Commissioned report from Norwegian
Forest and Landscape Institute 10/2008

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DRAFT PEST RISK ASSESSMENT REPORT ON THE SMALL SPRUCE BARK BEETLE, *IPS AMITINUS*

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Cover photo: Spruce with galleries of *Ips amitinus*. Photographer: Bjørn Økland, Norwegian Forest and Landscape Institute

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SUMMARY

The current report is a background for a Pest Risk Assessment (PRA) of the bark beetle species *Ips amitinus* in the PRA area of Norway, following the International Standards for Phytosanitary Measures ISPM 11 (FAO 2004). The report is based on updated information about distribution, pathogenicity and ecological information, which add to a previous PRA for this species. It is concluded that the risk of establishment is high with the current import and management practices. *I. amitinus* may potentially cause significant tree damage alone or in interaction with *Ips typographus*; however, the outcome is very much dependent on scenarios of climate development and population dynamics.

Key word: risk assessment, Norway, *Ips amitinus*, bark beetle

Other relevant publications from the current project: Økland, B. & Skarpaas, O. 2006. Risikovurdering av *Ips amitinus* ved tømmerimport - Sannsynlighet for introduksjon og effekt på barkbilleutbrudd. Oppdragsrapport fra Skogforsk 7/06: 1-10.

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1. STAGE 1: INITIATION

1.1. Point of initiation

The present draft pest risk assessment (PRA) report is initiated by the review or revision of a policy, and is made according to ISPM 11 (FAO, 2004). The report was commissioned by the Norwegian Scientific Committee for Food Safety (VKM), and has been used as a basis for the opinion of VKMs Panel on plant health (Panel 9). The panel's opinion is published on VKMs web-site (www.vkm.no).

Background for the initiation: The pest of concern, *Ips amitinus* (Eichhoff, 1872), has been detected several times in imported consignments (timber for pulp industry) in Norway since 2002. *I. amitinus* was until 2000 regulated as a quarantine pest in Norway. The pest was then removed from the list of regulated pests.

In order for the Norwegian Food Safety Authority to decide whether to revise the current policy on *I. amitinus* in Norway, the Authority, in a letter of 5th January 2007, requested a PRA from VKM. According to terms of reference, the PRA should be on *I. amitinus* as a plant pest in Norway. To answer the request from the Authority, VKM ordered the present draft PRA report from the Norwegian Forest Landscape Institute.

For more details about the basis for this initiation, it is referred to VKM.

1.2. Identification of PRA area

The PRA area is Norway.

1.3. Information

Information sources utilised for this PRA are all published material available in international scientific journals, books and reports, as well as personal communications, geographic data and unpublished results that have been made available to the risk assessors. Where these information sources have been used, this is indicated in the text by references enclosed in brackets.

1.4. Previous PRA

I. amitinus has been subjected to a previous PRA process (OEPP/EPPO, 1981) and was on the EPPO A2 list until 1996 (Smith et al. 1997). The previous PRA of EPPO is taken into account in the present PRA work with Norway as a PRA area. In addition, the present PRA report makes use of new relevant information that has come after the previous PRA documents (OEPP/EPPO 1981, Smith et al. 1997). Recent records indicate that *I. amitinus* may occur as a primary pest under certain conditions (see 2.1.2).

1.5. Conclusion of initiation

The previous PRA of *I. amitinus* is only partly valid due to new information. There is a need to revise the previous PRA of *I. amitinus* according to recent information about pest risk for this species.

2. STAGE 2: PEST RISK ASSESSMENT

2.1. Pest categorization

2.1.1. IDENTITY AND TAXONOMICAL POSITION OF THE PEST

Ips amitinus (Eichhoff, 1872) is clearly a single taxonomic entity and it can be adequately distinguished from other species. *I. amitinus* is taxonomically positioned in the subfamily Scolytinae in the family Curculionidae (Silfverberg 2004), within the insect order Coleoptera. Note that all bark beetles of the previous family Scolytidae are now placed as a subfamily Scolytinae within the family Curculionidae Latreille, 1802 (Silfverberg 2004). *Ips amitinus* (Eichhoff), 1872 was first described under the name *Tomicus amitinus* Eichhoff. Other synonyms are *Bostrichus duplicatus* Hlawa, 1870, *Ips amitinus* var. *montanus* Fuchs, 1913, *Ips amitinus* var. *montana* Schedl, 1979, and *Ips amitinus* var. *helveticus* Schedl, 1932, *Ips duplicatus* Hlawa, 1913, and *Ips amitinus* var. *montanus* Fuchs, 1913. Common popular names of the same species are small spruce bark beetle or smaller eight-toothed spruce bark beetle (English), petit bostryche du pin (French) and Kleiner 8-zähniger Fichtenborkenkäfer (German).

2.1.2. BIOLOGICAL INFORMATION OF THE PEST

The small spruce bark beetle, *Ips amitinus* (Figure 1), is a close relative of *Ips typographus*, with which it shares many biological characteristics. The body length of *I. amitinus* (3.5 to 4.5 mm) is somewhat smaller than for *I. typographus* (4.2 to 5.5 mm). The body colour is dark brown. Comparing to *I. typographus*, the body appear as more rounded, glossy and with more distinct punctuations. The sutures of the antennae clubs are almost straight in *I. amitinus*, while they are curved in *I. typographus*.

From the entrance holes of the males, *I. amitinus* makes star-like gallery system with 3 to 7 mother galleries coming from a central mating chamber (Figure 2). Their mother galleries tend to follow a more winding course than the mother galleries of *I. typographus*.

Like other *Ips* species, *I. amitinus* most often breeds in recently dead or weakened trees, but it can add to tree-killing, especially of younger trees and in plantations (Mihalciuc et al 2001, Novotny et al. 2002, Knižek 2001, Jurc & Bojović 2004, Jozef Vakula pers.comm.). *I.amitinus* prefers to breed in tree parts with relatively smaller dimensions compared to *I. typographus* (Smith et al. 1997). Galleries of this species are most often found on younger trees or in upper part of weakened trees, or on large-diameter of weakened trees in overlap with galleries of *Ips typographus*. (Jurc & Bojović 2004). It frequently appears together with *I. typographus* and can lead to withering of host trees where both species multiply at the same time (Jurc & Bojović 2004, Milos Knizek pers. comm.).

Depending on altitude and latitude, the flight begins in May-June, and the new generation is developed and appears from June to August. *I. amitinus* is probably univoltine in most of northern Europe and mountainous areas of Central Europe, while there may be two generations per year (bivoltine) at lower elevations (Jurc & Bojović 2004). Hibernation takes place in dead trunks or in the soil litter.

