The EPPO PRA for *Agrilus anxius*: Assessment for Norwegian conditions

Opinion of the Panel on Plant Health of the Norwegian Scientific Committee for Food Safety

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Acknowledgements

VKM has appointed a project group consisting of three VKM members and one external expert to answer the request from the Norwegian Food Safety Authority. The members of the project group are acknowledged for their valuable work on this opinion.

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Assessed by

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Summary

Agrilus anxius (bronze birch borer) is a specialist wood-borer of *Betula* spp. present in North America, from northern Canada to southern USA. So far the pest is not known to be present elsewhere. In North America *A. anxius* is the most serious pest of birch trees in forests and amenity plantings, causing widespread mortality of birch trees.

In 2011 EPPO published a Pest Risk Analysis (PRA) of *A. anxius*. According to this PRA, *A. anxius* represents an unacceptable risk to those parts of the EPPO region in which tree species of *Betula* are present. EPPO decided to add *A. anxius* to the EPPO A1 list in September 2011, thus recommending its member countries to regulate *A. anxius* as a quarantine pest.

During the last few years in Norway there has been import of wood chips for energy purposes, which is a potential pathway for introduction of *A. anxius*. The Norwegian Food Safety Authority needs a risk assessment of *A. anxius* for Norway as basis to decide whether *A. anxius* should be regulated as a quarantine pest in Norway, and if so, which phytosanitary measures should be implemented to prevent entry and establishment in Norway.

On this background the Norwegian Food Safety Authority, in a letter of 23rd November 2011, requested an assessment of the probability of entry and establishment and impact potential of *A. anxius* in Norway, and an evaluation of the effectiveness of relevant risk reducing measures addressing import of wood chips and other lumber of *Betula* spp. from countries where *A. anxius* is present. It was also requested that VKM uses the EPPO PRA as basis for the assessment.

The current document is VKM's answer to this request, and it was adopted by VKM's Panel on Plant Health 14th May 2012. The draft of this document was made by a project group consisting of three members of the panel and one external expert, mainly as contract work by the Norwegian Forest and Landscape Institute.

VKM regards the EPPO PRA for *A. anxius* as highly relevant to Norway. VKM regards all EPPO's assessments and ratings concerning entry, spread, establishment, and economic and environmental consequences of *A. anxius* in the EPPO region as entirely valid also for Norway as the PRA area. Thus, VKM gives the following main conclusions on these topics:

- The probability of entry of *A. anxius* to Norway is considered as low to medium, with a medium level of uncertainty.
- The probability of establishment is considered as very high, with low uncertainty.
- The probability of spread within Norway is considered as very high, with a low level of uncertainty.
- The endangered area is the whole forested area of southern Norway south of Nordland County, and Pasvik in eastern Finnmark.
- It is expected that the pest will have major economic consequences in the endangered area. On the whole, introduction would result in high mortality of birch throughout the endangered area, and major economic impacts (including major environmental impacts). The overall level of uncertainty is low.

Furthermore, VKM has identified the following four potential pathways for *A. anxius* into Norway: 1) wood chips, 2) plants for planting of *Betula* spp., 3) wood with or without bark of *Betula* spp., and 4) furniture and other objects made of untreated birch wood originating from North America. VKM finds that most information given in EPPO's PRA about risk reducing measures for each of the pathways applies to the PRA area of Norway as well. Some of the conclusions concerning risk reducing measures given by VKM are as follows:

- Pathway 1, 3 and 4: Limited period of entry as a measure against *A. anxius* can only be recommended on a case by case basis, given that the wood/chips is covered during transport, that outdoor storage is not allowed, and that all wood/chips are processed before February1st. This measure is unfeasible when large volumes of wood/chips from different import dates are stored together and cannot be distinguished on import dates.
- Pathway 1: Storing the chips for at least one year before export, under the strict control of the NPPO, as described in the EPPO PRA, is a suitable measure also for Norwegian conditions.
- Pathway 3 and 4: Storing the wood for at least two year before export, under the strict control of the NPPO, as described in the EPPO PRA, is a suitable measure also for Norwegian conditions.
- Pathway 2: Preventing infestation of the commodity by growing the crop in mesh houses or nets can be a safe measure against *A. anxius* when the mesh size does not allow entry of beetles, and if for at least two years no signs of *A. anxius* have been observed during two official inspections per year carried out at appropriate times, including immediately prior to export.
- Pathway 2: Limiting imports to stems below 2 cm diameter and scion below 1 cm may be a safe measure against *A. anxius*.
- Pathway 3 and 4: Removing both bark and the outer sapwood (min 1.27 cm) is suggested in the EPPO PRA a measure to ensure that the pest is not present. VKM considers squared wood without wanes to be a safe commodity regarding *A. anxius*. If applying this measure in imports to Norway, it may be necessary with a case-to-case permit to ensure that all outer sapwood that could contain *A. anxius* is absent.

Keywords

Agrilus anxius, bronze birch borer, Pest Risk Analysis (PRA), pest risk assessment, distribution, spread, establishment, entry, management options, wood chips, birch, import, impact, economic and environmental consequences

Contents

Background

Agrilus anxius (bronze birch borer) is a specialist wood-borer of *Betula* spp. present in North America, from northern Canada to southern USA. So far the pest is not known to be present elsewhere. In North America *A. anxius* is the most serious pest of birch trees in forests and amenity plantings, causing widespread mortality of birch trees (EPPO 2011a).

In 2011 EPPO published a Pest Risk Analysis (PRA) of *A. anxius* (EPPO 2011b). According to this PRA, *A. anxius* represents an unacceptable risk to those parts of the EPPO region in which tree species of *Betula* are present. The PRA also identified phytosanitary measures that can reduce the risk significantly. EPPO decided to add *A. anxius* to the EPPO A1 list in September 2011, thus recommending its member countries to regulate *A. anxius* as a quarantine pest.

The PRA of EPPO identified four relevant potential pathways for introduction of *A. anxius*: 1) Wood chips from Canada and the USA, containing *Betula* spp. 2) Plants for planting of *Betula* spp. from Canada and the USA 3) Wood with or without bark of *Betula* spp. from Canada and the USA 4) Furniture and other objects made of untreated birch wood from Canada and the USA. During the last few years in Norway there has been import of wood chips as described in pathway 1) for energy purposes.

On this background the Norwegian Food Safety Authority, in a letter of 23rd November 2011, requested an assessment of the probability of entry and establishment and impact potential of *A. anxius* in Norway, and an evaluation of the effectiveness of relevant risk reducing measures addressing import of wood chips and other lumber of *Betula* spp. from countries where *A. anxius* is present. It was also requested that VKM uses the EPPO PRA as basis for the assessment.

The Norwegian Food Safety Authority refers to the following EPPO PRA documents and draft data sheet: 11-16987, 11-16988, and 11-16903 (EPPO 2011b, 2011c, 2011a), and to data analysis by the Norwegian Forest and Landscape Institute from sampling of wood ships imported from Canada 2010 (Økland 2010).

The Norwegian Food Safety Authority will use VKM's assessment as basis to decide whether *A. anxius* should be regulated as a quarantine pest in Norway, and if so, which phytosanitary measures should be implemented to prevent entry and establishment in Norway.

VKM's Panel on Plant Health appointed a project group consisting of three members of the panel and one external expert to make a draft assessment answering the request from the Norwegian Food Safety Authority. The draft was mainly conducted as contract work by the Norwegian Forest and Landscape Institute. The assessment was adopted by the Panel on Plant Health at a meeting 14th May 2012.

Terms of reference

Based on the EPPO Pest Risk Analysis for *Agrilus anxius* (11-16987 (11-16902, 11 -16726, 10-16415)) (EPPO 2011b) and on the basis of what is known about specific conditions in Norway VKM is asked to give its opinion on the following:

1. The size of the import to Norway of potentially infested commodities and the probability of entry of *A. anxius* into Norway.
2. If there are quality differences in traded wood chips of birch, which could indicate that wood chips imported for different purposes represents different levels of probability of entry of *A. anxius*.
3. Probability of establishment and spread of *A. anxius* in Norway if individuals enter.
4. Linked to the assessments of the probabilities of entry and establishment, VKM is asked to give its opinion on possible reasons for why *A. anxius* so far has not been introduced into Europe, despite the history of import of non-coniferous wood, as described in the EPPO PRA.
5. Potential impacts of an establishment of *A. anxius* in Norway.
6. Effectiveness of relevant risk management options against the introduction of *A. anxius* via the import of commodities to Norway, in particular those identified in the EPPO PRA.

Assessment

1 Initiation of assessment

1.1 Identification of the PRA area

The PRA area is Norway.

1.2 Taxonomic position of the pest

The name of the pest is

Agrilus anxius, Gory (1841)

Common name: Bronze Birch Borer (BBB).

EPPO code: AGRLAX.

