



Pest risk assessment of *Phytophthora ramorum* in Norway

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Pest risk assessment of *Phytophthora ramorum* in Norway

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SUMMARY

Phytophthora ramorum S. Werres, A.W.A.M. de Cook & W.A. Man in't Veld is a newly described *Phytophthora*-species which is considered to be relatively recently introduced to both USA and Europe from an unknown area, or areas, of origin. The pathogen has a wide host range and causes a complexity of disease symptoms generally grouped into three categories: canker, foliage lesion, and dieback. In Europe the pathogen has been reported in 21 countries, Norway included; predominantly on ornamental plants in nurseries, but also outside nurseries in gardens and semi-natural environment, most often on rhododendrons.

The Norwegian Food Safety Authority needs a risk assessment of the pest as basis for an evaluation of a future phytosanitary risk management of *P. ramorum*, including whether the organism should be regulated as a quarantine pest in Norway. On this background the Norwegian Food Safety Authority, in a letter of 22nd August 2008, requested a pest risk assessment of *P. ramorum* from the Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM). The pest risk assessment was adopted by VKM's Panel on plant health (Panel 9) on a meeting 24th June 2009.

VKM's Panel 9 gives the following main conclusions of the risk assessment: 1) *P. ramorum* is present but not widely distributed in Norway, and the pest is under official control. The outdoors surveys of *P. ramorum* in Norway have not been conducted systematically over the whole country, and some uncertainty therefore still remains regarding the current distribution of *P. ramorum* in the PRA area. 2) The overall probability of entry of *P. ramorum* into Norway and the overall probability of establishment of *P. ramorum* in Norway are both rated as high with low levels of uncertainty; 3) In the absence of statutory control the probability for *P. ramorum* to be spread quickly in the PRA area by trade of host plants for planting is rated as high. The uncertainty of this assessment is low; 4) The part of the PRA area where presence of *P. ramorum* might result in economically important losses (the endangered area) is assessed to be most of the country of Norway, except where the climate is predicted to be unfavourable for the pest. However, this area must be regarded as a maximum estimate for the endangered area. On the other hand, a narrow and very conservative estimate for the endangered area can be defined based on the geographical distribution of highly susceptible host plants in Norway. This area is gardens and parks with *Rhododendron spp.*, *Viburnum spp.* and *F. sylvatica* and areas in the wild into which *Rhododendron spp.* has spread and woods with *F. sylvatica*. Woods with *F. sylvatica* is limited to the county of Vestfold and some small areas in the counties of Aust-Agder and Hordaland; 5) *P. ramorum* is likely to have moderate economic impact on the nurseries in the PRA area with current phytosanitary measures. Without any such regulations *P. ramorum* is likely to have major economic impact on the nursery industry of the PRA area. The levels of uncertainties of these assessments are low; 6) With current phytosanitary measures *P. ramorum* is likely to have moderate economic impact on parks and private gardens in parts of the PRA area. Without any such regulations *P. ramorum* is likely to have major economic impact in the best climatic zones of the PRA area. The levels of uncertainties of these assessments are low; 7) The impact of *P. ramorum* in coniferous and mixed forests of the PRA area is likely to be minor. The level of uncertainty of this assessment is medium. The impact of *P. ramorum* in natural and planted deciduous broadleaf forests of the PRA area is likely to be minor due to the scattered and limited distribution of the most susceptible species. The level of uncertainty of this assessment is medium; 8) The non-commercial and environmental consequences to natural environments in the PRA area are likely to be moderate. The level of uncertainty of this assessment is high.

KEY WORDS

Phytophthora ramorum, Pest Risk Analysis (PRA), pest risk assessment, ramorum bleeding canker, sudden oak death, ramorum dieback, ramorum blight

CONTRIBUTORS

Persons working for VKM, either as appointed members of the Committee or as *ad hoc*-experts, do this by virtue of their scientific expertise, not as representatives for his/her employers. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

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The Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM) has appointed an *ad hoc*-group consisting of both VKM members and external experts to answer the request from the Norwegian Food Safety Authority. The members of the *ad hoc*-group are acknowledged for their valuable work on this opinion.

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1. BACKGROUND

Phytophthora ramorum S. Werres, A.W.A.M. de Cook & W.A. Man in't Veld is a newly described *Phytophthora*-species (Werres *et al.* 2001) which is considered to be relatively recently introduced to both USA and Europe from an unknown area, or areas, of origin. The pathogen has a wide host range and causes a complexity of disease symptoms generally grouped into three categories: canker, foliage lesion, and dieback. Symptoms of ramorum dieback can be seen in figure 1.



Figure 1. Symptoms of ramorum dieback caused by *Phytophthora ramorum* in A) *Viburnum x bodnandense*, and B); *Rhododendron catawbiense*. Bergen, 2007. Photo: B. Toppe.

In Europe the pathogen has been reported in 21 countries (figure 2); predominantly on ornamental plants in nurseries, but also outside nurseries in gardens and semi-natural environment, most often on rhododendrons. Trees with bleeding cankers caused by *P. ramorum* have in Europe only been reported from the UK and the Netherlands, all in association with infected rhododendron. The mortality of trees in Europe is so far minimal. In 2008, natural infection in the important native heath and woodland species *Vaccinium myrtillus* was detected for the first time in the UK (CSL 2009).



Figure 2. Countries in Europe where *Phytophthora ramorum* has been detected (marked with dark grey). The pathogen has been reported from 19 EU countries, where it is under official control: Belgium, Czech Republic (eradicated nursery finding), Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Slovenia, Spain (including Mallorca), Sweden and the UK (all countries including the Channel Islands). It has also been recorded in Norway and Switzerland (Sansford *et al.* 2009). The map does not illustrate the geographic distribution of the pathogen within each country.

In parts of the western California and Oregon, USA, *P. ramorum* is causing extensive mortality in *Lithocarpus* and *Quercus* species. In addition, the pathogen also affects a wider range of woodland species including understorey and herbaceous plants. The impact on affected woodland ecosystems in USA is severe.

The first detection of *P. ramorum* in Norway was made in 2002 on rhododendron plants imported earlier the same year. Since then the pest has been found every year in nurseries and garden centres. In 2004 it was found for the first time in parks and private gardens, on young rhododendron plants, and in 2005 it was found on established plants of rhododendron and

viburnum. Based on symptoms observed by some growers, it is assumed that the organism was present in Norway even earlier than 2002. In September 2009, infection was confirmed for the first time in blueberry (*Vaccinium myrtillus*).

In 2003 the former Norwegian Agricultural Inspection Service (Landbrukstilsynet) implemented regulations on measures against *P. ramorum* (Landbruks- og matdepartementet 2003), with authorization in § 6 and § 40 of Regulations relating to plants and measures against pests (the plant health regulations) (Landbruks- og matdepartementet 2000). The background was that *P. ramorum* was considered as a potential quarantine pest in Norway, and pending more detailed knowledge on the organism and the result of ongoing risk analysis, it was decided to implement temporary measures to prevent further entry and spread. The measures were largely at the same level as measures in the EU countries, and like in the EU they have been revised several times.

In 2004 the Norwegian Crop Research Institute made a PRA for Norway, commissioned by the Norwegian Food Safety Authority (Herrero and Sletten 2004). Several countries have performed risk analysis for *P. ramorum* during the last few years, simultaneously with an extensive international research on the organism. In the UK the CSL/Forest Research made a Pest Risk Analysis (PRA) in 2003. This document was revised in 2007, in the shape of a Data Sheet (CSL-Forest Research 2007).

RAPRA (Risk Analysis for *P. ramorum*) was an EU-supported project, with the overall objective to produce a European PRA for *P. ramorum*, including risk management strategies and contingency plans applicable to the pathogen within the EU. The project started in 2004, and the PRA was published in February 2009 (Sansford *et al.* 2009).

In Norway surveillance and survey programmes have been conducted since 2003 (Herrero *et al.* 2006). In addition the Norwegian Food Safety Authority has performed import controls and surveys in Norwegian nurseries. This has resulted in numerous interceptions, and plant consignments have been rejected in import controls. Measures to eradicate the pest have been conducted when *P. ramorum* has been detected domestically. Similar control strategies have been implemented in the EU countries. Despite national and international measures imposed during the last few years, *P. ramorum* has spread via the nursery plant trade in Europe.

The Norwegian Food Safety Authority needs a risk assessment of the pest as basis for an evaluation of a future phytosanitary risk management of *P. ramorum*, including whether the organism should be regulated as a quarantine pest in Norway.

On this background the Norwegian Food Safety Authority, in a letter of 22nd August 2008, requested a pest risk assessment of *P. ramorum* from the Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM). The pest risk assessment was adopted by VKM's Panel 9 on a meeting 24th June 2009.

Be aware that the current document is a pest risk assessment, and not a PRA. A PRA consists of both a risk assessment and a risk management part. VKM performs purely the risk assessment, whereas the Norwegian Food Safety Authority is responsible for the risk management. However, since this pest risk assessment is part of a PRA process, the current document refers to the PRA term in several contexts, like the identification of the PRA area and referrals to former PRAs. This is in accordance with the international standard ISPM No. 11 (FAO 2004).

2. TERMS OF REFERENCE

The Norwegian Food Safety Authority requests a risk assessment of *P. ramorum* in accordance with the international standard ISPM No. 11 (FAO 2004).

The Norwegian Food Safety Authority wishes VKM to assess the following aspects in particular:

- a. The current status concerning the establishment and distribution of *P. ramorum* in Norway.
- b. Future potential for establishment and distribution in Norway.
- c. Consequences of an establishment in Norway, including the potential for damage to cultivated and wild plants in Norway, and possible economic and environmental effects from an establishment in near and more distant future. Also, an appraisal of effects of an expected climate change on distribution and potential for damage should be included.
- d. Probability for and consequences of a possible entry and establishment of mating type A2 in Norway.
- e. Possible important pathways for introduction and further spread of *P. ramorum* in Norway, including relevant host plants for a possible future regulation of *P. ramorum* as a quarantine pest.
- f. Control effects of the current measures in nurseries, including the possibilities for preventing further spread in Norway by nursery plant trade, and the possibilities for eradication of *P. ramorum* on locations where it has been detected and possibly established in Norway.

The Norwegian Food Safety Authority expects the final report of the RAPRA project to include a comprehensive PRA on *P. ramorum* for Europe. The VKM report should include an evaluation of the relevance for Norway of the RAPRA conclusions concerning risks for Europe.

3. INITIATION

3.1. Initiation points

3.1.1. PRA initiated by the review or revision of a policy

The current pest risk assessment (and the corresponding PRA) was initiated by the Norwegian Food Safety Authority as a basis for a review and possible revision of the current phytosanitary regulations. In Norway *P. ramorum* has since 2002 been treated as a potential quarantine pest. The Norwegian Food Safety Authority needs a risk assessment of the pest as basis for an evaluation of a future phytosanitary risk management of *P. ramorum*, including whether the organism should be regulated as a quarantine pest in Norway.

The timing of the PRA initiation is linked to an increased domestic distribution of the pathogen, to repeated interceptions in imported consignments despite measures taken, and to new knowledge about the pest. Considerable research on *P. ramorum* during the last years, and the very recent publication of the European PRA of *P. ramorum* (Sansford *et al.* 2009), has provided substantial new knowledge about the risk posed by the pathogen for Europe. The Norwegian Food Safety Authority has requested VKM in the current pest risk assessment to evaluate the relevance of the RAPRA conclusions for Norway.

3.2. Identification of PRA area

The PRA area is Norway.

3.3. Information

Information sources utilised for this pest risk assessment are published material available in international scientific journals, books and reports, as well as personal communications with persons involved in the area, geographical data, unpublished results, and information from the Norwegian Food Safety Authority that have been made available to the risk assessors. Where these information sources have been used, this is indicated in the text by references enclosed in brackets.

The current pest risk assessment is made according to the international standard ISPM No. 11 (FAO 2004).

3.3.1. Previous PRAs

Commissioned by the Norwegian Food Safety Authority, the Norwegian Institute for Agricultural and Environmental Research (Bioforsk) in 2004 did a PRA on *P. ramorum* (Herrero and Sletten 2004). The PRA referred to several outbreaks of the pathogen on rhododendron in Norwegian nurseries since 2002. With limited domestic rhododendron production the authors assumed that the pathway for *P. ramorum* was rhododendron imported from Germany and the Netherlands. On arrival the plants looked healthy, but latent infections initiated development of the disease later in the season. The authors concluded that *P. ramorum* has the potential for serious damage in several important plant species in Norway. Further spread of the pathogen should be arrested, and *P. ramorum* should maintain its status as quarantine pest for Norway.

Some of the most recent information on *P. ramorum* is summarized in a Data Sheet published in 2007, which also assessed the risk of *P. ramorum* to the UK (CSL-Forest Research 2007).

The most recent European PRA is the RAPRA Project which started in January 2004. The project aimed to determine the risks posed by *P. ramorum* to European trees, woodland ecosystems and other environmentally important habitats and ornamental plants in the nursery trade and in public gardens. The overall objective of the project was to produce a PRA for *P. ramorum* within the EU. The PRA was published February 2009 (Sansford *et al.* 2009). The RAPRA-PRA concludes that *P. ramorum* fulfils the criteria of a quarantine pest. The pathogen has been reported from 21 European countries (19 EU countries, Norway and Switzerland), mainly on non-tree hosts grown in containers at nurseries and retail garden centres. Some infected plants have been found outside nurseries in managed parks and gardens and/or in wild (woodland) situations, principally *Rhododendron*, *Viburnum*, *Camellia*, *Pieris* and *Magnolia* species. Infected trees with bleeding bark cankers have only been found in the UK (principally *Fagus sylvaticus* and various *Quercus* species) and the Netherlands (*F. sylvaticus* and *Quercus rubra*). In some of the affected areas, containment to suppress the level of inoculum for protection of susceptible trees and to reduce spread, has become necessary. This is because total eradication of the pathogen may not be possible in parts of the EU. Timber plantations and forests in favourable climate may be at risk where they have hosts that support sporulation as an understorey. A recent finding of *P. ramorum* on bilberry (*V. myrtillus*) in the UK demonstrates that also heathland habitats are at risk. The pathogen is classified as ‘not widely distributed’ in the EU, since it has the potential to become more widely spread in parts of Europe if phytosanitary measures were to be lifted. *P. ramorum* has a very large and expanding host range across a wide range of plant types. Host plants and suitable habitats are widely distributed in the EU. The pathogen is favoured by some nursery practices. In the absence of phytosanitary controls it is likely to spread rapidly within the EU through the trade network. The potential economic impact for the nursery trade in the EU is estimated as high. If controls are lifted, environmental impacts may become locally major. Social impacts and impact on tourism will increase as a result of damage to plants in managed gardens that are visited by the public (Sansford *et al.* 2009).

The most recent PRA for the USA was made in 2007 by USDA (United States Department of Agriculture) (Cave *et al.* 2007). They concluded that the risk presented by *P. ramorum* is high based upon actual and potential hosts in climate conducive to infection in most of the Eastern United States. In the USA the pathogen has a large number of hosts in multiple plant families, a high dispersal potential via trade and natural means, and the disease may have serious economic and environmental impacts.

3.4. Conclusion of initiation

The pest of concern is the Oomycete *Phytophthora ramorum*. The initiation point for this pest risk assessment (and the corresponding PRA) is the review or revision of policy by the Norwegian Food Safety Authority, including whether the organism should be regulated as a quarantine pest in Norway. The PRA area is Norway. The timing of initiation is linked to an increased domestic distribution of the pathogen, to repeated interceptions in imported consignments despite measures taken, and to new knowledge about the pest. The Norwegian PRA from 2004 needs to be updated. Relevance to Norway of the recent RAPRA-PRA (Sansford *et al.* 2009) is considered in the current pest risk assessment.

4. PEST RISK ASSESSMENT

4.1 Pest categorization

4.1.1 Identity of pest

4.1.1.1 Scientific name

Phytophthora ramorum S. Werres, A.W.A.M. de Cook & W.A. Man in't Veld (Werres *et al.* 2001)

4.1.1.2 Synonym

None

4.1.1.3 Common name of the disease

English: ramorum bleeding canker, sudden oak death, ramorum dieback, ramorum blight
Norsk: ramorum-greinvisning

4.1.1.4 Taxonomic position

Kingdom: Chromalveolata, Phylum: Heterokontophyta (heterkonts or stramenopiles), Class: Oomycetes, Order: Peronosporales, Family: Pythiaceae, Genus: *Phytophthora* (Sansford *et al.* 2009).

Special notes on taxonomy:

Genetic studies of *P. ramorum* have identified three lineages in the pathogen: EU1, NA1 and NA2 (Ivors *et al.* 2006). Only lineage EU1 has been detected in Europe. This lineage has also been detected in some North American nurseries. The NA1 lineage is present in Californian and Oregon forests and has also been detected in North American nurseries, while the NA2 lineage is found in, or can be traced back to nurseries in California and Washington State.

P. ramorum is heterothallic and both mating types (A1 and A2) are required for sexual reproduction. All USA lineages have proven to be of the A2 mating type, while the European lineage (including the Norwegian analysed isolates) is of the A1 mating type with the exception of three A2 mating type isolates from Belgium (Sansford *et al.* 2009). Sexual reproduction would result in relatively long-lived spores and potentially, greater genetic variability, thereby making control of the disease more difficult. So far sexual reproduction of *P. ramorum* has not been observed in nature.

The evolutionary history of *P. ramorum* is deduced from nuclear sequence data. It is suggested that the three lineages have been diverging for at least 11% of their history, estimated to be in the order of 165 000 to 500 000 years (Goss *et al.* 2009). There is strong evidence for previous recombination between the lineages, indicating that the ancestors of *P. ramorum* were members of a sexually reproducing population. The divergence of the three clonal lineages of *P. ramorum* supports a scenario in which the three lineages originated from different geographic locations that were sufficiently isolated from each other to allow independent evolution prior to introduction to North America and Europe (Goss *et al.* 2009). It is thus probable that the emergence of *P. ramorum* in North America and Europe was the result of three independent migration events.

P. ramorum is considered to have been introduced separately to North America (NA1 and NA2 lineages) and to Europe (EU1 lineage) via very occasional events that are considered to

have occurred relatively recently, e.g. potentially during the last 20–30 years based on genetic studies (Ivors *et al.* 2004, 2006; Mascheretti *et al.* 2008).

Although differences in aggressiveness, growth rate, colony type and sporangia morphology have been observed between the different lineages, DNA profiling studies have provided evidence that the European and North American isolates represent distinct populations of *P. ramorum*, and not distinct species (Ivors *et al.* 2004, 2006; Martin 2008; Grünwald *et al.* 2008a).

4.1.2 Presence or absence in PRA area

As shown in more details in the tables 1-3 below, *P. ramorum* has already been detected in trade of nursery plants in the PRA area. Outside nurseries and garden centres *P. ramorum* has been found on host species in managed parks and gardens, especially along the south-west coast of Norway. Most findings outside nurseries have been on *Rhododendron* spp. The pathogen is subject to official control.

In September 2009, infected blueberry (*Vaccinium myrtillus*) was found in a semi-managed park at the south-west coast of Norway (Herrero 2009, personal communication). The blueberry was growing close to an infected rhododendron. This recent finding is not incorporated in the tables and figures of the chapter, but should be kept in mind by the reader.

P. ramorum has still the potential to increase its host range and to become more widespread in Norway. There is also a potential for further entry of known or new lineage and/or mating types of the pathogen into the PRA area.