The considerable niche overlap between *I. amitinus* and *I. typographus* could suggest a similarity in fungal species vectored by these beetle species when they are co-occurring in the same area. However, there are only few empirical studies that allow a comparison of fungi vectored by *I. amitinus* and *I. typographus* from the same geographical area. According to studies in Austria (Kirisits 1999), there is a considerable overlap in fungi species found on these two bark beetle species, including one of the most pathogenic fungus on spruce, *Ceratocystiopsis polonica*.

Figure 1. Male of *Ips amitinus* in dorsal view (Jurc & Bojović 2004).

Figure 2. Gallery system of *Ips amitinus* (Jurc & Bojović 2004).

2.1.3. PRESENCE OR ABSENCE IN THE PRA AREA

In the PRA area, *I. amitinus* has recently been recorded a few times in imported timber in harbours (Kvamme et al. 2003, Thunes et al. 2004, Økland et al. 2005), and has been found hibernating under a timber store once (Økland et al. 2005). There are no records from forests in the PRA area.

A better verification of the presence or absence of *I. amitinus* in Norwegian forests near import sites would require an efficient pheromone or attractant for *I. amitinus*. Tests of commercial attractants for *I. amitinus* in breeding sites in Finland (Miikka Eriksson) and near import harbours in Sweden (Åke Lindelöw) and Norway (Bjørn Økland, Torstein Kvamme and Gro Wollebæk) show that *I. amitinus* individuals are not attracted even when this species is present in the surroundings. Similar experiences with attractants for *I. amitinus* are reported from Slovakia (Andrej Gubka and Jozef Vakula pers. comm.). Even if a functioning attractant could be found, detection may still be difficult if beetles migrate to the forests at rates that are lower than the detection threshold for a reasonable trapping effort (Skarpaas & Økland, in revision).

The following points suggest that it is unlikely that *I. amitinus* has become established in the PRA area:

1. Results from spatial population models show that species with strong dispersal capabilities and Allee effects (Allee 1949, Courchamp et al. 1999) may have difficulties in surpassing the threshold in individual numbers required to become established in new areas (Johnson et al. 2007). Many studies indicate that bark beetles have high flight capabilities and may disperse considerable distances from their tree of origin (Sauvard 2004, Piel et al. 2005). Experiments by releasing *I. typographus* into new areas indicate that the dispersing individuals need a sufficient number or support from a local reservoir of beetles to overcome and colonize a host (Grégoire et al. 2007).
2. It has been suggested that the dependency of aggregation in large numbers can be a source of Allee effects that makes it difficult for bark beetles with pheromone systems to become established when founder populations enter in low numbers of individuals and subpopulations (Liebhold & Tobin 2007).
3. *I. amitinus* has been encountered several times in imported timber in Sweden (Lundberg 1995, Lindelöw 2000, Åke Lindelöw pers. comm.), USA and New Zealand (Brockerhoff et al. 2006), but there are no records of establishments in forests from these countries.
4. A global study of bark beetle arrivals shows that several bark beetle species have failed to establish despite several arrivals in harbours (Haack 2001, Brockerhoff et al. 2006).

I. amitinus has shown a rapid range expansion over land in northern Europe. From Central Europe, it spread into Estonia in the 1930s (Zolk 1935, Mandelshtam 1999), into Finland in the 1950s (Koponen 1975) where it now is distributed almost all over the country up to 68 degrees north (Esko Hyvärinen pers. comm.), and into Russian Karelia and Murmansk during the last decades (Voolma et.al. 2004). It is likely that most of this range expansion has taken place by natural means (see 2.2.2). However, man-aided range expansions cannot be excluded: for instance, *I. amitinus* may have entered in Finland by crossing the Gulf of Finland from Estonia (Koponen 1975). *I. amitinus* may possibly spread from Finland and establish in Sweden and Norway, either by natural means, or via transport of coniferous timber (Koponen 1975, 1980). However, so far there are no records showing that this has happened.

2.1.4. REGULATORY STATUS

Norway: No regulation. The pest was removed from the national list of regulated pests in 2000.

EU: Listed in Council Directive 2000/29, Annex II/B (Greece, Ireland, Great Britain and Corsica are protected areas within EU, with regulation of the pest.)

EPPO: The pest was removed from the EPPO A2 list in 1996.

Europe elsewhere: Regulated as a quarantine pest in Turkey (EPPO PQR 4.6).

2.1.5. POTENTIAL FOR ESTABLISHMENT AND SPREAD IN PRA AREA

2.1.5.1. Presence of host-plant species

The most common conifer species in the PRA area, *Picea abies* and *Pinus sylvestris*, are also the main hosts of *I. amitinus* in the northern parts of Europe and in the central mountain region of Europe. Other species of *Pinus*, such as *P. cembra* and *P. mugo* may also serve as hosts in the mountain region of central Europe. *I. amitinus* has also been recorded from *Abies alba* and *Larix decidua* (OEPP/EPPO 1981, Smith et al. 1997). All of these other tree species are most often confined to horticulture use in Norway, and they are of minor importance in silviculture compared to the widely distributed *Picea abies* and *Pinus sylvestris* in Norway. About 6000 ha of *P. mugo* was planted in the western and northern part of Norway in the period 1860-1960, while only few plantations of *A. alba, L. decidua* and *P. cembra* are found in Norway.

2.1.5.2. Role of vectors

I. amitinus is not dependent on any vector for spreading.

2.1.5.3. Comparing ecoclimatic conditions of current distribution to PRA area

I. amitinus is widely distributed in Europe (Figure 3). According to Fauna Europaea (http://www.faunaeur.org), EPPO and recent publications (Jurc & Bojović 2004), this species is present in Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark (mainland), Estonia, Finland, France, Germany, Greece (mainland), Hungary, Italy (mainland), Latvia, Lithuania, Macedonia, Poland, Romania, Russia (north), Slovakia, Slovenia, Switzerland, the Netherlands, and former Yugoslavia (Incl. Serbia, Kosovo, Voivodina, Montenegro). *I. amitinus* is reported as common in countries like Bulgaria, Czech Republic, Finland, Germany and Poland, while the distribution is reported as restricted in many other countries of Europe. *I. amitinus* is common in the mountainous areas of Slovakia, Poland and the Czech Republic. *I. amitinus* has expanded northward in the eastern part of Fennoscandia and is recorded from Murmansk beyond the polar circle (Voolma et al. 2004).

