

**Risk assessment template developed under the "Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention"
Contract No 07.0202/2019/812602/ETU/ENV.D.2¹**

Name of organism: *Vespa mandarinia* Smith, 1852

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Risk Assessment Area: The risk assessment area is the territory of the European Union²⁷ and the United Kingdom, excluding the EU-outermost regions.

Peer review 1: Alan Stewart, University of Sussex, Brighton, UK

Peer review 2: Olaf Booy, GB Non-Native Species Secretariat

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¹ This template is based on the Great Britain non-native species risk assessment scheme (GBNNRA). A number of amendments have been introduced to ensure compliance with Regulation (EU) 1143/2014 on IAS and relevant legislation, including the Delegated Regulation (EU) 2018/968 of 30 April 2018, supplementing Regulation (EU) No 1143/2014 of the European Parliament and of the Council with regard to risk assessments in relation to invasive alien species (see <https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32018R0968>).

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SECTION A – Organism Information and Screening

A1. Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?

including the following elements:

- the taxonomic family, order and class to which the species belongs;
- the scientific name and author of the species, as well as a list of the most common synonym names;
- names used in commerce (if any)
- a list of the most common subspecies, lower taxa, varieties, breeds or hybrids

As a general rule, one risk assessment should be developed for a single species. However, there may be cases where it may be justified to develop one risk assessment covering more than one species (e.g. species belonging to the same genus with comparable or identical features and impact). It shall be clearly stated if the risk assessment covers more than one species, or if it excludes or only includes certain subspecies, lower taxa, hybrids, varieties or breeds (and if so, which subspecies, lower taxa, hybrids, varieties or breeds). Any such choice must be properly justified.

Response:

Scientific name (Class: Order: Family): *Vespa mandarinia* Smith, 1852 (Insecta: Hymenoptera: Vespidae)

Most common synonyms:

Vespa japonica Rad., 1857

Vespa latilineata Cameron, 1903

Vespa magnifica Smith, 1852

Vespa sonani Matsumura, 1930

Common English name: Asian giant hornet

Other common names: calabrone gigante asiatico (IT), Asiatische Riesenhornisse (DE), frelon géant (FR), Kiinanherhiläinen (FI)

Subspecies: Various sub-species and colour forms with different geographic ranges and varying in colours have been described in the literature. Archer (1995) mentions three sub-species *V. mandarinia mandarinia* (in China, Japan, Russia and Korea); *V. mandarinia magnifica* (Northern India, Nepal, Bhutan, Burma, Laos, Peninsular Malaysia, western China); *V. mandarinia nobilis* (Taiwan). *Vespa mandarinia japonica* is sometimes cited as sub-species but is rather a colour form (Archer 1995). All sub-species will be treated together in this risk assessment. No hybrids with other species are known.

A2. Provide information on the existence of other species that look very similar [that may be detected in the risk assessment area, either in the environment, in confinement or associated with a pathway of introduction]

Include both native and non-native species that could be confused with the species being assessed, including the following elements:

- other alien species with similar invasive characteristics, to be avoided as substitute species (in this case preparing a risk assessment for more than one species together may be considered);
- other alien species without similar invasive characteristics, potential substitute species;
- native species, potential misidentification and mis-targeting

Response:

There are 22 *Vespa* spp. worldwide, all occurring in some parts of Asia (Archer 2008; Smith Pardo et al. 2020). Four of them also occur in Europe: *Vespa crabro* L. and *V. orientalis* L. are native to Europe and *V. velutina* Lepeletier is an invasive alien species from East Asia. The fourth species, *V. bicolor* F., also non-native to Europe, is present in a small area in southern Spain since at least 2013 but does not seem to spread (Castro et al. 2019). All non-native species could potentially be invasive in Europe, but this risk assessment concerns *V. mandarinia*.

Vespa mandarinia can easily be separated from the four species occurring in Europe using morphological characters (Archer 1995, 2012; Smith Pardo et al. 2020). The most obvious character is the size of the wasps, the smallest workers of *V. mandarinia* measuring at least 35 mm (queens can exceed 50 mm) whereas only the largest queens of *V. crabro* reach 35 mm. It is most similar to *Vespa soror* du Buysson (a south-East Asian species) but the two species can be distinguished by the colour of their abdomen. In *V. soror*, the third to the sixth gastral terga in the female and to the seventh gastral terga in the male are black, whereas, in *V. mandarinia*, these terga are at least partly orange (Archer 1995).

A3. Does a relevant earlier risk assessment exist? Give details of any previous risk assessment, including the final scores and its validity in relation to the risk assessment area.

Response:

Two partial risk assessments have been produced for North America. Norderus et al. (2021) conducted a risk assessment of the establishment of *V. mandarinia* specifically on the Pacific Northwest and Zhu et al. (2020) assessed its ecological niche and invasion potential. None of the two, however, provide detailed assessments of the magnitude of impact. USDA (2020) has produced “New Pest Response Guidelines” following the recent observations of *V. mandarinia* in North. In Europe, risk assessments have been produced for *V. velutina* after this species became established (e.g. Marris et al. 2011) and, thus, although helpful, they are not fully relevant for *V. mandarinia* in Europe, where it is not yet present.

A4. Where is the organism native?

including the following elements:

- an indication of the continent or part of a continent, climatic zone and habitat where the species is naturally occurring

- if applicable, indicate whether the species could naturally spread into the risk assessment area

Response:

Vespa mandarinia is native to Asia, occurring in at least 9 Köppen climates from the continental, temperate and tropical groups. It has been recorded in the following countries: China, Japan, Russia, South Korea, India, Buthan, Nepal, Myanmar, Laos, Malaysia, Thailand, Vietnam (Archer 1995; GBIF 2020; Smith Pardo et al. 2020; USDA 2020). Smith Pardo et al. (2020) also includes Sri Lanka but Kumar and Srinivasan (2010) consider this as an error. The distribution records in Asia are indicated in Figure 1.

In Japan, *V. mandarinia* is associated with hilly country (850-1900m), nesting in the ground at a depth of 6-60cm. Nests are started in small mammal burrows and decayed root spaces. These cavities can be enlarged by the workers removing soil particles. A few nests have been found in hollow trees and a mud wall 1-2m above the ground. (Archer 2008). As for all Vespidae, nest building requires a sufficient amount of humidity and water availability (Matsuura and Yamane 1990)

Vespa mandarinia is a good flier but considering the distances involved, it cannot naturally spread on its own from its native area to the risk assessment area.

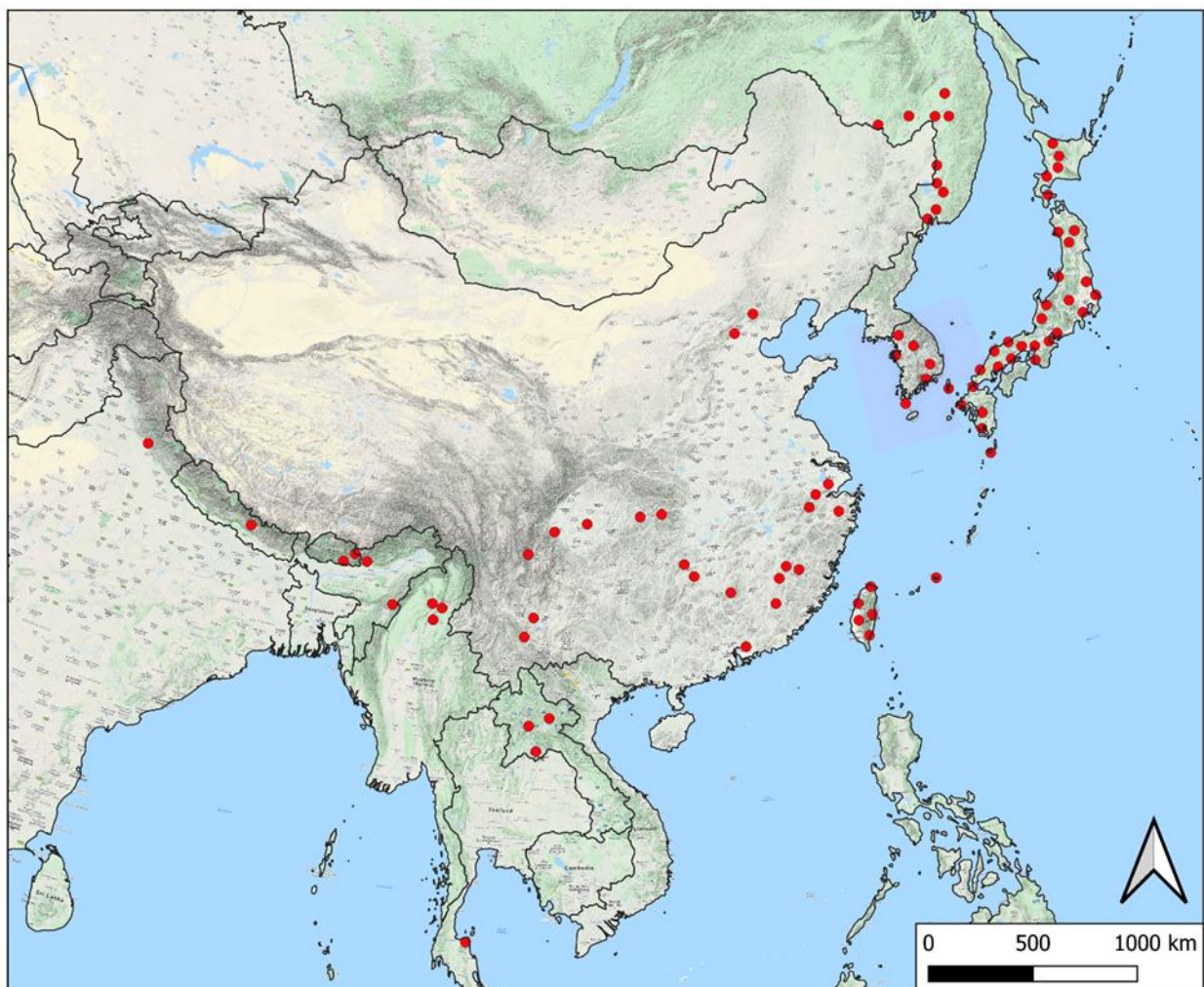


Figure 1. Distribution of *V. mandarinia* in Asia (background map from Google). Only the sites where precise occurrences are known are indicated in the map.

A5. What is the global non-native distribution of the organism outside the risk assessment area?

Response:

The first record outside its native range was in August and September 2019, when workers and a nest were found in Nanaimo, Vancouver Island, British Columbia, Canada. In 2019, workers were also observed on the mainland, in White Rock, south of Vancouver and close-by at two sites (Blaine and Bellingham) in Washington State (USA), suggesting that nests were also present on the mainland (USDA 2020). In May 2020, a live individual queen was captured at Langley, British Columbia and, by September 2020, several queens, workers and a male were also found in Custer, Birch Bay and Bellingham, Washington (Norderud et al. 2021; WSDA 2021). In October 2020, a nest was found and destroyed in Blaine and a new dead male was discovered in June 2021 in near Marysville (all Washington, WSDA 2021). Genetic analyses showed that the nest found on Vancouver Island and the individual found in Washington State belong to different lineages (Wilson et al. 2020).

A6. In which biogeographic region(s) or marine subregion(s) in the risk assessment area has the species been recorded and where is it established? The information needs to be given separately for recorded (including casual or transient occurrences) and established occurrences. “Established” means the process of an alien species successfully producing viable offspring with the likelihood of continued survival².

A6a. Recorded: List regions

A6b. Established: List regions

Freshwater / terrestrial biogeographic regions:

- Alpine, Atlantic, Black Sea, Boreal, Continental, Mediterranean, Pannonian, Steppic

Marine regions:

- Baltic Sea, North-east Atlantic Ocean, Mediterranean Sea, Black Sea

Marine subregions:

- Greater North Sea, incl. the Kattegat and the English Channel, Celtic Seas, Bay of Biscay and the Iberian Coast, Western Mediterranean Sea, Adriatic Sea, Ionian Sea, Central Mediterranean Sea, Aegean-Levantine Sea.

Comment on the sources of information on which the response is based and discuss any uncertainty in the response.

For delimitation of EU biogeographical regions please refer to <https://www.eea.europa.eu/data-and-maps/figures/biogeographical-regions-in-europe-2> (see also Annex VI).

² Convention on Biological Diversity, Decision VI/23

For delimitation of EU marine regions and subregions consider the Marine Strategy Framework Directive areas; please refer to <https://www.eea.europa.eu/data-and-maps/data/msfd-regions-and-subregions/technical-document/pdf> (see also Annex VI).

Response (6a):

No record yet in the risk assessment area. In GBIF (2020), a record from Germany could not be traced to the original source and seems erroneous.

Response (6b):

No establishment yet in the risk assessment area.

A7. In which biogeographic region(s) or marine subregion(s) in the risk assessment area could the species establish in the future under current climate and under foreseeable climate change? The information needs to be given separately for current climate and under foreseeable climate change conditions.

A7a. Current climate: List regions

A7b. Future climate: List regions

With regard to EU biogeographic and marine (sub)regions, see above.

With regard to climate change, provide information on

- the applied timeframe (e.g. 2050/2070)
- the applied scenario (e.g. RCP 4.5)
- what aspects of climate change are most likely to affect the risk assessment (e.g. increase in average winter temperature, increase in drought periods)

The assessment does not have to include a full range of simulations on the basis of different climate change scenarios, as long as an assessment with a clear explanation of the assumptions is provided. However, if new, original models are executed for this risk assessment, the following RCP pathways shall be applied: RCP 2.6 (likely range of 0.4-1.6°C global warming increase by 2065) and RCP 4.5 (likely range of 0.9-2.0°C global warming increase by 2065). Otherwise, the choice of the assessed scenario has to be explained.

Response (7a):

Based on present occurrences and the limited bioecological data available about the hornet, a CLIMEX model has been built, which integrates the weekly responses of an organism to climate using a series of annual indices.

The model (Seehansen and Kenis, unpublished) is described in Annex VIII. In CLIMEX, the potential for population growth is modeled combining growth based on temperature and soil moisture during favorable conditions using a Growth Index (GI), and stress indices (cold, wet, hot, dry) to determine the effect of abiotic stress on survival in unfavorable conditions. The growth and stress indices are calculated weekly and then combined into an overall annual index of climatic suitability, the

Ecoclimatic Index (EI). The EI ranges from 0 (no persistence possible) to 100 (optimal conditions), but in temperate climates, the maximum EI value is rather close to 50 and values of >20 are known to be sufficient to support substantial population densities.

The model shows that in its native range, *V. mandarinia* is mainly predicted to be present in humid subtropical and humid oceanic climates (Figure 2). The northern distribution of *V. mandarinia* is mainly limited by cold stress during the harsh winters of the subarctic regions and dry stress in the highlands and Mongolian desert. The southern and western distribution limits are mainly defined by heat stress.

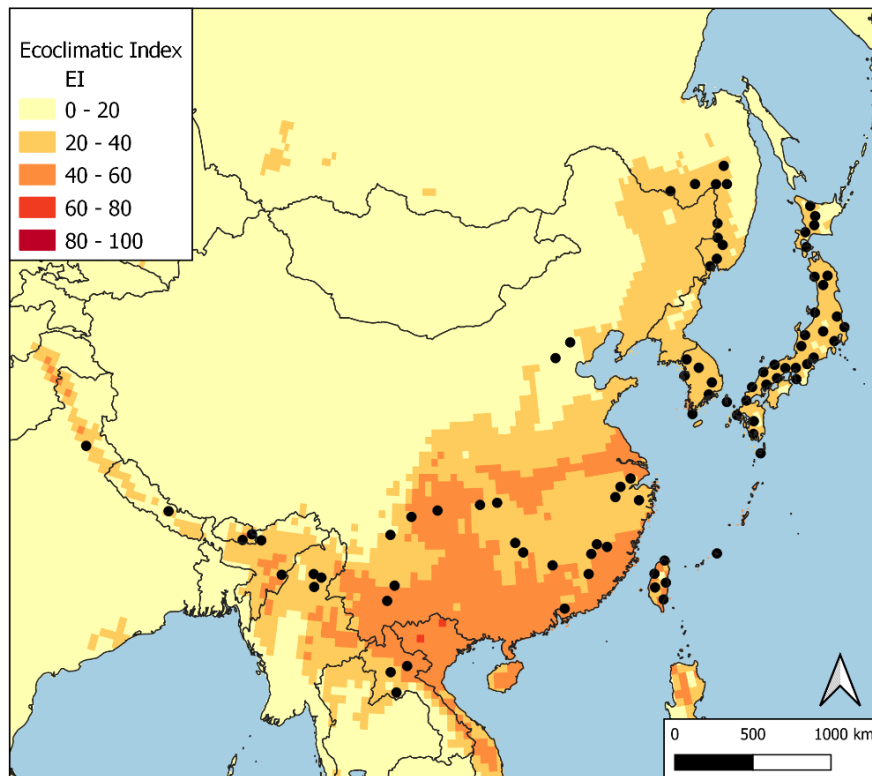


Figure 2: Observed (black points) and potential distribution of *V. mandarinia* in its native Asia as predicted by the Ecoclimatic Index (EI) from the CLIMEX model. Locations with EI>20 can be considered as climatically suitable for establishment and growth of *V. mandarinia*.

Under current climate, the most suitable biogeographic regions of Europe are predicted to be the Continental and Atlantic regions and the most humid parts of the Mediterranean, Black Sea and Pannonian regions (Figure 3). The Arctic, Boreal and Alpine regions will probably be too cold for establishment. The hornet is predicted to experience cold stress in the Alps, and in the subarctic region low mean temperatures, as well as a relatively short and dry growing season restrict population growth. The Steppic regions appear too dry to be suitable for *V. mandarinia*, defining the predicted southern distribution limits through dry stress. However, irrigated areas or humid microclimates may provide favourable areas for the hornet in the south.

