Department for Environment Food & Rural Affairs

Rapid Pest Risk Analysis (PRA) for:

Thaumetopoea pinivora

February 2016

Summary and conclusions of the rapid PRA

The northern pine processionary moth, *Thaumetopoea pinivora*, was identified as a potential risk to the UK through horizon scanning, and this PRA was requested to provide a more detailed assessment of the threat posed by this species. Like other species in the genus *Thaumetopoea*, as well as significant defoliation of pine trees in outbreak years, the larvae can also cause human health impacts through rashes caused by their urticating hairs. *Thaumetopoea pinivora* larvae feed over the spring and summer mostly on Scots pine (*Pinus sylvestris*), usually overwintering twice: as eggs the first year, and as pupae the second year. This is in contrast to the pine processionary moth (*T. pityocampa*), the subject of a rapid PRA in 2015, whose larvae actively feed throughout the winter. *Thaumetopoea pinivora* is mainly found around the Baltic Sea, though with scattered populations elsewhere in Europe, and is seldom found at high population densities. It is not known to be a pest of plantation pines. Thus, it is less likely than *T. pityocampa* to be present on imported plants as it is not associated with trees that are likely to be moved in trade, though the dormant eggs and pupae of *T. pinivora* are present on the trees for much longer. The risks posed by the two pine processionary moths are thus considered to be different in a number of aspects, and the ratings given in the two PRAs are not directly comparable.

Risk of entry

This was considered to be highest on plants for planting. Eggs are laid in a relatively cryptic mass round the needles of pine trees, while pupae are buried in the soil and could be associated with any plant imported with a sufficient quantity of soil. However, *T. pinivora* is apparently limited in distribution to trees growing on poor soil, and is not a known forestry plantation pest. Overall, entry on plants for planting was considered unlikely, but with medium confidence as data are incomplete. The import of soil as a commodity could contain pupae, but overall this pathway was considered very unlikely, with medium confidence as data on the quantities of soil imported to the UK are not collected. Cut branches were considered a very unlikely pathway with high confidence, as any eggs or larvae associated with this commodity would need to transfer to a new host to complete development. Natural spread, wood and hitchhiking were all considered to be pathways of negligible risk, and were not fully assessed.

Risk of establishment

There are very many uncertainties about what conditions most suitable for *T. pinivora* and hence this assessment is subject to a low level of confidence. Data from the native range are very fragmented, partial, and often difficult to piece together when assessing the overall risk to the UK. Even where information on variables was found, data on what the precise requirements of the pest might be are lacking. For example, while it is stated the moth prefers trees growing on poor soil, the exact reasons for this are unknown, though they may be linked to the trees growing more sparsely and thus providing more opportunities for early instar larvae to bask in sunlight. Overall, establishment was considered to be moderately likely outdoors, especially in more northern parts of the UK or in mountainous regions, and on pines grown in poor quality soil. These conditions were considered to be most favourable for establishment, but due to the many uncertainties all parts of the UK may be at some level of risk. This pest hatches in early spring, and prefers to feed on year-old pine needles. One factor that may hamper its establishment, at least in the southern part of the UK, is that the UK has comparatively mild winters, and the eggs may hatch much earlier than in the native range, still in winter. This would leave the early instar larvae vulnerable to a prolonged cold spell of weather. In winter, there will also be fewer hours of sunlight to allow the larvae to bask and raise their temperatures, and thus further reduce the chances of their survival.

Economic, environmental and social impact

The main impacts of *T. pinivora* are social, due to the urticating hairs present on the older larvae. These are released into the wider environment, and can cause skin rashes, breathing difficulties and even eye damage in humans and other animals, such as dogs. Hairs can still be present in the environment after the larvae have pupated, as the moulted skins continue to release the toxic hairs for some months.

Though the larvae do feed on pine needles, and complete defoliation has been recorded in outbreak years, no evidence of any long-term impacts on the trees, leading to economic or environmental impacts, were found. Additionally, outbreaks of *T. pinivora* are scarce and very seldom recorded in the native range, so in the overwhelming majority of years, the pest merely persists in a given area at a low level, causing very little damage.

Endangered area

Parts of the UK that have colder winters are considered most at risk, namely northern and mountainous areas, especially areas where *P. sylvestris* grows on poor-quality soil. This is because these areas most closely approximate the climatic conditions seen in the native range, which have very cold winters. However, this is very uncertain and all parts of the UK may potentially be at risk and could be included in the endangered area. Further, it is unclear if any part of the UK is at risk from economic or environmental impacts, but even low populations of *T. pinivora* have the potential to cause social impacts.

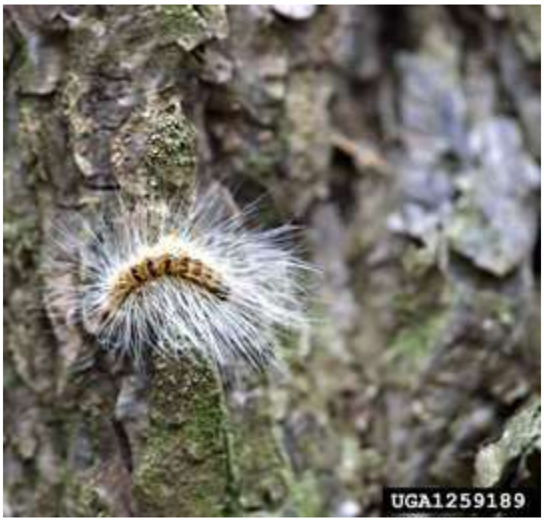
Risk management options

Continued exclusion would be the best option for the UK, as eradication measures are considered unlikely to succeed if the pest is able to spread into the wider environment. Requirements against eggs and larvae could be visual examination on pine trees for planting. However, visual detection of pupae buried in the soil is very difficult, and any measures targeted against the pupae (which could be present in the soil of any plant moved in trade from the range of *T. pinivora*) would be very difficult to design and implement.

Key uncertainties and topics that would benefit from further investigation

There are many uncertainties related to this pest, mostly relating to what conditions it requires in order to persist. Most of the research that exists has been done on one small population at the extreme southern tip of one Swedish island (Gotland), and the applicability of any or all of these results from the Gotland research to the wider population of *T. pinivora* is unknown. Thermal requirements for this pest are almost completely unknown, as are other factors, such as the intensity of sunlight required by early instar larvae, and other climatic factors. The importance of environmental factors is also unknown: this pest appears to be restricted to quite a narrow habitat range, apparently preferring trees on poor quality soils, which are slow-growing. So far, the attempts to quantify differences between outbreak and non-outbreak areas in Gotland have largely failed, and information on preferred habitat in other parts of this species' range are almost non-existent.