It should be mentioned that the outdoors surveys of *P. ramorum* in Norway have not been conducted systematically over the whole country. Some uncertainty therefore still remains regarding the current distribution of *P. ramorum* in the PRA area.

In November 2002, when *P. ramorum* was detected for the first time in Norway, the pathogen was isolated from *R. catawabiense* imported to a nursery earlier the same year. Following the first detection, the Norwegian Food Safety Authority has carried out surveys from 2003 to 2008. The results from these surveys are presented in tables 1-3.

Table 1. Number of samples analysed for *Phytophthora ramorum* in Norway in the period 2002-2008, and number of positive samples in the same period. Samples were taken from Norwegian nurseries, garden centres, outdoor sites, and import shipments to Norway.

	2002	2003	2004	2005	2006	2007	2008	All years
Nurseries and garden centres, total	1	20	149	268	339	287	147	1211
Positive samples from nurseries and garden centres	1	2	68	91	60	130	55	407
Outdoor sites, i.e. parks and private gardens, total	0	1	7	86	155	98	104	451
Positive samples from outdoor sites	0	0	5	18	44	29	46	142
Import samples, total	0	0	0	102	74	124	156	456
Positive import samples (interceptions)	0	0	0	6	9	32	24	71
Total number of samples tested	1	21	156	456	568	509	407	2118
Total number of positive samples	1	2	73	115	113	191	125	620

Table 2. Number of locations sampled for *Phytophthora ramorum*-analysis and number of locations with positive samples in Norway in the period 2002 – 2008. Samples were taken from two types of locations: nurseries and garden centres, or outdoor sites.

	2002	2003	2004	2005	2006	2007	2008
Nurseries and garden centres, total	1	10	47	74	64	54	48
Nurseries and garden centres with positive samples	1	2	27	31	29	24	28
Outdoor sites, i.e. parks and private gardens, total	0	1	4	12	29	20	17
Number of outdoor site with positive samples	0	0	2	7	10	14	12
Total number of locations sampled	1	11	51	86	93	74	65
Total number of locations with positive samples	1	2	29	38	39	38	40

Table 3. Hosts and detections of *Phytophthora ramorum* in nurseries/garden centres and parks/private gardens in Norway in the period 2002-2008.

	Nurseries and garden centres	Parks and private gardens
2002	<i>Rhododendron</i> sp. (1)	
2003	<i>Rhododendron</i> spp. (2)	
2004	<i>Rhododendron</i> spp. (66), <i>Pieris japonica</i> (1), <i>Kalmia</i> sp. (1)	<i>Rhododendron</i> spp. (5)
2005	<i>Rhododendron</i> spp. (91)	<i>Rhododendron</i> spp. (16), <i>Viburnum farreri</i> (syn. <i>V. fragrans</i>) (2)
2006	<i>Rhododendron</i> spp. (59), <i>Syringa vulgaris</i> (1)*	<i>Rhododendron</i> spp. (42), <i>Viburnum bodnantense</i> (1), <i>Viburnum</i> sp. (1)
2007	<i>Rhododendron</i> spp. (129), <i>Pieris</i> sp. (1)	<i>Rhododendron</i> spp. (28), <i>Pieris japonica</i> . (1)
2008**	<i>Rhododendron</i> spp. (55)	<i>Rhododendron</i> spp. (45), <i>Quercus</i> sp. (1)*

Between brackets number of detections.

* Detections made using DNA-analysis by real time PCR. The detection could not be confirmed by isolation

** The recent detection in *V. myrtillus* (September 2009) is not incorporated.

These records show that *P. ramorum* has been found on *Rhododendron* spp. in all years since it was first discovered in the PRA area in 2002. The increase in number of samples analysed from 2004 and forward, with the corresponding increase in positive detection, displays an expansion of the disease distribution, and it also reflects increased funding for surveys and identifications as well as an enlarged knowledge of the disease among inspectors.

In 2008 the number of samples analysed from nurseries and garden centres and the number of positive detections at the same locations decreased (table 1). Additional restrictions imposed in 2008 on the import of *Camellia* spp., *Kalmia* spp., *Pieris* spp., *Rhododendron* spp. (except *Rhododendron simsii*) and *Viburnum* spp. from Germany and the Netherlands reduced the amount of import and detections (table 5 and 6). At the same time the Norwegian production of rhododendron increased.

Outdoors, *P. ramorum* has been found on *Rhododendron* spp. in private and public gardens in the PRA area every year since 2004. This indicates that *P. ramorum* is present but not widely distributed in the PRA area. The disease is under subject to official control. The geographical distribution of the records of *P. ramorum* in Norway is illustrated in figures 3, 4 and 5. Figure 3 shows the geographical distribution in the PRA area. The map is restricted to Southern Norway since *P. ramorum* has not been found further north. Figure 4 and 5 give examples of local distribution of *P. ramorum* on rhododendrons in parks within and around the city of Bergen, Hordaland County. Systematic registrations of *P. ramorum* in the biggest parks of this city have revealed disease attacks of *P. ramorum* at several sites. The disease has reappeared at the same locations in consecutive years.

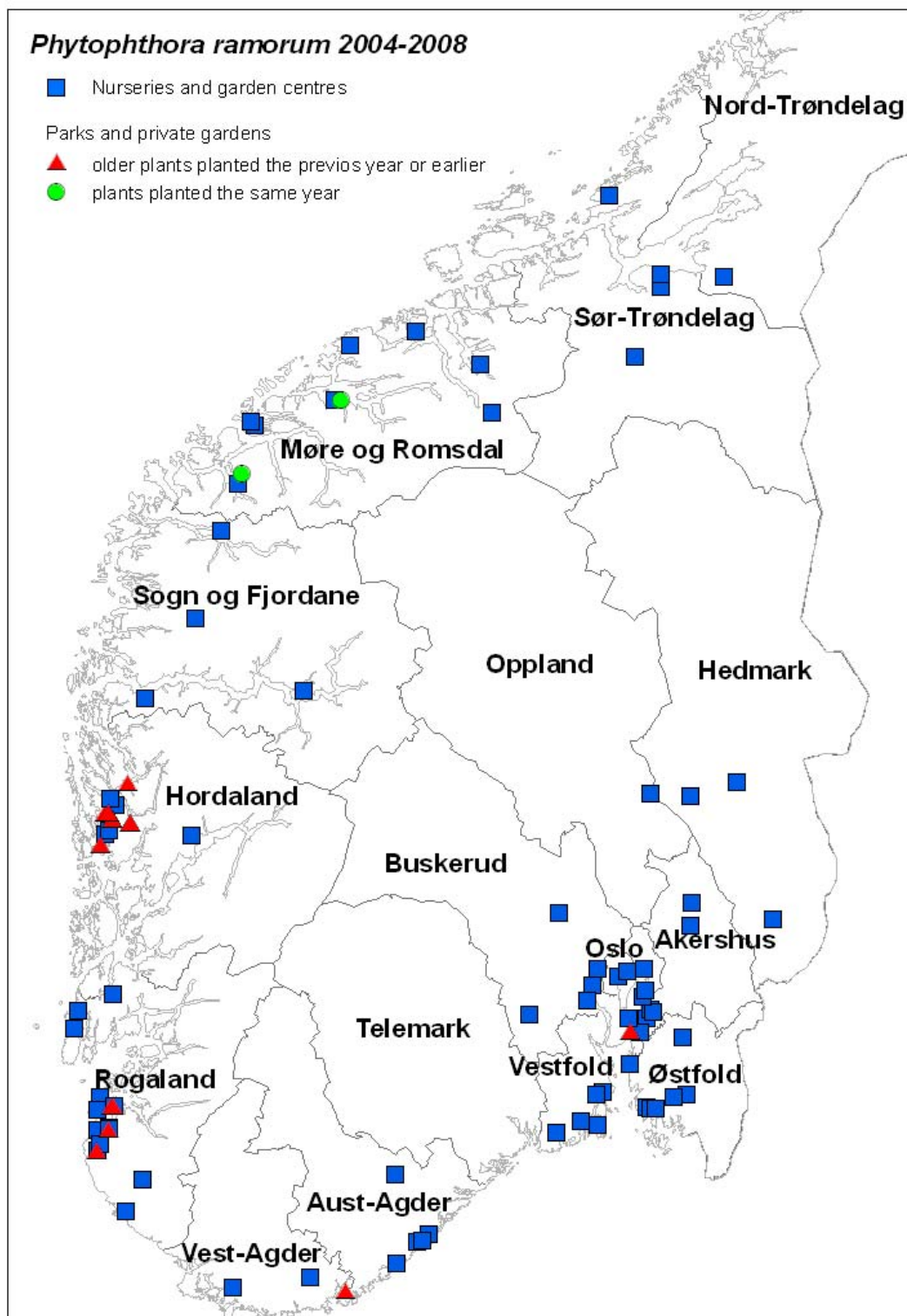


Figure 3. Geographical distribution of *Phytophthora ramorum* records in counties of Southern Norway. Interceptions of *P. ramorum* detected in imported plant material on arrival and before unpacking are not displayed. The map is restricted to Southern Norway since *P. ramorum* has not been found further north.

Norwegian Scientific Committee for Food Safety



Figure 5. Local records of *Phytophthora ramorum* detections on rhododendron in the city of Bergen, Hordaland County, displayed on an aerial photo background.

4.1.3 Regulatory status

Norway: Regulations on measures against *P. ramorum* were last amended 31st January 2008 (Landbruks- og matdepartementet 2003; 2008b). In Norway *P. ramorum* is currently treated as a potential quarantine pest.

EPPO: *P. ramorum* has been on the EPPO Alert list since 2001, but it is not yet included in the EPPO A1 and A2 Lists of pests recommended for regulation as quarantine pests.

The EU: The Commission Decision of 19th September 2002 on provisional emergency phytosanitary measures to prevent the introduction into and the spread of *P. ramorum* within the Community (2002/757/EC) prohibits introduction and spread of the pathogen, imposes restrictions on susceptible plant species and requires member states to conduct official surveys. The Decision was last amended 27th March 2007 (2007/201/EC).

Regulatory action against *P. ramorum* falls under Article 16 of the European Union Plant Health Directive. Member States must report new pests or pathogens and can take emergency actions to contain or eradicate them. Such actions have to be reported to the EU Commission, which then considers them with experts from the Member States at the Plant Health Standing Committee, normally within three months. The Standing Committee may then adopt EU-wide emergency measures which supersede any national ones already introduced (Hunter 2007).

The outcome of the RAPRA project, a PRA for EU (Sansford *et al.* 2009), was presented to the European Commission Standing Committee on Plant Health 2-3rd February 2009. The majority of the Member States requested the permanent regulation of *P. ramorum* and inclusion in the Directive. The Committee concluded that this request could be analysed by a technical working group (EC 2009).

Canada: In British Columbia infected ornamental plants in nurseries and landscape plantings have been detected and destroyed (Cave *et al.* 2007).

United States: *P. ramorum* has been confirmed and is quarantined in 14 counties in California. Since 10th January 2005, all nursery stock shipped interstate from California, Oregon and Washington State is regulated to prevent movement of this pathogen (Cave *et al.* 2007).

4.1.4 Potential for establishment and spread in the PRA area

Due to the availability of host species and a climate conducive to infection, there is a potential for establishment and spread of *P. ramorum* in the PRA area. The records of *P. ramorum* are presented in chapter 4.1.2. The fact that the pest has reappeared at the same locations in consecutive years, indicates that *P. ramorum* has the potential to establish at least in some parts of the PRA area. Both *Rhododendron* spp. and *Viburnum* spp. are popular and widespread ornamental species in managed parks and gardens in Southern Norway. They are most frequently planted along the west coast. Likewise, *Calluna* and *Vaccinium* species are examples of native host plants at particularly risk. Both genera are widespread in natural environments of the PRA area (figure 6). Susceptible tree species like *Fagus sylvatica*, are present both as a native forest plant at some locations, and as an ornamental tree in parks and gardens. Also other suitable hosts are available to establish and sustain a pest population in the PRA area.

Analysis of compared locations (see section 4.2.2.2) indicates that at least some parts of the PRA area have climates conducive to infection and establishment of *P. ramorum*.

After introduction, both natural (rain-splash, wind-driven rain) and human-assisted factors (soil and derbies attached to footwear or vehicles, trade of infected host plants) will aid in the dispersal of *P. ramorum* to locations in the PRA area where hosts and conducive climatic conditions are available.



Figure 6. *Rhododendron* growing in a mixed deciduous forest with a shrub layer dominated by *Vaccinium myrtillus* in the shaded parties and *Calluna vulgaris* in the open parts of the forest. The picture is from a coastal location in Vest-Agder County, Southern Norway (Photographer: T. Rafoss).

4.1.5 Potential for economic consequences in PRA area

Considering the host plants and habitats which occur in the PRA area, and the damage or loss caused by the pest in its area of current distribution in Europe and the USA, the pest could cause significant damage or loss to plants or other negative economic impacts (on the environment, on society, on export markets) in the PRA area.

Rhododendrons, which are one of the main host plants of the disease, are widely used in private and public gardens in the PRA area, especially along the west coast. The full economic damage caused by establishment of the pathogen on rhododendrons is not known because *P. ramorum* is under official control in the PRA area and in the other countries where the pathogen is known to occur (in Europe, the USA and Canada). In the city of Bergen there are examples from single parks where 1000 m² of rhododendrons have been destroyed.

In Europe *P. ramorum* has so far mainly been a problem in the nursery industry. The two host plant genera experiencing the greatest problems are *Rhododendron* and *Viburnum*. According to RAPRA, the current impact on nursery-grown ornamental species is thought to be moderate within the areas in which *P. ramorum* occurs in the EU, the USA, and Canada. This is in terms of yield, quality and control costs, excluding the cost of phytosanitary controls. When including the costs of phytosanitary controls, the impact is thought to be major. Losses in export markets arising from the presence of *P. ramorum* in the EU are not quantifiable but there are significant losses for some Member States including the Netherlands, Germany and Belgium. Losses in exports (including intra-state trade) have also occurred in the USA and Canada (Sansford *et al.* 2009).

In California the pathogen has caused economic damage in the form of reduced lumber production from infested forests and extra costs related to removal of dead trees to avoid forest fire. By the end of 2006, it was estimated that more than a million trees had been killed in California, with at least another million infected (Palmieri & Frankel 2006). These include tanoaks (*Lithocarpus densiflorus*) and North American *Quercus* species (*Q. agrifolia*, *Q. chrysolepis*, *Q. kelloggii* and *Q. parvula* var. *shrevei*). In Europe, several tree species have already been found with bleeding cankers, principally European beech (*Fagus sylvatica*) and North American red oaks (*Q. rubra*), all in association with infected rhododendron. The distribution of oak and beech species in the PRA area is given in section 4.2.2.1.

There are great concern and uncertainty regarding the potential of *P. ramorum* to infect other host plants of the wild flora in the PRA area. Pathogenicity tests and a recent finding in nature show that environmentally important understorey plants in Norway (e.g. *Calluna vulgaris* and *Vaccinium myrtillus*) could become infected. Also, understorey plants could represent a very important stage in a possible epidemic outbreak of the disease. Bleeding canker in trees has so far only been discovered in connection with an understorey host nearby that supports sporulation.

Damage or loss of trees and understorey species might cause disruption to the ecology and loss of recreational value of the area. The environmental (ecological) and social consequences have been considerable in parts of California (Carlsen 2003; Frankel 2003).

A more detailed analysis of the potential economic consequences is presented in section 4.3.

4.1.6 Conclusion of pest categorization

P. ramorum is present but not widely distributed in the PRA area. The pest is subject to official control in the PRA area.

Only A1 mating type, probably of EU1 lineage, has been found in the PRA area. The North American NA1 and NA2 lineages, both of the A2 mating type, have so far not been detected in the PRA area.

Due to the availability of hosts and a climate conducive to infection, there is a potential for establishment and spread of *P. ramorum* at least in parts of the PRA area. *P. ramorum* has still the potential to increase its host range and to become more widespread in Norway. There is a potential for further entry of known or new lineage and/or mating types of the pathogen into the PRA area.

The pest could cause significant loss or damage to plants or other serious negative economic impacts (on the environment, on society, on export markets) in the PRA area.

Thus, the current pest risk assessment is continued.

4.2. Assessment of the probability of introduction and spread

4.2.1 Probability of entry of the pest

The probability of entry of *P. ramorum* into the PRA area will vary with different pathways and different geographical origin of the commodity. The overall probability is based upon identification of pathways, the probability of the pest being associated with the pathway at origin, the probability of survival and multiplying during transport or storage and the probability of transfer to a suitable host after arrival. The significance and the uncertainty for each of these topics are addressed in the following paragraphs (4.2.1.1 – 4.2.1.5).

Probability of entry for each commodity type is assessed for four geographical origins where *P. ramorum* has been recorded: USA; Canada; the European countries (EU and Switzerland); and the unknown area or areas of origin for *P. ramorum*. It is speculated that the pathogen may have originated somewhere in Asia (Brasier *et al.* 2004; Goheen *et al.* 2005).

4.2.1.1 Identification of pathways

The newly published PRA for the 27 EU member states (Sansford *et al.* 2009) stated that *P. ramorum* is most likely to enter EU through the eight pathways listed in table 4. We identify the same eight pathways as the most significant for entry of *P. ramorum* into the PRA area, with plants for plantings as the most important. All the listed pathways relate to the entry of isolates of both European and non-European lineages. The non-European isolates potentially represent a higher risk due to their different genetic composition or adaptive fitness compared to the EU1 lineage isolates. All the listed pathways have a potential for introduction of the A2 mating type, which regardless of lineage might sexually recombine with EU1 lineage isolates of the A1 mating type.

There are no other pathways of importance identified than those shown in table 4. Natural spread of *P. ramorum* includes movement of water (rain, runoff, streams, rivers, and irrigation water), animals and aerial dissemination (of sporangia, zoospores and possibly chlamydospores). Strong winds, which are common during heavy rains along the California coast, may move the detached sporangia over great distances (Hansen *et al.* 2002). Similar weather events occur along the western coast of Norway. But, so far there is no evidence that natural spread should be considered as a pathway for entry.

Table 4. Potential pathways for introduction of *Phytophthora ramorum* from Europe (EU and Switzerland), the USA, Canada, or the unknown areas of origin.

A.	Plants for planting of known hosts
B.	Plants for planting of non-host species accompanied by contaminated, attached growing media
C.	Soil/growing media (with organic matter) as a commodity
D.	Soil as a contaminant (e.g. on footwear, machinery, vehicles etc.)
E.	Foliage and cut branches (for ornamental purposes) of foliar hosts
F.	Seeds and fruits of host plants
G.	Bark from host plants
H.	Wood from host plants

Pathway A. Plants for planting of known hosts

The likelihood of *P. ramorum* to enter the PRA area by plants for planting of known hosts (CLS 2009; USDA-APHIS 2008) is high with a low uncertainty due to the availability of data on import volumes and interceptions. This pathway is rated as the most likely pathway for introduction of *P. ramorum* into the PRA area. Depending on the geographical origin of the host plants, this pathway encompasses both the potential to introduce non-European isolates (NA1 & NA2 lineage, both of the A2 mating type) as well as the further entry of *P. ramorum*-isolates belonging to the European EU1 lineage, A1 mating type.

The pathway is direct since the end-use is planting of known host plants. A pathway is considered as direct if the consignments are placed in direct contact with host plants at its end use.