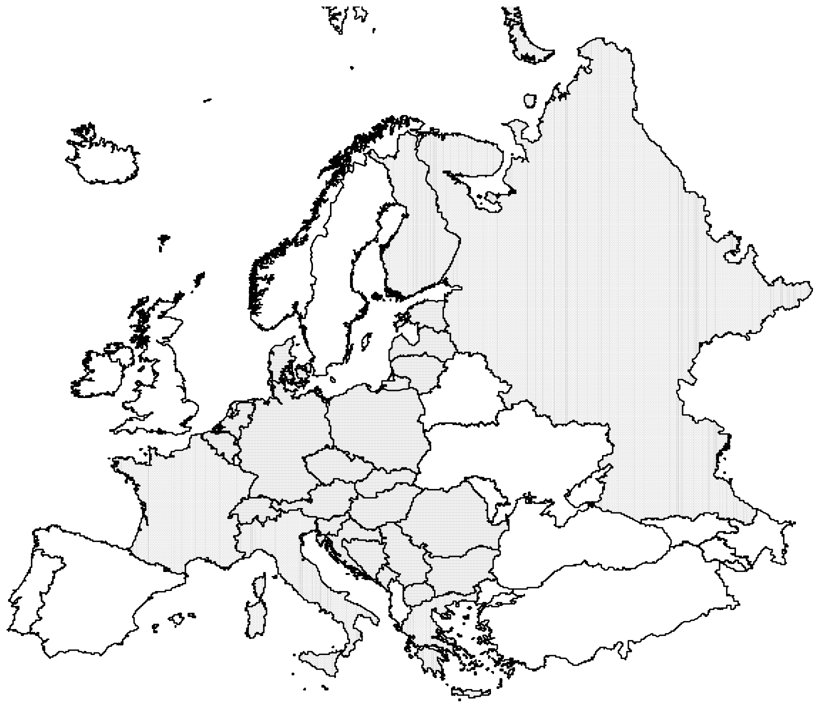

Figure 3. European countries with records of *Ips amitinus* (dotted). Note that this species is not present in the entire dotted polygons of the map.

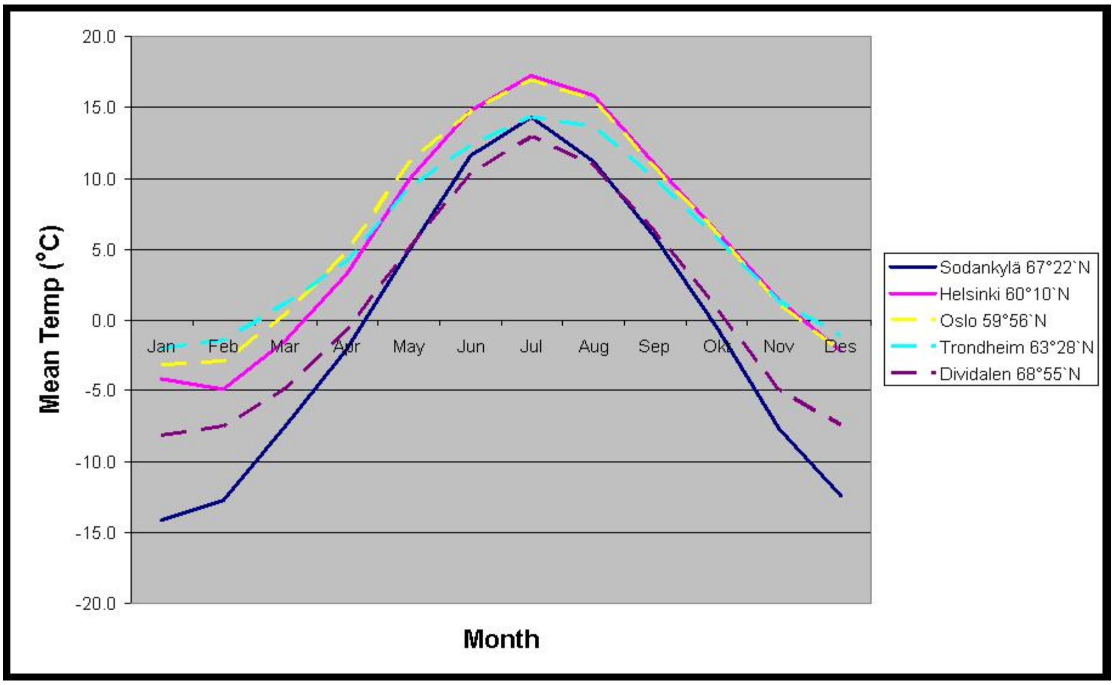

Figure 4. Temperature regimes (mean monthly temperatures of normal period 1971-2000) from three sites of the PRA area (dashed lines) and two sites within the northern distribution area of *Ips amitinus* in Finland (solid lines).

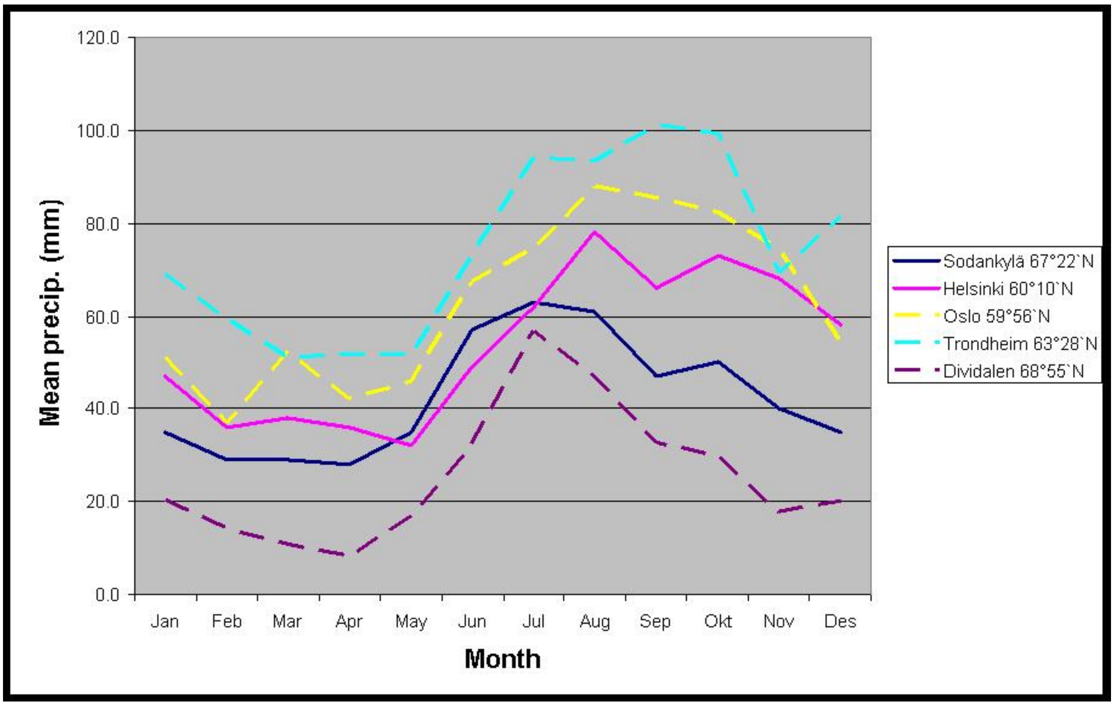

Figure 5. Mean monthly precipitation of the normal period 1971-2000 from three sites of the PRA area (dashed lines) and two sites within the northern distribution area of *Ips amitinus* in Finland (solid lines).

