

Risk Assessment of *Vespa velutina nigrithorax*

Name of Organism:	<i>Vespa velutina nigrithorax</i> du Buysson, 1905 – Asian hornet
Objective:	Assess the risks associated with this species in Ireland
Version:	V.1
Date:	12/07/2023
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Expert reviewer	

Stage 1 - Organism Information and Screening

Section A - Organism Information

Stage 2 - Detailed Assessment

Section A - Entry

Section B - Establishment

Section C - Spread

Section D - Impact

Section E - Conclusion

Section F - Additional Questions

About the risk assessment

This risk assessment is based on the **Non-native species APplication based Risk Analysis (NAPRA)** tool (version 2.66). NAPRA is a computer based tool for undertaking risk assessment of any non-native species. It was developed by the European and Mediterranean Plant Protection Organisation (EPPO) and adapted for Ireland and Northern Ireland by Invasive Species Ireland. It is based on the Computer Aided Pest Risk Analysis (CAPRA) software package which is a similar tool used by EPPO for risk assessment.

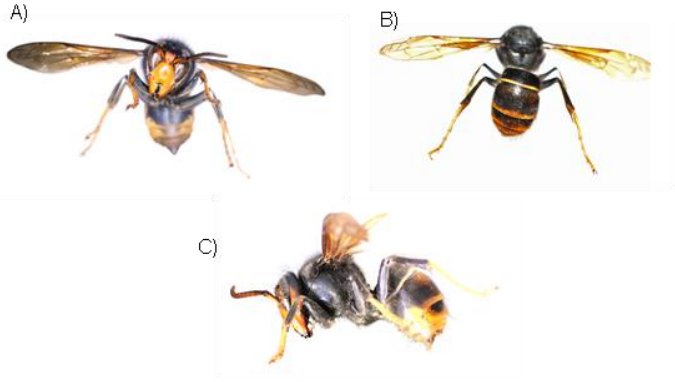
Notes: Confidence is rated as low, medium, high or very high.
Likelihood is rated as very unlikely, unlikely, moderately likely, likely or very likely.
The percentage categories are 0% - 10%, 11% - 33%, 34% - 67%, 68% - 90% or 91% - 100%.
N/A = not applicable.

Stage 1 - Organism Information and Screening: Section A - Organism Information			
<i>The aim of this section is to gather basic information about the organism.</i>			
N	QUESTION	RESPONSE	COMMENT
1	What is the reason for performing the risk assessment?	<i>Vespa velutina</i> is an invasive hornet in Europe and may colonise Ireland, with potentially multiple negative consequences.	A risk assessment is required as this species is listed as an Invasive Species of Union Concern under Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species.
2	Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	<i>Vespa velutina</i> Lepeletier, 1836 <i>Vespa velutina nigrithorax</i> du Buysson, 1905 – Asian hornet	<p>Taxonomy Kingdom: Animalia Phylum: Arthropoda Subphylum: Uniramia Class: Insecta Order: Hymenoptera Family: Vespidae Genus: <i>Vespa</i> Species: <i>velutina</i> Subspecies: <i>nigrithorax</i></p> <p>Common names: Asian black hornet; Asian hornet; yellow-legged hornet.</p> <p><i>Vespa velutina nigrithorax</i> is one of twenty two recognised <i>Vespa</i> species and the first non-native Vespidae species to establish in Europe (Beggs et al. 2011). Different authors recognise a number of subspecies of <i>V. velutina</i> based on geographic colour morphs (Archer, 2012; Perrard 2012), but currently eleven <i>Vespa velutina</i> subspecies are recognised (Laurino et al., 2020). A genetic study of <i>Vespa velutina</i>, including samples from France, Korea, and its native range in Asia showed that the Asian hornet population in France and Korea originated from the provinces of Jiangsu and Zhejiang in eastern China (Arca et al., 2015). A single fertilised queen, likely inseminated by several males, was responsible for the Asian hornet population in France (Arca et al., 2015). This individual, and subsequently the entire European Asian hornet population, belong to the subspecies <i>nigrithorax</i>, native to eastern China (Arca et al. 2015). Recent research at UCC, Ireland, has confirmed that all <i>V. velutina</i> in its invaded range</p>

