Pest Risk Analysis for *Dendrolimus pini*

Updated and revised document prepared by Professor Hugh Evans, Fellow of Forest Research incorporating text from the original PRA drafted by Dr Roger Moore and Dr Hugh Evans of Forest Research.

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(edited following comments from colleagues in FC and Defra)

Stage 1: Initiation

1.01 - Give the reason for performing the PRA

Following the first findings in Scotland, the pine lappet moth has been found in another area. Concerns raised by this new information, have led to the PRA being revisited, to help guide policy decisions for both forestry and wider plant health in the UK.

1.02a - Name of the pest

Dendrolimus pini (Linnaeus), Pine-tree lappet, Pine lappet moth
There are numerous sub-species including:
Dendrolimus pini adriatica Dabniel, 1959
Dendrolimus pini atlantica Le Cerf, 1932
Dendrolimus pini cedarensis Daniel, 1939
Dendrolimus pini colchis de Freina, 1983
Dendrolimus pini corsaria Schawerda 1926
Dendrolimus pini iberica Schawerda, 1926
Dendrolimus pini paulae Daniel 1959
Dendrolimus pini witti de Freina, 1979
(from http://eol.org/pages/382214/names)

1.02b - Indicate the type of the pest

Arthropod

1.02d - Indicate the taxonomic position

Insecta: Lepidoptera: Lasiocampidae

1.03 - Clearly define the PRA area

UK, including Northern Ireland and the Channel Islands

1.04 - Does a relevant earlier PRA exist?

Yes

A PRA was prepared in April 2009 and updated in September and October 2009. The current PRA is to provide a further update in relation to experience in the UK and elsewhere since the earlier PRA was prepared.

1.05 - Is the earlier PRA still entirely valid, or only partly valid (out of date, applied in different circumstances, for a similar but distinct pest, for another area with similar conditions)? Explain your judgement (edit in the part justification)

Not entirely valid

There has been considerable survey activity and consideration of management options in the period since the last modification of the earlier PRA in October 2009. This justifies a further examination of the conclusions from that PRA.

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

Mainly *Pinus* species. The primary host is Scots pine (*Pinus sylvestris*). *D. pini* may also represent a risk to Lodgepole pine (*Pinus contorta* var. *latifolia*) and Corsican pine (*Pinus ni*gra subsp. Laricio) in the UK. There are also records on other conifers including fir (*Abies* spp.), cedar (*Cedrus* spp.), juniper (*Juniperus*), spruce (*Picea*), Douglas fir (*Pseudotsuga menziesii*) and larch (*Larix* spp.).

1.07 - Specify the pest distribution for a pest initiated PRA, or the distribution of the pests identified in 2b for pathway initiated PRA

Dendrolimus pini is widely distributed throughout Europe and Asia and even recorded in North Africa (see Table 1 below).

Table 1. Distribution data for *Dendrolimus pini* (pine-tree lappet), based on data from CABI Crop Protection Compendium (http://www.cabi.org/cpc/).

Country	Distribution	References
ASIA		
China	Present	
AFRICA		
Morocco	Present	EPPO, 2014
EUROPE		
Austria	Unconfirmed record	
Belarus	Unconfirmed record	CAB Abstracts
Belgium	Common and local, higher in south.	http://uahost.uantwerpen.be/vve/checklists/lepidoptera/lasiocampidae/Dpini.htm
Croatia	Restricted distribution	EPPO, 2014
Czechoslovakia (former)	Unconfirmed record	
Denmark	Present	EPPO, 2014
Finland	Unconfirmed record	
France	Present, widespread except north	http://www.lepinet.fr/especes/nation/carte.php?e=l&id=31590
Germany	Present	
Hungary	Present	CAB Abstracts
Italy	Present	
Lithuania	Present	Sierpinska, 1998
Netherlands	Quite rare with fragmented distribution in areas with sandy soils	http://www.vlindernet.nl/vlindersoort.php?vlinderid=51
Norway	Early record, present distribution uncertain	Hopkins, 1908
Poland	Present	CAB Abstracts
Russian Federation (European part)	Present	Mozolevskaya et al., 2003
Sweden	Present	CAB Abstracts
Switzerland	Unconfirmed record	
UK	Restricted distribution	EPPO, 2014
-Scotland	Restricted distribution	EPPO, 2014
Ukraine	Present	Meshkova, 2003

Following discovery of breeding populations in Scotland in 2009, extensive surveys have delineated an infested zone in North-East Scotland which reflects the current known distribution of the pest. The current distribution is shown in Figure 1.

An extension to the known distribution was reported in 2015, with larvae being found in Glen Strathfarrar, approximately 25 km from the original Kiltarlity site. This suggests an expansion of range, although given that this was the first time this area had been surveyed, it is possible this breeding population was already in situ, rather than spread from the previously known area. There also remains a possibility that the findings are of an overlooked native species, as this part of Scotland is not generally a well recorded area in terms of moths, and there may be some difficulties distinguishing between the pine lappet moth and other very large caterpillars. This is, however, considered less likely, as although, not recently, surveys for pine beauty moth and pine looper moth

were carried out in Scotland for many years, and given that Strathfarrar pinewood is a SSSI the moth is more likely to have been spotted by Scottish Natural Heritiage surveyors and light traps here than in other more remote areas.

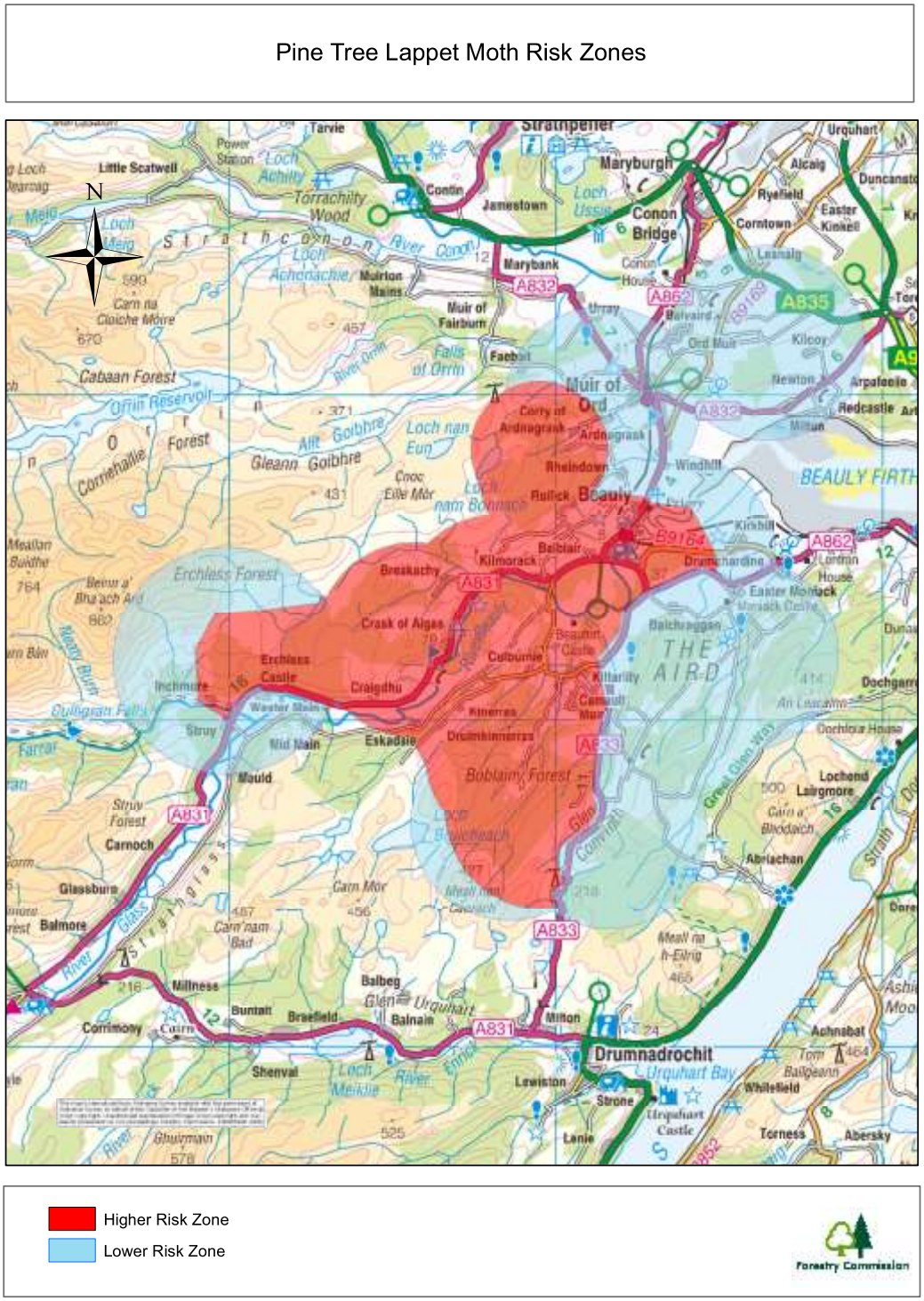


Figure 1: Distribution and risk zones for *Dendrolimus pini* in Scotland

Stage 2: Pest Risk Assessment Section A: Pest categorization

Background to the pest biology and damage potential

Dendrolimus pini is known to cause heavy and sometimes total defoliation, dieback and death of pine trees in parts of Europe and especially in Poland (Sierpinska, 1998) and Germany (Le Mellec and Michalzik, 2008). However, elsewhere in Europe outbreaks are rare or unreported. The moth is a continental European pest that is also recorded in the western part of Asia as well as Ukraine (Meshkova, 2003), Russia (Mozolevskaya et al., 2003) and North Africa. Consequently, it is adapted to a fairly wide range of ecoclimatic conditions. Its main outbreak areas appear to be in northern Germany and parts of Poland particularly after periods of dry and hot weather in summer. Following the first finding of adult moths in light traps in 2004 and of larvae in 2009, it has been confirmed as breeding in the PRA area and populations could potentially reach damaging levels during periods of suitable climatic conditions. The frequency of occurrence of these summer conditions is likely to be highly influenced by climate change, although the impact of variable spring and autumn conditions in a largely maritime climate, or parasitoids and other potentially naturally occurring biological controls, is not yet known.

The primary host is Scots pine (*Pinus sylvestris*). However, *D. pini* feeds on other pine species and coniferous host plants including fir, cedar, juniper, spruce, Douglas-fir and larch. *D. pini* may represent a risk to lodgepole pine (*Pinus contorta* var. *latifolia*) and Corsican pine (*Pinus ni*gra subsp. Laricio) as well as Scots pine in the UK, whilst any risk to the other conifer genera could impact on their important status as commercial and amenity crops.

Lifecycle

Adult moths emerge from pupae during June or July and live for 9-10 days, during which time they mate. The females each lay up to 250 eggs on twigs, needles and on the bark of host trees. The eggs hatch within 16-25 days**,** and the larvae feed on pine needles in the tree canopy until winter frosts begin, when they move down the tree trunks to over-winter in the interface between the litter and soil close to the base of trees. By this stage the larvae are in either the second or third instar growth stage.

In the following spring larvae emerge from the litter layer and move back up the trunk to the tree crown and continue feeding through to the seventh or eighth instar until pupation. Mature larvae are large and can reacha length of 8.0 cm. Pupation begins in May and June and lasts for 4-5 weeks. Pupae are formed inside loose, partially transparent cocoons, which can be found in tree crowns, bark crevices and under-storey vegetation.

In laboratory conditions it is possible for development from egg to adult to take place in only 6-7 months. In field conditions under our current climate a two-year cycle is believed to be the norm, but a one-year life-cycle under favourable conditions, and a three-year lifecycle under less favourable conditions are possible (Figure 2).

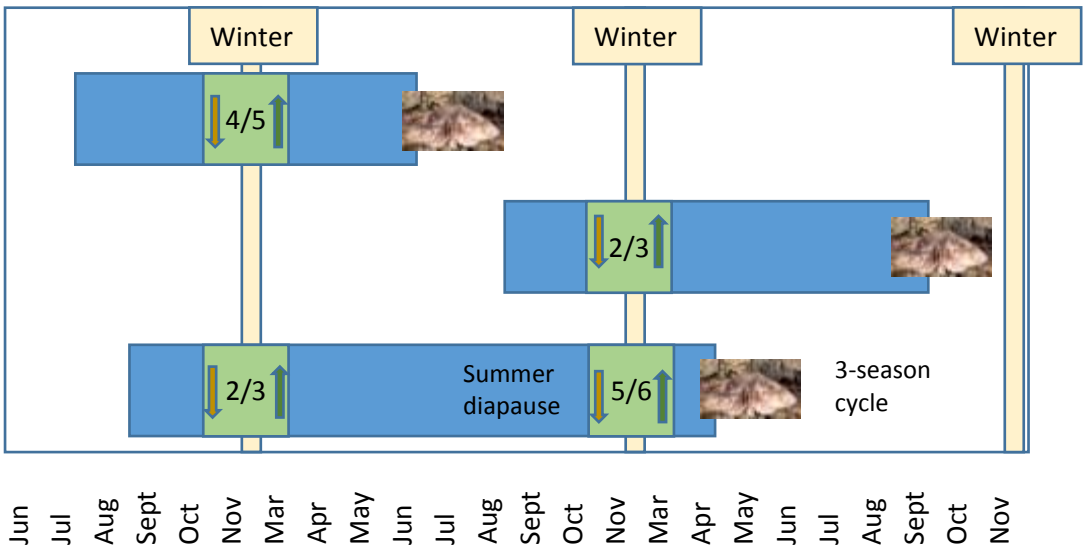


Figure 2: Life cycle of *Dendrolimus pini* indicating larval strategies for life cycles of different lengths. Arrows and numbers in winter period indicate larval migration down the trunk to soil and back to canopy in the following spring and the instars involved.