The current distribution area of the pest includes ecoclimatic conditions that are comparable with those of the PRA area or probably sufficiently similar for the pest to survive and thrive. The temperature regimes of representative localities in the PRA area (dashed lines in Figure 4) fall in between, or are almost similar to representative temperature regimes from the northern distribution area of *I. amitinus* in Finland (solid lines in Figure 4). Even though the climate of the PRA area is generally more oceanic than the northern distribution area of *I. amitinus* (Finland and Russia), both dry and wet areas are found in the PRA area (Figure 5). Furthermore, *I. amitinus* is also found in oceanic areas to the south of the PRA area (Denmark, Netherlands, Belgium and France). Thus, the climate is not expected to be a limitation for establishment in the PRA area (Norway).

2.1.6. POTENTIAL FOR ECONOMIC CONSEQUENCES IN PRA AREA

Forestry is important for economy in the PRA area. The tree species that are hosts for *I. amitinus* are also the most important tree species for forestry in the PRA area. If *I. amitinus* becomes established in the PRA area, it may potentially cause significant tree damage, either by influencing the frequency of bark beetle outbreaks in interaction with *I. typographus*, or by direct damage of spruce trees during high populations of *I. amitinus*. The damage is conditional on beetle population sizes, drought and windfall; see extended explanations under 2.3.1 and 2.3.2.

2.1.6.1. Role as pest in its current area of distribution

I. amitinus is considered as a pest in its area of origin in the sense that there are known cases of tree-killing. Even though *I. amitinus* is most often a secondary species on weakened or killed trees, it may kill trees under certain conditions. Cases of tree-killing by *I. amitinus* are reported from areas of southern Europe where the climate is warmer than in the PRA area (Jurc & Bojović 2004). Other cases of tree-killing are reported from forest stands with high densities of *I. amitinus* in the mountains of central Europe (Slovakia and the Czech Republic; Jozef Vakula and Milos Knizek pers. comm.). In such cases, *I. amitinus* may be a mortality factor of stressed trees (due to drought or beetle attacks) that would otherwise have survived in the absence of *I. amitinus* (Milos Knizek pers comm.). Two outbreaks by *I. amitinus* are reported from Slovenia in the years 2002 (Jurc & Bojović 2004) and 2005 (Ribič 2007). In Slovakia, *I. amitinus* has been recorded as a tree-killer during an outbreak in a 40-year-old spruce stand in 1993 (Suchý Vrch in Podspády), and it has been found to kill smaller trees in the on-going bark beetle outbreaks in the High Tatra mountains, following the huge windfelling episode in 2004 (Jozef Vakula pers. comm.). Also in other countries of central and southern Europe, *Ips amitinus* is mentioned as a species that can add to tree killing, especially in younger stands (Mihalciuc et al 2001, Novotny et al. 2002, Knižek 2001, Jurc & Bojović 2004, Milos Knizek pers.comm.). In addition, simulation modelling of the interaction between *Ips typographus* and *I. amitinus* shows that the frequency of bark beetle outbreaks in some periods may be higher when both species occur together compared to the situation when *I. typographus* occurs alone (Økland & Skarpaas 2006, Økland et al 2007).

The experiences with *I. amitinus* vary between countries. It is not regarded as a tree-killer in the northern distribution area (Estonia, Finland, Russian Karelia and Murmansk). In the BAWBILT database (Gilbert & Sauvard 2004), seven European countries mention *I. amitinus* as an important or moderately important pest species (see table 2 and 3 in Grégoire & Evans 2004). If climate plays a role in the pathogenicity of this species, the situation at northern latitudes may change during the ongoing global warming. Another possibility is that *I. amitinus* will need some time in a new area to build up populations before tree-killing will occur.

2.1.7. CONCLUSION OF PEST CATEGORIZATION

It is concluded that *Ips amitinus* could present a risk to the PRA area. *I. amitinus* is identified as a separate species. There are cases of tree-killing in its area of origin showing that this species may behave as a pest under certain conditions, and some European countries list this species as a pest (Grégoire & Evans 2004). In addition, *I. amitinus* can possibly increase the frequency of bark beetle outbreaks in Norway spruce forests due to its interaction with *I. typographus*. There are no records of established populations of *I. amitinus* within the PRA area. The main host plants of *I. amitinus* (*Picea abies* and *Pinus sylvestris*) are widely distributed and important tree species for forest economy in the PRA area. *I. amitinus* may potentially have significantly negative consequences for forest economy in the PRA area.

2.2. Assessment of the probability of introduction and spread

2.2.1. PROBABILITY OF ENTRY OF THE PEST

2.2.1.1. Identification of pathways

Table 1. Conifer commodities and their relevance as pathway for *I. amitinus*

Commodity	Relevance
Round wood	Highly relevant. It is very likely that *I. amitinus* can be transported by round wood with bark, and the imported volume of round wood with bark to the PRA area is significant.
Isolated bark	Low relevance. It is likely that *I. amitinus* may survive in bark isolated from trees and timber, especially in isolated bark that contains pieces of wood with bark. There is little import of isolated bark to the PRA area. However, some bark usually fall off from imported round wood during transport and handling.
Cut branches	Low relevance. It is likely that *I. amitinus* can be transported by cut branches; however, there is little import of cut branches to the PRA area.
Dunnage*	Low relevance, and only relevant when the dunnage is made from wood with bark. Survival of *I. amitinus* in dunnage with bark is moderately likely.
Wood chips	Low relevance, and only relevant when the wood chips are made from wood with bark. It is unlikely that *I. amitinus* will survive in wood chips after storing and transport, and the import of wood chips to the PRA area is low.
Plants for planting	Not relevant. It is very unlikely that *I. amitinus* will be transported by living plants.
Sawn wood	Not relevant. It is very unlikely that *I. amitinus* survives in wood without bark.
Wood packaging*	Not relevant for commodities without bark (pallets, boxes, crates, spools, shavings/excelsior).

* Commodities that are covered by international standard ISPM 15 on wood packaging material (FAO 2002).

Conifer commodities provide a potential pathway for many forest pests (Table 1). The most relevant pathways for *I. amitinus* are most likely the same as for most of the bark beetles included in the Commodity-Specific Phytosanitary Requirements for Coniferae, which is a new EPPO standard under preparation by EPPO (PM 8/2(1)). Using the commodity definitions of this standard, round wood with bark is probably the most efficient pathway for *I. amitinus*. Also isolated bark, dunnage and wood chips may under certain conditions provide a pathway for *I. amitinus*, while there appears to be few other relevant pathways (Table 1).

