Pest risk assessment of the Pine Wood Nematode (PWN) *Bursaphelenchus xylophilus* in Norway – Part 2

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Leif Sundheim
Bjørn Økland
Christer Magnusson
Birger Solberg
Trond Rafoss

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SUMMARY

Pine Wood Nematode (PWN, *Bursaphelenchus xylophilus*) is the causal agent of pine wilt disease (PWD). In 2007 PWN was widespread in USA, Canada, Japan and Taiwan, and had a more restricted distribution in Mexico, China, South-Korea and Portugal. Recently, PWN has become more widespread in Portugal and is no longer considered possible to eradicate in all sites of infection. Also, the nematode has been detected outside mainland Portugal with one incursion in Spain in 2008 and one on the island of Madeira in 2009.

The Norwegian Food Safety Authority (Mattilsynet) is concerned about the plant health risks and the consequences to the society if PWN should establish in Norway. The Norwegian Food Safety Authority needs a scientific assessment of the proposed measures in a contingency plan for PWN.

On this background The Norwegian Food Safety Authority requested a pest risk assessment of PWN from the Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM). Part 1 of the pest risk assessment (Initiation, Pest categorization and Assessment of probability of introduction and spread) was published by VKM in 2008. The current document is VKM's answer to Part 2 in the terms of reference (Assessment of potential economic consequences and assessment of the control effects of a preliminary contingency plan), and was adopted by VKM's Panel on Plant Health on a meeting 22 June 2010.

VKM's Panel 9 gives the following main conclusions of part 2 of the risk assessment: 1) Under the present climatic conditions, and if no control measures are taken, an introduction of PWN to the PRA area will not cause increased pine tree mortality. The uncertainty level of this assessment is low. 2) Assuming the IS92a climate change scenario for the period 2000-2049 (RegClim), which involves a ~2 ºC temperature increase by the end of the period, an introduction of PWN to the PRA area will, if no control measures are taken, cause a minor increase in pine tree mortality (300 trees per year on average) due to a higher sensitivity to expression of pine wilt disease in trees. The mortality can become larger if the temperature increase more than 2 ºC, and will gradually increase with time after 2049 due to spread of PWN. The uncertainty level of these assessments is medium to high. 3) Currently, effects of the presence of PWN in the PRA area on export of wood and wood products will be of little importance. The uncertainty level of this assessment is low. 4) It will be almost impossible to eradicate PWN once it has been introduced into the PRA area. The uncertainty level of this assessment is low. 5) The net present value of accumulated cost of a single eradication event as described in the preliminary contingency plan for the PRA area is approximately 700 million NOK. The net present value of accumulated cost of the contingency plan following one introduction event will be approximately 2000 million NOK for the initial 50 years. These costs are caused by reduced income from timber production and the expenses of eradication measures. The uncertainty level of these assessments is medium. 6) The negative effects of the control measures on the environment will be major. The uncertainty level of this assessment is low.

KEY WORDS

Bursaphelenchus xylophilus, contingency plan, control measures, economic consequences, Pest Risk Analysis (PRA), pest risk assessment, Pine Wilt Disease (PWD), Pine Wood Nematode (PWN)

CONTRIBUTORS

Persons working for the Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM), either as appointed members of the Committee or as *ad hoc*-experts, do this by virtue of their scientific expertise, and not as representatives for their employers. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

Acknowledgements

An *ad hoc*-group, consisting of both VKM members and external experts, was appointed by the Panel on Plant Health on 3rd September 2008. The *ad-hoc*-group has prepared a draft for final preparation by the panel. The members of the *ad hoc*-group are acknowledged for their valuable work with the pest risk assessment.

The members of the *ad hoc*-group are:

Leif Sundheim (chair), Panel on Plant Health

Christer Magnusson, Panel on Plant Health

Trond Rafoss, Panel on Plant Health

Bjørn Økland, Panel on Plant Health

Birger Solberg, Norwegian University of Life Sciences, Ås, Norway

The pest risk assessment is largely based on the results obtained by Økland *et al.* (2010a) and Bergseng *et al.* (manuscript), who are acknowledged for their valuable work and for providing their results to the *ad hoc*-group in a continuous dialogue. Even Bergseng and Terje Gobakken, both from the Norwegian University of Life Sciences, have participated and contributed to the discussion in two *ad hoc*-group meetings.