The PRA area and especially those parts of the PRA area where the moth is known to be breeding contains particularly important areas of native Scots pine in a national context, e.g. Caledonian pine forests. In its native range in Europe, heavy defoliation episodes are cyclic and can last for between 2 and 12 years (Sierpinska, 1998). However, through much of its range it is not considered a pest species. From these European experiences, it appears that the moth poses a potential risk particularly in areas of low summer rainfall or during periods of drought.

The pest is reported as feeding on *Pinus sylvestris* but is highly likely to be able to feed and reproduce on many species of *Pinus* as it also feeds on a number of trees in other genera. The genus is widespread in the PRA area, both in urban and rural environments, both of which represent ends of import pathways (see pathways section). Although formal climate matching has not been carried out, the periodic presence of very large populations of the moth in Europe especially in Poland, Germany and Lithuania indicates that climate limitations would not prevent establishment but could limit the scale of infestations due to the maritime rather than continental climate in the UK. Klimetzek, 1971; Wulf and Schumacher, 2008; Habermann *et al*. 2006; Anon, 2000; Patek *et al*. 2005; Adomas, 2003). Outbreaks have also been reported in Norway from 1900-03 (Hopkins, 1908), Ukraine (Meshkova, 2003) and Sweden (Björkman *et al,* 2012*)*). However, these outbreaks only occur after extremely hot and dry summers as the moth is thought to prefer a continental rather than an oceanic climate despite outbreaks occasionally occurring in the latter.

Based on its biology and impact in Europe and on the conclusions of the original PRA carried out in 2009, the pest poses a potential threat to pine trees in both managed forest and woodland situations as well as in the environment in the PRA area. Consequently, it represents a potential phytosanitary threat that requires appropriate action to reduce or eliminate its potential impact in the PRA area. The experience of the moth in Scotland and assessment of recent literature and experience in Europe have been used to refresh the 2009 PRA in the current version.

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

2.01a - Describe the relevant pathways and make a note of any obvious pathways that are impossible and record the reasons. Explain your judgement

The relevant potential pathways are:

• Plants for planting of woody hosts of *D. pini*

As indicated in the description of host plant species, these will be principally in the genus *Pinus* and are linked mainly to presence of overwintering larvae that can be present in the soil from October to April. They are, therefore, likely to be present during the dormant period of the host plant which is the most likely period for trade and international movement of plants for planting. Egg, larval and pupal cocoon stages on plant needles, shoots and living bark between April to October could also allow the moth to survive and move along this pathway. Any non-host plants for planting could also be a potential pathway, as larvae may over-winter in any soil. This could be especially true where nurseries are in forested areas in close proximity to infested pine or other host trees. A single larval specimen was introduced and reported on an imported pine tree from Italy and was bred through to a female moth in Essex in 1999 (UK Moths, http://ukmoths.org.uk/).

• Cut branches of host plants of *D. pini*

Eggs are laid on needles of host trees, larvae and pupal cocoons are on needles and in branches in the canopy. This could represent a possible pathway, but it is thought that trade in this commodity is unlikely.

• Roundwood of pine with bark present

Depending on the time of year, there could be eggs or pupal cocoons present on the bark of cut stems of pine. Trade in this commodity is prohibited for all conifer timber entering the UK, due to the UK Protected Zone against several species of *Ips* bark beetles (Curculionidae: Scolytinae) which requires that conifer wood should be either bark-free or treated to comply with requirements for absence of these bark beetles. These regulations apply to any EU countries where *D. pini* is known to occur. Similar rules for compliance with freedom from non-European Scolytidae apply to Non-EU third countries including those were *D. pini* is known to be present (e.g. Russia).

• Isolated/ separated bark of conifers

Eggs could be associated with this pathway and, after hatching, could successfully find their way to a host tree. This is considered to be an unlikely pathway, since isolated bark of conifers is also subject to EU Protected Zone and third-country requirements to ensure freedom from bark beetles and other pests and pathogens.

• Contamination of machinery and vehicles or contaminated soil on machinery and vehicles.

Branches with eggs or pupal cocoons may get stuck in machinery and vehicles or soil transported on machinery and vehicles working in infested areas and being transported to the UK.

• Natural spread

The adult male is a strong flier and is regarded as being able to fly from Europe to the south coast of the UK. Records of captures of males include Norwich in 1809, Guernsey in 1989 and 1997, Isle of Wight in 1996 and 2010, Cornwall in 2003 and Kent in 2004 (referred to by UK Moths (http://ukmoths.org.uk/) and other moth recording schemes in UK). Whilst these could have arisen from initial introductions of larvae that subsequently developed through to adults, it is more likely that they were rare migrant male moths directly from populations on the European mainland. However, the female is not such a strong flier and is unlikely to be able to migrate directly to the PRA area. With regard to the current known infested area in the UK, there are no previous records of migration to the area near Inverness. The moth population in Scotland is being monitored using light traps to which male moths are strongly attracted, providing confirmation of their strong capacity for flight.

• Hitch-hiking with baggage and transport

As with many pests, there is the possibility that life stages of the pest could be accidentally or deliberately carried with baggage and in transport (including forest machinery) during travel from infested areas. Whilst this possibility remains, there is no direct evidence that it could have led to the breeding population in Scotland. However, as indicated for the main pathways, this would have required either living adult females or either larval or pupal stages with appropriate substrates (e.g. soil or wood with bark) to be present in the vehicles.

• Overlooked resident

It is possible that the species may be an overlooked resident as it occurs in a relatively under-recorded part of Scotland in relation to moth survey and monitoring by entomologists, and there have been a number of publications debating the possibility (Leverton, 2016). However, the finding of male moths in light traps in 2004 indicates that there is some coverage in the area, and since 2008, there have been more targeted trapping efforts in the area, by both Forestry Commission Scotland and Butterfly Conservation (Leverton, 2016). The possibility of the moth being resident is thought to be unlikely due to its very limited distribution in the area compared with the wide distribution of the host tree species in the same area. Many contiguous Scots pine hosts are growing under similar climatic conditions and appear not yet to be colonised by *D. pini*. In addition, initial DNA analysis reveals a lower genetic diversity when compared to a small number of German specimens (H. Inslely *pers comm* and A' Hara & Cottrell, 2013). There has been further molecular work by A' Hara and Cottrell (Forest Research unpublished data), which has found three distinct molecular groups of *D. pini* across its European range, and the Scottish population seems to most closely match the group found in eastern France, South-west Germany, Switzerland, Italy, Greece and the Balkans, and while the justification for this grouping (e.g. numbers of samples taken , and their location) has not been seen, it does seem to point to the introduction in Scotland coming from this area.

2.01b - List the relevant pathways that will be considered for entry and/or management. Some pathways may not be considered in detail in the entry section due to lack of data but will be considered in the management part.

- Plants for planting of host plants
- Contaminated machinery or vehicles

Pathway 1: Plants for planting of host plants

2.03 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account the biology of the pest?

Likely
Level of uncertainty: low

Plants for planting in a nursery or other site of production in an area where the pest is present could be a source for egg, larval or pupal stages of the moth. The key component of this pathway is that the place of production of potential host plants should be in sufficiently close proximity to infested trees to be attractive to locally flying female moths. The likelihood of infestation will also increase if the local moth population is at a high density as is noted in Germany and Poland occasionally.

2.04 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account *current management* **conditions?**

Moderately likely
Level of uncertainty: medium

Larvae would not be easy to detect in soil during the plant dormant period and could be present at moderately high concentration, especially in outbreak years. The likelihood of soil-based life stages being present will depend on the size of the plants when prepared for transportation. Smaller plants will have either no root ball (bare-rooted) or a small root ball which would reduce the likelihood of large over-wintering larvae being present. Larger trees that are moved complete with a root ball will have a much higher likelihood of such larvae being present and, therefore, may not be detected in nursery inspections in the dormant season. During the growing season of the plants, larvae and pupae could be present on bark and foliage. Any plants being moved during the spring to autumn period would have a higher probability of eggs, larvae or pupae being present, although larger larvae would be more likely to be detected during pre-shipment inspections.

2.05 - Consider the volume of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this volume will support entry?

Likely
Level of uncertainty: low

There is increasing movement of plants for planting of a wide range of plant genera into and throughout the EU including to the PRA area. Table 2 shows data from Eurostat on the import of live forest trees into the UK for the last ten years. The data is given in quantities of 100kg. It should be noted that not all of this material will be hosts for *D. pini*, but the figures give an indication of the quantities of trees which are entering the UK, just over 32 million tonnes mostly from sources within the EU.

Table 2: Eurostat data on the quantity (in 100 kgs) of live forest trees imported into the UK during the period 2005 – 2015. Totals for all trade within and from outside the EU are given, as well as major exporting countries, all of which are within the EU.

Exporter	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
All trade within EU	37449	27615	58429	54578	34157	22152	34377	20204	12819	5136	14297	321,213
NETHERLANDS	16459	13921	41171	32108	20029	12450	14273	5044	2646	1459	7255	166,815
BELGIUM (and LUXBG -> 1998)	935	3139	1873	1172	1780	5822	11263	11134	6770	1546	2026	47,460
GERMANY	6234	1407	5360	7390	1512	144		746	1296	194	284	24,567
ITALY	5624	1688	1967	2209	1611	472	7526	1988	380	194	2382	26,041
FRANCE	3074	1620	2070	3510	2567	38	168		239		627	13,913
DENMARK	3423	4869	4027	4257	3806	46			4	1713	146	22,291
IRELAND	1645	847	740	3538	1799	1998	1029		994		420	13,010
SPAIN	2	124	499	35	956	1182	118	1292	472	30	1157	5,867
All trade from outside EU	395	146	171		3	690	760	304	85	401	137	3,092

However for Forestry purposes, most plants are grown from seed and import of actual planting material is relatively low. Table 3 (below) is taken from data on the UK imports of Forest Reproductive Material (FRM), from 2003-2013 and shows the imports of host genera of *D. pini*. The pest is confirmed to be present in Belgium, Denmark, France and Germany.

Table 3. UK imports of Forest Reproductive Material in the genera *Abies*, *Larix*, *Picea, Pinus* and *Pseudotsuga*, from 2003-2013. There were no records of imports of FRM in the genera *Cedrus* or *Juniperus*.

Species	**Country**	**Nature of FRM**	**Quantity (plants or parts of plants)**	**Year**
Abies cephalonica (ace)	Czech Republic	parts of plants	2000	2007
Larix decidua (lde)	Czech Republic	parts of plants	5.5	2009
Larix kaempferi (lka)	Germany	planting stock (bareroot)	1100	2003
Larix x eurolepis (leu)	Belgium	planting stock (bareroot)	100	2003
Picea abies (pab)	France	planting stock (bareroot)	10000	2003
Picea sitchensis (psi)	Netherlands	parts of plants	2000	2012
Pinus nigra (pni)	Denmark	planting stock (bareroot)	500	2005
Pinus pinaster (ppa)	Belgium	planting stock (containers)	4.2	2012
Pseudotsuga menziesii (pme)	France	planting stock (bareroot)	3000	2003

The majority of movement of *Pinus* plants for planting into the UK is through the nursery trade. Figures from the pre-notification data for *Pinus* for the import season 2015-16 record 1026 separate consignments, comprising 409,470 trees / plants of *Pinus*. Plants were imported from a range of EU countries, but 1011 of the recorded consignments came from countries in which *D. pini* is recorded.

2.06 - Consider the frequency of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this frequency will support entry?

Unlikely
Level of uncertainty: medium

As indicated in the tables given in 2.05, the frequency of trade in plants for planting depends on the tree species in question, its end use and the country of origin. However, it should also be noted that the general plant health restrictions on this trade and the tendency for most trees in the category to be moved in the dormant season reduces the frequency of entry by the pest. However, the larger the plant, the greater the probability that life stages that can easily survive the transit period along the pathway will be present.

2.07 - How likely is the pest to survive during transport or storage?

Very likely
Level of uncertainty: low

If plants for planting, complete with soil, are imported there is high likelihood of the soil-based larval stages surviving during transport or storage. Stages, including eggs, larvae and pupae on the trunk and foliage could also survive transport but would only be present on plants moved during the growth season of the plant.

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

Very unlikely
Level of uncertainty: low
This is considered to be extremely unlikely. The only possibility would be adults emerging, mating and females laying eggs on the host trees in the period from lifting of plants to their subsequent planting.

2.09 - Under current inspection procedures how likely is the pest to enter the PRA area undetected?

Likely
Level of uncertainty: low

Current inspection regimes generally do not include specific inspection for *D. pini*. Several pests and pathogens of the known hosts are, however, included in the EU Plant Health Directive (EU Council Directive 2000/29/EC (as amended)). The majority of *Pinus* imported into the UK will be ornamental trees. They are subject to a pre-notification scheme, should have plant passports and if they are over 3 metres will have to meet the UK wide Protected Zone requirements for *Ips amitinus*, *I. duplicatus* and *I. typographus*. The requirements for bark beetles are that the plants originate from a pest free place of production, which many nurseries will be compliant with, for named pests but may not include specific inspection for *D. pini* or other moths. Plant passports will not cover unregulated pests, however, they do mean that the plants should have been checked prior to import. Currently the UK Plant Health Seeds Inspectorate (PHSI) target consignments from specific origins, based on risk from certain pests such as pine wood nematode and pine processionary moth, the distribution of which does cross over with *D. pini*, but does not match. Life stages of *D. pini* in the soil would be very difficult to detect, whereas stages on the foliage/bark would be easier to spot. However, eggs

and small larvae would be difficult to find even within a specific inspection regime. By contrast large larvae would be relatively easy to detect. Since most plant movements of host trees for *D. pini* are likely to be in the dormant season and are also regulated for several pest organisms, there will either be prohibition or specific requirement to be free of particular pests under an inspection regime, which will aid the detection of *D. pini*.