Images of the pest



Thaumetopoea pinivora larva on a tree trunk © Landesforstpräsidium Sachsen, Bugwood.org

Museum set specimen of adult *Thaumetopoea pinivora* © Vítězslav Maňák

Images of other life stages, such as eggs and early instar larval masses, are available in several sources, including Larsson (2006) and Ronnas (2011).

Is there a need for a detailed PRA or for a more detailed analysis of particular sections of the PRA? If yes, select the PRA area (UK or EU) and the PRA scheme (UK or EPPO) to be used.

No	✓				
Yes		PRA area: UK or EU		PRA scheme: UK or EPPO	

While there are significant uncertainties remaining about many aspects of this PRA, these are very unlikely to be resolved by a more detailed PRA. The remaining uncertainties are due to a lack of primary research and unavailable data, and further investigations at this time are unlikely to provide significant new information that will affect the assessments made in this PRA.

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

Yes Statutory action	✓	No Statutory action	

This is a very occasionally damaging pest of pine trees that is not found in the UK and as such, measures against this pest could be considered proportionate, to prevent the introduction of a non-native plant pest.

At least in its native range, this appears to be primarily a pest with impacts on human health, rather than on trees. However, at least in Scotland, the uncertainty over potential impacts on the iconic Caledonian pine forest means action against *T. pinivora* would be proportionate under plant health legislation. There are similar areas of potentially vulnerable forest elsewhere in the UK, for example Thetford forest, which has large areas of *P. sylvestris* growing on a mix of poor (sandy) and rich soils.

Stage 1: Initiation

1. What is the name of the pest?

Thaumetopoea pinivora (Treitschke 1834) (Lepidoptera, Thaumetopoeidae). Northern pine processionary moth.

The name eastern pine processionary moth may also be used for this species, as well as for an entirely different species, *Thaumetopoea wilkinsoni*.

2. What initiated this rapid PRA?

Horizon scanning identified this processionary moth, which feeds on pines, as being a species of potential concern to the UK. As a consequence, *T. pinivora* was assessed for inclusion in the UK Plant Health Risk Register[1]. During the discussions around this pest, the Plant Health Risk Group decided that a PRA was the best way of further assessing the level of risk posed to the UK from *T. pinivora.*

3. What is the PRA area?

The PRA area is the United Kingdom of Great Britain and Northern Ireland.

Stage 2: Risk Assessment

4. What is the pest's status in the EC Plant Health Directive (Council Directive 2000/29/EC[2]) and in the lists of EPPO[3]?

This pest is not listed in the EC Plant Health Directive and is not recommended for regulation as a quarantine pest by EPPO, nor is it on the EPPO Alert List.

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

Thaumetopoea pinivora is apparently only known from Europe (Table 1), where it has a rather scattered distribution, centred round the Baltic Sea but including populations in

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[1] https://secure.fera.defra.gov.uk/phiw/riskRegister/

[2] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000L0029:20100113:EN:PDF

[3] https://www.eppo.int/QUARANTINE/quarantine.htm

small disjunct mountainous areas in France and Spain (see Table 1). In northern parts of its range, i.e. round the Baltic Sea, it is found at lower altitudes.

Not included in Table 1 are reports from Bulgaria (Tsankov, 1985), Moldova (Schintlmeister, 2016), the Czech Republic and Romania (cited in Larsson *et al.*, 2008). The Romanian record is considered very improbable by Székely (1999), who was reviewing the list of Macrolepidoptera reported as present in Romania. All of the countries listed above are outside the area generally considered to be within the range of *T. pinivora*, and do not appear in detailed reviews of the distribution, such as those by Ronnas (2011) or Basso *et al.* (2015). Therefore, they are not considered further in this PRA.

Table 1: Distribution of *Thaumetopoea pinivora* (from Basso *et al.* (2015) unless otherwise stated)

North America:	No records
Central America:	No records
South America:	No records
Europe:	Denmark (island of Bornholm) (Wolff, 1938) France (limited areas in the South and East, such as Hautes-Alps and Haute-Loire (sketch map in Leraut, 2006)) Germany (limited eastern areas only (Brasicke, 2013)) Lithuania Poland Russia (Kalingrad) (Maslov *et al.*, 2009; Shapoval & Shapoval, 2007; Tsankov *et al.*, 1993) Spain (limited mountainous areas. Maps provided in Hódar *et al.* (2016)) Sweden (islands of Gotland and Öland: no known breeding populations on the mainland) (Ronnas, 2011)
Africa:	No records
Asia:	No records
Oceania:	No records

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

This pest has never been detected in the UK, nor intercepted on consignments of imported material. There are no UK species of moth with which *T. pinivora* might be confused (though careful examination might be necessary), but it is similar to *T. pityocampa*, which is also absent from the UK. However, both species are in France and Spain and thus, if detected on imported material, might need to be distinguished. Hence, some notes are given below on the separation of the two species.

The eggs of both species are laid round pine needles, and are covered with scales from the anal tuft of the female. These scales may help to distinguish the species, as *T. pinivora* scales are usually less than 2 mm long, while *T. pityocampa* are mostly 3 mm or longer (from image reproduced in Gomboc & Germain, 2004). There may also be a difference in the way the eggs are laid, with *T. pinivora* depositing eggs from the top to the bottom of the pine needle, while *T. pityocampa* egg laying usually starts from the bottom of the needle and moves up, at least in Greek populations (Tsankov *et al.*, 1993).

Larvae of the two species may be separated using their life histories. *Thaumetopoea pinivora* larvae hatch in early spring and are found through to early summer, feed only on pine and do not build silken nests. In contrast, *T. pityocampa* larvae hatch in late autumn and feed through the winter, are found on several coniferous species (including pine), and live in silken nests (Gomboc & Germain, 2004).

Though superficially rather similar in appearance, information is available on how to separate the two species as adults, with a structure called a canthus on the head allowing reliable separation of *T. pinivora* and *T. pityocampa* (images provided in Gomboc & Germain, 2004). Wing markings also show subtle differences between the two species (Gomboc & Germain, 2004; Leraut, 2006).