Assessed by

Panel on Plant Health (Panel 9):

Before April 2010: Leif Sundheim (chair), May Bente Brurberg, Trond Hofsvang, Christer Magnusson, Trond Rafoss, Brita Toppe, Anne Marte Tronsmo, and Bjørn Økland.

After April 2010: Leif Sundheim (chair), Trond Hofsvang, Christer Magnusson, Trond Rafoss, Arild Sletten, Halvor Solheim, Brita Toppe, Anne Marte Tronsmo and Bjørn Økland.

Scientific coordinator from the secretariat: Elin Thingnæs Lid (before March 2010) and Åshild Ergon (from March 2010)

CONTENTS

1. BACKGROUND

Pine Wood Nematode (PWN, *Bursaphelenchus xylophilus*) is the casual agent of pine wilt disease (PWD). In 2007 PWN was widespread in USA, Canada, Japan and Taiwan, but had a more restricted distribution in Mexico, China, South-Korea and Portugal (EPPO 2007). Recently, PWN has become more widespread in Portugal and is no longer considered possible to eradicate at all sites of infection (EC 2008). Also, the nematode has been detected outside mainland Portugal with one incursion in Spain in 2008 (EPPO 2010) and one on the island of Madeira in 2009 (EC 2010). The pest is not known to exist in the PRA area, Norway. The Norwegian Food Safety Authority (Mattilsynet), in a letter of 21st February 2008, requested a pest risk assessment of PWN from the Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM). Part 1 of the pest risk assessment (Initiation, Pest categorization and Assessment of probability of introduction and spread) was published by VKM on the 26th September 2008 (VKM 2008). The present document is VKM's reply to Part 2 in terms of reference (Assessment of potential economic consequences and Assessment of the control effects of a preliminary contingency plan), and was adopted by VKM's Panel on Plant Health on a meeting 22 June 2010).

The present document is part of a Pest Risk Assessment, and is not a complete Pest Risk Analysis (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 pest risk assessment of PWN (*B. xylophilus*), 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:

Part 1

a. The probability of introduction (entry and establishment) and spread of PWN through import of different types of plants and wood products under the current Norwegian phytosanitary regulations.

b. How will a possible change in the regulations, to allow import of conifer plants and plant parts, and untreated conifer timber and wood products from Pest Free Areas (PFAs) in Portugal, affect the probability for introduction of the pest?

Part 2

a. Which consequences in forest production and economy might a possible future introduction and spread of PWN have if no control measures are imposed? What might be the effects of expected climatic changes during the next 10, 30, 60 and 80 years on the pest, provided that no control measures are imposed?

b. Following a possible introduction of PWN into Norwegian landscapes, what control effects will the measures in the preliminary Contingency Plan, chapter 6.2, have, provided that control is implemented according to the Plan? What is the probability for eradication of the pest by the proposed measures? What will be the economic consequences of the control measures?

The Norwegian Food Safety Authority (Mattilsynet) might raise additional questions later, including environmental and social consequences of a possible future establishment and spread of PWN.

3. INITIATION

The current PRA was initiated by the Norwegian Food Safety Authority as a basis for a review and possible revision of its policy. The PRA area is Norway. The initiation of the PRA is described in section 3.1 of part 1 (VKM 2008).

3.1 Information

The PRA (part 2) is largely based on two recent scientific publications produced by members of the *ad hoc*-group and colleagues. These are 1) an evaluation of current contingency plans for PWN (Økland *et al*. 2010a) and 2) a report on economic consequences of a potential introduction of PWN including implementation of the contingency plan (Bergseng *et al*. manuscript).

Since the publication of part 1 of this PRA, EPPO has conducted a PRA for PWN in Europe (EPPO 2009). The present pest risk assessment is complementary to EPPOs PRA by specifically considering:

- The economic consequences of PWN in the PRA area, including the assumption of a climate change scenario,
- The probability of the pest to survive eradication programmes in the PRA area (Norway).
- The consequences of implementing the proposed contingency plan.

The PRA is made according to the international standard ISPM No. 11 (FAO 2004).

