Dendrolimus sibiricus
Pest Report to support ranking of EU candidate priority pests

EFSA (European Food Safety Authority),

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1. Introduction to the report

This document is one of the 28 Pest Reports produced by the EFSA Working Group on EU Priority Pests under task 3 of the mandate M-2017-0136. It supports the corresponding Pest Datasheet published together on Zenodo[1] and applies the methodology described in the Methodology Report published on the EFSA Journal (EFSA, 2019).

This Pest Report has five sections. In addition to this introduction, a conclusion and references, there are two key sections, sections 2 and 3.

Section 2 first summarises the relevant information on the pest related to its biology and taxonomy. The second part of Section 2 provides a review of the host range and the hosts present in the EU in order to select the hosts that will be evaluated in the expert elicitations on yield and quality losses. The third part of Section 2 identifies the area of potential distribution in the EU based on the pest's current distribution and assessments of the area where hosts are present, the climate is suitable for establishment and transient populations may be present. The fourth part of Section 2 assesses the extent to which the presence of the pest in the EU is likely to result in increased treatments of plant protection products. The fifth part of section 2 reviews additional potential effects due to increases in mycotoxin contamination or the transmission of pathogens.

In Section 3, the expert elicitations that assess potential yield losses, quality losses, the spread rate and the time to detection are described in detail. For each elicitation, the general and specific assumptions are outlined, the parameters to be estimated are selected, the question is defined, the evidence is reviewed and uncertainties are identified. The elicited values for the five quantiles are then given and compared to a fitted distribution both in a table and with graphs to show more clearly, for example, the magnitude and distribution of uncertainty. A short conclusion is then provided.

The report has two appendices. Appendix A contains a host list created by amalgamating the host lists in the EPPO Global Database (EPPO, online) and the CABI Crop Protection Compendium (CABI, 2018). Appendix B provides a summary of the evidence used in the expert elicitations.

It should be noted that this report is based on information available up to the last day of the meeting[2] that the Priority Pests WG dedicated to the assessment of this specific pest. Therefore, more recent information has not been taken into account.

For *Dendrolimus sibiricus* the following documents were used as key references: pest risk categorisation by EFSA PLH Panel (2018) and a pest risk analysis (PRA) by Norway (VKM, 2018).

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[1] Open-access repository developed under the European OpenAIRE program and operated by CERN, https://about.zenodo.org/

[2] The minutes of the Working Group on EU Priority Pests are available at http://www.efsa.europa.eu/sites/default/files/wgs/plant-health/wg-plh-EU_Priority_pests.pdf

2. The biology, ecology and distribution of the pest

2.1. Summary of the biology and taxonomy

Dendrolimus sibiricus Tschetv. (Lepidoptera: Lasiocampidae) is a single taxonomic entity. *Dendrolimus sibiricus* and *Dendrolimus superans* are closely related and share a common ancestor (Kononov et al., 2016). Currently they are considered to be two separate species, although their identification remains difficult, as proven by a recent study suggesting that the presence of *D. superans* in South Korea is actually the result of a misidentification of *D. sibiricus* (Jeong et al., 2018). *D. sibiricus* is also sympatric in a part of its host range with *Dendrolimus pini*: the two species respond to the same synthetic sex pheromones (Baranchikov et al., 2006).

The biology of *D. sibiricus* is well studied in northeast Asia, its native range, where extensive outbreaks have been recorded in the last century (Florov, 1938; Prozorov, 1952; Boldaruev, 1955; Geispitz, 1957; Rozhkov, 1963, 1981; Vshivkova, 1976, 2004; Kirichenko, 2002; Baranchikov and Kirichenko, 2002a—b; Kirichenko and Baranchikov, 2004a—b, 2005, 2007).

Its life cycle usually varies from 2 to 3 years (Prozorov, 1952; Boldaruev, 1955; Rozhkov, 1963). A light/dark (LD) 12:12 h photoperiod initiates larval diapause (Geispitz, 1957) and diapausing larvae overwinter once or twice depending on the length of their life cycle (Boldaruev, 1955; Rozhkov, 1963). In the first year, larvae develop to the second, third or fourth instar before coiling up in the litter and overwintering. They appear in early spring of the following year (late April–early May), feed extensively and complete their development in June, except for those which overwinter in a second time (Rozhkov, 1963). During this period, they cause the most significant damage since mature larvae (the two last instars) consume nearly 90% of all biomass eaten during the whole larval stage (Kirichenko, 2002; Baranchikov et al., 2002a—b).

Larvae that spend their first winter in the second–third instars are usually not able to complete development in the spring of the following year, so in summer they enter summer diapause (characterised by slow movement and development while in the tree crowns) and overwinter in the forest floor in the fourth or fifth instar to complete their development and pupate in the third year (Baranchikov and Kirichenko, 2002a—b). Such a complex life cycle requires 5–11 months of active larvae development.

Dendrolimus sibiricus is considered to be the most important defoliator of coniferous species in Russia and Kazakhstan (Rozhkov, 1963; Epova and Pleshanov, 1995; Vorontsov, 1995; Baranchikov et al., 2001; Vinokurov and Isaev, 2002), and of *Larix gmelinii* in China (Yang and Gu, 1995).

2.2. Host plants

2.2.1. List of hosts

The potential host range of this pest is restricted to the Pinaceae family. The most severe outbreaks in Siberia occur in the stands predominantly occupied by the preferred species Siberian larch (*Larix sibirica*), Siberian fir (*Abies sibirica*), Siberian pine (*Pinus sibirica*) and are generally favoured by droughts, low precipitation and increased air temperatures at the beginning of the vegetative period (Kharuk et al., 2017; EFSA PLH Panel, 2018). It also feeds on Siberian spruce (*Picea obovata*) but, on this host, females only lay up to 150 eggs, much less than the 400 eggs per female observed on larch (Kirichenko, 2002; Kirichenko and Baranchikov, 2004a—b).