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

Moderately likely
Level of uncertainty: low

Since the principal pathway is plants for planting, larvae hatching from eggs or emerging from the soil will be able to feed immediately on both the original plant and on other suitable host plants in the vicinity. Larvae or pupae already present could complete development and emerge as adults, which could fly to local pine and conifer hosts which are widespread in the PRA area and not restricted to Forestry situations.

2.11 - The probability of entry for the pathway should be described

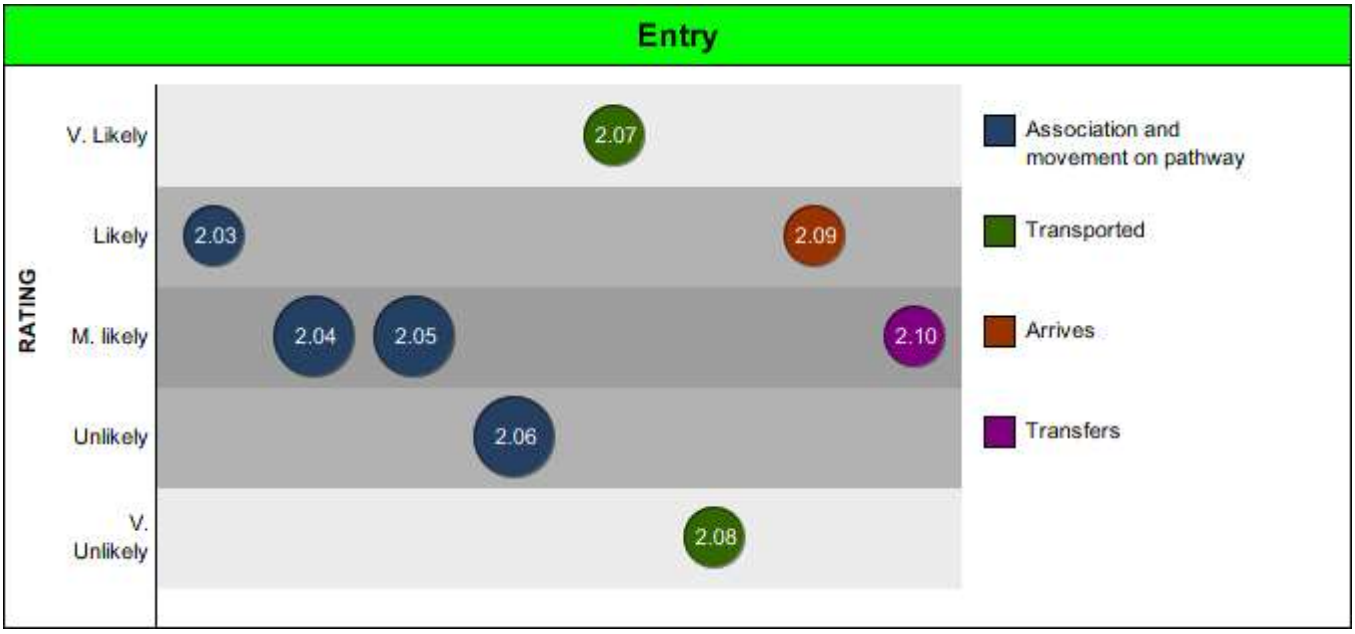
Moderately likely
Level of uncertainty: medium

The probability of entry for this pathway is considered to be moderately likely. This is a lower level than the previous PRA, taking account of the high level of regulation of the conifer plants for planting pathway both into and within the EU. Thus, although there is some trade in live plants the mitigation provided by inspection and certification will reduce the overall likelihood of entry.

The schematic below summarises the situation. Bubble graphs, referring to each question in the section, show the given score on a five-point scale for each category on the y-axis while the size of the bubble shows the uncertainty associated with that score; the greater the uncertainty, the larger the bubble. A small bubble represents greater confidence, a narrower focus on the target score. Colour coding of the bubbles shows the thematic cluster for each group of questions.

Overall summary scores (and uncertainty) for each category are displayed as greys bars in the background of the bubble chart. A very dark grey bar shows Low uncertainty in the chosen score but becomes less dark and the surrounding grey areas are more diffuse as uncertainty in the summary score increases.

Figure 2: Schematic showing the ratings of different aspects of entry on plants for planting.



: Smaller bubble size for low uncertainty 

: Larger bubble size for medium uncertainty

Pathway 2: Contaminated machinery or vehicles.

2.03 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account the biology of the pest?

Unlikely
Level of uncertainty: medium

The life stages of the pest could associate with soil (particularly) and trunk/branch material (less likely) and any of these could potentially contaminate machinery or vehicles working within the forest environment.

2.04 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account current management conditions?

Unlikely
Level of uncertainty: medium

Although it is possible that machinery could harbour plant material and soil containing life stages of the moth, this is considered to be less likely than the plants for planting pathway, particularly as there is likely to be general hygiene carried out prior to movement of machinery. However, the risk does remain, particularly if awareness of biosecurity requirements to keep machinery clean is not high, and should be included.

2.05 - Consider the volume of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this volume will support entry?

Very unlikely
Level of uncertainty: low

Movement of vehicles associated with forest operations (e.g. whole tree harvesters, forwarders,

forest tractors) from countries where the moth is present to the PRA area is likely to be low and sporadic.

2.06 - Consider the frequency of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this frequency will support entry?

Very unlikely
Level of uncertainty: low

As indicated, there is likely to be a low frequency of movement of machinery associated with forest operations along the pathway unless there are episodes requiring rapid and increased capacity of machinery in a given area. These would be identified and surveillance increased accordingly, thus keeping the overall risk small.

2.07 - How likely is the pest to survive during transport or storage?

Moderately likely
Level of uncertainty: medium

There is little knowledge on the phytosanitary risks posed by plant debris and soil on machinery in relation to this particular pest. It is likely that eggs, pupae and, to a lesser extent, smaller larvae could survive on branches and woody debris and overwintering larvae associated with soil would have a higher likelihood of survival. However, debris is most likely to be small and fragmented, with chance of physical damage to all life stages. Thus, if debris does become associated with machinery, the likelihood of survival along the pathway is rated moderately likely.

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

Very unlikely
Level of uncertainty: low

Other than emergence of moths and mating in transit with possible egg laying 'en route' there is no likelihood of multiplication during transport. The risk is very low.

2.09 - Under current inspection procedures how likely is the pest to enter the PRA area undetected?

Unlikely
Level of uncertainty: low

Given the heightened awareness of both *D. pini* and other prohibited pests and, particularly, pathogens of trees being carried on contaminated machinery, the requirement for heightened biosecurity measures is now high and will, therefore, tend to reduce the likelihood of the pest entering undetected (e.g. http://www.forestry.gov.uk/biosecurity). However, the risk is not reduced to such a low level that the pathway can be ignored.

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

Moderately likely
Level of uncertainty: low

Since the type of machinery that could be contaminated by the pest is likely to be used in similar situations in forests and woodlands in the PRA area, if the pest was present it could transfer to the local environment where hosts could be widespread and in close proximity.

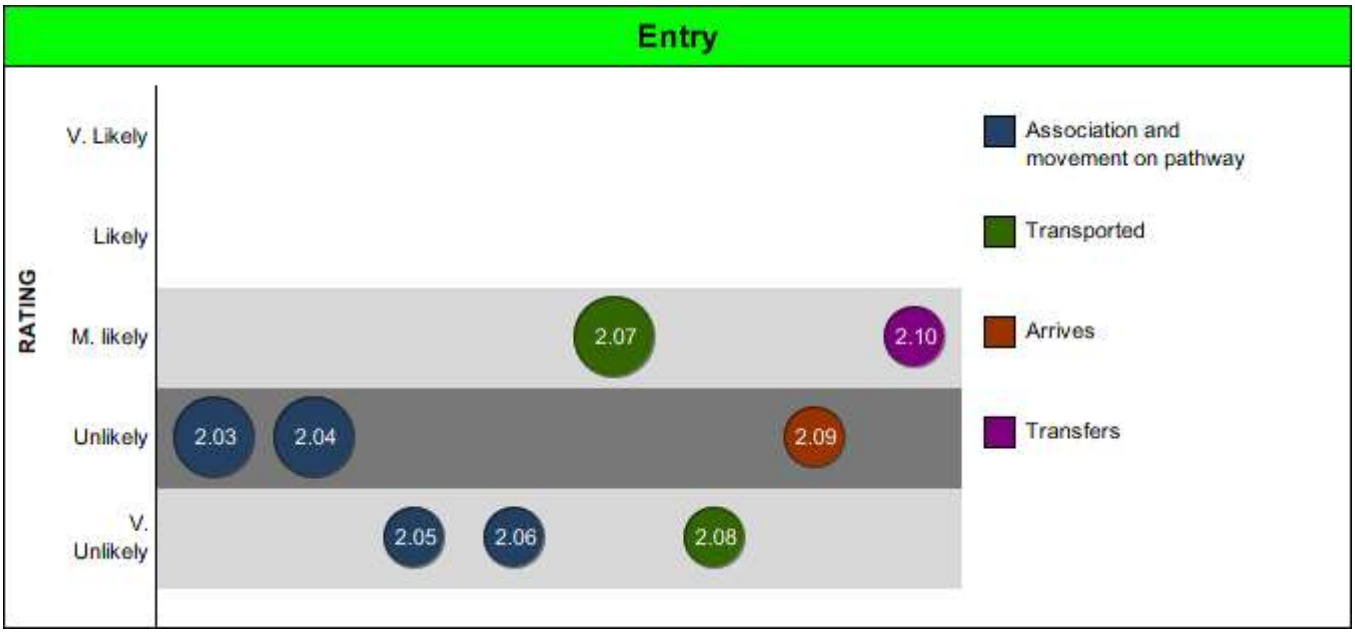
2.11 - The probability of entry for the pathway should be described

Unlikely
Level of uncertainty: low

Considering both the relatively small movement of machinery from *D. pini* infested areas to the PRA area and the generally heightened awareness of the need for high biosecurity with regard to keeping machinery working in forest areas clean, the overall risk from this pathway can be judged to be small.

The visualisation of the relative risks is shown below.

Figure 3: Schematic showing the ratings of different aspects of entry on contaminated machinery and vehicles.



: Smaller bubble size for low uncertainty 

: Larger bubble size for medium uncertainty

2.13b - Describe the overall probability of entry taking into account the risk presented by different pathways and estimate the overall likelihood of entry into the PRA area for this pest (comment on the key issues that lead to this conclusion).

Moderately likely
Level of uncertainty: medium

The most likely pathway for entry is plants for planting. Taking account of the controls already in place for plants for planting pathway, the overall risk of entry from this pathway can be considered to be 'moderately likely'. In reality, the numbers of plants that would be traded from areas known to have high populations of the moth are likely to be low and would be subject to strict inspection for a range of pests and pathogens as indicated in the EU Directive 2000/29/EC. Other pathways are considered lower risk, but may still be subject to management measures.

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

Seven factors may influence the limits to the area of potential establishment and the suitability for establishment within this area:

- **1 - Host plants and suitable habitats**
- **2 - Alternate hosts and other essential species**
- **3 - Climatic suitability**
- **4 - Other abiotic factors**
- **5 - Competition and natural enemies**
- **6 - The managed environment**
- **7 - Protected cultivation**

No.	Factor	Is the factor likely to have an influence on the limits to the area of potential establishment?	Is the factor likely to have an influence on the suitability of the area of potential establishment?	Justification
1	Host plants and suitable habitats (see note for Q3.01)	Yes (see 3.01)	Yes (see 3.09)	
2	Alternate hosts and other essential species	No	No	No alternate hosts are involved in the cycle of this pest.
3	Climatic suitability	Yes (see 3.03)	Yes (see 3.11)	
4	Other abiotic factors	No	No	There are no known other abiotic factors that would affect establishment of the pest.
5	Competition and natural enemies	No	No	There are other defoliators on pine in the UK that could affect food availability for young larvae of pine-tree lappet moth. Many of these such as pine beauty moth are also present in Europe and do not prevent outbreaks there (Sukovata, 2003). Consequently, it is unlikely that this would affect establishment in the UK unless there was complete coincidence of life cycle and direct competition for limited food resources on the same plant very early in the establishment phase. Generalist natural enemies could have some impact on pest population build up, but this is not likely during the establishment phase. The species has many natural enemies including bats, several species of birds, entomogenous fungi and parasitic flies and wasps. In diverse woodlands these may prevent *D .pini* populations from building up to pest levels but this is probably less likely in forestry plantations.
6	The managed environment	Yes (see 3.06)	Yes (see 3.14 / 3.15)	
7	Protected cultivation	No	No	This pest has no association with protected cultivation.

Host plants and suitable habitats

3.01 - Identify and describe the area where the host plants or suitable habitats are present in the PRA area outside protected cultivation.

Suitable host plants are widespread throughout the PRA area especially in non-urban locations throughout Scotland and much of the rest of the UK.

Climatic suitability

3.03 - Does all the area identified as being suitable for establishment in previous question(s) have a suitable climate for establishment?

Yes

The climatic conditions in the UK are similar to parts of the continent where the species occurs. However, in Poland, Germany and Russia where *D. pini* is known to outbreak most frequently climatic conditions are more extreme, with hotter summers and colder winters than is generally the case in the UK (see section 3.11), which may account for the lack of outbreak occurrences to date in Scotland. However, climate change may produce conditions thought to cause this pest species to outbreak in the future.