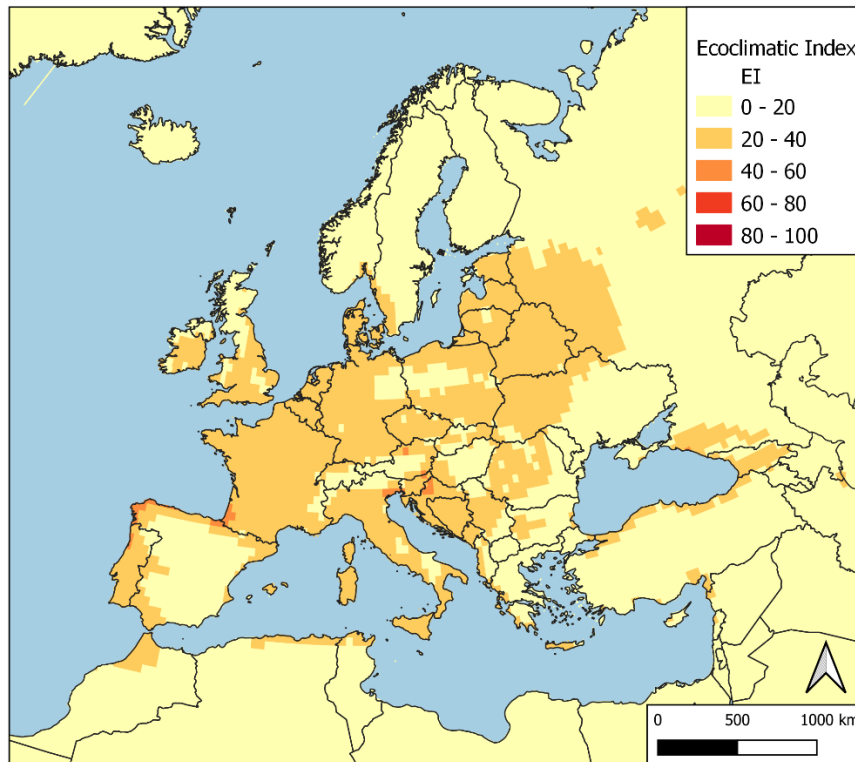


Figure 3: Potential distribution of *V. mandarinia* in Europe and northern Africa as predicted by the Ecoclimatic Index (EI) from the CLIMEX model. Locations with $EI > 20$ can be considered as climatically suitable for establishment and growth of *V. mandarinia*.

Response (7b):

A CLIMEX Ecoclimatic Index map (Figure 4) shows the likely occurrence of *V. mandarinia* in Europe in 2080, following the A1B climate change scenario, which is comparable to the RCP 4.5 scenario (RCP scenarios are not available in CLIMEX). In the future, increases in average temperatures are likely to favour establishment in the warmest areas of the Boreal and Alpine regions. In contrast, increased summer drought in Southern and Eastern Europe will make some parts of the Mediterranean and Continental regions and most of the Pannonian, Black Sea and Steppic regions unsuitable without irrigation. Especially the predicted loss of suitable area in north-eastern Europe are due to dryer summers that may severely restrict population growth of the hornet.

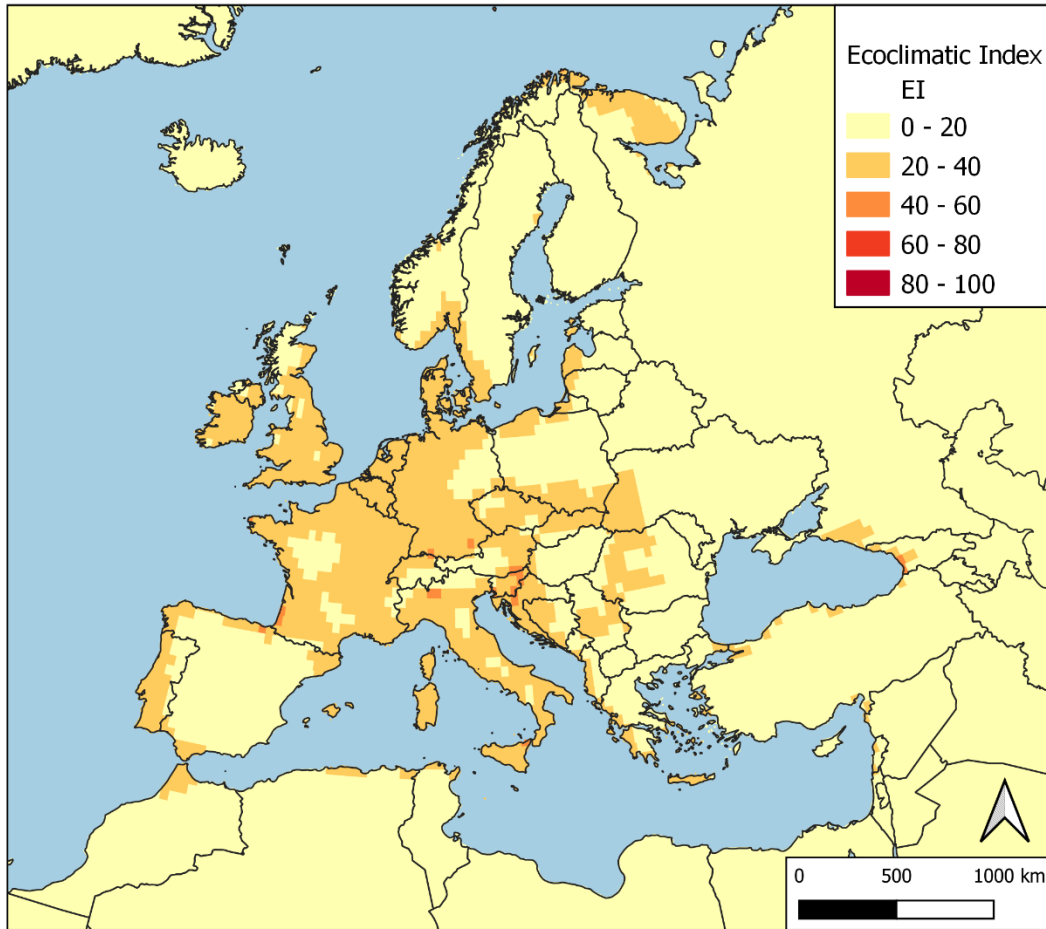


Figure 4: Potential distribution of *V. mandarinia* in Europe and northern Africa in 2080, as predicted by the Ecoclimatic Index (EI) from the CLIMEX model using the A1B scenario. Locations with $EI > 20$ can be considered as climatically suitable for establishment and growth of *V. mandarinia*.

A8. In which EU Member States has the species been recorded and in which EU Member States has it established? List them with an indication of the timeline of observations. The information needs to be given separately for recorded and established occurrences.

A8a. Recorded: List Member States

A8b. Established: List Member States

Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom

The description of the invasion history of the species shall include information on countries invaded and an indication of the timeline of the first observations, establishment and spread.

Response (8a):

No record yet in the risk assessment area. In GBIF (2020), a record from Germany seems erroneous

Response (8b):

No establishment yet in the risk assessment area

A9. In which EU Member States could the species establish in the future under current climate and under foreseeable climate change? The information needs be given separately for current climate and under foreseeable climate change conditions.

A9a. Current climate: List Member States

A9b. Future climate: List Member States

With regard to EU Member States, see above.

With regard to climate change, provide information on

- the applied timeframe (e.g. 2050/2070)
- the applied scenario (e.g. RCP 4.5)
- what aspects of climate change are most likely to affect the risk assessment (e.g. increase in average winter temperature, increase in drought periods)

The assessment does not have to include a full range of simulations on the basis of different climate change scenarios, as long as an assessment with a clear explanation of the assumptions is provided. However, if new, original models are executed for this risk assessment, the following RCP pathways shall be applied: RCP 2.6 (likely range of 0.4-1.6°C global warming increase by 2065) and RCP 4.5 (likely range of 0.9-2.0°C global warming increase by 2065). Otherwise, the choice of the assessed scenario has to be explained.

Response (9a):

Almost all member states are at least partly suitable for establishment. Establishment in Finland and Sweden will probably be limited by cold average temperatures whereas, in Cyprus, drought may hamper establishment (Figure 3).

Response (9b):

In the future, under the A1B scenario (see Q A7b) climate may become suitable at higher altitudes and latitudes, e.g. in Sweden and Finland because of increased average temperatures in particular during brood development, whereas Eastern European and Mediterranean countries may become less suitable because of increased summer droughts (Figure 4).

A10. Is the organism known to be invasive (i.e. to threaten or adversely impact upon biodiversity and related ecosystem services) anywhere outside the risk assessment area?

Response:

No information is available on the species impact in invaded areas.

Since August 2019, a nest and workers have been found at three sites in British Columbia, Canada and a nest and various specimens have been found at several locations in Washington State, USA (USDA 2020; WSDA 2021). However, it is not known whether these populations will become invasive.

Many Vespinae, including *Vespa* spp., are invasive worldwide, threatening biodiversity and various ecosystem services. See Beggs et al. (2011) for a review on the ecological effects of invasive alien Vespidae. The mechanisms of ecological impacts of invasive Vespidae include: direct predation on native species, in particular invertebrates; competition for food (invertebrates, honeydew, sap runs etc.) with other insects but also birds; competition for space, in particular other vespids; predation on honeybees and wild bees affecting pollination services, etc.

A11. In which biogeographic region(s) or marine subregion(s) in the risk assessment area has the species shown signs of invasiveness? Indicate the area endangered by the organism as detailed as possible.

Freshwater / terrestrial biogeographic regions:

- Alpine, Atlantic, Black Sea, Boreal, Continental, Mediterranean, Pannonian, Steppic

Marine regions:

- Baltic Sea, North-east Atlantic Ocean, Mediterranean Sea, Black Sea

Marine subregions:

Greater North Sea, incl. the Kattegat and the English Channel, Celtic Seas, Bay of Biscay and the Iberian Coast, Western Mediterranean Sea, Adriatic Sea, Ionian Sea, Central Mediterranean Sea, Aegean-Levantine Sea

Response:

The species is not yet present in the risk assessment area.

A12. In which EU Member States has the species shown signs of invasiveness? Indicate the area endangered by the organism as detailed as possible.

Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom

Response:

The species is not yet present in the risk assessment area.

A13. Describe any known socio-economic benefits of the organism.

including the following elements:

- Description of known uses for the species, including a list and description of known uses in the risk assessment area and third countries, if relevant.
- Description of social and economic benefits deriving from those uses, including a description of the environmental, social and economic relevance of each of those uses and an indication of associated beneficiaries, quantitatively and/or qualitatively depending on what information is available.

If the information available is not sufficient to provide a description of those benefits for the entire risk assessment area, qualitative data or different case studies from across the risk assessment area or third countries shall be used, if available.

Response:

In Asia, larvae and pupae of *V. mandarinia* are considered a delicacy. They are traded and consumed in various ways. They are also considered to have medicinal properties (Nonaka 2008; Ying et al. 2008; Ho 2019). To our knowledge, live *V. mandarinia* are not traded in Europe but at least one entire nest containing live larvae and pupae was intercepted in USA (Smith Pardo et al. 2020) suggesting that illegal trade of nests does occur outside Asia.

SECTION B – Detailed assessment

Important instructions:

- In the case of lack of information the assessors are requested to use a standardized answer: “No information has been found.”
- With regard to the scoring of the likelihood of events or the magnitude of impacts see Annexes I and II.
- With regard to the confidence levels, see Annex III.
- Highlight the selected response score and confidence level in **bold** but keep the other scores in normal text (so that the selected score is evident in the final document).

1 PROBABILITY OF INTRODUCTION AND ENTRY

Important instructions:

- **Introduction** is the movement of the species into the risk assessment area (it may be either in captive conditions and/or in the environment, depending on the relevant pathways).
- **Entry** is the release/escape/arrival in the environment, i.e. occurrence in the wild
- Introduction and entry may coincide for species entering through pathways such as “corridor” or “unaided”, but it also may differ. If different, please consider all relevant pathways, both for the introduction into the risk assessment area and the entry in the environment.
- The classification of pathways developed by the Convention of Biological Diversity (CBD) should be used (see Annex IV). For detailed explanations of the CBD pathway classification scheme consult the IUCN/CEH guidance document³ and the provided key to pathways⁴.
- For organisms which are already present (recorded or established) in the risk assessment area, the likelihood of introduction and entry should be scored as “very likely” by default.
- Repeated (independent) introductions and entries at separate locations in the risk assessment area should be considered here (see Qu. 1.7).

Qu. 1.1. List relevant pathways through which the organism could be introduced into the risk assessment area and/or enter into the environment. Where possible give details about the specific origins and end points of the pathways as well as a description of any associated commodities.

For each pathway answer questions 1.2 to 1.7 (copy and paste additional rows at the end of this section as necessary). Please attribute unique identifiers to each question if you consider more than one pathway, e.g. 1.2a, 1.3a, etc. and then 1.2b, 1.3b etc. for the next pathway.

In this context a pathway is the route or mechanism of introduction and/or entry of the species.

³ <https://circabc.europa.eu/sd/a/738e82a8-f0a6-47c6-8f3b-aeddb535b83b/TSSR-2016-010%20CBD%20categories%20on%20pathways%20Final.pdf>

⁴ <https://circabc.europa.eu/sd/a/Oaeba7f1-c8c2-45a1-9ba3-bcb91a9f039d/TSSR-2016-010%20CBD%20pathways%20key%20full%20only.pdf>

The description of commodities with which the introduction of the species is generally associated shall include a list and description of commodities with an indication of associated risks (e.g. the volume of trade; the likelihood of a commodity being contaminated or acting as vector).

If there are no active pathways or potential future pathways this should be stated explicitly here, and there is no need to answer the questions 1.2-1.9.

The pathways considered in this risk assessment are:

- A. Transport - Contaminant (nursery material)
- B. Transport - Contaminant (transportation of habitat material) (other than nursery material)
- C. Transport - Stowaway (container/bulk)
- D. Escaped from confinement (live food and live bait)

Vespa mandarinia presently occurs too far from the risk assessment area to consider that the hornet can enter “unaided”. Thus, all pathways considered here will be human-assisted. There is very limited information on the potential pathways that can be used by *V. mandarinia* to enter new continents. Non-native Vespidae are not listed as quarantine pests in the EU and, therefore, records do not appear in the national and international lists of intercepted pests. Thus, there is hardly any information available from Europe except that the congeneric and invasive alien species *Vespa velutina* probably arrived in Europe in bonsai pottery from Asia (Arca et al. 2015). Smith Pardo et al. (2020) mentioned that, from 2010 to 2018, there have been close to 50 interceptions of *Vespa* spp. and *Vespula* spp. at US ports of entry and that little less than half of those interceptions were hornets, including *V. mandarinia*. They did not mention on which pathways and which commodities these interceptions were made. However, these data, and the recent introductions of *V. mandarinia* in North America (USDA 2020) along with various *Vespa* spp., *Vespula* spp. and *Polistes* spp. worldwide (Beggs et al. 2011) show that vespids, including *V. mandarinia* can be transported between continents. While queens, males and workers can potentially travel, only mated queens will be able to build a new colony. *Vespa mandarinia* queens overwinter singly, usually in cavities excavated in the soil, or occasionally in rotten wood or straw. Thus, the transport of mated queens from autumn to spring (before, during and after overwintering) is the most likely means of long-distance dispersal. Single queens may unintentionally be transported as contaminant of soil (e.g. soil for construction, potted plants) or rotten wood or straw in which they overwinter, or as stowaway in any kind of good in containers. Theoretically, a mated queen could also travel freely, outside containers, in ships or planes but these pathways were considered too unlikely to be mentioned here. Similarly, Transport – stowaway (vehicle) was not included and assessed in this section because it is considered highly unlikely that a queen would travel successfully by train or truck from East Asia, though not impossible. However, this pathway is considered in the spread section for the possibility of secondary translocation within the risk assessment area after introduction.

The introduction of a single mated queen is potentially sufficient to establish a colony. The introduction of *V. velutina* in France was due to a single queen that had mated multiple times, or a very small number of overwintering queens that had mated singly (Arca et al. 2015).

One of the interceptions of significance in USA mentioned by Smith Pardo et al. (2020) was an entire nest of *V. mandarinia* containing live brood and pupae that was sent via express courier from Asia, probably for consumption or as traditional medicine (USDA 2020). Thus, intentional importations of nests are considered here as well.

A. Transport - Contaminant (nursery material)

Qu. 1.2a. Is introduction and/or entry along this pathway intentional (e.g. the organism is imported for trade) or unintentional (e.g. the organism is a contaminant of imported goods)?

RESPONSE	intentional unintentional	CONFIDENCE	low medium high
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Response:

The introduction and/or entry along this pathway is unintentional. Queens overwinter mainly in a hole that they have excavated in the soil (Matsuura and Sakagami 1973; Archer 1995). Thus, any kind of soil or similar substrate that is transported with nursery material can potentially transport an overwintering queen.

Qu. 1.3a. How likely is it that large numbers of the organism will be introduced and/or enter into the environment through this pathway from the point(s) of origin over the course of one year?

including the following elements:

- discuss how likely the organism is to get onto the pathway in the first place. Also comment on the volume of movement along this pathway.
- an indication of the propagule pressure (e.g. estimated volume or number of individuals / propagules, or frequency of passage through pathway), including the likelihood of reinvasion after eradication
- if relevant, comment on the likelihood of introduction and/or entry based on propagule pressure (i.e. for some species low propagule pressure (1-2 individuals) could result in subsequent establishment whereas for others high propagule pressure (many thousands of individuals) may not.

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

There is no data on *V. mandarinia* or other *Vespa* spp. travelling in potted plants. The import of soil and related substrates to Europe has been much reduced in recent years. Nevertheless, a large amount of plants still arrive in Europe with soil or in pots (with substrates) from East Asia every year and, although the soil/substrate is supposed to be sterile, it is possible that hornets can enter the soil/substrates just before or during transport.

Qu. 1.4a. How likely is the organism to survive, reproduce, or increase during transport and storage along the pathway (excluding management practices that would kill the organism)?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Queens are very strong insects. They do not feed nor reproduce in their overwintering site (Matsuura and Sakagami 1973; Archer 1995) and can probably survive long ship journeys.

Qu. 1.5a. How likely is the organism to survive existing management practices before and during transport and storage along the pathway?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

In international horticultural trade, plant material is supposed to be free of pests and soil/substrate should be sterile, but hornets can enter the soil/substrates after treatments, just before or during transport. Only a small portion of the plant material imported to the EU is inspected and the imported pots are quickly dispersed into the EU (Eschen et al. 2015).

Qu. 1.6a. How likely is the organism to be introduced into the risk assessment area or entry into the environment undetected?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Although a *V. mandarinia* queen is rather big (4-5 cm), the cavity in which it overwinters is usually plugged (Archer 1995) and it can easily remain undetected during intercontinental transport and dispatching to the final destinations.

Qu. 1.7a. How isolated or widespread are possible points of introduction and/or entry into the environment in the risk assessment area?