The pest is an arthropod.

Class: Insecta, Order: Coleoptera, Family: Buprestidae, Genus: *Agrilus*, Species: *anxius*.

1.3 Is the pest present in the PRA area?

No, the pest is not present in the PRA area. The pest has not been registered outside North America, its natural area of distribution.

1.4 Regulation status

A. anxius was added to the EPPO A1 list in 2011.

2 Biological information

A summary of the biology of *A. anxius* is presented in the *A. anxius* EPPO datasheets on pests recommended for regulation (EPPO 2011a). *Agrilus anxius* is omnipresent throughout the range of birch in USA and Canada. All North American *Betula* spp. are moderately susceptible if stressed, except *B. nigra* which is rarely attacked. All Asian and European *Betula* spp. are highly susceptible, except *B. nana* which is not reported as a host (EPPO 2011a; Nielsen et al. 2011). In Norway, *B. pendula* (common name in Norwegian: "Hengebjørk") and *B. pubescens* ("Bjørk") are expected hosts. In addition several *Betula* spp. are sold as ornamentals in Norway, *B. utilis* ("Himalayabjørk") and *B. albosinensis* ("Rødbjørk"), amongst others. *Betula nana* ("Dvergbjørk") is not reported as a host.

Agrilus anxius is active from May to August, and eggs are laid in the bark. Larvae hatch and bore through to the cambium, where they feed and complete their life cycle in one or two years (Baker 1972; Solomon 1995).

3 Relevance of EPPO's PRA

The PRA for *A. anxius* performed by EPPO (2011b) is regarded as highly relevant to Norway. The information given in this PRA corresponds well with Norwegian conditions. Questions that might be specific for Norway are discussed in chapters 5-10 of the current document. These chapters present VKM's answers to the Terms of Reference.

4 Literature

The EPPO PRA reference list was used as the main source of literature information (EPPO 2011b). In addition electronic searches were performed containing the species name "*Agrilus anxius*" in various combinations with other relevant words in the following scientific databases: CAB Direct (2012), JSTOR (2012), Science Direct (2012), Springer Link (2012), Web of Knowledge (2012) and WorldCat (2012). The references in these sources were screened for additional relevant publications. Publications of all ages were included.

5 The size of the import to Norway of potentially infested commodities and the probability of entry of *Agrilus anxius* (question 1 in Terms of Reference)

EPPO's assessments and ratings concerning probability of entry of *A. anxius* in the EPPO region (EPPO 2011b, Stage 2, Section B, steps 1.1-1.14) is regarded valid also for the PRA area of Norway. Thus, the probability of entry of *A. anxius* to Norway is considered as low to medium, with a medium level of uncertainty.

One of the main factors influencing the probability of entry is the size and import of commodities that are potential pathways for *A. anxius*. Table 1 shows the total import from North America (USA and Canada) in the period 1999 – 2011 of commodities that are potential pathways for *A. anxius* into Norway. All data are from Statistics Norway (SSB 2012). The table shows that in the period 1999 – 2011 Norway has imported 65 624 metric tons (241 347 m^3) of non-coniferous wood chips (commodity code 44012200) from North America. According to SSB (2012) the chips arrived in two shipments, 215 000 m^3 in April 2010 and 26 347 m^3 in June 2010. Both shipments were imported by one company. The Norwegian Food Safety Authority sampled both shipments, and according to information given to the Authority, these two shipments contained 30% birch, mainly *Betula alleghaniensis* and some *B. papyrifera*. Samples from the first shipment were analysed by the Norwegian Forest and Landscape Institute (Økland 2010) and by the Norwegian Institute for Agricultural and Environmental Research (Bioforsk). Traces of *Agrilus*-like galleries and outlet holes were found on the chips. However, it could not be verified whether these traces belonged to *A. anxius* or not. Anatomical analysis of the samples showed presence of *Betula* spp., but also woods of conifers and ash were found.

The volume of imported wood chips in general is expected to increase to satisfy demands for energy production (EPPO 2011b). A Norwegian wood pellet company aimed at a yearly import of 1.2 million m^3 of wood chips (Biowood Norway AS 2012), but during its first year of operation the company failed to meet its aims due to various production problems.

According to the Norwegian Food Safety Authority there has been no import of plants for planting of *Betula* spp. from North America during the period 2002-2011. This is in accordance with data from SSB (2012) in Table 1, showing no import of trees and shrubs (commodity code 6029931) from North America in the period 1999-2011. Also, there has been no import of pulpwood of birch (44039902) from North America in this period.

Imports from North America vary in time and quantity between years. For example, all the lumber of birch (44039901) arrived in the year 2000, while fuel wood (44011000) was imported in both 2000 and 2006. Sawdust, wood waste and scrap (44013009) were imported in all consecutive years between 2002 and 2008. Fuel wood of birch could clearly be a likely pathway for *A. anxius*. It is also worth questioning which tree species the commodity of fuel wood (44011000) actually contain.

“Wood chunks" or "biomass chunks” are pieces of wood larger than wood chips. “Wood chunks” were not considered as a pathway in the EPPO PRA, but this commodity is only mentioned as a note under wood chips (EPPO 2011b). “Wood chunks” have previously been imported to Norway, but it is uncertain to what extent it is imported at present. It is not registered under a specific commodity code in Norway, and thus, no statistics exist for this specific commodity (SSB 2012). If “wood chunks” of *Betula* spp. are imported from North America to Norway, they will present equal or greater risk than wood chips. Furthermore, large particles may follow imports classified as wood chips. For example, the samples from the boat load of wood chips imported to Norway in 2010 contained chips from 1.6 to 22.9 cm measured along their maximum length (EPPO 2011b), and inspection by the Norwegian Food Safety Authority on the import site revealed even larger pieces than this (Kåre Willumsen, the Norwegian Food Safety Authority, pers. comm.).

No other significant import of commodities containing *Betula* spp. to Norway is known to occur at the time of writing.

Table 1: Import to Norway from North America (USA and Canada) of commodities that are potential pathways for *Agrilus anxius*. Total import in the period 1999 – 2011. Source: SSB 2012.

Commodity code	Commodity name*		Total import to Norway from North America (USA + Canada) in the period 1999 – 2011	
	English	**Norwegian**	**metric tons**	**m^3**
44011000	Fuel wood (in logs, billets, twigs, faggots or similar forms)	Ved til brensel	516**	898**
44012200	Non-coniferous wood in chips or particles	Treflis el trespon av lauvtrær	65 624***	241 347***
44013009	Sawdust, wood waste and scrap (whether or not agglomerated in logs, briquettes, pellets or similar forms, not chips or shavings)	Treavfall; også i briketter, pellet o.l., ikke flis eller spon	141**	7 174**
44039901	Lumber of birch (whether or not stripped of bark or sapwood, or roughly squared, not pulpwood)	Tømmer av bjørk, også avbarket el grovt tilskåret, ikke massevirke	13.5	16.0
44039902	Wood for pulping, of birch	Massevirke av bjørk	0	0
44042000	Non-coniferous. Hoopwood; split poles; piles, pickets and stakes of wood, pointed but not sawn lengthwise; wooden sticks, roughly trimmed but not turned, bent or otherwise worked, suitable for the manufacture of walking-sticks, umbrellas, tool handles or the like; chipwood and the like.	Emner av lauvtrær til tønnebånd, stolper/staur, spaserstokk, paraply, skaft o.l.	0.69	0
06029931	Trees and shrubs (except Buxus, Dracaena, Laurus, Camellia, Araucaria, Ilex, Magnolia, Arecaceae, Hamamelis, Aucuba)	Trær og busker, unntatt buksbom, drake-, laurbærtre, kamelia, kransgran, kristtorn, magnolia, palmer, trollhassel, vinterpryd	0	0

* The commodity codes and the commodity names in Norwegian are exactly as given by SSB (2012). In English the commodity names can be somewhat adjusted for increased readability. ** We do not know whether birch was present in this import or not. *** We do know birch was present in this import.

6 Are there quality differences in traded wood chips of birch, which could indicate that wood chips imported for different purposes represents different levels of probability of entry of *Agrilus anxius* (question 2 in Terms of Reference)?

Yes, there are quality differences in traded wood chips of birch. This difference could indicate that wood chips imported for different purposes represent different levels of probability of entry of *A. anxius*.