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

The main host is *Pinus sylvestris* (Scots pine) (Larsson & Battisti, 2015), but there are also records on *P. nigra* (black pine), with one population in Spain feeding exclusively on this host even though *P. sylvestris* was available (Hódar *et al.*, 2016). *Pinus mugo* (mountain pine) is another recorded host (Larsson & Battisti, 2015).

Pinus sylvestris is an important native species to the UK, and is very widely distributed throughout the country (BSBI maps, 2016). It is an environmentally important species, especially in Scotland (e.g. in the Caledonian pine forest), is grown as a forestry tree and, to a more limited extent, is also grown as an amenity tree in parks and gardens. *Pinus nigra* is found throughout the UK, but is more widely distributed in the south, while *P. mugo* is the least commonly planted species of the three (BSBI maps, 2016).

Juniperus (juniper) is also recorded as a host by Robinson *et al.* (2010). No other records of non-*Pinus* hosts for *T. pinivora* could be found elsewhere in the literature. Larsson *et al.* (2008) explicitly state that juniper is not attacked by *T. pinivora* in Gotland, despite the neighbouring pine trees being defoliated. Accordingly, *Juniperus* is not included in the assessments carried out in the remainder of this PRA.

8. What pathways provide opportunities for the pest to enter and transfer to a suitable host and what is the likelihood of entering the UK/PRA area?

The lifecycle of *T. pinivora* differs markedly from *T. pityocampa*, another pine processionary moth that was the subject of a Defra Rapid PRA in 2015, and thus many of the details discussed in the pathways are different between the two PRAs. *Thaumetopoea pinivora* has larvae which feed actively only in the spring and summer, and it usually overwinters twice, spending the first winter as eggs and the second as pupae. Thus there is a relatively long period over the whole life cycle in which it is dormant and relatively cryptic. In contrast, the previous PRA covered *T. pityocampa*, whose larvae actively feed throughout the winter, and which has only a short duration for both the egg and pupal life stages.

Plants for planting

Eggs are laid in a flattened mass round pine needles (in July/August in Gotland, Sweden), which overwinter before hatching the next spring (around mid-April) (Ronnas, 2011). Larvae are highly gregarious and tend to feed mostly at night. Early instar larvae bask in sunlight in large groups, typically at the ends of branches (but do not usually build silken nests). Older larvae are more likely to hide during the day, on the trunk or larger branches, again without building nests. Larvae feed on mature needles through the late spring and into the summer before pupating in the soil (around July in Gotland (Larsson *et al.*, 2008)). The pupae overwinter in cocoons underground, most emerging around a year later for a very brief adult flight period during which the next generation of eggs are laid (Larsson *et al.*, 2008). Though conclusive data are lacking, Larsson *et al.* (2008) consider it likely that some pupae undergo prolonged diapause, thus lengthening the lifecycle to three years or more. Larvae seem likely to be noticed on plants moved in trade, but eggs (and pupae if soil is present) could travel on this commodity.

The UK does import host species of pine from countries where *T. pinivora* occurs (see Tables 2 and 3), and all imports of pine are now subject to a statutory notification scheme in England, Scotland and Wales. Imports of bare-rooted trees will only have eggs associated with them, as pupae are found in the soil. Eggs are, however, quite cryptic and present for a long time, including over winter when trees are most likely to be moved. Eggs thus transported will remain with their host, and the larvae will be able to feed upon hatching. However, new hosts may need to be located to enable the larvae to complete development if the imported trees are small. As the larvae are sociable, the local defoliation could be significant, especially if the consignment has been split up and/or consists of small trees, thus reducing the quantity of needles available to the larvae. As well as causing defoliation, early instar larvae bask in large groups on the tips of branches (Larsson *et al.*, 2008), a behaviour that will considerably aid the detection of larval colonies on any post-import inspections that might be carried out. A factor that will lessen the association of *T. pinivora* with imported pine trees is that this is not generally considered to be a pest of commercial forestry trees. Ronnas (2011) sampled populations from across Europe by collecting larvae, and noted that populations of *T. pinivora* were only found on poor-quality soil with slow-growing trees, and were not associated with pines grown commercially on richer soils. This might be related to the higher density of plantation trees providing fewer opportunities for larvae to bask in sunlight. Additionally, while the data provided in Tables 2 and 3 covers whole countries, *T. pinivora* is only found in a limited area in each of the countries listed: for example, one island in Denmark, or small mountainous areas in the South and East of France (and plant nurseries are not usually found in mountainous regions, as the plants grow much more slowly). Thus, only a fraction (if any) of these imported trees may originate from areas where the pest is found.

Table 2. Imports of *Pinus nigra* and *P. sylvestris* (including both trees in containers with soil, and bareroot) from countries within the EU where *Thaumetopoea pinivora* is present, between 2003 and 2012. Source: Forestry Reproductive Material Database.

Host species	Origin	Year	Number of trees	Type
Pinus nigra	Denmark	2005	500	Bareroot
	Germany	2013	125	Bareroot
Pinus sylvestris	Denmark	2005	400	Bareroot
		2012	2,500	Bareroot
	France	2003	9,000	Bareroot (total of 4 consignments)
		2004	6,500	Bareroot (3 consignments)
		2009	20,700	Bareroot (4 consignments)
	Germany	2011	5,000	Bareroot
	*Czech Republic**	*2007*	*30,000*	*Containerised*

* The Czech Republic is not part of the validated species range of *T. pinivora* presented in Table 1. However, some sources do mention that *T. pinivora* is present in the Czech Republic, and thus, for completeness, Czech *Pinus* imports have been included in Table 2.

Table 3. Imports of *Pinus* (not always differentiated by species) to the UK, recorded under the statutory notification scheme, from countries where *Thaumetopoea pinivora* is present.