The first records of *I. amitinus* arriving in the PRA area were made in samples from imported Baltic timber with bark (Kvamme et al. 2003, Thunes et al. 2004, Økland et al. 2005). Some of these samples consisted of bark remnants from the deck below the imported timber. The samples were stored for several weeks before living beetles were extracted. Thus, *I. amitinus* may survive in isolated bark sufficiently long to be transported long distances. Round wood with bark for pulp production may be imported in large volumes, and further assessment will be limited to this pathway.

Natural spread as a pathway: *I. amitinus* may possibly continue to spread from its northern distribution area in Finland and into the PRA area (Norway). *I. amitinus* is currently found to the west of Rovaniemi and north to the level of Lake Lokka and Porttipahta (about 68 degrees) in Finland (Esko Hyvärinen pers. comm.). However, it is difficult to predict too what extent *I. amitinus* will spread further in future, and how an eventual spread will develop. It is uncertain to what extent invasion speed is a regulated process (Starrfelt & Kokko 2008), and to what extent the rate of spread in future can be predicted from rate of spread in the past. If a further spread of *I. amitinus* proceeds into Sweden and Norway, the most likely route of a natural spread is through areas covered by conifer forests. The conifer forests of spruce (*Picea abies*) or pine (*Pinus sylvestris*) are more or less continuous from the northern distribution area of *I. amitinus* in Finland to parts of the PRA area. According to Koponen (1980), the rate of spread up to Muhos (near Oulo) in Finland in the period 1950-1979 was on average 20 km per year; while the further spread towards north in Finland might have been slower. It is not known how the direction of further spread will be, and how the rate of spread is influenced by environmental factors, such as density of forests and local climate. The shortest distance from the northern distribution area of *I. amitinus* in Finland (Lake Lokka and Porttipahta) to the pine forests of Pasvik in the northeastern part of the PRA area is about 140 km. Assuming straight spread with the same speed as in southern Finland, *I. amitinus* could potentially reach Pasvik within 7 years. However, the pine forest in Pasvik is isolated from the main areas of spruce and pine in southern and central Norway. Furthermore, a bigger part of the northern border between Norway and Sweden are mountainous areas with few or no coniferous trees. Thus, reaching the continuous forests of both spruce and pine in southern and central Norway would require a different spreading route through Sweden and into southern Nordland or Nord-Trøndelag. Using the shortest distance through conifer forest from *I. amitinus* localities in Finland (west of Rovaniemi) to southern Nordland or Nord-Trøndelag counties (500 – 600 km) and the rate of spread in Finland (Koponen 1980), *I. amitinus* could potentially reach the PRA area by natural spread within 25-30 years.

2.2.1.2. Probability of the pest being associated with the pathway at origin

For the most relevant pathway (round timber with bark; see 2.2.1.1), it is very likely that *I. amitinus* is associated with the pathway at origin. This species is common in the countries from which timber is imported to the PRA area, and there are no other entry points for *I. amitinus* during the ship transport to the PRA area. Currently, no known cultivation practices or treatments of consignments (debarking, irrigation of timber etc) are applied to reduce the concentration of *I. amitinus* entering the pathway at the origin. When we also assume a fairly high survival during transport or storage (see 2.2.1.3), the concentration of the pest on the pathway is likely to be equally high or somewhat higher at the origin than at the port of arrival in the PRA-area. The average density of *I. amitinus* specimens based on pulp wood samples from six ships coming from Estonia was 12 beetles per m^3 (SD = 11 beetles per m^3; Kvamme et al. 2003, Thunes et al. 2004, Skarpaas & Økland, in revision). Thus, it is very likely that the concentration of *I. amitinus* on the pathway at origin is fairly high. *I. amitinus* has not occurred in samples from saw timber, which usually holds a much better quality than pulp wood. However, round wood for export to saw mills may not be excluded as a possible pathway for *I. amitinus*.

The volume of the movement along the pathway may be characterized as massive. During the last five years, more than 3 mill. cubic meters round wood with bark of coniferous trees has been imported to the PRA area from countries where *I. amitinus* is present, the largest proportion being coniferous pulp wood (Figure 6). Some of the largest companies have reported weekly ship transport during the summer months in the previous years. Thus, the frequency of movement along the pathway is high, possibly in the order of millions of beetles annually.

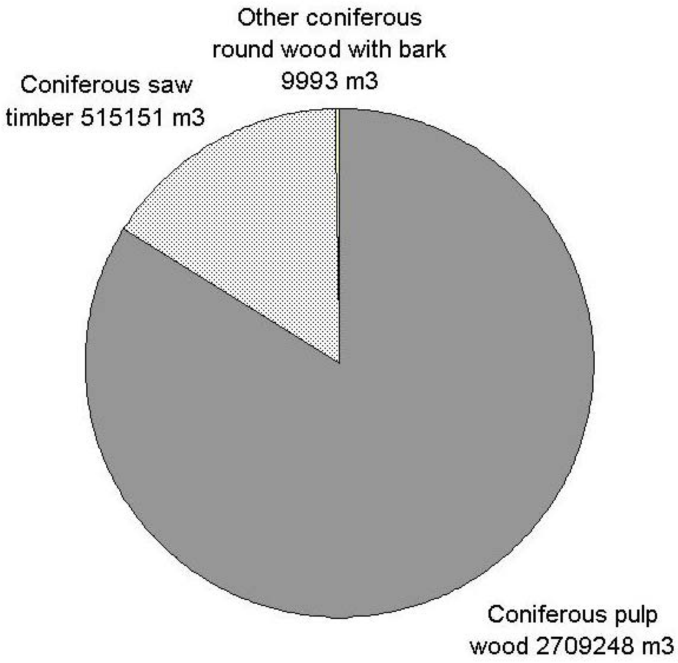

Figure 6. The import volume of coniferous round wood with bark from the Baltic states, Russia and Poland to the PRA area in the period 2002-2006. Source: www.ssb.no

2.2.1.3. Probability of survival and multiplying during transport or storage

Studies of survival of *I. amitinus* during transport or storage are lacking. The sub-cortical galleries of *I. amitinus* represent a sheltered microhabitat, which may be less exposed to natural enemies and favourable for survival of egg and larvae. The temperatures during transport are expected to be about the same or somewhat higher than the temperature regimes of its natural habitat (under bark of dead or weakened trees in forests; see 2.1.5). Higher temperatures may possibly be favourable for egg and larval development. On the other hand, early transports during mating and preparation of brood chambers may be less favourable for survival and multiplying due to the darkness and unnatural conditions in the hold of a ship. The density of *I. amitinus* in bark samples from timber ships (see 2.2.1.2) and timber storages (Økland et al. 2005) indicate that the probability of survival during transport or storage is very high. Furthermore, it is likely that the conditions during transport and storage are suitable for beetle development, such as continuing larval development, pupation, forming new galleries, mating and oviposition.