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			<p>in Europe are descended from a single mated queen arriving into France from China around 2004 (Dillane et al., 2022).</p> <p><i>V. velutina</i> is unlikely to be misidentified as a different hornet as Ireland does not have the European native hornet species, <i>Vespa crabro</i>. However, native wasps and sawflies, such as the giant wood wasp, <i>Urocerus gigas</i>, are more likely to be misidentified due to their size and similar colour patterns (black and yellow banded). It is possible that the European hornet, <i>V. crabro</i>, native to the southern UK and mainland Europe, will be occasionally found in Ireland, through sporadic natural and anthropogenic introductions, and as such could be confused for the Asian hornet. However, the European hornet is a non-native species to Ireland and should therefore be reported and verified by officials, as for <i>V. velutina</i>.</p>
3	If not a single taxonomic entity, can it be redefined? (if necessary use the response box to re-define the organism and carry on)		N/A
4	Describe the organism.		<p><i>Vespa velutina</i> is a medium to large, social vespids that builds large communal nests, primarily located in predator-inaccessible spaces, such as tall trees and buildings. They are versatile and resilient to environmental changes and are highly adaptable. As for other large vespids, <i>V. velutina</i> is strongly predatory on other insects, mainly Hymenoptera. Notably, they are also major predators of the honeybee, <i>Apis mellifera</i>. Overall, they have a generalist diet, and have been reported scavenging waste food, roadkill, and fish (e.g. Perrard et al., 2009; Rome et al., 2021).</p> <p>There is little distinct morphological differences between future queens (gynes) and worker females. Mass is a not a good indicator of caste as hornet's mass varies throughout the season. Workers are smaller than the queen in early summer but by autumn they are the same (Monceau et al. 2014). Size, however, can be used to distinguish between castes in early summer: queens can be up to 3cm in length while workers are slightly smaller at roughly 2-2.5 cm in length. The increase in size later in the summer makes it more difficult to</p>

Stage 1 - Organism Information and Screening: Section A - Organism Information

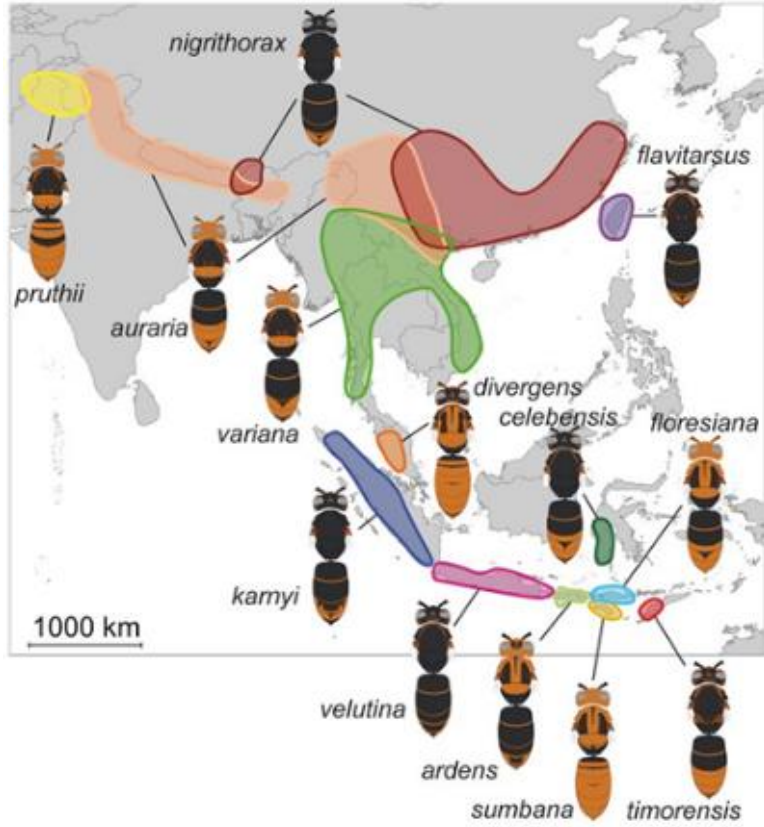
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			<p>distinguish queen from worker. Wing shape has also shown to be useful for distinguishing queens from workers (Monceau et al. 2014).</p> <p><i>Vespa velutina nigrithorax</i> can be identified as follows (Fig. 1): the head is elongated, dark brown/black apart from the mouthparts and face, which are orange. Antennae are brown dorsally and orange ventrally. Sparse hair is found on the body and face and the wings are a translucent brown. The thorax is entirely dark brown/black. The dorsal side of the abdomen is dark brown/black with clear margins marked by a thin yellow/orange band on the first, second and third segment; fourth segment is orange with a small triangular notch at the top. The top (proximal) of the leg is brown, and the tarsus (leg segment furthest from the body) is yellow which helps distinguish it further from other species. The sex differences in <i>V. velutina</i> consist of the absence of a stinger and longer antennae for males (Edwards, 1980).</p>  <p>Figure 1: Identification of <i>Vespa velutina nigrithorax</i>. A) Face and ventral side of abdomen, B) Dorsal side of thorax and abdomen, C) Lateral view. Source: A. O’Hanlon, National Museum of Ireland</p>