Origin	Jan 2013-Jan 2015		Jan 2015-Dec 2015	
	Number of notifications	Number of trees	Number of notifications	Number of trees
Denmark	68	28,220	0	–
France	11	114	20	1,833
Germany	109	3,447	269	3,872
Spain	2	30	0	–
Unknown	*50*	*1,404*	*0*	*–*

While eggs will only be associated with host plants, pupae could be transported in the soil of any plant grown in the vicinity of an infestation. As pupae are hidden underground, they are very unlikely to be detected during any plant health inspection. It is possible that pupae can have a prolonged diapause (Montoya & Robredo, 1972), meaning it could be several years before adults emerge. Pupae from Spain also show the ability to emerge within the same year of larval feeding, i.e., the lifecycle may last only one year for some individuals (Montoya & Robredo, 1972), which would reduce the chances of these pupae being associated with plants for planting. Once emerged, adults are the most mobile life-stage and it is probable that they would be able to locate suitable hosts for egg-laying. The volume of nursery plants for export grown in the vicinity of infested trees is unknown, but as *T. pinivora* has a relatively limited geographical distribution, and is not present in many areas that export a large number of plants to the UK, the risk of association of *T. pinivora* pupae with soil of rooted plants is not considered to be high.

Overall, the pathway of plants for planting, including both pine trees with eggs and all containerised plants with pupae, is considered to be unlikely, with medium confidence as many aspects of this pathway have little or no data to enable an accurate assessment to be made.

Soil

Pupation takes place in the soil (Larsson *et al.*, 2008), and so soil moved from areas where this pest is present could contain the pest. Larvae dig into suitable pupation sites as a group (Larsson, 2006), and thus there are likely to be a number of pupae in the same location, increasing the chances of sufficient numbers of individuals being imported to be capable of founding a new population. However, pupae are relatively large and it is considered likely that they would either be crushed and damaged during soil collection, or detected. Soil from Kalingrad (Russia) is a prohibited commodity under the EU Plant Health Directive 2000/29/EC (Annex III), but soil can be imported from European countries where the species is present, and this trade is unregulated. The volume of trade is not recorded, thus the potential volumes of soil moved from infested areas of Europe into the UK are unknown, though as *T. pinivora* has a relatively limited geographical distribution, total volumes seem likely to be very small. Overall, transport of viable pupae in soil is considered very unlikely, with medium confidence due to the uncertainties over the trade in soil.

Transport in soil associated with plants for planting is covered under that pathway in the discussion of pupae.

Cut plant parts

Cut branches of conifers are imported to the UK, e.g. for use in floral wreaths. Eggs and larvae could both be associated with this commodity, but larvae are conspicuous, especially as they are very sociable and live in large groups (though, unlike some other processionary caterpillars, they do not usually build nests). Therefore, it is most likely that egg masses on pine needles would be associated with the cut branches. Data on trade by tree species, or even genus, are not available, but the UK has imported small quantities of “Fresh conifer branches, suitable for bouquets or ornamental purposes” from Denmark and Germany in 2012, 2013 and 2014 (EUROSTAT data, retrieved 2 February 2016), the total ranging from a maximum of 206 tonnes in 2012 to a minimum of 48 tonnes in 2014. However, the pest is considered very unlikely to be associated with these imports, for a number of reasons. Firstly, the data presented for cut branch imports are for all conifer species, and pine will only make up an (unknown) proportion of these. Secondly, *T. pinivora* is not associated with all species of pine, further reducing the quantity of branches that might be infested. Thirdly, geographical limitations will apply: *T. pinivora* is only recorded from one island in Denmark, and is apparently also limited to the East of Germany (Basso *et al.*, 2015). Again, this reduces the proportion of branches from these countries, taken as a whole, which might contain the pest. And fourthly, as noted in under the plants for planting pathway, *T. pinivora* appears to be associated with slow-growing pine on poor soils (Ronnas, 2011), which are not the sort of trees whose branches would be cut for ornamental purposes.

If eggs were imported on cut branches, the behaviour of the newly-hatched larvae will make detection much easier since they live gregariously, and during the daytime, the early instars bask in a mass on the tips of the foliage (Larsson *et al.*, 2008). Given that wreaths, etc., are usually hung in highly visible places, it seems likely that an infestation would be detected once the larvae had hatched. Cut foliage also has a short lifespan, and will rapidly degrade and be disposed of. If larvae do emerge and are not detected, they will need to locate a suitable new host to continue development, and early instar larvae are not a particularly mobile life stage. If the foliage was discarded before the eggs hatched in a manner that did not destroy the eggs, such as on a garden compost heap, again, the larvae would need to locate a suitable host. Overall, the pathway of cut plant parts is considered very unlikely, with high confidence.

Christmas trees were not considered to be part of this pathway, as these are not usually *Pinus* species. However, if any import of Christmas trees were to consist of pine, the same considerations regarding limited commodity lifespan and the need for the pest to transfer to a new host listed for cut branches would also apply to Christmas trees.

Plants for planting	Very unlikely	☐	Unlikely	✓	Moderately likely	☐	Likely	☐	Very likely	☐
Confidence	High Confidence	☐	Medium Confidence	✓	Low Confidence	☐				

Soil	Very unlikely	✓	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely	☐

Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐	

Cut plant parts	Very unlikely ☑	Unlikely ☐	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		

Natural spread was not considered as a pathway, as though the findings of adults on the Swedish mainland are attributed to migrants from the islands where this pest is present, there is no evidence of dispersal over the longer distances such as would be required to reach the UK.

Wood was not considered as a pathway as eggs are laid on needles. Larvae may rest on the trunk, but in a highly conspicuous mass that is likely to be detected (and/or crushed during transport), and any survivors would need to locate growing trees to continue their development. Pupae are found in the soil. Thus, no life stage is likely to be associated with imported wood.

Hitchhiking was also not considered to be a pathway, as adults are very short-lived with females only surviving for a few days (Larsson *et al.*, 2008). As the species has a two-year lifecycle, at least in Sweden, just in terms of probabilities, the chances of adults being present and transported with non-host commodities is very small. Even if it does occur, it needs to be a mated female (or sufficient numbers of both sexes for them to be able to locate one another after arrival), and the female moth needs to survive long enough to locate a suitable host. Therefore, hitchhiking is also not considered to be a viable pathway for this pest.

9. If the pest needs a vector, is it present in the UK/PRA area?

This is a free-living insect and no vector is required.

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

The UK climate may affect this pest's ability to establish. The UK has an oceanic climate, with relatively mild and wet winters, while much of this pest's range has a continental climate, with much colder and drier winters. The isolated populations in France and Spain are found in mountainous areas, which again are comparatively cold in winter.