4. PEST RISK ASSESSMENT

Part 1 of the PRA, published in 2008, contains “Pest categorization” and “Assessment of probability of introduction and spread” (VKM 2008). Part 1 also assesses the probability of introduction and spread of PWN from untreated timber and wood of conifers originating from PFAs (Pest Free Areas) in Portugal.

4.1 Assessment of pest survival under eradication programmes

Most questions about establishment and spread in the PRA area specified in ISPM 11 have been answered in the part 1 of the PRA (VKM 2008). The present document answers one question that was left for part 2 (see point b of part 2 under terms of reference):

What is the probability for eradication of the pest by the proposed measures?

4.1.1 Biological characteristics of relevance

A model (ForestETP-model) has been developed by the EU-funded PHRAME project to predict plant host physiological behaviour and mortality following PWN infestation in Europe (Evans *et al*. 2008). Initial results suggested that there is a good agreement between predictions made by the model and the actual mortality of pine trees (PWD) in the infested areas of Portugal. Application of the ForestETP-model in Sweden under current climatic conditions showed that the probability of PWD development in infested trees is small and restricted to limited incidences of PWD in years when summer temperatures are higher than normal in Southern Sweden (Jordbruksverket 2008). A characteristic observed in many biological invasions is that there is typically a period of time from the arrival of a non-indigenous species until the population has become sufficiently large to be detected. Even when an invasive species creates visible symptoms, there may be a significant time lag from arrival until detection. For example, Liebhold and Tobin (2006) reported a delay of approximately 12 years from the initial accidental introduction of the gypsy moth in North America until populations reached a detectable level. For the detection of *Dendroctonus micans* in UK, the delay was at least nine years (King and Fielding 1989, Gilbert *et al*. 2003). Since there is a very low probability that the first spreading individuals of the PWN cause visible symptoms of PWD, the detection of a new PWN infestation must rely on surveys.

4.1.2 Description of the current regular survey programme

Regular PWN surveys were started in the Nordic countries in 2000, the year after the first detection in Portugal (1999), and have continued up to date. In Norway the regular survey is based on the EC Pinewood Nematode Survey Protocol 2000 (FVO 2000) and the document Nordic Pine Wood Nematode Survey, Draft Manual 2000-02-11 by Magnusson *et al*. (2000). The sampling is not dependent on visible symptoms of pine wilt disease, but is focussed on wood items with signs of *Monochamus* activity. Each sample requires extraction of nematodes and nematode identification by microscopy and often PCR-methods to verify the presence or absence of PWN. The sampling is stratified to risk areas, which are defined as circular areas with a 50 km radius around points with high risk of introductions (e.g. ports of entry). Within each risk area, most samples are taken from selected types of logging waste in felling sites, which is the most important breeding habitat of *Monochamus* species in Scandinavia. From logging waste, samples are taken selectively from tops and thick branches (> 5 cm diameter) with signs of *Monochamus* activity (e.g. exit holes, galleries or typical wood shavings). In the period 2000-2006 the Norwegian PWN survey included 3165 samples obtained from ten risk areas (Magnusson *et al*. 2007). This level of about 450 samples per year represents about 0.02 % of the estimated number of suitable objects with *Monochamus* marks in the total sampling area of the survey.

4.1.3 Description of the preliminary contingency plan

The draft contingency plan for the PRA area prescribes complete logging and destruction of all host conifer trees within a circle of 3 km around each point of PWN detection (Mattilsynet 2007). As the dominant tree species in Norway, spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*), both are preferred hosts of the potential vectors for PWN in Norway (*Monochamus sutor* and *M. galloprovincialis*), logging and destruction of all host conifers around an infestation point usually implies a continuous clear-cut area. The operations of logging and destructions must be completed before the start of the next flight season of the vector beetles (May/June). Since partly burnt wood is a very attractive breeding habitat for *M. sutor* (Forsslund 1934), destruction of trees by burning must be complete. According to statistics of the National Forest Inventory of Norway (Larsson *et al*. 2007), a circular area of 3 km radius in the forest of SE Norway contains on an average about 2.7 million coniferous trees. Around the clear-cut zone, the draft contingency plan prescribes an observation zone 17 km wide for intensive monitoring (3000 samples in total, analysed within the shortest possible time) and pre-emptive measures. If additional infestations are found, new areas of logging (radius 3 km) and observation zones (17 km) are to be established around the new infestation points (Mattilsynet 2007).