There is a big difference between the quality of wood chips needed for different purposes, and wood chips for energy production are often made from low-quality wood. According to Asikainen (2010 and references therein), wood that does not meet the quality demands for lumber because of low quality, production damage, damage by disease, drought or damages by insects, are processed and turned into fuel wood products, i.e. wood chips for pellets production. Further, it is stated that residues from forest harvesting, which can be any part of a tree, including the tops, branches, crowns, foliage, stumps and roots can be used for energy. Also, wood from salvage harvesting, that is from “sick, dying and dead trees in stands damaged by fire, wind, disease or insects” (Hall 2002) and from “forest stands degraded by poor harvesting and management or natural disturbances” (Asikainen 2010), can be removed for use as fuel wood. During logging of large volumes by forest harvesters, it is impossible to distinguish between stressed trees attacked by *A. anxius* and healthy trees. *Agrilus anxius* may be present in the outer sapwood at any time of the year, and is difficult to detect by visual inspection. Therefore, it is not likely that *A. anxius*-infested wood can be avoided as raw material for wood chips production (Økland et al. 2012). Trees can also be attacked high above ground in the canopies. In some years, there are few attacks of *A. anxius* observed, while in other years (especially drought periods) the pest can be frequent in the same area (Robert Haack, per. comm. 2010). The two shipments of wood chips that were sampled by the Norwegian Food Safety Authority were supposed to contain mixtures of unregulated deciduous tree species, but they proved to contain wood of both conifers and regulated deciduous tree species (Økland 2010). This indicates that it is not only difficult to distinguish between healthy and unhealthy trees, but it is also a challenge to avoid unwanted tree species and debris.

There is no import of pulpwood of birch to Norway from North America (Table 1). In Norway pulp is made of spruce of high quality. Companies like Borregaard buy spruce timber and produce their own chips to ensure that the chips satisfy their quality demands (Øyvind Rognstad, Borregaard, pers. comm., 9th March 2012)

As yet there are no other commodities than non-coniferous wood chips, shavings or particles (commodity code 44012200) containing wood chips of *Betula* spp. being imported from North America to Norway. Wood chips for pellet production may contain low quality wood, which increases the probability for *A. anxius* to enter.

7 Probability of establishment and spread of *Agrilus anxius* in Norway if individuals enter (question 3 in Terms of Reference)

7.1 Probability of establishment in the PRA area

EPPO's assessments and ratings concerning probability of establishment of *A. anxius* in the EPPO region (EPPO 2011b, Stage 2, Section B, steps 1.15-1.29) is regarded valid also for the PRA area of Norway. Thus, the probability of establishment of *A. anxius* in Norway is considered as very high, with low uncertainty.

7.1.1 Availability of host plants in the PRA area

There is abundant availability of birch (*Betula* spp.) all over the PRA area. In Norway, *B. pendula* (common name in Norwegian: "Hengebjørk") and *B. pubescens* ("Bjørk") are expected hosts. In addition several *Betula* spp. are sold as ornamentals in Norway, *B. utilis* ("Himalayabjørk") and *B. albosinensis* ("Rødbjørk"), amongst others.

Experiments have shown that *B. pendula* and *B. pubescens* are highly susceptible and suffer 100% mortality from *A. anxius* attacks (Nielsen et al. 2011). And according to EPPO (2011b) "overall stress is not a factor that will greatly influence the susceptibility of European and Asian birch trees in the EPPO region because they are highly susceptible even when healthy."

The density of birch increases with altitude. In southern Norway the alpine tree line reaches 1100 meters above sea level (m.a.s.l.), in Sør-Trøndelag and Nord-Trøndelag Counties the tree line is around 600-700 m.a.s.l., and consists mostly of *B. pubescens*. *Betula pendula* can be found as high as 900 m.a.s.l. in Ottadalen, Oppland County (Lid et al. 1994). *Betula nana* ("Dvergbjørk") grows at a higher elevation (1700 m.a.s.l.), but it has never been documented as a host. This could be related to thermal constraints and small stem size (EPPO 2011b). It is uncertain how many meters above sea level *A. anxius* can establish, but at the northern limit of distribution an establishment will probably be restricted by temperature rather than by the distribution of the birch host.

7.1.2 Suitable climate within the PRA area

The Köppen-Geiger climate maps (Peel et al. 2007) shows that Norway and North America share several climate zones, mainly within the continental (D) and temperate (C) zones (Appendix Figures 1 and 2). The south and west coast of Norway has an oceanic climate (Cfb and Cfc) with no dry seasons and warm summers. Norway also has a humid continental climate (Dfb) with severe winters, no dry seasons and warm summers, and a subarctic climate (Dfc) with summers wetter than winters (Hess & McKnight 2011). The subarctic continental climate (Dfc) and the tundra climate (ET) in south-central Norway, the alpine plateau of Hardangervidda, are overrepresented in this model due to low resolution in the data. Based on local knowledge the ET zone extends to far towards the west coast (Appendix Figure 1) where conditions are expected to correspond to Cfb (Peel et al. 2007). In North America *A. anxius* is distributed through humid continental climate (Dfb and Dfa), marine west coast climate (Cfb), and probably also in subarctic climate (Dfc) in Alaska, amongst others. The distribution of *A. anxius* is given by EPPO's PRA in Stage 1, section 7 (EPPO 2011b).

The sole importer of deciduous wood chips (commodity nr. 44012200, Table 1) to Norway is located at Averøy, an area defined as Cfc, subpolar oceanic climates by the Köppen-Geiger climate classification system (Appendix Figure 1). The Cfc climate type is also found in British Columbia and Alaska (Appendix Figure 2). *A. anxius* is present in these two states (EPPO 2011b). In fact, in North America *A. anxius* is registered in states and provinces containing all climate types in Norway, except for ET.

A Köppen-Geiger climate type map of Europe is shown in Appendix Figure 3. According to EPPO (2011b) "there is low uncertainty that the climate in the EPPO region is suitable for establishment, and *A. anxius* rather seems to be restricted by the presence of *Betula* spp.". Birch is distributed all over Norway, and the counties of Nordland and Troms have the largest occurrence of birch in the country. VKM therefore finds it more likely that other factors, rather than the distribution of birch alone, will limit the distribution of *A. anxius* in Norway.

The EPPO PRA (2011b) further states that "Considering a degree-days accumulation with base 10°C and the northern limit of collection localities noted by Bright (1987), it appears that *A. anxius* cannot develop in zones where degree-day accumulation is between 0 and 250. If we apply this to the EPPO region, then *A. anxius* may not develop in most of Norway (except the southern Coast) and in northern Sweden and Finland". However, the degree-days map presented in the EPPO PRA (Appendix 1, Figure 2a, in EPPO 2011b) and the map presented in Appendix Figure 4 in the current document probably underestimate the zones where degree-day accumulation is between 0 and 250 because the resolution in the data does not capture all areas having degree-day sums above 250. The maps have a 10x10 minute spatial resolution, and either lacks data (the same problem as in Peel et al. (2007)) or possibly fails to differentiate between the steep altitude gradient along the west coast. Also the collection localities of *A. anxius* noted by Bright (1987) are few and inaccurate. *Agrilus anxius* is believed to occur across North America, in the whole area of distribution of *Betula* ssp. (Baker 1972). This can be seen in Appendix Figure 2.

7.1.3 Endangered area of the PRA area

The area of Norway where the day-degree sum is above 250 (with base temperature 10°C) correspond to some extent with the distribution of *B. pendula* (EPPO 2011b), as according to distribution maps of *B. pendula* provided by EUFORGEN (2012) (Appendix Figure 5) and also maps by Hultén and Fries (1986) and Børset (1985). Thus, the distribution of *B. pendula* may be the most likely indication of the geographical distribution potential of *A. anxius* in Norway. However, due to topographic variations, it is difficult to draw an exact altitudinal limit within southern Norway. Therefore, the whole forested area of southern Norway, south of Nordland County should be regarded as an endangered area.

According to Børset (1985) *B. pendula* is recorded as far north as Pasvikdalen, Finnmark County (isolated population in the Pasvik Wally 69°30N) where the mean temperature is 10.1°C in the period June-September. The Gulf Stream reaching the norwegian coast causes milder climate at higher latitudes as compared to North America. Bright (1987) recorded *A. anxius* as far north as Alaska and Alberta about the 60th and 61st latitude north. The 60th and 61st latitude north also runs through Norway, and gives *A. anxius* equal photoperiodic regimes, which is the most predictable indicator for seasonal changes and for avoiding seasonally adverse conditions by diapause.

It is important to note that the winter season and periods below 0°C is not a disadvantage. On the contrary, sub-zero temperature is necessary for survival of many insects. Baker (1972) mentions that *A. anxius* needs to be subjected to freezing temperatures to complete its life cycle. Thus, it cannot be excluded that *A. anxius* could establish small populations in eastern Finnmark.

In conclusion, the endangered area is the whole forested area of southern Norway south of Nordland County, and Pasvik in eastern Finnmark. Given the limited scientific knowledge on the climatic requirements of *A. anxius*, an assessment of its potential for establishment in Norway must rely mainly on climatic comparisons with its current area of distribution.

7.2 Probability of spread within the PRA area

VKM regards EPPO's assessments and ratings concerning probability of spread of *A. anxius* in the EPPO region (EPPO 2011b, Stage 2, Section B, steps 1.30 – 1.33 as entirely valid for Norwegian conditions. Thus, the probability of spread within Norway is considered as very high, with a low level of uncertainty.