For the Swedish population of *T. pinivora* in the south of Gotland, which has been most studied, the eggs hatch around mid-April and the average temperature during the first instar was 8.4°C (Ronnas, 2011). In Germany, the larval feeding period is reported as either July-August, or a little earlier, in May-June (Gabler, 1951). In Spain, larvae hatch around March (Montoya & Robredo, 1972). The threshold temperature for the development of *T. pinivora* eggs appears to be around 3–5°C (Ronnas, 2011). Though no values for the required threshold of accumulated day degrees above this temperature are available, Ronnas (2011) does note that the eggs begin to accumulate "temperature-hours" before mid-winter. The UK has much milder winters than the areas around the Baltic (including, for example, eastern areas of Germany), suggesting that the larvae in the UK might hatch very early in the season, even during winter. Ronnas (2011) notes that the winter of 2007-8 was very warm in Gotland, Sweden, and that *T. pinivora* eggs hatched in the middle of winter that season, but provides no further details, for example, on survival rates. In Spain, eggs hatch in March (Montoya & Robredo, 1972), but *T. pinivora* is present at altitude in Spain (and France), and thus data on what temperatures the larvae experience are lacking, as climate data from these mountainous regions could not be found. There is considerable uncertainty generally over what temperatures are suitable or favourable for development. For example, the recent discovery of a small population of *T. pinivora* in Spain was almost 400 km south of the previously known most southerly population; and this new population was found at a comparatively low altitude of 1,500 m which is less than might be predicted based on the locations and altitudes of the other known Spanish populations (Hódar *et al.*, 2016). It was also feeding on *P. nigra* and not *P. sylvestris*, though *P. sylvestris* was also growing in the region (Hódar *et al.*, 2016).This is new information, and suggests that there might be some plasticity as to how *T. pinivora* is able to develop in different environments, though genetic studies suggest that all populations across the entire range have the same main haplotype and also show little difference in microsatellite alleles (Cassel-Lundhagen *et al.*, 2015). It is unclear why *T. pinivora* is not more widely distributed.

The information above suggests that any eggs transported to the UK are likely to hatch comparatively early in the year due to the milder winters. However, in a field experiment where hatching dates were manipulated to be one month early (March 11th), around the normal hatching time (April 10th) or one month late (May 10th), only larvae that hatched later in the season showed lower survival, which was due to increased predation (Ronnas, 2011). Thus, hatching slightly early might not, in itself, prove to be detrimental to survival, though the effects of emerging more than one month early have not been studied. As the larvae prefer to feed on needles that are a year old, even when fresh needles are available (Aimi *et al.*, 2008), the larvae would be able to find their preferred food even if they hatched before the new growth of needles in the spring. However, it does suggest that northern and/or mountainous areas of the UK may be more favourable for *T. pinivora*, though this is highly uncertain and it is possible that populations may be able to establish throughout the UK. Winter and early spring temperatures in the southern part of the UK will be higher, potentially causing the eggs to hatch comparatively early in the winter, which would leave them vulnerable to prolonged periods of cold temperatures and other unfavourable weather as the winter progresses. While sunlight may help to raise the temperature of early instar larval colonies, as the day length in mid-winter is considerably shorter than day length in mid-April (when the larvae hatch in Gotland), even southern sunnier parts of the UK will have fewer hours of sunlight available in mid-winter for the larvae to bask in. As the larvae hatch in the spring in their native range, it is expected that they might have some cold tolerance, but may not be able to survive through protracted cold spells. Temperatures in northern areas of the UK, or at higher altitudes, will be cooler, meaning the eggs will develop more slowly over the winter, and thus are likely to hatch later in the winter or early spring, which corresponds to their usual life cycle. While the factors that influence egg hatching are unclear, day length (photoperiod) probably does not contribute, as Ronnas (2011) mentions that larvae hatched mid-winter one year when temperatures were mild in Gotland.

Once the larvae have hatched they use sunlight to increase their temperature (especially in the early instars), by basking in a mass at the tips of branches (Battisti *et al.*, 2013), and do not build nests unlike other *Thaumetopoea* species. In a field experiment on first instar larvae, daytime temperatures inside a colony in full light were around 7°C higher than the surroundings, while colonies with 90% shading only achieved temperatures 1-2°C above the ambient levels (Battisti *et al.*, 2013). However, the length of time for larvae to reach the second instar was not affected by the amount of light the colony received, nor was the survival rate affected, though the larvae in the shaded treatments had gained less weight (Battisti *et al.*, 2013). Larvae feed at night and spend the day resting in the sun, digesting the previous night's food, probably using the solar energy to help convert the food into body mass. Battisti *et al.* (2013) theorise that the growth rate rather than the development rate of the larvae is affected by shading, thus producing smaller larvae which will, presumably, be at a disadvantage as development continues (e.g., reduced survival), when compared to the larvae exposed to full sun. However, without a clear idea of when the eggs might hatch in the UK, it is not possible to make a sensible comparison of conditions in the UK with those in the native range. Nor is it clear which parts of the UK might be more suitable for establishment based on solar radiation and temperatures in the first months of the year, though areas with a lower temperature (i.e. closer to that in the native range) and a higher level of sunshine in late winter and early spring would seem to be at higher risk.

Another factor that might affect establishment is the reduced viability of small colonies. While it is expected that entire egg masses (containing around 100-200 eggs (Larsson & Battisti, 2015)) could be transported to the UK, thus potentially resulting in large numbers of larvae, conditions upon arrival may be sub-optimal for larval development, thus resulting in lower survival rates. While theoretically only one male and female need to survive to adulthood to perpetuate the population, larvae in larger colonies have a higher survival rate, thus increasing the chances of some individuals surviving to adulthood. In a field experiment in Gotland, Ronnas *et al.* (2010) found that percentage survival of colonies of 10 larvae was around 45%, 100 larvae about 65% and for 300 larvae in a colony, just over 70% survived; larvae in the smallest colony size also gained significantly less weight than the two largest colonies. Gabler (1951) had previously noted that smaller egg masses resulted in weaker colonies.

Thaumetopoea pinivora does appear to be quite susceptible to relatively small changes in its environment. The outbreak in Gotland, Sweden is very restricted in area, with high densities of larval colonies only found in a small area of about 3,000 ha (Larsson *et al.*, 2008). In a field experiment on translocating larvae in Gotland, Aimi *et al.* (2008) found that larvae moved to a non-outbreak area had a lower survival rate (54%) but faster development rates (27 days for the first instar) compared to larvae moved within the outbreak area (75% and 30 days respectively). As the distances the larvae were moved were around 15 km, this suggests they are susceptible to very localised environmental factors, though what these are have not been identified to date.