4.1.4 Probability of the pest surviving eradication programmes

A simulation model was applied to evaluate the probability of successful eradication of a hypothetical introduction by the current contingency plan in the PRA area by Økland *et al*. (2010a). In this model, it was assumed that import of one PWN infested object leads to PWN-infection of dead wood objects utilized by the local *Monochamus* populations in the lowlands of South-Eastern Norway (*M. sutor* and/or *M. galloprovincialis*), which in turn starts a spread of PWN to an increasing proportion of the existing *Monochamus* population and its habitat objects. The parameters were in a most realistic way based on empirical data and experiments using the best available information for potential *Monochamus* vectors in combination with biological and climatic information from Scandinavian forest systems. The current survey program was used for detection of PWN in the model script, while the current contingency plan was implemented for eradication of detected infestations. Repeated simulations were used to estimate the probability of successful eradication by the contingency plan. The results showed the probability of successful eradication to be consistently low (mean 3.5%) (Økland *et al*. 2010a). The poor success did not change significantly by varying the biological parameters in sensitivity analyses. Delayed detection seemed to be a major factor for the low success of eradication. The average time until detection was 14 years. The parameters of the survey program and the contingency plan were changed to search for improvements that could lead to more efficient eradication. Increasing the width of the observation zone had a negative impact on the eradication success, due to a lower sampling density as a result of the larger zone area. Increasing the area of tree removal, did not give an eradication success exceeding 60%, even for very large areas (radius > 12 km). Increasing the number of samples to 60 000 samples per year resulted in a 95% eradication success. Even when both the number of survey samples and the area of tree removal were increased simultaneously, a 99% probability of successful eradication demanded unrealistically high levels of survey sampling (10 000 samples per year) and forest clearing (radius of 8 km, equivalent to 201 km^2).

4.1.5 Conclusion of the assessment of pest survival under eradication programmes

It will be almost impossible to eradicate the pest once it has been introduced into the PRA area, mainly due to the low probability of detection. It is very likely that the pest could survive the eradication programmes in the PRA area. It is unlikely that a high success of eradication can be achieved by adjusting the parameters involved in the survey program and the draft contingency plan. The uncertainty level of these assessments is low.

4.2 Assessment of potential economic consequences

4.2.1 Negative effects of PWN in its current area of distribution

The principal damage caused by PWN is the wilting of infested and susceptible trees (Pine Wilt Disease - PWD). Information on PWN, PWD, the vectors (*Monochamus* spp.), and the conifer host species, are found in sections 4.1.1.5, 4.1.4 and 4.2.2.1 of part 1 of the PRA. Damage such as partial mortality of the tree crown and die-back of single branches and reduced growth rate are difficult to estimate. PWN is considered to be indigenous to North-America, where most domestic conifers are tolerant or resistant to the disease. In countries where it has been introduced and where the climate is conducive for PWD, PWN has caused considerable damage. Large resources are spent every year on its control. Annual losses in Japan are approximately 1 million m^3 of timber (Mamiya 2004). In Portugal almost 24 million € were spent in 2001-2009 on control measures (EPPO 2009).

4.2.2 Negative effects of an introduction of PWN on forest production if no control measures are taken

Bergseng *et al.* (manuscript) has combined the ForestETP-model (see 4.1.1) with the model for initial spread of PWN in South-Eastern Norway developed by Økland *et al.* (2010a) to predict potential forest mortality due to PWD in South-Eastern Norway. The models assume natural spread from a single introduction and no human-mediated spread. According to the model results, when no control measures are taken, the number of infestations will increase exponentially with time. Under the present climatic conditions, however, PWN will cause very low mortality in the PRA area. With the expected increase in temperature due to global warming the mortality rates caused by development of PWD could potentially increase. Assuming a global warming, the model estimations were based on the climate change scenario IS92a developed by RegClim (http://noserc.met.no/effect), using a fairly warm place in South-Eastern Norway (Blindern/Oslo, 59°56'N 28 10°43'E) for the whole scenario period (2000-2049). With this scenario, which corresponds to a temperature increase of ~2°C from 2000 to 2049, Bergseng *et al*. (manuscript) predicted a low mortality (mean 300 trees per year and introduction event the PRA area). Even though the spreading model underlying this estimate was based on best available information, deviations in the assumptions about the biological parameters and the influence of a warmer climate on the spreading process could lead to different estimates of infestation and mortality rates of trees. However, such deviations are expected to be about the same in the analyses with and without control measures. While the result of the model is not expected to give exact estimates of future tree mortality due to PWN, the estimates can still be useful for comparing the outcome with and without control measures. While it was asked for effects up to 80 years in future (see 2a in Chapter 2), the estimation was limited to the period up to 2049 by the length of the temperature scenario (see above) and the computational memory capacity when running the individual-based spreading model with exponential growth over long time series.