Table 1: List of potential hosts provided by EFSA PLH Panel (2018)

Family	Genus	Species in Asia (native range)	Species in Europe (outside native range)
Pinaceae	Abies	A. sibirica, A. sachalinensis, A. nephrolepis	A. alba, A. nordmanniana, A. grandis
	Larix	L. sibirica, L. kurilensis, L. gmelinii, L. cajanderi	L. decidua
	Pinus (five-needle)	P. sibirica, P. pumila, P. koraiensis	P. strobus
	Pinus (two-needle)	P. sylvestris	P. sylvestris, P. nigra
	Picea	P. obovata, P. ajanensis	P. abies, P. sitchensis
	Pseudotsuga	–	P. menziesii
	Tsuga	–	T. canadensis
	Cedrus	–	C. atlantica

Kirichenko et al. (2009) provide some additional supporting evidence concerning the most favourable hosts, stating that experiments with larvae in petri dishes are artificial, since the hosts are selected by the females when laying eggs. Kirichenko et al. (2011), with a trial on potted plants of the different host species, show that favourable hosts allow higher survival, better larval development, and as a result, yield heavier pupae and adults with higher longevity.

Appendix A provides the full list of hosts.

2.2.2. Main hosts in the European Union

Larix decidua appears to be a suitable host for *D. sibiricus* (Kirichenko et al., 2011) and is widespread in the EU (Da Roch et al., 2016).

Larch is typically more resistant than other coniferous species to severe defoliation due to its ability to regrow needles after an outbreak (Pleshanov, 1982). However, continuous outbreaks may weaken larch trees on a large scale. For instance, during an outbreak in 1999–2002 in the Republic of Yakutia, the Siberian moth killed 0.5 million hectares of Siberian larch trees out of 8 million hectares that were infested (Vinokurov and Isaev, 2002).

In boreal taiga forests, mixed stands predominated by fir, spruce and five-needle pine are severely attacked by the pest, resulting in dramatic forest decline (Boldaruev, 1955; Rozhkov, 1963; Baranchikov and Kondakov, 1997; Kharuk et al., 2017).

Pinus sylvestris represents a poor diet for *D. sibiricus* (Kirichenko, 2002). On this host high first instar larvae mortality (up to 93%) was observed with the potential consequence of pest population collapse (Kirichenko and Baranchikov, 2004ab, 2007); therefore *D. sibiricus* switches to *P. sylvestris* only in the absence of more favourable hosts (Kirichenko, 2002). Similar observations were collected by Kirichenko et al. (2008) comparing the effect of different hosts on first instar larvae performance, although the authors did not use the main hosts as a control.

Table 2: Survival and relative growth rate of *D. sibiricus* first instar larvae on different EU coniferous species observed by Kirichenko et al. (2008)

Family	Host species	Larval survival (%)	larval Relative Growth Rate (RGR, mg/mg/day)
Pinaceae	Pseudotsuga menziesii	94.2	0.209
	Cedrus atlántica	92.3	0.221
	Picea abies	90.4	0.231
	Picea sitchensis	88.5	0.236
	Pinus strobus	86.5	0.245
	Pinus silvestris	72.1	0.189
	Tsuga canadensis	69.2	0.194
	Abies grandis	64.5	0.233
	Abies alba	57.7	0.223
	Pinus nigra	32.7	0.170
Taxaceae	Taxus baccata	0	–
Cupressaceae	Cupressus sempervirens	0	–

2.2.3. Hosts selected for the evaluation

No difference in terms of pest preferences and host vulnerability for EU host species are reported in the literature, except for *P. sylvestris* (Kirichenko, 2002). Therefore, the assessment of impact is conducted on the potential coniferous host species mentioned in EFSA PLH Panel (2018) (see Table 1) which are the most relevant for commercial plantations in the EU. Potential losses on other ornamental, non-native potential host species are not considered.

Urban areas, natural forests and commercial plantations are assessed together.

2.3. Area of potential distribution

2.3.1. Area of current distribution

Figure 1 provides an overview on the current area of distribution of the pest. *Dendrolimus sibiricus* is found in Russia (from the west of the Ural Mountains in the European part of Russia to the Primorsky Krai in the Russian Far East), Kazakhstan, Mongolia, China (in the provinces of Jilin, Liaoning, Beijing, and Neimenggu), Democratic People's Republic of Korea, Republic of Korea (Hou 1987; EPPO 2005; Hardin and Suazo, 2012). In Russia its presence either overlaps with *D. pini* or *D. superans*, as shown by Kononov et al. (2016) providing a map on the distribution of *D. sibiricus* and other related *Dendrolimus* species in Eurasia.

In the assessment area no outbreaks have yet been reported.

Dendrolimus sibiricus (DENDSI)

○ Present   ● Transient

2019-05-12
(c) EPPO https://gd.eppo.int

Figure 1 Distribution map of *Dendrolimus sibiricus* by EPPO Global Database accessed 12/05/2019.

2.3.2. Area of potential establishment

Two CLIMEX analysis are currently available on *D. sibiricus* in the EU, both based on Flament et al. (unpublished), largely built on the distribution map by Rozhkov (1963): one by the Polish Institute of Plant Protection-NRI (Kubasik et al., 2017) and the other by the University of Eastern Finland (Möykkynen and Pukkala, 2014). Both concluded that in a large part of northern and central Europe there are suitable climatic conditions for pest survival. These results contrast with a previous work by Baranchikov et al. (2010) that, based on an unspecified bioclimatic model, concluded that the milder winter conditions in Europe would be largely unsuitable for the survival of the larvae usually overwintering in the leaf litter under snow cover.

According to Kharuk et al. (2018), the present northern border of focal distribution of the Siberian silk moth is approximated by the sum of temperatures within the range 1200–1300°C.

A recent assessment made by VKM (2018) also supports the importance of snow cover when overwintering in the leaf litter. Since this aspect cannot readily be integrated into the CLIMEX model, predictions of winter survival outside its current area of establishment are unreliable.

In the Norwegian pest risk assessment (VKM, 2018) it was concluded that the potential host species available in Norway are not those on which dramatic damage could be expected. Wet summers (as in Norway) are also not likely to be suitable for this pest, although no evidence is available to confirm this aspect.

In its current area of distribution, the snow cover is likely to occur throughout the winter providing protection for its overwintering stages. Some northern parts of Norway have winter conditions more similar to Siberia, while in the Norwegian coastal areas climatic conditions alternate between frost and milder weather.

