozeb was found to be particularly effective having some residual fungitoxicity. Utkhede *et al*. (1997) found that a strain of *Enterobacter aerogenes* applied as a soil drench to naturally infected *C. lawsoniana* trees appeared to control the disease and led to an increase in tree growth.

In the UK, growers have a range of fungicides available for use on ornamental nursery stock. The active ingredients etridiazole, fosetyl-aluminium, metalaxly-M and propamocarb hydrochloride are registered for use as drench treatments against *Phytophthora* root rots (Anon., 2006). The target pathogen is mainly *P. cinnamomi* but other less common *Phytophthora* species can cause similar root disease symptoms to this pathogen. These fungicides are likely to have efficacy against *P. lateralis.* Control is likely to be less effective in a field soil situation and chemical soil sterilisation with metham-sodium or dazomet may reduce levels of disease, but this is dependent on soil type, cultivation (if any) and the time of year of application. Fosetyl-aluminium is already widely used as a soil drench in UK ornamental conifer production as and when *Phytophthora* disease(s) become a problem. However, the use of some fungicides may only result in symptom suppression and resistance may arise. Currently, none are readily available for use against disease outbreaks in the wider environment.

Cultural control measures suggested for nursery situations include general good hygiene measures, prevention of the introduction or movement of infested soil or infected plant material. Avoiding the use of susceptible varieties is also recommended. More specifically, while investigating control methods for *P. lateralis* Hunt and O'Reilly (1984) found excellent survival and compatibility of scions of *C. lawsoniana* grafted to rootstocks of *C. formosensis* or *C. thyoides* over a two year observation period but grafting to *C. nootkatensis* or *C. pisifera* was unsatisfactory.

A range of cultural measures usually associated with good hygiene practices was recommended by the US federal agencies managing *P. lateralis* in the forest areas of Oregon, Washington and California in order to prevent further spread of the disease. These have been reviewed by Greenup (1998) and Hansen *et al*. (2000) and include: conducting forestry operations in summertime to reduce the chances of spore movement, cleaning of vehicles and equipment to remove soil and plant material, wide spacing of susceptible hosts, growing hosts on sites unfavourable for disease spread, regulating the harvesting of *C. lawsoniana* timber, and road closures in infested areas. Special consideration was also given to the design of roads to ensure they were not conducive to spreading the disease.

A breeding programme to generate varieties of *C. lawsoniana* resistant to *P. lateralis* has also been underway in the USA since the 1980s and has yielded promising results (Hansen *et al*., 2000; Sniezko *et al*, 2012). In 2010, the first operational planting of *P. lateralis* disease resistant trees was undertaken in northern California with ~41,000 disease-resistant seedlings planted on 1,400 acres.

In the UK, where disease outbreaks are found, management has been via official Plant Health Statutory Control Notices issued by the Plant Health Inspectorate or the Forestry Commission to the affected grower or landowner. Measures usually require felling of dead and dying trees, with affected material and associated debris destroyed, either by burning, or chipping and deep burial provided no other Lawson cypress are in the vicinity. Where appropriate, disinfectant mats are placed at exit points from public sites, and staff and visitors are asked to use them to kill pathogen inoculum that might be picked up and transferred on footwear. Notices are also erected at the public sites to inform visitors of the infection and to encourage sensible biosecurity measures such as keeping to footpaths, keeping dogs on leads, and not taking cuttings from plants in the park. Soil movement is prohibited and cleared affected areas should not be replanted with known susceptible plant species.

18. Summary and Conclusions of the Pest Risk Analysis

P. lateralis is present in the UK but subject to official control. It also has the potential to enter the country on imported plant material (where permitted) and in associated soil or growing media from other affected European countries (France, The Netherlands and Belgium), from Asia which is the likely origin of the pathogen, and possibly also from North America although the prohibition of conifer imports from this region should prevent entry.