In 2012, Sweden discovered an outbreak, which covered 1.5 Ha, on the island of Furuskar in the Stockhold archipelago. While it is uncertain what the precise triggers were for the Swedish outbreak, it would appear that sequences of unusually warm weather, combined with low natural enemy prevalence and tree stress, are contributory. Christer Bjorkman, Goran Nordlander and Ake Lindelow from SLU in Sweden (Personal Communication by email exchange, January 2016) indicate that there have been no further outbreaks on Furuskar Island, although the trees were badly affected by subsequent attacks by pine shoot beetle, *Tomicus piniperda*. In 2013 some feeding damage caused by *D. pini* was noted on the neighbouring island of Sandskar, but this did not develop further when visited in 2014. Ake Lindelow also indicated that a possible infestation on an island in the Trosa archipelago south of Stockholm leading to heavy defoliation may have been caused by *D. pini*; this is being investigated.

Again, summers in this area of Sweden (Stockholm) are significantly hotter and winters much colder than the area of current outbreak in the UK (Inverness) (see Fig 3, section 3.11). Also apart from July and August, Inverness has consistently higher monthly rainfall, and more days per month with rainfall throughout the year than Stockholm (see Figs 4 and 5, section 3.11). This reflects the difference between the Atlantic climate of Scotland and the more continental climate of Stockholm, and perhaps the possibility that tree stress could have been contributed to by low rainfall as well as the rocky nature of the island where this outbreak occurred.

A recent study by Ray *et al* (2016) employed principal component analysis, the Seljaninov hydrothermal coefficient and decision-tree models on climate observations to analyse European, particularly German, historical outbreaks to predict locations and timings of potential future outbreaks. Using the modelling approach, the authors predicted that for "two of the three more westerly and inland Caledonian Pine Forest Reserve sites [Glenmore and Glen Affric]…the projected summer climate… would remain wet and cool through the 21st century." However, the Great Glen Caledonian Pine Forest and more easterly and lowland Scottish plantation forests of *P. sylvestris* look likely to change over time to having "higher probabilities of years with Seljaninov coefficient values associated with *D. pini* outbreaks" as the 21st century progresses. Predictive maps indictating the probabilities of areas experiencing Seljaninov coefficients in the range 1.0 – 1.5 are shown in Fig 4, taken from Ray *et al* (2016). However, it is also important to note that this coefficient was developed in Poland, where spring / autumn onsets are likely to be more predictable and uniform than in a maritime climate such as the UK. To date, the potential impact of this has not been investigated as thoroughly as the summer temperature influences.

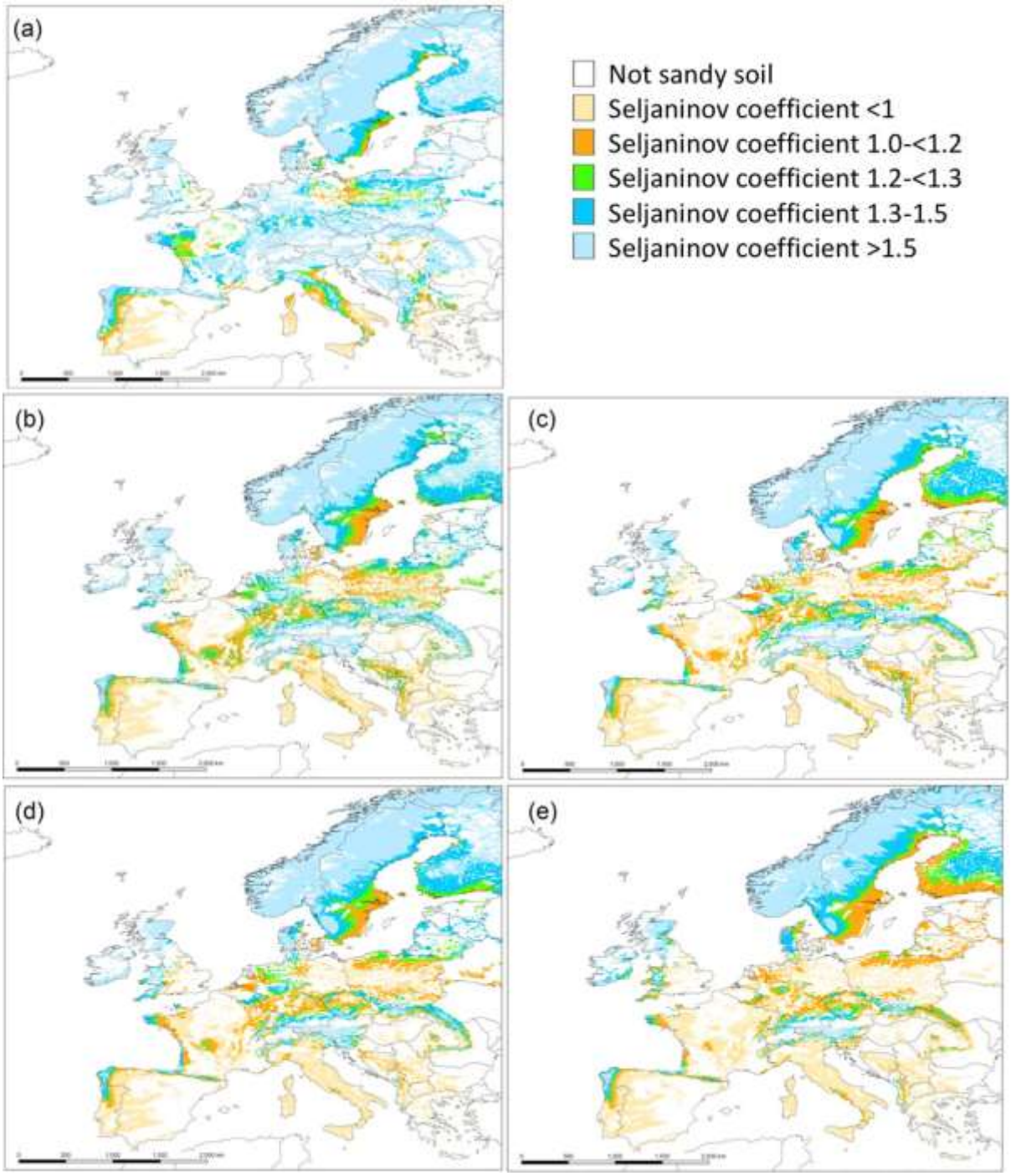


Figure 4 (a–e) Comparison of the Seljaninov coefficient below, between and above the range 1.0–1.5 in regions of freely draining, infertile, soil types (Liedekerke et al., 2006) associated with *Pinus sylvestris* forest in Europe that could be suitable for damaging outbreaks of *Dendrolimus pini*. (a) Baseline climate 1961–1990, (b) projected Seljaninov coefficient from HadCM3 A1B in 2050, (c) projected Seljaninov coefficient from HadCM3 A1B in 2080, (d) projected Seljaninov coefficient from ECHAM5 A1B in 2050 and (e) projected Seljaninov coefficient from ECHAM5 A1B in 2080. From Ray *et al* (2016)

3.06 - Is all the area identified as being suitable for establishment in previous questions likely to remain unchanged despite the management of the environment?

Yes

If linked to plants for forestry planting, the insect will be in close proximity to other food resources in a forestry environment. Scots pine and other conifers remain the dominant commercial forestry crop

in Scotland and Wales and are high-value amenity and environmental components of the environment in the rest of the PRA area. The threat to remnant ancient Caledonian pines remains a high cause for concern even though these are not managed commercially.
If brought in on ornamental plants for planting, there may be a lower risk of transfer to Forestry environments of key concern, and it is possible that infestation in nurseries, landscaping or on private properties would be noticed sooner due to management of these areas, but the UK wide distribution of the hosts of this pest means there still remains a risk of population establishment in the wider environment.

3.08 - By combining the cumulative responses to previous questions with the response to question 3.07, identify the part of the PRA area where the presence of host plants or suitable habitats and other factors favour the establishment of the pest.

The pest has established in a restricted part of the PRA area and surveys since 2009 have indicated successful larval development and small-scale spread from the initial foci of infestation. Climatic conditions in the PRA area as a whole are suitable, especially in the southern parts of the UK, where the summers are warmer; and host plants are widely distributed. Thus establishment is both confirmed and also very likely in other areas of the PRA area should the pest spread from the current restricted area. The finding of a new infestation at Glen Strathfarrar, approximately 25 km from the original Kiltarlity site suggests local spread, although it is not known how long the Glen Strathfarrar population has been present or whether, if the hypothesis of *D. pini* being an overlooked native is correct, it is simply the finding of a long-established local population. In any case, the finding in a native Caledonian pine site is being taken seriously with investigation of mating disruption to reduce or eliminate any population build up in the area.

Host plants and suitable habitats

3.09 - How likely is the distribution of hosts or suitable habitats in the area of potential establishment to favour establishment?

Very likely
Level of uncertainty: low

The wide distribution of suitable host plants habitats throughout the PRA area indicate that the moth could survive and potentially increase in any part of the PRA area, thus favouring establishment.

Climatic suitability

3.11 - Based on the area of potential establishment already identified, how similar are the climatic conditions that would affect pest establishment to those in the current area of distribution?

Largely similar
Level of uncertainty: medium

Based on the Köppen-Geiger climate zones in the EU (see PRATIQUE Rating Guidance on Climate Suitability and a valuable description of the use of vegetation as climate indicators, as originally proposed by Wladimir Köppen, and subsequently modified by Rudolf Geiger and others, in Kottek, *et al*, 2006) the UK (PRA area) is classified under the following categories:

Cfb: Warm temperate, fully humid, warm summer (91.8%) and
Cfc: Warm temperate, fully humid, cool summer (8.2%).

This is typical of an Atlantic climate zone.
With regard to the areas where *D. pini* has most regular and large outbreaks, the classifications are:

Germany:

Cfb: Warm temperate, fully humid, warm summer (99.5%) and
Dfb: Snow, fully humid, warm summer (0.5%)

Poland:
Cfb: Warm temperate, fully humid, warm summer (68.1%) and
Dfb: Snow, fully humid, warm summer (31.9%)

Figures 5 – 7 compare the minimum and maximum temperatures, average monthly rainfall and average number of rain days in Inverness (1981-2010) (close to the UK established population area) and Stockholm (1961-1990) (close to the Swedish island where an outbreak of *D. pini* recently occurred).

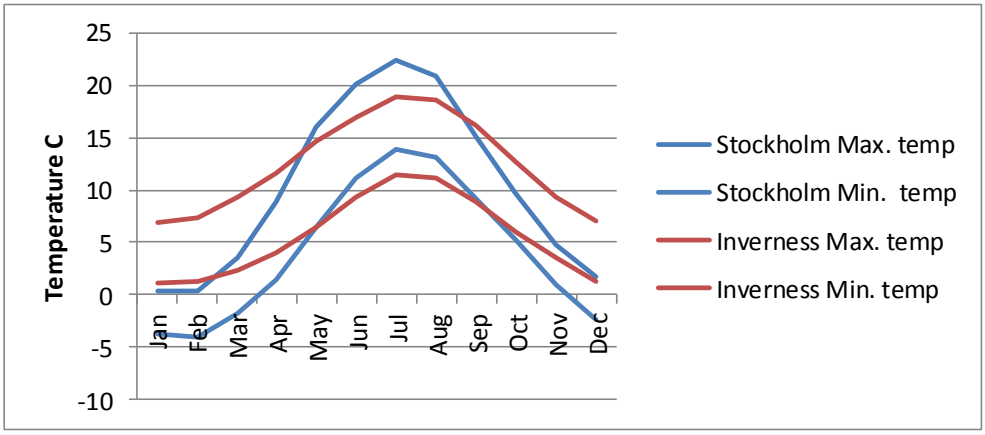


Fig. 5: Minimum and maximum temperature data for Stockholm and Inverness. Data taken from Norwegian Met. Office and UK Met. Office data: http://www.yr.no/place/Sweden/Stockholm/Furusk%C3%A4r~3224123/statistics.html; http://www.metoffice.gov.uk/public/weather/climate/gfhyzzs9

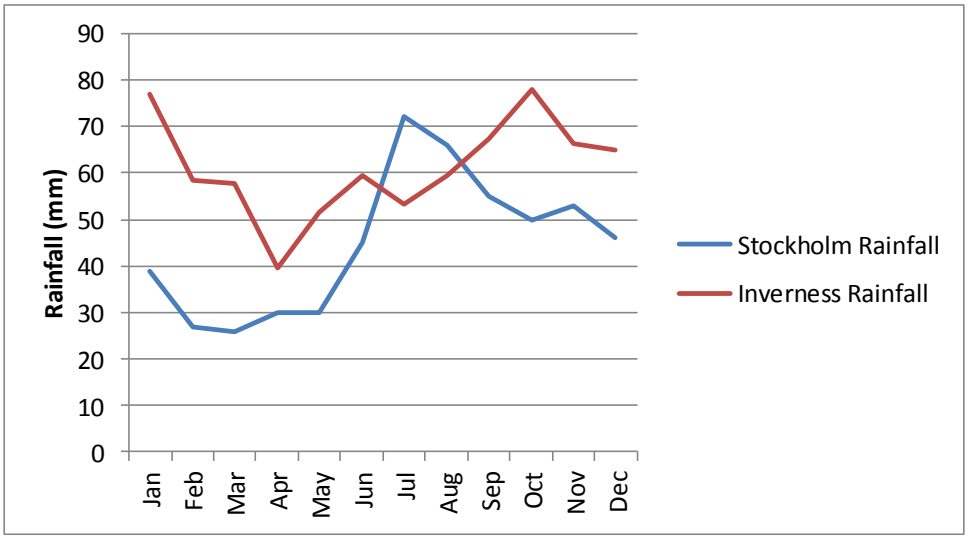


Fig. 6: Average monthly rainfall (mm). Data taken from Stockholm climate and temperature (http://www.stockholm.climatemps.com/) and UK Met Office (http://www.metoffice.gov.uk/public/weather/climate/gfhyzzs9)