CLIMEX has limitations when modelling pests with more than a one-year life cycle, and a stage in the leaf litter with survival affected by snow cover. The CLIMEX results for *D. sibiricus* show that the climate in

Western EU is more suitable than Eastern EU but this is doubtful, considering that the most suitable climatic conditions for this pest are in the Siberian region of Russia. According to Rozhkov (1963):

- winter diapause temperature induction: from 0.5°C for pine populations to 4.4°C for larch populations;

- winter diapause temperature termination: from 2°C for pine populations to 5.5-7°C for larch populations.

Due to the complexity of this species biology and its responses to climate, no areas in the EU can be excluded with certainty and the area of potential distribution has been considered to be wherever hosts are grown in the EU.

2.3.3. Transient populations

Dendrolimus sibiricus is not expected to form transient populations in the EU (for "transient" see the definition in EFSA, 2019).

2.3.4. Conclusions on the area of potential distribution

D. sibiricus is characterized by a complex interaction between its life cycle strategies (survival and development, including diapause) and environmental conditions (e.g., threshold temperatures, thermal requirements, snow cover) influencing the adaptation and the distribution of the species. Although such complexity does not make it possible to derive reliable maps projecting the area of potential distribution, it is considered to be very unlikely that the Mediterranean climate will be suitable for establishment and this has been excluded. Therefore, the area of potential distribution coincides with the area where the main hosts are present throughout the EU except for areas of southern EU with a Mediterranean climate (Figure 2).
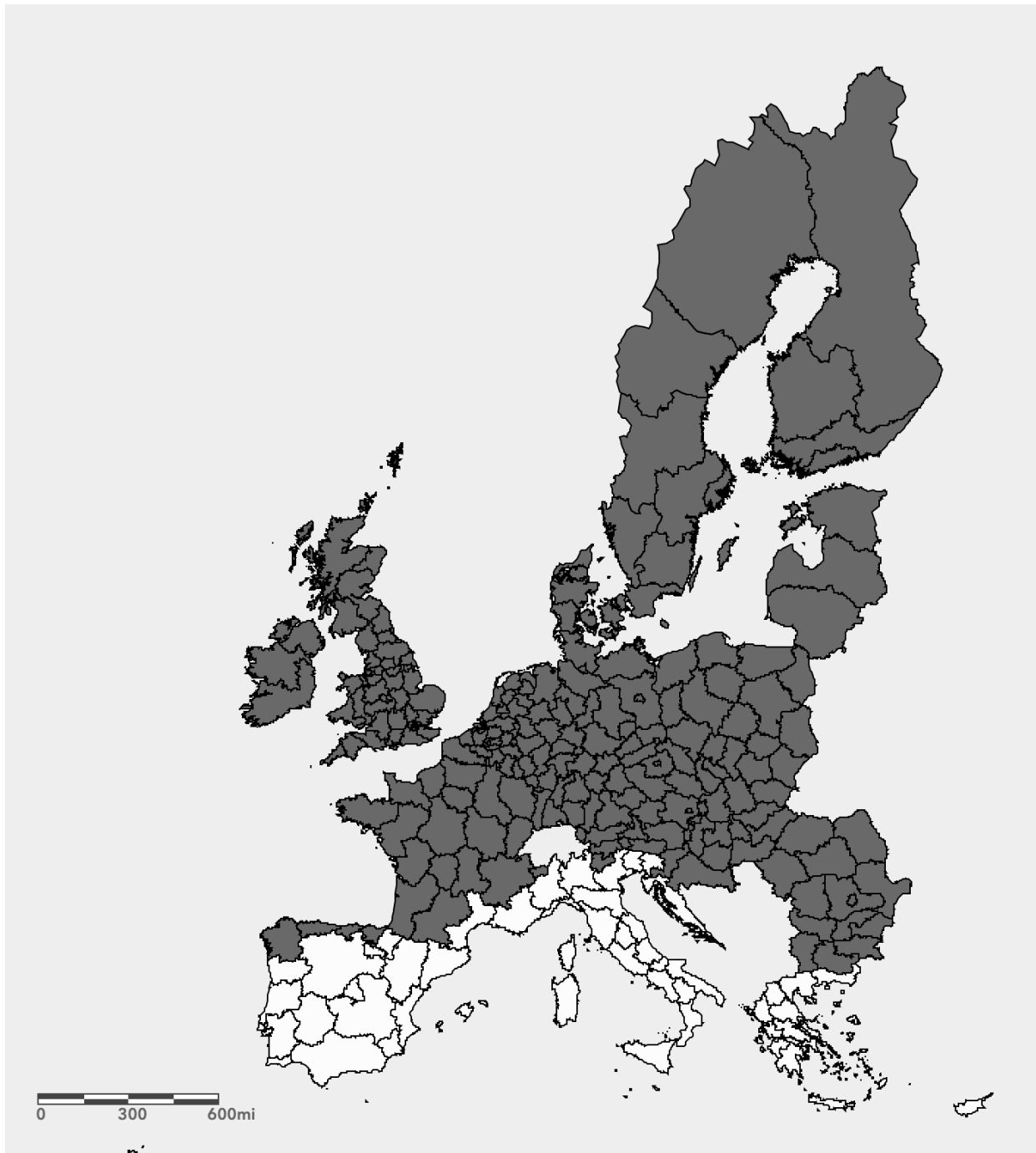
Figure 2 The potential distribution of the pest in the EU NUTS2 regions based on the scenarios established for assessing the impacts of the pest by the EFSA Working Group on EU Priority Pests (EFSA, 2019). This link provides an online interactive version of the map that can be used to explore the data further: https://arcg.is/1emXK0

2.4. Expected change in the use of plant protection products

The control of *D. sibiricus* with PPPs is limited to aerial chemical or bacterial treatments, when regulations permit (EFSA PLH Panel, 2018).

In 1966–1970, in the larch forests of Khabarovsk Krai a high mortality rate (70–99.5%) at the egg stage from infections by *Telenomus* and *Ooencyrtus* Ashmead was observed, resulting in a 60–70% mortality of caterpillars (Pavlov et al., 2018 citing Yurchenko, 2007). In the current Siberian outbreak, a low rate of control by natural enemies has been observed (Pavlov et al., 2018).

Due to the fact that no effective treatments with plant protection products (PPPs) are currently available, the most suitable PPP indicator is Case "A" and the category is "0" based on Table 3.