Since the first discovery of *P. ramorum* in Norway in 2002, the pest has been detected 71 times at the border as interceptions on known host plants for planting imported from European countries (table 1, section 4.1.2). The interceptions are most often on *Rhododendron* spp. but the pathogen has also been found on *Pieris japonica* and *Viburnum* sp. The trends in yearly import of these most important hosts and the country of origin are shown in table 5 and 6.

A full list of known natural hosts, last updated 9th October 2008, along with experimental data on susceptibility of potential host is presented in the PRA for EU (Appendix II; natural hosts and Appendix III; Species susceptibilities to *P. ramorum* as determined by experimental tests) (Sansford *et al.* 2009). Furthermore, an updated list of natural hosts of *P. ramorum* with symptoms and locations are available from Central Science Laboratory in England (CSL 2009). This list was last updated 26th February 2009. Four new natural hosts in Europe are included: *Ilex aquifolium*, *Lithocarpus glabra*, *Vaccinium myrtillus* and *Vaccinium vitis-idaea*, all findings located in UK. Those four are not mentioned in the Appendix II-list in the PRA for EU (Sansford *et al.* 2009). The lists of hosts are believed to continuously increase as the knowledge about the pathogen increases.

To date the full range of natural hosts in Europe include species of *Acer*, *Aesculus*, *Arbutus*, *Calluna*, *Camellia*, *Cinnamomum*, *Choisya*, *Cornus*, *Castanea*, *Castanopsis*, *Drimys*, *Eucalyptus*, *Fagus*, *Fraxinus*, *Griselinia*, *Hamamelis*, *Ilex*, *Klamia*, *Laurus*, *Leucothoe*, *Lithocarpus*, *Lonicera*, *Magnolia*, *Michelia*, *Nothofagus*, *Osmathus*, *Parrotia*, *Photinia*,

Pieris, *Quercus*, *Rhododendron*, *Ribes*, *Salix*, *Schima*, *Sequoia*, *Syringa*, *Taxus*, *Umbellularia*, *Viburnum*, and *Vaccinium* (CSL 2009).

From the USA, a list of regulated hosts is presented by United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA-APHIS 2008). In this list, plants that are naturally infected by *P. ramorum*, and have had Koch's postulate completed, documented, reviewed, and accepted, are presented.

With the recent additional restrictions imposed in 2008 on the import of *Camellia* spp., *Kalmia* spp., *Pieris* spp., *Rhododendron* spp. (except *Rhododendron simsii*) and *Viburnum* spp. into the PRA area from Germany and the Netherlands, it is expected that the frequency of entry of *P. ramorum* will be reduced. However, the ongoing spread of this pest within Europe may increase the frequency of entry from other pathways. Generally, the frequency of entry of *P. ramorum* will depend on what policy the EU finally decides in relation to *P. ramorum*.

Table 5. Trends in the number of consignments of the most important host plants for *Phytophthora ramorum* entering Norway. Each consignment represents one "Phytosanitary Certificate". There is no available information about the total amount of single plants in each consignment, except for *Rhododendron* spp. (see table 6). Source: The Norwegian Food Safety Authority.

Year	Total number of consignments with nursery stocks.	Number of consignments with CKPRV*	Country of origin for CKPRV consignments	Number of consignments sampled	Number of consignments with <i>P. ramorum</i>
2005	3433	631	NL (359), DE (123), DK (117), GB (16), BE (6), SE (4), FR (2), US (2), PL (1), FI (1)	46	5
2006	3413	525	NL (243), DE (184), DK (74), GB (13), BE (4), FR (3), SE (2), IT (2)	43	6
2007	3613	667	NL (453), DE (145), DK (49), GB (10), BE (5), SE (3), PL (1), FR (1)	59	22
2008	3609	242	NL (88), DK (55), DE (33), BE (30), GB (16), FR (13), SE (4), PL (3)	39	14

* CKPRV = *Camellia*, *Kalmia*, *Pieris*, *Rhododendron* and *Viburnum*

Table 6. Trends in import volumes of *Rhododendron* spp. for planting, except *R. simsii*, into Norway in the period 1999-2008. Source: Norsk Gartnerforbund.

Year	Kg	Value (NOK)	Numbers of plants
1999	632 582	10 087 163	-
2000	549 522	7 194 923	-
2001	579 214	8 341 362	239 991
2002	675 445	9 713 463	292 008
2003	648 895	8 597 463	208 137
2004	581 245	9 017 998	220 494
2005	621 121	10 297 096	264 669
2006	848 412	11 127 226	263 581
2007	829 221	11 626 118	225 602
2008	528 578	8 910 504	228 774

Pathway B. Plants for planting of non-host species accompanied by contaminated, attached growing media

The likelihood of *P. ramorum* to enter the PRA area through plants for planting of non-host accompanied by contaminated attached growing media is medium with a high uncertainty surrounding the data. It represents a direct pathway if the plants are planted in areas where hosts occur. Table 5 presents the total number of consignments of imported nursery stocks to Norway, including non-hosts. It is assumed that these non-hosts could contain some unknown hosts or contaminated soil. Depending on the geographical origin of the commodity, this pathway encompasses both the potential to introduce non-European isolates (NA1 & NA2 lineage, both of the A2 mating type) as well as the further entry of *P. ramorum*-isolates belonging to the European EU1 lineage, A1 mating type.

Pathway C. Soil/growing media (with organic matter) as a commodity

The likelihood of *P. ramorum* to enter the PRA area with contaminated soil is rated as medium, with a high level of uncertainty. Soil and growing media represent a potential direct pathway if it is used for planting of host plants (Parke and Lewis 2007). *P. ramorum* has the potential to contaminate soil and growing medium if infected debris is present, and has a potential to survive significant periods of time in potting media (> 12 months) (Linderman and Davis 2006). Soil and growing media with organic matter could therefore represent a significant and direct pathway if imported from areas where the disease occurs. Depending on the geographical origin of the soil/growing media, this pathway encompasses both the potential to introduce non-European isolates (NA1 & NA2 lineage, both of the A2 mating type) as well as the further entry of *P. ramorum*-isolates belonging to the European EU1 lineage, A1 mating type.

The import of soil and organic growing media into the PRA area is banned from countries outside Europe (Landbruks- og matdepartementet 2000). Import of growing medium (except sphagnum) from European countries needs to be followed by a Phytosanitary Certificate (Landbruks- og matdepartementet 2000). The import of soil and growing medium occurs most often from Sweden, but in the period from 2003-2009 import has also originated from

Denmark, Estonia, Finland Germany, The Dominican Republic, The Netherlands, The United Kingdom, Lao People's Democratic Republic and Sri Lanka.

Full access to the quantity of import from each country is difficult since the registrations are done on a phytosanitary certificates basis, which does not give easily available information about quantity in each shipment.

Pathway D. Soil as a contaminant (e.g. on footwear, machinery, vehicles, etc.)

The likelihood of *P. ramorum* to enter the PRA area through this pathway is low with a high uncertainty due to the difficulty with enumerating the frequency of entry through contaminated footwear or machinery. From woodland areas in the USA it is shown that especially footwear used for hiking represents a potential direct pathway for *P. ramorum* (Cushman *et al.* 2008). If such footwear is not cleaned or disinfected, and contaminating soil/derbies are kept moist, it can represent a direct pathway if the footwear later is used in an area of hosts in the PRA area. Depending on the geographical origin of the contaminant, this pathway encompasses both the potential to introduce non-European isolates (NA1 & NA2 lineage, both of the A2 mating type) as well as the further entry of *P. ramorum*-isolates belonging to the European EU1 lineage, A1 mating type.

Pathway E. Foliage and cut branches (for ornamental purposes) of foliar hosts

The likelihood of *P. ramorum* to enter the PRA area by foliage and cut branches of foliar host is low, but with a high uncertainty. The uncertainty is connected with the lack of knowledge of import volumes, frequency, countries of origin, and the lack of inspection in these products at the border. Pathway E is an indirect pathway (via composts), and therefore represent a lower-risk route of entry compared to for example plants for planting. Depending on the geographical origin of the foliage and cut branches, this pathway encompasses both the potential to introduce non-European isolates (NA1 & NA2 lineage, both of the A2 mating type) as well as the further entry of *P. ramorum*-isolates belonging to the European EU1 lineage, A1 mating type.

Numerous hosts of *P. ramorum* are popular for cut flower production, including *Acer*, *Camellia*, *Hamamelis*, *Kalmia*, *Pieris*, *Rhododendron* and *Syringa*. Some of these genera are imported as cut branches for ornamental use in the PRA area. An example is blooming *Viburnum*, a well known host plant, which is imported as cut flower and used for decorations. As in the EU, there are no claims of Phytosanitary Certificates when importing these products to the PRA area, and consequently no specific phytosanitary controls for *P. ramorum* on this material at arrival.

In addition there is a significant import of cut Christmas trees to Norway from European countries. In later years the import has decreased due to increased domestic production, but still there is a yearly import of 350.000-450.000 trees, most of them from Denmark (Landbruks- og matdepartementet 2008a).

So far *P. ramorum* has not been recorded in Christmas tree plantations in Europe, and at the moment the probability of entry by import of Christmas trees are very low. However, different species in the Pinaceae (*Abies concolor*, *A. grandis*, *A. magnifica*, and *Pseudotsuga menziesii*) are natural hosts of *P. ramorum* in the USA. In experimental tests, species such as *Abies procera* (Nobel fir) are rated with a high susceptibility when the inoculations are done by detached leaved dipped in zoospore suspensions, but with a medium to low susceptibility when using other inoculation methods (Sansford *et al.* 2009).

Pathway F. Seeds and fruits of host plants

The likelihood of *P. ramorum* to enter the PRA area by seed or fruits of hosts is rated as low with a high uncertainty. Depending on the geographical origin of the fruit and seed, this pathway encompasses both the potential to introduce non-European isolates (NA1 & NA2 lineage, both of the A2 mating type) as well as the further entry of *P. ramorum*-isolates belonging to the European EU1 lineage, A1 mating type.

There are limited data available on the susceptibility of fruits and the potential of fruits and seeds of various hosts as significant pathways. So far seed transmission of *P. ramorum* is not known, but fruits of ornamental and environmentally important plants have been shown to be susceptible to infection (Moralejo *et al.* 2007; Denman *et al.* 2008). Seeds used for planting represent a direct pathway if *P. ramorum* is transmitted via seed. When seeds and fruits are used for human consumption the probability of entry is low as the end-use does not complete the pathway. There is limited information available on the volume of imported seeds and fruits of known, susceptible natural hosts from areas where the pathogen is known to occur.

Pathway G. Bark from host plants

The likelihood of *P. ramorum* to enter the PRA area by bark of host plants is low, but with a high uncertainty surrounding the rating due to lack of data. Movements of contaminated cut bark provide the pathogen with pathways for introduction into new areas. Chlamydospores, which are potentially relatively long-lived, have been reported in bark phloem and xylem tissue of some tree species (Parke *et al.* 2008). Isolated bark could represent a direct pathway since bark is used for mulching in nurseries, gardens or recreation areas and thereby have the opportunity to direct contact with host plants at arrival. This is most likely to be conifer bark. The likelihood of *P. ramorum* to follow this pathway is highest for bark originating in the USA and in the pathogens unknown area/s of origin. The likelihood is less for bark originating in Canada or Europe since infections in forests of woodlands so far are not reported from these areas. Today the use of non-conifer bark is limited in the PRA area. Import of conifer bark is prohibited from Portugal and from all countries outside Europe. Import from Europe need to be followed by a phytosanitary certificate. Bark of *Acer macrophyllum* Pursh., *Aesculus californica* Nutt., *Lithocarpus densiflorus* (H & A) or *Quercus* L., with origin in the USA, is prohibited to import due to phytosanitary regulations against *P. ramorum* (Landbruks- og matdepartementet 2003).

Pathway H. Wood from known host plants

The likelihood of *P. ramorum* to enter the PRA area by wood from susceptible trees is medium with a high uncertainty concerning the data. Wood from susceptible trees would most often be an indirect pathway, based on the most likely end-uses of imported wood. However, if the imported wood is stored in open air close to host plants, it could represent a more direct pathway.

P. ramorum is able to colonize the xylem that underlies infected bark. Both hyphae and chlamydospores can be found in such tissue (Brown & Brasier 2007; Parke *et al.* 2008). Debarking would therefore not be sufficient to eliminate the pathogen.

A pathway potentially exists by importing susceptible wood from infected woodland in the USA and in the yet unknown area/s of origin for *P. ramorum*. Currently *P. ramorum* has not

been detected in Canadian and European forests or woodlands. Susceptible wood from these areas does therefore not represent a pathway at present. In Europe, *P. ramorum* has been detected only on single trees in parks in the UK and in the Netherlands.

Today there are phytosanitary restrictions on the import of wood from host plants in areas where *P. ramorum* is known to occur. The current import volume of wood from the USA is negligible. Under the Norwegian regulations on measures against *P. ramorum*, there are special restrictions on import of all plant material, including wood, of named host plants of *P. ramorum* (Landbruks- og matdepartementet 2003). Imports of wood of *Acer macrophyllum*, *Aesculus californica*, *Lithocarpus densiflorus*, *Quercus* spp. and *Taxus brevifolia* originating in the USA are especially listed, and only permitted entry into the PRA area if they come from a *P. ramorum*-free area or if they have received a specific treatment against *P. ramorum* (Landbruks- og matdepartementet 2003).

The recent focus on bio energy has the potential to create new pathways for entry of *P. ramorum* into the PRA area. A new factory is under construction in Møre og Romsdal County to make wood pellets from wood chips (BioWood Norway 2009). In the long run this activity is planned to be based on Norwegian wood chips, but in periods the production might need additional supplement of imported wood chips from i.e. North America. Such import could represent a possible pathway for *P. ramorum* if the wood chips are made from infected host plants without sufficient treatment, and the shipments are stored in open air at arrival in the PRA area with host plants in the surroundings.

Due to the planned import of wood chips the probability of this pathway is medium for the PRA area, while it is considered low by the EU (Sansford *et al.* 2009).

4.2.1.2 Probability of the pest being associated with the pathway at origin

The probability of *P. ramorum* being associated with each pathway at origin varies according to geographical origin and commodity.

The probability is highest for plants for planting of hosts originating from infected areas in Europe, the USA and the unknown areas of origin of the pathogen. The ratings of probabilities and uncertainties for the pest being associated with the pathways at origin are given for each pathway in table 7.

Table 7. Estimates of the probability of *Phytophthora ramorum* being associated with each commodity pathway at origin in relation to geographical source. The probability of the pathogen is ranked according to the following scheme: Very unlikely; Unlikely; Moderately likely; Likely; Very Likely. Uncertainty for each estimate is given in brackets, and is ranked according to the following scheme: Low; medium; high.

Probability of the pest being associated with the pathway at origin with associated levels of uncertainty						
Commodity pathway	Pathway type	Europe (EU/Switzerland)	USA	Canada	Unknown area/s of origin	
A Plants for planting (Hosts)	Direct	Likely (low uncertainty)	Likely (low uncertainty)	Moderately likely (medium uncertainty)	Likely (high uncertainty)	
B Plants for planting (Non-Hosts) accompanied by contaminated growing media	Direct	Likely (medium uncertainty)	Likely (medium uncertainty)	Moderately likely (medium uncertainty)	Likely (high uncertainty)	
C Soil/growing media as a commodity	Direct	Moderately likely (medium uncertainty)	Moderately likely (high uncertainty)	Unlikely (medium uncertainty)	Moderately likely (high uncertainty)	
D Soil as a contaminant	Direct	Moderately likely (medium uncertainty)	Moderately likely (medium uncertainty)	Unlikely (medium uncertainty)	Moderately likely (high uncertainty)	
E Foliage and cut branches(for ornamental purposes) of foliar hosts	Indirect	Likely (medium uncertainty)	Likely (medium uncertainty)	Moderately likely (medium uncertainty)	Likely (high uncertainty)	
F Seeds and fruits of host plants	Direct/Indirect	Unlikely (medium uncertainty)	Unlikely (medium uncertainty)	Unlikely (medium uncertainty)	Unlikely (high uncertainty)	
G Bark from host plants	Direct	Unlikely (medium uncertainty)	Likely (low uncertainty)	Very unlikely (medium uncertainty)	Likely (high uncertainty)	
H Wood form hosts ^a	Indirect/Direct	Unlikely (medium uncertainty)	Likely (low uncertainty)	Unlikely (medium uncertainty)	Likely (high uncertainty)	

^a Susceptible wood prior to treatment.

In the EU member states, the pathogen has primarily been found in nurseries (all of the EU1 lineage). The locations of infected nurseries within the EU are reported to be widely distributed, but the proportion of infected nurseries has been generally low (<5 % of nurseries nationally in EU) (Sansford *et al.* 2009). Countries in Europe where *P. ramorum* has been detected are shown in figure 2. Most findings outside of nurseries in Europe have been on hardy shrub hosts, principally *Rhododendron*, *Viburnum*, *Camellia*, *Pieris* and *Magnolia* species. The number of infected trees with bleeding canker in Europe is currently small and restricted to the UK and the Netherlands (Sansford *et al.* 2009). In Poland the pathogen has been detected in rivers (Orlikowski *et al.* 2007).

Considering the most important pathway (known host plants for planting), *P. ramorum* is recorded as present in several of the countries which export nursery plants to the PRA area. In

North America the pathogen has been reported in the wild in parts of California and Oregon. Infected material has been found in nurseries in more than 20 other states. Most infected plants in the USA are associated with the clonally reproducing North American (NA1) lineage of the A2 mating type. There are also nursery findings of the EU1 lineage of A1 mating type and the NA2 lineage of A2 mating type (Sansford *et al.* 2009).

Prevalence of *P. ramorum* on commodities from Canada is less likely since the pathogen has only been recorded in a relatively few nurseries, and it has not yet been found in forests. All affected nurseries and residential plantings have been subject to eradication (Sansford *et al.* 2009).

Prevalence of *P. ramorum* on material coming from the pathogens unknown area/s of origin is uncertain. In the PRA for EU (Sansford *et al.* 2009) it is stated that the original introduction of the EU1 lineage of the pathogen into Europe proved that a pathway has previously existed. This is most likely to have been plants for planting, though whether these were nursery-grown plants or plant collections made from the wild is not known.

The probability of *P. ramorum* occurring in a viable stage when associated with commodities is high. Both mycelium, sporangia, zoospores, and chlamydospores have the potential to be associated with infected plants, although this may vary with host species, the plant part concerned and the time of year. For further information on this we refer to the recent PRA for EU (Sansford *et al.* 2009).

Volume and frequency of movement along the different pathways are addressed in 4.2.1.1. Seasonal timing of the import cannot prevent importation of the disease. For the most important pathway, known host plants for planting, the import to Norway occur most frequently in the early spring, but with a supplement import throughout the growing season. Infected plants arriving during mild and humid period may have a higher incidence, since these conditions favour the pathogen.

The likelihood of the concentration of *P. ramorum* being high on the pathway at origin will depend on the commodity, the place of origin, the cultivation practices and the treatments that have been applied. This is discussed in detail in the PRA for EU (Sansford *et al.* 2009). The same aspects as discussed in the PRA for EU are relevant for Norway as a PRA area.

4.2.1.3 Probability of survival and multiplying during transport or storage

For all relevant pathways there are high probabilities for *P. ramorum* to survive and multiply during transport or storage. The level of uncertainty in this assessment is low.