RESPONSE	isolated widespread ubiquitous	CONFIDENCE	low medium high
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Response:

Horticultural products can enter the risk assessment area at various ports of entry and are usually quickly distributed within the EU. Queens are good fliers and can build nests in various environments (Matsuura and Sakagami 1973; Archer 1995). Thus, they would have no difficulty in reaching suitable habitats for nesting.

Qu. 1.8a. Estimate the overall likelihood of introduction into the risk assessment area and/or entry into the environment based on this pathway?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

There is no data on this pathway and it is not clear how frequently queens could enter soil and other substrates accompanying traded potted plants and other plant material. Probably this is a rather infrequent event considering that large amounts of soil or other substrates are transported every year into the EU and no occurrence of *V. mandarinia* has been ever recorded in Europe. However, once a queen has entered the commodity to build its overwintering site, the probability of arriving safely and entering the risk assessment area is rather high, considering that queens are strong and long-lived animals, and that the cavity in which they overwinter is usually plugged.

B. Transport - Contaminant (transportation of habitat material) (other than nursery material)

Qu. 1.2b. Is introduction and/or entry along this pathway intentional (e.g. the organism is imported for trade) or unintentional (e.g. the organism is a contaminant of imported goods)?

RESPONSE	intentional unintentional	CONFIDENCE	low medium high
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Response:

The introduction and/or entry along this pathway is unintentional. Queens overwinter mainly in a hole that they have excavated in the soil, but also occasionally in rotting wood, piles of straw, etc. (Matsuura and Sakagami 1973; Archer 1995). Thus, this pathway covers these overwintering substrates other than soil in potted plants, which is covered in pathway A above.

Qu. 1.3b. How likely is it that large numbers of the organism will be introduced and/or enter into the environment through this pathway from the point(s) of origin over the course of one year?

including the following elements:

- discuss how likely the organism is to get onto the pathway in the first place. Also comment on the volume of movement along this pathway.
- an indication of the propagule pressure (e.g. estimated volume or number of individuals / propagules, or frequency of passage through pathway), including the likelihood of reinvasion after eradication
- if relevant, comment on the likelihood of introduction and/or entry based on propagule pressure (i.e. for some species low propagule pressure (1-2 individuals) could result in subsequent establishment whereas for others high propagule pressure (many thousands of individuals) may not.

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

There is no data on *V. mandarinia* or other *Vespa* spp. travelling in suitable habitats such as straw and rotting wood. While rotting wood is unlikely to be imported intentionally, various amounts of items made of straw arrive in Europe from East Asia every year and it is possible that these can host overwintering hornets. Items made of straw may include handicraft, horticulture and gardening material, packing material, etc.

Qu. 1.4b. How likely is the organism to survive, reproduce, or increase during transport and storage along the pathway (excluding management practices that would kill the organism)?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Queens are very strong insects. They do not feed nor reproduce in their overwintering site (Matsuura and Sakagami 1973; Archer 1995) and can probably survive long ship journeys.

Qu. 1.5b. How likely is the organism to survive existing management practices before and during transport and storage along the pathway?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

There is no data on existing management practices on imported straw items. These can be quickly dispatched to the whole risk assessment area.

Qu. 1.6b. How likely is the organism to be introduced into the risk assessment area or entry into the environment undetected?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Although a *V. mandarinia* queen is rather big (4-5 cm), the cavity in which it overwinters is usually plugged (Archer 1995) and it can easily remain undetected during transport and dispatching to the final destinations.

Qu. 1.7b. How isolated or widespread are possible points of introduction and/or entry into the environment in the risk assessment area?

RESPONSE	isolated	CONFIDENCE	low
	widespread		medium
	ubiquitous		high

Response:

Such commodities can enter the risk assessment area at various ports of entry and can be quickly distributed within the EU. Queens are good fliers and can build nests in various environments (Matsuura and Sakagami 1973; Archer 1995). Thus, they would have no difficulty in reaching suitable habitats for nesting.

Qu. 1.8b. Estimate the overall likelihood of introduction into the risk assessment area and/or entry into the environment based on this pathway?

RESPONSE	very unlikely	CONFIDENCE	low
	unlikely		medium
	moderately likely		high
	likely		
	very likely		

Response:

There is no data on this pathway and it is not clear how frequently queens could be transported in straw material, rotting wood and similar overwintering habitats. Probably this is an infrequent event. However, once a queen has entered the commodity to build its overwintering site, the probability of arriving safely and entering the risk assessment area is rather high, considering that queens are strong and long-lived animals, and that the cavity in which they overwinter is usually plugged.

C. Transport-Stowaway (container/bulk)

Qu. 1.2c. Is introduction and/or entry along this pathway intentional (e.g. the organism is imported for trade) or unintentional (e.g. the organism is a contaminant of imported goods)?

RESPONSE	intentional unintentional	CONFIDENCE	low medium high
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Response:

The introduction and/or entry along this pathway is unintentional. In their search for overwintering sites, or when emerging from overwintering sites between autumn and spring, queens can easily hide in various type of containers and can be shipped with any kind of good in containers with various transport means (ships and planes).

Qu. 1.3c. How likely is it that large numbers of the organism will be introduced and/or enter into the environment through this pathway from the point(s) of origin over the course of one year?

including the following elements:

- discuss how likely the organism is to get onto the pathway in the first place. Also comment on the volume of movement along this pathway.
- an indication of the propagule pressure (e.g. estimated volume or number of individuals / propagules, or frequency of passage through pathway), including the likelihood of reinvasion after eradication
- if relevant, comment on the likelihood of introduction and/or entry based on propagule pressure (i.e. for some species low propagule pressure (1-2 individuals) could result in subsequent establishment whereas for others high propagule pressure (many thousands of individuals) may not.

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

There is no data to define which goods and containers are the most likely to carry queens. However, the number and variety of commodities and containers that can potentially transport queens is unlimited and, thus, we believe that queens are more likely to be transported as stowaways in containers than as contaminants of soil. At arrival, queens can easily escape and build a nest in the vicinity of the port of entry, or be transported with the container into any region of the risk assessment area.

Qu. 1.4c. How likely is the organism to survive, reproduce, or increase during transport and storage along the pathway (excluding management practices that would kill the organism)?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Queens are very strong insects. They do not feed nor reproduce in their overwintering site (Matsuura and Sakagami 1973; Archer 1995). Thus, they can probably survive long journeys, especially if they find an overwintering site in the container. Once the container is open and the commodity has been delivered, the queen can escape and easily find a suitable habitat for nesting since nests are commonly found in various habitats from forests to urban green spaces (Matsuura and Sakagami 1973; USDA 2020).

Qu. 1.5c. How likely is the organism to survive existing management practices before and during transport and storage along the pathway?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

This will depend on the management practices used in the transport conditions but none will target Vespidae and it is unlikely that any management practice will affect the transported queen along the pathway and within the risk assessment area after transport and dispatching to the final destination.

Qu. 1.6c. How likely is the organism to be introduced into the risk assessment area or entry into the environment undetected?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Queens are very big (4-5 cm) and may be quite obvious when they simply hitchhike in a container. However, overwintering queens are usually hidden and are easily missed when transported.

Qu. 1.7c. How isolated or widespread are possible points of introduction and/or entry into the environment in the risk assessment area?

RESPONSE	isolated widespread ubiquitous	CONFIDENCE	low medium high
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Response:

Containers can enter the risk assessment area at various ports of entry and can also be quickly sent anywhere within the EU. Queens are good fliers and can build nests in various environments, from forests to urban areas (Matsuura and Sakagami 1973; Archer 1995; USDA 2020). Thus, they would have no difficulty in reaching suitable habitats for nesting.

Qu. 1.8c. Estimate the overall likelihood of introduction into the risk assessment area and/or entry into the environment based on this pathway?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

There is no data on this pathway and it is not clear how frequently queens could be transported as stowaway between continents. However, considering that the number and variety of commodities and containers that can potentially transport queens is unlimited, queens are probably more likely to be transported as stowaway than as contaminant of soil or straw.

D. Escaped from confinement (live food and live baits)

Qu. 1.2d. Is introduction and/or entry along this pathway intentional (e.g. the organism is imported for trade) or unintentional (e.g. the organism is a contaminant of imported goods)?

RESPONSE	intentional unintentional	CONFIDENCE	low medium high
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Response:

This pathway has been added because among the ca. 50 reported interceptions of Vespidae in ports of entry in USA, one was an entire nest of *V. mandarinia* with live larvae and pupae sent by express courier from Asia (Smith-Pardo et al. 2020). It is not known precisely why this nest was sent to USA, but it is likely that it was for human consumption. In Asia, larvae and pupae of *V. mandarinia* are considered a delicacy, and consumed in various ways. They are also considered to have medicinal properties (Nonaka 2008; Ying et al. 2008; Ho 2019). Larvae and pupae are consumed fresh. People collect nests and leave larvae and pupae alive within the combs of the nests until they are ready to be prepared (Nonaka 2008).

Qu. 1.3d. How likely is it that large numbers of the organism will be introduced and/or enter into the environment through this pathway from the point(s) of origin over the course of one year?

including the following elements:

- discuss how likely the organism is to get onto the pathway in the first place. Also comment on the volume of movement along this pathway.
- an indication of the propagule pressure (e.g. estimated volume or number of individuals / propagules, or frequency of passage through pathway), including the likelihood of reinvasion after eradication
- if relevant, comment on the likelihood of introduction and/or entry based on propagule pressure (i.e. for some species low propagule pressure (1-2 individuals) could result in subsequent establishment whereas for others high propagule pressure (many thousands of individuals) may not.

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Such shipments are probably rare events, but these nests may contain hundreds of larvae and pupae that can become adults and escape, if they are not consumed, representing a potential pathway of introduction (USDA 2020).

Qu. 1.4d. How likely is the organism to survive, reproduce, or increase during transport and storage along the pathway (excluding management practices that would kill the organism)?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Depending on the time of year, the larvae and pupae in the nests may be workers, males or reproductive females. However, hornet-hunters usually harvest nests late in the season when workers are rearing sexuals. Thus, it is likely that hornets harvested for consumption would contain high-risk castes, i.e. sexuals (Nonaka 2008; USDA 2020). Larvae are likely to die during transport if they are not yet mature, in the absence of adult hornet caretakers. In contrast, pupae are likely to remain alive and viable for an extended period. These have the potential to mature into adults and escape to establish a population (USDA 2020). The larvae or pupae in nests will not reproduce or increase during transport.

Qu. 1.5d. How likely is the organism to survive existing management practices before and during transport and storage along the pathway?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

There is no particular management in such express courier shipments, which are usually delivered within a few days. However, larvae and pupae are meant to be preserved, cooked and eaten and only if the nests are discarded will the insects escape into the wild. Furthermore, even if they are sexuals, they have to mate to establish in the following year.

Qu. 1.6d. How likely is the organism to be introduced into the risk assessment area or entry into the environment undetected?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Most such express courier shipments are not opened at ports of entry and usually remain undetected until the recipient receives it. However, larvae and pupae are meant to be preserved, cooked and eaten and only if the nests are discarded will the insects escape into the wild. Furthermore, even if they are sexuals, they have to mate to establish in the following year.

Qu. 1.7d. How isolated or widespread are possible points of introduction and/or entry into the environment in the risk assessment area?

RESPONSE	isolated widespread ubiquitous	CONFIDENCE	low medium high
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Response:

The recipient can be anywhere in the risk assessment area.

Qu. 1.8d. Estimate the overall likelihood of introduction into the risk assessment area and/or entry into the environment based on this pathway?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

The likelihood of introduction along this pathway is unlikely because such shipments are probably very rare events, particularly to Europe. Furthermore, if such a nest was delivered to the recipient, it would likely be for human consumption. Finally, if some hornets escaped, they would have to be of both sexes, mate (45% of *V. mandarinia* queens emerging from nests are not fertilized (Archer 2012)), and the queen would need to survive the winter. This, such a pathway of introduction is much less likely than those involving a mated queen arriving as contaminant or as stowaway.

Qu. 1.9. Estimate the overall likelihood of introduction into the risk assessment area or entry into the environment based on all pathways and specify if different in relevant biogeographical regions in current conditions.

Provide a thorough assessment of the risk of introduction in relevant biogeographical regions in current conditions: providing insight in to the risk of introduction into the risk assessment area.

RESPONSE	very unlikely unlikely moderately likely likely	CONFIDENCE	low medium high
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	very likely		
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Response:

Data on pathways of invasion of *Vespa* spp. and Vespidea in general are hardly available. However, considering the high numbers of -detrimental- introductions of invasive Vespidae worldwide in recent years (Beggs et al. 2011; USDA 2020), it is likely that non-intentional transports of wasps and hornets are rather common. The transport of mated *Vespa mandarinia* queens from autumn to spring is the most likely means of long-distance dispersion and only mated queens are able to build a new colony. Single queens may unintentionally be transported as contaminant of soil or rotten wood or straw in which they overwinter, or as stowaway in any kind of good, container or vehicle. Considering that the number and variety of commodities and containers that can potentially transport queens is unlimited, queens are probably more likely to be transported as stowaway.

The likelihood of introduction into the risk assessment area or entry into the environment based on all pathways does not vary among biogeographical regions.

Qu. 1.10. Estimate the overall likelihood of introduction into the risk assessment area or entry into the environment based on all pathways in foreseeable climate change conditions?

Thorough assessment of the risk of introduction in relevant biogeographical regions in foreseeable climate change conditions: explaining how foreseeable climate change conditions will influence this risk.

With regard to climate change, provide information on

- the applied timeframe (e.g. 2050/2070)
- the applied scenario (e.g. RCP 4.5)
- what aspects of climate change are most likely to affect the likelihood of introduction (e.g. change in trade or user preferences)

The thorough assessment does not have to include a full range of simulations on the basis of different climate change scenarios, as long as an assessment of likely introduction within a medium timeframe scenario (e.g. 30-50 years) with a clear explanation of the assumptions is provided. However, if new, original models are executed for this risk assessment, the following RCP pathways shall be applied: RCP 2.6 (likely range of 0.4-1.6°C global warming increase by 2065) and RCP 4.5 (likely range of 0.9-2.0°C global warming increase by 2065). Otherwise, the choice of the assessed scenario has to be explained.

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Climate change should not influence negatively or positively the likelihood of introduction into the risk assessment area.

2 PROBABILITY OF ESTABLISHMENT

Important instructions:

- For organisms which are already established in parts of the risk assessment area or have previously been eradicated, the likelihood of establishment should be scored as “very likely” by default.
- Discuss the risk also for those parts of the risk assessment area, where the species is not yet established.

Qu. 2.1. How likely is it that the organism will be able to establish in the risk assessment area based on similarity of climatic and abiotic conditions in its distribution elsewhere in the world?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

The climate model made for this risk assessment (Figures 2-4) suggests that a large part of the risk assessment area is climatically suitable for the establishment of *V. mandarinia*, whose native distribution includes a wide variety of abiotic conditions and climates (present in at least 9 Köppen climates from the continental, temperate and tropical groups) from the Russian Far East in the north to Thailand and Malaysia in the south (Matsuura and Sakagami 1973; Matsuura and Yamane 1990; Archer 1995). The climate model showed that, under current climate, the most suitable biogeographic regions are the Continental and Atlantic regions (Figure 3, see also Annex VIII). Establishment will also be possible in the most humid parts of the Mediterranean, Black Sea and Pannonian regions. The Arctic, Boreal and Alpine regions will probably be too cold for establishment while the Steppic region appear too dry to be suitable for *V. mandarinia*. However, in this last region, irrigated areas or humid microclimates may be favourable for the hornet. The ecological niche model developed by Zhu et al. (2020) mostly for North America also shows a global risk map and the ecological suitability presented for Europe is very similar to the CLIMEX model presented in Figure 3 and Annex VIII, with the exception of Fennoscandia which is presented as largely suitable.

Qu. 2.2. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in the risk assessment area? Consider if the organism specifically requires another species to complete its life cycle.

RESPONSE	very isolated isolated moderately widespread widespread ubiquitous	CONFIDENCE	low medium high
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Response:

In its area of origin, *V. mandarinia* is widespread and inhabits a large variety of habitats and is particularly abundant in forests and urban green spaces (USDA 2020). *Vespa mandarinia* does not have particular ecological requirements except that nest building and maintaining require humidity. Nests are built mainly in cavities in the soil, such as rodent or reptile burrows, or in rotten tree root systems. They are polyphagous, feeding on a large variety of prey, mainly insects, as well as sugary food such as tree sap and fruits (Matsuura and Sakagami 1973; Matsuura and Yamane 1990; Archer 1995).

Qu. 2.3. How likely is it that establishment will occur despite competition from existing species in the risk assessment area?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

In its area of origin, *V. mandarinia* co-occurs with several hornet and other wasps, among which *V. crabro* and *V. velutina*, which are two of the three hornets occurring in Europe. Matsuura and Yamane (1990) provide a detailed review of the competitive interactions among *Vespa* spp. and also with other vespidae genera. In general, they consider that the differences in the life history traits among *Vespa* spp. (e.g. different nesting or foraging behaviour) reduce interspecific competition. However, in most cases, when interspecific competition exists, it is in favour of *V. mandarinia*. For example, in spring, queens eat fermenting sap that seeps from tree wounds, which they fiercely defend against other insects, including other *V. mandarinia* queens (Matsuura and Sakagami, 1973; Matsuura, 1984). Recently, Kwon and Choi (2020) showed that, in Korea, *V. mandarinia* had the highest aggressive score towards other hornet species, including the European hornet *V. crabro*. *Vespa mandarinia* is not only able to attack bee hives but it is also the only hornet that can organize group attacks and complete destructions of nests of other *Vespa* spp. (including *V. crabro*) and *Vespula* spp., as described in Matsuura and Sakagami (1973) and Matsuura and Yamane (1990).

Qu. 2.4. How likely is it that establishment will occur despite predators, parasites or pathogens already present in the risk assessment area?

RESPONSE	N/A very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Although *Vespa* spp. have a whole range of natural enemies, most of them are not species-specific (Matsuura and Yamane, 1990). Natural enemies of the European hornet such as parasitic insects and nematodes (Turchi and Derijard 2018) and various birds (Monceau et al. 2014) have not been able to prevent the establishment and spread of the invasive alien *Vespa velutina*. This latter is not controlled by natural enemies in Europe, at least when in the nest. Predation on single queens and workers has been poorly studied.

Qu. 2.5. How likely is the organism to establish despite existing management practices in the risk assessment area? Explain if existing management practices could facilitate establishment.