The main hosts of *P. lateralis* are *Chamaecyparis* species, particularly *C. lawsoniana*, with reports on other species such as *Thuja occidentalis* and *T. plicata* a rarity. Published records on some plant or tree species have been the subject of debate and for a variety of reasons are usually viewed as misidentifications (E. Hansen, Oregon, USA, 2006, *personal communication*). There is, therefore, uncertainty in this PRA regarding the published (and potential) host range of *P. lateralis* which requires experimental investigation to support the assessment of likely spread, economic and social impacts, and risk management.

Since *P. lateralis* has been found in a number of EU Member States and is considered established in France and the Netherlands, there is a risk of the pathogen being spread around Europe on exported host species. The Netherlands has recently (December 2013) ceased phytosanitary measures against *P. lateralis* and this could substantially increase the risks of the pathogen being imported from The Netherlands, a major plant nursery import/export hub, on host plants and in soil. Because imports of *Chamaecyparis* spp. from outside of the EU are prohibited with the exception of specific derogations for bonsai, the most likely pathways of entry from outside the EU are either as infected *T. brevifolia*, *T. occidentalis* or as a contaminant of soil or growing media associated with this host or with non-host plants.

P. lateralis has caused significant damage to the native population of *Chamaecyparis lawsoniana* and destroyed the cedar production industry in Washington and Oregon. The near 100% mortality rate of *P. lateralis* on *C. lawsoniana* makes this pathogen a considerable threat to amenity and nursery production of this host in the UK. However, *P. lateralis* does not seem to be as virulent on other hosts. For example, mortality of *T. brevifolia* has only been observed in areas where inoculum levels are high and conditions are optimum for pathogen spread and survival, e.g. riverbanks, and the one report of infected *Thuja occidentalis* involved foliage infections which killed the young trees approximately three years after infection was confirmed (Schlenzig *et al.*, 2014).

Since it is possible that the pathogen’s host range is greater than is currently known, there is a risk of the pathogen establishing on other plant and tree species. For example, the confirmation of infected *Chamaecyparis pisifera*, *Thuja plicata* and *Juniperus sabina* (Table 2) are new host records. *P. lateralis* is currently causing major problems to the populations of *C. lawsoniana* in a number of managed landscapes in the UK. Should the pathogen become established in the nursery trade, ornamental production of *C. lawsoniana* is likely to be seriously threatened and nursery production of *C. lawsoniana* might have to be abandoned.

There is also potential for different *Phytophthora* species to hybridise with each other, potentially leading to changes in virulence and host range, ultimately creating new, unforeseen problems. This has been observed previously in the UK and resulted in a new species, *Phytophthora alni,* being recognised (Brasier, 2001).

In the absence of other data, specifically data determining the host range of *P. lateralis* with regards to UK species and on non-UK species imported from the USA and Asia, as well as data regarding the hybridisation potential of *P. lateralis* with *Phytophthora* species already present in the UK, it is recommended that consideration be given to surveys of known susceptible hosts within the UK. The Aboriculture Association has invited their members to assist in the completion of a survey aimed at identifying locations of trees affected with *P. lateralis*, with the survey remaining open until mid-March 2015:
http://www.trees.org.uk/Phytophthora-lateralis-survey
At the time of writing, this survey has yet to close and thus no results are yet available.

This PRA therefore indicates that:

Spread is: Likely to be relatively slow through natural processes but rapid when associated with plants for planting. Movement of contaminated soil and planting medium to host growing areas could efficiently spread the pathogen. In addition, the potential for aerial spread by the pathogen observed in France and Scotland may also play a role in spread.

Establishment is: Based on UK *C. lawsoniana* findings in the wider environment, establishment is scored as very likely.

Economic, environmental and social impacts are expected to be: Small to medium, with economic impacts likely to be highest for producers of ornamental *Chamaecyparis* plants.

Endangered area: Throughout the UK.