For plants for plantings the survival is confirmed by positive identification of the disease at arrival and further by development of latent infections after arrival. The survival of *P. ramorum* in plants during transportation is also demonstrated in USA, when infected stocks in 21 States were traced to infected nurseries in California (USDA 2007).

Chlamydospores are often formed inside host tissue, and they are unlikely to be dislodged during standard harvesting, handling and shipping operations. The pathogen is therefore likely to survive during transport for all the eight assessed pathways. Linderman and Davis (2006) showed that sporangia inoculated into a range of growing media components survived for up to 6 months and chlamydospores survived for up to 12 months. Survival in soil on footwear or machinery is likely to be reduced by drying (Cushman *et al.* 2008). The pathogen can also survive in bark and wood. The RAPRA project concluded that it is very likely that the pathogen can survive transport and storage on a range of commodity types. Interception data for traded plants and other publications support this view. A list of arguments for this is

presented in the PRA for EU (Sansford *et al.* 2009). The same aspects are relevant for Norway as a PRA area.

4.2.1.4 Probability of pest surviving existing pest management procedures

The likelihood of the pathogen to survive existing pest management procedures will vary from unlikely to very likely depending on the commodity and the phytosanitary measures applied. The level of uncertainty is low to medium. For all pathways and all geographical origins the ability for the pathogen to remain undetected will be affected by the method of inspection by the exporting country's NPPO and if required by the Norwegian regulations. Similarly, the likelihood of the pathogen surviving any phytosanitary measures required by Norwegian legislation will depend on the effectiveness of their application and their efficacy. For each pathway ratings of the probability for survival, and uncertainties of the ratings, are given below.

Pathway A and B. Plants for planting of known host plant species and non-host plants species accompanied by contaminated, attached growing media

It is moderately likely that *P. ramorum* will survive existing pest management procedures given by Landbruks- og matdepartementet (2003). The pest may be present on plants for planting even if the plants originate from an area in which there is an official statement that *P. ramorum* does not occur. It is also moderately likely that the pathogen will remain undetected on plants for planting that are inspected and tested prior to export to the PRA area from nurseries in areas where the pathogen occurs (Europe, USA, Canada, or its unknown area or areas of origin). The uncertainties of these assessments are low.

Norwegian regulations against *P. ramorum* have measures related to imports of host plants (Landbruks- og matdepartementet 2003). The plants shall be accompanied by a phytosanitary certificate, which shall only be issued when the consignment has been officially inspected within 2 days before the issuance of the certificate. The consignment must have been found free from *P. ramorum* in this inspection. Further, *P. ramorum* should not have been observed on any susceptible plant at the place of production during official inspections, carried out at least twice at appropriate times when the plants are in active growth in the course of the last complete cycle of vegetation. If signs of *P. ramorum* have been found on susceptible plants at the place of production, appropriate measures should have been implemented to eradicate the harmful organism before consignments were shipped to Norway (Landbruks- og matdepartementet 2003).

The detection of *P. ramorum* in inspections can be difficult and affected by a variety of factors. The leaf, shoot or stem symptoms are not unique to *P. ramorum*, and the pathogen therefore can be difficult to identify. Infected plants may be easily missed since similar symptoms can be caused by other plant pathogens or by physiological conditions. In rhododendron, infected leaves are easily overlooked, and therefore not always easy to observe. There is further a possibility that the plants carry the disease without showing obvious symptoms. Such latent infections would not be detected at the time of inspection. Chlamydospores of *P. ramorum* are found in healthy-appearing roots of rhododendron (Kessel *et al.* 2007), and sporulation from naturally infected but asymptomatic foliage is reported on foliage plants (Denman *et al.* 2008). Symptoms of *P. ramorum* may also be masked by the use of fungicides that suppress disease development without eradicating the pathogen (Tjosvold *et al.* 2005). Furthermore detection of *P. ramorum* will be affected by the

method of inspection, the experience of the inspector and the approach to sampling as well as by the method of testing for symptoms.

In 2008, 14 consignments of rhododendrons were rejected on arrival in the PRA area due to positive detections of *P. ramorum*. The status of the production area for these 14 consignments was at the phytosanitary certificate informed to be as follows:

- A) (7%) The plants originate in an area in which, in accordance with the relevant International Standard for Phytosanitary Measures, ISPM No. 4 (FAO 2006), there is an official statement that *P. ramorum* does not occur.
- B) (57%) No signs of *P. ramorum* have been observed on any susceptible plant at the place of production during official inspections, carried out at least twice at appropriate times when the plants are in active growth in the course of the last complete cycle of vegetation. The plants have been found free from *P. ramorum* in these inspections and by laboratory testing of any suspicious symptoms.
- C) (7%) Signs of *P. ramorum* have been found on susceptible plants at the place of production, but appropriate measures have been implemented to eradicate the harmful organism before consignments has been shipped to Norway.

In addition, 21 % of the consignments were declared to be of status B) and C), and 7% to be of status A) and B).

This underlines the probability of pest surviving existing pest management procedures, and the difficulties with identifying the disease in inspections.

Pathway C and D. Soil and growing media as a commodity and soil as a contaminant

The import of soil and organic growing media into the PRA area is prohibited from countries outside Europe (Landbruks- og matdepartementet 2000). Import of growing medium (except sphagnum) from European countries need to be followed by a Phytosanitary Certificate. If *P. ramorum* is present in soil/growing media it is unlikely to be detected and there is a high probability to survive existing pest management procedures. It is even more likely that footwear and machineries can carry soil contaminated with *P. ramorum* since these articles would not be subjected to official inspection by local NPPOs. The uncertainties of these assessments are low.

Pathway E and F. Foliage and cut branches, and seeds and fruits of host plants

The probability of *P. ramorum* to survive pest management for these two pathways is high due to the lack of specific requirements of these products in the Norwegian regulations on measures against *P. ramorum* (Landbruks- og matdepartementet 2003). If the pathogen was present on such host material it would therefore not be constrained by any phytosanitary measures, and it would not be detected by NPPOs prior to export (Sansford *et al.* 2009). The Norwegian regulations are concurrent with EU legislations at this point.

Pathway G. Bark from host plants

According to the current Norwegian plant health regulations it is prohibited to import bark of conifers from Portugal and all countries outside Europe (Landbruks- og matdepartementet 2000). Import of bark from Europe should be followed by a phytosanitary certificate. Further,

it is prohibited to import bark of *Acer macrophyllum* Pursh., *Aesculus californica* Nutt., *Lithocarpus densiflorus* (H & A) and *Quercus* L. originating in the USA (Landbruks- og matdepartementet 2003). Isolated bark of *Castanea* is prohibited from all countries outside Europe, and import of *Quercus* spp. bark from North America is banned. Together these represent the most susceptible bark hosts, and thus *P. ramorum* is constrained from entering on bark from the USA. But if bark from other potential hosts is imported, the pathogen could survive existing pest management procedures.

P. ramorum is so far not present in forests in Canada and bark from this area is not currently a pathway of entry. Likewise *P. ramorum* does not currently occur in forests or woods in Europe, so there is very low likelihood of it remaining undetected on bark entering from this source. But, bleeding cankers have been found in trees in Europe, and bark represents a theoretical pathway of entry from EU countries. The hosts that occur in the country or countries of origin are not known so it is possible, with the exception of Norwegian requirements for bark of conifers, that the pathogen could enter undetected on bark of hosts from this source.

Pathway H. Wood from host plants

With the current legislations on import of wood (Landbruks- og matdepartementet 2000, 2003), the probability of *P. ramorum* to survive undetected in susceptible wood originating in the USA or the pathogen's unknown areas of origin is considered as very low with a moderate uncertainty. The only possibility to survive existing pest management procedures is connected to import of wood of unknown hosts, or failure in the treatment or visible inspection of the wood before shipment. From EU and Canada the probability is even lower due to low infection of woodlands, and therefore the possibility is low to survive pest management procedures.

Trees of *Acer macrophyllum* Pursh., *Aesculus californica* Nutt., *Lithocarpus densiflorus* (H & A), *Quercus* L. and *Taxus brevifolia* Nutt, originating in USA, may only be imported into Norway if they are accompanied by a phytosanitary certificate (Landbruks- og Matdepartementet 2003). Here it should be stated that the wood originates in areas in which non-European isolates of *P. ramorum* is known not to occur, or that the wood are treated after different options (kiln-drying to water content <20% of dry matter, disinfected by appropriate hot water treatment). The PRA for EU concluded that these regulations should ensure that the probability of *P. ramorum* on wood entering from USA remaining undetected is very low. This is concurrent with the view for Norway as a PRA area. The exception is wood of *Toxicodendron diversilobum* which is not listed in the legislation although it is a canker host. However, this host is not harvested for wood (Sansford *et al.* 2009).

4.2.1.5. Probability of transfer to a suitable host

The probability of transfer of *P. ramorum* to a suitable host after arrival in the PRA area will vary with different pathways.

Regarding the pathway of plants for planting, the pest is already present on a suitable host. *Rhododendron* is a commonly used plant in private and public gardens in the PRA area. It is very likely that the pathogen would be transferred to other hosts in Norwegian nurseries and garden centres. The conditions in nurseries and garden centers with close spacing of plants and sprinkler watering favour the dispersal of the pathogen. This is documented by the continued findings of *P. ramorum* within the nursery trade both in Norway (section 4.1) and in Europe (Sansford *et al.* 2009). Furthermore, *P. ramorum* is very likely to transfer to a

suitable environment, when sold to the consumer. The environments of parks and private gardens, at least along the west coast of Norway, are very likely to support the pathogen.

It is moderately likely that *P. ramorum* could be transferred from plants for planting to host plants in natural environments. Outside nurseries, in parks and private gardens, the pathogen has been detected primarily along the west coast of Norway on *Rhododendron* and *Viburnum* (see section 4.1.2.). *P. ramorum* is known in natural and semi-natural environments across a range of climatic regions in Europe (Sansford *et al.* 2009). So far the routes by which transfer has occurred to these sites are not known. The pathogen might have followed infected plants for plantings. Also, these environments might have been infected through dispersal of inoculum from infected plants either by natural spread or through human activity. Recently, natural infection of *P. ramorum* was detected in blueberry (*Vaccinium myrtillus*) in a semi-managed park at the south-west coast of Norway (Herrero 2009, personal communication). The sampled blueberry was growing close to an infected rhododendron plant.

The report from the RAPRA project (Sansford *et al.* 2009) presents a list of factors that will influence the probability of transfer to suitable hosts: the type of commodity; the proximity of nurseries to the habitats of concern; the presence and susceptibility of host plants in the local environment; the degree of human activity in these habitats; climatic and seasonal factors favoring natural dispersal and spread, principally rainfall; the natural dispersal potential of the pathogen or whether infected plants are directly planted into the managed or natural environment (Sansford *et al.* 2009). The same factors are also relevant for Norway as a PRA area. Along the west coast of Norway rhododendron is a commonly planted host plant, there are human activities in private gardens and parks of concern, and there is heavy precipitation (2-3000 mm year) favouring natural dispersal of *P. ramorum*. The dispersal potential is also addressed in chapter 4.2.2.1.

Transfer from contaminated soil/growing media as a commodity is moderately likely but will only occur if hosts are planted in the contaminated material.

Transfer from contaminated footwear of travellers is possible, but considered unlikely, especially as the pathogen tends not to survive so well in soil/debris on footwear that is not kept moist (Cushman *et al.* 2008). So far there has been no evidence for introduction of *P. ramorum* from USA (North American lineages) to Europe or internally in the USA via contaminated footwear (Sansford *et al.* 2009).

The pathogen is unlikely to be transferred to suitable hosts via commodities that are processed or are not intended for planting, i.e. cut foliage/branches, fruits, infected/contaminated timber. Transfer will only occur if the pathogen survives the processing of the infected material, and the end-product is used on hosts.

Seeds are unlikely to transfer the pathogen. Based on the current evidence, there is no indication that *P. ramorum* is either seed-borne or seed-transmitted. Fruit will only potentially transfer the pathogen if the fruit is composted, and the pathogen survived the composting process and the end product of the compost is used for planting hosts (Sansford *et al.* 2009).

There are no data to support spread via contaminated wood chips imported from outside the PRA area. This may occur if hosts are planted in the contaminated material or is growing close to preliminary stores in open air.

In terms of transfer to at-risk woodland habitats, the presence and abundance of a key foliar host/s, such as rhododendron or possibly other understory plants as *Vaccinium* spp. is a critical factor.

4.2.1.6. Summarised probability of entry for each pathway

The probability of entry is rated below for each identified pathway. The probabilities are based on scenarios where there are no phytosanitary controls, and on the different factors discussed in 4.2.1.1-4.2.1.6. The uncertainties are estimated as low for all pathway origins, except for plants for plantings from unknown areas of origin which have high uncertainty. The conclusions in this PRA on the probability of entry are concurrent to the conclusions made in the PRA for EU (Sansford *et al.* 2009).

A and B. Plants for planting: These represent the greatest potential for entry from countries where *P. ramorum* exists (EU, Switzerland, USA, Canada, and the pathogens unknown areas of origin). Most host plants imported to the PRA area have their origin in EU. Host plants for planting clearly represent a high probability of entry. Non-host plants for planting represent a lower probability, even though there is the potential for inoculum to be present in any accompanying growing media or even roots.

C and D. Soil/growing media: In the absence of any controls, soil or growing media as a commodity are likely to represent moderate probabilities of entry, depending on the country of origin, normal treatment practices, and whether host plants are planted in the commodity as the end use. Soil as a contaminant (e.g. attached to footwear etc) is likely to represent only a low or very low probability of entry.

E and F. Foliage/branches, and seeds and fruits of hosts represent very low probabilities of entry. Cut foliage and branches of hosts are likely to be used for ornamental purposes. If the plant material is fresh there is a potential for the pathogen to be present. Should the material be composted there is a very low probability that *P. ramorum* will survive the composting process and be transferred to a host if the compost is used on host plants. Seed infection has not been demonstrated for *P. ramorum*, though fruits of some hosts can become infected (Moralejo *et al.* 2007). There is therefore a low probability that *P. ramorum* will be seed-borne, if not actually seed transmitted. Fruits themselves also represent a low probability for entry of *P. ramorum*, based on the likely end use of fruits from susceptible trees/shrubs, although composted fruit, like other composted material poses a potential. Cut Christmas trees represent a low risk since *P. ramorum* so far is not found in European Christmas tree plantations.

G and H. Bark and wood of host plants: Isolated bark of tree hosts from countries with *P. ramorum* infections represents a moderate probability of entry since *P. ramorum* can colonize phloem and cambial tissues and may produce spores in or on these tissues; the likely end use may also increase the relative probability. Wood itself represents a low probability of entry, even though *P. ramorum* has been shown to be able to colonize sapwood underlying bark lesions. Xylem can support the production of chlamydospores. The likely end uses of wood and likely treatments (e.g. kiln drying) might mitigate the probability of entry. If imported wood are stored outdoors in open air at arrival in the PRA area, the probability of entry by wood might increase.

4.2.2 Probability of establishment

The probability of establishment of *P. ramorum* in the PRA area will vary with the availability of suitable hosts, suitability of the environment, biological characteristics of the pest, and the effects of existing pest management practices. The significance and the uncertainty for each of these topics are addressed in the following paragraphs (4.2.2.1 – 4.2.2.4).

4.2.2.1 Availability of suitable hosts, alternate hosts and vectors in the PRA area

P. ramorum has a very broad host range across a wide range of plant genera and there is an abundant availability of suitable hosts in the PRA area. The uncertainty surrounding this data is low.

P. ramorum has under natural conditions infected more than 130 species from over 75 plant genera representing over 37 families (Sansford *et al.* 2009). The species that are considered as natural hosts per October 2008 are listed in the PRA for EU, APENDIX II (Sansford *et al.* 2009). Species susceptibilities to *P. ramorum* as determined by experimental tests are shown in APPENDIX III (Sansford *et al.* 2009). Furthermore, an updated website with list of natural hosts of *P. ramorum* with symptoms and locations are available from the Central Science Laboratory (CSL 2009). From the USA, a list of regulated hosts is presented by United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA-APHIS 2008). In this list, plants that are naturally infected by *P. ramorum*, and have had Koch's postulate completed, documented, reviewed, and accepted, are presented.

The type of hosts that are affected varies between countries, and the pathogen causes different types of disease on different species. In Norway, *Rhododendron* spp. have proved to be important host plants for *P. ramorum*. *Rhododendron* spp. are widespread and popular ornamental species in private gardens and public parks in Norway. However, these host plants thrive best in the coastal regions along the south-western coast of Norway. Also, other proven host plants, like *Pieris* spp. and *Viburnum* spp. are widely used as ornamentals in Norwegian gardens.

In Europe, *Rhododendron* spp. have so far been the most important hosts of *P. ramorum*. *Rhododendron* spp. are foliar hosts that support sporulation, and thereby plays a key role in driving the epidemics (Sansford *et al.* 2009). In Great Britain *R. ponticum* is the most important species which has the potential to support production of inoculum all year round (Defra 2008). *R. ponticum* is not known to be naturalized in Norway. So far there has been little scientific information available about susceptibility levels of different *Rhododendron* species and cultivars to *P. ramorum*. Dobbelaere *et al.* (2008) report susceptibility of all 80 *Rhododendron* species when tested with methods for inoculation of *P. ramorum* which involved wounded and non-wounded leaves. If inoculation was done on non-wounded leaves, considerable difference in level of resistance between cultivars or species was revealed. Using non-wounded leaves, a few *Rhododendron* species and cultivars consistently showed very low levels of disease expression. These include the cultivars 'Gartnerdirector Riger', 'Red Jack' and 'Fantastica'. In contrast, other cultivars were highly susceptible. Similar reports of differences in susceptibility among *Viburnum* species and cultivars are reported by Grünwald *et al.* (2008b).

There are great concern and uncertainty regarding the potential of *P. ramorum* to infect other host plants, especially important species of the wild flora in the PRA area. Pathogenicity tests conducted by inoculating intact and detached leaves of different host have shown that environmentally important understorey plants in Norway (e.g. *Calluna vulgaris*, *Vaccinium*

myrtillus and *V. vitis-idaea*) can be infected. Recent findings (September 2009) of naturally infected *V. myrtillus* in Norway confirm this. *V. myrtillus* is common throughout whole Norway. In Poland natural infection of *P. ramorum* has been detected in nursery plants of *C. vulgaris* (Orlikowski & Szkuta 2004). Recently *V. myrtillus* was found naturally infected outdoors in the UK (CSL 2009). Also *V. vitis-idaea* has been found naturally infected in UK, but in nurseries only (CSL 2009). The geographical distribution of natural hosts of *P. ramorum* that are common in Norway is shown in table 10.

In Norway, the two species of oak, *Quercus petraea* and *Q. robur*, occur in the wild flora. *Quercus petraea* grows along the coast from the Oslofjord and north to Nordfjord, Sogn og Fjordane County. *Q. robur* is distributed in south-eastern parts of Norway north to the region of Ringsaker, Hedmark County and along the coast of Southern Norway north to Ørlandet, Sør-Trøndelag County (Mitchell 1977). Oaks form forests mainly in the counties of Vest-Agder and Aust-Agder, but smaller oak woods occurs in the counties of Østfold, Sogn og Fjordane and Møre og Romsdal as well. These two species belong to the group of white oaks, which are known to be less susceptible than the group of red oaks subjected to Sudden Oak Death from *P. ramorum* in America. Red oak (*Q. rubra*) belonging to the red oaks occurs in Norway in parks only, where some very old specimens exists. In 2008, a single tree of *Q. rubra* with bleeding stem canker in a park along the west coast of Norway tested positive for *P. ramorum* in a DNA test.