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

In the European countries affected by the invasion of *V. velutina*, management practices in place to control the spread of the invasive alien species (see management annex), including trapping and nest destruction, may facilitate rapid responses against *V. mandarinia* and help prevent its establishment (Turchi and Derijard 2018). However, the two species strongly differ in their nesting behavior, *V. mandarinia*'s nests being underground whereas *V. velutina*, as *V. crabro*, nest are mainly built in trees and buildings (Matsuura and Yamane 2020).

Qu. 2.6. How likely is it that biological properties of the organism would allow it to survive eradication campaigns in the risk assessment area?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Eradication campaigns would include (1) the finding and destruction of nests in case individuals are found; (2) trapping campaigns to assess the presence of hornets in the eradication region. Underground nests are not easy to locate but protocols are available (USDA 2020, and see management annex). Depending on the time of the year during which the nests are found, queens may have already left (from October on) and will then be very difficult to localize. One of the main biological properties that makes eradication difficult is the high reproductive and dispersal rate of the organism. It is likely that if early eradication fails, the outbreak would increase in scale to a point that would make eradication very difficult.

Qu. 2.7. How likely are the biological characteristics of the organism to facilitate its establishment in the risk assessment area?

including the following elements:

- a list and description of the reproduction mechanisms of the species in relation to the environmental conditions in the risk assessment area
- an indication of the propagule pressure of the species (e.g. number of gametes, seeds, eggs or propagules, number of reproductive cycles per year) of each of those reproduction mechanisms in relation to the environmental conditions in the risk assessment area.
- If relevant, comment on the likelihood of establishment based on propagule pressure (i.e. for some species low propagule pressure (1-2 individuals) could result in establishment whereas for others high propagule pressure (many thousands of individuals) may not.
- If relevant, comment on the adaptability of the organism to facilitate its establishment and if low genetic diversity in the founder population would have an influence on establishment.

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

The life cycle of *V. mandarinia* is described in details in Matsuura and Sakagami (1973), Matsuura and Yamane (1990) and Archer (1995) and can be summarized as follows. Mated queens overwinter in moist soil cavities, rotting wood or piles of straw. The entrance of the cavity is plugged and the queen passes the winter hanging from the top of the chamber. In spring, they start feeding to develop their ovaries, and search for a nesting site in soil (e.g. rodent's burrow) or in root systems of rotten trees. Then, queens build their nest, first alone and then with the first workers. In summer, the queens become totally nest-bounded. Mature nests contain an average of 2,712 cells, but this number is highly variable, and cells can be reused two or three times in the season (Matsuura and Koike, 2002). In autumn, the nests start producing sexuals. An average colony will produce about 212 males and 205 females (Archer, 1995). Males emerge before females and wait for females at the nests' entrance to mate. Males die before the winter and mated females overwinter. This biology allows single females to colonize, alone, a new area and produce sufficient amounts of sexuals to ensure their establishment.

It has been shown that the *V. velutina* established in France originated from one or a few queens (Arca et al. 2015), suggesting that a very low propagule pressure is sufficient for the establishment of hornet species.

Qu. 2.8. If the organism does not establish, then how likely is it that casual populations will continue to occur?

Consider, for example, a species which cannot reproduce in the risk assessment area, because of unsuitable climatic conditions or host plants, but is present because of recurring introduction, entry and release events. This may also apply for long-living organisms.

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Introductions of hornets are probably rather unlikely events but little information is available on introduction events.

Qu. 2.9. Estimate the overall likelihood of establishment in the risk assessment area under current climatic conditions. In addition, details of the likelihood of establishment in relevant biogeographical regions under current climatic conditions should be provided.

Thorough assessment of the risk of establishment in relevant biogeographical regions in current conditions: providing insight in the risk of establishment in (new areas in) the risk assessment area.

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

If queens are introduced, establishment can be considered very likely in a large part of the risk assessment area, considering the climatic suitability (Figure 3), the availability of suitable habitats, the ability of single mated queens to colonize new areas, the high fecundity and the high competitiveness of the species (Matsuura and Sakagami 1973; Matsuura and Yamane 1990; Archer 1995). Climate models suggest that the establishment would be particularly likely in the Continental and Atlantic regions (Figure 3). Establishment will also be possible in the most humid parts of the Mediterranean, Black Sea and Pannonian regions. The Arctic, boreal and Alpine regions will probably be too cold for

establishment while the Steppic regions appear too dry to be suitable for *V. mandarinia*. However, in this last region, irrigated areas or humid microclimates may be favourable for the hornet.

Qu. 2.10. Estimate the overall likelihood of establishment in the risk assessment area under foreseeable climate change conditions. In addition, details of the likelihood of establishment in relevant biogeographical regions under foreseeable climate change conditions should be provided.

Thorough assessment of the risk of establishment in relevant biogeographical regions in foreseeable climate change conditions: explaining how foreseeable climate change conditions will influence this risk.

With regard to climate change, provide information on

- the applied timeframe (e.g. 2050/2070)
- the applied scenario (e.g. RCP 4.5)
- what aspects of climate change are most likely to affect the likelihood of establishment (e.g. increase in average winter temperature, increase in drought periods)

The thorough assessment does not have to include a full range of simulations on the basis of different climate change scenarios, as long as an assessment of likely establishment within a medium timeframe scenario (e.g. 30-50 years) with a clear explanation of the assumptions is provided. However, if new, original models are executed for this risk assessment, the following RCP pathways shall be applied: RCP 2.6 (likely range of 0.4-1.6°C global warming increase by 2065) and RCP 4.5 (likely range of 0.9-2.0°C global warming increase by 2065). Otherwise, the choice of the assessed scenario has to be explained.

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Considering the wide climatic suitability of *V. mandarinia*, the general likelihood of establishment in Europe will not change under climate change scenarios. However, it is predicted that, with time, northern regions and high elevation areas will become more suitable because increased temperatures will allow the full development of a nest in summer whereas the Mediterranean and Continental Regions will become less suitable because of increased drought whereas humidity is needed for the building and maintenance of vespids nests.

3 PROBABILITY OF SPREAD

Important instructions:

- Spread is defined as the expansion of the geographical distribution of an alien species within the risk assessment area.
- Repeated releases at separate locations do not represent continuous spread and should be considered in the probability of introduction and entry section (Qu. 1.7).

Qu. 3.1. How important is the expected spread of this organism within the risk assessment area by natural means? (List and comment on each of the mechanisms for natural spread.)

including the following elements:

- a list and description of the natural spread mechanisms of the species in relation to the environmental conditions in the risk assessment area.
- an indication of the rate of spread discussed in relation to the species biology and the environmental conditions in the risk assessment area.

The description of spread patterns here refers to the CBD pathway category “Unaided (Natural Spread)”. It should include elements of the species life history and behavioural traits able to explain its ability to spread, including: reproduction or growth strategy, dispersal capacity, longevity, dietary requirements, environmental and climatic requirements, specialist or generalist characteristics.

RESPONSE	minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

Vespa mandarinia workers and queens are strong fliers. Workers usually forage in a radius of one to two kilometers around their nest but are capable of foraging up to eight kilometers away from the nest (Matsuura and Sakagami 1973). There is no reliable data on the flying capacities of queens. Abe et al. (1995) reported that *V. mandarinia* can fly at speeds of over 30 kilometers per hour and cover about 100 km in a single day but this information needs verification (USDA 2020). For comparison, queens of the invasive *V. velutina* can fly an average of 25 km/day in flight mill experiments (Sauvard et al. 2018). In nature, queens may not spread that fast, but they may cover very long distances during their extensive flight periods (i.e., before and after hibernation). *Vespa velutina* has spread an average of 78 km/year in the first years of its invasion in France (Robinet et al. 2017), but only 18 km/year in Italy (Bertolino et al. 2016) and 10–20 km/year in South Korea (Choi et al. 2012). Human-mediated dispersal may not be necessarily responsible for the hornet’s rapid range expansion even though the initial jumps to UK, Portugal or the Netherlands are likely due to transport of goods (Robinet et al. 2017, 2019).

Qu. 3.2a. List and describe relevant pathways of spread other than "unaided". For each pathway answer questions 3.3 to 3.9 (copy and paste additional rows at the end of this section as necessary). Please attribute unique identifiers to each question if you consider more than one pathway, e.g. 3.3a, 3.4a, etc. and then 3.3b, 3.4b etc. for the next pathway.

including the following elements:

- a list and description of pathways of spread with an indication of their importance and associated risks (e.g. the likelihood of spread in the risk assessment area, based on these pathways; likelihood of survival, or reproduction, or increase during transport and storage; ability and likelihood of transfer from the pathway to a suitable habitat or host) in relation to the environmental conditions in the risk assessment area.
- an indication of the rate of spread for each pathway discussed in relation to the species biology and the environmental conditions in the risk assessment area.
- All relevant pathways of spread (except “Unaided (Natural Spread)”, which is assessed in Qu. 3.1) should be considered. The classification of pathways developed by the Convention of Biological Diversity shall be used (see Annex IV).

Even though workers could be transported by humans, only the transport of mated queens will allow the species to spread. And, because the transport of full, active nests in summer is highly unlikely, only the transport of mated queens from autumn to spring should be considered. Single queens may unintentionally be transported as contaminant of nursery material and transportation of habitat material in which they overwinter or as stowaway in any kind of good, container or vehicle.

The pathways of spread considered in the risk assessment are:

- A. Transport - Contaminant (nursery material)
- B. Transport - Contaminant (other than soil of nursery material)
- C. Transport - stowaway (Container/Bulk)
- D. Transport - stowaway (vehicles)

A. Transport - Contaminant (nursery material)

Qu. 3.3a. Is spread along this pathway intentional (e.g. the organism is deliberately transported from one place to another) or unintentional (e.g. the organism is a contaminant of translocated goods within the risk assessment area)?

RESPONSE	intentional	CONFIDENCE	low
	unintentional		medium
			high

Response:

Queens overwinter mainly in a hole that they have excavated in the soil. (Matsuura and Sakagami 1973; Archer 1995). Thus, any kind of soil or similar substrate related to the movement of nursery material, in particular soil in potted plants can potentially transport an overwintering queen.

Qu. 3.4a. How likely is it that a number of individuals sufficient to originate a viable population will spread along this pathway from the point(s) of origin over the course of one year?

including the following elements:

- an indication of the propagule pressure (e.g. estimated volume or number of specimens, or frequency of passage through pathway), including the likelihood of reinvasion after eradication
- if appropriate, indicate the rate of spread along this pathway
- if appropriate, include an explanation of the relevance of the number of individuals for spread with regard to the biology of species (e.g. some species may not necessarily rely on large numbers of individuals).

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Only one mated queen is needed to form a colony in a newly invaded region, as observed in the arrival and spread of *V. velutina* in Europe (Arca et al. 2015; Robinet et al. 2017; 2019), and it is assumed that this could occur also for *V. mandarinia*.

Qu. 3.5a. How likely is the organism to survive, reproduce, or increase during transport and storage along the pathway (excluding management practices that would kill the organism)?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Queens are very strong insects. They do not feed nor reproduce in their overwintering site (Matsuura and Sakagami 1973; Archer 1995). Soil of potted plants is likely to remain intact during transport.

Qu. 3.6a. How likely is the organism to survive existing management practices during spread?

RESPONSE	very unlikely unlikely	CONFIDENCE	low medium
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	moderately likely likely very likely		high
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Response:

Phytosanitary practices in the horticultural sector may accidentally harm queens hidden in soil of potted plants when plants are treated with insecticides. However only some of the plants traded or moved within EU are treated with insecticides.

Qu. 3.7a. How likely is the organism to spread in the risk assessment area undetected?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Although the organism is rather big, the cavity in which a queen overwinters is usually plugged (Archer 1995) and it can easily remain undetected during transport until a viable population is established.

Qu. 3.8a. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host during spread?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Queens are good fliers and can build nests in various habitats, from forests to urban green areas (Matsuura and Sakagami 1973; Archer 1995). Thus, they would have no difficulty in reaching suitable habitats for nesting.

Qu. 3.9a. Estimate the overall potential rate of spread based on this pathway in relation to the environmental conditions in the risk assessment area. (please provide quantitative data where possible).

RESPONSE	very slowly slowly moderately rapidly very rapidly	CONFIDENCE	low medium high
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Response:

The spread of overwintering queens in soil is likely, considering the amount of soil in the horticulture sector transported within the risk assessment area. However, it must be noted that, almost two decades after the invasion of *V. velutina* in Europe, and after having invaded nine countries, little is known about the part of human-mediated dispersal in the fast spread of the hornet and on the underlying mechanisms (Robinet et al. 2017; 2019).

B. Transport - Contaminant (transportation of habitat material) (other than soil of nursery material)

Qu. 3.3b. Is spread along this pathway intentional (e.g. the organism is deliberately transported from one place to another) or unintentional (e.g. the organism is a contaminant of translocated goods within the risk assessment area)?

RESPONSE	intentional unintentional	CONFIDENCE	low medium high
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Response:

Queens overwinter mainly in a hole that they have excavated in the soil, but also occasionally in rotting wood, piles of straw, etc. (Matsuura and Sakagami 1973; Archer 1995). Thus, any kind of soil or similar substrate, except soil of nursery material (e.g. soil for construction), straw, rotting wood, etc. can potentially transport an overwintering queen.

Qu. 3.4b. How likely is it that a number of individuals sufficient to originate a viable population will spread along this pathway from the point(s) of origin over the course of one year?

including the following elements:

- an indication of the propagule pressure (e.g. estimated volume or number of specimens, or frequency of passage through pathway), including the likelihood of reinvasion after eradication

- if appropriate, indicate the rate of spread along this pathway
- if appropriate, include an explanation of the relevance of the number of individuals for spread with regard to the biology of species (e.g. some species may not necessarily rely on large numbers of individuals).

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Only one mated *V. mandarinia* queen is needed to form a colony in a newly invaded region, as observed in the arrival and spread of *V. velutina* in Europe (Arca et al. 2015; Robinet et al. 2017; 2019) and it is assumed that this could occur also for *V. mandarinia*.

Qu. 3.5b. How likely is the organism to survive, reproduce, or increase during transport and storage along the pathway (excluding management practices that would kill the organism)?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Queens are very strong insects. They do not feed nor reproduce in their overwintering site. Soil is often shaken during transport, which will not favour the survival of the queen. However, other substrates such as straw can be easily transported undisturbed, soil of potted plants is more likely to remain intact.

Qu. 3.6b. How likely is the organism to survive existing management practices during spread?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Within the risk assessment area, soil not related to nursery material and straw are usually transported without management practice.

Qu. 3.7b. How likely is the organism to spread in the risk assessment area undetected?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Although a *V. mandarinia* queen is very big, the cavity in which a queen overwinters is usually plugged (Archer 1995) and it can easily remain undetected during transport until a viable population is established.

Qu. 3.8b. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host during spread?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Queens are good fliers and can build nests in various habitats, from forests to urban green areas (Matsuura and Sakagami 1973; Archer 1995). Thus, they would have no difficulty in reaching suitable habitats for nesting.

Qu. 3.9b. Estimate the overall potential rate of spread based on this pathway in relation to the environmental conditions in the risk assessment area. (please provide quantitative data where possible).

RESPONSE	very slowly slowly moderately	CONFIDENCE	low medium high
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	rapidly very rapidly		
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Response:

The spread of overwintering queens in soil is likely, considering the amount of soil, straw and other potential overwintering substrates transported within the risk assessment area. However, it must be noted that, almost two decades after the invasion of *V. velutina* in Europe, and after having invaded ten countries, very little is known about the part of human-mediated dispersal in the fast spread of the hornet and on the underlying mechanisms (Robinet et al. 2017; 2019)

C. Transport - stowaway (Container/Bulk)

Qu. 3.3c. Is spread along this pathway intentional (e.g. the organism is deliberately transported from one place to another) or unintentional (e.g. the organism is a contaminant of translocated goods within the risk assessment area)?

RESPONSE	intentional unintentional	CONFIDENCE	low medium high
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Response:

Mated queens can travel hidden in many sorts of containers containing any kind of goods (e.g. pottery, fruits, meat/fish, furniture, etc.), before or after having built an overwintering site.

Qu. 3.4c. How likely is it that a number of individuals sufficient to originate a viable population will spread along this pathway from the point(s) of origin over the course of one year?

including the following elements:

- an indication of the propagule pressure (e.g. estimated volume or number of specimens, or frequency of passage through pathway), including the likelihood of reinvasion after eradication
- if appropriate, indicate the rate of spread along this pathway
- if appropriate, include an explanation of the relevance of the number of individuals for spread with regard to the biology of species (e.g. some species may not necessarily rely on large numbers of individuals).

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Only one mated queen is needed to form a colony in a newly invaded region, as observed in the arrival and spread of *V. velutina* in Europe (Arca et al. 2015; Robinet et al. 2017; 2019), and it is assumed that this could occur also for *V. mandarinia*.

Qu. 3.5c. How likely is the organism to survive, reproduce, or increase during transport and storage along the pathway (excluding management practices that would kill the organism)?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Queens are very strong insects that can survive harsh conditions. Transports of containers within the risk assessment areas are usually very short. In winter, queens do not feed much and can stay hidden a long time. They do not reproduce during that period (Matsuura and Sakagami 1973).

Qu. 3.6c. How likely is the organism to survive existing management practices during spread?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

This will depend on the management practices used in the containers' transport conditions but none will target Vespidae and it is unlikely that management practices will affect the transported queen within the risk assessment area.

Qu. 3.7c. How likely is the organism to spread in the risk assessment area undetected?

RESPONSE	very unlikely unlikely moderately likely likely	CONFIDENCE	low medium high
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	very likely		
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Response:

Queens are very big (4-5 cm) and are quite obvious when the container is inspected. However, in large containers queens in winter are usually hidden in the transported goods and are easily missed when transported.

Qu. 3.8c. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host during spread?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Queens are good fliers and can build nests in various habitats, from forests to urban green areas (Matsuura and Sakagami 1973; Archer 1995). Thus, from the arrival destination of the container, they would have no difficulty in reaching suitable habitats for nesting or finding overwintering sites, depending in the season.

Qu. 3.9c. Estimate the overall potential rate of spread based on this pathway in relation to the environmental conditions in the risk assessment area. (please provide quantitative data where possible).

RESPONSE	very slowly slowly moderately rapidly very rapidly	CONFIDENCE	low medium high
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Response:

The spread of queens in winter in any kind of container is likely and may be fast, considering the amount of opportunities to be transported that way. However, it must be noted that, almost two decades after the invasion of *V. velutina* in Europe, and after having invaded ten countries, very little is known about the part of human-mediated dispersal in the fast spread of the hornet and on the underlying mechanisms (Robinet et al. 2017; 2019).