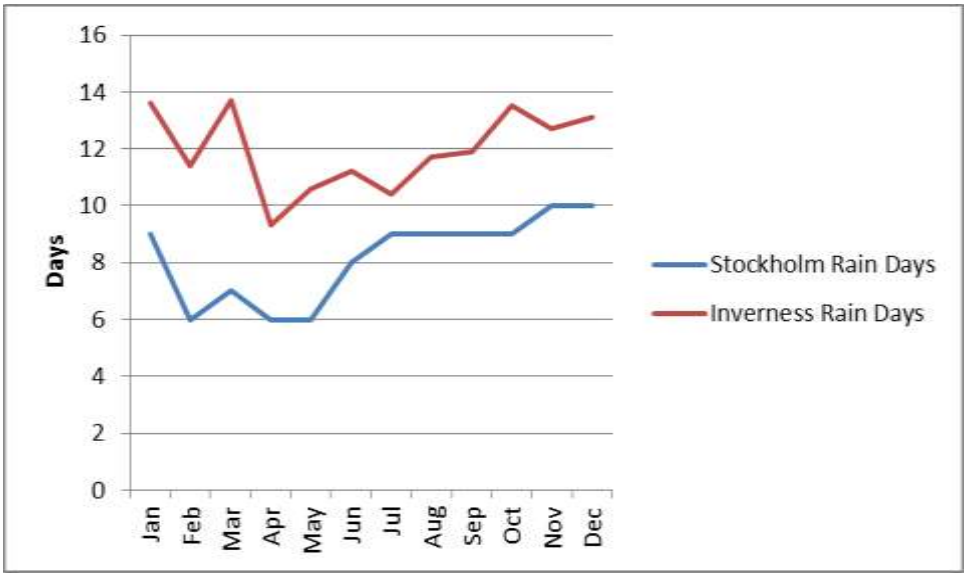


Fig. 7: Average number of rain days, per month. Data taken from Stockholm climate and temperature (http://www.stockholm.climatemps.com/) and UK Met Office (http://www.metoffice.gov.uk/public/weather/climate/gfhyzzs9)

This suggests that climatic conditions are largely similar to the outbreak areas, although some variations in both summer (hotter in outbreak areas) and winter (colder in outbreak areas) temperatures are apparent. The greatest area of uncertainty in climate matching is the transition from Atlantic to continental climate zones in the areas where the most frequent *D. pini* outbreaks have been recorded (e.g. in Poland - Sierpinska (1998)). Given that a population is established in Scotland, the differences that do occur may be more closely linked with the potential for outbreak populations, than whether the pest can establish. Ray *et al* (2016) suggest in their conclusion that by 2080 low-land regions of north-east Scotland may experience outbreaks, but also that these are likely to be as rare as currently found in northern Germany.

The managed environment

3.14 - How favourable for establishment is the managed environment in the area of potential establishment?

Highly favourable
Level of uncertainty: low

There is wide cultivation and management of pine and other conifers, especially in Scotland and Wales and the extensive amenity plantings of Scots pine in southern England. Additionally pines and other conifers are popular in gardens, parks and landscaping. This indicates that establishment of the moth throughout the PRA area is highly likely.

3.15 - How likely is the pest to establish despite existing pest management practice?

Very likely
Level of uncertainty: low

Apart from specific surveys to determine the extent of the current breeding population of the moth in Scotland, there is no management practice specific to the pest. General forestry management practice, including further planting of suitable conifer hosts and maintenance of conifer woodlands for amenity and conservation purposes ensures a plentiful supply of breeding material for the moth. However, it should be noted, that there is an underlying drive in UK Forestry to diversify monocultures, which would help to limit potential impacts on one species alone.

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

Likely
Level of uncertainty: medium

This pest's development is on average spread over two seasons, but with a range from one to three seasons (http://www.forestry.gov.uk/pinetreelappet#lifecycle;), a supposition supported by the work of lepidopterist enthusiasts (Leverton, 2016), although this remains under investigation under Scottish conditions. This should make it possible to locate and manage the late instar larvae of one generation and the early instar larvae of the next generation in the same year. However, it will be difficult to locate any low density populations in the environment which could mean they build up in many separate locations. Fortunately, the female stage does not fly long distances but, nevertheless, local dispersal could result in many foci of infestation and these would all be liable to result in viable populations due to their relatively high reproductive rates.

3.18 - Is the pest highly adaptable?

Yes, highly or very highly adaptable
Level of uncertainty: low

The pest and its genus are very widespread throughout Europe and Asia and can cause severe defoliation. However, damaging outbreaks of *D. pini* are often cyclic, associated with populations with one generation per year, and probably occur due to predator/prey interactions and their interaction with suitable climatic conditions and tree stress. Outbreaks are only common in a small part of *D. pini*'s range but climate change will undoubtedly play a part in altering the temporal and spatial distribution of these outbreaks in the future. As indicated earlier, the recent 'surprise' outbreak on an island in the Stockholm Archipelago indicates that populations can respond to subtle changes in climate and build up relatively rapidly to damaging levels, which on Furuskar Island appeared to be linked to unusually high temperatures in July 2010 and April 2011, but average precipitation in July-August 2011 (Bjorkmann *et al*. 2013). Although there is little information on biological or ecological differences in local populations, the presence of a number of sub-species of *D. pini* throughout the known range of the pest (see 1.02a) suggests adaptability to a range of environmental drivers, as does the pests ability to reproduce over either 1, 2 or 3 years.

3.19 - How widely has the pest established in new areas outside its original area of distribution? (specify the instances, if possible; note that if the original area is not known, answer the question only based on the countries/continents where it is known to occur)

Not widely
Level of uncertainty: medium

The male moth has been captured very infrequently in the PRA area but, prior to the establishment of the population near Inverness was previously, believed to have been a migrant rather than introduced. There are no records in Europe of establishment of pest populations remote from the known distribution range of the moth. More local spread of up to 1.7 km may have occurred to initiate the outbreak on Furuskar Island, Sweden, but this generally confirms the very low dispersal capacity of female moths.

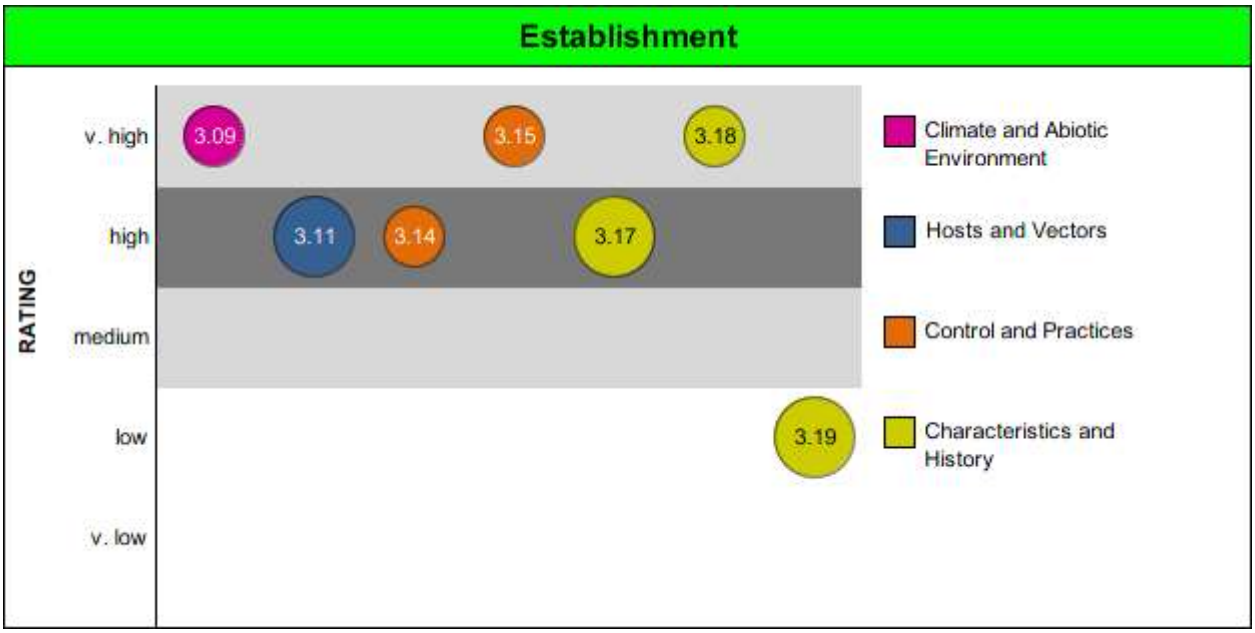
3.20 - The overall probability of establishment should be described.

High
Level of uncertainty: low

The pest has established in a restricted part of the PRA area and surveys since 2009 have confirmed this to be the case, with only local spread being recorded (up to 25 km if the Glen Strathfarrar population arose recently from the original breeding population at Kiltarlity). Climatic

conditions in the PRA region are suitable and host plants are widely distributed. The overall likelihood of establishment is high.

Figure 8. Schematic showing the ratings of different factors affecting potential for establishment.



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: Larger bubble size for medium uncertainty

Stage 2: Pest Risk Assessment Section B: Conclusion of introduction

Conclusion on the probability of introduction.
The overall probability of further introductions is **likely**.

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

Spread is defined as the expansion of the geographical distribution of a pest within an area. Spread potential is an important element in determining how quickly impact is expressed and how readily a pest can be contained. In the case of intentionally imported plants, the assessment of spread concerns spread from the intended habitat or the intended use to an unintended habitat, where the pest may establish. Further spread may then occur to other unintended habitats. The nature and extent of the intended habitat and the nature and amount of the intended use in that habitat will also influence the probability of spread. Some pests may not have injurious effects on plants immediately after they establish, and in particular may only spread after a certain time. In assessing the probability of spread, this should be considered, based on evidence of such behaviour.

4.01 - What is the most likely rate of spread by natural means (in the PRA area)?

Low rate of spread
Level of uncertainty: low

The natural spread of the moth by flight of females is regarded as very low, with female moths likely to fly only a few kilometres at most. However, definitive information on this characteristic is lacking, particularly since there is a possibility of females flying further when initial egg laying has taken place (Sierpinska, 1998). Local spread within and between adjacent forests could result in gradual spread from foci of infestation. The new finding at Glen Strathfarrar in 2015 suggests local spread from Kiltarlity, which is approximately 25 km away, although there is also the possibility that the population was already present and had previously been overlooked.

4.02 - What is the most likely rate of spread by human assistance (in the PRA area)?

High rate of spread
Level of uncertainty: low

Plants for planting are moved both nationally and internationally which, combined particularly with the cryptic nature of the egg and over-wintering larval stage, could result in rapid movement of the pest within the PRA area. This is dependent on the likelihood of association between the moth and the plants at the point of origin and this is dealt with under management. There is also the possibility of eggs and young larvae on the bark of sawn timber which could be moved throughout the PRA area. Since the current focus of infestation is small and moth population density is still low, the likelihood of human-assisted movement remains small but could change to more significant levels if *D. pini* populations increase. Following the discovery of breeding populations of the moth, timber movement from the infested area was restricted to the winter, i.e. just 3 months. In the light of experience and evaluation of risk since 2009, timber movement is now permitted outside the period of highest risk, i.e. timber can be moved, with baseline biosecurity precautions, from mid-May to the end of August.

4.03 - Describe the overall rate of spread

Moderate rate of spread
Level of uncertainty: medium

Natural spread from foci of infestation will be low resulting from restricted flight distances by female moths. However, human-assisted spread could be very rapid due to long-distance transport and volume of trade of plants for planting and possibly on sawn timber. Overall, this is likely to give a moderate rate of spread since the plants for planting pathway is recognised and can be managed.

4.04 - What is your best estimate of the time needed for the pest to reach its maximum extent in the PRA area?

Extremely long
Level of uncertainty: high

Natural spread, combined with relatively low climate suitability for rapid population growth (but high suitability for establishment) would result in an **extremely long** period (many years) to reach maximum extent by expansion of the current restricted population in Scotland. A more unpredictable expansion arising from human-assisted spread and establishment of foci in more climatically suitable areas in southern Britain could result in more rapid population build-up and further spread. Whilst being very difficult to predict, this could occur in a low number of years compared with natural spread. An increase in population density in Scotland could result in movement within one year if the projected pathways are fulfilled. However, as with all human-assisted pathway movements, this is highly unpredictable but relatively manageable if measures are put in place (see management section).

4.05 - Based on your responses to questions 4.01, 4.02, and 4.04 while taking into account any current presence of the pest, what proportion of the area of potential establishment do you expect to have been invaded by the organism after 5 years?

Extremely small
Level of uncertainty: medium

The current extremely restricted distribution of the pest and the fact that the distribution has only increased to a small extent since 2009, when intensive monitoring was put in place, suggests that the proportion of area of potential establishment will remain **extremely small** after 5 years. However, if human-assisted spread takes place the proportion could increase rapidly if the moth established in more climatically suitable areas such as the New Forest where there is extensive Scots pine.

Stage 2: Pest Risk Assessment Section B: Eradication, containment of the pest and transient populations

5.01 - Based on its biological characteristics, how likely is it that the pest could survive eradication programmes in the area of potential establishment?