2.2.1.4. Probability of pest surviving existing pest management procedures

According to the BAWBILT database of Europe, three countries have reported sanitary clearfelling against *I. amitinus*, and five countries do selective thinning due to this species (Grégoire & Evans 2004). The most relevant commodity is timber with bark for pulp production. To our knowledge, treatment of pulp wood (debarking, kiln-drying, sorting, cleaning, irrigation etc) is not carried out to reduce the content of *I. amitinus* in the countries of origin, nor after reception in the PRA area. Thus, it is very likely that *I. amitinus* survives and remain undetected during existing phytosanitary measures for pulp wood.

2.2.1.5. Probability of transfer to a suitable host

After arrival to ports in the PRA area, there is a limited further distribution of the most abundant commodity. Typically, the pulp wood is transported directly to intermediate stores before being processed in the industry. Most processing plants are close to the port of entry. Imported saw timber may be transported inland to local saw mills, which implies that this commodity is distributed more widely than pulp wood. The consignments of round wood arrive most frequently in the summer months (May-August), which is the most suitable time of year for pest establishment.

The probability of reaching suitable hosts in the surrounding forests is a function of distances between storage sites and forest and the volumes of imported timber (Skarpaas & Økland, in revision). Under current practices, suitable hosts are within short distances from the intermediate timber storages, where imported timber can be stored up to several months, also within the swarming season (Økland et al. 2005). According to results from simulation models, it is likely that imported individuals of *I. amitinus* may reach suitable hosts under current timber import practices (Skarpaas & Økland, in revision).

In conclusion, the assessment in 2.2.1.1-2.2.1.5 suggests that the probability that *I. amitinus* may enter the PRA area and arrive at a suitable host is high.

2.2.2. PROBABILITY OF ESTABLISHMENT

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

The main hosts of *I. amitinus* are Norway spruce *Picea abies* and Scots pine *P. sylvestris* (Smith et al. 1997). These tree species are very widely distributed in the PRA area. *P. abies* occurs naturally in most of central and south-eastern Norway (except in alpine regions), where it is the dominant species in climax forest communities. *P. abies* is also currently spreading in western Norway, where it has been introduced in many new areas for forestry purposes. *P. sylvestris* is even more widely distributed, overlapping and complementing the distribution of *P. abies* by covering drier, wetter and colder areas (further information is given at Statistics Norway, www.ssb.no/skog_en).

2.2.2.2. Suitability of environment

The environment of the PRA area should be suitable for the establishment of *I. amitinus*, as the conditions are largely similar to its area of origin (see 2.1.5.3). *I. amitinus* is thriving well in climates to the south of the PRA area and is also found in northern areas such as Finland, Karelia and Murmansk (Voolma et al. 2004) with climates that are largely similar to that of the northern part of the PRA area. The abiotic factors in parts of the area of origin are largely similar to that of the PRA area. Both the PRA area and the northern distribution area of *I. amitinus* are covered by boreal forests dominated by *P. abies* and *P. sylvestris*.

I. amitinus may interact with several species in the PRA area, the most important being *I. typographus*. The assembly of interacting species (*I. typographus* and other bark beetles with overlapping habitat, as well as predators) in the PRA area is largely the same as in areas where *I. amitinus* has expanded in the last decades, such as Estonia, Finland, Russian Karelia and Murmansk (Voolma et al. 2004). Thus, it is very likely that establishment will not be prevented by competition from existing species or natural enemies in the PRA area.

2.2.2.3. Cultural practices and control measures

The managed environment in the PRA area is highly favourable for establishment of *I. amitinus*. The tree species composition, abiotic factors and climatic factors in the PRA area are largely the same as in northern areas where *I. amitinus* is thriving (see 2.1.5.1, and 2.1.5.3). Currently, there are no control or husbandry measures to prevent establishment of *I. amitinus* in the PRA area. There are hardly any examples of successful eradication programmes after an invasive forest pest has been established and has started to spread. It is very likely that *I. amitinus* could survive eradication programmes in the PRA area after it has established.

2.2.2.4. Other characteristics of the pest affecting the probability of establishment

Even though the probability of arriving a suitable host in the PRA area is high (2.2.1.1-2.2.1.5), characteristics of certain bark beetles (including *I. amitinus*) may affect the probability of establishment. The establishment of some bark beetle species seems to be negatively influenced by Allee effects, as they have failed to become established despite frequent arrivals in harbours (Haack 2001, Brockerhoff et al. 2006). Even though *I. typographus* has been intercepted by port inspectors in the United States 286 times from 1985-2001 (Haack 2001), this species has not become established in North America. Similarly, *I. amitinus* has been encountered in harbours of Norway, Sweden, New Zealand and USA without being found as an established species in these countries. Paradoxically, high dispersal ability may inhibit invasion ability when an Allee effect is present (Johnson et al. 2007). Even though Allee effects may reduce the establishment success of alien bark beetles, repeated arrivals may increase the probability of establishment. A worldwide study of invasive bark beetles showed that new establishments of bark beetles do occur, and that frequently intercepted species were about four times as likely to become established as rarely intercepted species (Brockerhoff et al. 2006).

Considering the wide range of climate and habitats in its distribution area, *I. amitinus* appears to be a highly adaptable species. *I. amitinus* has spread into new areas outside its original distribution (see 2.1.3). Apparently, new establishments are likely to happen under the high propagule pressures that are present during expansion over land. On the other hand, establishment appears to be less frequent when *I. amitinus* and other bark beetles enter in harbours after sea transports (see above). In such cases, short-lived transient populations may occur in the PRA area. *I. amitinus* was found to hibernate under a timber storage site in southern Norway during the winter 2003/2004 (Økland et al. 2005). Full establishment is likely to happen after repeated trials (see above; Brockerhoff et al. 2006).

2.2.2.5. Conclusion of the assessment from 2.2.2.1 – 2.2.2.4.

It is likely that *I. amitinus* will become established in the future with the current import practice (large volumes and few control measures). Even though many arrivals do not result in establishments due to Allee effects (see 2.2.1.9), it is likely that establishment will happen when the frequency of entering beetles is high (Brockerhoff et al. 2006, Skarpaas & Økland, in revision). The environment of the PRA area should be suitable for establishment of *I. amitinus* as the main hosts (*Picea abies* and *Pinus sylvestris*) are very widely distributed in the PRA area, the climate of the PRA area is largely similar to the area of origin, and it is not likely that interactive species (competitors or natural enemies) will prevent establishment.