D. Transport - stowaway (vehicles)

Qu. 3.3d. Is spread along this pathway intentional (e.g. the organism is deliberately transported from one place to another) or unintentional (e.g. the organism is a contaminant of translocated goods within the risk assessment area)?

RESPONSE	intentional	CONFIDENCE	low
	unintentional		medium
			high

Response:

Mated queens can travel hidden in many types of vehicles, e.g. trucks, trains, cars, etc., before or after having built an overwintering site.

Qu. 3.4d. How likely is it that a number of individuals sufficient to originate a viable population will spread along this pathway from the point(s) of origin over the course of one year?

including the following elements:

- an indication of the propagule pressure (e.g. estimated volume or number of specimens, or frequency of passage through pathway), including the likelihood of reinvasion after eradication
- if appropriate, indicate the rate of spread along this pathway
- if appropriate, include an explanation of the relevance of the number of individuals for spread with regard to the biology of species (e.g. some species may not necessarily rely on large numbers of individuals).

RESPONSE	very unlikely	CONFIDENCE	low
	unlikely		medium
	moderately likely		high
	likely		
	very likely		

Response:

Only one mated queen is needed to form a colony in a newly invaded region, as observed in the arrival and spread of *V. velutina* in Europe (Arca et al. 2015; Robinet et al. 2017; 2019), and it is assumed that this could occur also for *V. mandarinia*.

Qu. 3.5d. How likely is the organism to survive, reproduce, or increase during transport and storage along the pathway (excluding management practices that would kill the organism)?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Queens are very strong and long-lived insects. Journeys in vehicles within the risk assessment areas can be very short and queens would surely survive such short journeys. Mated females will start building nests only in spring (Matsuura and Sakagami 1973; Archer 1995).

Qu. 3.6d. How likely is the organism to survive existing management practices during spread?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

This will depend on the management practices used in the vehicles (usually very little in the EU) but none will target Vespidae and it is unlikely that management practices will affect the transported queen.

Qu. 3.7d. How likely is the organism to spread in the risk assessment area undetected?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Queens are very big (4-5 cm) and are quite obvious when they simply hitchhike in a vehicle. However, in winter queens are usually not moving as actively as workers and, thus, a hidden queen can be transported undetected in large vehicles (trucks, trains), but less so in cars.

Qu. 3.8d. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host during spread?

RESPONSE	very unlikely unlikely moderately likely likely very likely	CONFIDENCE	low medium high
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Response:

Queens are good fliers and can build nests in various habitats, from forests to urban green areas (Matsuura and Sakagami 1973; Archer 1995). Thus, from the arrival destination of the vehicle (or during transport), they would have no difficulty in reaching suitable habitats for nesting or finding overwintering sites, depending in the season.

Qu. 3.9d. Estimate the overall potential rate of spread based on this pathway in relation to the environmental conditions in the risk assessment area. (please provide quantitative data where possible).

RESPONSE	very slowly slowly moderately rapidly very rapidly	CONFIDENCE	low medium high
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Response:

The spread of *V. mandarinia* queens in winter in any kind of vehicle is possible and may be fast. However, it must be noted that, almost two decades after the invasion of *V. velutina* in Europe, and after having invaded ten countries, very little is known about the part of human-mediated dispersal in the fast spread of the hornet and on the underlying mechanisms (Robinet et al. 2017; 2019).

End of pathway assessment, repeat Qu. 3.3 to 3.9. as necessary using separate identifiers.

Qu. 3.10. Within the risk assessment area, how difficult would it be to contain the organism in relation to these pathways of spread?

RESPONSE	very easy easy	CONFIDENCE	low medium
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	with some difficulty difficult very difficult		high
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Response:

Despite numerous efforts, all countries have failed to contain the spread of *V. velutina* in Europe, with the potential exception of UK and Mallorca where the species may have been eradicated (Monceau et al. 2014; Robinet et al. 2019; Jones et al. 2020; Leza et al. 2021), so it is doubtful that they would be more successful with *V. mandarinia*. Eradication may be easier than containment. Eradication successes against invasive alien Vespidae have been reported elsewhere in the world, e.g. against *Vespula germanica* in Western Australia (Tennant et al. 2011), suggesting that eradication would be possible if carried out at a very early stage of the invasion. However, once there is an established and spreading population it will be very difficult to contain its spread.

Qu. 3.11. Estimate the overall potential rate of spread in relevant biogeographical regions under current conditions for this organism in the risk assessment area (indicate any key issues and provide quantitative data where possible).

Thorough assessment of the risk of spread in relevant biogeographical regions in current conditions, providing insight in the risk of spread into (new areas in) the risk assessment area.

RESPONSE	very slowly slowly moderately rapidly very rapidly	CONFIDENCE	low medium high
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Response:

Considering the strong flying capacities of the queens, their ability to travel as soil contaminant or as stowaway in various types of containers, and based on the fast spread of *V. velutina* in Europe, which invaded 10 countries in 16 years, it is highly likely that *V. mandarinia* would spread very rapidly in the risk assessment area, in particular in the most favourable biogeographical regions such as continental and atlantic regions.

Qu. 3.12. Estimate the overall potential rate of spread in relevant biogeographical regions in foreseeable climate change conditions (provide quantitative data where possible).

Thorough assessment of the risk of spread in relevant biogeographical regions in foreseeable climate change conditions: explaining how foreseeable climate change conditions will influence this risk, specifically if rates of spread are likely slowed down or accelerated.

RESPONSE	very slowly slowly	CONFIDENCE	low medium
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	moderately rapidly very rapidly		high
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Response:

The general risk of spread in the risk assessment area should not be influenced by changing climatic conditions, but spread may become more or less likely depending on whether regions become more or less suitable for the organism (see section on likelihood of establishment). It may also become more rapid spread better survival, faster growth.

4 MAGNITUDE OF IMPACT

Important instructions:

- Questions 4.1-4.5 relate to biodiversity and ecosystem impacts, 4.6-4.8 to impacts on ecosystem services, 4.9-4.13 to economic impact, 4.14-4.15 to social and human health impact, and 4.16-4.18 to other impacts. These impacts can be interlinked, for example, a disease may cause impacts on biodiversity and/or ecosystem functioning that leads to impacts on ecosystem services and finally economic impacts. In such cases the assessor should try to note the different impacts where most appropriate, cross-referencing between questions when needed.
- Each set of questions starts with the impact elsewhere in the world, then considers impacts in the risk assessment area (=EU excluding outermost regions) separating known impacts to date (i.e. past and current impacts) from potential future impacts (including foreseeable climate change).
- Only negative impacts are considered in this section (socio-economic benefits are considered in Qu. A.7)

Biodiversity and ecosystem impacts

Qu. 4.1. How important is the impact of the organism on biodiversity at all levels of organisation caused by the organism in its non-native range excluding the risk assessment area?

including the following elements:

- Biodiversity means the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems
- impacted chemical, physical or structural characteristics and functioning of ecosystems

RESPONSE	N/A	CONFIDENCE	
	minimal		low
	minor		medium
	moderate		high
	major		
	massive		

Response:

Vespa mandarinia has never been studied outside its native range. It was only recently observed invading Western North America. Therefore, it is too early to assess impacts in its non-native range.

Qu. 4.2. How important is the current known impact of the organism on biodiversity at all levels of organisation (e.g. decline in native species, changes in native species communities, hybridisation) in the risk assessment area (include any past impact in your response)?

Discuss impacts that are currently occurring or are likely occurring or have occurred in the past in the risk assessment area. Where there is no direct evidence of impact in the risk assessment area (for example no studies have been conducted), evidence from outside of the risk assessment area can be used to infer impacts within the risk assessment area.

RESPONSE	N/A minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

Vespa mandarinia is not present in the risk assessment area.

Qu. 4.3. How important is the potential future impact of the organism on biodiversity at all levels of organisation likely to be in the risk assessment area?

See comment above. The potential future impact shall be assessed only for the risk assessment area.

RESPONSE	minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

Vespa mandarinia can directly affect biodiversity in two ways: as predator of invertebrates or as competitors of other organisms, in particular Vespidae. Based on our knowledge of the insect in its native range, where it is a voracious predator and strong competitor, the impact on biodiversity may be major or massive. However, since it has not yet been invasive anywhere (the new introduction into North America is too recent to gather any information on impact) an assessment on impact on biodiversity can only be made with very low confidence.

Firstly, *Vespa mandarinia* is a polyphagous predator on a whole spectrum of large invertebrates such as caterpillars, spiders, mantids, beetles, etc. (USDA 2020). However, the most spectacular predatory behaviour of *V. mandarinia* is its mass attacks against nests of other social Hymenoptera, such as bees and wasps of the genera *Vespa*, *Vespula* and *Polistes*, during which they attack, kill and occupy nests, sometimes during several days, to feed their own larvae (Matsuura and Sakagami 1973; Matsuura and Yamane 1990). Such behaviour has also been observed against *V. crabro* in Japan (Matsuura 1984).

Secondly, it competes with other vespids for nesting sites and food. Data from its native range suggests that it can outcompete other vespids (Matsuura and Yamane 1990). In spring, queens eat fermenting sap that seeps from tree wounds, which they fiercely defend against other insects,

(Matsuura and Sakagami 1973; Matsuura 1984). Differences in nesting behaviour reduce interspecific competition among Vespidae. In Europe, *V. mandarinia* would not compete with *V. velutina* that usually nests in tree branches. But *Vespula* spp. and *V. crabro* are more generalist and partly nest in soil cavities or tree holes and could therefore be adversely affected by *V. mandarinia*. Competition with other organisms is also likely. For example, the invasion of the European *Vespula vulgaris* in New Zealand resulted in severe competition for food (sap runs, honeydew etc.) and in the decline of several bird and insect species (Beggs et al. 2011). In Japan, *V. mandarinia* also feeds abundantly on tree sap and is known to occupy the highest position in terms of interspecific relationship and to monopolize tree sap and other food sources by chasing off all visitors, not only other *Vespa* species but any other kind of insect, including beetles, butterflies and moths (Matsuura and Yamane 1990)

The potential impact of its likely predation on honey bees also may have an impact on biodiversity because it may affect pollination services (see Q. 4.8).

Qu. 4.4. How important is decline in conservation value with regard to European and national nature conservation legislation caused by the organism currently in the risk assessment area?
including the following elements:

- native species impacted, including red list species, endemic species and species listed in the Birds and Habitats directives
- protected sites impacted, in particular Natura 2000
- habitats impacted, in particular habitats listed in the Habitats Directive, or red list habitats
- the ecological status of water bodies according to the Water Framework Directive and environmental status of the marine environment according to the Marine Strategy Framework Directive

RESPONSE	N/A minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

Vespa mandarinia is not present in the risk assessment area.

Qu. 4.5. How important is decline in conservation value with regard to European and national nature conservation legislation caused by the organism likely to be in the future in the risk assessment area?
including the following elements:

- native species impacted, including red list species and species listed in the Birds and Habitats directives
- protected sites impacted, in particular Natura 2000
- habitats impacted, in particular habitats listed in the Habitats Directive, or red list habitats

- the ecological status of water bodies according to the Water Framework Directive and environmental status of the marine environment according to the Marine Strategy Framework Directive

RESPONSE	minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

At present, it is very difficult to assess which native species would be most affected by *V. mandarinia* and, thus, whether a decline in conservation value will occur. However, it can be assumed that one of the most likely affected species may be *V. crabro* (see Qu. 4.3), which is a red list species in some countries and regions (e.g. in Germany, and in Austria, States of Steiermark and Oberösterreich). More generally, *V. mandarinia* is known to prey on large insects such as scarab and longhorn beetles (Matsuura 1988), mantids (Matsuura 1984), and large caterpillars (Matsuura and Sakagami 1973) and it is likely that, if introduced into Europe, they will prey on red list and protected insects, including species listed in the Habitats directive.

It is not yet possible to assess whether protected sites and habitats will be particularly invaded by the hornet, but it is highly likely that many of them will be invaded, in particular those in the Atlantic and Continental biogeographic regions containing forest areas.

Ecosystem Services impacts

Qu. 4.6. How important is the impact of the organism on provisioning, regulating, and cultural services in its non-native range excluding the risk assessment area?

- For a list of services use the CICES classification V5.1 provided in Annex V.
- Impacts on ecosystem services build on the observed impacts on biodiversity (habitat, species, genetic, functional) but focus exclusively on reflecting these changes in relation to their links with socio-economic well-being.
- Quantitative data should be provided whenever available and references duly reported.
- In absence of specific studies or other direct evidences this should be clearly stated by using the standard answer “No information has been found on the issue”. This is necessary to avoid confusion between “no information found” and “no impact found”.

RESPONSE	N/A minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

Vespa mandarinia has never been studied outside its native range. It was only recently observed invading Western North America.

Qu. 4.7. How important is the impact of the organism on provisioning, regulating, and cultural services currently in the different biogeographic regions or marine sub-regions where the species has established in the risk assessment area (include any past impact in your response)?

- See guidance to Qu. 4.6.

RESPONSE	N/A minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

Vespa mandarinia is not present in the risk assessment area.

Qu. 4.8. How important is the impact of the organism on provisioning, regulating, and cultural services likely to be in the different biogeographic regions or marine sub-regions where the species can establish in the risk assessment area in the future?

- See guidance to Qu. 4.6.

RESPONSE	minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

Vespa mandarinia may affect provisioning and regulating ecosystem services mainly through its potential impact on honeybees and wild pollinators, i.e. on pollination services. Impacts on provisioning services include effects on biomass of cultivated and wild plants and reared animals; impacts on regulating services include effects on life cycle maintenance. The effect on honeybees in Europe may be particularly important. In Asia, it is considered as a major predator of honey bees (see Qu. 4.9). Its impact is much higher than that of *V. velutina*, which is threatening apiculture in Western Europe (Monceau et al. 2014). *Vespa mandarinia*, being an additional threat to the European apiculture and pollinators, may have the following consequences. European beekeeping and honey

production are already threatened by various factors, such as parasites, viruses, insecticides, climate change, habitat fragmentation, small hive beetle (*Aethina tumida*) and *Vespa velutina*. The additional threat of *V. mandarinia* may lead to the abandonment of beekeeping activity, which would affect the European honey production. In addition, many crops rely mainly on honey bees and other bees (which may also be affected) for pollination. A further decline of honey bees and wild bees may have serious effects on yields. Fedele et al. (2019) provide a method to assess the impact on apple, pear and peach production through pollination reduction, but their numbers provided are based on a pollination reduction of 65% which is probably exaggerated. In fact, there is presently no reliable quantification on the effect of *V. velutina* on honeybee populations and, as a result, on pollination of cultivated and also of wild plants. In a recent study in Spain, it was observed that *V. velutina* affects pollination of a wild native plant, *Mentha suaveolens*, through changes in abundance and behaviour of floral visitors, including honeybees, bumblebees, small hymenopterans and syrphids (Rojas-Nossa and Calviño-Cancela 2020).

Economic impacts

Qu. 4.9. How great is the overall economic cost caused by the organism within its current area of distribution (excluding the risk assessment area), including both costs of / loss due to damage and the cost of current management.

- Where economic costs of / loss due to the organism have been quantified for a species anywhere in the world these should be reported here. The assessment of the potential costs of / loss due to damage shall describe those costs quantitatively and/or qualitatively depending on what information is available. Cost of / loss due to damage within different economic sectors can be a direct or indirect consequence of the earlier-noted impacts on ecosystem services. In such case, please provide an indication of the interlinkage. As far as possible, it would be useful to separate costs of / loss due to the organism from costs of current management.

RESPONSE	minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

To our knowledge, there is no quantitative data on economic costs related to *V. mandarinia* in its area or origin. But there are at least two categories of damage that lead to economic costs.

Firstly, according to Matsuura and Yamane (1990), *Vespa mandarinia* is considered as “the most serious enemy of both cultivated and wild honeybees in Japan”. In Asia, it is considered to have a much higher impact on honey bees than *V. velutina*, which is threatening apiculture in Western Europe. As for *V. velutina* and other hornets, workers can attack and kill bees singly at the entrance to hives. However, the most damaging attack strategy, called the “slaughter strategy”, consists in attacking a hive in groups of a few dozen workers. An entire bee hive of 30’000 bees can be destroyed in a few hours. The hornets first kill the guard bees to enter the hive, then kill the other bees to finally retrieve the bee larvae and pupa to bring them to their own larvae. This process can take several days

during which the attacked hive will be occupied by the hornets. This strategy has been described in details by Matsuura and Sakagami (1973). In Japan, many beekeepers transfer hives in summer from mountains to plains to avoid the attacks of *V. mandarinia* (Matsuura and Sakagami, 1973). It must be noted that *V. mandarinia* is particularly damaging for the European honey bee *Apis mellifera* while the Asian species *Apis cerana* has developed defense mechanisms such as passive retreat and rapid mass attacks to heat up and kill the hornets (Matsuura and Sakagami 1973).

Economic costs are also related to *V. mandarinia* being a human nuisance. In particular, its impact on human health through its painful stings may trigger serious costs (see Qu 4.14). Furthermore, the economics of recreational activities and tourism in places where the hornets could be prevalent.

Qu. 4.10. How great is the economic cost of / loss due to damage (excluding costs of management) of the organism currently in the risk assessment area (include any past costs in your response)?

- Where economic costs of / loss due to the organism have been quantified for a species anywhere in the EU these should be reported here. Assessment of the potential costs of damage on human health, safety, and the economy, including the cost of non-action. A full economic assessment at EU scale might not be possible, but qualitative data or different case studies from across the EU (or third countries if relevant) may provide useful information to inform decision making. In absence of specific studies or other direct evidences this should be clearly stated by using the standard answer “No information has been found on the issue”. This is necessary to avoid confusion between “no information found” and “no impact found”. Cost of / loss due to damage within different economic sectors can be a direct or indirect consequence of the earlier-noted impacts on ecosystem services. In such case, please provide an indication of the interlinkage.

RESPONSE	N/A	CONFIDENCE	low
	minimal		medium
	minor		high
	moderate		
	major		
	massive		

Response:
Vespa mandarinia is not present in the risk assessment area.

Qu. 4.11. How great is the economic cost of / loss due to damage (excluding costs of management) of the organism likely to be in the future in the risk assessment area?

- See guidance to Qu. 4.10.