Likely
Level of uncertainty: low

As indicated by the results of annual surveys since 2009 using light traps, pheromone traps and sticky bands on tree trunks to assess larval migration to and from soil in the infested area in Scotland, the pest is very difficult to find when it is at low density, and it is especially difficult to locate trees that have larval populations present. It does not seem practical to attempt eradication using aerially applied pesticides such as *Bacillus thuringiensis.* It also seems unlikely that application of *Bt* would be effective in complete eradication since the two-year life cycle would make it difficult to deliver effective dosages to all the larvae present in the environment. Mating disruption of male moths is also being considered but this method has not been tested against the moth and tends to result in population reduction rather than eradication potential (Carde & Minks, 1995). With this constraint in mind, the conclusion for this question is that the pest could survive eradication programmes.

5.02 - Based on its biological characteristics, how likely is it that the pest will not be contained in case of an outbreak within the PRA area ?

Unlikely
Level of uncertainty: low

If the pest is not contained by local climatic conditions then the likelihood of containing the pest within the currently identified infested area depends on identifying the full extent of the infestations and applying containment measures to restrict both natural and, particularly, human-assisted spread. Given that a second or satellite population has recently been discovered in Glen Starthfarrar, it seems that identifying the extent of the population area is not straightforward. Within the local context in Scotland, it is important to stop further spread especially into areas of native Caledonian pine. Preventing natural spread is extremely difficult, but steps can be, and have already been taken to reduce the likelihood of human assisted spread.

5.03 - Are transient populations likely to occur in the PRA area through natural migration or entry through man's activities (including intentional release into the environment) or spread from established populations?

No
Level of uncertainty: medium

It is unlikely, but possible at extremely low probability, that gravid female moths could fly or be blown from continental Europe after depositing the majority, but not all, of their eggs. However, this is felt to be insignificant and certainly not demonstrated compared with the plants for planting pathway. Until recently only very infrequent male migrant moths (ca. 6 specimens) have been collected in light traps on the south coast of England (in ca. 60 years). None had been reported from Scotland until 2004 and following the establishment of annual networks of pheromone traps around the Inverness-shire site from 2009, a total of 257 male moths had been captured up to 2014. Although trap density per year has increased from 282 to 412, the numbers of moths captured have not fluctuated in proportion to the increased trapping effort. It can be concluded that the captured moths are from a local breeding population rather than from migrants.

Human assisted movement into the PRA area through the identified pathways is the most likely route of entry and establishment, although there remains the uncertainty over the species being an

overlooked resident.

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

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

Major
Level of uncertainty: low

The impacts of the moth in its range in Europe where it is a pest are through loss of growth increment as a result of severe or complete defoliation of host trees. Severe defoliation can also lead to the weakening of the trees allowing attacks by other organisms, as is the case on Furuskar Island in Sweden where pine shoot beetle attack has increased considerably even though *D. pini* populations have returned to low levels (Goran Nordlander, personal communication January 2016). In extreme cases, and periodically, complete defoliation can result in tree mortality. Outbreaks in its main area of influence, notably Poland and Germany, are, like many forest pests, periodic and as pointed out by Sierpinska (1996) have become more prevalent in the 20th century (see Table 1 from that paper, reproduced below)

Table 1. Pine moth outbreaks in Poland, 1791-1996

Years	Region of occurrence
1791 - 1792	West Pomerania
1863 - 1872	from Saxony to Masuria
1905 - 1909	Zagan Forest
1925 - 1927	Pomerania and Mazovia
1936 - 1937	Kurp Forest, Tuchola Coniferous Forest and Poznan province
1946 - 1952	West Pomerania, Zagan Forest, Kurp Forest and White Forest
1956 - 1957	Poznan and Tarnow provinces
1964 - 1975	from Notec Forest on the west to Augustow Forest on the north-east and Solska Forest
1982 - 1985	Pomerania and Zielona Gora province
1992 - 1996	Zielona Gora province, Tuchola Coniferous Forest, White Forest and Green Forest

The latter was by far the largest of the recorded outbreak periods, peaking at around 58,000 ha.

Although precise costs were not given, it was noted in the above paper that in the period 1946-1995, more than 200,000 hectares were treated by aerial application to manage the moth populations in Poland.

Significant defoliation was seen in the Mediterranean region of Croatia in 2014, however this was followed by good recovery of the trees in the following year. This recovery is believed to have been enabled by the naturally occurring entomopathogenic fungus *Beauveria bassiana*, which killed caterpillars overwintering in the soil (Pernek, 2014).

Damage caused by the current, limited population in Scotland has been **low**. This may be due to differing environmental conditions compared to the continent not encouraging a population outbreak – the population in Scotland appears to have a two year generation cycle, compared to predominantly a one year cycle seen in areas of Germany where the pest is most important (Möller, K (2012), or the trees possibly being under less stress than is supposed in the outbreak on Furuskar Island in Sweden. The recent model predictions by Ray *et al* (2016) suggest that, under future climates, the likelihood of outbreaks in parts of Scotland and elsewhere in the United Kingdom increases over time.

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

Moderate
Level of uncertainty: medium

Tree damage similar to that noted in its continental Europe range could occur in the PRA area, where pine trees are a major component of forests and woodlands and of high economic, social and environmental value. Since outbreaks in its native range in Europe are associated with hot, dry summers, such climatic triggers would need to be present in the PRA area. These are most likely to be encountered in the south of the PRA area (notably southern England). In parts of the PRA area, other biotic agents, such as pine sawfly (*Neodiprion sertifer*), pine beauty moth (*Panolis flammea*) and pine looper moth (*Bupalus piniaria*), cause defoliation and could combine with *D. pini* to increase tree damage and possible mortality.

Personal communication (January 2016) from Goran Nordlander in relation to the outbreak on Furuskar Island in Sweden indicated that trees that had been attacked in 2012 were still alive in 2013 but by 2014 were being heavily attacked by pine shoot beetle, *Tomicus piniperda*, indicating weakness in the trees and increased susceptibility to bark beetle attack. The surprise nature of the attack and very low frequency of attacks in Sweden suggest that prediction of when attacks are likely in the PRA area will be difficult bearing in mind that climate change will affect conditions in the future, but also that the situation may be more complicated, with other factors that may stress trees also playing a role.

6.03 - How great a negative effect is the pest likely to have on yield and/or quality of cultivated plants in the PRA area without any additional control measures?

Moderate
Level of uncertainty: medium

Reductions in growth and, at the highest attack densities, tree mortality could occur if the pest was able to reach similar population levels to those noted in Germany and Poland, and such situations are only likely to occur in Forestry situations, not nurseries. However, there is medium uncertainty about whether this level of population growth could occur under the climate conditions in the PRA area, although the recent paper by Ray *et al* (2016) suggests an increased likelihood of outbreaks occurring in some areas in the future. Risk modelling for *D. pini* establishment and outbreaks for the USA has also included projections for European conditions, with mapping suggesting a high likelihood of growth and survival over most of the United Kingdom (http://uspest.org/wea/Dendrolimus_pini_model.pdf) (Figure 9).

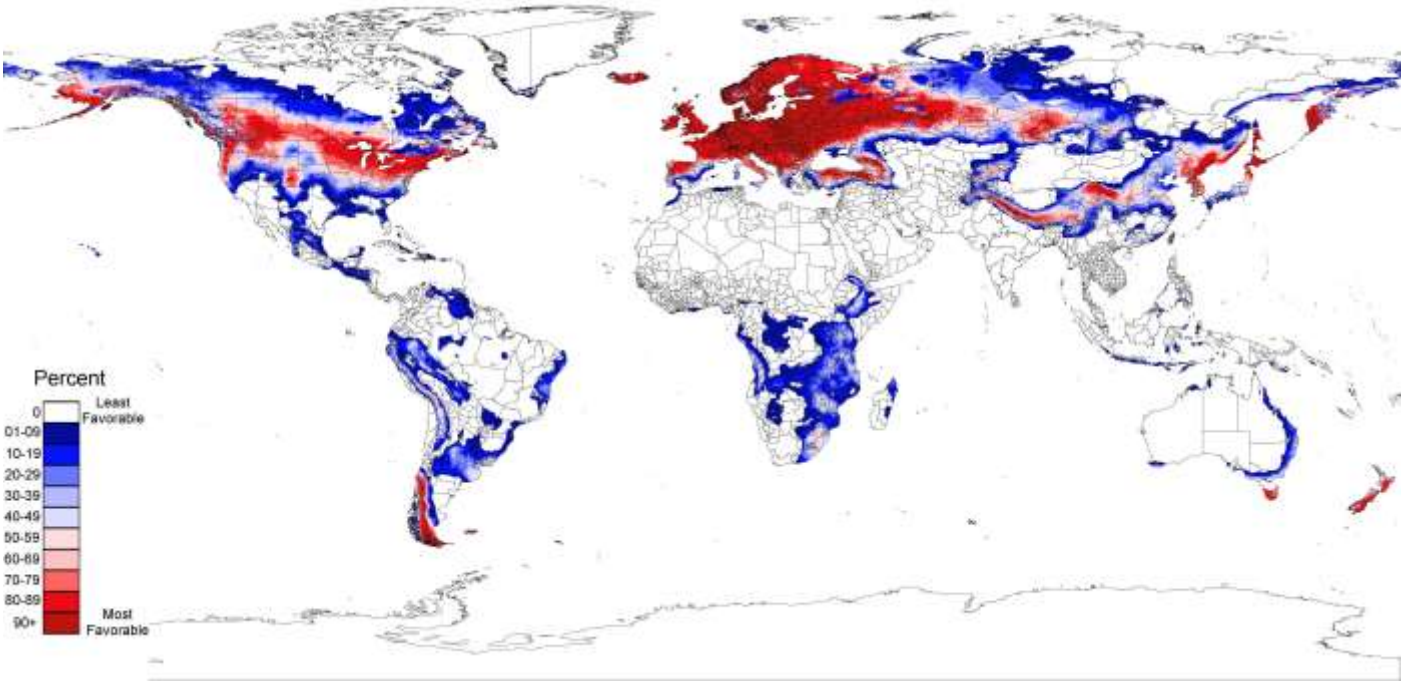

Figure 9: NAPPFAST Risk Map for Establishment Potential Based on Climatic Suitability of *Dendrolimus pini* in the Conterminous United States (map created by Jessica Engels, Roger

Magarey and Dan Borchart; USDA-APHIS-PPQ, Raleigh, NC). The NAPPFAST risk map describes the relative climatic suitability (on a scale of 1-10) for a pest to grow and survive. The maps are based on 10-years of daily data from NAPPFAST. A value of one represents a low likelihood of pest growth and survival, while a 10 indicates high likelihood of pest growth and survival. From USDA (2012)

The recent outbreak on an island in Sweden does indicate that, despite apparently limiting average climate conditions, it is still possible to have massive population increase; however, there is also the possibility that abiotic conditions other than climate may also have been having an effect. Additionally, it is not known if there are any naturally occurring parasitoids or other potential biological control agents already in the UK, which may affect population levels, as occurred in the recently recorded outbreak in Croatia (Pernek, 2014). To date, high density attacks have not been found in the parts of the PRA area in which the pest has established. Taking the worst case, but acknowledging uncertainty, the overall view is that the negative effect is likely to be moderate.

6.04 - How great a negative effect is the pest likely to have on yield and/or quality of cultivated plants in the PRA area when all potential measures legally available to the producer are applied, without phytosanitary measures?

Moderate
Level of uncertainty: low

It would be difficult and expensive to control the pest especially once it is firmly established (which appears to be the case currently in parts of Scotland). Although the aerial application of insecticides against other damaging moth species (*Panolis flammea* and *Bupalus piniaria*) has been carried out (last spraying took place in 1992/3) in the Scottish part of the PRA area occupied by *D. pini*, there are strong environmental reasons to avoid such processes unless they are essential. Other potential techniques such as tree glue-banding (to capture migrating larvae on the trunks - currently being used, but proving particularly challenging in the newly discovered outbreak in Glen Strathfarrar where trunk fissures and difficult access to trees make application of bands ineffective or impractical) and mating disruption (potential, but no current testing or detailed knowledge) could be employed but these are most valuable at lowering population densities and are not feasible for eradication. In view of the above, if populations increase in density then damage will increase despite application of the existing control measures listed.

6.05 - How great an increase in production costs (including control costs) is likely to be caused by the pest in the PRA area in the absence of phytosanitary measures?

Minor
Level of uncertainty: low

Increased surveillance in relation to protection of the pine forests and woodlands in the UK is likely to increase costs of managed forest protection measures. If the pest was to increase to damaging levels, loss of growth increment and potential tree mortality would also need to be factored into general production (i.e. projected yields and downstream income reduction), control and management costs. Forestry and ornamental nurseries may incur costs due to an increase in the use of chemical controls and establishing place of production freedom from the pest.

6.06 - Based on the total market, i.e. the size of the domestic market plus any export market, for the plants and plant product(s) at risk, what will be the likely impact of a loss in export markets, e.g. as a result of trading partners imposing export bans from the PRA area?

Minor
Level of uncertainty: low

There is the possibility that other countries, notably Ireland (which does not currently have *D. pini*

and which is likely to wish to keep the pest out of the country), would require phytosanitary measures to avoid possible importation of the pest, thus adding to costs of exportation of wood from the PRA area. The domestic market would only be impacted if loss of growth (less yield per ha) and, potentially, early and non-planned harvesting of wood which might impact on the demand side for export and reduce the price achieved by the grower.

6.07 - To what extent will direct impacts be borne by producers?

Minor extent
Level of uncertainty: medium

Since massive tree mortality is unlikely, the impacts will be potentially due to loss of growth increment or the need to fell prematurely which, again, would result in less yield per ha. However, since pine is not the sole conifer in most forest operations, the overall impact is likely to be relatively low unless there was, unexpectedly, a great increase in tree mortality and the possible need to switch tree species.