The continuous diffusion of a population front, as a result of population growth, could be as much as 16-32 km/year (EPPO 2011b). But strong individuals may fly as far as 20 km/day. The closely related *Agrilus planipennis* is spreading 20 km per year in the USA (Prasad et al. 2010), and it is also spreading in Russia (Baranchikov et al. 2008).

Birch is the most popular and sought-after firewood in Norway and is traded across the PRA area. After an initial establishment, this trade would most probably facilitate and increase the domestic spread of *A. anxius*. Considering that birch is the most common tree in the PRA area, accounting for 41% of total number of trees, an outbreak would most likely be impossible to contain.

8 Reasons for *Agrilus anxius* not being introduced despite historical imports (question 4 in Terms of Reference)

According to the EPPO PRA on *A. anxius*, birch wood has been imported from North America to Europe during the last years (EPPO 2011b). The Norwegian Food Safety Authority requests an evaluation of possible reasons for why *A. anxius* has not already been established in Europe. Generally, this kind of questions are associated with weak reasoning, since absence of observations up to now does not give sufficient basis to estimate the likelihood of establishments in the future. Using the absence of introductions as an argument for low risk is a debated issue in the scientific literature (Sansford et al. 2008). Due to the poor basis of information, discussion of the reasons for *A. anxius* not being introduced in Europe must be speculative. Five potential reasons for *A. anxius* apparently not being introduced despite historical imports are discussed below in this section. It cannot be excluded that *A. anxius* might already have been introduced to Europe undetected (i.e. point 5 below):

1. Birch forests are scarce or not available in the vicinity of import sites.
2. The actual amount of imported birch to areas with host plants (where birch forests are present) has been relatively small.
3. The import of large volumes of birch has been limited in time.
4. Absence of introductions in Europe is a matter of stochasticity.
5. Introductions of *A. anxius* may have happened without being recorded.

1. **Birch forests are scarce or not available in the vicinity of import sites**

The import statistics given in EPPO's PRA (EPPO 2011b) do not reveal information about position of the import sites and the availability of birch in the surroundings of these sites. The question of position of the import sites is especially important in the Nordic countries, where birch trees tend to be more frequent and more often stand-forming tree species.

VKM concludes that this potential reason can neither be confirmed nor rejected due to lack of information.

2. **Relatively small amounts of birch import to areas with host plants**

In EPPO's PRA the available information about historical imports is given in Appendix 2 "Data on Canada (A) and USA (B) exports to the PRA area" (EPPO 2011b). There are no specific data on imports of birch as wood chips, i.e. pure versus mixed, or on proportion of birch in mixed wood chips. However, the import of hardwood chips from North America to certain countries of the EPPO PRA area is rapidly increasing (EPPO 2011b). In some of the years during the period 2006-2010, significant volumes of non-coniferous wood have been imported from Canada to some European countries in the form of chips, logs for pulping, and lumber. Birch is included in all of these categories. However, specific information about the fractions of birch in the exported volumes is not given. Also, in the export statistics from USA to Europe the amount of birch cannot be separated in most of the categories of hardwood, except for hardwood logs of birch given under the commodity code 4403990030 and lumber of birch given under the codes 4407990050, 4407990051, and 4407990110 (EPPO 2011b).

VKM concludes that this is a potential reason that can neither be confirmed nor rejected due to lack of information.

3. **The import of large volumes of birch has been limited in time**

The import statistics given in EPPO's PRA (EPPO 2011b) does not give information about the period before 2006. According to the text in the PRA (page 10 point 1.5), the import of hardwood chips from North America to certain countries of Europe is rapidly increasing. EPPO's PRA anticipates that this increase will continue to allow EU countries to meet the targets of the EU energy policy for 2020 (EPPO 2011b). Given an increasing trend, the import of birch may have been lower in the years before 2006.

VKM concludes this might be a potential reason. However, we lack information for a full judgment.

4. **Absence of introductions in Europe is a matter of stochasticity**

The probability functions of introduction are in many cases expected to be non-linear (Brockerhoff et al. 2006; Liebhold & Tobin 2008). Imported commodities may arrive repeatedly before introduction and establishment happen (Liebhold & Tobin 2008; Mercader et al. 2009). The more often a species arrives at a location, the more likely it is to invade (Liebhold & Tobin 2008; Taylor & Hastings 2005). For example, Brockerhoff et al. (2006) showed that frequently intercepted bark beetle species are about four times more likely to successfully invade an area than species that are intercepted rarely. Thus, despite information about import volumes, it is difficult to predict exactly in what year introductions will happen.

For example, it is assumed that very large volumes of ash wood commodities may have been imported to North America in the years before the introduction of emerald ash borer (*Agrilus planipennis*) happened, and there was a lag period until it was detected (McCullough & Katovic 2008). Following its introduction, *A. planipennis* established easily and spread fast. If the question about the probability of introducing *A. planipennis* had been raised before the introduction, no introduction under import of large volumes of ash wood commodities might have suggested a low probability. However, *A. planipennis* was introduced and several publications indicate that repeated arrivals may be necessary before the introduction happens (Brockerhoff et al. 2006; Liebhold & Tobin 2008; Mercader et al. 2009). It might be tempting to raise the argument that a potentially risky import activity is safe, because it is likely that imports has caused repeated (undocumented) entries of the pest organism, without resulting in pest establishment. However, this kind of reasoning is weak. As mentioned above, it is difficult to predict when introductions will happen, even when the environmental conditions are suitable for pest establishment.

VKM concludes that absence of introduction so far might possibly be a result of stochasticity.

5. Introduction of *Agrilus anxius* has happened without being recorded

Arrival of a new pest on birch would most likely be noticed. If an establishment had happened we assume that spread of *A. anxius* would lead to expansion of an increasing area with dying birch trees. No such observations are known. However, both theoretical and empirical studies indicate that detection delays occur (Liebhold & Tobin 2008; McCullough & Katovic 2008; Shigesada & Kawasaki 1997). For instance, a delay of approximately 12 years was reported for detecting the presence of the gypsy moth in North America (Liebhold & Tobin 2008), and at least nine years was required for detection of *Dendroctonus micans* in the United Kingdom (Gilbert et al. 2003; King & Fielding 1989). Even when monitoring traps are used, the arriving species may often go undetected by the traps (Skarpaas & Økland 2009), which may lead to a delay in detection (Lee 2002; Liebhold & Tobin 2008). Furthermore, it took several years before *A. planipennis* and *Agrilus sulcicollis* Lacordaire were detected in North America (Jendek & Grebennikov 2009; McCullough & Katovic 2008).

VKM concludes that it cannot be excluded that introduction of *A. anxius* has happened without being recorded yet.

9 Potential impacts of an establishment of *Agrilus anxius* in Norway (question 5 in Terms of Reference)

EPPO's assessments and ratings concerning potential economic consequences of *A. anxius* in the EPPO region (EPPO 2011b, Section B: steps 2.1-2.16) are regarded as valid also for Norwegian conditions. Thus, VKM concludes that due to the higher susceptibility of European birch species, it is expected that the pest would have major economic consequences in the endangered area of the PRA area. On the whole, introduction would result in high mortality of birch throughout the endangered area, and major economic impacts (including major environmental impacts). Overall level of uncertainty is low.

In Norway, birch accounts for 16% (118 464 000 m^3) of the total volume of trees (without bark in productive forest classified as forestry land) (Aksel Granhus, pers. comm. 30 March 2012).The endangered area of Norway is southern Norway south of Nordland County, and Pasvik in eastern Finnmark. A large proportion of the forest tree volume is birch, see Table 2.

Table 2: Percentage of forest volume being birch in different parts of Norway. This is without bark in productive forest classified as forestry land. (Aksel Granhus, pers. comm. 30.03.2012).

Part of Norway	Counties	% of forest volume being birch
Eastern Norway	Østfold, Oslo, Akershus, Hedmark	10
Mid Norway	Oppland, Buskerud, Vestfold	12
Central Norway	Nord-Trøndelag, Sør-Trøndelag	14
The south coast	Aust-Agder, Vest-Agder, Telemark	12
The west coast	Rogaland, Hordaland, Sogn og Fjordane, Møre og Romsdal	22

An estimated value for birch in Norway is not available, but an introduction of *A. anxius* could undoubtedly have major economic impact.