RESPONSE	minimal	CONFIDENCE	low
	minor		medium
	moderate		high
	major		

	massive		
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Response:

Given that *Vespa mandarinia* is a serious pest in its native range through its impact on honey bees and human health, there is no reason to think that impacts would be lower in climatically suitable areas in Europe. *Vespa velutina* became a more serious predator of honey bees in Europe than in East Asia, where *V. mandarinia* is considered as much more problematic for honey bees and human health than *V. velutina*. In addition, *V. mandarinia* is particularly damaging for the European honey bee *Apis mellifera* while the Asian species *Apis cerana* has developed defence mechanisms such as passive retreat and rapid mass attacks to heat up and kill the hornets (Matsuura and Sakagami 1973). European beekeeping and honey production are already threatened by a series of various factors, such as parasites, viruses, insecticides, climate change, habitat fragmentation, small hive beetle and *Vespa velutina*. The additional threat of *V. mandarinia* may lead to the abandonment of bee hives, which would affect the European production of honey. In France alone, the annual revenue from apiculture was €135M in 2015 (Barbet-Massin et al. 2020). Even a small reduction in honey production by *V. mandarinia* may lead to substantial losses for the sector in Europe. In addition, many crops rely mainly on honey bees and other bees (which may also be affected) for pollination. A further decline of honey bees and wild bees may have serious effects on crop yields, as estimated for *V. velutina* (Fedele et al. 2019). It is estimated that the yearly pollination services to agriculture are worth €2 billion in France alone (Gallai et al. 2009), so, even a very small effect of *V. mandarinia* on pollination services would lead to severe losses.

Qu. 4.12. How great are the economic costs / losses associated with managing this organism currently in the risk assessment area (include any past costs in your response)?

- In absence of specific studies or other direct evidences this should be clearly stated by using the standard answer “No information has been found on the issue”. This is necessary to avoid confusion between “no information found” and “no impact found”.

RESPONSE	N/A	CONFIDENCE	low medium high
	minimal minor moderate major massive		

Response:

Vespa mandarinia is not present in the risk assessment area.

Qu. 4.13. How great are the economic costs / losses associated with managing this organism likely to be in the future in the risk assessment area?

- See guidance to Qu. 4.12.

RESPONSE	minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

Management costs will depend on the magnitude of impact in the risk assessment area, which cannot be assessed precisely for the moment, since the organism is not yet in the risk assessment area and is just starting to invade another region for the first time. To assess management costs, it is best to use the invasion of *V. velutina* in Europe as comparison. Management costs related to *V. velutina* have never been assessed globally. They mainly consist of (1) surveillance programmes and information campaigns in the recently invaded areas, (2) locating and destroying nests, (3) trapping campaigns to capture queens in spring (these are not always considered effective but widely practiced), (4) various management strategies to protect hives; and (5) funding research programmes. So far, only the cost of nest removal has been precisely quantified. Barbet-Massin et al. (2020) estimated that nest destruction cost €23 million between 2006 and 2015 in France. The yearly cost is increasing as the species keeps spreading and could reach €11.9 million in France, €9.0 million in Italy and €8.6 million in the United Kingdom, if the species fills its current climatically suitable distribution. The authors also stated that, “although more work will be needed to estimate the cost of the Asian yellow-legged hornet on apiculture and pollination services, they likely exceed the current costs of control with nest destruction. It could thus be worth increasing control efforts by aiming at destroying a higher percentage of nests”.

The introduction of *V. mandarinia* in Europe would require similar management strategies, keeping in mind that *V. mandarinia* is considered as being more problematic than *V. velutina* in East Asia. The cost of nest removal (100-400 Eur/nest) for *V. velutina* may be different for *V. mandarinia*, which nests in the soil rather than in trees and buildings.

Social and human health impacts

Qu. 4.14. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism for the risk assessment area and for third countries, if relevant (e.g. with similar eco-climatic conditions).

The description of the known impact and the assessment of potential future impact on human health, safety and the economy, shall, if relevant, include information on

- illnesses, allergies or other affections to humans that may derive directly or indirectly from a species;
- damages provoked directly or indirectly by a species with consequences for the safety of people, property or infrastructure;
- direct or indirect disruption of, or other consequences for, an economic or social activity due to the presence of a species.

Social and human health impacts can be a direct or indirect consequence of the earlier-noted impacts on ecosystem services. In such case, please provide an indication of the interlinkage.

RESPONSE	minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

Vespa mandarinia has a powerful sting, which is a hazard to human health. Workers can be aggressive when they feel that their nest is threatened and, since nests are in the ground, they are easily overlooked by walkers. In Japan, fatalities due to *V. mandarinia* stings are estimated to range from 30 to 50 persons each year (Yanagawa et al. 2008). While most victims are allergic and die from anaphylaxis or sudden cardiac arrest, others die from multiple organ failure including rhabdomyolysis, renal failure, liver dysfunction, respiratory failure, and disseminated intravascular coagulopathy. In China, in a three months period in July - October 2013, *V. mandarinia* killed 42 and injured 1,675 people in three cities in the southern part of Shaanxi Province (Liu et al. 2016).

Qu. 4.15. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism in the future for the risk assessment area.

- In absence of specific studies or other direct evidences this should be clearly stated by using the standard answer “No information has been found on the issue”. This is necessary to avoid confusion between “no information found” and “no impact found”.

RESPONSE	minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

In some European countries, the invasion of *V. velutina* in Europe led to a significant increase in casualties due to hornet stings (e.g. in Spain, Feás 2021; Vidal 2021) (): *Vespa mandarinia*'s stings are more painful and dangerous, and workers can be more aggressive because the nests are more accessible and easily overlooked. If, as observed for *V. velutina*, *V. mandarinia* becomes more abundant in the invaded range than in its native range, this hornet could become a serious human health issue.

Other impacts

Qu. 4.16. How important is the organism in facilitating other damaging organisms (e.g. diseases) as food source, a host, a symbiont or a vector etc.?

RESPONSE	N/A minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

No information found.

Qu. 4.17. How important might other impacts not already covered by previous questions be resulting from introduction of the organism?

RESPONSE	N/A minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

No information found.

Qu. 4.18. How important are the expected impacts of the organism despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present in the risk assessment area?

RESPONSE	minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

Although *Vespa* spp. have a whole range of natural enemies, such as parasitic insects and nematodes and birds, most of them are not species-specific (Matsuura and Yamane, 1990). Natural enemies of the European hornet have not been able to prevent the invasion of *Vespa velutina* in Europe (Monceau et al. 2014; Turchi and Derijard 2018). Colonies of the latter do not seem to be controlled by natural enemies in Europe. Predation on single queens and workers has been poorly studied and may be more important. It is not clear how the impact of *V. velutina* would be without natural enemies.

Qu. 4.19. Estimate the overall impact in the risk assessment area under current climate conditions. In addition, details of overall impact in relevant biogeographical regions should be provided.

Thorough assessment of the overall impact on biodiversity and ecosystem services, with impacts on economy as well as social and human health as aggravating factors, in current conditions.

RESPONSE	minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

If introduced into the risk assessment area, *V. mandarinia* is likely to cause severe impacts on the economy, the environment and human health, mainly through its aggressive predatory behaviour towards honey bees and other insects and its harmful stings to humans. The severity of these impacts remains difficult to assess. However, in Asia, *V. mandarinia* is considered, in all aspects, more harmful than *V. velutina*, which is already regarded a serious invasive alien species. Impacts are likely to be higher in regions that are most favourable for *V. mandarinia*, in particular the Continental and Atlantic regions and part of the Mediterranean region (see section 2 on likelihood of establishment).

Qu. 4.20. Estimate the overall impact in the risk assessment area in foreseeable climate change conditions. In addition, details of overall impact in relevant biogeographical regions should be provided.

Thorough assessment of the overall impact on biodiversity and ecosystem services, with impacts on economy as well as social and human health as aggravating factors, under future conditions.

RESPONSE	minimal minor moderate major massive	CONFIDENCE	low medium high
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Response:

Climate change is likely to modify the geographical distribution of impact magnitude (i.e. increase in the north, decrease in the south and east), but not the average magnitude of impact for the risk assessment area in general.

RISK SUMMARIES			
	RESPONSE	CONFIDENCE	COMMENT
Summarise Introduction and Entry*	very unlikely unlikely moderately likely likely very likely	low medium high	Data on pathways of invasion of <i>Vespa</i> spp. are rare. However, considering the high numbers of introductions of invasive Vespidae worldwide in recent years, it is likely that non-intentional transports of wasps and hornets are rather common. The transport of mated <i>Vespa mandarinia</i> queens from autumn to spring is the most likely mean of long-distance dispersal. Single queens may unintentionally be transported as contaminants of soil or straws in which they overwinter, or as stowaways in any kind of good, container or vehicle. Climate change should not affect the likelihood of introduction.
Summarise Establishment*	very unlikely unlikely moderately likely likely very likely	low medium high	If queens are introduced, establishment can be considered very likely in a large part of the risk assessment area, considering the climatic suitability, the availability of suitable habitats, the ability of single mated queens to colonize new areas, the high fecundity and the high competitiveness of the species. Climate models suggest that the establishment would be particularly likely in the Continental and Atlantic regions, and parts of the Mediterranean region. The general likelihood of establishment in Europe will not change under climate change scenarios, even though some regions may become less and others more favourable.

Summarise Spread*	very slowly slowly moderately rapidly very rapidly	low medium high	Considering the strong flying capacities of the queens, their ability to travel as soil contaminants or as stowaways in various types of containers, and based on the fast spread of <i>V. velutina</i> in Europe, it is highly likely that <i>V. mandarinia</i> would spread rapidly in the risk assessment area. The general risk of spread in the risk assessment area will not be influenced by changing climatic conditions, but spread may become more or less easy depending on whether regions become more or less suitable for the organism.
Summarise Impact*	minimal minor moderate major massive	low medium high	If introduced into the risk assessment area, <i>V. mandarinia</i> is likely to cause severe impacts on the economy, the environment and human health, mainly through its aggressive predatory behaviour towards honey bees and other insects and its harmful stings to humans. The severity of these impacts remains difficult to assess. However, in Asia, <i>V. mandarinia</i> is considered, in all aspects, more harmful than <i>V. velutina</i> , which is already regarded a serious invasive species. Climate change is likely to modify the geographical distribution of impact magnitude but not the average magnitude of impact for the risk assessment area.
Conclusion of the risk assessment (overall risk)	low moderate high	low medium high	The likelihood of introduction of <i>V. mandarinia</i> can only be assessed with low confidence because of a lack of quantitative data on interceptions and pathways of entry. In contrast, establishment is highly likely in a

			large part of the risk assessment area and, if the organism becomes established, there is little doubt that it will spread fast and cause significant environmental, economic and social impacts.
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*in current climate conditions and in foreseeable future climate conditions

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Distribution Summary

Please answer as follows:

- Yes if recorded, established or invasive
- if not recorded, established or invasive
- ? Unknown; data deficient

The columns refer to the answers to Questions A5 to A12 under Section A.

For data on marine species at the Member State level, delete Member States that have no marine borders.

In all other cases, provide answers for all columns.

Member States and the United Kingdom

	Recorded	Established (currently)	Possible establishment (under current climate)	Possible establishment (under foreseeable climate)	Invasive (currently)
Austria	-	-	Yes	Yes	-
Belgium	-	-	Yes	Yes	-
Bulgaria	-	-	Yes	?	-
Croatia	-	-	Yes	Yes	-
Cyprus	-	-	?	?	-
Czech Republic	-	-	Yes	Yes	-
Denmark	-	-	Yes	Yes	-
Estonia	-	-	?	?	-
Finland	-	-	?	?	-
France	-	-	Yes	Yes	-
Germany	-	-	Yes	Yes	-
Greece	-	-	Yes	Yes	-
Hungary	-	-	Yes	?	-
Ireland	-	-	Yes	Yes	-
Italy	-	-	Yes	Yes	-
Latvia	-	-	Yes	Yes	-
Lithuania	-	-	Yes	Yes	-
Luxembourg	-	-	Yes	Yes	-
Malta	-	-	Yes	?	-
Netherlands	-	-	Yes	Yes	-
Poland	-	-	Yes	Yes	-
Portugal	-	-	Yes	Yes	-
Romania	-	-	Yes	Yes	-
Slovakia	-	-	Yes	Yes	-
Slovenia	-	-	Yes	Yes	-
Spain	-	-	Yes	Yes	-
Sweden	-	-	Yes	Yes	-
United Kingdom	-	-	Yes	Yes	-

Biogeographical regions of the risk assessment area

	Recorded	Established (currently)	Possible establishment (under current climate)	Possible establishment (under foreseeable climate)	Invasive (currently)
Alpine	-	-	?	Yes	-
Atlantic	-	-	Yes	Yes	-
Black Sea	-	-	Yes	Yes	-
Boreal	-	-	?	Yes	-
Continental	-	-	Yes	Yes	-
Mediterranean	-	-	Yes	?	-
Pannonian	-	-	Yes	Yes	-
Steppic	-	-	?	?	-

Marine regions and subregions of the risk assessment area

	Recorded	Established (currently)	Possible establishment (under current climate)	Possible establishment (under foreseeable climate)	Invasive (currently)
Baltic Sea					
Black Sea					
North-east Atlantic Ocean					
Bay of Biscay and the Iberian Coast					
Celtic Sea					
Greater North Sea					
Mediterranean Sea					
Adriatic Sea					
Aegean-Levantine Sea					
Ionian Sea and the Central Mediterranean Sea					
Western Mediterranean Sea					

ANNEX I Scoring of Likelihoods of Events

(taken from UK Non-native Organism Risk Assessment Scheme User Manual, Version 3.3, 28.02.2005)

Score	Description	Frequency
Very unlikely	This sort of event is theoretically possible, but is never known to have occurred and is not expected to occur	1 in 10,000 years
Unlikely	This sort of event has occurred somewhere at least once in the last millenium	1 in 1,000 years
Moderately likely	This sort of event has occurred somewhere at least once in the last century	1 in 100 years
Likely	This sort of event has happened on several occasions elsewhere, or on at least once in the last decade	1 in 10 years
Very likely	This sort of event happens continually and would be expected to occur	Once a year

ANNEX II Scoring of Magnitude of Impacts

(modified from UK Non-native Organism Risk Assessment Scheme User Manual, Version 3.3, 28.02.2005)

Score	Biodiversity and ecosystem impact	Ecosystem Services impact	Economic impact (Monetary loss and response costs per year)	Social and human health impact, and other impacts
	<i>Question 5.1-5</i>	<i>Question 5.6-8</i>	<i>Question 5.9-13</i>	<i>Question 5.14-18</i>
Minimal	Local, short-term population loss, no significant ecosystem effect	No services affected ⁵	Up to 10,000 Euro	No social disruption. Local, mild, short-term reversible effects to individuals.
Minor	Some ecosystem impact, reversible changes, localised	Local and temporary, reversible effects to one or few services	10,000-100,000 Euro	Significant concern expressed at local level. Mild short-term reversible effects to identifiable groups, localised.
Moderate	Measureable long-term damage to populations and ecosystem, but reversible; little spread, no extinction	Measureable, temporary, local and reversible effects on one or several services	100,000-1,000,000 Euro	Temporary changes to normal activities at local level. Minor irreversible effects and/or larger numbers covered by reversible effects, localised.
Major	Long-term irreversible ecosystem change, spreading beyond local area	Local and irreversible or widespread and reversible effects on one / several services	1,000,000-10,000,000 Euro	Some permanent change of activity locally, concern expressed over wider area. Significant irreversible effects locally or reversible effects over large area.
Massive	Widespread, long-term population loss or extinction, affecting several species with serious ecosystem effects	Widespread and irreversible effects on one / several services	Above 10,000,000 Euro	Long-term social change, significant loss of employment, migration from affected area. Widespread, severe, long-term, irreversible health effects.

⁵ Not to be confused with “no impact”.

ANNEX III Scoring of Confidence Levels

(modified from Bacher et al. 2017)

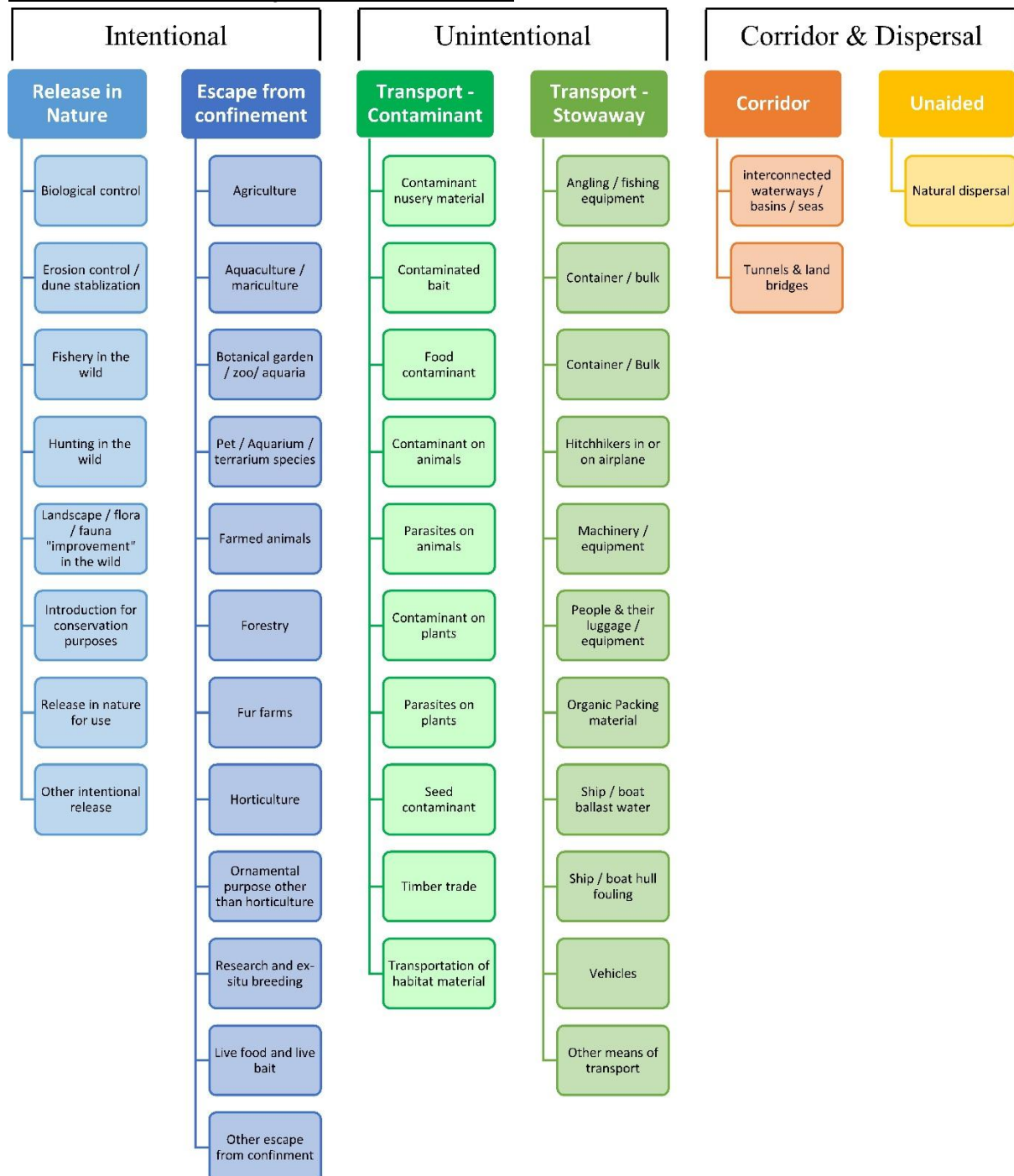
Each answer provided in the risk assessment must include an assessment of the level of confidence attached to that answer, reflecting the possibility that information needed for the answer is not available or is insufficient or available but conflicting.