Suitable hosts, especially the preferred host of *P. sylvestris*, are widely distributed throughout the UK (BSBI maps, 2016). However, the distribution of preferred hosts is likely to be lower than the absolute host distribution might suggest, as in its native range, *T. pinivora* is found on slow-growing pine trees in poor soil (Ronnas, 2011) and many pines in the UK will be found in richer soils, and be faster-growing than those apparently chosen by the moth. While maps of the soil types and the distribution of pine in the UK could be compared, accurate data on what soil types apparently suit the moth in its native range are not available. Therefore, mapping areas of coniferous trees on various soil types in the UK would not add to the assessment of the establishment potential of *T. pinivora* in the UK at present. It may also be that poor soils mean the trees are more widely spaced, allowing more sunlight to reach the early instar larvae – and if this is the case, the precise soil type is not a factor, other than not being optimal for pine tree growth. However, a population may be capable of feeding and developing on faster-growing trees, especially if the trees were isolated (for example in urban areas): a tree exposed to more sunlight is potentially more suitable for early instar larvae to grow and develop on.

Overall, it is very unclear exactly what conditions *T. pinivora* needs in its native range, and what factors might influence areas where it can thrive, areas where it can survive at a low level, and areas where it is unable to persist. This pest does appear to have a relatively narrow range of preferred environments, and it is unclear if any part of the UK will have conditions where these might be met. If establishment in the UK is possible, it may be more likely in northern or mountainous regions where winter temperatures are lower and the pest is less likely to hatch early and subsequently be exposed to prolonged periods of cold weather as vulnerable larvae. However the data are very scarce and establishment in southern parts of the UK may also be possible. Areas containing scattered Scots pine trees (perhaps also on poorer sandy soils) would also be more at risk. Establishment in these areas of higher risk, especially in combination, is rated as moderately likely. As there are so many unresolved issues about what environmental and climatic conditions this pest needs, and thus how suitable any part of the UK might be for it to establish, the confidence surrounding this assessment is low.

Establishment under protections is considered very unlikely with high confidence, as *Pinus* are not usually grown under such conditions. For trees that are grown in such conditions, infestations are likely to be noticed at an early stage, and control measures may be applied. Conditions under protected cultivation may also be too warm for successful establishment.

Outdoors	Very unlikely	☐	Unlikely	☐	Moderately likely	☑	Likely	☐	Very likely ☐
Confidence	High Confidence	☐	Medium Confidence	☐	Low Confidence	☑			

Under protection	Very unlikely	☑	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely ☐
Confidence	High Confidence	☑	Medium Confidence	☐	Low Confidence	☐			

11. How quickly could the pest spread in the UK/PRA area?

Though data on the distances females can disperse are lacking, as with many processionary moths it appears that they do not fly long distances and adults only live for a very short time (Ronnas, 2011). Though females do lay eggs in batches, and thus may potentially be capable of slightly longer flights after the first batch has been laid, there is no evidence of this happening in the current range. While males are occasionally recorded as migrants in its native range (e.g. Sweden: Palmqvist, 1997), and are capable of longer-distance dispersal, males cannot found a new population. Genetic analysis of different populations within the fragmented European distribution suggests that the most likely hypothesis is that these are relict populations remaining after historical habitat fragmentation, and are not the result of recent dispersal/introduction and establishment events (Hódar *et al.*, 2016). It is possible that some small populations have been overlooked, but males are attracted to light traps and there are quite a number of amateur entomologists across Europe who run such traps and report their findings. Thus, *T. pinivora* is unlikely to be found in much wider areas of Europe than currently reported (though the recent finding of a new population in Spain by Hódar *et al.* (2016) does demonstrate that some populations may be overlooked). In countries where the closely related and externally similar *T. pityocampa* is absent, potential mis-identification of *T. pinivora* would seem less likely to occur. Overall, the rate of natural spread has been assessed as slow, with high confidence as no data were found that suggested this pest has spread to new locations (other than presumed northwards colonisation following the last glacial retreat).

Spread in trade is subject to more uncertainty. While eggs and pupae could be transported with plants quite widely, as both these life stages are cryptic and present for long periods, it is unclear how attractive small pine trees, such as would be most commonly moved in trade, would be to *T. pinivora*. Additionally, as discussed under the plants for planting pathway, this moth does not appear to favour plantation trees, and thus is less likely to be moved with trade in plants. Also, no records were found of this species being detected moving in trade. Overall, spread with trade is considered to be at moderate pace, with medium confidence.

Natural spread	Very slowly ☐	Slowly ✓	Moderate pace ☐	Quickly ☐	Very quickly ☐
Confidence	High Confidence ✓	Medium Confidence ☐	Low Confidence ☐		

With trade	Very slowly ☐	Slowly ☐	Moderate pace ✓	Quickly ☐	Very quickly ☐
Confidence	High Confidence ☐	Medium Confidence ✓	Low Confidence ☐		

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

In its native range, there are very seldom outbreaks of *T. pinivora*. It is not clear what causes populations of this pest to increase to damaging levels, but historical outbreaks do appear to be generally quite limited geographically and do not appear to follow the pattern of cyclical outbreaks, such as are seen in many other forestry pests. Reports of this species are rather scarce and very dated, excepting publications prompted by the recent outbreak in Sweden. No outbreaks (or indeed non-outbreak populations) appear have been recorded in plantation pines, and those outbreaks for which data are available appear to be on sparsely growing trees on poor soils, that is, pines present in the natural environment rather than managed forestry trees. No evidence was found of cumulative impacts of *T. pinivora* and any other pest or pathogen affecting pine trees, perhaps due to the scarcity of reports of damage due to *T. pinivora*. Where the ranges of *T. pinivora* and *T. pityocampa* overlap (limited parts of France and Spain), again no data are available on cumulative impacts of the two species.