Table 3: Expected changes in the use of Plant Protection Products (PPPs) following *Dendrolimus sibiricus* establishment in the EU in relation to four cases (A-D) and three level score (0-2) for the expected change in the use of PPPs.

Expected change in the use of PPPs	Case	PPPs indicator
PPPs effective against the pest are not available/feasible in the EU	**A**	**0**
PPPs applied against other pests in the risk assessment area are also effective against the pest, without increasing the amount/number of treatments	B	0
PPPs applied against other pests in the risk assessment area are also effective against the pest but only if the amount/number of treatments is increased	C	1
A significant increase in the use of PPPs is not sufficient to control the pest: only new integrated strategies combining different tactics are likely to be effective	D	2

2.5. Additional potential effects

2.5.1. Mycotoxins

The species is not known to be related to problems caused by mycotoxins.

However, *D. sibiricus* can be potentially harmful to humans. The fifth and sixth larval instars have urticant setae that may cause allergic reactions (Rozhkov, 1963).

2.5.2. Capacity to transmit pathogens

The species is not known to vector any plant pathogens.

3. Expert Knowledge Elicitation report

3.1. Yield and quality losses

3.1.1. Structured expert judgement

3.1.1.1. *Generic scenario assumptions*

All the generic scenario assumptions common to the assessments of all the priority pests are listed in the section 2.4.1.1 of the Methodology Report (EFSA, 2019).

3.1.1.2. *Specific scenario assumptions*

- Susceptible hosts are living trees that would be killed by *D. sibiricus*

- Host preferences and vulnerability is considered to be the same for all potential EU host species *Larix*, *Pinus*, *Pseudotsuga* and *Abies*

- The damage is assumed to be the same in all the different climatic zones in the area of potential distribution

- Urban areas, natural forests and commercial plantations are assessed together

- The economic impact assessment only considers commercial plantations of the European potential coniferous host species in the EU mentioned in EFSA PLH Panel (2018) (see Table 1) and does not take into account the potential losses on other ornamental, non-native potential host species which are less widely grown

- There is a uniform age distribution of host species, from very young to the end of the rotation in the area of potential establishment

- Areas of the Southern EU with a Mediterranean climatic zone are excluded from the assessment

- Although *Larix* is deciduous, since the larvae eat new shoots the impact on this species is considered together with the impact on other host species

3.1.1.3. *Selection of the parameter(s) estimated*

The EKE for forest plantations took into account the assessment of the mortality rate caused by *D. sibiricus*, since it is assumed that infested trees do not reach the normal size for harvesting. The estimation of mortality is not affected by any replanting.

3.1.1.4. *Defined question(s)*

What is the percentage yield loss in *Larix, Pinus, Pseudotsuga* and *Abies* under the scenario assumptions in the area of the EU under assessment for *Dendrolimus sibiricus*, as defined in the Pest Report?

3.1.1.5. *Evidence selected*

The experts reviewed the evidence obtained from the literature (see Table B.1 in Appendix B) selecting the data and references used as the key evidence for the EKE on impact. Some general points were made:

- By extrapolation: stressed trees are more prone to higher impacts

- Koricheva et al. (1998) noted that drought can be detrimental to tree recovery following pest attacks

- There are no effective management options available against defoliators

- VKM (2018) summarised the key differences between the Siberian and Norwegian climatic conditions

- In spite of multiple opportunities for natural and human assisted spread, this pest has never been found in Europe (including Western Russia)

- Kharuk et al. (2017): 45% of losses are due to xylophagous insects acting as secondary pests after *Dendrolimus* attacks

- Kirichenko et al. (2008 and 2011): the main evidence concerning EU potential hosts and suitability is based on one experiment in petri dishes and one in potted plants

- On the one hand *Larix* is known to be a preferred host so it is attractive to *D. sibiricus* but on the other hand it also has a stronger resilience to attacks since a new leaf flush can be expected after attack (Kirichenko, 2019)

- According to Epova (1999) a localised outbreak has been recorded on Scots pine (*P. sylvestris*) in Siberia in the Irkutsk region in the 1990s. Since *P. sylvestris* is not recorded as a favourable host, it is difficult to interpret the implication of this outbreak.

3.1.1.6. *Uncertainties identified*

- There is considerable uncertainty concerning the host range and potential for outbreaks on species outside the Siberian region. Apart from Epova (1999), all the recorded outbreaks are on species that are not widely grown in EU

- The suitability of European climatic conditions: it is not known how well this pest can survive mild, variable and wet winters in Europe

- Very limited evidence is available concerning the different level of susceptibility to *D. sibiricus* attacks on different host species, apart from Kirichenko et al. (2008, 2011)

- Effect of competition with other pest species and control by natural enemies

- It is not known how stress will impact potential host vulnerability to a *D. sibiricus* attack

3.1.2. Elicited values for yield losses

What is the percentage yield loss in *Larix, Pinus, Pseudotsuga* and *Abies* under the scenario assumptions in the area of the EU under assessment for *D. sibiricus*, as defined in the Pest Report?

The five elicited values on yield loss on forest trees on which the group agreed are reported in the table below.

Table 4:   The 5 elicited values on yield loss (%) in forests

Percentile	1%	25%	50%	75%	99%
Expert elicitation	0%	0.25%	0.5%	1%	10%

3.1.2.1. *Justification for the elicited values for yield loss on coniferous hosts*

Reasoning for a scenario which would lead to high yield loss (99th percentile / upper limit)

The upper value of yield loss occurs when there is a relatively high density of the pest population, which occurs in situations of:

- Drought stress
- Consecutive years of cold winters favouring overwintering survival and/or warm summers favouring short life cycles

The relatively low value is due:

- Primarily to climate, which is generally unsuitable in the EU, due to the differences with the climate in the current area of distribution and therefore considered unlikely to support population densities that would cause high tree mortality
- Presence of favourable hosts e.g. *Larix decidua, Pseudotsuga menziesii, Pinus strobus* (although *P. sylvestris*, which is not among the most favourable hosts, is widespread)
- Scattered distribution of hosts
- Presence of competitors and effect of secondary pests

Reasoning for a scenario which would lead to low yield loss (1st percentile / lower limit)

The lower value of yield loss is given by the scattered presence of hosts which are the least suitable (*P. sylvestris*) and climatic conditions that are not ideal (wet and variable winters). Defoliation and tree death would take more than one year.