Following the discovery of breeding populations of the moth, timber movement restrictions had a significant impact on cost and practicality when they were first introduced (initially, timber movement from the infested area was restricted to the winter, i.e. just 3 months). In the light of experience and evaluation of risk since 2009, timber movement is now permitted outside the period of highest risk, i.e. timber can be moved, with baseline biosecurity precautions, from mid-May to the end of August. However, this remains under review and extension or increase in timber movement restrictions could result in potentially higher costs to owners by preventing extraction during the drier summer months plus added paperwork via Plant Health administration requirements.

6.08.0A - Do you consider that the question on the environmental impact caused by the pest within its current area of invasion can be answered?

Yes

There is sufficient information to conclude that the moth could cause defoliation (leading to growth losses and loss of amenity and environmental value, including impacts on ecosystem services) or even tree death and, therefore, there could be significant environmental impact.

6.08.01 - To what extent does the pest cause a decline in native species?

Low extent
Level of uncertainty: medium

There is currently no detectable impact on either the host tree (Scots pine) or other species in the same ecosystem. Thus the current response is that there is a low extent of native species decline in the affected part of the PRA area. There is no evidence of permanent decline of other species in any part of the moths current range.

6.08.02 - To what extent does the pest cause changes in the composition and structure of native species communities?

Low extent
Level of uncertainty: medium

In view of the current restricted distribution of the pest and its very low population density, there is no measurable change in the composition and structure of native species communities in the PRA area. Recent communication with Goran Nordlander concerning the outbreak on Furuskar Island, Sweden confirmed that the defoliation had a significant effect on ground vegetation and bird populations; " It was also extremely quiet on the island as there were almost no birds in the trees".

6.08.03 - To what extent does the pest hybridize with native species?
Low extent
Level of uncertainty: low
There are no native species that could hybridize with the pest, and no records of this pest ever doing so elsewhere in its range.

Alteration of ecosystem processes and patterns

6.08.04 - To what extent does the pest cause physical modifications of habitats (e.g. changes to the hydrology, significant increase of water turbidity, light interception, alteration of river banks, changes in fire regime, etc.)?

Medium extent
Level of uncertainty: low

By causing occasional severe defoliation and tree death, the pest can cause considerable alteration to a range of ecosystem services, including tree species mix, soil stability, water flow and light interception which could affect ground flora. See question below for more detail.

6.08.05 - To what extent does the pest cause changes in nutrient cycling and availability (e.g. significant changes in nutrient pools in topsoils or in water)?

Medium extent
Level of uncertainty: medium

Leaf litter production and nutrient impacts of larval faeces from extreme defoliation have been noted as significant factors in nutrient cycling by Larsson & Tenow (1980). During high population outbreak episodes the combination of needle loss and nutrient transfer to the ground through insect faeces can be significant contributors to nutrient movement and potential loss. Recent communication with Goran Nordlander concerning the outbreak on Furuskar Island, Sweden confirmed that the defoliation had a significant effect on ground vegetation and bird populations; "The ground vegetation at Furuskar was remarkably affected in 2014 by the fertlizing caused by the dying trees and by more sunlight reaching the ground. There was more grass than before and the blueberry (*Vaccinium myrtillus*) and heather had grown unusually tall. ".

6.08.06 - To what extent does the pest cause modifications of natural successions (e.g. acceleration or temporary freezing of successions)?

Low extent
Level of uncertainty: medium

There is no evidence of this in the pests' current distribution. Although tree mortality, as an extreme event, could cause changes in natural succession, the overall impact on such processes is likely to be low, particularly since there are many other host trees available to dilute the effect of the moth on natural regeneration processes.

6.08.07 - To what extent does the pest disrupt trophic and mutualistic interactions (e.g. disruption of food web, pollination or plant-mycorrhiza webs leading to ecosystem imbalance)?

Medium extent
Level of uncertainty: medium

There could be effects on biodiversity and effects on understorey vegetation (positive effects if light penetration is increased arising from defoliation) in severe defoliation episodes. This does not appear to be a very significant effect in the natural range of the moth since defoliation episodes tend to be episodic and tree growth and regeneration does not appear to be affected during low density

periods of the moth cycle. The recent outbreak on Furuskar Island in Sweden provided evidence that changes in nutrient availability and light penetration had a significant effect on understorey vegetation and on bird populations on the island (Goran Nordlander personal communication; see question above).

Conservation impacts

6.08.08 - To what extent does the pest occur in habitats of high conservation value (includes all officially protected nature conservation habitats)?

Medium extent
Level of uncertainty: low

The moth has a very wide geographical range which spans sites of high conservation value. With regard to the PRA area, the main concern is the possible establishment of the pest in areas where the relict Caledonian Scots pine is prevalent. Impacts through defoliation and tree loss have impacted ecosystem services in the main outbreak areas in Europe. Apart from the obvious effects arising directly through defoliation (Sierpinska, 1998), other impacts include changes to the C:N ratio in forest soils arising from large quantities of larval frass in outbreak situations (Le Mellec *et al*, 2009).

6.08.09 - To what extent does the pest cause harm to rare or vulnerable species (includes all species classified as rare, vulnerable or endangered in official national or regional lists within the PRA area)?

Medium extent
Level of uncertainty: medium

As indicated above, one of the main concerns is the potential impact on Caledonian Scots pine which could be severely affected at high moth densities. Hence, considerable effort is being expended on reducing the likelihood of the moth reaching centres of native Scots pine in Scotland.

6.08 - How important is the environmental impact caused by the pest within its current area of invasion?

Moderate
Level of uncertainty: low

As a periodic pest of Scots pine and other conifers, there are some outbreak periods (sometimes over a number of years) when severe defoliation makes it necessary to control the moth using insecticides (Sierpinska 1998; Adomas, 2003; Gowacka et al. 2000; Moeller *et al*. 1998). Currently in Scotland the moth is at very low levels and no visible defoliation has been detected. However, the concern remains that populations levels similar to mainland Europe could be experienced, especially if the moth reaches the warmer parts of the PRA area, or if the climate changed.

6.09.0a - Considering the conclusion of the establishment part (on hosts and habitats, climatic conditions, abiotic factors, management methods), are the conditions in the PRA area sufficiently similar to expect a similar impact?

Yes
Level of uncertainty: moderate.

The wide distribution of suitable tree hosts and the climatic conditions throughout the PRA area, but especially in the south of England, indicate that impacts from the pest could be reasonably high. However, uncertainty is given as moderate, as the combination of factors leading to significant defoliation appears to be more complex than climatic temperatures.

6.09.0b - Does the same native species or community, or the same threatened ecosystem

services, occur in the PRA area and, if not, is it known whether the native species or communities, or ecosystem service in the PRA area are similarly and significantly susceptible?

Yes
Level of uncertainty: low

Tree species (Scots and other pines as well as alternative conifer species) are widely available throughout the PRA area and are likely to be under the same level of threat from the pest.

6.09 - How important is the environmental impact likely to be in the PRA area?

Moderate
Level of uncertainty: low

Dendrolimus pini could cause considerable damage and loss of vigour to pine trees in the ancient Caledonian Pine Forests of Scotland as well as to pine and, occasionally, other conifer species of economic, amenity and social value across the UK as a whole. The expected low frequency of heavy defoliation, however, would mean that the impacts would be periodic and there could be episodes when there is little or no impact.

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

Moderate
Level of uncertainty: low

The interaction of people and trees is an increasingly important element in determining the potential of social damage arising from biotic, abiotic or anthropogenic influences (Cheng, Kruger & Daniels 2003). The various episodes of defoliation from *D. pini* and other defoliating species of pine have received considerable attention in Europe, leading to frequent applications of pesticides to protect the trees.

As noted by Moore, Allard & Malagnoux (2006), citing Diaz (2005), contact with living or dead *D. pini* larvae or pupae can result in skin dermatitis, inflammatory arthritis, cartilage inflammation, chronic osteoarthritis and, rarely, acute scleritis (inflammation of the tough white outer coat of the eyeball). Whilst these are most likely to be encountered when populations of the moth are extremely high, they serve as a warning that additional human and animal health issues could be encountered.

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

Moderate
Level of uncertainty: low

The increase in public access to forests in the PRA area, potential human and animal health issues and the greater awareness of the environmental and amenity values of public and private forests indicates that damage arising from the moth could have a considerable social impact. The expected low frequency of heavy defoliation, however, would mean that the impacts would be periodic and there could be episodes when there is little or no impact.

6.12 - To what extent is the pest likely to disrupt existing biological or integrated systems for control of other pests?

Minimal
Level of uncertainty: low

There are currently little or no biological or integrated systems for control of other pests on the same

host tree species. Previously, direct application of microbial agents to manage pine beauty moth populations could have been affected by measures to control *D. pini*. The decreased planting of lodgepole pine (*Pinus contorta*) in Scotland has reduced the prevalence of pine beauty moth and direct measures to control populations have not been needed since the early 1990s. However, since the timing of damage is similar, the same measures would have controlled both pests and hence there would be minimal impact.

During the initial phase of timber movement restrictions in managing *D. pini* in Scotland there were collateral impacts in terms of thinning and, to a lesser extent, clear felling. If this had continued, this would have had significant implications for the management of foliar fungal pathogens such as Dothistroma needle blight for which opening up the canopy by thinning is a component of management.

6.13 - How great an increase in other costs resulting from introduction is likely to occur?

Minor
Level of uncertainty: low

As indicated above, the increase in costs relate mainly to increased surveillance and, potentially, to longer-term impacts on the ability to export to Ireland. Taken together, these are not likely to be significant, at least in the immediate future.

6.15a - Describe the overall economic impact *(sensus stricto)*

Moderate
Level of uncertainty: moderate

The economic, environmental and social impacts are at present likely to be most significant in Scotland but, if the pest spreads, or is introduced elsewhere, could be more important in the remainder of the PRA area where Scots and other pines are prevalent. Infestation levels and damage could be periodically high, depending on the cyclic nature of the defoliation episodes, as observed in continental Europe, however there is moderate uncertainty as outbreaks appear to be due to a combination of factors, including temperature, moisture and the generation time for the moth.

6.15b - With reference to the area of potential establishment identified in Q3.08, identify the area which at highest risk from economic, environmental and social impacts. Summarize the impact and indicate how these may change in future.

Moderate
Level of uncertainty: low

Although environmental impact could be relatively high in Scotland due to the possible effects on Caledonian pine, the greatest potential for population growth remains in the south of the PRA area (southern England and eastern parts of Wales) where climatic suitability combined with high host tree availability are likely to be more conducive to population growth by the pest.

In terms of economic impact in the currently affected part of the PRA, pinewoods form a very significant component (up to 50%) of the woodland resource in the potentially more vulnerable area of north-east Scotland. These are already facing tree health challenges from other pests and pathogens, so the arrival or spread of an additional potential tree pest would be of significant concern to the commercial timber sector in this area.

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

c2 - Degree of uncertainty : list sources of uncertainty

The main areas of uncertainty relate to the likelihood of the pest reaching outbreak population densities under the range of climates and other abiotic conditions likely to be encountered in the PRA area. In Scotland, the infestations are currently limited in extent and severity and it is, therefore, still too early in the infestation cycle to draw firm conclusions on future population trends. The fact that the moth can outbreak in its current European range in a range of climatic and environmental conditions suggests that outbreaks could also occur in the PRA area, particularly in the warmer and drier southern parts of the area.

There is little uncertainty concerning the principal pathways by which the moth probably arrived in the PRA area and by which it could still be moved both into and within the PRA area.

c3 - Conclusion of the pest risk assessment

Although there is relatively limited new information since the original PRA was prepared in 2009, the overall conclusion remains that the pest poses a potential threat to pine trees in both forest and woodland situations throughout the PRA area. Consequently, it continues to represent a potential phytosanitary threat that requires continued vigilance in its current area of infestation in Scotland and attention to the possibility that, through the identified pathways, the pest could extend its range into other parts of the PRA area where the impacts could be greater if the moth was to establish.

Stage 3: Pest Risk Management

A decision has to be made to determine whether the risk from any pest/pathway combination is an acceptable risk. This decision will be based on the relationship between the level of risk identified in the pest risk assessment stage (i.e. the combination of the probability of introduction and the potential economic impact) and the importance/desirability of the trade that carries the risk of introduction of the pest.

7.01 - Is the risk identified in the Pest Risk Assessment stage for all pest/pathway combinations an acceptable risk?

No

There are clear risks from the principal pathways identified.

7.02 - Is natural spread one of the pathways?

No

The very limited flight capacity of the female moth indicates that natural spread is a low risk pathway, particularly for new entry to the PRA area.

Pathway 1: Plants for planting of host plants

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

Yes

Although relatively restricted due to issues from a number of pests and pathogens, the movement of live plant hosts is an identified risk.

7.09 - If the pest is a plant, is it the commodity itself?

No

The pest is an insect that is moved on the plant.

7.10 - Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest? (if yes, specify the measures in the justification)

Yes

Level of uncertainty: low

Although *D. pini* is not a regulated pest in the EU Directive, there are a number of other pests and pathogens that place restrictions on the movement of plants for planting and could, therefore, either prohibit plant movements of make it easier to spot contamination by *D. pini*. Whilst there might not directly prevent the introduction of the pest, they could reduce the overall likelihood of arrival (see Council Directive 2000/29/EC and its modifications). As documented in the entry section, the majority of *Pinus* imported into the UK will be ornamental trees. They are subject to a pre-notification scheme, should have plant passports and if they are over 3 metres tall will have to meet the UK wide Protected Zone requirements for *Ips amitinus*, *I. duplicatus* and *I. typographus*. The requirements for bark beetles are that the plants originate from a pest free place of production, which many nurseries will be. Plant passports will not cover unregulated pests, however, they do mean that the plants should have been checked prior to import. Currently the UK Plant Health Seeds Inspectorate (PHSI) target consignments from specific origins, based on risk from certain pests such as pine wood nematode and pine processionary moth, the distribution of which does cross over with *D. pini*, but does not match it.