Risk management:

Prospects of eradicating the pest from non-nursery situations are considered poor or virtually impossible. Measures are available to reduce the impact including the possibility of resistant genotypes of *C. lawsoniana* (see 17) but require further evaluation and research. Areas of major uncertainty and research are shown below in Table 4. Future outbreak sites will be subject to Plant Health Statutory Notices which specify eradication and containment measures under Article 16 (2) of the Plant Health Directive (Anon., 2000).

19. Is there a need for a more detailed PRA?

Yes ☐ No ☒ X

Version 2, May 2014

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Table 4: Major Uncertainties and Further Work

Section of PRA	Uncertainties	Further work which may be needed to improve the PRA
Taxonomy	-Genetic variability and whether the different confirmed lineages of the pathogen exist in association with particular hosts or have different biological requirements and possibly could even undermine current products of the resistance breeding programme in the USA. For example, Hoitink and Schmitthenner (1974) reported that their isolates of *P. lateralis* from rhododendron had a different temperature range for growth than reported for other isolates. -The relationship between isolates found in North America, Taiwan and Europe.	-microsatellite or RAD profiling of isolates from the different lineages to assess genetic diversity in relation to evolutionary pathways
Distribution	-Why *P. lateralis* is not more widespread in the USA - Distribution of the pathogen within France and a survey of other EU countries including The Netherlands	-Further information needed on factors favouring limited distribution in the USA, other than the natural distribution of its main host, *C. lawsoniana*
Hosts	-Host range of *P. lateralis*, testing both Pacific northwest and UK lineages already present in the country, particularly with regards to species native to the UK and *Chamaecyparis* species.	-Determining the pathogenicity of the pathogen's different lineages for important UK native species.
Pathway	-Whether absence of symptoms is an indication of an absence of the pathogen. -The origin of the pathogen.	-Determination of a latency period on various hosts. Investigations of the symptom suppressive activity of various fungicides. -Information on origin of introductions into the USA, UK and France.
Establishment	-Whether the UK climate is suitable for the spread of the pathogen.	-Use of climate comparison software to determine the climate similarities.
Spread	-Determining the rate of spread of the pathogen from nurseries to the natural environment. - Determine the persistence of the pathogen in soil at outbreak sites and risk of spread in soil.	-Epidemiological modelling.

Impact	-Whether post-introduction evolutionary change can increase virulence.	-Assess the ability of *P. lateralis* to hybridise with Phytophthora species in the UK, such as *P. ramorum*.
Management	-Control options for the pathogen in UK plantation and nursery situations.	-Efficacy of commonly used disease control measures on nurseries against *P. lateralis*.

References

Abad ZG, Creswell T, Jones RK, Shew HD. 1994. Occurrence of *Phytophthora* species on various hosts in North Carolina. *Plant Disease* **78**, 830.

Anon. 2000 (as amended). Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. *Official Journal of the European Communities* **43 no. L 169**, 1-143 (2004 unofficial consolidation).

Anon. 2006. The UK Pesticide Guide 2005. Editor R. Whitehead. CABI Publishing. 637pp.

Atkinson RG. 1965. *Phytophthora* species inciting root rot of *Chamaecyparis lawsoniana* and other ornamentals in coastal British Columbia. *Canadian Journal of Botany* **43**, 1471-1475.

Atkinson RG. 1970. Evaluation of some dithocarbamate fungicides as soil drenches against *Phytophthora* root rot of *Chamaecyparis lawsoniana*. *Canadian Journal of Plant Science* **50**, 565-568.

Betlejewski F, Casavan K, Dawson A, Goheen DG, Mastrofini K, Rose DL, White DE. 2003. A range-wide assessment of Port-Orford-Cedar (*Chamaecyparis lawsoniana*) on federal lands**.** Portland, OR: U.S. Department of Agriculture, Forest Service, and U.S. Department of the Interior, Bureau of Land Management; pp. 182. Available from: http://www.fs.fed.us/r6/dorena/publications/in/poc-range-wide-assessment

Brasier CM. 2001. Rapid evolution of introduced plant pathogens via interspecific hybridization. *Bioscience* **51**, 123-133.