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5	Does a relevant earlier risk assessment exist? (give details of any previous risk assessment for Ireland)	Yes Kelly et al 2013	A prioritisation risk assessment undertaken as part of the Risk Analysis and Prioritisation For Invasive and Non-native Species in Ireland and Northern Ireland (Kelly et al. 2013), in which <i>Vespa velutina nigrithorax</i> was designated as a “high risk” invasive species. However, this assessment was used to understand the relative risk associated with a large array of species and did not explore the specific risks and uncertainties surrounding <i>V. velutina nigrithorax</i> or pathways of concern associated with this species.
6	If there is an earlier Risk Assessment is it still entirely valid, or only partly valid?	Partly valid	The prioritisation risk assessment is considered partly valid as the purpose of the assessment was to analyse the risk of large species groups and not individual species. The assessment, carried out in 2012, is now outdated given that <i>Vespa velutina nigrithorax</i> has considerably increased its invaded range in Europe in the last decade. Individuals and nests have been reported in southern England every year since 2017 and a single Asian hornet was reported in Ireland in May 2021. Additionally, European trade routes have changed as a result of the withdrawal of the UK from the EU, introducing more direct trade between Ireland and mainland Europe via Irish ports. This may impact the risk previously associated with the pathways of concern.
7	Where is the organism native?	SE Asia	<i>Vespa velutina</i> is native to Asia, including Afghanistan, Bhutan, China, Northeast India, parts of Indonesia, Japan, Laos, Malaysia, Myanmar, Nepal, Pakistan, South Korea, Taiwan, Thailand and Vietnam (Archer, 1994; Carpenter and Kojima, 1997) (Fig. 2). <i>Vespa velutina nigrithorax</i> is a subspecies of <i>V. velutina</i> with a native range in temperate zones in Southeast Asia (Arca et al., 2015). They are typically found between an altitude of 200m -800 m but can be found in smaller numbers above and below these markers (Leza et al., 2018).

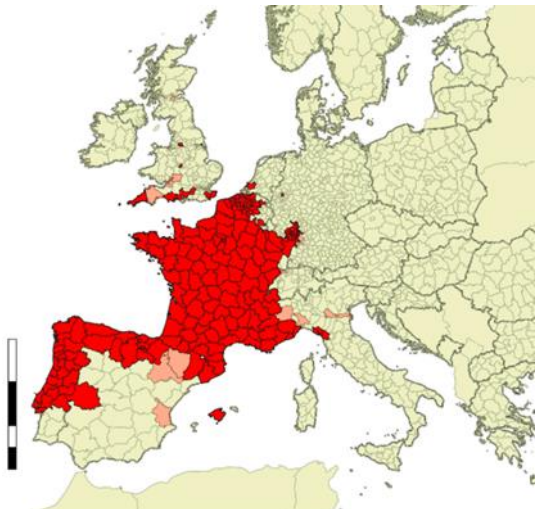
Stage 1 - Organism Information and Screening: Section A - Organism Information

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N	QUESTION	RESPONSE	COMMENT
			 <p>Figure 2: Known distribution of <i>Vespa velutina</i> subspp. In South-East Asia. Source Perrard et al. (2014).</p>