High presence of competitors.

Siberian data indicates that 50% mortality probably represents the maximum possible. The uncertainty is due to what could happen in the EU conditions.

Reasoning for a central scenario equally likely to over- or underestimate the yield loss (50th percentile / median)

The median value of yield loss is due to the assessment that 5 out of 1000 trees would die. This pest can produce very high damage levels in other areas, but such damage has been observed sporadically over a very large time slot.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

The uncertainty is equally distributed, with lower probability expected for higher values.

3.1.2.2. Estimation of the uncertainty distribution for yield loss on coniferous hosts

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 5: Fitted values of the uncertainty distribution on the yield loss (%) on coniferous hosts

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	0%					0.25%		0.5%		1%					10%
Fitted distribution	0.03%	0.05%	0.08%	0.12%	0.18%	0.25%	0.32%	0.50%	0.77%	1.00%	1.38%	2.00%	3.21%	5.05%	9.10%

Fitted distribution: LogLogistic (0,0.0050003,1.5839), @RISK7.5

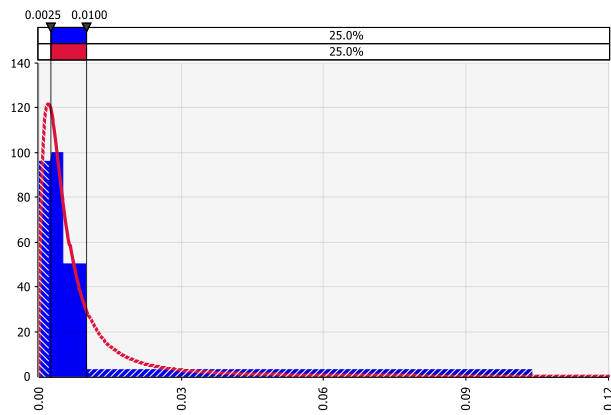**Figure 3** Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on coniferous hosts.
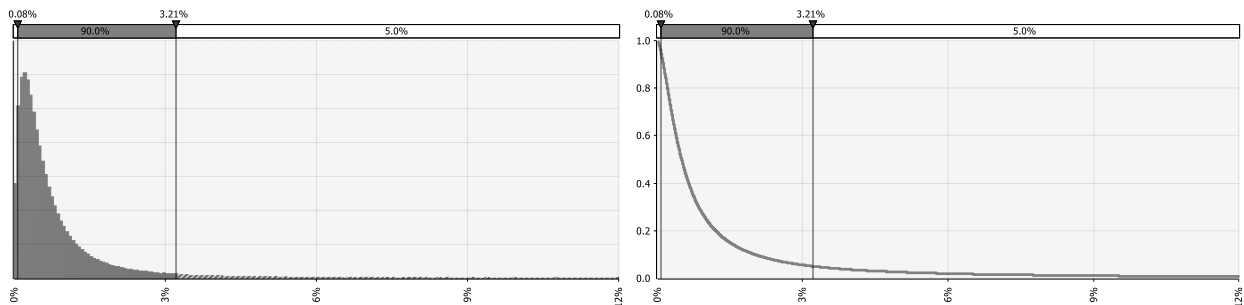

Figure 4 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on coniferous hosts.

3.1.3. Conclusions on yield and quality losses

Based on the general and specific scenarios considered in this assessment, the proportion (in %) of yield losses (here with the meaning of percentage mortality) is estimated to be 0.5% (with a 95% uncertainty range of 0.05 – 5.05%).

3.2. Spread rate

3.2.1. Structured expert judgement

3.2.1.1. Generic scenario assumptions

All the generic scenario assumptions common to the assessments of all the priority pests are listed in the section 2.4.2.1 of the Methodology Report (EFSA, 2019).

3.2.1.2. Specific scenario assumptions

- Since local displacement of logs is not considered to be relevant to short distance dispersal, the spread rate takes into account only the active and passive natural spread
- Spread rate is from a low level population but not in an invasion scenario
- Different host species do not influence the spread rate
- Hitchhiking is excluded as it is not confirmed to be a major component of spread
- Population with 2 year cycle is considered, as an average between 1 and 3 year cycle

3.2.1.3. Selection of the parameter(s) estimated

The spread rate has been assessed as the number of metres per year.

3.2.1.4. Defined question(s)

What is the spread rate in 1 year for an isolated focus within this scenario based on average European conditions? (units: m/year)

3.2.1.5. Evidence selected

The experts reviewed the evidence obtained from the literature (see Table B.2 in Appendix B) selecting the data and references used as the key evidence for the EKE on spread rate.

- Kharuk et al., 2017
- Möykkynen T and Pukkala T, 2014 (uncertainties in the figures as authors do not differentiate between male and female flights)

3.2.1.6. Uncertainties identified

- Observations are based on male adults trapping while the assessment is focused on females spread capacity
- Very limited information on spread

- The most likely number of years to complete its life cycle based on the average climatic conditions in the EU
- It is not known how climatic conditions in the EU could influence the flight performance of adults

3.2.2. Elicited values for the spread rate

What is the spread rate in 1 year for an isolated focus within this scenario based on average European conditions? (units: m/year)

The five elicited values on the spread rate on which the group agreed are reported in the table below.

Table 6:   The 5 elicited values on spread rate (m/y)

Percentile	1%	25%	50%	75%	99%
Expert elicitation	1,000	5,000	10,000	15,000	40,000

3.2.2.1.   Justification for the elicited values of the spread rate

Reasoning for a scenario which would lead to wide spread (99th percentile / upper limit)

The upper value could be expected to be close to the lower limits provided by the literature (17 km/year). However, this is relatively conservative due to the difficulty in making precise measurements. Old observations show that 50 km is possible and an extreme of 63 km for a male was observed recently by Baranchikov (2019). High summer temperatures and lack of geographic barriers could increase the spread capacity of adults.

Reasoning for a scenario, which would lead to limited spread (1st percentile / lower limit)

This pest is a good flier so spread is expected to remain high (1 km/year) even in completely new environments.