The responses in the risk assessment should clearly support the choice of the confidence level.

Confidence level	Description
Low	There is no direct observational evidence to support the assessment, e.g. only inferred data have been used as supporting evidence <i>and/or</i> Impacts are recorded at a spatial scale which is unlikely to be relevant to the assessment area <i>and/or</i> Evidence is poor and difficult to interpret, e.g. because it is strongly ambiguous <i>and/or</i> The information sources are considered to be of low quality or contain information that is unreliable.
Medium	There is some direct observational evidence to support the assessment, but some information is inferred <i>and/or</i> Impacts are recorded at a small spatial scale, but rescaling of the data to relevant scales of the assessment area is considered reliable, or to embrace little uncertainty <i>and/or</i> The interpretation of the data is to some extent ambiguous or contradictory.
High	There is direct relevant observational evidence to support the assessment (including causality) <i>and</i> Impacts are recorded at a comparable scale <i>and/or</i> There are reliable/good quality data sources on impacts of the taxa <i>and</i> The interpretation of data/information is straightforward <i>and/or</i> Data/information are not controversial or contradictory.

ANNEX IV CBD pathway categorisation scheme

Overview of CBD pathway categorisation scheme showing how the 44 pathways relate to the six main pathway categories. All of the pathways can be broadly classified into 1) those that involve intentional transport (blue), 2) those in which the taxa are unintentionally transported (green) and 3) those where taxa moved between regions without direct transportation by humans and/or via artificial corridors (orange and yellow). **Note that the pathways in the category “Escape from confinement” can be considered intentional for the introduction into the risk assessment area and unintentional for the entry into the environment.**



ANNEX V Ecosystem services classification (CICES V5.1, simplified) and examples

For the purposes of this risk assessment, please feel free to use what seems as the most appropriate category / level / combination of impact (Section – Division – Group), reflecting information available.

Section	Division	Group	Examples (i.e. relevant CICES “classes”)
Provisioning	Biomass	Cultivated <i>terrestrial</i> plants	<p>Cultivated terrestrial plants (including fungi, algae) grown for <u>nutritional purposes</u>; <u>Fibres and other materials</u> from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials); Cultivated plants (including fungi, algae) grown as a <u>source of energy</u></p> <p><i>Example: negative impacts of non-native organisms to crops, orchards, timber etc.</i></p>
		Cultivated <i>aquatic</i> plants	<p>Plants cultivated by in- situ aquaculture grown for <u>nutritional purposes</u>; <u>Fibres and other materials</u> from in-situ aquaculture for direct use or processing (excluding genetic materials); Plants cultivated by in- situ aquaculture grown as an <u>energy source</u>.</p> <p><i>Example: negative impacts of non-native organisms to aquatic plants cultivated for nutrition, gardening etc. purposes.</i></p>
		Reared animals	<p>Animals reared for <u>nutritional purposes</u>; <u>Fibres and other materials</u> from reared animals for direct use or processing (excluding genetic materials); Animals reared to provide <u>energy</u> (including mechanical)</p> <p><i>Example: negative impacts of non-native organisms to livestock</i></p>
		Reared <i>aquatic</i> animals	<p>Animals reared by in-situ aquaculture for <u>nutritional purposes</u>; <u>Fibres and other materials</u> from animals grown by in-situ aquaculture for direct use or processing (excluding genetic materials); Animals reared by in-situ aquaculture as an <u>energy source</u></p> <p><i>Example: negative impacts of non-native organisms to fish farming</i></p>
		Wild plants (terrestrial and aquatic)	<p>Wild plants (terrestrial and aquatic, including fungi, algae) used for <u>nutrition</u>; <u>Fibres and other materials</u> from wild plants for direct use or processing (excluding genetic materials); Wild plants (terrestrial and aquatic, including fungi, algae) used as a <u>source of energy</u></p> <p><i>Example: reduction in the availability of wild plants (e.g. wild berries, ornamentals) due to non-native organisms (competition, spread of disease etc.)</i></p>
		Wild animals (terrestrial and aquatic)	<p>Wild animals (terrestrial and aquatic) used for <u>nutritional purposes</u>; <u>Fibres and other materials</u> from wild animals for direct use or processing (excluding genetic materials); Wild animals (terrestrial and aquatic) used as a <u>source of energy</u></p>

			<i>Example: reduction in the availability of wild animals (e.g. fish stocks, game) due to non-native organisms (competition, predations, spread of disease etc.)</i>
	Genetic material from all biota	Genetic material from plants, algae or fungi	<p><u>Seeds, spores and other plant materials</u> collected for maintaining or establishing a population; Higher and lower plants (whole organisms) used to <u>breed new strains or varieties</u>; Individual genes extracted from higher and lower plants for the <u>design and construction of new biological entities</u></p> <p><i>Example: negative impacts of non-native organisms due to interbreeding</i></p>
		Genetic material from animals	<p>Animal material collected for the purposes of maintaining or establishing a population; Wild animals (whole organisms) used to breed new strains or varieties; Individual genes extracted from organisms for the design and construction of new biological entities</p> <p><i>Example: negative impacts of non-native organisms due to interbreeding</i></p>
	Water ⁶	Surface water used for nutrition, materials or energy	<p>Surface water for <u>drinking</u>; Surface water used as a material (<u>non-drinking purposes</u>); Freshwater surface water, coastal and marine water used as an <u>energy source</u></p> <p><i>Example: loss of access to surface water due to spread of non-native organisms</i></p>
		Ground water for used for nutrition, materials or energy	<p>Ground (and subsurface) water for <u>drinking</u>; Ground water (and subsurface) used as a material (<u>non-drinking purposes</u>); Ground water (and subsurface) used as an <u>energy source</u></p> <p><i>Example: reduced availability of ground water due to spread of non-native organisms and associated increase of ground water consumption by vegetation.</i></p>
Regulation & Maintenance	Transformation of biochemical or physical inputs to ecosystems	Mediation of wastes or toxic substances of anthropogenic origin by living processes	<p><u>Bio-remediation</u> by micro-organisms, algae, plants, and animals; <u>Filtration/sequestration/storage/accumulation</u> by micro-organisms, algae, plants, and animals</p> <p><i>Example: changes caused by non-native organisms to ecosystem functioning and ability to filtrate etc. waste or toxics</i></p>
		Mediation of nuisances of anthropogenic origin	<p><u>Smell reduction</u>; <u>noise attenuation</u>; <u>visual screening</u> (e.g. by means of green infrastructure)</p> <p><i>Example: changes caused by non-native organisms to ecosystem structure, leading to reduced ability to mediate nuisances.</i></p>
	Regulation of physical, chemical, biological conditions	Baseline flows and extreme event regulation	<p>Control of <u>erosion</u> rates; Buffering and attenuation of <u>mass movement</u>; <u>Hydrological cycle and water flow regulation</u> (Including flood control, and coastal protection); <u>Wind</u> protection; <u>Fire</u> protection</p>

⁶ Note: in the CICES classification provisioning of water is considered as an abiotic service whereas the rest of ecosystem services listed here are considered biotic.

			<p><i>Example: changes caused by non-native organisms to ecosystem functioning or structure leading to, for example, destabilisation of soil, increased risk or intensity of wild fires etc.</i></p>
		<p>Lifecycle maintenance, habitat and gene pool protection</p>	<p>Pollination (or 'gamete' dispersal in a marine context); <u>Seed dispersal</u>; Maintaining <u>nursery populations and habitats</u> (Including gene pool protection)</p> <p><i>Example: changes caused by non-native organisms to the abundance and/or distribution of wild pollinators; changes to the availability / quality of nursery habitats for fisheries</i></p>
		<p>Pest and disease control</p>	<p>Pest control; Disease control</p> <p><i>Example: changes caused by non-native organisms to the abundance and/or distribution of pests</i></p>
		<p>Soil quality regulation</p>	<p><u>Weathering processes</u> and their effect on soil quality; <u>Decomposition and fixing processes</u> and their effect on soil quality</p> <p><i>Example: changes caused by non-native organisms to vegetation structure and/or soil fauna leading to reduced soil quality</i></p>
		<p>Water conditions</p>	<p>Regulation of the <u>chemical condition</u> of freshwaters by living processes; Regulation of the chemical condition of salt waters by living processes</p> <p><i>Example: changes caused by non-native organisms to buffer strips along water courses that remove nutrients in runoff and/or fish communities that regulate the resilience and resistance of water bodies to eutrophication</i></p>
		<p>Atmospheric composition and conditions</p>	<p>Regulation of <u>chemical composition</u> of atmosphere and oceans; Regulation of <u>temperature and humidity</u>, including ventilation and transpiration</p> <p><i>Example: changes caused by non-native organisms to ecosystems' ability to sequester carbon and/or evaporative cooling (e.g. by urban trees)</i></p>
Cultural	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	<p>Physical and experiential interactions with natural environment</p>	<p>Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through <u>active or immersive interactions</u>; Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through <u>passive or observational interactions</u></p> <p><i>Example: changes caused by non-native organisms to the qualities of ecosystems (structure, species composition etc.) that make it attractive for recreation, wild life watching etc.</i></p>
		<p>Intellectual and representative interactions with natural environment</p>	<p>Characteristics of living systems that enable <u>scientific investigation</u> or the creation of traditional ecological knowledge; Characteristics of living systems that enable <u>education and training</u>; Characteristics of living systems that are resonant in terms of <u>culture or heritage</u>; Characteristics of living systems that enable <u>aesthetic experiences</u></p>

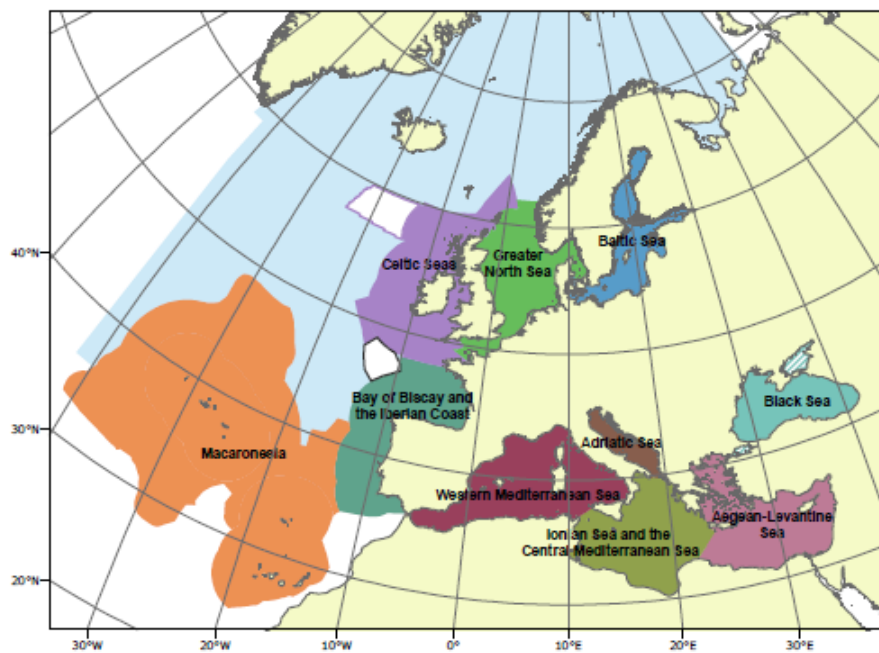
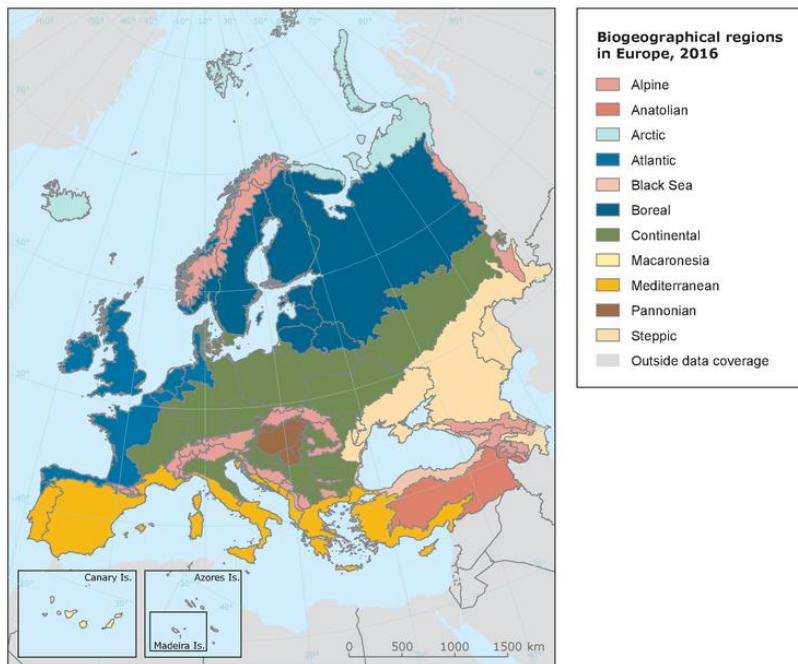
			<i>Example: changes caused by non-native organisms to the qualities of ecosystems (structure, species composition etc.) that have cultural importance</i>
	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	<p>Elements of living systems that have <u>symbolic meaning</u>;</p> <p>Elements of living systems that have <u>sacred or religious meaning</u>;</p> <p>Elements of living systems used for <u>entertainment or representation</u></p> <p><i>Example: changes caused by non-native organisms to the qualities of ecosystems (structure, species composition etc.) that have sacred or religious meaning</i></p>
		Other biotic characteristics that have a non-use value	<p>Characteristics or features of living systems that have an <u>existence value</u>;</p> <p>Characteristics or features of living systems that have an <u>option or bequest value</u></p> <p><i>Example: changes caused by non-native organisms to ecosystems designated as wilderness areas, habitats of endangered species etc.</i></p>

ANNEX VI EU Biogeographic Regions and MSFD Subregions

See <https://www.eea.europa.eu/data-and-maps/figures/biogeographical-regions-in-europe-2> ,
http://ec.europa.eu/environment/nature/natura2000/biogeog_regions/

and

<https://www.eea.europa.eu/data-and-maps/data/msfd-regions-and-subregions-1/technical-document/pdf>



ANNEX VII Delegated Regulation (EU) 2018/968 of 30 April 2018

see <https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32018R0968>

ANNEX VIII Modelling the potential geographic distribution of the Asian giant hornet *Vespa mandarinia* using CLIMEX

M. Lukas Seehausen & Marc Kenis

Methods

About CLIMEX

The bioclimatic models were developed using CLIMEX 4.1 (Kriticos et al. 2016) that integrates the weekly responses of a population to climate using a series of annual indices. The bioclimatic modelling process has been previously described in numerous publications (Vera et al. 2002; Sutherst and Maywald 2005; Poutsma et al. 2008; Olfert et al. 2012), and thus, only a brief description of the CLIMEX program and parameters is provided here. CLIMEX uses an annual Growth Index (GI) to describe the potential for population growth as a function of temperature and soil moisture during favorable conditions, and stress indices (cold, wet, hot, dry) to determine the effect of abiotic stress on survival in unfavorable conditions. The weekly GI is a function of temperature (TI), diapause (DI) and moisture (MI). The growth and stress indices are calculated weekly and then combined into an overall annual index of climatic suitability, the Ecoclimatic Index (EI), which ranges from EI = 0 for locations where the species is not able to persist to EI = 100 for locations that are optimal for the species. However, in temperate climates, the maximum EI value is rather close to 50 and values of >20 are usually considered sufficient to support substantial population densities (Sutherst et al. 2007).

Fitting CLIMEX parameters

Very little is known about the ecoclimatic responses of *V. mandarinia*. Therefore, initial model parameter values were based on the slightly modified values for *V. germanica*, published for the congeneric Asian hornet *Vespa velutina* by Ibáñez-Justicia and Loomans (2011) and Park and Jung (2016). However, because *V. mandarinia* is clearly more cold-tolerant, as especially indicated by its northern distribution in Russia (Siberian Zoological Museum), we further modified the values, especially of the cold stress parameters, until the simulated potential geographical distribution indicated by the Ecoclimatic Index (EI) agreed with the currently known native distribution of *V. mandarinia*.

The CliMond10 climate data set was used as input into the model to predict the native Asian and the potential distribution in Europe and North America (Kriticos et al. 2012). The CliMond data set was developed for species bioclimatic modelling, including both correlative and process-based mechanistic models. The 10' gridded data set includes a hybrid historical data set (based on CRU CL2.0 and WorldClim; centered on 1975). A climate data set with a lower resolution, 30' gridded data, but including more recent data, centered on 1995, was used for modeling the potential distribution and stresses at the global scale. The potential distribution of *V. mandarinia* in 2080 as predicted by the Ecoclimatic Index was modelled using the A1B scenario included in the CLIMEX software.

The CLIMEX parameter values for the present models were calibrated as follows: The limiting low and lower optimal soil moisture were almost the same as for the *V. germanica* models, allowing development above the permanent wilting point. However, upper optimal and limiting high soil moisture were decreased, reflecting the fact that hornet activity is decreased at heavy rainfalls (Rodríguez-Flores et al. 2018). Wet stress starting at 200% (index=2.0) water holding capacity (i.e., significant water run-off) with a relatively steep increase also reflects this fact, while allowing for heavy rain falls that the hornet may experience in southern Asia. Dry stress parameters were kept the same as specified for the *V. germanica* model.