Brasier CM, Franceschini S, Vettraino AM, Hansen EM, Green S, Robin C, Webber JF, Vannini A. 2012. Four phenotypically distinct lineages in *Phytophthora lateralis*. *Fungal Biology* **116**, 1232-1249.

Brasier CM, Vettraino AM, Chang TT, Vannini A. 2010. *Phytophthora lateralis* discovered in an old growth *Chamaecyparis* forest in Taiwan. *Plant Pathology* **59**, 595–603.

Britt C, Johnston M, 2008. Trees in Towns II: a new survey of urban trees in England and their condition and management. Research for amenity trees no. 9. Communities and Local Government. Available from: http://gtgkm.org.uk/documents/trees-in-towns-ii-1271349201.pdf

CABI. 2006. *Forestry Compendium* [http://www.cabi.org/compendia/fc/].

DeNitto GA, Kliejunas JT, 1991. First Report of *Phytophthora lateralis* on Pacific Yew. *Plant Disease* **75**, 968.

Erwin DC, Ribeiro OK. 1996. *Phytophthora lateralis.* In *Phytophthora diseases worldwide*. American Phytopathological Society, St Paul, 365-367.

Farr DF, Rossman AY, Palm ME, McCray EB, Undated. Fungal Databases, Systematic Botany & Mycology Laboratory, ARS, USDA. Retrieved 13th February, 2006, from http://nt.ars-grin.gov/fungaldatabases/.

Foster WR, MacSwan IC. 1954. Report of Plant Pathology Branch. Report of the British Columbia Department of Agriculture 1953, CC62-CC66. [Abstract from *Review of Applied Mycology*].

Gadgil PD. 2005. Fungi on trees and shrubs in New Zealand. *Fungi of New Zealand* Volume 4. Fungal Diversity Press, Hong Kong, 437 pp.

Green S, Brasier CM, Schlenzig A, McCracken A, MacAskill GA, Wilson M, Webber JF. 2013. The destructive invasive pathogen *Phytophthora lateralis* found on *Chamaecyparis lawsoniana* across the UK. *Forest Pathology* **43**, 19-28.

Green, S., Webber, J. 2012. The emerging threat from Phytophthora to trees in Scotland. *Scottish Forestry* **66**, 9-16.

Greenup M. 1998. Managing *Chamaecyparis lawsoniana* (Port-Orford-Cedar) to control the root disease caused by Phytophthora lateralis in the Pacific Northwest, USA. In *Coastally Restricted Forests*. Laderman, AD (Ed). Oxford University Press Inc. New York, 93-100.

Hall G. 1991. *Phytophthora lateralis*. *IMI Descriptions of Fungi and Bacteria* No. 1065.

Hansen EM. 1985. Forest Pathogens of North West North America and their potential for damage in Britain. *Forest Record* 129, Forestry Commission, UK.

Hansen EM, Goheen DJ, Jules ES, Ullian B. 2000. Managing Port-Orford-Cedar and the introduced pathogen *Phytophthora lateralis. Plant Disease* **84**, 4-14.

Hoitink HA, Schmitthenner AF. 1974. Relative prevalence and virulence of *Phytophthora* species involved in rhododendron root rot. *Phytopathology* **64**, 1371-1374.

Hunt RS, O'Reilly HJ. 1984. Evaluation of control of Lawson cypress root rot with resistant root stocks. *Canadian Journal of Plant Pathology* **6**, 172-174.

Kliejunas JT. 1994. Port Orford Cedar Root Disease. *Freemontia* **22**, 3-11.

Kliejunas JT, Adams DH. 1981. *Phytophthora* root rot of Port-Orford-cedar in California. *Plant Disease* **65**, 446-447.