Stage 1 - Organism Information and Screening: Section A - Organism Information

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8	What is the current global distribution of the organism (excluding Ireland)?	<p>Native range and established in South Korea, Japan, France, Spain, Portugal, Channel Islands, Belgium, and Northern Italy; has been recorded in Germany, Netherlands, Switzerland, Balearic Islands, and southern England but not considered to be established in these countries.</p>	<p>In addition to countries within its native range, established populations exist in South Korea, Japan (Tsushima Island and Kyushu Island) (Kim et al., 2006; Minoshima et al., 2015; Kishi and Goka, 2017). In Europe, the organism is now established in France, Spain, Portugal, Channel Islands, Belgium, and Northern Italy (Grosso-Silva and Maia, 2013; Goldarazena et al., 2015; Laurino et al., 2020) (Fig. 3). Nest and individuals have also been recorded in Germany, Netherlands, Switzerland, Balearic Islands, and southern England, but are not considered established populations at this time (Budge et al., 2017; Leza et al., 2018; Herrera et al., 2019; Husemann et al., 2020)</p>  <p>Figure 3: Most recently-published distribution of <i>V. velutina nigrithorax</i> in Europe. Red = established or reported in 2018 and 2019. Light red = previously reported in the area but not after 2017. Source: Laurino et al. (2020).</p>

Stage 1 - Organism Information and Screening: Section A - Organism Information

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9	What is the current distribution of the organism in Ireland?	A single recent record in Co. Dublin.	<p>At present only one record has been verified for this species in Ireland. A single hornet was discovered on the 25th of April 2021 in Dublin 3, Co. Dublin (Figure 4). The hornet was subsequently collected by a government official, and no other individuals or nests were detected.</p>  <p>Figure 4: Map showing the verified record for <i>Vespa velutina nigrithorax</i> - Asian hornet in Ireland per 10km² in Ireland. Source: National Biodiversity Data Centre, 2021, edited 07/01/2022.</p>
10	Is the organism known to be invasive anywhere in the world?	Yes	<p><i>V. velutina</i> is considered highly invasive in Europe, negatively affecting native biodiversity and ecosystem services (e.g., pollination) through predation, competition, and the spread of disease. The Asian hornet (subspecies: <i>nigrithorax</i>) is listed as an invasive species of EU concern under Regulations (EU) 1143/2014. The species was first accidentally introduced to France in 2004</p>

Stage 1 - Organism Information and Screening: Section A - Organism Information

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			<p>and has since expanded its territory to cover a significant area of western Europe (see answer to N. 9) (Laurino et al., 2020).</p> <p><i>V.v.nigrithorax</i> is an apex insect predator, with a broad preference for honeybees but their diet mostly depends on the habitat they inhabit, and the relative local abundance of potential prey species. In France, a single Asian hornet colony can consume up to 11 kg of insect biomass in one season (Rome et al., 2021). The Asian hornet is of particular importance to the honey bee industry. In 2010, Gironde, France reported up to 30% of honeybee colonies were lost due to impacts from the invasive Asian hornet (Monceau and Thiery, 2016). Asian hornets not only predate directly on honeybees, but also induce stress, leading to greater susceptibility to diseases, as well as causing foraging paralysis (the reluctance of honeybees to leave hives in order to forage) and homing failure (Leza et al., 2019; Laurino et al., 2020; Requier et al., 2019; 2020). In Spain, honeybees and other pollinators have been reported to change their foraging behaviour in the presence of hornets, resulting in a reduction to flower visitation time and quantity of pollen being transferred to native plants, such that the negative direct impact on honeybees can have serious indirect impacts on pollination services (Rojas-Nossa and Calvino-Cancela, 2020). Additionally, <i>V. velutina</i> could potentially introduce harmful pathogens and parasites to native Hymenoptera. <i>V. velutina</i> in France and China can act as a vector of an acute paralysis virus that infects <i>Apis mellifera</i> (Blanchard et al., 2008). In South Korea and Japan, <i>V. velutina nigrithorax</i>, can compete with native hornets for resources and nesting sites (Cini et al., 2018; Ikegami et al., 2020) They have also been reported to engage in interspecific mating, which may lead to reproductive interference for native species <i>V. similima</i> (Yamaskai et al., 2019).</p> <p>Although the species is not considered any more dangerous to humans than native hornets or wasps, it can pose a threat to human health and safety (Feas, 2021). An increase sting risk has been reported in urban areas. Galicia (N. Spain) has reported an increase in the number and severity of reactions in people exposed to insect venom, with over 70% suspected to have been stung by an</p>

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			Asian hornet (Feas, 2021). In 2020, three fatalities were reported in Galicia, Spain, as a result of direct interaction with Asian hornets (Feas, 2021).

Stage 2 - Detailed assessment: Section A - Entry

This section evaluates the probability of entry of an organism into Ireland. For organisms which are already present, only complete the entry section for currently active pathways of entry and potential future pathways. The entry section need not be completed for pathways which have allowed an organism to enter in the past but are no longer active.