The ForestETP-model has also been used to simulate the mortality of trees following an infestation with PWN in Sweden (Jordbruksverket 2008). In this report the estimated percentages of PWD are given for trees that have already been infested by PWN. It was concluded that in the current climate of Sweden trees might occasionally be killed by PWD during hot summers. With the predicted climatic conditions in Southern Sweden at the end of the century, the mortality (PWD) of already infested trees might be comparable to European areas where a mortality of infested trees is predicted to be 24-40 % under the present climate (Jordbruksverket 2008). While Jordbruksverket (2008) refers to the speed of the “frontier” of PWD spread in Japanese studies, estimates of the percent of infested trees per area during spread conditions are lacking. Instead of giving any estimate of tree mortality of all pines in the area, the Swedish study estimates the cost due to PWD assuming different mortality rates of pines ranging from 1 – 100 % (see figure 16 in Jordbruksverket 2008).

Mortality of PWN-infested trees is strongly dependent on summer temperatures and to some extent on water availability. Predictions of mortality in the future are therefore complicated by the uncertainty in predicting the future climate. The mortality rate of pines on an area basis is likely to increase with time as long as summer temperatures are rising and also due to spread of PWN within the PRA area. If PWN becomes more widespread in Europe and/or if import of material potentially infested by PWN increases, the number of entries are likely to increase, as is the potential damage from PWD. Human-mediated dispersal plays a fundamental role in the spread of PWN in China (Robinet *et al*. 2009) and could also facilitate spread within the PRA area.

4.2.3 Economic consequences of an introduction of PWN if no control measures are taken

Using the estimates from the ForestETP-model (Jordbruksverket 2008) and meteorological data, Bergseng *et al*. (manuscript) estimated a mortality rate of infested trees close to 0 %, and consequently no costs under the present climatic conditions in South-Eastern Norway. Assuming a climate change scenario IS92a (http://noserc.met.no/effect) in the period 2000-2049, no human-mediated dispersal, and no control measures upon an introduction of PWN, they estimated a low tree mortality and an accumulated direct cost (the monetary value of the lost trees) of only between 80 000 (at 4 % interest rate) and 160 000 NOK (at 2 % interest rate) per introduction event over the whole period up to 2049. Deviations in the assumptions can lead to different estimates of infestation and mortality rates of trees, as described under 4.2.1.2, which also could change the cost estimates given here.

The economic estimates of the cost resulting from natural spread from a single introduction of PWN without control measures in Sweden are uncertain and presented for mortality rates of pines ranging from 1 to 100% and for speed of frontier spread ranging from 3 to 10 km per year. The cost is below 50 million SEK with 1% mortality and a frontier speed of 3 km per year, while in a worst case scenario of 100% mortality and frontier speed of 10 km per year, the cost is 14 500 million SEK (figure 16 in Jordbruksverket 2008).

4.2.4 Economic costs of control measures

Bergseng *et al*. (manuscript) developed an economic evaluation model to estimate the cost of establishing eradication and observation zones around infested trees according to the preliminary contingency plan (Mattilsynet 2007) in South-Eastern Norway. The accumulated cost of different cost factors per hectare over a 50 year period is given in Table 1. The net present value of the accumulated cost of one eradication measure as described in section 4.1.3 was estimated to be around 700 million NOK (Table 2), assuming that all harvested wood at the initial harvest would be disposed by burning. The net present value of the accumulated costs of the preliminary contingency plan following one introduction event was estimated to be 2700, 2200 and 1700 million NOK for interest rates of 2, 3 and 4%, respectively. The cost estimates are based on the average land use class distribution in the region and the corresponding tree density. The costs of eradication will depend on the continuity of the forest cover and urbanization. The costs will probably be lower in in open landscapes than in dense forests. The cost estimates were based on the present climatic conditions and serve as a low estimate of the costs under the expected climatic change. Even though there are considerable uncertainties regarding many of the factors in the analysis, particularly the cost of burning, the economic cost is very high.