Reasoning for a central scenario, equally likely to over- or underestimate the spread (50th percentile / median)

The median value takes into account the data reported in Kharuk et al. (2017) in combination with an expected lower environmental suitability of the EU compared with Siberia. The coverage of larch is not uniform, resulting in feeding of larvae on suboptimal host plants. EU continental climates could be similar to Siberia in summer, but by averaging the whole EU situation, this reduces the average spread rate.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

The precision is given by the confidence in the median, and a lower likelihood is expected for values close to the upper limit.

3.2.2.2. Estimation of the uncertainty distribution for the spread rate

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 7: Fitted values of the uncertainty distribution on the spread rate (m/y)

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	1,000					5,000		10,000		15,000					40,000
Fitted distribution	700	1,200	1,800	2,800	3,900	5,300	6,600	9,500	13,100	15,600	18,900	22,800	28,100	33,100	39,700

Fitted distribution: Gamma (1.8291,6.2867), @RISK7.5
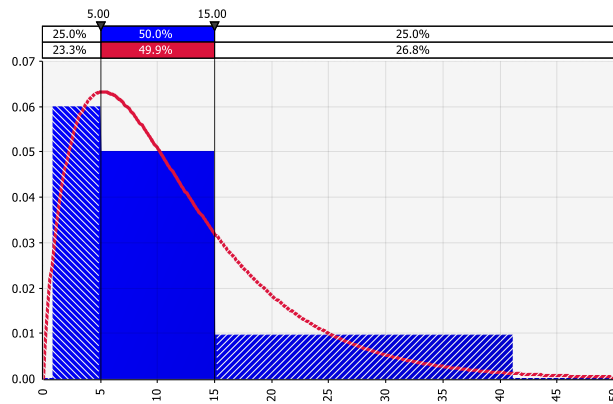

Figure 5 Comparison of judged values (histogram in blue) and fitted distribution (red line) for spread rate.
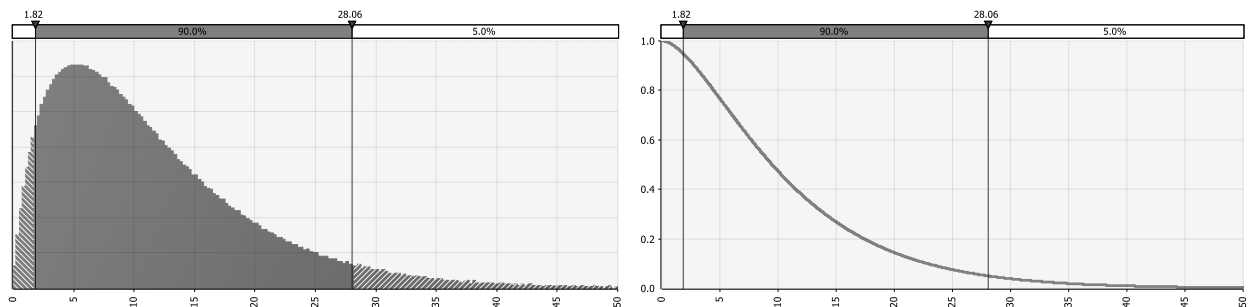

Figure 6 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for spread rate.

3.2.3. Conclusions on the spread rate

Based on the general and specific scenarios considered in this assessment, the maximum distance expected to be covered in one year by *D. sibiricus* is 9.5 km (with a 95% uncertainty range of 1.2 - 33 km).

3.3. Time to detection

3.3.1. Structured expert judgement

3.3.1.1. Generic scenario assumptions

All the generic scenario assumptions common to the assessments of all the priority pests are listed in the section 2.4.2.1 of the Methodology Report (EFSA, 2019).

3.3.1.2. Specific scenario assumptions

- The time to detection takes into account the potentially different conditions in forests and urban areas

3.3.1.3. Selection of the parameter(s) estimated

The time for detection has been assessed as the number of years between the first event of pest transfer to a suitable host and its detection.

3.3.1.4. Defined question(s)

What is the time between the event of pest transfer to a suitable host and its first detection within this scenario based on average European conditions? (unit: years)

3.3.1.5. Evidence selected

- Not noticeable at small densities
- It can be easily confused with other *Dendrolimus* species

3.3.1.6. Uncertainties identified

- Variability of the interval between two monitoring sessions in forest stands of the different parts of the assessment area.

3.3.2. Elicited values for the time to detection

What is the time between the event of pest transfer to a suitable host and its first detection within this scenario based on average European conditions? (unit: years)

The five elicited values on time to detection on which the group agreed are reported in the table below.

Table 8: The 5 elicited values on time to detection (years)

Percentile	1%	25%	50%	75%	99%
Expert elicitation	2	10	16	26	40

3.3.2.1. Justification for the elicited values of the time to detection

Reasoning for a scenario which would lead to a long time for detection (99th percentile / upper limit)

The upper value is given by the possibility of an outbreak in woodland. It could be on hosts able to recover or on not very suitable hosts (*P. sylvestris*) maintaining a very low population density. The EU could not be very suitable.

Reasoning for a scenario which would lead to a short time for detection (1st percentile / lower limit)

The lower value with fast detection is due to situations where a rapid increase in the size of an outbreak focus occurs, based on Kharuk et al. (2018, fig 3d). It also takes into account the effectiveness of detection of individuals by scientists and the number of generations needed for the population to be noticed.

A bit less than 2 years is required to observe the first-generation larvae. However, this is still a very unlikely situation. Cocoons on trunks can be spotted when they are at sufficiently high densities.

Two years before detection could be realistic without *D. pini*, but the widespread distribution of *D. pini* could mask the presence of this new pest.

Reasoning for a central scenario, equally likely to over- or underestimate the time for detection (50th percentile / median)

The median value is related to the fact that in order for *D. sibiricus* to be detected a population should be present on *Larix* at high densities. On *Pinus* it can easily be confused with *D. pini*. *Larix* is likely to be found close to human habitations where infestations are easier to spot.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

The precision is mainly driven by the fact that extremely high values are much less likely to happen compared to central values.