Observations of *V. velutina*'s colonies activity in France indicated that no activity outside the nest takes place at air temperatures <10°C (Perrard et al. 2009). However, to include *V. mandarinia*'s presence in

south-eastern Russia and northern Japan, the limiting low temperature and also the day-degree threshold temperature for the accumulation of cold stress was decreased to 8°C. The lower optimal temperature was kept as for the *V. germanica* model, however, the upper optimal temperature and the limiting high temperature for development were slightly increased (by 2°C), allowing for the hornet's southern distribution limits and reflecting the fact that this species rather nests in concealed places, such as in the ground at a depth of 6-60cm, e.g. in small mammal burrows or decayed root spaces, or in hollow trees (Matsuura & Sakagami 1973; Archer 1995). The limiting high temperature for development is relatively difficult to measure for hornets, because they are known to actively adjust air temperature in nests through behaviors such as ventilation, regurgitation of water, and wing vibration (Perrard et al. 2009). Therefore, values for limiting high temperatures and heat stress were adjusted in an iterative manner until the native distribution was accurately predicted by the model. However, the resulting values are similar to those previously published for *Vespa velutina* (Ibáñez-Justicia and Loomans 2011; Park and Jung 2016).

The cold stress threshold temperature and its rate of increase were estimated based on the information that mated queens overwinter protected in special cavities excavated into moderately moist soil. The entrance of the cavity is plugged and the queen passes the winter hanging from the top of the chamber (Matsuura and Sakagami 1973; Archer 1995). Thus, the hornet can withstand temperatures well below the freezing point and would only be affected by cold stress if the soil under the snow freezes deep enough. However, once the temperature falls below a critical threshold, queens are expected to freeze to death rather quickly. Like for heat stress, the values for the cold stress threshold and its rate were adjusted in an iterative manner until the native distribution was accurately predicted by the model. The resulting cold stress threshold was -30°C with a rate of -0.0007. It has to be understood that this value is a threshold value for air temperature, and does not reflect soil temperatures under the snow.

Degree-days per generation are not used in this model because like other hornets, foundresses of *V. mandarinia* produce offspring continuously over the season without discrete generations.

Results

The resulting parameters (Table 1) lead to an accurately predicted native distribution (Figure A1). The global distribution of the Ecoclimatic Index indicating the potential distribution of *V. mandarinia*, as well as the heat stress, cold stress, and dry stress that are limiting its potential distribution are shown in Figure A2. Figure A3 represents the potential distribution of *V. mandarinia* in Europe and northern Africa as predicted by the Ecoclimatic Index from the CLIMEX model and Figure A4 shows the potential distribution of *V. mandarinia* in the same area in 2080 using the A1B scenario.

Results are discussed in the risk assessment.

Table 1: CLIMEX model parameters used to predict the distribution of *Vespa mandarinia* in non-native areas around the world.

Group	Parameter	Description	Value
Moisture Index	SMO	Limiting low soil moisture	0.15
	SM1	Lower optimal soil moisture	0.6
	SM2	Upper optimal soil moisture	1
	SM3	Limiting high soil moisture	2
Temperature Index	DV0	Limiting low temperature	8°C
	DV1	Lower optimal temperature	18°C
	DV2	Upper optimal temperature	28°C
	DV3	Limiting high temperature	34°C
Cold Stress	TTCS	Cold stress threshold	-30°C
	THCS	Cold stress temperature rate	-0.0007
	DTCS	Cold stress degree-day threshold	8°C
	DHCS	Cold stress degree-day rate	-0.00001
	TTCSA	Average cold stress degree-day threshold	8
	THCSA		0
Heat Stress	TTHS	Heat stress temperature threshold	34°C
	THHS	Heat stress temperature rate	0.003
	DTHS		0
	DHHS		0
Dry Stress	SMDS	Dry stress threshold	0.15
	HDS	Dry stress rate	-0.008
Wet Stress	SMWS	Wet stress threshold	2.0
	HWS	Wet stress rate	0.002
Day-degree accumulation above DV0	DV0	Limiting low temperature	8°C
	DV3	Limiting high temperature	34°C
	MTS	Model time step	7
Day-degree accumulation above DVCS	DVCS	Cold stress DD threshold temperature	8°C
	DV4	Dummy parameter	100
	MTS	Model time step	7
Day-degree accumulation above DVHS	DVHS	Heat stress DD threshold temperature	34°C
	DV4	Dummy parameter	100
	MTS	Model time step	7
Degree-days per generation	PDD		0

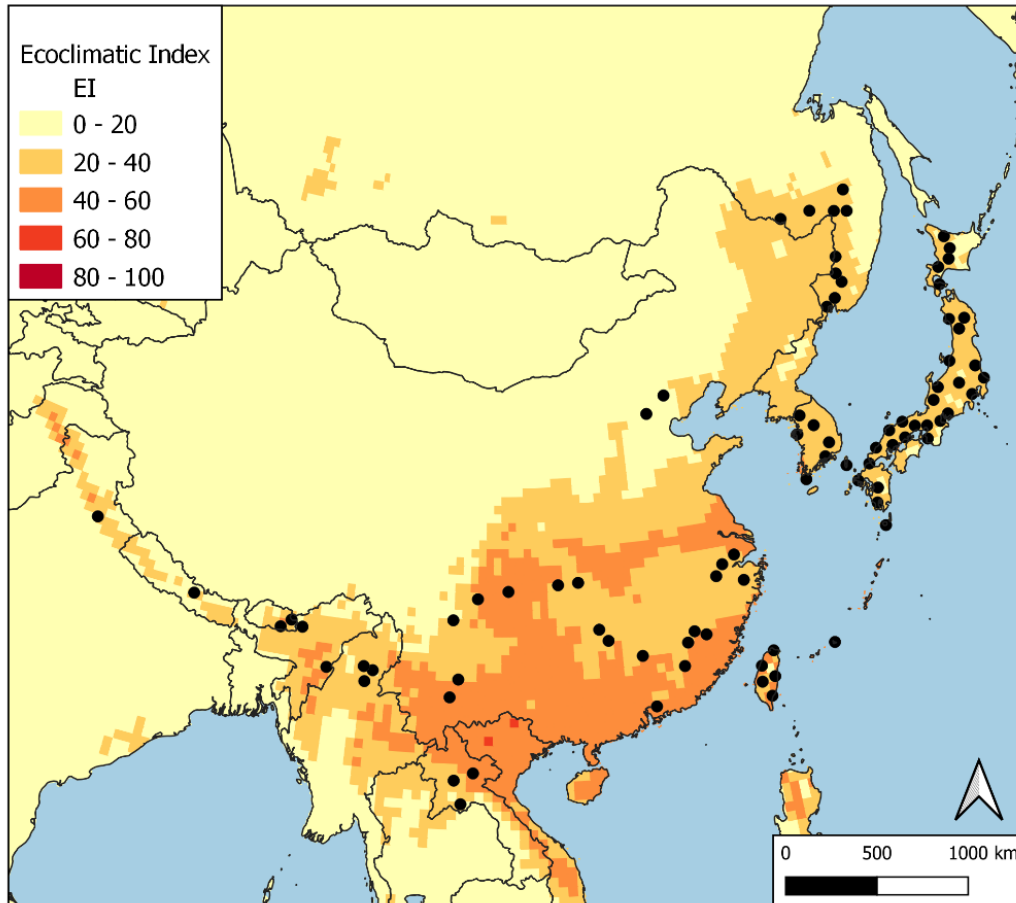


Figure A1: Ecoclimatic Index (EI) from the CLIMEX model for *Vespa mandarinia* in Asia. Black points represent the known native distribution of *V. mandarinia* in Asia from the Global Biodiversity Information Facility (GBIF) and the literature. Locations with $EI > 20$ can be considered as climatically suitable for establishment and growth of *V. mandarinia*

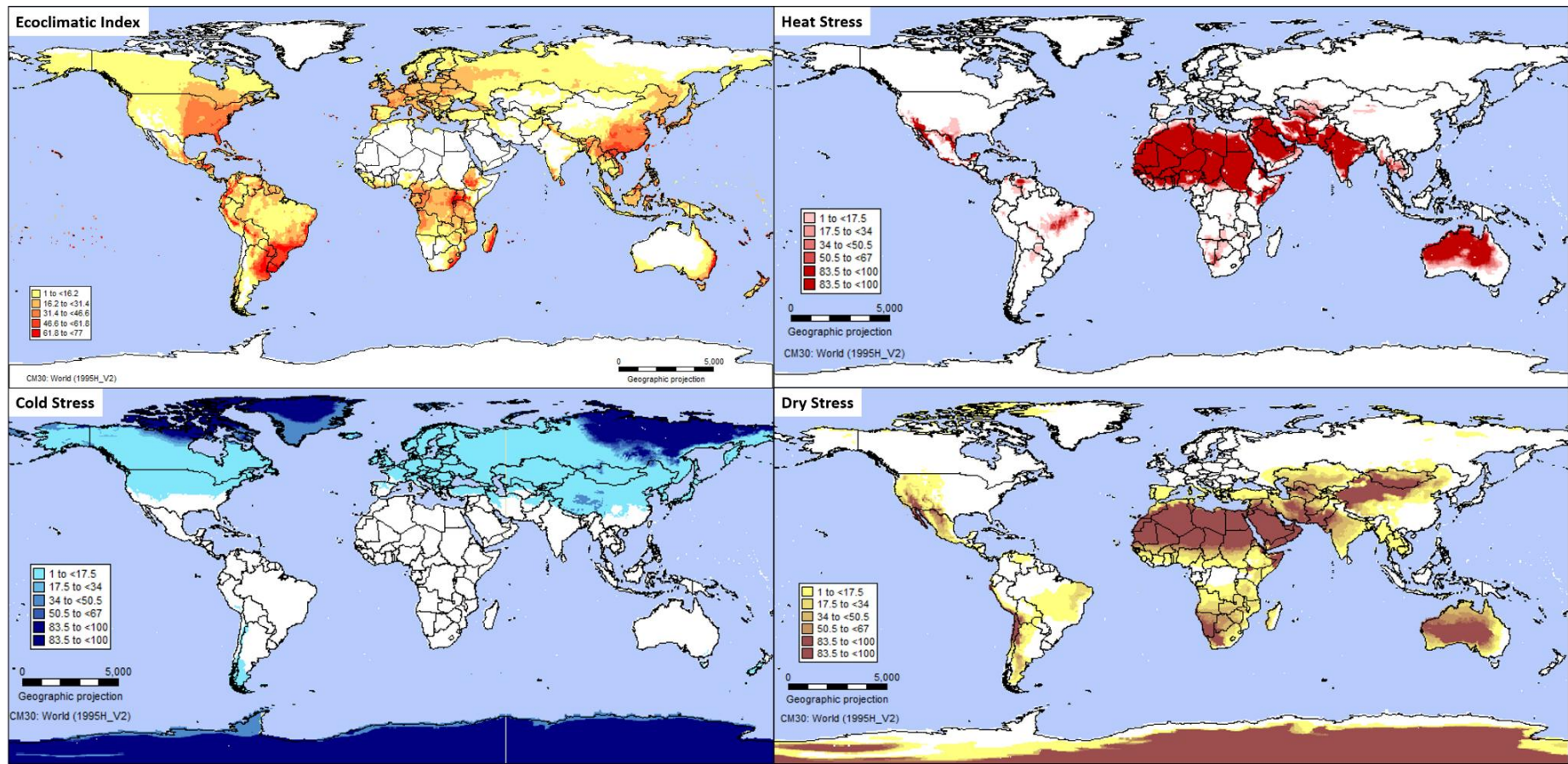


Figure A2: Global distribution of the Ecoclimatic Index (EI), heat stress, cold stress, and dry stress as predicted by the CLIMEX model for *Vespa mandarinia*.

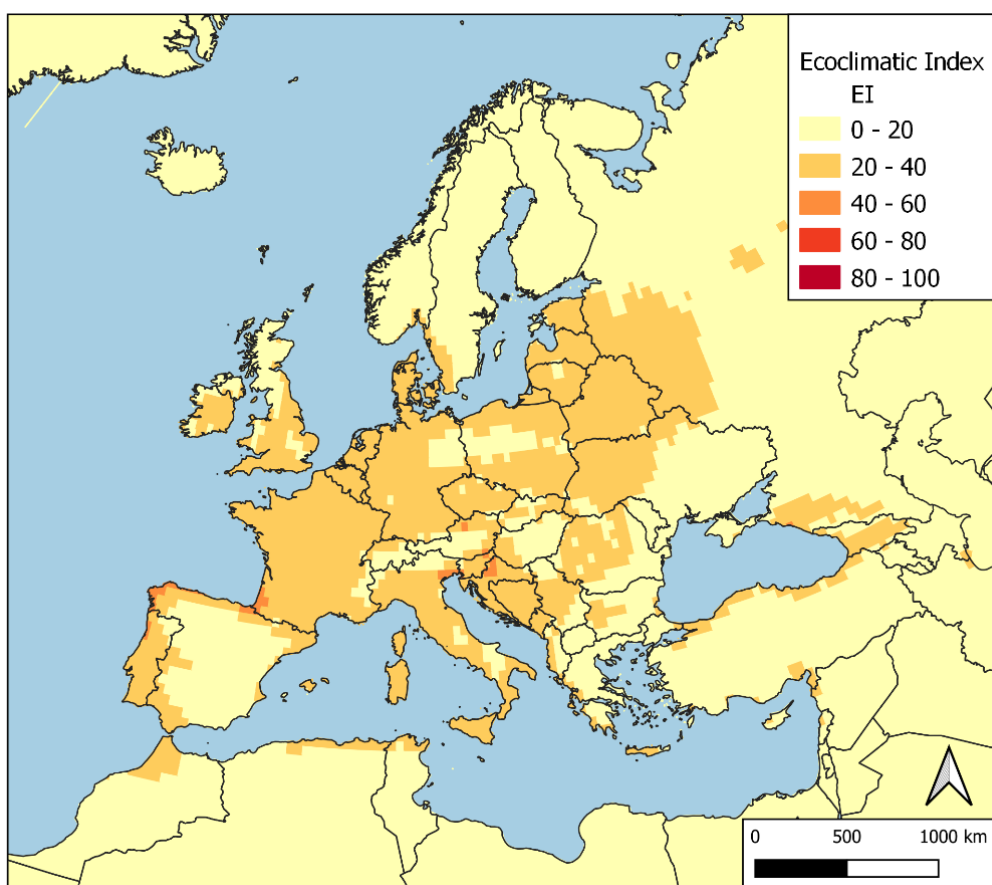


Figure A3: Potential distribution of *V. mandarinia* in Europe and northern Africa as predicted by the Ecoclimatic Index (EI) from the CLIMEX model. Locations with EI>20 can be considered as climatically suitable for establishment and growth of *V. mandarinia*.

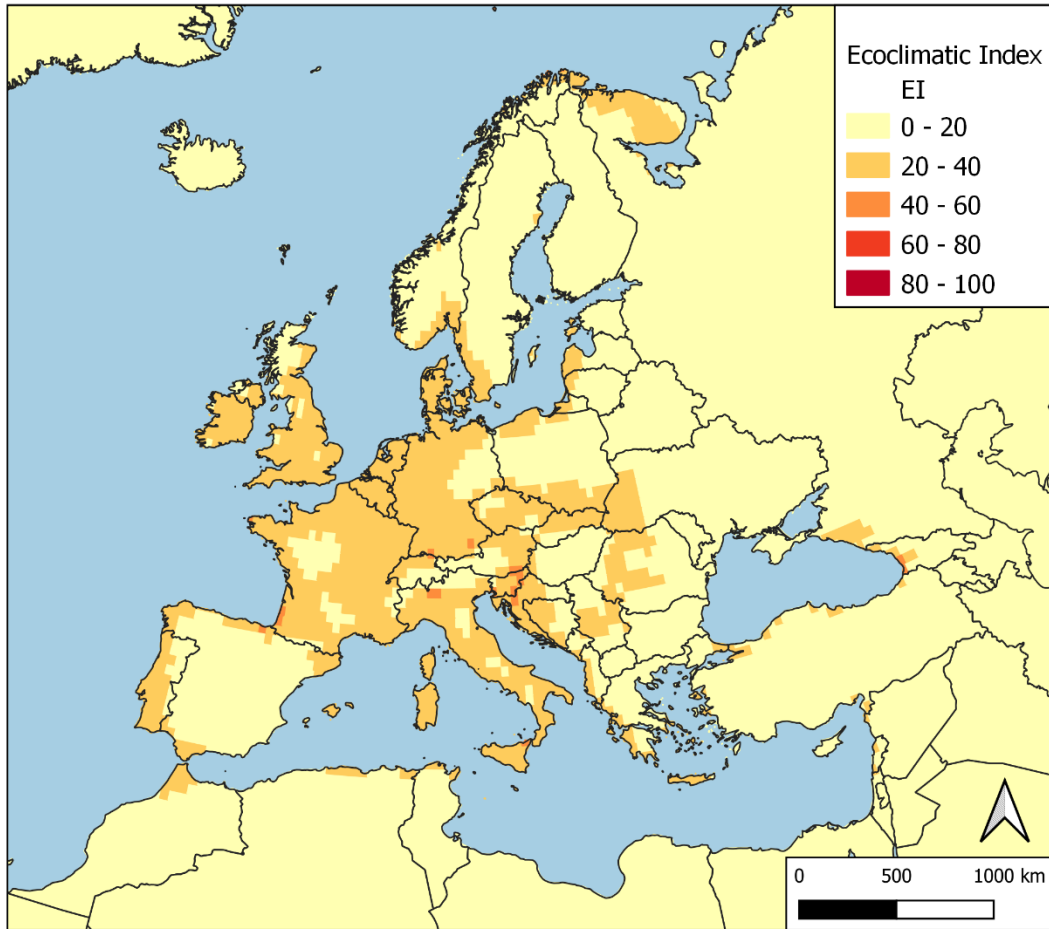


Figure A4: Potential distribution of *V. mandarinia* in Europe and northern Africa in 2080, as predicted by the Ecoclimatic Index (EI) from the CLIMEX model using the A1B scenario. Locations with $EI > 20$ can be considered as climatically suitable for establishment and growth of *V. mandarinia*.

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