A. anxius is native to North America and has coevolved with its hosts. Little is known of the effects the pest has on other plant species it might interact with. The closely related *A. planipennis* (Emerald ash borer) is native to Asia, and was introduced to North America in 2002. This pest is now killing millions of trees in the USA and Canada, threatening endemic ash species, and changing structure and function of forests that provide food and shelter for several species (Gandhi & Herms 2010; Poland & McCullough 2006). *Betula* spp. are the most common tree by number in Norway (41%). It is a dominant genus that defines the distribution of other species that are dependent on birch or other species associated with birch forest. In general, tree mortality causes gap formations and changes in light regimes and increases the amount of dead wood. Gap formations and changed light regimes alter ecological interactions (competition, herbivory, predation and facilitation). This also causes changes in biogeochemistry. The ultimate consequence is changes in diversity and abundance (Gandhi & Herms 2010). Breeding birds can lose their habitats (Canterbury & Blockstein 1997) and the diversity of Lepidoptera may decline (Martel & Mauffette 1997).

According to Niemela and Mattson (1996) the species load on *Betula* spp. could be greater in Fennoscandia than in North America. For example, *B. pubescens* has a species load of 100 in Fennoscandia, while *B. glandulosa* has a species load of 30-40 in the Canadian regions of Labrador and northern Quebec. In Norway, repeated large-scale attacks on birch by *Epirrita autumnata* Borkhausen ("Fjellbjørkemåler") can kill trees, causing changes in canopy cover and thus changes in light regimes, which in turn change the structure of the undergrowth. This causes changes in grazing patterns and nutrient cycles. In some high altitude areas birch forest has been unable to recover after such attacks. It is important to emphasize that *A. anxius* causes 100% mortality on European birch species, as opposed to *E. autumnata* which is a defoliator and rarely kills birch.

Although an estimated value of birch in Norway is unavailable, VKM regards EPPO's evaluation of economic and ecological impact as valid also for Norway as a PRA area. This is because of the abundance of birch in Norway.

10 Effectiveness of relevant risk management options against the introduction of *Agrilus anxius* via the import of commodities to Norway, in particular those identified in the EPPO PRA (question 6 in Terms of Reference)

EPPO's PRA for *A. anxius* includes the pathways 1) wood chips, 2) plants for planting of *Betula* spp., 3) wood with or without bark of *Betula* spp., and 4) furniture and other objects made of untreated birch wood originating from North America. VKM finds that most information given in EPPO's PRA about measures for each of the pathways (EPPO 2011b, Stage 3: Pest Risk Management) applies to the PRA area of Norway as well. Some of the measures expected as relevant according to current and future imports are discussed in detail in the following text (their section numbers in the EPPO PRA document are given in brackets).

In accordance with the committee's remit, VKM has not evaluated whether the measures are economically cost-effective, have undesirable social or environmental consequences, or interfere with international trade.

10.1 Pathway 1: Wood chips originating from North America

10.1.1 Chipping down to a certain size (3.16)

The Working Party on Phytosanitary Regulations concludes that this management option should not be recommended for the time being due to uncertainties concerning safe chip size (EPPO 2011b). VKM finds that this conclusion is also valid for Norway as a PRA area.

The Working Party stated that further research is required to determine the safe size for wood chips in relation to *A. anxius* before allowing trade of wood chips commodities. It also should be checked that chipping by commercial companies will produce chips only of the required dimension (EPPO 2011b). VKM finds that these considerations by the Working Party on Phytosanitary Regulations are valid also when importing birch wood chips to Norway.

It seems difficult to obtain research data that can fully guarantee a safe chip size: The phytosanitary requirement against *A. planipennis* that the wood "has been processed into pieces of not more than 2.5 cm thickness and width" (EU 2000) is based on a previous chipping experiment using a low number of trunks compared to the large volumes imported in practice (McCullouch et al. 2007). Based on sampling statistics and simulation experiments it is likely that surviving prepupae could be found when a large volume of trunks (corresponding to the volume of current wood chips imports) is used in the experiment (Økland et al. 2012). However, a field experiment of sufficient size to set a maximum chip size would be very demanding. A computer simulation based on a large number of trunks shows that absence of surviving *A. anxius* in the resulting chips would require chip thicknesses of 6 mm or less (Økland et al. 2012).

In addition, the relationship between the screen sizes used during grinding and the maximum dimensions of the chips is obscure (EPPO 2011b). Chipping with a certain screen size produces a variety of chip sizes; a maximum size is only guaranteed in 2 dimensions, while the third dimension can vary (e.g. 2.5 x 2.5 x 10 cm). There is no proper statistics for the relationship between screen size and the actual chip size produced.

VKM concludes that chipping down to a certain chip size is not recommended as a safe measure against *A. anxius*, because a safe size for wood chips has not been determined.

10.1.2 Other treatments of chips (3.16, 3.31)

Other treatments of chips, such as heat treatment, fumigation and irradiation are discussed in EPPO's PRA (EPPO 2011b). The effect of these treatments on the lethality of *A. anxius* has not been tested. EPPO recommend fumigation by methyl bromide or sulphuryl fluoride for other insect species. One of the requirements for fumigation is separate treatment units no larger than 2 m^3 to ensure efficient treatment, which appears unrealistic when handling ship loads of wood chips. Handling and storing of very large volumes of chips treated by toxic compounds will also raise questions about safety for workers and environment. Also, it seems difficult to ensure irradiation which kills all beetles when applied in practice for large quantities of chips.

VKM concludes that heat treatment, fumigation or irradiation are not recommended as safe measures against *A. anxius* as long as further research is needed for safe implementation of these measures in practice (EPPO 2011b). Furthermore, these measures do not appear to be feasible when importing large volumes of wood chips.

10.1.3 Limited periods of entry (3.19, 3.31)

Importing in winter time and processing in time before emergence of beetles is discussed as a measure. The EPPO's PRA (EPPO 2011b) stated that the chips should be covered during transport, and that outdoor storage should not be allowed. The EPPO PRA concluded that the specifications of the requirements need to be done on a case by case basis depending on the origin and the country of destination. It is however expected that *A. anxius* may occur in all regions where birch is harvested in North America.

It is difficult to set a safe period under Norwegian conditions due to uncertainties. E.g. it should be kept in mind the large variability of warming periods in late winter and early spring. Furthermore, it should be taken into account that the time until emergence may be shortened due to the warming effect of covered transport or indoor storing. A final date of processing should not be later than 1 February. In current import stores in Norway, it seems impossible to distinguish imports of chips made some months ago and to ensure processing before a new flight season.

VKM concludes that limited period of entry as a measure against *A. anxius* can only be recommended on a case by case basis when both transport and storing are closed and all chips are processed before 1 February. This measure is unfeasible when large volumes of wood chips from different import dates are stored together and cannot be distinguished on import dates.

10.1.4 Preventing infestation of the commodity by storing the crop in specified conditions (3.22, 3.31)

EPPO (2011b) concludes that wood chips could be stored in the exporting country under the strict control of the NPPO for a sufficient period, i.e. one year, since only prepupae and pupae would be likely to survive the chipping process and should have emerged as adults within this period of time.

VKM concludes that this measure as described by EPPO (EPPO 2011b) is suitable also for Norwegian conditions.

10.1.5 Pest-free area (3.27)

Pest-free area is mentioned as a possible measure in theory (EPPO 2011b). However, *A. anxius* is widely distributed where birch is growing in North America. Furthermore, adults are strong fliers and are capable of a natural spread of 16 to 32 km per year (EPPO 2011b).

(EPPO 2011b) concludes that pest-free areas do not appear to be a safe measure. VKM considers this conclusion to be valid also for Norway.

10.2 Pathway 2: Plants for planting of Betula spp. originating from North America

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

VKM conclude that post-entry quarantine is not recommended as a safe phytosanitary measure against *A. anxius*. Under post-entry quarantine there is a possibility that the pest can follow the plants and still remain undetected. This measure might also be unfeasible since the duration of the quarantine must be at least two years.

10.2.2 Preventing infestation of the commodity by growing the crop in specified conditions (3.22, 3.32)

When mesh houses or nets are suggested in EPPO’s PRA (EPPO 2011b), it is important to keep in mind that it is difficult, and may be unfeasible, to control that the applied mesh or net is so fine that the small and slender beetle cannot enter. Furthermore, ensuring that no beetle enters a greenhouse can be difficult without protection by gate systems at the doorway.

VKM concludes that this measure can be a safe against *A. anxius* when the mesh size does not allow entry of beetles, and if inspection has been performed as described in the EPPO PRA’s section 3.32 for this pathway (EPPO 2011b): “The plants should be grown under specified conditions (insect-proof) and for at least two years no signs of *A. anxius* have been observed during two official inspections per year carried out at appropriate times, including immediately prior to export”.

10.2.3 Harvesting only at certain times of the year and at specific crop ages or growth stages (3.23, 3.30)

Since the larvae or pupae can be present in the wood throughout the year, import of small plants (stems below 2 cm diameter and scion below 1 cm) must be under careful control. It is however difficult to control that all stems are below the limit and without *A. anxius* when commodities contain large numbers of plants of variable stem sizes.