Ostrofsky WD, Pratt RG, Roth LF. 1977. Detection of *Phytophthora lateralis* in soil organic matter and factors that affect its survival. *Phytopathology* **67**, 79-84.

NPPO. 2013. December 2013 Pest Report – The Netherlands. National Plant Protection Organisation, Wageningen, The Netherlands.

NVWA. 2013. Pest Risk Assessment for *Phytophthora lateralis*. Netherlands Food and Consumer Product Safety Authority, Utrecht, The Netherlands.

Pennycook SR. 1989. Part II. Fungal plant diseases recorded in New Zealand. *Plant Diseases Recorded in New Zealand* **2**, 5-502. Auckland: Plant Diseases Division, DSIR.

Pratt RG, Roth LF, Hansen EM, Ostrofsky WD. 1976. Identity and pathogenicity of species of *Phytophthora* causing root rot of Douglas-fir in the Pacific Northwest. *Phytopathology* **66**, 710-714.

Preston CD, Pearman DA, Dines TD. 2002. *New Atlas of British and Irish Flora*. Oxford University Press, Oxford.

RHS. 2014. *Royal Horticultural Society Plant Finder website*.

[http://www.rhs.org.uk/rhsplantfinder/plantfinder.asp]

Roberts PD, Urs RR, French-Monar RD, Horrine MS, Seijo TE, McGovern RJ. 2005. Survival and recovery of *Phytophthora capsici* and oomycetes in tailwater and soil from vegetables fields in Florida. *Annals of Applied Biology* **146**, 351-359.

Robertson GI. 1982. Kiwifruit can tolerate *Phytophthora*, but not 'wet feet'. *Orchardist of New Zealand* **55**, 148-151.

Robin C. Piou D, Feau N, Douzon G, Schenck N, Hansen EM. 2011. Root and aerial infections of *Chamaecyparis lawsoniana* by *Phytophthora lateralis*: a new threat for European countries. *Forest Pathology* **41**, 417-424.

Roth LF, Bynumm HH, Nelson EE. 1972. Phytophthora root rot of Port Orford Cedar. US Department of Agriculture Forest Service. Pest Leaflet 131. 7pp.

Schlenzig A, Campbell R., Mulholland V. 2011. *Thuja occidentalis*: a new host for *Phytophthora lateralis. New Disease Reports* **24**, 8.

Schlenzig A, Campbell R., Eden R. 2014. First report of *Phytophthora lateralis* on *Chamaecyparis pisifera. New Disease Reports* **29**, 15. http://dx.doi.org/10.5197/j.2044-0588.2014.029.015

Sinclair WA, Lyon HH, Johnson WT. 1987. Phytophthora root rot of Port Orford cedar. In *Diseases of trees and shrubs*. Comstock Publishing, Ithaca, New York, 288.

Sniezko RA, Hamlin, J, Hansen, EM. 2012. Operational programme to develop *Phytophthpra laterali*s-resistant populations of Port-Orford-Cedar (*Chamaecyparis lawsoniana*). Proceedings of the 4th International Workshop on the Genetics of Host-Parasite Interactions in Forestry. General Technical Report PSW-GTR-240, pages 65-79.

Tucker CM, Milbrath JA. 1942. Root rot of *Chamaecyparis* caused by a species of *Phytophthora. Mycologia* **34**, 94-101.

Utkhede R, Stephen W, Wong S. 1997. Control of *Phytophthora lateralis* root rot of Lawson cypress with *Enterobacter aerogenes*. *Journal of Arboriculture* **23**, 144-146.

Webber, J.F.; Vettraino, A.M.; Chang, T.T.; Bellgard, S.E.; Brasier, C.M.; Vannini, A., 2012: Isolation of *Phytophthora lateralis* from *Chamaecyparis* foliage in Taiwan. *Forest Pathology* **42**, 136-143.