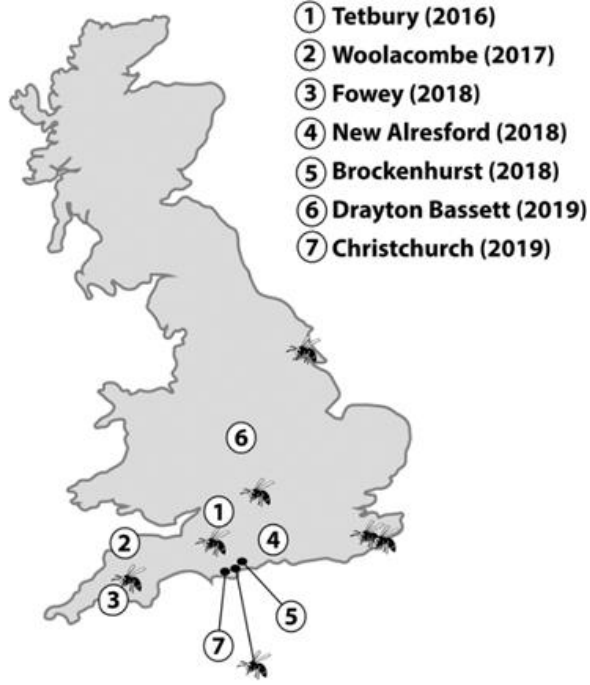
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.01	How many active/future pathways are relevant to the potential entry of this organism (n/a, very few, few, moderate number, many or very many)?	Many	High	The known active and potential introduction pathways to the risk assessment area involve (i) natural dispersal, (ii) the movement of natural or man-made goods between Ireland, UK and mainland Europe, that can provide shelter or food for <i>Vespa velutina</i> at different life stages, and (iii) the movement of people (Marris et al., 2011).
1.02	List <u>significant</u> pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways.	<ol style="list-style-type: none"> 1. Flight – natural dispersal 2. Movement of wood and wood products 3. Movement of fruit/cut flowers 4. Movement of man-made goods that provide suitable harbourages 5. Horticulture trade (including soil) 6. Movement of commercial and vehicles themselves 7. Movement of honeybee hives 	n/a	<p>Invasive insects can be introduced to new areas by natural dispersal or human mediated dispersal (CDB, 2014). The first Asian hornet introduced to Europe was accidentally imported in ceramic goods from China and quickly spread via natural dispersal and human-mediated vectors, which helped transport hornets large distances (Villemant et al., 2011).</p> <p>(1) <i>Vespa velutina</i> is a flying insect. Queens (inseminated gynes) naturally disperse in search of suitable hibernating spots for winter and often again in spring to find a suitable site for nest-building. (2) Queens of <i>V. velutina</i> and other hornets, are known to shelter under the bark of trees and secondary nests are most often found on trees. Gynes may therefore be found in transported timber, particularly where bark is left on the timber. The end point of this pathway depends on the product and its use. Timber commodities may end up at warehouses, sawmills, construction sites and domestic dwellings. (3) Hornets and other Vespid wasps are known to eat fruit, particularly in late summer, when seeking carbohydrate-rich food sources. A single Asian hornet was accidentally imported to Glasgow, Scotland, via a consignment of fruit, but was trapped at the destination warehouse. The end points of this pathway are most likely warehouses, supermarkets, and grocers. (4) Man-made goods like pottery, or horticultural equipment, can often provide shelter to hibernating queens, as they can be stored outside, prior to shipping to retail outlets. (5) Entire underground nests of <i>V. velutina</i> can be imported in consignments of soil, such as that found in pots and larger containers</p>