2.2.3. PROBABILITY OF SPREAD AFTER ESTABLISHMENT

It is difficult to predict future spread. Comparing with Finland, it is likely that *I. amitinus* will spread by natural means if it becomes established in forests in the PRA area. In Finland, this species spread about 20 km per year during 29 years (Koponen 1980). In 1950, the first captures in Finland were made in the southernmost part of the country, which is located at about the same latitude as Oslo. In 1979, *I. amitinus* had been recorded in Muhos (near Oulo), and in Taivalkoski with latitude about the same as Hattfjelldal in northern Norway. Thus, the fast spread in Finland took place in a latitudinal range corresponding to a major part of the latitudinal range of spruce (*Picea abies*) in the PRA area.

The relatively constant rate of spread in Finland may indicate that the spread happened by natural means and was not a stratified process consisting of human transport followed by natural spread (Liebhold & Tobin 2007). A constant rate of spread agrees with common integral functions of natural spreading, which describes the radius of the wave front as a linear function of time (Williamson 1996). It is however moderately likely that the spread of *I. amitinus* in the PRA area could be aided by human assistance, even though the pattern of spread in Finland does not indicate that it is dependent on human assistance for rapid spread. Human transport may become increasingly important if more logging waste of conifer trees is taken into use as biofuel. It is likely that the spread of the pest will not be contained within the PRA area, since the coniferous forests are continuous between Norway and Sweden.

2.2.4. CONCLUSION ON THE PROBABILITY OF INTRODUCTION AND SPREAD

There is a high probability of introduction and spread of *I. amitinus* in the PRA area with the current import practice. The environment of the PRA area should be suitable for establishment of *I. amitinus* as the main hosts (*Picea abies* and *Pinus sylvestris*) are very widely distributed in the PRA area, the climate of the PRA area is largely similar to the area of origin, and it is not likely that interactive species (competitors or natural enemies) will prevent establishment. It is likely that the further spread of *I. amitinus* in the PRA area will be by natural means if it becomes established in the PRA area, and it is likely that it will continue spreading to neighbouring areas (Sweden) that share continuous forests with the PRA area.

2.3. Assessment of potential economic consequences

2.3.1. PEST EFFECTS

2.3.1.1. Direct pest effects

Introduction of *I. amitinus* may potentially increase the frequency of bark beetle outbreaks due to a possible interaction effect with *I. typographus* (Økland & Skarpaas 2006). This effect is conditional and may vary with the population sizes of the species and environmental conditions, such as the frequency and severity of drought and windfall, etc. (see 2.3.2).

Even though *I. amitinus* generally is considered to be a secondary species, it may kill trees under certain conditions. Cases of tree-killing by *I. amitinus* are reported from areas with a warmer climate than the PRA area (Jurc & Bojović 2004), while this species is not regarded as a tree-killer in the northern distribution area (the Baltic states, Finland, Russian Karelia and Murmansk). However, a warmer future climate may increase the risk of tree-killing by *I. amitinus* in northern areas as well. Furthermore, *I. amitinus* has been present a relatively short time in the northern areas, and it is known that introduced species in some cases may need some time to build up populations to harmful levels (Williamson 1996). Other cases of tree-killing by *I. amitinus* are connected with high population densities of other bark beetles (Jozef Vakula and Milos Knizek pers. comm.). In such cases, *I. amitinus* may be a mortality factor in stressed trees that would otherwise have survived in the absence of *I. amitinus* (Milos Knizek pers comm.).

2.3.1.2. Indirect pest effects

The indirect economic consequences may be significant. Value reductions of the conifer forests and forest products may have an indirect effect on industries that rely on coniferous raw materials, and on service activities associated with forestry. Bark beetle outbreaks do imply extra costs due to control measures and silvicultural practices. Indirect effects do also include possible effects on biodiversity and recreational values as a result of forest disturbances during outbreaks. When large bark beetle outbreaks change the forest environment, many species may be affected and the recreational value may be reduced.

2.3.2. ANALYSIS OF ECONOMIC CONSEQUENCES

The direct economic consequences are assessed as the loss of raw material of spruce for timber products due to the presence of the pest. In the non-epidemic year 2006, the total harvest of spruce in Norway was 5 515 000 m^3 with an average price of 320 Norwegian kroner (NOK) per m^3 (www.ssb.no). The last outbreak (1971–1981) of *I. typographus* in Norway killed the equivalent of 5,000,000 m^3 of spruce timber (Bakke 1989), which amounts to 1,600,000,000 NOK (≈ 199,281,600 €) in 2006 prices.

An introduction of *I. amitinus* may under certain conditions increase the frequency of bark beetle outbreaks in the PRA area (Økland & Skarpaas 2006). A resource-based Gompertz model has already been formulated for *I. typographus* and has been analyzed with particular reference to the population dynamics of *I. typographus* in Scandinavia, for which a comprehensive literature allows full parameterization (Økland & Bjørnstad, 2006). It reproduces the general behaviour of the bark beetle outbreak dynamics reasonably well, and the results are consistent with historical outbreak periods in Norway. This model has been extended to include a second species that uses the same resources (Økland & Skarpaas 2006). Increasing abundance of a second bark beetle species (and its fungal associates) may contribute to surpassing the threshold for colonizing living trees, and thereby change the frequency of outbreak periods. The frequency of years in which the interacting bark beetle species have a positive influence on each other is highly variable, as it depends on the population size of both species and the rate of accumulation of breeding resources (Økland & Skarpaas 2006). Using empirical data on niche overlap between *I. typographus* and *I. amitinus* (Zumr 1984), the change in number of outbreaks periods due to the second species (*I. amitinus*) was tested in simulations by the above-mentioned model. Assuming that *I. amitinus* is much less aggressive than *I. typographus*, the relative ability of *I. amitinus* to kill trees compared to the ability of *I. typographus* to kill trees was set to values ranging from 0.01% to 10%. The mean increase in number of outbreaks periods per simulated time series varied from 19 to 32%, while maximum values of increase ranged from 0 to 45%. A decrease in number of outbreak periods was also observed in some simulations.

According to these rough estimates, the direct economic consequences of introducing *I. amitinus* may potentially be significant. If the direct cost of each outbreak by *I. typographus* is about 1,600,000,000 NOK (see above) per 74 years (average time between outbreaks in simulations, Økland & Bjørnstad 2006), the average loss per year by *I. typographus* alone is estimated to about 21 mill. NOK (≈ 2,615,000 €). In a hypothetical worst-case scenario, where *I. amitinus* is fully expressing its potential economic consequences, the frequency of outbreak periods is increased by 45% due to the interaction effect between *I. typographus* and *I. amitinus*, which gives an average increase in yearly loss of about 9.7 mill. NOK (≈1,208,000 €). A smaller part of the loss may be subtracted, because some of the killed trees might be utilized as raw material for pulp or fire wood. On the other hand, the losses may also be higher due to the volume of spruce killed directly by *I. amitinus*.