Table 1. Approximate costs of establishing eradication and observation zones around infested trees expressed as net present value at time of contingency implementation on an area basis. From Bergseng *et al*. (manuscript).

Zone	Cost factor	Approximate cost (NOK/ha at 2-4 % interest rate)
Eradication zone	Land expectation value loss	~500 – 1 000
	Stocking value loss	~8 100 – 10 500
	Harvesting cost	~8 000
	Costs for treating stumps with pesticide	~3 000
	Clearing host trees for 50 years	~6 200 – 7 400
	Disposal of wood	~7 000
	Sum for eradication zone	**~32 700 – 36 900**
Observation zone	Forest value loss	~4 500 – 5 200
	Survey costs	~0
	Sum for observation zone	**~4 500 – 5 200**

Table 2. The approximate total cost of one eradication measure expressed as the net present value at the time of contingency implementation. From Bergseng *et al*. (manuscript).

Zone	Approximate cost (million NOK at 2-4 % interest rate)
Eradication zone (radius 3 km = 2827.4 ha)	~90 – 100
Observation zone (radius 17 km = 122836.3 ha)	~550 -650
Total cost for one action	**~660 – 750**

Eriksson *et al*. (2008) analyzed the cost of two different control strategies: an eradication strategy and a containment strategy. The eradication strategy involves the destruction of all host trees at the site of infection and 3 km around it (host-free zone), and in addition a 10 km wide observation zone outside the host-free zone. Assuming that the host-free zone is 16 km in diameter and must be maintained for 20 years, that the interest rate is 2.5 % and that 50 % of the harvested wood is burned and the rest is chipped and used as biomass for bioenergy, they estimated the net accumulated cost of one eradication measure to be between 301 and 1390 million SEK, depending on region and share of forest land. Thus the cost estimates conducted by Bergseng *et al* (manuscript) and Eriksson *et al*. (2008) fall in the same range. Eriksson *et al*. (2008) also estimated the cost of an alternative containment strategy. The containment strategy was more costly than the eradication strategy when the infested area was small, but less expensive when the infested area was large, the turning point being an eradication zone of 34 km in diameter.

4.2.6 Consequences of the pest and control measures on the environment

Both pine mortality due to PWD and the eradication zones of the contingency plan are expected to have significant environmental consequences. The environmental consequences of the contingency plan are expected to be large-scaled, while the environmental consequences due to PWD will depend on the scale and severity of tree mortality. Ecosystem effects due to tree mortality caused by forest insect pests have been studied in various parts of the world; however, the literature on ecosystem effects is limited. Some of the effects have been reviewed by Gandhi and Herms (2010) and Økland *et al*. (2010b). Extensive tree mortality over large areas will have impact on forest structure and species composition, understorey vegetation, hydrological and nutrient regimes, and animal biodiversity. According to Gandhi and Herms (2010), large-scaled tree mortality caused by alien insect herbivores alters the dynamics of canopy gaps, coarse woody debris, biogeochemical cycling, and ecological interactions among organisms in terrestrial and aquatic systems, with consequent effects on forest composition, structure, and function. According to Økland *et al*. (2010b), extended areas of tree mortality may experience increased erosion due to reduced forest cover. The effect may be more extensive in areas with reduction of tree density, canopy cover and changes in tree-species composition and tree-species dominance in favour of non-host tree species and more dead wood. There may be extensive changes in community structures of vegetation, invertebrates, usually with declining abundance of species depending on living trees and increasing abundance of species that benefit from more dead wood and open habitats (Økland *et al*. 2010b).