				<p>of imported garden plants and fruit trees. End point could be a number of destinations, but most likely include plant nurseries, garden centres and wholesalers. (6) Asian hornet gynes may hide (or become trapped) in freight containers and commercial lorries transporting goods to and from Ireland and UK/ continental regions and may also be unwittingly transported in domestic transport (e.g., cars, campervans, boats) returning to Ireland from invaded regions. The endpoint could be a very large number of destinations, but would all pass through Irish freight ports, <i>en route</i> to their final destination. The sole individual found in Ireland in 2021 is likely to have been brought into Dublin port. (7) Honeybees make up a significant portion of the Asian hornet's diet, and individuals are often found near hives, where they predate on bees leaving and entering the hive. Wasps and hornets have been found in the roofs of hives. Direct importation of whole or parts of hives may therefore represent a high-risk potential pathway. The endpoint of this pathway is likely to be a beekeeping business or individual beekeepers.</p>
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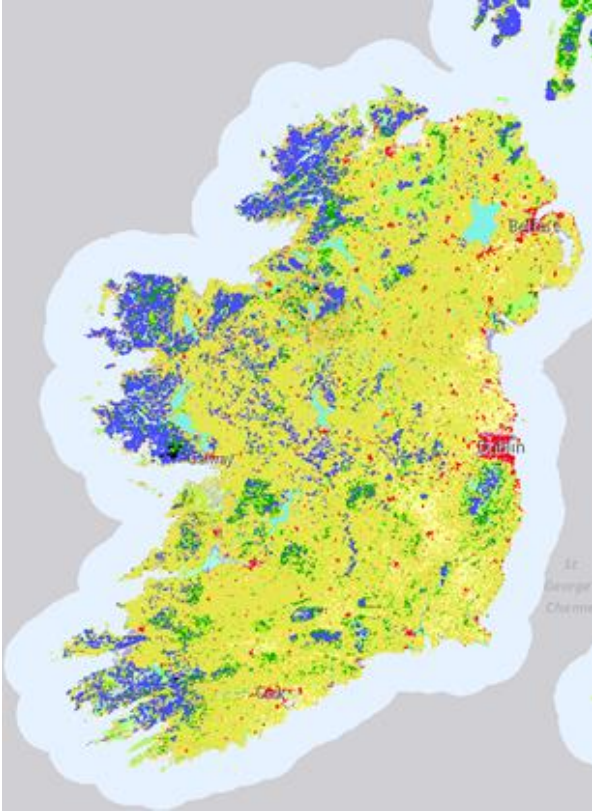
Pathway 1 – Natural dispersal by flight				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	ACCIDENTAL	HIGH	<p>Young, fertilised queens do not stay in the maternal nest. In late autumn, they disperse away from the nest to find a suitable overwintering location. They disperse a second time in spring away from overwintering sites to build a primary nest. Asian hornets are most likely to travel along these pathways during both of these dispersal movements, but the dispersal flight to locate overwintering sites may be the more important, as quiescent overwintering mated queens are more likely to be imported with freight and traded goods. Under the right conditions, queens can travel anywhere between 18-40 km a day in search of suitable overwintering or nesting sites (Rome et al., 2021; Robinet et al., 2017).</p> <p>In Ireland's case, the nearest large population of <i>V. velutina</i> is along the north-west coast of France (approx. 600km from the Irish coast),</p>

Pathway 1 – Natural dispersal by flight				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				with an average density of 16 nests per km ² in some areas (D. Thiery, <i>pers comms</i> . May 2021). The shortest flight distance between the island of Jersey, off the western coast of France, and mainland France is approximately 27 km. Since 2016, <i>V. velutina</i> has been recorded in Jersey annually, mostly along the east coast (83 nests in 2019) (Gov.je, 2021). The highest number of <i>V. velutina</i> queens in Jersey was recorded in spring 2021, most likely due both to high population densities along the French coast and easterly winds favouring dispersal.
1.04	How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?	Unlikely	High	The concentration of an organism along a pathway depends on the size of a population in any given area. At present, the nearest known established population of <i>V. velutina</i> is in France, where there is a high nest density along the northern coast (D. Thiery, <i>pers comms</i> . May 2021). A single nest can produce up to 350 gynes from September to November (Monceau and Thiery, 2016), and these will seek overwintering sites, which may include goods and freight lorries which may then transport the gynes to Ireland. Natural dispersal (by flight) is unlikely to occur, due to the great distance between France and Ireland (approx.. 600km). The closest landmass to Ireland is Great Britain, where there is a transient (so far unestablished) Asian hornet population. At present, all nests and individuals reported in the UK are destroyed as soon as detected and so individuals are unlikely to travel along the Ireland/GB pathway in any numbers.
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	Likely	High	It is likely that the species could enter Ireland by flight undetected and without the knowledge of relevant authorities. The risk of <i>Vespa velutina</i> entering Ireland along this pathway is highest on the East coast, due to its proximity to the UK and continental Europe. The east coast of Ireland is an estimated 450km from Carlingford to Carnsore Point, Wexford and is predominantly composed of sandy beaches and sheltered bays (Boelens et al., 1999). DAFM and NI's DAERA oversee a voluntary sentinel hive programme to monitor for the Asian hornet. These hives are spread throughout Ireland, with higher concentrations along the east coast and near major ports (Dublin, Cork, Belfast).