VKM concludes that limiting imports to stems below 2 cm diameter and scion below 1 cm may be a safe measure against *A. anxius*. It may however be unfeasible to control that all stems are below the limit in large commodities of imported plants.

10.3 Pathway 3: Birch wood with or without bark originating from North America

Beside the various commodities of round wood with or without bark (see Table 1), our evaluation includes the pathway of fuel wood.

10.3.1 Destroying pest in the consignment by treatment (3.16, 3.31)

No specific heat treatment has been developed for *A. anxius*. As pointed out in EPPO's PRA, there are tests of the heat treatment procedure for the close relative *A. planipennis* (EPPO 2011b). A scientific opinion published by EFSA (EFSA Panel on Plant Health 2011) concludes that a control level of 99% to ensure absence of *A. planipennis*, the temperature of the heat treatment of 60 min should be higher than 70 °C. Since heat treatment is based on the core temperature, this measure may not be feasible for thick trunks and large quantities.

The same objections are raised for irradiation. There is no specific test of disinfestation of wood with ionizing radiation for *A. anxius*, and it is questioned how efficient and feasible this measure is for thick trunk and large quantities.

VKM concludes that heat treatment, fumigation or irradiation are not recommended as safe measures against *A. anxius* as long as further research is needed for safe implementation of these measures in practice (EPPO 2011b). Furthermore, these measures do not appear to be feasible when importing large volumes of birch wood with or without bark.

10.3.2 Remove certain parts of the plant or plant products (3.17, 3.31)

Removing both bark and the outer sapwood (min 1.27 cm) is suggested as a measure to ensure that the pest is not present (EPPO 2011b). The quality of this measure may depend on the equipment for the removal when used on round wood with bark.

VKM considers squared wood without wanes to be a safe commodity regarding *A. anxius*. If applying this measure in imports to Norway, it may be necessary with a case-to-case permit to ensure that all outer sapwood that could contain *A. anxius* is absent.

10.3.3 Limited periods of entry (3.19, 3.31)

Importing during winter time and processing in time before emergence of beetles is discussed as a control measure. As for wood chips, outdoor storage should not be allowed due to several uncertainties (EPPO 2011b). The time until emergence may be even shorter by indoor storing due to the warming effects.

An important weakness of todays practice is that it seems difficult to distinguish recent wood imports from those imported earlier e.g. within the last months. Therefore, it seems difficult to guarantee processing of the wood before a new *A. anxius* flight season.

VKM concludes that limited period of entry as a safe measure against *A. anxius* can only be recommended on a case by case basis when both transport and storing are closed and all wood is processed before 1 February. This measure may be unfeasible when large volumes of wood from different import dates are stored together and cannot be distinguished on import dates.

10.3.4 Preventing infestation of the commodity by storing the crop in specified conditions (3.22, 3.31)

It is assumed that no adults will emerge two years after cutting, and that the pest cannot re-infest cut wood. Using this measure, the wood must be stored under suitable conditions before export for at least two year under the strict control of the NPPO to ensure compliance with these requirements.

VKM concludes that this measure as described by EPPO (EPPO 2011b) is suitable also for Norway as a PRA area.

10.4 Pathway 4: Furniture and other objects made of untreated birch wood originating from North America

According to the report of a Pest Risk Analysis (EPPO 2011c), fourth instars, pre-pupae and pupae may be present in untreated/air dried/bark-covered sapwood, and that this is often the case in rustic birch furniture where whole logs with intact bark are used to construct table legs, bed frames, etc.

VKM considers the risk from this pathway to be similar to the risk from pathway 3, wood with bark. The requirement of removing both bark and the outer sapwood (min 1.27 cm) must be satisfied to ensure absence of *A. anxius*.

Data gaps

Categories of the custom codes

The custom code categories are in many cases coarse groups that are not divided in the best way to identify the most relevant commodities for invasive species. For example, some of the custom codes for wooden commodities do not distinguish between tree species. Obviously, there is a need of custom codes that are more relevant for invasion of biological organisms. However, a change of numbers may be difficult as e.g. the current base numbers of the codes are international and cannot be changed for a single country. Furthermore, there may be commodities that are not covered by the current categories, such as “Wood chunks" or "biomass chunks”.

“Wood chunks" or "biomass chunks” have previously been imported to Norway for industrial use (Simen Gjølsjø pers. comm.) The status of this import is unknown at the time of writing. The extent of historic import and under which commodity code it has been imported is also unknown. But it is clear that if “wood chunks" of *Betula* is imported from North America to Norway it presents equal or greater risk than imported wood chips of the same origin. VKM recommends to survey the extent of imports of “wood chunks" to Norway, and to clarify if import is ongoing.

Environmental requirements of the species

Birch has a key role in the forest ecosystem of Norway, as well as on the Scandinavian Peninsula, where forest still dominate in most areas. A pest like *A. anxius* could threaten species of forest ecosystems of high importance to the PRA area. More research and information needs to be gathered on environmental requirements of the species. The northern limits of distribution as well as how many meters above sea level the species will establish are mostly governed by temperature and winter survivorship. Research on other limiting environmental factors would also be helpful. Research concerning flight ability would also be of importance. More information on occurrence points and limiting environmental factors could be used to generate niche models to predict the potential geographic distributions. A niche model together with information on flight ability would be of importance in a management situation.

Conclusion

The EPPO PRA for *A. anxius* published (EPPO 2011) is regarded as highly relevant to Norway. The information given in the EPPO PRA corresponds well with Norwegian conditions. VKM regards all EPPO's assessments and ratings concerning entry, spread, establishment, and economic and environmental consequences of *A. anxius* in the EPPO region as entirely valid also for Norway as the PRA area. Thus, VKM gives the following main conclusions on these topics:

- The probability of entry of *A. anxius* to Norway is considered as low to medium, with a medium level of uncertainty.
- The probability of establishment is considered as very high, with low uncertainty.
- The probability of spread within Norway is considered as very high, with a low level of uncertainty.
- It is expected that the pest will have major economic consequences in the endangered area of the PRA area. On the whole, introduction would result in high mortality of birch throughout the endangered area, and major economic impacts (including major environmental impacts). The overall level of uncertainty is low.

The endangered area is the whole forested area of southern Norway south of Nordland County, and Pasvik in eastern Finnmark.

Appendix

Table 1: Description of Köppen climate symbols and defining criteria in Appendix Figures 1-3. From Peel et al. 2007.

1st	2nd	3rd	Description	Criteria*
A			Tropical	$T_{cold} \geq 18$
	f		- Rainforest	$P_{dry} \geq 60$
	m		- Monsoon	Not (Af) & $P_{dry} \geq 100–MAP/25$
	w		- Savannah	Not (Af) & $P_{dry} < 100–MAP/25$
B			Arid	$MAP < 10 \times P_{threshold}$
	W		- Desert	$MAP < 5 \times P_{threshold}$
	S		- Steppe	$MAP \geq 5 \times P_{threshold}$
		h	- Hot	$MAT \geq 18$
		k	- Cold	$MAT < 18$
C			Temperate	Thot>10 & $0 < T_{cold} < 18$
	s		- Dry summer	$P_{sdry} < 40$ & $P_{sdry} < P_{wwet}/3$
	w		- Dry winter	$P_{wdry} < P_{swet}/10$
	f		- Without dry season	Not (Cs) or (Cw)
		a	- Hot summer	$T_{hot} \geq 22$
		b	- Warm summer	Not (a) & $T_{mon10} \geq 4$
		c	- Cold summer	Not (a or b) & $1 \leq T_{mon10} < 4$
D			Cold	$T_{hot} > 10$ & $T_{cold} \leq 0$
	s		- Dry summer	$P_{sdry} < 40$ & $P_{sdry} < P_{wwet}/3$
	w		- Dry winter	$P_{wdry} < P_{swet}/10$
	f		- Without dry seasons	Not (Ds) or (Dw)
		a	- Hot summer	$T_{hot} \geq 22$
		b	- Warm summer	Not (a) & $T_{mon10} \geq 4$
		c	- Cold summer	Not (a, b or d)
		d	- Very Cold Winter	Not (a or b) & $T_{cold} < –38$
E			Polar	$T_{hot} < 10$
	T		- Tundra	$T_{hot} > 0$
	F		- Frost	$T_{hot} \leq 0$

*MAP = mean annual precipitation, MAT = mean annual temperature, T_{hot} = temperature of the hottest month, T_{cold} = temperature of the coldest month, Tmon10 = number of months where the temperature is above 10, P_{dry} = precipitation of the driest month, P_{sdry} = precipitation of the driest month in summer, P_{wdry} = precipitation of the driest month in winter, P_{swet} = precipitation of the wettest month in summer, P_{wwet} = precipitation of the wettest month in winter, $P_{threshold}$ = varies according to the following rules (if 70% of MAP occurs in winter then $P_{threshold}$ = 2 x MAT, if 70% of MAP occurs in summer then $P_{threshold}$ = 2 x MAT + 28, otherwise $P_{threshold}$ = 2 x MAT + 14). Summer (winter) is defined as the warmer (cooler) six month period of ONDJFM and AMJJAS.