Bergseng *et al*. (manuscript) estimated that if the preliminary contingency plan were carried out, the accumulated area of eradication zones 50 years after a single entry of PWN would be approximately 900 km^2. Environmental costs due to control measures like those outlined in the preliminary contingency plan are likely to be large. The control measures include a complete clearing of conifers in large areas over minimum 20 years, and this will dramatically alter the ecosystem in that area (as described above) as well as increasing the likelihood of erosion. The consequences will be particularly serious if the pest establishes in an area of conserved virgin forest. Clear-cutting of such areas could potentially cause the extinction of rare species. The control measures of the preliminary contingency plan will also most likely have large negative effects on the value of recreational areas. Large clear-cuts and obvious traces from forest operations are little appreciated by the public in Scandinavia (Gundersen and Frivold 2008). A large proportion of the forests area is relatively close to urban and populated areas. Thus, it is likely that control measures would involve trees in gardens, parks and recreational areas of value to the general public. In addition, the burning of large quantities of wood will produce smoke and dust that can have negative effects on the health of humans and animals. Burning of wood will also release greenhouse gases.

4.2.7 Consequences of the pest on export markets

If PWN is found to be present in the PRA area, this will have consequences for export of conifer wood-based products to pest-free areas of the world, since PWN is classified as a quarantine pest for many countries. Relevant products are firewood and roundwood. Other forest industry products are sufficiently heat-treated to meet the international standard to prevent spread of quarantine diseases (ISPM No. 15, FAO 2002). The current export of firewood and roundwood from the PRA area is modest and in all cases less than the import of these commodities (Statistics Norway 2010). At present it should thus be possible to find domestic markets for these products. Future changes in the wood markets might change the export patterns.

Large-scaled control measures could also have negative effects on local forestry and business related to the forest areas treated by the control measures.

4.2.8 Endangered area

PWN can establish in all forested parts of the PRA area, but is more likely to do so in the South-Eastern parts where its potential vectors are more abundant. PWD is also likely to develop more rapidly in the South-Eastern parts of the PRA, where summer temperatures are highest. The costs will be largest in areas of South-Eastern Norway that have a high share of forest land, e.g. the counties Hedmark, Oppland and Buskerud. Negative effects of control measures on the environment will be largest in areas of South-Eastern Norway with conserved virgin forests.

4.2.9 Conclusion of the assessment of economic consequences

If PWN was introduced to the PRA area and no control measures were taken, it would not, under the present climatic conditions, cause PWD and therefore not result in increased pine tree mortality, economic costs or negative effects on the environment. The current export of firewood and roundwood from the PRA area is minor and negative effects on this export are therefore not expected to be important. The uncertainty level of these assessments is low.

Due to global warming an increase in summer temperatures in the PRA area is expected. Under the IS92a climate change scenario for the period 2000-2049, the effects of a single introduction of PWN will be minor, if no control measures are taken (approximately 300 dead trees per year on average and a total cost of approximately 100 000 NOK over the whole period). The negative effects will be larger if summer temperatures increase more than predicted in the IS92a scenario, and will gradually increase with time due to spread of the PWN infection within the PRA. The uncertainty level of these assessments is medium to high. The highest uncertainties are associated with future summer temperatures, the natural dispersal rates of PWN, and the role of human-mediated dispersal of infested wood.

A conservative estimate of the cost of one eradication event as described in the preliminary contingency plan for the PRA area is approximately 700 million NOK. Due to expected spread of the PWN the total cost of one introduction event will be approximately 2000 million NOK over a 50 year period. The uncertainty level of these assessments is medium. Uncertainties are associated with the rate of spread and the cost of destruction of wood by burning.

The negative effects of the control measures on the environment will be major. The uncertainty level of this assessment is low. The negative effects of the control measures will increase with time due to a gradually increasing spread of PWN.