7.11 - Are the measures likely to change in the foreseeable future?

Yes
Level of uncertainty: low

Changes to the EU Directive 200/29/EC are being made regularly and the recent review of the EU Plant Health Regime may lead to changes in the ways in which Plants for Planting are dealt with at the EU level. The concept of the 'clean plant' could result in fewer pests in general moving along this commodity pathway (see https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/307355/pb14168-plant-health-strategy.pdf).

Options at the place of production

7.13 - Can the pest be reliably detected by visual inspection at the place of production (if the answer is yes specify the period and if possible appropriate frequency, if only certain stages of the pest can be detected answer yes as the measure could be considered in combination with other measures in a Systems Approach)?

Yes in a Systems Approach
Level of uncertainty: medium

Complementary answer:
Visual inspection at the place of production

Visual examination of plants for planting for the presence of larvae and pupal cocoons during the growing season should reveal the presence of infestation. However, eggs would be more difficult to see and could be potentially missed. Any indication of infestation in the immediate vicinity of the place of production would also serve to warn of possible contamination. During the dormant season the presence of larvae in the soil beneath the plants would be impossible to detect visually. Consequently the periods during egg production and larval dormancy would make it difficult to detect infestation visually on plants for planting. However, a systems approach in which inspections concentrate on the larval stages feeding on the host plants in the two seasons prior to lifting the plants for onward movement could, at least partially, overcome the difficulties of inspecting for eggs and soil-located larvae.

7.14 - Can the pest be reliably detected by testing at the place of production? (if only certain stages of the pest can be detected by testing answer yes as the measure could be considered in combination with other measures in a Systems Approach)

NO
Level of uncertainty: low

Other than visual inspection, there is no reliable testing method.

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

Yes in a Systems Approach
Level of uncertainty: low

Complementary answer:
Specified treatment of the crop

Insecticide treatment of the plants at the time of adult flight could act as a preventative measure. However, there are no data to support this approach and it would require verification. Routine application of a contact or systemic insecticide to trees to kill feeding larvae could also be an option but, again, this would need to be tested and would not be a measure of choice because of the difficulty of ensuring adequate coverage and efficacy. The location of place of plant production

would also be need to be separated from natural pine forest/woodland to ensure no larvae were able to gain access to the planting medium for over-wintering. These measures would need to be combined in a systems approach to ensure high awareness of moth activity in the general area and increased inspection, combined with possible insecticide treatments, to ensure pest freedom.

Whilst these measures are theoretically possible, their implementation in practice could be very difficult due to cost and time constraints.

7.16 - Can infestation of the commodity be reliably prevented by growing resistant cultivars? (This question is not relevant for pest plants)

No
Level of uncertainty: low

There is no evidence to support the view that resistant cultivars of pine or other conifer hosts are available.

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

Yes in a Systems Approach
Level of uncertainty: low

Complementary answer:
Specified growing conditions of the crop

Protected indoor greenhouse conditions throughout the production cycle with a sterilised growing medium may be sufficient to ensure that the chances of infestation are kept to a minimum. This would also need to be combined with knowledge of local population pressure to ensure that the likelihood of female moths being attracted to the area (e.g. flight of adults to lighting at the place of production) and laying eggs on the protected plants is accounted for. It is possible that this could be used for forest reproductive material and small ornamentals, but unlikely that it could be used for large ornamental plants.

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

No
Level of uncertainty: low

Plants for planting could have live stages of the moth at any time of the year. The nature of trade in this pathway tends to favour the dormant season when the larval stage is present in the soil and hence this is also the time when it is most difficult to spot the moth.

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

Yes in a Systems Approach
Level of uncertainty: medium

Complementary answer:
Certification scheme

The earlier comments in relation to intensive inspections during at least two larval feeding periods on the plants and awareness of the risk of egg laying during the final year of growth prior to lifting of plants for onward movement could be covered in a certification scheme within a systems approach.

However, this would need to be developed specifically and is not a current method of production and may not be feasible in practice.

7.20 - Based on your answer to question 4.01 (low rate of spread with low uncertainty), select the rate of spread.

Low rate of spread
Level of uncertainty: low

Complementary answer:
Pest-free place of production or pest free area

The natural rate of spread is low and will reduce the likelihood of females ovipositing on plants for planting provided that the place of production is separated from adjacent standing crops.

7.21 - The possible measure is: pest-free place of production or pest free area
Can this be reliably guaranteed?

No
Level of uncertainty: medium

Within a systems approach the pest-free place of production could work well provided that a strict regime of inspection supported by high awareness of moth activity in forests nearest to the place of production. Under current regimes this cannot be reliably guaranteed, but could be developed for the future. It would, however, increase costs for the producers and its practicality in the longer term would need to be assessed in relation to cost and efficacy.

Options after harvest, at pre-clearance or during transport

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

No
Level of uncertainty: low

Since the most likely time to move consignments is during the dormant period of the host plant (although larger potted trees could be moved at other times of the year), visual inspection for the presence of larvae in the soil is not regarded as a reliable visual inspection procedure.

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

No
Level of uncertainty: low

Other than visual inspection, there is no reliable testing method.

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

Yes as standalone measure
Level of uncertainty: medium

Application of a systemic or contact insecticide would deal with stages on the host plant itself. A soil drench with suitable insecticide could kill the soil-based larval stages during the dormant season. However, these measures have not been developed for this particular pest. The use of sterile soil

medium could remove the soil-based larval stages but this would need to be carried out by replacing the existing growing medium in the period after larval migration to the soil has taken place.

7.25 - Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment? (This question is not relevant for pest plants)

Yes in a Systems Approach
Level of uncertainty: medium

Complementary answer:
Specified treatment of the consignment

It would not be possible to remove any parts of the plant during the growing season but removal of the soil and replacement with sterile growing medium after larvae have migrated to the soil in the dormant season of the plant could minimise the likelihood of the pest being present.

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

Yes in a Systems Approach
Level of uncertainty: medium

Complementary answer:
Specific handling/packing methods

Use of bare-rooted stock during the dormant season would remove all overwintering larval stages. Similarly, replacement of the growing medium with new sterile growing medium during the dormant season would remove overwintering larvae and render the plants pest-free.

Options that can be implemented after entry of consignments

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

Yes in a Systems Approach
Level of uncertainty: medium

During the usual period for moving plants in the dormant season, it would be impossible to detect larvae unless the soil was removed completely from the roots and inspected carefully. This is not practical for large numbers of plants. If the plants were imported during the growing season, careful inspection could reveal feeding larvae, but this would be unreliable for small larvae (or any remaining unhatched eggs). Conceivably, a period of post-entry quarantine under secure containment (greenhouse or polytunnel) during the whole of the growing season could reveal any emergent larvae that could have escaped detection. However, this is unlikely to be practical in large-scale practice.

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

No
Level of uncertainty: medium

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

impacts?

Yes
Level of uncertainty: high

Complementary answer:
Internal surveillance and/or eradication or containment campaign

In theory, inspection of plants during the year after planting could reveal any larval feeding in time for the plants to be treated with insecticide to prevent development to pupae and new adults. This would require intensive inspection and effective application of insecticides (contact or systemic) to ensure complete freedom from the pest. Whilst theoretically possible, this is likely to prove difficult and expensive in practice. Use of pheromone traps (for emergent male moths) and light traps (for adults of both sexes) could supplement visual inspections but would be too late to prevent spread of the pest.

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

Q.	Standalone	System Approach	Possible Measure	Uncertainty
7.13		X	visual inspection at the place of production	medium
7.15		X	specified treatment of the crop	low
7.17		X	specified growing conditions of the crop	low
7.19		X	certification scheme	medium
7.20		X	pest-free place of production or pest free area	medium
7.24	X		specified treatment of the consignment	medium
7.25		X	removal of certain parts of the plant products	medium
7.26		X	specific handling/packing methods	medium
7.27		X	Potential for special case post-entry quarantine	medium
7.29	X		internal surveillance and/or eradication or containment campaign	high

Yes

A systems approach at the place of production could result in pest freedom provided that the combination of measures are applied rigorously. The practicality in terms of efficacy and cost of such a systems approach would need to be assessed to determine whether it could be put into place at acceptable cost in financial and resource terms.

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

No
Level of uncertainty: medium

As indicated, a combination of measures within a systems approach would need to be applied to act both in parallel and in sequence to reduce the likelihood of pest presence on the pathway.

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

Yes
Level of uncertainty: medium

Combinations of measures, especially those that use knowledge of local pest pressure, distance from the nearest infested forest and rigorous inspection of plants during the growing season when feeding larvae would be present, could result in pest freedom. This can be further enhanced by replacing soil with sterile growing medium prior to onward distribution of plants during the dormant season.

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

Level of uncertainty: medium

These measures are **very likely** to interfere with international trade. All measures of growing under controlled conditions and monitoring of environment around the production area would be likely to have a significant effect on production costs. Apart from the increased surveillance and phytosanitary inspectorate costs, the additional labour and material costs of re-planting with sterile media prior to despatch in the plants' dormant season will further increase the overall cost.

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

Level of uncertainty: medium

It is difficult to estimate whether the combination of measures are cost-effective. If the trade is high value then the measures could ensure that such a trade continues. However, these measures also have to be combined with measures to ensure freedom from other pests and pathogens (see EC Directive 200/29/EC) that may require further inspection or treatment measures. The only measures that could have undesirable social or environmental consequences are application of insecticides that could impact on those handling the plants or could affect non-target organisms that could be associated with the plants.

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

No

Whilst the combination of measures identified could enable international trade to continue, the difficulty of ensuring pest freedom without greatly increasing costs suggests that the measures may be difficult to apply or have poor producer uptake.

Pathway 2: Contaminated machinery or vehicles

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

No

7.07 - Is the pathway that is being considered the entry with human travellers?

Yes

Machinery and vehicles is a human-mediated pathway.

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

Yes
Level of uncertainty: low
Complementary answer:

Internal surveillance of campaign to "keep it clean".

Thorough cleaning of machinery to remove soil and plant parts and debris at departure from infested areas would be effective in minimising the risk of pest movement along this pathway. The UK could undertake surveillance of this cleaning being carried out.

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

Q.	Standalone	System Approach	Possible Measure	Uncertainty
7.29	X		Thorough cleaning and inspection of machinery and vehicles at point of departure. Internal surveillance of cleaning campaign.	low

Yes

High awareness by operators, combined with thorough cleaning and subsequent inspection to ensure freedom from possible contamination.

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

No
Level of uncertainty: medium

A combination of measures (inspection, awareness, cleaning) is required.

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

Yes
Level of uncertainty: medium

Inspection, awareness and cleaning.

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

Level of uncertainty: low

The international movement of machinery is difficult to quantify but the measures to apply are relatively low cost and are part of good biosecurity management and, overall, should not interfere with international trade.

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

Level of uncertainty: low

The measures are relatively low-cost to apply and do not have undesirable consequences.

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

Yes

Awareness, inspection, cleaning and further inspection.

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

The plants for planting pathway is by far the most important pathway.

7.42 - All the measures or combination of measures identified as being appropriate for each pathway or for the commodity can be considered for inclusion in phytosanitary regulations in order to offer a choice of different measures to trading partners. Data requirements for surveillance and monitoring to be provided by the exporting country should be specified.

7.43 - In addition to the measure(s) selected to be applied by the exporting country, a phytosanitary certificate (PC) may be required for certain commodities. The PC is an attestation by the exporting country that the requirements of the importing country have been fulfilled. In certain circumstances, an additional declaration on the PC may be needed (see EPPO Standard PM 1/1(2) Use of phytosanitary certificates).

7.44 - If there are no measures that reduce the risk for a pathway, or if the only effective measures unduly interfere with international trade (e.g. prohibition), are not cost-effective or have undesirable social or environmental consequences, the conclusion of the pest risk management stage may be that introduction cannot be prevented. In the case of pest with a high natural spread capacity, regional communication and collaboration is important.

7.45 - Summarize the conclusions of the Pest Risk Management stage. List all potential management options and indicate their effectiveness. Uncertainties should be identified.

Eradication and containment for *Dendrolimus pini* depends very much on early detection of small populations of the moth. In the context of the current PRA, the aim is to survey and track what appears to be a pioneer population of the moth, which still appears to be restricted in its distribution and population size. In view of the environmental sensitivity, uncertainty about this potential pest's status as a non-native or native species, and the fact that the population is, at least currently, not showing signs of increasing to damaging outbreak levels, aerial application of pesticides is not a realistic option. An important measure is to prevent further spread of the moth by human means, especially to the areas of Caledonian pinewoods in Scotland and to the rest of the PRA area where climate conditions might be more conducive to increased population growth.

With regard to the PRA area as a whole, potential measures to reduce further incursions from outside the UK have been identified and these are based principally on managing the plants for planting pathway through place of production freedom (a range of possible measures in combination within a systems approach) followed by rigorous post-entry inspection, potentially linked to specific post-landing quarantine procedures. These approaches could also be effective in tracking and managing the infestation already present in the PRA area and in minimising the likelihood of spread and further introductions. The level of uncertainty is dependent on the quality of survey and inspection and, provided these are rigorous, there should be high likelihood of successful application of the measures. In relation to cost-benefit assessment of these measures, although this has not been carried out formally, it is likely that they would prove difficult to apply and expensive in practice to apply outside of the UK. In terms of managing the current UK infestation and preventing human mediated spread, they may be more manageable.

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