The indirect economic consequences are not quantified here.

2.3.3. CONCLUSION ON THE ASSESSMENT OF ECONOMIC CONSEQUENCES

It is concluded that *I. amitinus* possibly can cause significant damage by itself or by adding to damaging effects by *I. typographus* during outbreaks. These effects may have a negative impact on forest economy in the PRA area. The significances of direct and indirect losses are uncertain as they depend on climatic development and interactions with another species.

2.3.3.1. Endangered area

The endangered area, where presence of *I. amitinus* potentially can cause economically important loss is the distribution areas of *Picea abies* and *Pinus sylvestris* in Norway (see 2.2.2.1). It is implicit in the considerations that the ranges of these tree species and the areas of high bark beetle outbreak risk may be further expanded by forest re-growth and planting (esp. *Picea abies* in western Norway), and be shifted towards higher latitudes and altitudes with increasing temperature (global warming).

2.4. Degree of uncertainty

There is a moderate level of uncertainty regarding the presence or absence in PRA area. A better verification of the presence or absence of *I. amitinus* in Norwegian forests near import sites would require an efficient pheromone or attractant for *I. amitinus*. Even if a functioning attractant could be found, detection may still be difficult if beetles migrate to the forests at rates that are lower than the detection threshold for a reasonable trapping effort (Skarpaas & Økland, in revision).

There is a moderate level of uncertainty regarding the natural spread as a pathway for entry of *I. amitinus* into the PRA area. It is difficult to predict to what extent *I. amitinus* will spread naturally from its current distributions in Europe, like its northern distribution areas in Finland, and how an eventual spread will develop. It is uncertain to what extent invasion speed is a regulated process (Starrfelt & Kokko 2008), and to what extent the rate of spread in future can be predicted from rate of spread in the past.

There is a moderate level of uncertainty regarding the probability of establishment. The assessment of establishment potential relies partly on the assumptions that *I. amitinus* is facing an Allee effect at the entry points (Johnson et al. 2007, Liebhold & Tobin 2007), and that bark beetles that enter frequently tend to overcome this Allee effect after repeated trials (Brockerhoff et al. 2006). These assumptions are supported by both ecological theory and empirical observations; however, we are not in position to test the establishment risk of *I. amitinus* in the PRA area directly.

There is a high level of uncertainty regarding the assessment of potential economic consequences. The assessment of economical consequences by introducing *I. amitinus* relies on a number of assumptions, such as (a) model estimates for time between bark beetle outbreaks with and without interaction with *I. amitinus*, (b) cost of bark beetle outbreaks derived from the outbreak within the PRA area in the 1970s, and (c) increased risk of infection by *I. amitinus* due to global warming and the time needed for population build-up after introduction. Even in the simulation of the interaction effects (point a above), there is a variation from 0 to 50% increase of outbreak frequency due to the presence of *I. amitinus*. Such large variation in outcomes is intrinsic in the current models, and is realistic in the sense that large variation in the time between outbreak periods is also observed in historical data of *I. typographus* outbreaks (Økland & Bjørnstad 2006). We know that the outcome in reality depends on the scenarios of climatic factors (drought periods, windfall episodes) and the development of population sizes. Thus, the estimates presented here are not meant as exact predictions, but illustrations of potential economic loss in a worst case scenario.

2.5. Conclusion and summary of the pest risk assessment

In the PRA area (Norway), *I. amitinus* has recently been recorded a few times in imported timber in harbours, and has been found hibernating under a timber store once. There are no records from forests in the PRA area, and several points suggest that it is unlikely that *I. amitinus* has become established in the PRA area. Based on this, the probability that *I. amitinus* is established in Norway to day is considered as low.

I. amitinus may possibly continue to spread naturally from its northern distribution area in Finland and into the PRA area. However, it is difficult to predict to what extent *I. amitinus* will spread, and how an eventual spread will develop.

The massive transport along some of the commodity pathways implies that the probability that *I. amitinus* enters the PRA area is high. This species is likely to survive the current procedures of transport and storage, and distances from points of entry into natural habitats in forests are short. The climatic and environmental conditions of the PRA area are largely similar to the area of origin, and management practice or natural enemies are not likely to prevent establishment in the PRA area.

Allee effects may explain why *I. amitinus* has not become established after repeated arrivals by imported timber to Norway, Sweden, USA and New Zealand, and also why many other bark beetle species have entered in harbours in different countries without becoming established in forests. However, it may also just be a matter of repeated trials, since a worldwide study of invasive bark beetles showed that new establishments of bark beetles happen more often for species that have been frequently intercepted in import harbours.

Thus, the probability for introduction (entry and establishment) as a result of import of certain wood products from countries where the pest exists is considered as high with the current import practice. Round wood with bark has high relevance as pathway for *I. amitinus*. The commodities of isolated bark, cut branches, dunnage and wood chips have low relevance, whereas plants for planting, sawn wood and wood packaging are considered as not relevant.

If *I. amitinus* becomes established, it is likely to spread by natural means in the PRA area and into neighbouring areas (Sweden) that share continuous forests with the PRA area.

If *I. amitinus* is introduced into the PRA area, it is expected that the forest damage will be minor in the beginning. However, if this species becomes more widespread and abundant, it may potentially increase the frequency of bark beetle outbreaks due to its interaction with *I. typographus*, and it may contribute to forest damage during outbreaks. These damaging effects are conditional and may vary with the development of population sizes of the species, and the occurrence of drought periods and windfall episodes.

These damaging effects may have a negative impact on forest economy in the PRA area. The direct economic consequences are assessed as the loss of raw material of spruce for timber products. The average loss per year by *I. typographus* alone is estimated to about 21 mill. NOK (≈ 2,615,000 €). In a hypothetical worst-case scenario, where *I. amitinus* is fully expressing its potential economic consequences, the frequency of outbreak periods is increased by 45 % due to interaction effects between *I. typographus* and *I. amitinus*, which gives an average increase in yearly loss of about 9.7 mill. NOK (≈1,208,000 €).

The indirect economic consequences may also be significant, like effects on industries that rely on coniferous raw materials, effects on service activities associated with forestry, extra costs due to control measures and silvicultural practices, and possible effects on biodiversity and recreational values. The indirect economic consequences are not quantified here.

Even though *I. amitinus* is generally considered to be a secondary species, it may kill trees under certain conditions. Current and historical records of tree killing by *I. amitinus* are from southern areas with a warmer climate than the PRA area, but the potential of forest damage and tree-killing in northern areas may increase with global warming.

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