In artificial inoculation tests, European beech (*Fagus sylvatica*) has been shown to be among the highly susceptible host plants to *P. ramorum*. It is also known that European beech has been infected by *P. ramorum* by natural means in Europe. In Norway, European beech is growing in the wild along the coast from the county of Vestfold to Hordaland but forms forests only in Vestfold County, with the exception of a small forest in Hordaland County (Larsson & Søgne 2003).

P. ramorum has been found to cause leaf blight on ash (*Fraxinus excelsior*) growing outdoors in the UK (Sansford *et al.* 2009). Ash is common in Norway, naturalized in the east to Øyer in Oppland County and Trysil in Hedmark County. Along the coast it is common up to Nord-Trøndelag County and occurs occasionally to Harstad in Troms County. *Acer pseudoplatanus* and *Aesculus hippocastanum* are also known outdoor host plants in Europe. They are naturalized in Norway, but they do not occur as frequently as ash. For other host plants occurring in Norway, see table 10.

The non-native host plants *Pseudotsuga menziesii* and *Abies grandis* are grown in Christmas tree plantations in Norway, and along with other Christmas tree species they could potentially be affected. The pathogen has not killed adult plants in the pine family. However, it has been shown to cause damage to small plants in nurseries. *Picea sitchensis* is in most inoculation tests reported to have low susceptibility, but medium or high susceptibility is also reported (Sansford *et al.* 2009).

Table 10. Hosts of *P. ramorum* that are common in Norway and have been seen infected naturally in Norway or elsewhere.

Scientific Name	Common Name/ Norwegian name	Family	Symptoms in Norway	Geographical distribution in nature*
Trees (native or naturalized)				
<i>Acer pseudoplatanus</i>	Sycamore/Platanlønn	<i>Araceae</i>	Not detected	Naturalized in the east to lake Mjøsa (Hedmark and Oppland Counties), along the west coast to Nordland County. http://www2.artsdatabanken.no/faktaark/Faktaark45.pdf
<i>Aesculus hippocastanum</i>	Horse chestnut/Hestekastanje	<i>Hippocastanaceae</i>	Not detected	Naturalized in the east to Akershus and Buskerud Counties, along the west coast to Sør-Trøndelag County.
<i>Fagus sylvatica</i>	European beech/Bøk	<i>Fagaceae</i>	Not detected	Forest in Vestfold County. Along the coast from Vestfold County to Aust-Agder County. Small forest in Hordaland County. Naturalized in the east to Akershus and Buskerud Counties, along the west coast to Sør-Trøndelag County.
<i>Fraxinus excelsior</i>	Ash/Ask	<i>Oleaceae</i>	Not detected	In the east to Øyer in Oppland County and Trysil in Hedmark County. Along the coast, common to Nord-Trøndelag. Spread to Harstad in Troms County.
<i>Salix caprea</i>	Goat willow/Selje	<i>Salicaceae</i>	Not detected	Common in all Norway
<i>Taxus baccata</i>	Yew/Barlind	<i>Taxaceae</i>	Not detected	In the east to lake Mjøsa (Akershus County). Along the coast to Møre og Romsdal County
<i>Quercus petraea</i>	Sessile oak/Vintereik	<i>Fagaceae</i>	Not detected	Along the coast, common from Østfold County to Møre og Romsdal County. Spread to Sør-Trøndelag
Ornamental trees (only cultured)				
<i>Abies concolor</i>	White fir	<i>Pinaceae</i>	Not detected	
<i>Abies grandis</i>	Grand fir/Kjempeedelgran	<i>Pinaceae</i>	Not detected	
<i>Castanea sativa</i>	Sweet chestnut/Edelkastanje	<i>Fagaceae</i>	Not detected	
<i>Pseudotsuga menziesii</i>	Douglas fir/Douglasgran	<i>Pinaceae</i>	Not detected	
<i>Quercus rubra</i>	Northern red oak/Rødeik	<i>Fagaceae</i>	Not detected	
<i>Quercus sp.**</i>		<i>Fagaceae</i>	Canker dieback	

Table 10. continues

Scrubs (native or naturalized)				
<i>Calluna vulgaris</i>	Heath/Røsslyng			Common in all Norway
<i>Rhododendron</i> <i>spp.</i>	Rhododendron/Rododendron	<i>Ericaceae</i>	Leaf blight, dieback	Moderately naturalized in south-western parts of Norway
<i>Rosa rugosa</i>	Rugosa rose/Rynkerose	<i>Rosaceae</i>	Not detected	Naturalized in the east to Hedmark and Oppland Counties, along the coast to Troms County http://www2.artsdatabanken.no/faktaark/Faktaark46.pdf
<i>Syringa vulgaris</i>	Lilac/Syrin	<i>Oleaceae</i>	Unknown	Naturalized to Nord-Trøndelag County
<i>Vaccinium myrtillus</i>	Bilberry/Blåbær	<i>Ericaceae</i>	Dark lesions***	Common throughout Norway
<i>Vaccinium vitis-idaea</i>	Cowberry/Tyttebær	<i>Ericaceae</i>	Not detected	Common throughout Norway
<i>Viburnum spp.</i>	Viburnum/Krossved	<i>Caprifoliaceae</i>	Canker, leaf blight, dieback	<i>Viburnum opulus</i> common to Nordland County <i>Viburnum lantana</i> naturalized, mainly around the Oslo fjord
Ornamentals of minor importance (only cultured)				
<i>Camellia spp.</i>	Camellia/Kamelia	<i>Theaceae</i>	Not detected	
<i>Hamamelis virginiana</i>	Virginian witch hazel/Virginatrollhassel	<i>Hamamelidaceae</i>	Not detected	
<i>Kalmia spp.</i>	Mountain laurel/Kalmia	<i>Ericaceae</i>	Foliar spots	
<i>Laurus nobilis</i>	Bay laurel/Laurbær	<i>Lauraceae</i>	Not detected	
<i>Magnolia kobus</i>	Magnolia/Magnolia	<i>Magnoliaceae</i>	Not detected	
<i>Pieris spp.</i>	Andromeda, Pieris/Piramidalis	<i>Ericaceae</i>	Leaf blight, dieback	
<i>Sequoia sempervirens</i>	Coast redwood/Kystesequoia	<i>Taxodiaceae</i>	Not detected	

*Data obtained from Artsdatabanken (The Norwegian Biodiversity Information Centre, <http://www.biodiversity.no>)

**American red oak, probably *Q. kelloggii*

*** Natural infection detected September 2009 (Herrero 2009, personal communication)

4.2.2.2 Suitability of environment

The environmental conditions are considered to be suitable for *P. ramorum* in some parts of the PRA area, with a low level of uncertainty. The assessments behind this conclusion are given below.

Climate is an important factor that affects establishment of *P. ramorum*, and climate suitability of the PRA area is therefore analysed in this section. Other abiotic factors like soil type and pH are not known to affect the establishment potential of *P. ramorum* directly. The pathogen has no known natural enemies or competitors in the PRA area that will prevent establishment. When it comes to protected cultivation, the environmental conditions are likely to be broadly similar in the PRA area compared to other areas where the pathogen occurs, since environmental conditions in protected cultivation (temperature, humidity, and irrigation) usually are controlled and optimised for plant growth (Sansford *et al.* 2009).

The evidence on occurrence and survival of *P. ramorum* in Norway indicates that climate will not prevent establishment of this organism in the PRA area. The observation records (figure 3) show that the climate in the coastal regions of south-western Norway is favorable for establishment of *P. ramorum*. One analysis of establishment potential conducted in the RAPRA project (Sansford *et al.* 2009) corresponds quite closely with the observed distribution so far, both in Norway and Europe in general (risk ranking method by Meentemeyer *et al.* 2004). Other analyses of suitability of environment (see below) suggest that *P. ramorum* also has a potential for establishment further east compared to where it has been observed to occur so far.

Previous CLIMEX ‘compare locations’ analysis for P. ramorum

The CLIMEX “compare locations” method is described in Appendix 1.

Venette and Cohen (2006) have studied the potential climatic suitability for establishment of *P. ramorum* within the contiguous United States. They developed a simulation model, using the CLIMEX software and its “compare locations” technique for this purpose. Regarding the approach to estimate climatic responses of the pest for use in CLIMEX, Venette and Cohen (2006) stated that it was not possible to generate CLIMEX parameters using the iterative geographic fitting procedure because the worldwide distribution of the pathogen is poorly characterized. Instead they applied the option to derived CLIMEX parameter estimates for *P. ramorum* from reports in the literature. Temperature requirements of the pathogen were based on results from in vitro experiments by Werres *et al.* (2001), where temperature limits and optimum for vegetative growth of *P. ramorum* were determined by culturing the isolates on carrot piece agar at 11 different temperatures between 2 °C and 37 °C in the dark. Moreover, Venette and Cohen (2006) stated that moisture requirements for the growth of the pathogen were poorly understood. Thus, they chose to use soil moisture parameters estimated for a related species, *P. cinnamomi*. Temperature requirements were used to calculate a temperature index (TI), and moisture requirements to calculate a moisture index (MI). These indices together constitute the growth index (GI) calculated by CLIMEX. Preliminary data on the effects of environmental stresses for the pathogen were available from Defra (2004) when Venette and Cohen (2006) conducted their study. However, they found that these data were not detailed enough to allow for the calculation of stress parameters. Venette and Cohen (2006) therefore suggested that stress indices estimated for *P. cinnamomi* could be used, but they did not include these parameters in the baseline model to predict establishment potential for *P. ramorum*.

CLIMEX 'compare locations' analysis for P. ramorum in Norway

In the following our results from running CLIMEX with climate data for the country of Norway are presented. The analysis is based on the 10 minute latitude-longitude grid cell global climate dataset (1961-1990) from the Climatic Research Unit (New *et al.* 2002) and the temperature and moisture parameters used in the baseline model of Venette and Cohen (2006), with all stress indices set to zero. The parameter values are presented in table 11.

Table 11. Temperature and moisture parameter values determined by Venette and Cohen (2006) to characterize growth requirements for *Phytophthora ramorum*. These parameters are included in their baseline model to simulate climatic suitability of an area. In the current risk assessment the parameters are used in CLIMEX to map potential *P. ramorum* distribution in Norway.

Parameter	Definition	Value
Temperature ^a		
DV0	Lower limit for growth	2
DV1	Lower optimum for growth	17
DV2	Upper optimum for growth	25
DV3	Upper limit for growth	30
Moisture ^b		
	Lower limit for growth	0.4
	Lower optimum for growth	0.7
	Upper optimum for growth	1.3
	Upper limit for growth	3.0

^aUnits in °C.

^bExpressed as a proportion of soil moisture holding capacity (=1 at saturation). These parameters are estimated for *P. cinnamomi*

The results from the CLIMEX analysis predict that most of the PRA area, except for the mountains in Southern Norway and the inland of Northern Norway, has a climate either favourable (11-25) or very favourable (≥ 26) for establishment (figure 7). This result can be considered as a worst case scenario since stress indices for the pathogen are set to zero. Rainfall, which is important for spread of *P. ramorum*, is not included as a parameter in the model. Unfortunately the necessary information to predict the area more precisely by CLIMEX analysis is not yet available.

Recently, Tooley *et al.* (2008) studied recovery of *P. ramorum* following exposure to temperature extremes. They found that *P. ramorum* was capable of surviving some highly adverse temperature conditions for at least 7 days both as free chlamydospores in sand and within infected host tissue (*Rhododendron* variety Cunningham's White). For cold treatments, *P. ramorum* was recovered from infected leaf disks at 0 and -10 °C after 7 days. At -20 °C, recovery declined rapidly after 1 to 3 days and no recovery was obtained after 4 days.

Comparison of the recorded distribution of *P. ramorum* in Norway versus CLIMEX-based predictions of its establishment potential, indicate a deviation in the predicted potential distribution versus the recorded distribution of the pathogen. Generally, a key challenge in predicting potential geographic distribution of plant pathogens is that not only the environmental requirements set by the pathogen must be considered, but also those of the host plant. Moreover, environmental tolerance limits related to survival of plant pathogens usually

goes beyond those of their host plant, at least when considering the pathogen's most resistant life cycle stages. A potential explanation of the deviation of the predicted versus the observed distribution may be that the observed distribution of *P. ramorum* is related to the distribution of the main host plant so far, namely *Rhododendron* spp.

Other analyses of the suitability of environment for P. ramorum

The RAPRA project has assessed suitability of climate for *P. ramorum* in Europe by four different methods. Two of these are described by Sutherst and Maywald (1985) and incorporated in the CLIMEX tool, namely 1) the match climates and 2) the compare locations methods. The other two methods are 3) the Risk ranking approach by Meentemeyer *et al.* (2004) and 4) the Genetic Algorithm for Rule-set Production by Kluza *et al.* (2007). The results from these analyses of suitability of climate for *P. ramorum* in Europe generally indicate that countries south and west from Norway have more suitable climates than Norway. The exception is the risk ranking approach by Meentemeyer *et al.* (2004) which, when used in the RAPRA project, indicate that the western coastal regions of Norway have risk ranks similar to the western coastal regions of the UK (Sansford *et al.* 2009). This result corresponds with the distribution pattern observed for *P. ramorum* in Norway. Meentemeyer *et al.* (2004) developed a ranking system specifically to predict potential *P. ramorum* distribution in California. This approach allows not only climatic parameters to be considered, but also other factors such as availability of host species and various elements of human activity. The RAPRA project applied this approach to Europe, but constrained the analysis to solely climatic parameters (Sansford *et al.* 2009), which means that the climate conditions that best described the known distribution of *P. ramorum* in California were used to predict the suitability of European climates for *P. ramorum*. It must be noted that this approach has the potential to confound climatic requirements of the pathogen with climatic requirements of the host plant, as mentioned previously.

Establishment potential for P. ramorum in Norway under a Climate change scenario

The CLIMEX compare locations method has an option that allows simple climate change studies to be made. Figure 8 shows the results from running the compare locations method with the parameters for *P. ramorum* from Venette and Cohen (2006) under a simple +2 °C climate scenario. A temperature increase will increase the areas with favourable and very favourable climate, while the areas with unfavourable climate ($EI \leq 10$) shrink to the highest mountains and the northernmost inlands of Norway.

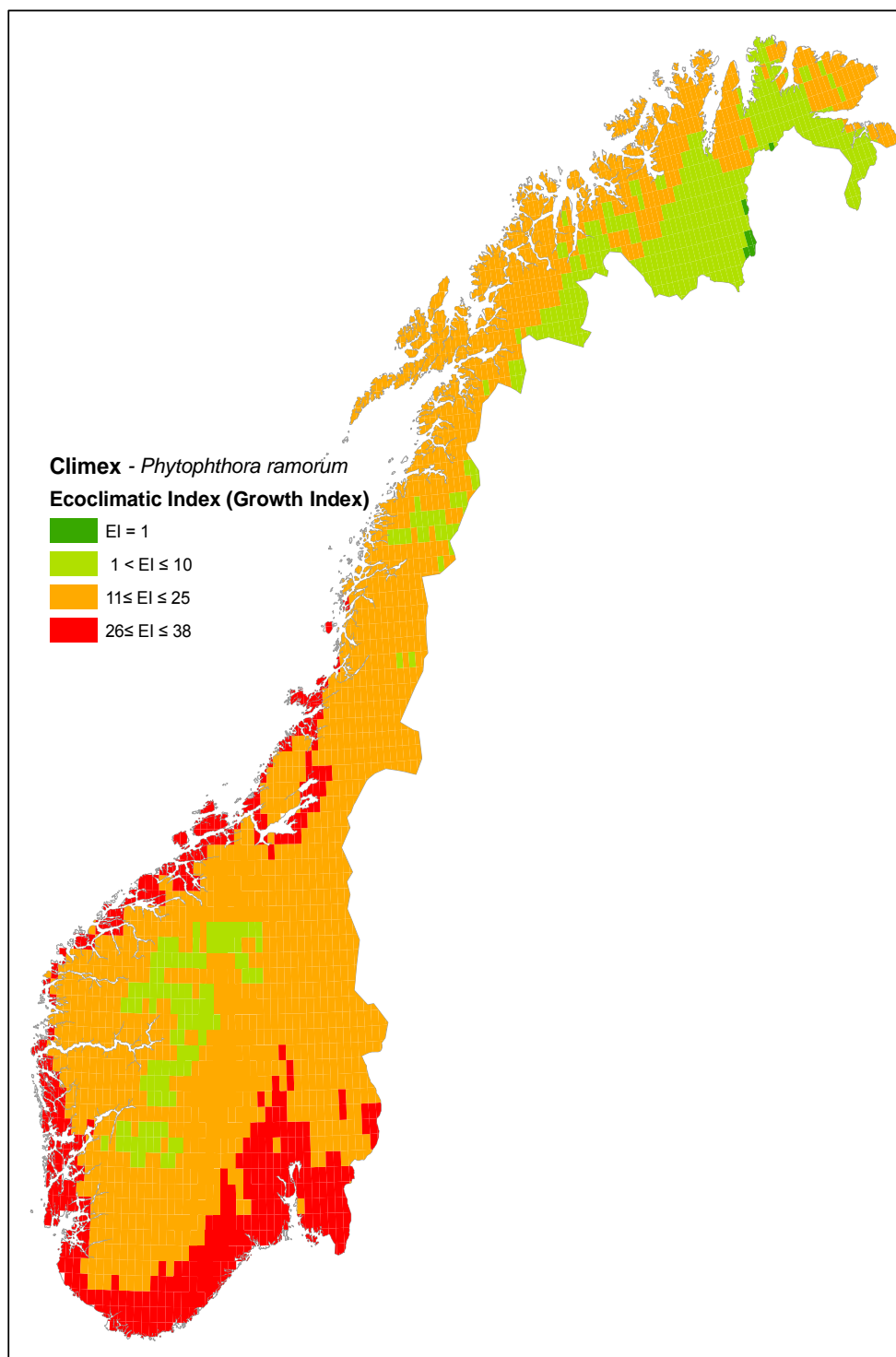


Figure 7. Potential geographical distribution for *Phytophthora ramorum* in Norway based on the 1961-1990 climate in Norway, interpolated to a 10 min latitude/longitude grid, and CLIMEX parameters for the pathogen used by Venette and Cohen (2006). All stress indices for the pathogen are set to 0, and the displayed ecoclimatic index (EI) is therefore equal to the growth index (GI). EI indicates the suitability of the environment for the pathogen: $0 < EI \leq 10$: marginal; $11 \leq EI \leq 25$: favourable; $EI > 25$: highly favourable.