In a review of historical damage in Germany, Sobczyk (2012) attributed outbreaks in Dresden in 1756, 1779 and 1792 to *T. pinivora*, but notes that very little damage due to this moth was reported at any time during the following centuries. There are reports of 2,500 ha being affected by *T. pinivora* in Hoyerswerda, Saxony between 1947 and 1949 (mentioned in Brasicke, 2013), though no details of the damage caused were found. Later, in the 1970s on the Baltic Sea coast, it was noted that the larvae can be a human health problem (Eichler, 1976). In 2001, *T. pinivora* was mentioned as one of the most serious forest pests in the regions of Niedersachsen and Schleswig-Holstein Germany (which are relatively low altitude): though it was restricted to small areas, these showed high levels of feeding damage (Hartmann *et al.*, 2001). Recent reports support this suggestion of highly localised impacts, with Möller (2013) noting feeding damage was reported over 123 ha in Brandenburg, but that it was only noticeable in 10 ha of this area, and that defoliation only occurred in 1 ha. By the time of the next mention of *T. pinivora* in this series of reports two years later, Ebert *et al.* (2015) stated that the damage was, so far, “unproblematic” (writing in May).

There are reports from West Prussia (now Poland) between 1916 and 1918, where *T. pinivora* was considered abundant, and control methods were investigated (Krausse, 1919). In Poland in the 1930s, *T. pinivora* was considered very scarce, and the populations were considered to be controlled naturally by predators (Kozlowski & Chacharowska, 1939).

In East Prussia (present day Russian Kalingrad) in the 1930s, *T. pinivora* was regarded as abundant on the coast, but of no importance as a plant pest – though efforts were made to control it because of the effects on visitors at a seaside resort (Schedl, 1937). The only quantified report of damage that could be found was from Kalingrad, where defoliation was estimated as between 5 and 15%, but it was not considered that this affected the trees' survival (Maslov *et al.*, 2009). Rather, the main impact was considered to be on visitors to the National Park, some of whom suffered allergic reactions (Maslov *et al.*, 2009) .

The comparatively recent outbreak in the extreme south of Gotland, a Swedish island, have been the focus of much recent work, and the various research prompted by that outbreak has informed most of this PRA. The first published reports of a large population of *T. pinivora* in southern Gotland were from 2006 (Holm & Larsson, 2006; Larsson, 2006), noting that the population had been high since at least 2002 (Granberg *et al.*, 2008). *Thaumetopoea pinivora* had been present in the outbreak area for years at lower numbers, and Ronnas (2011) cites anecdotal evidence that it had been present in the south of Gotland since at least the 1930s. While extensive defoliation occurred in 2006, when populations were very high (Larsson *et al.*, 2008), no evidence was found that suggested this defoliation had a long-term impact on tree health. A factor that might minimise the impacts is that, due to the two year lifecycle, populations are only high in alternate years (Larsson *et al.*, 2008) and thus trees that suffer a high level of defoliation have a year to recover.

The first reports on the Gotland outbreak mentioned the allergic effects of the larval hairs on humans. Human impacts in 2006 were recorded in some detail by Holm *et al.* (2009). They reported that most people exposed to high levels of the setae get allergic skin reactions, with many people with severe reactions leaving the area during the time the larvae are active. Breathing difficulties and eye inflammation were also recorded, but Holm *et al.* (2009) noted that in these cases it could be difficult to attribute the causes to exposure to larval setae, as oppose to other causes of allergies, such as pollen. Of the 4,000 people who responded to a questionnaire in southern Gotland, 18% reported symptoms and about a third of these stated they were severely affected; as would be expected, the percentage of people reporting impacts was much higher if they lived in the heavily infested areas (Holm *et al.*, 2009).

Additional problems with control have arisen in the outbreak area in the south of Gotland, Sweden. This is because the impacts of the outbreak have primarily been on human health, rather than as a plant health issue. A good review of the political situation that arose over the early years of the Gotland outbreak is provided in Granberg *et al.* (2008), detailing the interactions between stakeholders (mostly local residents) and the local municipal authority. Further problems arose to do with the environmental impacts of spraying with *Bacillus thuringiensis* subsp*. kurstaki*, which acts against Lepidoptera in general, thus potentially also affecting some of the rare species present in southern Gotland (Granberg *et al.*, 2008).

Overall, therefore, the impact of *T. pinivora* in its native range appears to be almost entirely social, i.e., the health effects on humans and other animals. While outbreaks do occur, they are apparently very rare and the economic and environmental impacts are assessed as small with medium confidence. Social impacts in the form of rashes and other allergic effects can be seen in susceptible individuals even when there is a low density of larvae, though impacts are greater with higher populations of the pest. Therefore social impacts are rated separately, and are judged to be medium, with high confidence as a lot of data on the human health impacts are available.

Economic & environmental impacts	Very small ☐	Small ☑	Medium ☐	Large ☐	Very large ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

Social impacts	Very small ☐	Small ☐	Medium ☑	Large ☐	Very large ☐
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		

13. What is the pest's potential to cause economic, environmental and social impacts in the UK/PRA area?

Potential economic impacts in the UK are considered to be very small. This is not a known pest of commercially planted trees in its native range, and it appears to prefer more isolated trees, where the early instar larvae can bask in sunlight. There is also a suggestion that it appears to prefer trees on poor soils that are slow-growing. Neither of these conditions are likely to be found in trees planted for forestry purposes, which is where the main economic impacts of this pest are likely to be seen.

Potential environmental impacts are considered to be small. *Pinus sylvestris* is a native conifer, and can be an important species in mixed or ancient woodlands, such as the Caledonian pine forest. There is thus a chance that *T. pinivora* may have some environmental impacts if it was to reach outbreak levels, though it should be noted little evidence of environmental impacts were found from the areas of its current distribution. No evidence of cumulative impacts with other forestry pests was found in its native range, nor any references on the impacts of the urticating hairs on wildlife, so it is not considered likely that significant cumulative impacts would occur in the UK. As outbreaks of *T. pinivora* in the native range have been limited, both in distribution and in time, it is considered unlikely that sustained environmental damage to significant proportions of the UK's Scots pine would occur.

It is unclear what factors might enable or limit populations reaching damaging levels in the native range, let alone which might be important if this pest were to establish in the UK, thus the judgements for economic and environmental impacts are both made with only low confidence.

Potential social impacts are, however, higher, even at the low population densities likely in the UK. Like other species in the genus *Thaumetopoea*, larvae from the third instar on possess urticating hairs that can cause allergic reactions in humans, dogs and other animals. Moulted cuticles containing the urticating setae remain in the trees for some months, thus continuing to release the setae even after the larvae have pupated (Ronnas, 2011). Overall, social impacts are assessed as medium, as the setae of *T. pinivora* larvae do cause allergic reactions (see question 12, impacts in the existing distribution). However, confidence in this judgement is only medium, as while urban and amenity trees are more likely to be isolated and thus suitable for *T. pinivora* larvae to bask, colonies may be more readily located in such situations and considerable efforts to control them may be put in place, reducing or eliminating the populations. Pines in amenity woodlands are not considered to be particularly vulnerable, as woodland trees are more likely to be shaded by other trees and less likely to be grown on poor soil, and thus would be less suitable for larval development. However, if there were infestations of *T. pinivora* in scenic areas, such as the remnants of the Caledonian pine forest, this could reduce visitor numbers and hence have additional impacts on the local economy due to the lower number of visits to the area.