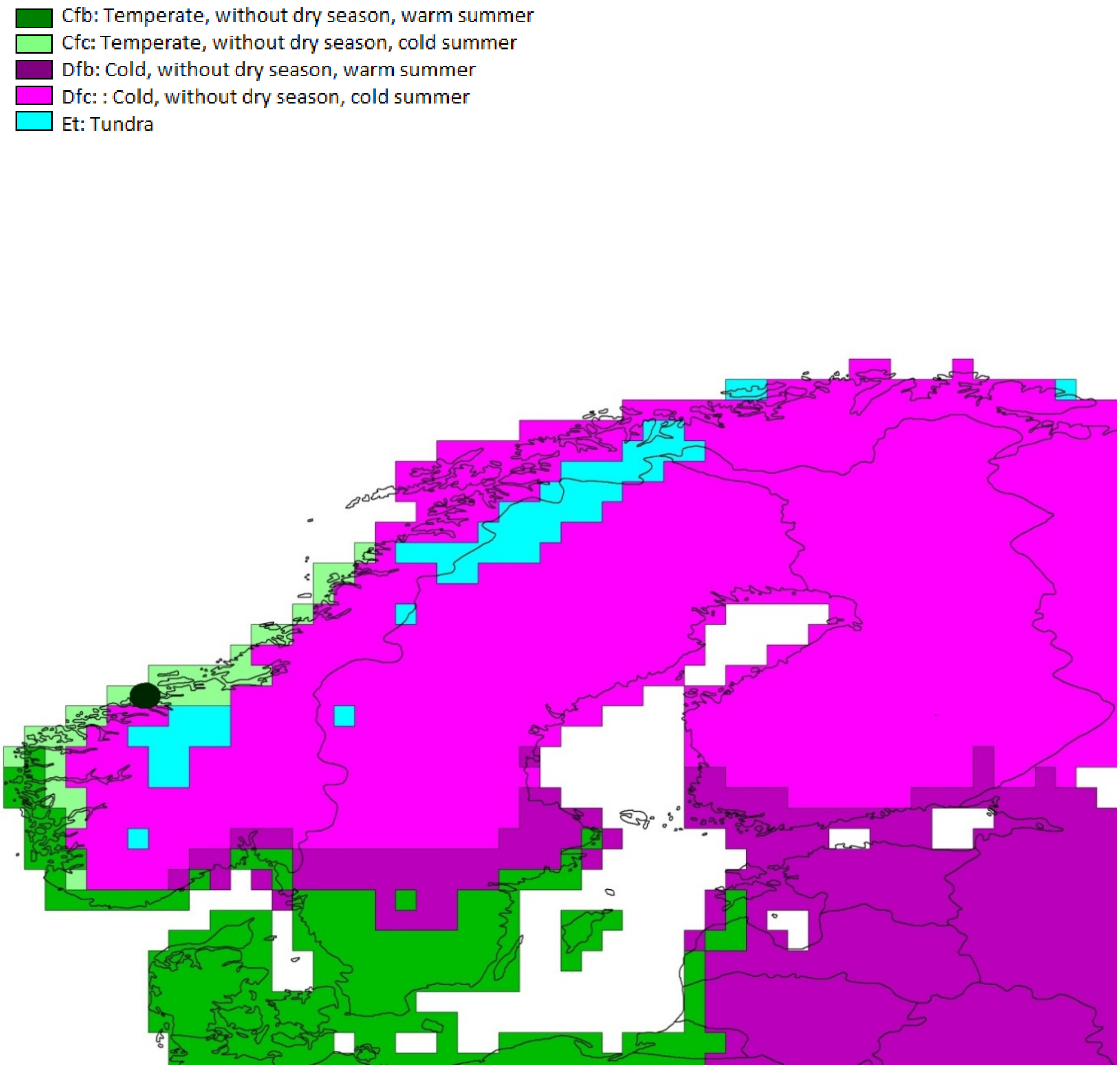

Figure 1: The different climate zones in Norway as according to the Köppen-Geiger climate classification system. GIS data provided by Kottek and Rubel (2012). Description of Köppen climate symbols and defining criteria are given in Appendix Table 1.

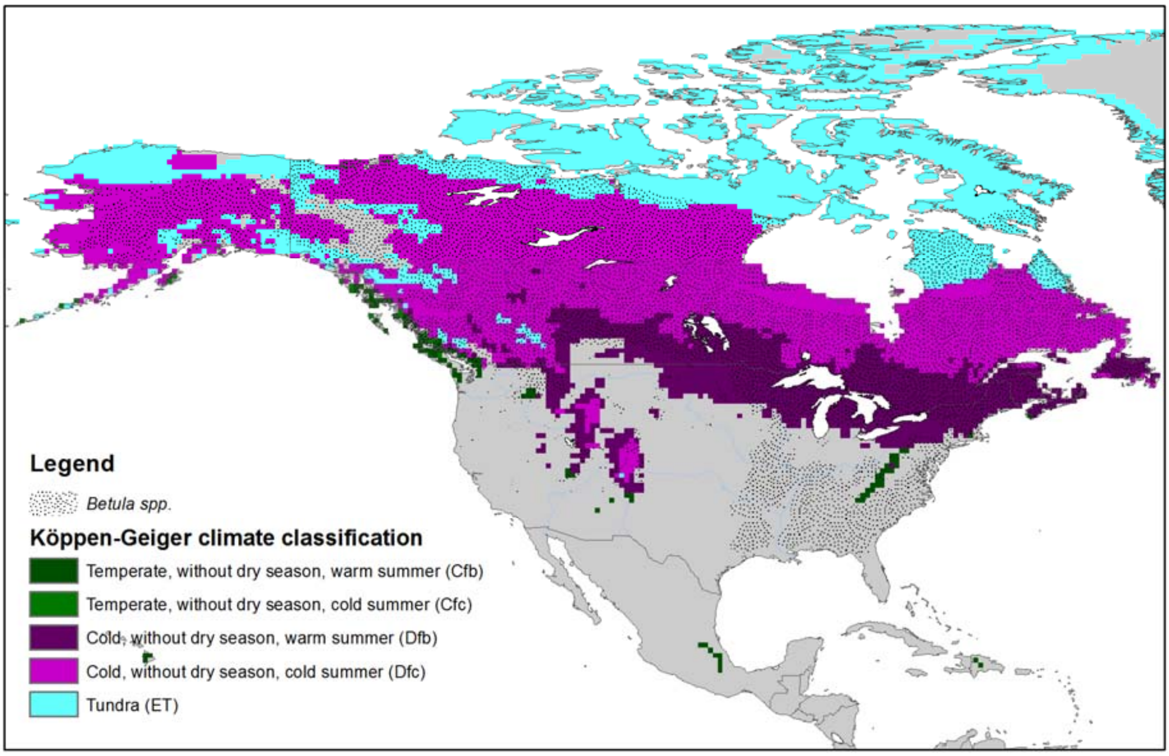

Figure 2: A confined Köppen-Geiger climate type map of North America, showing only the climate classifications in common with Norway. The map also shows the extent of *Betula* spp. in North America. GIS data provided by Kottek and Rubel (2012). *Betula* spp. Distribution data provided by USDA Forest Service (2012). Description of Köppen climate symbols and defining criteria are given in Appendix Table 1.