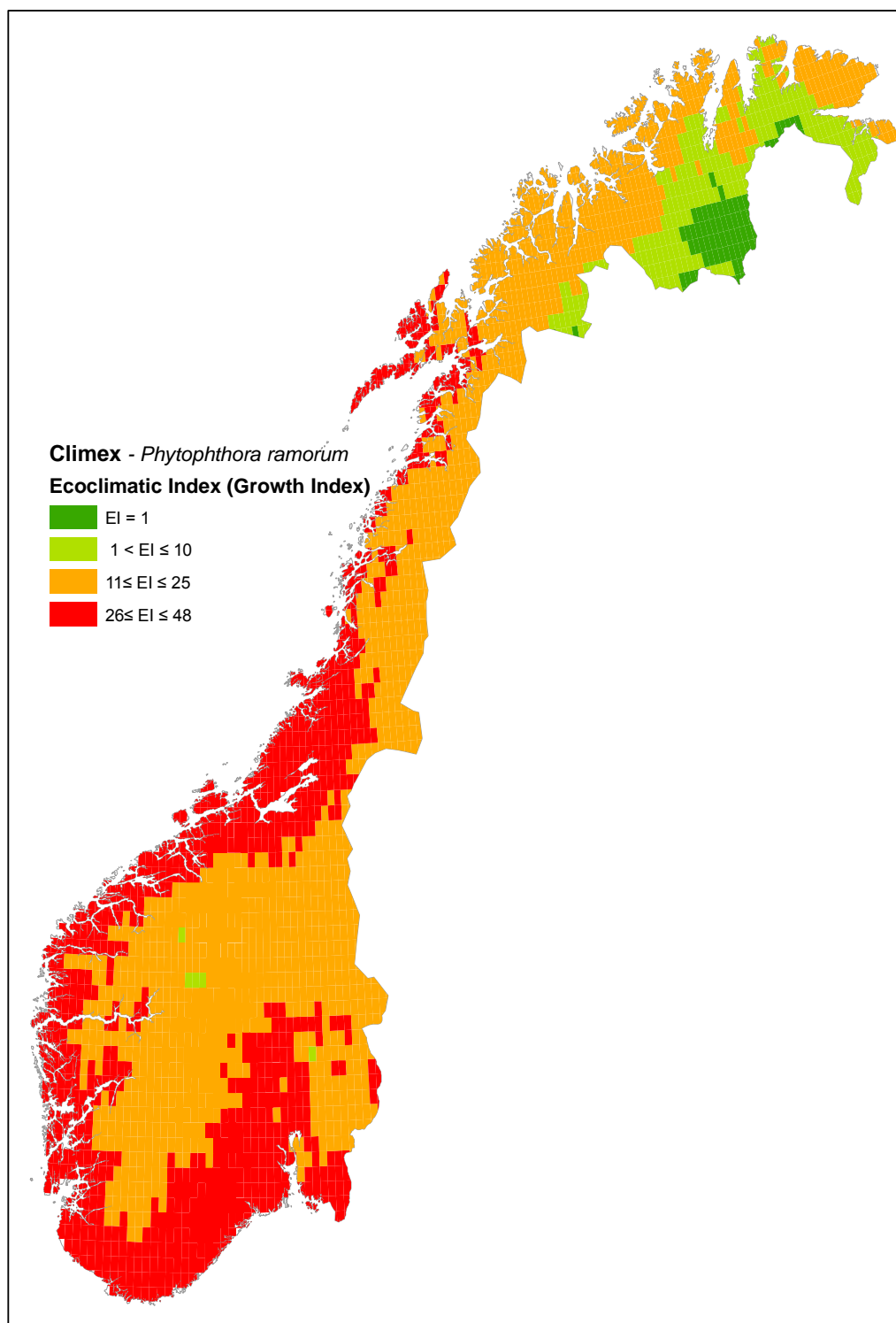


Figure 8. Climate change scenario +2°C for potential geographical distribution of *Phytophthora ramorum* in Norway. Other assumptions equal to those behind figure 7. Ecoclimatic index (EI) indicates the suitability of the environment for the pathogen: $0 < EI \leq 10$: marginal; $11 \leq EI \leq 25$: favourable; $EI > 25$: highly favourable.

4.2.2.3 Cultural practices and control measures

The managed environment in parts of the PRA area is favourable for establishment of *P. ramorum*. It is unlikely that existing pest management practice in the PRA area will prevent establishment of the disease. Based on biological characteristics, it is moderately likely that the pest could survive eradication programmes in Norway. The uncertainty surrounding these questions is low.

Favourability of the managed environment in the PRA area to establishment

The managed environment in Norwegian nurseries, garden centres, private gardens and public greens are all favourable for establishment of *P. ramorum*. The uncertainty is low.

In nurseries and garden centres, host plants are abundantly available with *Rhododendron* species as the most common. The plants are closely placed and sprinkler irrigation favours the pathogen. Trade networks, which are common between Norwegian nurseries and garden centres, favour a wider establishment of the pathogen.

In parks and private gardens, the environment is also considered favourable due to availability of hosts and conducive climate. Mutual use of equipments and lawnmowers at different sites, are examples of management practises that will support the spread and establishment of *P. ramorum*. Once introduced into parks and gardens, establishment is favoured by the soil-born phase of the pathogen. In this phase the pathogen can survive for longer time in soil and leaf litter, at least three years in parks of the UK; 1.5 years in soil in the Netherlands; 2 years in infected chipped wooden material. (Sansford *et al.* 2009)

Likelihood of the existing pest management practice to prevent establishment of the disease

It is unlikely, with low uncertainty, that the pest management practise currently used in nurseries, garden centres, parks and private gardens in the PRA area will prevent establishment of *P. ramorum*. The disease has become present in trade and outdoors in both Norway and EU with the existing management practice (Sansford *et al.* 2009).

The Norwegian Food Safety Authority has so far treated *P. ramorum* as a potential quarantine pest according to current regulations (Landbruks- og matdepartementet 2003). For nurseries and garden centres the phytosanitary measures used has included among others destruction of all hosts in a radius of 2 m from the infested plant, and further quarantine at the production site for three months for all hosts in a radius of 10 m. This is concurrent with the phytosanitary measurements taken in the EU (Commission Decision 2002/757).

The current regulations do not give any specific description of phytosanitary measures for use when *P. ramorum* is detected in private gardens or public greens, but some internal guidelines given by The Norwegian Food Safety Authority have been followed. These guidelines include measures varying from removal of infected branches to removal of whole trees or bushes which requires judgment by the inspector in each situation.

Likelihood to survive eradication programs in the PRA area, based on the biological characteristics of the pathogen.

It is moderately likely that the pest could survive eradication programs in the PRA area. The uncertainty is moderate. The most important biological characteristics that would contribute to the ability of *P. ramorum* to survive eradication programs in both nursery situations and in the landscape are listed by Sansford *et al.* (2009) as follows: the ability to produce thick-

walled chlamydospores that can survive long periods in soil or debris; the ability to recolonize new growth from cut stumps of established shrubs/trees and to colonize and persist in roots of some host species; the ability to persist in the aquatic environment, though the epidemiological significance of this is uncertain; the ability to disperse longer distances than is possible by splash dispersal (typically up to 10–15m), including via turbulent air (1km or up to 3–5km) or via contaminated soil/debris attached to feet, thereby reducing the effectiveness of buffer zones; the ability to infect a very wide range of host species; and the ability to develop resistance to some commonly-used fungicides.

Control effects of the current measures taken in nurseries and garden centres in the PRA area

Up to date, there are variable effects of the phytosanitary measures taken against *P. ramorum* both in nurseries and garden centres in the PRA area. The uncertainty of this assessment is medium to high due to lack of information.

In order to provide reliable information on this issue, all districts of the Norwegian Food Safety Authority were asked for their observations. In general the phytosanitary measures taken in nurseries and garden centres have given satisfactory control at some locations, and less satisfying control at others. It is difficult to obtain a complete overview of the situation due to lack of information. In Rogaland County the district officers reported a re-detection of *P. ramorum* in approximately 70-80% of the nurseries and garden centre sites later the same season, and in about 50-60% of the sites the following year. Rogaland County represents the most intensive nursery area in Norway, with an optimal climate for both the disease and the most important host plants. The high frequency of re-infections in nurseries and garden centres after phytosanitary measures in this county could be due to favourable environmental conditions and consequently better conditions for pathogen establishment and disease development. On the other hand, in Hordaland County, which also has a favourable climate, at least for rhododendrons, the control effect of measures carried out in nurseries and garden centres seems to be satisfactory with no observations in repeated inspections.

When *P. ramorum* is re-detected in nurseries and garden centres after completion of phytosanitary measures, this does not necessarily mean that the control effects are low-grade. New plant materials, host plants for *P. ramorum* included, arrive in most of the nurseries and garden centres throughout the whole summer season. These new entries could be latently infected by *P. ramorum*. The control effect of the phytosanitary measures could therefore be satisfactory. New inoculums brought into the site by newly purchased plants could possibly explain some of the apparently poor effect of control measures.

Most of the Norwegian garden centres do not keep plants for overwintering, and they do often have ground or tables that can be cleaned satisfactorily. If host plants within a radius of two meters of the diseased plant are destroyed, and the host plants within 10 meters are kept in quarantine, eradication of the infection should be possible if the cleaning and removal of all infected plant debris over the whole place are conducted properly. However, this presupposes that all infected plants are identified which in practice could be difficult due to latent infection and movement of plants within the nursery area. Furthermore, it presupposes that all new plants brought into the site are healthy (and strictly controlled before entry) and that there is no re-introduction of inoculums by natural spread from infection in the surroundings. In nursery environments, survival after eradication measures is considered to primarily be due to survival of the pathogen in the underlying soil or debris (Sansford *et al.* 2009). From USA successful eradication is reported in nurseries where all infected and neighbouring plant materials are destroyed by incineration and the nursery and surrounding environments subsequently surveyed for the pathogen (Osterbauer 2004).

For nurseries with production of plants in the ground, eradication of the infection may be more difficult. In the nursery environment, survival after eradication measures is considered to primarily be due to survival of the pathogen in the underlying soil or debris, presumably as chlamydospores, even though there is the possibility that it could also be surviving as root infections or sporangia and/or chlamydospores in growing media of potted plants (Sansford *et al.* 2009). In the UK, emergency measures have resulted in a decline in the number of positive finds during inspections in nurseries.

In nurseries, there is the potential for *P. ramorum* to persist undetected as infections/colonisations of roots of host plants (Sansford *et al.* 2009). The pathogen can also potentially survive in contaminated growing media of both host and non-host material, via both sporangia and chlamydospores. This ability for the pathogen to persist as propagules in growing media or undetected in host roots, could enable the pathogen to survive the eradication measures in nurseries and increase the possibility of the pathogen to re-occur or spread undetected (Sansford *et al.* 2009).

Control-effects of existing pest management practice in private gardens and parks and possibilities for eradication of P. ramorum from places where it has been found and is likely to be established

In parks and private gardens the control effects of existing pest management practice in the PRA area have so far been variable, but mostly with a low effect. Based on the pest's biological characteristics, it is moderately likely that *P. ramorum* could survive eradication programs in the PRA area. The uncertainty of this assessment is low.

P. ramorum has been found in private and public gardens in four counties of Norway: Hordaland (limited to the city of Bergen and its surroundings), Rogaland and Akershus and late in 2008 also in the county of Vest-Agder. Detections of *P. ramorum* on well established plants have been made mainly in the south-western coastland, with a few records only in the south-east part of the country. At most places the phytosanitary measures taken after detection of *P. ramorum* have included removal of diseased branches and removal of plant debris and to a lesser degree, removal of whole plants for plantings.

Common to all locations where *P. ramorum* has been found on well established plants are the reports of lower efficiency of the phytosanitary measures taken, than the effect of measures carried out in nurseries and garden centres. In Bergen, which has the most frequent findings in outdoor rhododendrons, the disease has been eradicated in 15 % of the cases only, and consequently *P. ramorum* are re-detected in 85 % of the locations in following seasons. The re-detection and spread of the disease, for instance as in Nygårdsparken (figure 5) and Gamlehaugen in Bergen, indicate that the measures chosen have not given the expected effects.

The possibility to eradicate the disease in places where it is already present is considered as low with the current disease management practise, especially in parts of the PRA-area with climate favourable for the disease (along the south-west coast of Norway). To succeed with the eradication of *P. ramorum* from places where it is found, more restrictive eradication measures are required.

The pathogen's ability to produce long-lived and thick-walled chlamydospores is rated as the most important characteristic that would enable *P. ramorum* to survive eradication programs (Sansford *et al.* 2009). In a research field in Bergen (Hordaland County), the pathogen has been shown to survive in the soil or plant debris (Herrero *et al.* 2008). In the same field it has been observed that after removal of infected rhododendrons, the pathogen is able to re-infect

regrowth from cut stumps either via the stump directly or as a result of the stump/bark becoming infected via inoculum splashed from the soil surface. This highlights the importance of preventing rhododendron regrowth, either by fully removing stumps, or by treating stumps with herbicides. Furthermore, a successful eradication will require that the disease is not reintroduced by trade in infected plant material.

P. ramorum has also the ability to survive in roots, mostly as asymptomatic infections. This may also enable the pathogen to survive eradication programs, since the pathogen may persist below ground for longer periods of time (Sansford *et al.* 2009).

P. ramorum sporangia are typically dispersed by rain splash over short distances. However, *P. ramorum* can also be spread in nurseries and parks via wind-blown infected debris which could reduce the impact of measures that are based solely on splash-dispersal distances. Such wind-blown spread of detached leaves is common in parks in Bergen (Hordaland County).

From England it is known that if more than a few plants are affected, then outbreaks in natural and semi-natural environments are generally more difficult to eradicate than outbreaks in nurseries and garden centres. The resources required for removing or cutting back plants, removing and treating plant debris, control of substantial re-growth, hygiene measures and restrictions in access to the affected area, are often substantial and are required over long periods. On the other hand, experiments in historical gardens in UK has shown that by completely removing infected rhododendron and other foliage hosts, new plant infections has been prevented, although the pathogen can still be detected in soil and water sources (Defra 2008).

The very wide host range of *P. ramorum* might have a negative impact on the success of eradication. Susceptible plants will probably be infected and not be encompassed in current measures.

Other control measures

Phytophthora-species are in general difficult to control. Suppressive measures include sanitation, disinfection, the use of fungicides and fumigants and changes in the growing practise like treatment to avoid dissemination by water, change in watering practice and change in the beds beneath the pots. Sanitation practice should include removing and testing of symptomatic stock, sterilisation of potting media, and disinfection of tools, benches, workers shoes, gloves and other equipments.

In Norway, the following fungicides are available for use against *Phytophthora* spp. in nursery stocks: metalaxyl –M (Ridomil Gold Granulate), propamocarb (Previcur N), and fosetyl aluminium (Aliette 80 WG). There are several international tests performed to evaluate these registered products against *Phytophthora* spp. in general and against *P. ramorum* in particular. It seems like most fungicides are more effective as “protectants” than as “curatives”, and they will not exclude the pathogen from already infested plants (Tjosvold *et al.* 2005). Fungicide treatments (preventive or curative) are by the Norwegian Food Safety Authority not included in current phytosanitary measures against *P. ramorum* in Norway.

Disease-free propagation material and resistant cultivars are also effective control measures. So far there is little available scientific information on the susceptibility of different rhododendron varieties to *P. ramorum*. But some of the information is referred to in section 4.2.2.1.

At the production sites, the most important control options would be to prevent the disease by changes in the growing practises (clean water, avoid sprinkling water, general high hygiene standards, lift the production from the ground, clean cuttings etc.).

4.2.2.4 Other characteristics of the pest affecting the probability of establishment

It is likely that the reproductive strategy of the pest and duration of its life cycle could aid establishment, and it is likely that a relatively small pathogen population could become established. The pathogen is moderately adaptable and has been introduced occasionally to new areas outside its area of origin. The uncertainty is low for all these assessments.

The probability of the pathogens reproductive strategy and the duration of its life cycle to aid establishment.

P. ramorum has a flexible and adaptive reproduction strategy that most likely would favour establishment. This species produce vegetative hyphae and four types of spores: sporangia, zoospores, chlamydospores (asexually formed resting spores) and oospores (sexually formed resting spores). All spore types, except oospores, are found in nature.

Sporangia are produced asexually on leaf lesions from specialized hyphae (sporangiophores) emerging through stomata or wounds. The sporangia are deciduous and their primary function is dispersal. Sporangia release motile zoospores in moisture (optimal 93-100%) or they may germinate directly to produce mycelium. Zoospores are released from the sporangia under cool, moist conditions. The zoospores are motile before encysting, and the cysts may be dispersed further by rain-splash.

The large and thick-walled chlamydospores have a major role in survival of the disease. They are produced asexually in infected leaves, shoots, bark phloem and xylem tissues (Parke *et al.* 2008). The life cycle duration is extended under adverse conditions via chlamydospores in leaves, debris and soil.

Oospores are the sexual spores of *P. ramorum*. Since this species is heterothallic, two different mating types, A1 and A2, are needed for fertilization and oospore formation. Most European isolates of *P. ramorum* are A1 and most North American isolates are A2. More recently a few A2 mating types have been found in Europe and a limited number of A1 mating types have been identified in nursery stocks in USA and Canada (Hansen *et al.* 2003). Oospores are so far not detected in nature, but in the laboratory oospores can be produced in rhododendron stems (Werres & Zielke 2003) and in vitro (Hansen *et al.* 2003). There is some uncertainty concerning whether the mating system is fully functional, and the importance of oospores with regards to survival and sexual reproduction for *P. ramorum* is still unknown (Brasier *et al.* 2007). If the mating system was functional, the production of oospores could favour establishment since, like chlamydospores, oospores are likely to facilitate long-term survival. Under optimal conditions generation time can be relatively rapid, thus favouring establishment and spread.

The probability of small populations to become established.

Small populations of *P. ramorum* are likely to become established in the PRA area. The repeated findings of *P. ramorum* in rhododendrons in parks along the south-west coast of Norway support the view that small populations can become established and survive if the climate is suitable and susceptible plants are available.

The probability of the pest to adapt

P. ramorum is moderately adaptable (Sansford *et al.* 2009). The different lineages of the pathogen in Europe and in the USA indicate that *P. ramorum* could readily evolve. The ability to adapt would be enhanced by sexual reproduction, but even in the absence of sexual reproduction genetic recombination may occur through somatic hybridization (Brasier 2008).

Introduction to new areas from its area of origin

P. ramorum is considered to have been introduced separately to North America (NA1 and NA2 lineages) and to Europe (EU1 lineage) via very occasional events that are considered to have occurred relatively recently, e.g. potentially in the last 20–30 years. These assumptions are based on genetic studies (Ivors *et al.* 2006; Mascheretti *et al.* 2008). Once introduced to North America and to Europe, more regular introductions and spread from the initial points of entry have occurred (Sansford *et al.* 2009). In Europe, the pathogen was first detected in Germany and the Netherlands in the early 1990's and has since spread to other European countries (Sansford *et al.* 2009). In both Europe and the USA, the limited degree of genetic variation in the populations suggests recent and limited introductions (Ivors *et al.* 2006; Brasier 2008).

4.2.3 Probability of spread after establishment

In the absence of statutory control there are high probabilities for *P. ramorum* to be spread quickly in the PRA area by trade of host plants for planting. The uncertainty of this assessment is low. Planting of infected plants will bring the pathogen from the nurseries into the environment. Natural spread is likely to be slower due to the predominance in the pathogen of short-distance spread. In parts of the PRA area, where climate events are favourable and there is an abundance of continuous hosts, natural spread could be significantly more rapid.

Spread by natural means

P. ramorum has the opportunities for natural spread in the PRA area, but it is only moderately likely that this spread would be rapid. The PRA for EU (Sansford *et al.* 2009) clarify that natural spread will depend on a variety of factors, including: pathogen factor, most importantly those relating to spore production, spore dispersal and pathogen survival (i.e. infection pressure); host factors, especially the availability of fragmentation and susceptible habitats/hosts; climatic factors, especially those conditions that influence the degree of infection pressure.