Economic impacts	Very small	✓	Small		Medium		Large		Very large	
Confidence	High Confidence		Medium Confidence		Low Confidence	✓				
Environ - mental impacts	Very small		Small	✓	Medium		Large		Very large	
Confidence	High Confidence		Medium Confidence		Low Confidence	✓				
Social impacts	Very small		Small		Medium	✓	Large		Very large	
Confidence	High Confidence		Medium Confidence	✓	Low Confidence					

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

Thaumetopoea pinivora is not a known vector of any plant pathogen.

15. What is the area endangered by the pest?

There is considerable uncertainty about this judgement. Northern areas and/or mountainous regions in the UK are considered to be at higher risk for establishment of *T. pinivora* as the winters in the south of the country may be too warm and lead to the pest hatching too early. However, as climatic or other variables that influence elements of the life cycle, such as hatching and larval survival are not known, establishment in any part of the UK, including southern England, could occur. Areas of low-density Scots pine, or trees at the edge of a wood, would appear to be especially vulnerable. However, the factors that lead to outbreaks of this species are not understood, and it may be that no part of the UK is suitable for the establishment of economically or environmentally damaging populations. If this were the case, then amenity pine trees (with the more northern parts of the UK again considered most at risk) would comprise the endangered area, as the social impacts from the urticating hairs of even low populations of the larvae would become the most important consequence of *T. pinivora* establishing.

Stage 3: Pest Risk Management

16. What are the risk management options for the UK/PRA area?

Exclusion

Given *T. pinivora* is not known to be present in the UK, and has not been intercepted to date, the prospects for continued exclusion would seem to be good. However, the existing prohibition on conifers from non-European countries will not mitigate the risk of entry as this pest is present within other EU member states and areas of European Russia. Also, as much of the distribution of this pest is within the EU the current import requirements which apply to conifer species from third countries do not apply to trees from many parts of this species' range, other than in very small parts of its range such as Kalingrad (Russia). However it is unlikely the existing requirements for conifer plants from European third countries would reduce the risk of entry of *T. pinivora*. The UK's statutory notification scheme applies to pine trees, but while this would enable trace-back of trees in the event of an infestation being discovered, the notification scheme will not, in itself, prevent entry of this pest. Both egg masses (laid around needles) and pupae (buried in soil) have been identified as potentially associated with imported plants for planting.

The introduction of new UK legislation to mitigate the risk of entry could be considered, as much of the pest native range is within the EU and thus legislation which applied to the whole EU would not be appropriate. However, the UK could consider whether applying for protected zone statue would be appropriate but the benefits of this would need to be considered against the relatively low levels of damage caused by the pest and the difficulty of implementing fully effective measures.

Appropriate measures could be introduced on a place of production and its immediate vicinity. Careful visual examination could be used to establish freedom from egg masses and larval colonies on *Pinus* spp. on a production location. Pest freedom in the immediate vicinity of the location of production would also provide mitigation against entry on plants for planting.

Measures against pupae would be very difficult to design and implement, as pupae are buried in the soil and thus undetectable visually. Additionally, some pupae undergo extended diapause and thus persist in the soil for two years, or perhaps even longer. As larvae may move some distance from their host tree before pupating, potentially any rooted plant with a reasonable quantity of soil may contain the pest, and reasonable and proportionate measures against all rooted plants for planting from the pest's current distribution would be very costly and impractical to implement. Either all rooted plants would need to be moved without soil (bare rooted), or every plant nursery exporting any species of plant would need to inspect the immediate vicinity and be found to be free from *T. pinivora*.

In addition to requirements for pest free place of production, requirements that *Pinus* spp. originate in a pest free area could be used as *T. pinivora* has a restricted distribution within the EU. This included restricted distribution within several countries in its native range, such as Denmark, France, Spain and Sweden. As *T. pinivora* is limited in distribution, Pest Free Areas may be another option.

Eradication and containment

If an infestation was found at an early stage when still restricted to the infested imported plants, eradication would theoretically be possible, especially if it were eggs or larvae that were detected, rather than the pupae with the possibility of emerged adults. However, if the pest had spread to the wider environment and become established, eradication would be much less likely to succeed, unless detected very early while the population was still small, and perhaps restricted to smaller trees. If *T. pinivora* was present on mature trees, spraying options become more limited, simply due to the practical difficulties of reaching all parts of a large tree, though methods such as ultra-low volume (ULV) spraying are available to overcome some of these difficulties. However, even using ULV, there are still issues around potential contamination of the wider environment, including nearby water. If the pest was present in anything other than very localised areas, again, reaching all potentially infested parts of the area at risk would be challenging. While *T. pinivora* does not build nests, larvae are very gregarious and mechanical removal methods may be another option, especially during the early instars where larvae congregate at the tips of branches, which could be cut off and disposed of safely. However, older larvae usually spend the day resting on larger branches or tree trunks, and would be more difficult to remove from the tree. Additionally, as older larvae contain urticating hairs, release of these through the disturbance of mechanical collection pose an additional danger to the operator. There are, however, methods for capturing mature larvae as they move from the tree to the ground to pupate, such as sticky bands placed around the trunks. Even if affected trees were completely removed, it would be difficult to be sure that all affected trees had been located, unless the host population in the area was very small. Additionally, the pest has a 2-year lifecycle in much of northern Europe, and thus control measures and monitoring would need to be in place for a substantial period of time to ensure any outbreak had been eradicated, especially as there is some evidence that some of the pupae can undergo extended diapause, prolonging the life-cycle to three years in length, or perhaps even more. While the sex pheromones of *T. pinivora* have been identified (Frerot & Demolin, 1993), no commercial lures appear to be available. Therefore, monitoring for adults would need to be with light traps and pheromone traps could not be used to define the area of any outbreak. However, due to the short adult life-span, searching for groups of larvae on pine trees in the spring may be a more reliable method of detection overall.

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