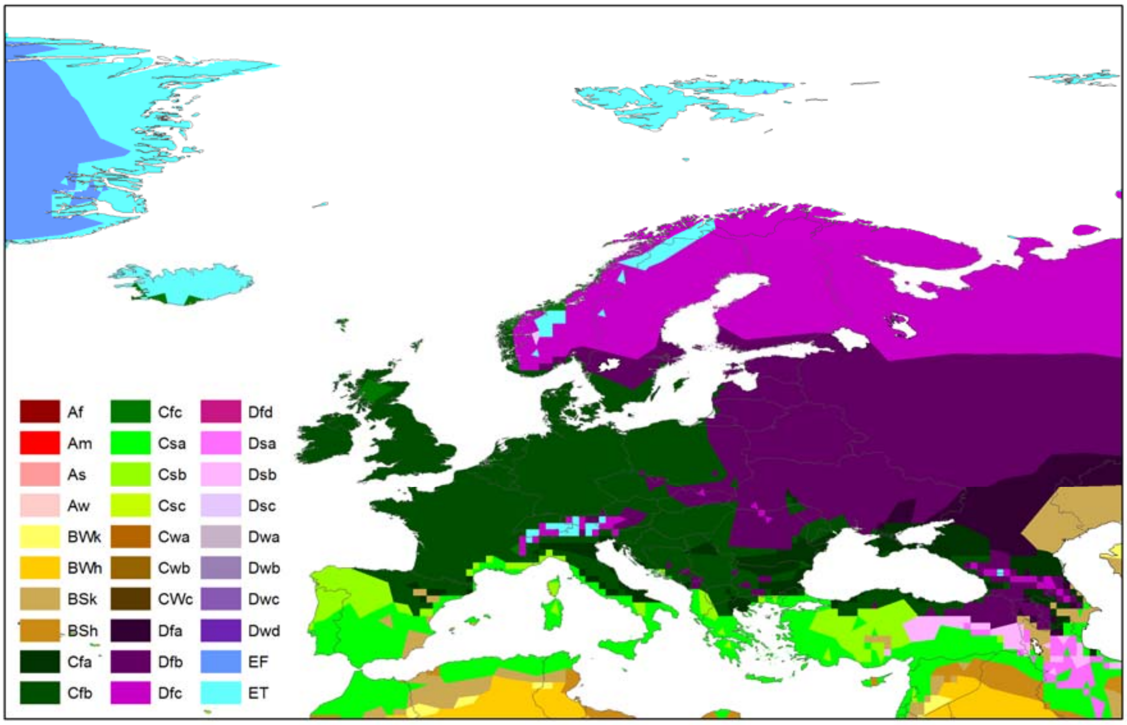

Figure 3: **Köppen-Geiger climate type map of Europe. GIS data provided by Kottek and Rubel (2012). Description of Köppen climate symbols and defining criteria are given in Appendix Table 1.**

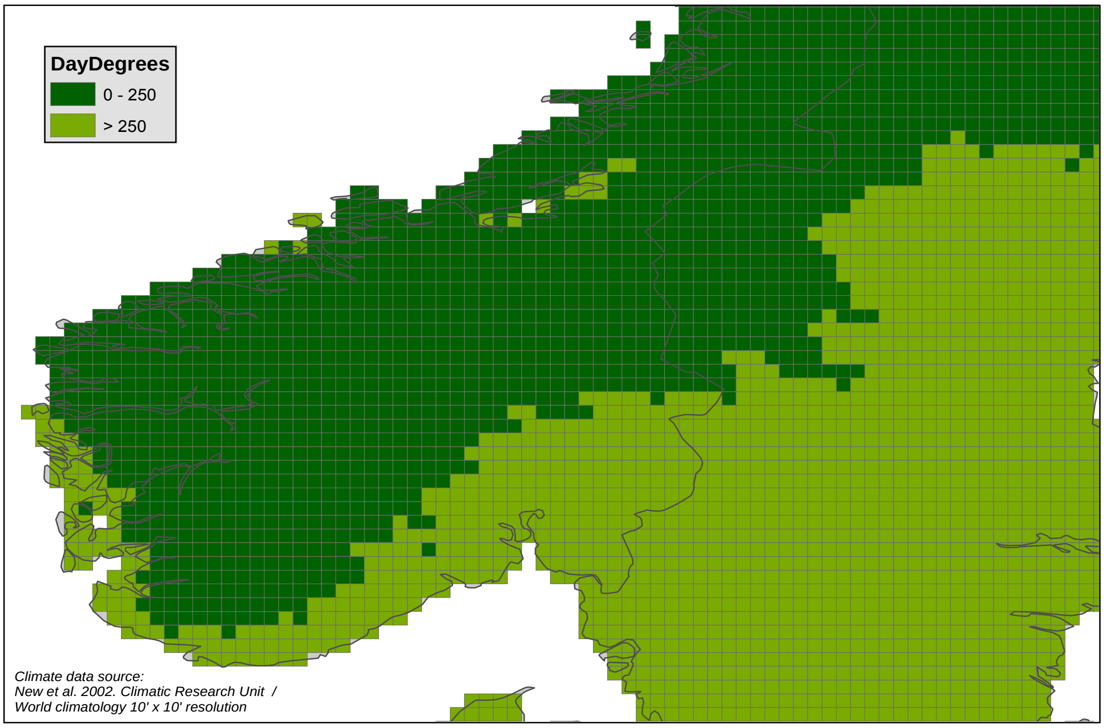

Figure 4: **Map of southern Norway showing degree day accumulation at 10°C base temperature. Calculations of the day-degree sums were conducted in Climex (Sutherst et al. 2007) based on the 1961-1990 10x10 minute spatial resolution climatology developed by New et al. (2002). The part of Norway shown in this map corresponds to the endangered area of Norway concerning establishment and potential damage from *Agrilus anxius*. The model of this map probably underestimates the zones where degree-day accumulation is between 0 and 250. The map either lacks data (the same problem as in Peel et al. (2007)) or possibly fails to differentiate between the steep altitude gradient along the west coast.**

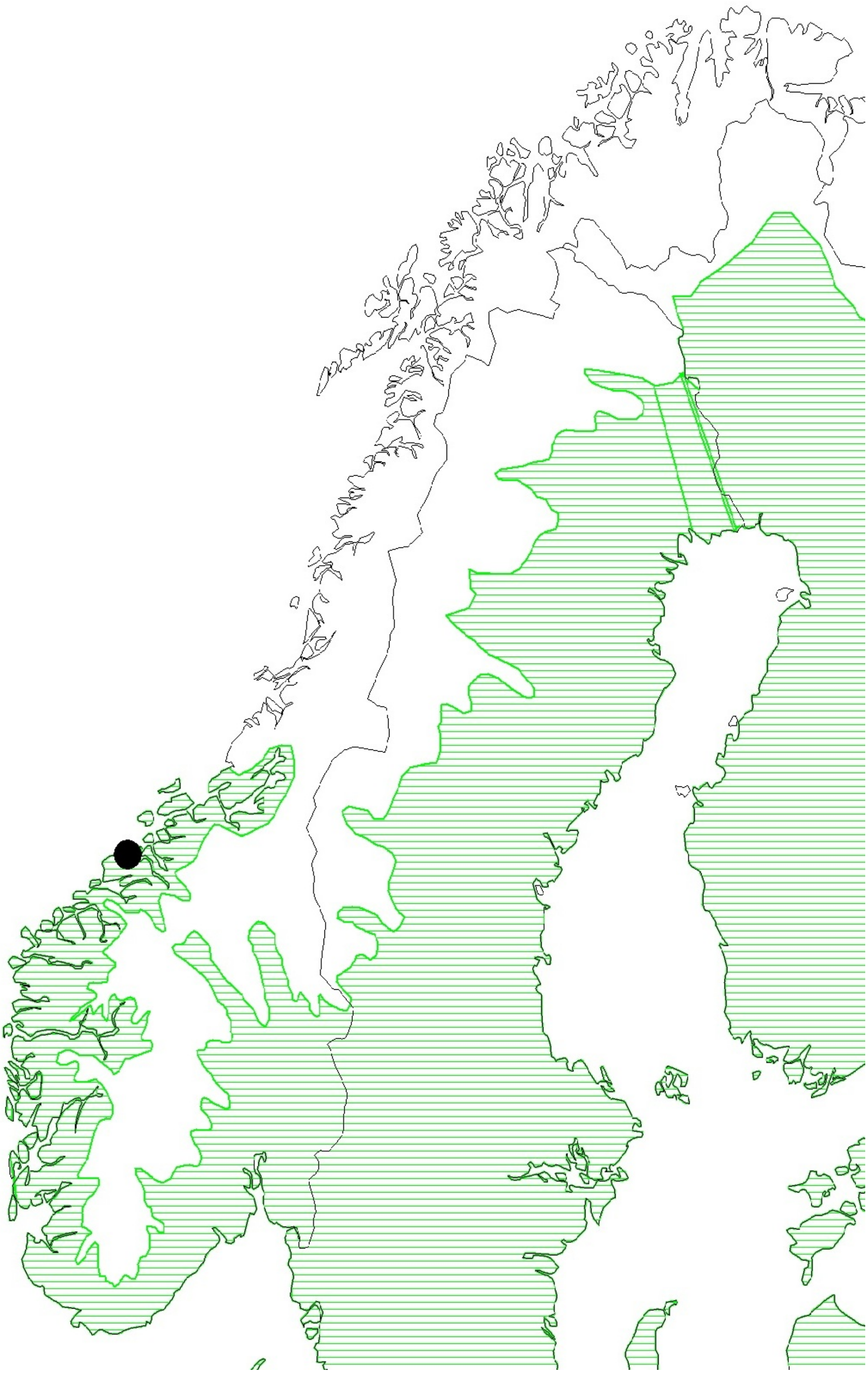

Figure 5: Distribution of *Betula pendula* (common name in Norwegian: "Hengebjørk") in Norway (green shading). The black circle marks the port of entry of all imported deciduous wood chips to Norway. Distribution map provided by EUFORGEN (2012).

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