5. CONCLUSION

- Under the present climatic conditions, and if no control measures are taken, an introduction of PWN to the PRA area will not cause increased pine tree mortality. The uncertainty level of this assessment is low.
- Under the RegClim IS92a climate change scenario for the period 2000-2049, an introduction of PWN to the PRA area will, if no control measures are taken, cause a minor increase in pine tree mortality, at least up to 2049 (300 trees per year on average). The mortality can become larger if the temperature increase more than predicted, and will gradually increase with time after 2049 due to spread of PWN. The uncertainty level of this assessment is medium to high.
- At present the effects of the presence of PWN on export of wood and wood products will be of little importance. The uncertainty level of this assessment is low.
- The environmental effects of an introduction of PWN to the PRA area are, under the present climatic conditions, expected to be very low when no control measures are taken. The uncertainty level of this assessment is low. Under the IS92a climate change scenario for the period 2000-2049, an introduction of PWN to the PRA area will, if no control measures are taken, cause only minor environmental effects. The uncertainty level of this assessment is medium to high.
- It will be almost impossible to eradicate PWN once it has been introduced to the PRA area. The uncertainty level of this assessment is low.
- The net present value of accumulated costs of a single eradication event as described in the preliminary contingency plan for the PRA area is approximately 700 million NOK. Due to expected spread, the net present value of accumulated costs of eradication attempts following one introduction event will be approximately 2000 million NOK for the first 50 years. These costs are caused by reduced income from timber production and the expenses of eradication measures. The uncertainty levels of these assessments are medium.
- The negative effects of the control measures on the environment will be major. The uncertainty level of this assessment is low.

6. ANSWERS TO TERMS OF REFERENCE

All the aspects that The Norwegian Food Safety Authority requested to be assessed in part 2 (see chapter 2 – 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 aspect or question.

a. Which consequences in forest production and economy might a possible future introduction and spread of PWN have if no control measures are imposed? What might be the effects of expected climatic changes during the next 10, 30, 60 and 80 years on the pest, provided that no control measures are imposed?

Under the present climatic conditions PWN will not cause the development of PWD. If PWN was introduced and spread in the PRA area and no control measures were taken, there would be no significant effects on tree mortality and economic costs due to tree mortality. Wood export from the PRA area is minor, and any negative effects that may arise would not be important. The uncertainty level of these assessments is low.

Due to global warming an increase in summer temperatures in the PRA area is expected. Using the climate change scenario IS92a developed by RegClim in its full length (2001-2049), the effects of a single introduction of PWN will still be minor for at least up to the middle of the century, if no control measures are taken (about 300 dead trees per year on average and a total cost of approximately 100 000 NOK over the whole period). The negative effects can become more significant if summer temperatures increase more than expected, and will gradually increase with time due to nematode spread within the PRA and a continuous increase in temperatures. The uncertainty level of these assessments is medium to high. Uncertainties are associated with summer temperatures in the future, the natural spreading rates of PWN, and the role of human-mediated dispersal of infested material.

b. Following a possible introduction of PWN into Norwegian landscapes, what control effects will the measures in the preliminary Contingency Plan, chapter 6.2, have, provided that control is implemented according to the Plan? What is the probability for eradication of the pest by the proposed measures? What will be the economic consequences of the control measures?

It will be almost impossible to eradicate the pest once it has been introduced into the PRA area, mainly due to the low probability of detection. The uncertainty level of this assessment is low. The probability of eradication by the proposed measures is below 5 %.

The cost of one eradication event as described in the preliminary contingency plan for the PRA area will be approximately 700 million NOK in total over a 50 year period. Due to expected spread the total cost of one introduction event will be approximately 2000 million NOK over a 50 year period. The uncertainty level of these assessments is medium. Uncertainties are associated with the rate of spread and the cost of destruction of wood by burning. The cost of the control measures will increase with time due to a gradually increasing spread.

7. CONSIDERATIONS FOR FUTURE RESEARCH AND ASSESSMENTS

The study of consequences of a PWN introduction and the preliminary contingency plan (Bergseng *et al*. manuscript) is limited to one climate change scenario (IS92a by RegClim). Performing sensitivity analyses of the climate assumptions in the model could have illustrated the uncertainty that was stated for the effects under a climate change in our assessment (medium to high).

Further research and assessments should be focused on management options that have the highest probability of success. The probability of successful containment of the pest as mentioned by Jordbruksverket (2008) was not tested by simulation. It is assumed that the probability of successful containment is low due to delayed detection, in the same way as demonstrated for the eradication approach in the contingency plan (Økland *et al*. 2010a).

If eradication and containment should not be possible, the following options may be important to reduce damage and cost due to PWN in the PRA area:

- Import control: Investments in strategies that can prevent the entry of the pest in the PRA area.
- Slowing of spread: There are control measures that probably could slow the spread of PWN should it be introduced in the PRA area. This could reduce damage and costs. Evaluations of the efficiency of such measures and calculation of the benefit by slowing the spread of the pest is beyond the question in the terms of reference, but may be relevant for further research and development.

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