3.3.2.2. Estimation of the uncertainty distribution for the time to detection

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 9: Fitted values of the uncertainty distribution on the time to detection (years)

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	2					10		16		26					40
Fitted distribution	1.4	2.4	3.6	5.5	7.6	9.9	12.1	16.5	21.6	24.7	28.7	33.3	38.8	43.8	49.8

Fitted distribution: Weibull (1.7156,20.450), @RISK7.5
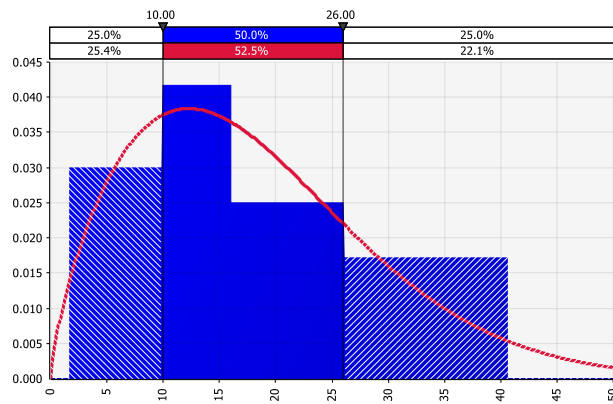

Figure 7 Comparison of judged values (histogram in blue) and fitted distribution (red line) for time to detection.
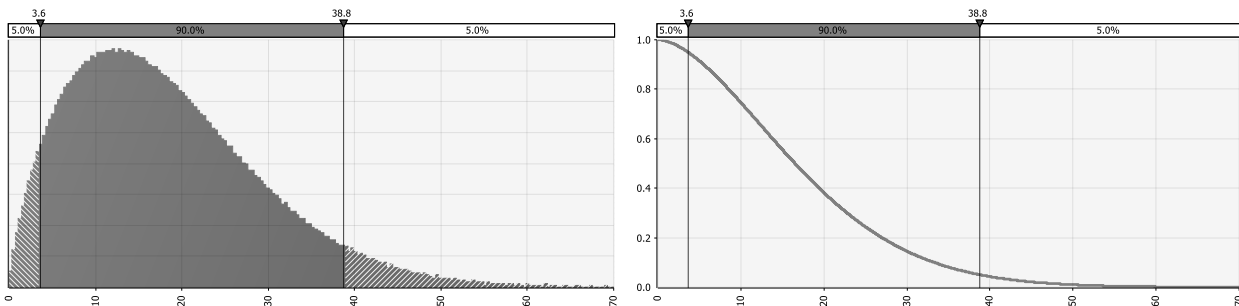

Figure 8 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for time to detection.

3.3.3. Conclusions on the time to detection

Based on the general and specific scenarios considered in this assessment, the time between the event of pest transfer to a suitable host and its detection is estimated to be 16.5 years (with a 95% uncertainty range of 2.5 – 43.8 years).

4. Conclusions

Hosts selection

No difference in terms of pest preferences and host vulnerability for EU host species are reported in the literature. Therefore, the assessment of impact is conducted on the potential coniferous host species mentioned in EFSA PLH Panel (2018) which are the most relevant for commercial plantations in the EU. Potential losses on other ornamental, non-native potential host species are not considered.

Urban areas, natural forests and commercial plantations are assessed all together.

Area of potential distribution

D. sibiricus is characterized by a complex interaction between its life cycle strategies (survival and development, including diapause) and environmental conditions (e.g., threshold temperatures, thermal requirements, snow cover) influencing the adaptation and the distribution of the species. Although such complexity does not make it possible to derive reliable maps projecting the area of potential distribution, it is considered to be very unlikely that the Mediterranean climate will be suitable for establishment and this has been excluded. Therefore, the area of potential distribution coincides with the area where the main hosts are present throughout the EU except for areas of southern EU with a Mediterranean climate.

Expected change in the use of plant protected products

Due to the fact that no effective treatments with plant protection products (PPPs) are currently available, the most suitable PPP indicator is Case "A" and the category is "0".

Yield and quality losses

Based on the general and specific scenarios considered in this assessment, the proportion (in %) of yield losses (here with the meaning of percentage mortality) is estimated to be 0.5% (with a 95% uncertainty range of 0.05 – 5.05%).

Spread rate

Based on the general and specific scenarios considered in this assessment, the maximum distance expected to be covered in one year by *D. sibiricus* is 9.5 km (with a 95% uncertainty range of 1.2 - 33 km).

Time for detection after entry

Based on the general and specific scenarios considered in this assessment, the time between the event of pest transfer to a suitable host and its detection is estimated to be 16.5 years (with a 95% uncertainty range of 2.5 – 43.8 years).

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Appendix A – CABI/EPPO host list

The following list, defined in the Methodology Report (EFSA, 2019) as the full list of host plants, is compiled merging the information from the most recent PRAs, the CABI Crop Protection Compendium and the EPPO Global Database. Hosts from the CABI list classified as 'Unknown', as well as hosts from the EPPO list classified as 'Alternate', 'Artificial', or 'Incidental' have been excluded from the list.

Genus	Species epithet
Abies	
Abies	*nephrolepis*
Abies	*sachalinensis*
Abies	*sibirica*
Larix	
Larix	*gmelinii*
Larix	*sibirica*
Picea	
Picea	*jezoensis*
Picea	*obovata*
Pinus	
Pinus	*koraiensis*
Pinus	*sibirica*
Pseudotsuga	*menziesii*
Tsuga	

Appendix B – Evidence tables

B.1 Summary on the evidence supporting the elicitation of yield and quality losses

Susceptibility	Infection	Symptoms	Impact	Additional information	Reference	Limitation/uncertainties
	Incidence	*Severity*	*Losses*			
Species not indicated			*D. sibiricus* damaged 7 million ha of forests in Western Siberia and Chita Oblast, causing the death of entire stands over half of this area.	25 years (1932–1957)	Kolomiets, 1958 (cited by EFSA PLH Panel, 2018)	
Species not indicated			During an outbreak, in 3–4 weeks, up to 30 tonnes/ha of needle fragments and zoogenic matter (frass, dead bodies of larvae, pupae and adult moths) fall on the litter.		Soldatov et al., 2000	From EFSA PLH Panel, 2018 (original paper in Russian)
Species not indicated			Literally, during one season, all foliage in the affected tree stands is eaten by larvae and enters the soil so that the latter becomes highly fertile.		Baranchikov et al., 2000	From EFSA PLH Panel, 2018 (original paper in Russian)
Species not indicated			The damage promotes activity of soil microbiota resulting in rapid release of significant quantities of matter and energy contained in the forest litter. Grassy cover develops intensively and as a consequence, severely disturbed plantations are replaced by non-forest ecosystems.		Baranchikov et al., 2002 a and b, Perevoznikova et al., 2001	From EFSA PLH Panel, 2018 (original paper in Russian)
Stand predominantly occupied by firs			during a 2-year defoliation, the additional emission of carbon reached 0.64 million tonnes in 1999.	impact in terms of carbon balance	Baranchikov et al., 2002 a and b	From EFSA PLH Panel, 2018 (original paper in Russian)
Species not indicated	From 1990 to 2001: 4.2 to 6858 * 103 ha		The 1995–1996 outbreak in Siberia reportedly caused 38–48 per cent mortality of trees.	area of pest foci, by years the same values a provided at regional level in table 3	Mozolevskya et al., 2002	