In Norway, natural spread of the pathogen has only been observed to some extends in parks along the south-west coast of the country. In these parks there is also human assisted spread by visitors and maintenance of plantings, and this area has heavy precipitation (2-3000 mm/year) which would promote rain splash as the most important natural dispersal at a local level. Typical dispersal distances by rainsplash are in the order of up to 10-20 m depending on the topography and the plant community structure (Chastagner *et al.* 2008; Mascheretti *et al.* 2008).

Long-distance dispersal by natural means includes movement by aerial dissemination (of sporangia, zoospores and possibly chlamydospores) during major weather events such as

wind driven rain and turbulent air. Such long-distance spread could transport the pathogen up to several kilometers away, and this type of dissemination is postulated to be responsible for spread of the NA1-A2 mating type in California and Oregon (Hansen 2008). Similar weather events also occur along the south-west coast of Norway, indicating the possibility of long-distance dispersal by natural means in this part of the PRA area.

The frequency of such long-distance dispersal events via wind-driven rain or turbulent air will most likely depend on the frequency of the storm events responsible, the amount of infected plants at the source, and the presence of hosts at the sites where inoculum is deposited. This highlights the importance of both climatic and host factors in determining the potential for the pathogen to spread rapidly (Sansford *et al.* 2009). Along the south-west coast of Norway, the abundance of rhododendron as a host plant, the amount of rain and the occasionally special weather events, increase the possibility of rapidly spread by natural means in these areas. However, in Europe rapid natural spread beyond the local scale has not yet been observed (Sansford *et al.* 2009). Most infections outside nurseries have been attributed to the human-mediated movement of infected plants, though there is some statistical evidence for natural spread from nurseries to nearby (within 1 km) semi-natural environments (Jeger 2008).

In infested parks in Hordaland County, natural spread by wind-blown debris has been observed. In *Rhododendron* spp., leaves infected by *P. ramorum* are detached very rapidly, and are easily transported by wind. The significance of this dispersal pathway is not yet known. More rapid and long-distance natural spread could also occur via the movement of contaminated soil on the feet of animals or via inoculums in water sources (Sansford *et al.* 2009).

Spread by human assistance

There are very high probabilities for *P. ramorum* to be spread quickly by human-mediated means in the PRA area, most significantly through the commercial movement of infected plants for planting. The uncertainty of this assessment is low.

The rapid spread within Norway by trade of infected host plants (even under statutory control) is confirmed by the expansion of the geographical distribution of the pathogen (section 4.1.2). *P. ramorum* is found in nurseries and garden centers at many different geographical locations in the south of Norway and the disease is very likely to spread quickly throughout the nursery network within the PRA area.

Scale-free networks are used as a description of the ornamental trade network structures in the UK (Sansford *et al.* 2009). Scale-free networks are characterized by super-connected nodes and have a low epidemic threshold; therefore the pathogen could spread rapidly through the network in the absence of controls and then into the environment (Jeger *et al.* 2007).

Possibilities of spread through other human-mediated means include soil/debris attached to footwear and potentially also on tyres of bikes and cars, movement of potentially infected wood, bark, cut foliage. Seeds or fruits are considered less important for rapid spread, primarily due to the end use of the material (Sansford *et al.* 2009).

Probability for the pest to be contained within the PRA area based on biological characteristics and the possibilities for limiting future spread in Norway by nursery plant trade.

There are moderately high probabilities for *P. ramorum* to be contained within the PRA area, due to the pathogen's biological characteristics. The uncertainty of this assessment is low.

P. ramorum has a limited possibility to be spread over long distances by natural means. This limited natural spread favours the containment of the disease within the PRA area. However, long-distance natural spread by turbulent air and wind-blown infected debris might occur to some extent along the south-west coast of Norway. This would decrease the probabilities for containments to some degree.

Host plants, and potential unknown hosts might escape current statutory controls. However, in Norway rhododendron is the commercial host plant within trade where *P. ramorum* is most frequently recorded (section 4.1.2). This predominance of a specific ornamental host would favour containment measures being successful if the measures are targeted at the most frequent hosts at major nodes in trade like production nurseries, wholesalers or major distribution centers (Sansford *et al.* 2009).

The possibilities for limiting further spread of *P. ramorum* in Norway by nursery plant trade will depend upon further containment measures and more intensive inspections both in trade and at the production sites to ensure trade in disease-free host plants.

The production of rhododendrons in Norwegian nurseries is limited and more than 50% of the trade of this important host is based on import of plants from other countries (table 5 and 6). The control of spread will therefore also depend to a large degree on regulations, inspection and measures against the disease taken in other countries.

4.2.4 Conclusions on the probability of introduction and spread

Probability of entry:

The overall probability of entry of *P. ramorum* into the PRA area is rated as high, with a low level of uncertainty. This assessment is based upon identification of pathways, import volume, the probability of the pest being associated with the pathway at origin, the probability of survival and multiplying during transport or storage and the probability of transfer to a suitable host after arrival.

Probability of establishment:

The overall probability of establishment of *P. ramorum* in the PRA area is rated as high, with a low level of uncertainty. This assessment is based on detection of the pathogen every year since 2002, availability of hosts, suitability of the environment in at least parts of the PRA area, biological characteristics of the pest, and the effects of existing pest management practices.

Probability of spread after establishment:

In the absence of statutory control the probability for *P. ramorum* to be spread quickly in the PRA area by trade of host plants for planting is rated as high. The uncertainty of this assessment is low. Planting of infected plants will bring the pathogen from the nurseries into the environment. Natural spread is likely to be slower due to the predominant short-distance spread of the pathogen. In parts of the PRA area where the climate events are favourable and where there is an abundance of continuous hosts, natural spread could be significantly more rapid.

4.2.4.1 Conclusion regarding endangered areas

At the present stage of knowledge about host susceptibility, epidemiology, and environmental requirements of *P. ramorum*, the endangered area is the most of the country of Norway, except where the climate is predicted to be unfavourable (figure 7). Host plants for *P. ramorum* are present in all areas where the climate is predicted to be favourable. However, this area must be regarded as a maximum estimate for the endangered area. On the other hand, a narrow and very conservative estimate for the endangered area can be defined based on the geographical distribution of highly susceptible host plants in Norway. This area is gardens and parks with *Rhododendron spp.*, *Viburnum spp.*, red oak, and *F. sylvatica*, and areas in the wild into which *Rhododendron spp.* has spread and woods with *F. sylvatica*. Woods with *F. sylvatica* is limited to the county of Vestfold and some small areas in the counties of Aust-Agder and Hordaland.

4.3. Assessment of potential economic consequences

4.3.1 Pest effects

4.3.1.1 Direct pest effects

P. ramorum causes a complexity of disease symptoms generally grouped into three categories: canker, foliage lesion, and dieback. Leaves, shoots, and buds are affected on a wide range of host species. Most infected plants are weakened (reduced growth and reproduction, and more susceptible to other plant pests and to stress), and in worst cases the whole plant or whole plant communities dies.

Known and potential host species that could become affected in the PRA area are given in section 4.2.2.1.

In cultivated nursery plants the pathogen causes quality losses, making the plants unsalable because of the infection. Importing companies, nurseries and garden centers in the PRA area have suffered substantial losses due to *P. ramorum* infections. In many cases the disease has appeared later in garden centers or other commercial companies marketing rhododendron. Complaints from customers have forced the seller to accept diseased plants for destruction. Also, the companies have had to carefully grade the plants to avoid selling infected plants which later could develop symptoms.

Like in cultivated nursery plants, loss of quality and visual damage are the main effects on plants in parks and managed gardens. Symptoms caused by *P. ramorum* have a negative effect on the aesthetic appearance of the affected area. Public parks and amenity areas have had considerable expenses in removal and destruction of diseased plants in addition to the cost of replanting.

Also when it comes to wild plants and vegetation, *P. ramorum* might have a negative effect on the aesthetic appearance of the affected area due to symptoms. The main concern, however, is the weakening and perhaps even loss of plants and trees caused by *P. ramorum* infections. Such direct effects of *P. ramorum* on wild plants might in worst case be considerable.

4.3.1.2 Indirect pest effects

The current requirement in the PRA area is among others that infected plants and all susceptible vegetation within 2 m radius of the diseased plants must be destroyed. Also, associated growing media and plant debris must be destroyed. With similar regulations in force Defra (2008) calculated an estimated loss of £2.2 million for UK over a 20 year period.

Potential indirect effects of *P. ramorum* infections on plants in parks and managed gardens are removal of infected branches or whole trees or bushes to stop further spread, which also can cause visual damage. Visual damage can reduce the recreation value and tourism of the affected areas.

Potential indirect effects of *P. ramorum* infections in wild plants are loss of recreation areas and disruption of ecosystems. Such indirect effects of *P. ramorum* on wild plant habitats might in worst case be considerable.

4.3.2 Analysis of economic consequences

In Europe the pathogen has been detected in Norway, Switzerland and the following EU countries: Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland,

Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Slovenia, Spain, Sweden and the UK (Sansford *et al.* 2009). Outside Europe the pathogen is known from Canada and USA.

Nurseries in the PRA area are importing from the EU approximately 50 % of the rhododendron plants commercialized. Also, a large portion is imported of the genera *Kalmia*, *Pieris*, *Syringa* and *Viburnum*. In the PRA area these genera have had cases of infected plants. The import into the PRA area of *P. ramorum* susceptible plants from USA and Canada is negligible.

4.3.2.1 Analysis of commercial consequences

It is very likely that *P. ramorum* will survive eradication programs in the PRA area. In UK and the Netherlands the thick-walled chlamydospores have been demonstrated to survive in the soil for several years (Turner *et al.* 2008; Turner 2007). In nurseries the pathogen survives in the soil, on roots and in debris following eradication measures (Linderman & Davis 2006). However, new nursery outbreaks in Europe have decreased from 255 in 2004 and 203 in 2005 to 108 in 2006 (Slawson *et al.* 2008).

Nurseries

The pathogen *P. ramorum* is likely to have moderate economic impact on the nurseries in the PRA area with current phytosanitary measures. Without any such regulations *P. ramorum* is likely to have major economic impact on the nursery industry of the PRA area.

The levels of uncertainties of these assessments are low.

The nursery environment favours *P. ramorum* epidemics. A humid microclimate and a wide range of susceptible plants are conducive for disease development. In a nursery plants are closely spaced and irrigation, pruning and other handling of the plants increase the risk of spreading propagules of *P. ramorum*.

In the PRA area the pathogen has been detected at nurseries up to Sør-Trøndelag County, latitude 63.5° N (figure 3). Phytosanitary measures have reduced the number of detections in nurseries from 130 in 2007 to 55 in 2008 (table 3).

In nurseries in the EU *P. ramorum* is widely distributed, but with low incidence. The current phytosanitary measures are reducing the number of new outbreaks in the EU (Sansford *et al.* 2009).

Relaxing the phytosanitary measures enforced in the PRA area will probably increase the number of outbreaks caused by *P. ramorum* in the nurseries. Since the import of susceptible species from EU countries is large, the PRA area depends to a large extent on the control measures imposed by the EU. Removing the current phytosanitary control in EU will increase the probability of importing the pathogen from nurseries in EU into the PRA area.

The actions taken in England and Wales to control *P. ramorum* in the nursery trade have reduced long-distance spread. Jeger (2008) concluded that a policy of containment and eradication is justified to reduce the rate of spread of the pathogen, but that complete eradication of *P. ramorum* from the UK is unlikely.

Parks and managed gardens

With current phytosanitary measures *P. ramorum* is likely to have moderate economic impact on parks and private gardens in the best climatic zones of the PRA area. Without any such regulations *P. ramorum* is likely to have major economic impact in the best climatic zones of the PRA area.

The levels of uncertainties of these assessments are low.

In managed gardens of the EU *P. ramorum* is well established in the south and west of the UK and in parts of the Netherlands, and the pathogen is causing obvious damage. Lifting the current phytosanitary control measures will increase the spread in areas where hosts are cultivated in parks and gardens (Sansford *et al.* 2009).

In the PRA area the pathogen has been detected on plants in the genera *Rhododendron*, *Pieris* and *Viburnum* in parks and private gardens. Most detections have been in Hordaland County, with single cases in Rogaland, Aust-Agder and Vestfold Counties.

Forestry

Massive tree death caused by *P. ramorum* in forests has not been seen in Europe or Canada (Sansford *et al.* 2009). Establishment of *P. ramorum* in forests will require sporulating hosts within or near the forest. In coniferous or mixed deciduous forests establishment of *P. ramorum* will only occur if the trees themselves support sporulation, or if there are non-tree hosts that support sporulation within or near the forest (Sansford *et al.* 2009).

The most important forest types of the PRA area are: Coniferous and mixed forests, and deciduous broadleaf forest.

Coniferous and mixed forests

Coniferous and mixed forests are the dominating forest types in the PRA area. The main coniferous species are Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*). Mixed coniferous/deciduous broadleaf forests are common in the PRA area. Current management practices encourage mixture of up to 10 % broadleaf trees in coniferous forests. *Betula* spp. are the dominant broadleaf species in mixed forests. Norway spruce is the most important forest tree species in South-eastern and Central Norway with a distribution north to Saltdal, Nordland County. Planted Norway spruce grows north to Finnmark County. *P. sylvestris* var. *sylvestris* has a distribution north to Nordland County, while *P. sylvestris* var. *lapponica* grows in mountains in Southern Norway and throughout Northern Norway to Sør-Varanger, Finnmark County (Elven 2005).

Scots pine is not considered susceptible to *P. ramorum*. The disease has never been detected on Norway spruce, but in inoculation experiments *P. abies* has shown low to moderate susceptibility (Sansford *et al.* 2009).

The Sitka spruce (*Picea sitchensis*) is the most prevalent of the conifers recently introduced into the PRA area. The Sitka spruce is planted along the western coast north to Troms County. It is commonly naturalized in south-western, coastal parts of the PRA area, north to Vega, Nordland County (Elven 2005). *P. sitchensis* had in inoculations tests low to moderate susceptibility to *P. ramorum* (Sansford *et al.* 2009). The distribution of Sitka spruce is of low significance compared to the distribution of Norway spruce and Scots pine.

Infection on susceptible understorey *Vaccinium* spp. vegetation will potentially produce inoculum of *P. ramorum* and increase the risk of infection in susceptible coniferous species.

The impact of *P. ramorum* in coniferous and mixed forests of the PRA area is likely to be minor. The level of uncertainty of this assessment is medium.

Deciduous broadleaf forest

The birch (*Betula pubescens*) and other *Betula* spp. are the dominant broadleaf species both in the lowlands, at higher altitudes and at northern latitudes throughout the PRA area (Elven 2005). *Betula* spp. are considered to have low susceptibility to *P. ramorum*.

The oak species *Q. petraea* grows in the coastal areas from the Oslofjord to Møre og Romsdal County, while *Q. robur* is more widely distributed both in coastal areas and in the inland of South-eastern Norway north to Hedmark and Oppland Counties, with scattered forests along the coast north to Møre og Romsdal County (Elven 2005). Both these *Quercus* spp. are considered not very susceptible to *P. ramorum*. The more susceptible red oak (*Q. rubra*) is a less common, planted park tree in the best climatic zones along the coast north to Bergen, Hordaland County. European beech (*Fagus sylvatica*), which is highly susceptible, forms small forests in the coastal areas from Vestfold County to Hordaland County. Ash (*Fraxinus excelsior*) is growing in south-eastern Norway, in coastal areas and is naturalized north to Steigen, Nordland County (Elven 2005). Leaf infections on ash have been seen in Europe.

Infection on susceptible understorey *Vaccinium* spp. vegetation will potentially produce inoculum of *P. ramorum* and increase the risk of infection in susceptible broadleaf species.

The impact of *P. ramorum* in natural and planted deciduous broadleaf forests of the PRA area is likely to be minor due to the scattered and limited distribution of the most susceptible species. The level of uncertainty of this assessment is medium.

4.3.2.2 Non-commercial and environmental consequences

The non-commercial and environmental consequences to natural environments in the PRA area are likely to be moderate. The level of uncertainty of this assessment is high.

In Europe *P. ramorum* has been found outside parks and managed gardens in UK, France, Germany, Ireland and the Netherlands (Sansford *et al.* 2009). The UK has had more outdoor cases than other European countries. Kehlenbeck (2008) described scenarios for future environmental impact of the pathogen in Europe. In Northern Europe where trees with stem cankers might be growing in association with infected rhododendron the impact is moderate as the environmental impact affects only a few areas. This is not likely to change unless there is a dramatic change in the presence of infected foliar hosts that support sporulation and provide inoculums to infect tree stem hosts.

Heathland and heather environments may be affected by *P. ramorum*. Such ecosystems are abundant in the PRA area, and some of the wild-growing shrubs and heathland plants of the PRA area are known or potential hosts of *P. ramorum*. A recently published Norwegian flora (Elven 2005) gives the distribution of native *Ericaceae* species (table 12). Of the two species in the genus *Rhododendron*, *R. lapponicae* is common in mountains, while *R. tomentosum* only grows in the northernmost counties of Troms and Finnmark. No data are available on their susceptibility. However, both are unlikely to be exposed for the pathogen since climate is not favourable for the pathogen in these parts of the PRA area. *Calluna vulgaris* and *Vaccinium myrtillus* are common in the PRA area, and they were classified as highly

susceptible in inoculation experiments (Kaminsky & Wagner 2008). Recently *V. myrtillus* was found naturally infected outdoors in Norway (Herrero 2009, personal communication), and last year it was found naturally infected outdoors in the UK (CSL 2009). In nurseries, infection of *V. vitis-ideae* is reported in UK, and nursery findings in *C. vulgaris* are reported in Poland (CSL 2009). Infection of *Arctostaphylos uva-ursi* is reported from nurseries in USA (CSL 2009). *Erica cinerea* was classified as moderately susceptible, while *Oxycoccus palustris* (syn. *Vaccinium oxycoccus*) proved to be highly susceptible and developed symptoms when wounded (Kaminsky & Wagner 2008). The same authors found cultivars of *Erica carnea* to be highly susceptible. Data on susceptibility of other native *Ericaceae* are not known.

In the PRA area *P. ramorum* has not been found outside parks and managed gardens. In the country the heathlands ecosystems cover large, non-forested coastal areas with a climate conducive for the pathogen. Vegetation above the tree line grows at rather cool temperatures, which lower the risk of *P. ramorum* epidemics. *Ericaceae* species form understorey vegetation in coniferous and deciduous forests throughout the PRA area.

Economic value of non-cultivated vegetation in heathlands is difficult to quantify. It has been postulated that the cost of an invasive species like *P. ramorum* will rise with time. This relatively slow spreading pathogen compared to causal agents of crop diseases will have the long term effect of reducing the environmental value for future generation (Waage *et al.* 2005).

Table 12. Some potential, native hosts for *Phytophthora ramorum*, listed in Norsk Flora (Elven 2005).