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			1932-1957 damaged 7 million hectares of forest and killed 50% of the trees	West Siberia and Chita Oblast	Baranchikov and Montgomery, 2014; EPPO, 2005	
Species not indicated						
Species not indicated			1954-1957 > 1.5 million ha trees killed.	Forests near the Ket and Chulym rivers	Kharuk et al., 2016	
Species not indicated	The 2017 outbreak spanned 800 000 ha		Conifer mortality within about 300 000 ha.		Kharuk et al., 2017	
Abies sibirica			Fir tree dies if larvae of *D. sibiricus* have consumed all its needles, although needles phytomass corresponds to 3% of the total phytomass of a 100-year-old tree.		Soukhovolsky and Ivanova, 2018	Summary from another reference
Species not indicated		In 2016, defoliation > 50%		Right bank of the Yenisei River, peculiar in low-mountain relief with large number of small streams drying in summer.	Pavlov et al., 2018	

B.2 Summary on the evidence supporting the elicitation of the spread rate

Spread	Additional information	Reference
Up to 100 km/year	This value is the result of a simple calculation at the basis of these 100 km (actually 120 km) for females and 280 km for males. There were no direct observations on these distances. Moths are unable for active flights after 7 days of their life The daily flight duration time is 1.5 – 5 hours, often 3. To lay its 300 eggs average female spent 3 hours So during her life she has only 12 hours for flights.	Baranchikov, 2019

	The speed (here are observations on short distances in the field) is 2,5 m per sec for females and 5,2 for males.	
Distance from forest edge/number of males in trap (%) 0/38 1/26 2-3/10 4-7/ 12 8-15/15 16-31/ 5 32-63 / 2 More than 63/ 1 The longest flight was 65 km.	Personal observations with SM pheromone traps which were put in the stepper on different distances from the conifer forest edge. The distribution of moths caught was the follows: (*The summary of %% may not be 100 – as coming from the graph*)	Baranchikov, 2019
Adults can disperse from 15 up to 50 km.	The larvae do not balloon.	Pet'ko, 2004
50 km northwards in 3 years (2014-2017) → 16-17 km/year on average	The related outbreak covers 800000 ha in 2017 (200.000 ha in 2016). The warming and increase of climate aridity and increasing growing season allowed *D. sibiricus* to spread.	Kharuk et al., 2018
Average 50 km/year	Coming from observations probably of localized outbreaks	Kirichenko et al., 2009

B.3 Summary on the evidence supporting the elicitation of the time to detection

Reference	Case	Aspect	Results / evidence
Detection methods			
Baranchikov et al., 2004a,b, 2006; Pet'ko, 2004; Pet'ko et al., 2004, 2016	Surveillance of adults	Effects on detectability	Pheromone traps were designed and tested: they can be used from June to July, when adults emerge. This method is sensitive and may allow detection even at low population density but taking into account that *D. pini* has been observed to respond to the same attractants.

Petko, 2004	Surveillance of larvae	Effects on detectability	Sampling of larvae has very low probability of success in case of low population densities.
Petko et al., 2016			*D. sibiricus* and *D. pini* are not reliably distinguishable based on their external morphology and only the diagnostics of their male genitalia may confirm species identity.
Ilyinskiy, 1965	Surveillance of larvae	Effects on detectability	late April–early June: mature larvae can be found by beating the main trunk of potential host plants.
Rozhkov, 1963	Surveillance of larvae	Effects on detectability	September–October: larvae can be found in the litter under damaged trees, where they overwinter.
EFSA PLH Panel, 2018	Identification of adults		Taxonomic keys developed by Rozhkov (1963) are still reference tools to identify *D. sibiricus*.
Mikkola and Stahls, 2008; Kononov et al., 2016	Identification of larvae and adults		Via DNA barcoding or ITS2 spacer, of nuclear ribosomal gene sequence, by comparison with reference specimens of *D. sibiricus* originating from Russia and deposited in Genbank (NCBI, online).
Biology of the pest			
EFSA PLH Panel, 2018	Reproduction	Effects on incidence	150–400 eggs (usually 200–300)/ female although bigger females lay significantly more eggs than small ones.
EFSA PLH Panel, 2018	Life cycle	Effects on detectability	Eggs are 3mm, attached by bunches (from 3–10 up to 100 eggs) to host plant needles and twigs.
EFSA PLH Panel, 2018	Life cycle	Effects on detectability	Eggs hatched from middle June to beginning July and eggs development takes 13–22 days.
EFSA PLH Panel, 2018	Life cycle	Additional information	Larvae have five to six instars (exceptionally seven). First instar larvae are about 3–4 mm in length. Body length of mature larvae may reach 100 mm (but usually varies from 50 to 60 mm).
Kirichenko and Baranchikov, 2004ab	Behaviour	Effects on detectability	Larvae of young and middle instars (I–IV) have better growth, development and survival in groups, whereas older larvae (V–VI instars) prefer staying individually and therefore they effectively spread in the tree crowns.
Prozorov, 1952; Rozhkov, 1963	Adults	Effects on detectability	Adults do not feed and live 5–18 days (usually 7–10 days). Size females > males.
Pleshanov, 1982	Behaviour	Effects on incidence	Tree defoliation can be repeated during 2–3 successive years which can result in tree death, especially when outbreaks occur during hot and dry summers.
Host conditions during the period of potential detection			
Kirichenko and Baranchikov, 2004ab	Host preference		Development on larch provides the highest survival rate (up to 75%) in first instar larvae (most sensitive to food quality) and results in the heaviest females, with high fecundity (up to 400 eggs per female).