Scientific name	Norwegian name	Southern Norway distribution	Northern Norway distribution
<i>Rhododendron lapponicae</i>	Lapprose	Alkaline soil, dry mountain areas, rare	Alkaline soil, rather common
<i>Loiseleuria procumbens</i>	Greplyng	Dry mountain areas, common	In mountains and lowlands, common
<i>Phyllodoce caerulea</i>	Blålyng	Common in mountain forest and mountains	Common in mountains and lowlands
<i>Andromeda polifolia</i>	Kvitlyng	Common in wet forests, marshes	Common in wet forests, marshes
<i>Arctostaphylos uva-ursi</i>	Mjølbær	Dry forested areas, common.	Dry forested areas, common
<i>Arctous alpinus</i>	Rypebær	Common in mountains and hills	Common in mountains and hills
<i>Erica tetralix</i>	Klokkelyng	Wet marshes and heathers, rather common in coastal areas	Wet marshes and heathers to Nordland.
<i>Erica. cinerea</i>	Purpurlyng	Heathers, rather common in coastal areas	Absent
<i>Calluna vulgaris</i>	Røsslyng	Common on heathers, in forests, acid soil	Common in heathers, forests, acid soil
<i>Vaccinium vitis-idaea</i>	Tyttebær	Common	Common
<i>V. uliginosum</i>	Bløkkebær	Common on marshes and other wet areas	Common in marshes and other wet areas
<i>V. myrtillus</i>	Blåbær	Common	Common
<i>Oxycoccus palustris</i>	Stortranebær	Common, except in coastal areas	Not very common
<i>O. microcarpus</i>	Småtranebær	Common on marshes	Common on marshes
<i>Empetrum nigrum</i>	Krekling	Common	Common

4.3.3 Conclusion of the assessment of economic consequences

The pathogen *P. ramorum* is likely to have moderate economic impact on the nurseries in the PRA area with current phytosanitary measures. Without any such regulations *P. ramorum* is likely to have major economic impact on the nursery industry of the PRA area. The level of uncertainty is low.

With current phytosanitary measures *P. ramorum* is likely to have moderate economic impact on parks and private gardens in parts of the PRA area. Without any such regulations *P. ramorum* is likely to have major economic impact in the best climatic zones of the PRA area. The level of uncertainty is low.

The impact of *P. ramorum* in coniferous and mixed forests of the PRA area is likely to be minor. The level of uncertainty of this assessment is medium.

The impact of *P. ramorum* in natural and planted deciduous broadleaf forests of the PRA area is likely to be minor due to the scattered and limited distribution of the most susceptible species. The level of uncertainty of this assessment is medium.

The non-commercial and environmental consequences to natural environments in the PRA area are likely to be moderate. The level of uncertainty is high.

4.3.3.1 Endangered area

The part of the PRA area where presence of *P. ramorum* might result in economically important losses is identified and described in section 4.2.4.1.

5. CONCLUSION OF THE PEST RISK ASSESSMENT

Pest status of the PRA area:

The pest of concern in this pest risk assessment is the Oomycete *Phytophthora ramorum*. The PRA area is Norway. *P. ramorum* is present but not widely distributed in the PRA area, and the pest is under official control in the PRA area. The outdoors surveys of *P. ramorum* in Norway have not been conducted systematically over the whole country, and some uncertainty therefore still remains regarding the current distribution of *P. ramorum* in the PRA area.

Probability of introduction and spread:

The overall probability of entry of *P. ramorum* into the PRA area is rated as high, with a low level of uncertainty. This assessment is based upon identification of pathways, import volume, the probability of the pest being associated with the pathway at origin, the probability of survival and multiplying during transport or storage and the probability of transfer to a suitable host after arrival.

The overall probability of establishment of *P. ramorum* in the PRA area is rated as high, with a low level of uncertainty. This assessment is based on detection of the pathogen every year since 2002, availability of hosts, suitability of the environment in at least parts of the PRA area, biological characteristics of the pest, and the effects of existing pest management practices.

In the absence of statutory control the probability for *P. ramorum* to be spread quickly in the PRA area by trade of host plants for planting is rated as high. The uncertainty of this assessment is low. Planting of infected plants will bring the pathogen from the nurseries into the environment. Natural spread is likely to be slower due to the predominant short-distance spread of the pathogen. In parts of the PRA area where the climate events are favourable and where there is an abundance of continuous hosts, natural spread could be significantly more rapid.

Conclusion regarding endangered areas:

The part of the PRA area where presence of *P. ramorum* might result in economically important losses (the endangered area) is assessed to be the most of the country of Norway, except where the climate is predicted to be unfavourable for the pest (figure 7). However, this area must be regarded as a maximum estimate for the endangered area. On the other hand, a narrow and very conservative estimate for the endangered area can be defined based on the geographical distribution of highly susceptible host plants in Norway. This area is gardens and parks with *Rhododendron spp.*, *Viburnum spp.*, red oak, and *Fagus sylvatica*, and areas in the wild into which *Rhododendron spp.* has spread and woods with *F. sylvatica*. Woodlands with *F. sylvatica* are limited to the county of Vestfold and some small areas in the counties of Aust-Agder and Hordaland.

Conclusion of the assessment of economic consequences

The pathogen *P. ramorum* is likely to have moderate economic impact on the nurseries in the PRA area with current phytosanitary measures. Without any such regulations *P. ramorum* is

likely to have major economic impact on the nursery industry of the PRA area. The levels of uncertainties of these assessments are low.

With current phytosanitary measures *P. ramorum* is likely to have moderate economic impact on parks and private gardens in parts of the PRA area. Without any such regulations *P. ramorum* is likely to have major economic impact in the best climatic zones of the PRA area. The levels of uncertainties of these assessments are low.

The impact of *P. ramorum* in coniferous and mixed forests of the PRA area is likely to be minor. The level of uncertainty of this assessment is medium.

The impact of *P. ramorum* in natural and planted deciduous broadleaf forests of the PRA area is likely to be minor due to the scattered and limited distribution of the most susceptible species. The level of uncertainty of this assessment is medium.

The non-commercial and environmental consequences to natural environments in the PRA area are likely to be moderate. The level of uncertainty of this assessment is high.

6. ANSWER TO TERMS OF REFERENCE

All questions a-f in terms of reference have been addressed in the previous chapters of the risk assessment. This chapter is meant as an overview, principally repeating the main points of the risk assessment for each question.

a. The current status concerning the establishment and distribution of *Phytophthora ramorum* in Norway.

P. ramorum is present but not widely distributed in Norway, and the pest is under official control.

As shown in more details in section 4.1.2, *P. ramorum* has been detected in trade of nursery plants in the PRA area. Outside nurseries and garden centres *P. ramorum* has been found on host species in managed parks and gardens, especially along the south-west coast of Norway. Most findings outside nurseries have been on *Rhododendron* spp. Recently (September 2009), naturally infected blueberry (*Vaccinium myrtillus*) was detected in a semi-managed park at the south-west coast of Norway.

It should be mentioned that the outdoors surveys of *P. ramorum* in Norway have not been conducted systematically over the whole country. Some uncertainty therefore still remains regarding the current distribution of *P. ramorum* in the PRA area.

b. Future potential for establishment and distribution in Norway.

P. ramorum has still the potential to increase its host range and to become more widespread in Norway. There is also a potential for further entry of known or new lineage and/or mating types of the pathogen into the PRA area.

In the absence of statutory control there are high probabilities for *P. ramorum* to be spread quickly in the PRA area by trade of host plants for planting (see section 4.2.3 for more information). The uncertainty of this assessment is low. Planting of infected plants will bring the pathogen from the nurseries into the environment. Natural spread is likely to be slower due to the predominance in the pathogen of short-distance spread. In parts of the PRA area, where climate events are favourable and there is an abundance of continuous hosts, natural spread could be significantly more rapid.

At the present stage of knowledge about host susceptibility, epidemiology, and environmental requirements of *P. ramorum*, the endangered area is the most of the country of Norway, except where the climate is predicted to be unfavourable (figure 7, section 4.2.2.2). Host plants for *P. ramorum* are present in all areas where the climate is predicted to be favourable. However, this area must be regarded as a maximum estimate for the endangered area. On the other hand, a narrow and very conservative estimate for the endangered area can be defined based on the geographical distribution of highly susceptible host plants in Norway. This area is gardens and parks with *Rhododendron* spp., *Viburnum* spp., red oak, and *F. sylvatica*, and areas in the wild into which *Rhododendron* spp. has spread and woods with *F. sylvatica*. Woods with *F. sylvatica* is limited to the county of Vestfold and some small areas in the counties of Aust-Agder and Hordaland.

According to a simple simulation of a climate change (section 4.2.2.2), a temperature increase of +2 °C will increase the areas with favourable and very favourable climate, while the areas with unfavourable climate will shrink to the highest mountains and the northernmost inlands of Norway.

- c. Consequences of an establishment in Norway, including the potential for damage to cultivated and wild plants in Norway, and possible economic and environmental effects from an establishment in near and more distant future. Also, an appraisal of effects of an expected climate change on distribution and potential for damage should be included.**

P. ramorum causes a complexity of disease symptoms generally grouped into three categories: canker, foliage lesion, and dieback (see section 4.3.1). Leaves, shoots, and buds are affected on a wide range of host species. Most infected plants are weakened (reduced growth and reproduction, and more susceptible to other plant pests and to stress), and in worst cases the whole plant or whole plant communities dies.

Known and potential host species that could become affected in the PRA area are given in section 4.2.2.1. Direct and indirect effects *P. ramorum* infections are described in section 4.3.1.1 and 4.3.1.2.

P. ramorum is likely to have moderate economic impact on the nurseries in the PRA area with current phytosanitary measures. Without any such regulations *P. ramorum* is likely to have major economic impact on the nursery industry of the PRA area. The levels of uncertainties of these assessments are low.

With current phytosanitary measures *P. ramorum* is likely to have moderate economic impact on parks and private gardens in the best climatic zones of the PRA area. Without any such regulations *P. ramorum* is likely to have major economic impact in the best climatic zones of the PRA area. The levels of uncertainties of these assessments are low.

The impact of *P. ramorum* in coniferous and mixed forests of the PRA area is likely to be minor. The level of uncertainty of this assessment is medium.

The impact of *P. ramorum* in natural and planted deciduous broadleaf forests of the PRA area is likely to be minor due to the scattered and limited distribution of the most susceptible species. The level of uncertainty of this assessment is medium.

The non-commercial and environmental consequences to natural environments in the PRA area are likely to be moderate. The level of uncertainty of this assessment is high.

Results from running the CLIMEX “compare locations” method under a simple +2 °C climate scenario indicate that a temperature raise will increase the areas with favourable and very favourable climate. The areas with unfavourable climate will shrink to the highest mountains and the northernmost inland of Norway (compare figure 7 and 8, section 4.2.2.2).

- d. Probability for and consequences of a possible entry and establishment of mating type A2 in Norway.**

Probability for entry and establishment of mating type A2 in Norway:

The overall probability for entry of *P. ramorum* (both mating type A1 & A2) into the PRA area is listed in section 4.2.1. The probability is based upon identification of pathways, the probability of the pest being associated with the pathway at origin, the probability of survival and multiplying during transport or storage and the probability of transfer to a suitable host after arrival. All the listed terms relate to the entry of isolates of both European and non-European lineages of the pathogen. For all pathways there is also a potential for introduction of the A2 mating type, which regardless of lineage might sexually recombine with EU1 lineage isolates of the A1 mating type. The non-European isolates potentially represent a

higher risk due to their different genetic composition or adaptive fitness compared to the EU1 lineage isolates.

The A2 mating type is dominant among the North American isolates of *P. ramorum*. Only a few isolates of A2 mating type have so far been detected in Europe. The probability of entry of mating type A2 from Europe is therefore rated as low independent of current phytosanitary regulations. The uncertainty is moderate. The probability of entry of A2 mating type from USA, Canada and the pathogens unknown area/s of origin is rated as low with current phytosanitary regulations. Without phytosanitary regulations the probability for entry from those areas is rated as high. The uncertainty is low.

The overall probability of establishment of *P. ramorum* when first introduced is rated as high (section 4.2.4). It is assumed that the probability will be the same regardless of mating type. The overall assessment of establishment is based on the availability of hosts, the suitability of the environment in at least parts of the PRA area, the biological characteristics of the pest, and the effects of existing pest management practices. The significance and the uncertainty for each of these topics are addressed in the paragraphs (4.2.2.1 – 4.2.2.4).

Consequences of a possible entry and establishment of mating type A2 in Norway:

The coexistence of A1 and A2 at the same location suggests the potential for sexual recombination like in the case of *P. infestans*, where both clonal and sexual reproduction exists. Sexual reproduction in nature has not yet been documented in *P. ramorum*. In the laboratory oospores can be produced, but gemetangial formation is still unusually sparse, and it still remains unclear whether *P. ramorum* is truly A1/A2 outcrossing or whether its sexual breeding system is functional. If recombination (sexual or somatic) were to occur between the European and the American lineages, further additive allelic variation is likely to be generated and there is a risk that recombination could lead to the generation of further adaptive variation. The production of oospores (sexual formed resting spores) itself could favour establishment since, like chlamydospores, they are likely to facilitate longer-term survival.

e. Possible important pathways for introduction and further spread of *P. ramorum* in Norway, including relevant host plants for a possible future regulation of *P. ramorum* as a quarantine pest.

Possible pathways for entry:

P. ramorum is likely to enter the PRA area through one or more of eight different pathways: 1) Plants for planting of known host; 2) Plants for planting of non-host species accompanied by contaminated, attached growing media; 3) Soil/growing media (with organic matter) as a commodity; 4) Soil as a contaminant (e.g. on footwear, machinery, vehicles etc.); 5) Foliage and cut branches (for ornamental purposes) of foliar hosts; 6) Seeds and fruits of host plants 7) Bark from host plants 8) Wood from host plants. Read more about the different pathways in section 4.2.1.1.

Plants for planting represent the greatest potential for entry from countries where *P. ramorum* exists (EU, Switzerland, USA, Canada, and the pathogens unknown areas of origin). Most host plants imported to the PRA area have their origin in EU. Host plants for planting clearly represent a high probability of entry. Non-host plants for planting represent a lower probability, even though there is the potential for inoculum to be present in any accompanying growing media or even roots.

Possible pathways for further spread:

In the absence of statutory control there are high probabilities for *P. ramorum* to be spread quickly in the PRA area by trade of host plants for planting. The uncertainty of this assessment is low. Planting of infected plants will bring the pathogen from the nurseries into the environment. Natural spread is likely to be slower due to the predominance in the pathogen of short-distance spread. In parts of the PRA area, where climate events are favourable and there is an abundance of continuous hosts, natural spread could be significantly more rapid. Read more about spread in section 4.2.3.

Host lists:

P. ramorum has under natural conditions infected more than 130 species from over 75 plant genera representing over 37 plant families. The availability of host plants in Norway is discussed in section 4.2.2.1, and known host plants of *P. ramorum* that are common in Norway are listed in figure 10. The lists of hosts are believed to continuously increase as the knowledge about the pathogen increases:

- The species that are considered as natural hosts per October 2008 are listed in the PRA for EU (<http://rapra.csl.gov.uk/>), APPENDIX II. Species susceptibilities to *P. ramorum* as determined by experimental tests are shown in APPENDIX III (Sansford *et al.* 2009).
- Furthermore, an updated website with list of natural hosts of *P. ramorum* with symptoms and locations are available from Central Science Laboratory (CSL 2009):

<http://www.fera.defra.gov.uk/plants/plantHealth/documents/suscept.pdf>

This list was last updated 26.02.09. Four new natural hosts in Europe are included: *Ilex aquifolium*, *Lithocarpus glabra*, *Vaccinium myrtillus* and *Vaccinium vitis-idaea*, all findings located in UK. Those four are not mentioned in the Appendix II-list in the PRA for EU.

- From the USA, a list of regulated hosts is presented by United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA-APHIS 2008). In this list, plants that are naturally infected by *P. ramorum*, and have had Koch's postulate completed, documented, reviewed, and accepted, are presented:

http://www.aphis.usda.gov/plant_health/plant_pest_info/pram/downloads/pdf_files/usdaprlist.pdf

This list is frequently updated. The most current version is posted at: http://www.aphis.usda.gov/plant_health/plant_pest_info/pram/resources.shtml

f. Control effects of the current measures in nurseries, including the possibilities for preventing further spread in Norway by nursery plant trade, and the possibilities for eradication of *P. ramorum* on locations where it has been detected and possibly established in Norway.

These questions are discussed in detail in section 4.2.2.3 and 4.2.3 in the risk assessment, together with an overview of current phytosanitary measures that are used against *P. ramorum* in Norway.

Control effects of the current measures taken in nurseries and garden centres:

Up to date, there is a variable effect of the phytosanitary measures taken against *P. ramorum* both in nurseries and garden centres in the PRA area. The uncertainty of this assessment is medium to high due to lack of information. For more details, see section 4.2.2.3.

The possibilities for preventing further spread in Norway by nursery plant trade:

There are moderately high probabilities for *P. ramorum* to be contained within the PRA area, due to the pathogen's biological characteristics. The uncertainty of this assessment is low.

The possibilities for limiting further spread of *P. ramorum* in Norway by nursery plant trade will depend upon further containment measures and more intensive inspections both in trade and at the production sites to ensure supply of disease-free host plants to the trade. For more details, see section 4.2.3.

The possibilities for eradication of *P. ramorum* from places where it has been found and is likely to be established

The possibility to eradicate the disease in places where it is already present is considered as low with the current disease management practise, especially in parts of the PRA-area with climate favourable for the disease (along the south-west coast of Norway). To succeed with the eradication of *P. ramorum* from places where it is found, more restrictive eradication measures are required. For more details, see section 4.2.2.3.

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APPENDIX

About climex ‘compare locations’ analysis

CLIMEX is a method and a tool to predict the potential geographical distribution of organisms based on climate (Sutherst & Maywald 1985; Sutherst *et al.* 1999, 2007). The most important function of CLIMEX is the ‘compare locations’ function where CLIMEX calculates an ecoclimatic index (EI) which reflects the combined potential for population growth during favourable periods and persistence during stressful periods for the pathogen. The EI is scaled between 0 and 100, with an EI close to 0 indicating that the location is not favourable for the long-term survival of the species. EI values of 100 are only achievable under constant and ideal conditions comparable in incubators. Calculation of the EI depends on the climatic requirements/tolerances of a species and climatic conditions at a given site. Specifically, EI is calculated using:

$$EI = \left[\frac{100}{52} \sum_{w=1}^{52} (TI_w \times MI_w) \right] \times \left[\left(1 - \frac{CS}{100} \right) \left(1 - \frac{HS}{100} \right) \left(1 - \frac{DS}{100} \right) \left(1 - \frac{WS}{100} \right) \right]$$

where w is the week of the year; TI_w the temperature index for week w ; MI_w the moisture index for week w ; CS the annual cold stress, HS the annual heat stress, DS the annual drought stress, and WS the annual wet stress. Each stress index is calculated on a weekly basis and expressed as a sum over the year.

The growth index, which represents the suitability of the location for growth and development, is calculated according to how close temperatures, moistures and day lengths are to a pest’s known maxima, minima and optima. In the unfavourable periods, a stress index is estimated according to the degree to which the climate is too wet, dry, hot, or cold. The overall suitability of the location is represented by the ecoclimatic index (EI), formed by the product of these two indices.

One way to estimate responses to temperature, moisture and other factors could be by trial and error to try to reflect the known distribution of the pest, assuming that, in the centre of its range, the growth index will be at its maximum and the stress indices at minimum, while at the edges of its range, the opposite will occur. Another way is to obtain climatic responses by the organism by research or from readily available research results. Once CLIMEX has satisfactorily mirrored its current distribution, ecoclimatic indices can be calculated from meteorological data in the PRA area and mapped. Generally, great care must be taken in using CLIMEX, principally because climate is not the only factor that influences distribution.