Pathway 1 – Natural dispersal by flight				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				DAFM increased monitoring traps in Dublin City and County, as well as ports, in response to the first Asian hornet discovered in Dublin in 2021 (DAFM, 2021, D. Harty, <i>pers.comm.</i> May 2021).
1.06	How likely is the organism to survive during passage along the pathway?	Unlikely	Medium	<p>Although the species is robust and can tolerate a range of conditions, it is unlikely that the species would survive during the passage along this pathway. It is extremely unlikely that a hornet would be able to reach Ireland from mainland Europe by flight (approx 600km distance from Ireland). The main risk of introduction via natural dispersal comes from Great Britain as it is the closest land mass to Ireland where hornets are present. <i>Vespa velutina</i> was first confirmed in Great Britain in 2016. Nests and individuals have been reported in Southern England every year since, but it is not considered an established population based on genetic analysis of each outbreak (Keeling et al. 2017; Jones et al., 2020). It is highly unlikely that the Asian hornets can spread from the UK to Ireland via natural dispersal based on the current location of all known UK nests (Fig. 5). It is notable that no secondary nests have been found in England, indicating that gynes do not disperse to locate secondary nests, nor do they disperse away from these nests to locate overwintering sites (Jones et al., 2020). The distance from the known <i>Vespa</i> nest site in Woolacombe, SW England, to the nearest Irish coastline (Wexford) is 186 km. Additionally, all known nests are destroyed when discovered (Jones et al., 2020). However, if <i>Vespa velutina</i> were to increase its distribution and density in the UK, the likelihood of natural dispersal to Ireland necessarily will increase proportionally. The shortest distance between the islands of Ireland and Great Britain is across the Irish channel between the Straits of Moyle, Northern Ireland, and Kintyre, Scotland, at 18 km. However, the current location of nests in Southern England (Figure 5) suggests that, were the Asian hornet within Great Britain to establish and extend its range (not thought likely at present), it is most likely to expand into Wales before making its way northwards (Roy et al. unpublished). The closest point between the coast of Wales and Ireland is 50 km. This is just over the known</p>

Pathway 1 – Natural dispersal by flight				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				<p>distance of flight for queen hornets, but it is possible that certain weather conditions (wind direction) could aid flight dispersal (Marris et al., 2011).</p>  <p> ① Tetbury (2016) ② Woolacombe (2017) ③ Fowey (2018) ④ New Alresford (2018) ⑤ Brockenhurst (2018) ⑥ Drayton Bassett (2019) ⑦ Christchurch (2019) </p> <p>Figure 5: Sightings and nest location in UK (2016-2019): Source: Jones et al. 2020</p>
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	Unlikely	Medium	<p><i>V. velutina</i> are generally active between April and November in the Atlantic Area, the time depending on location temperature and climate. Nest densities peak in August and September and adults are most likely to arrive during these months. As sterile female worker hornets cannot establish a colony no matter what time of year they arrive, autumn-dispersing mated queens (up to 500 per nest) seeking</p>

Pathway 1 – Natural dispersal by flight				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				to find overwintering sites, and spring-emerging queens seeking to build primary nests, represent the greatest invasion risk. A queen may thus arrive at two separate times: (1) In spring when they come out of hibernation and are searching for a nest site (2) In autumn when they are looking for a suitable area to hibernate.
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	Unlikely	Medium	<p>It is believed that an adult worker hornet can survive several days outside the nest (up to 100 hours) (Poidatz et al. 2018). However, workers cannot survive without a colony, and would not live for long in the risk assessment area. Queens are far more robust and adaptable and would not need to travel far in the risk assessment zone to find suitable habitat. <i>V. velutina</i> are highly adaptable, and can occur in multiple different habitats and at different elevations (e.g., forest, urban, agriculture, coastal) (Rodriguez-Flores et al. 2018, Kim et al. 2020). Nests have been found on man-made infrastructure such as road signs, electricity poles and buildings, underground, on cliffs and in vegetation such as trees and shrubs (Franklin et al. 2017, Carvalho et al. 2020). Along the east coast of Ireland (and northern Ireland), there are two major cities (Dublin and Belfast) and several smaller towns and cities surrounded by agricultural land and semi-natural woodland, all of which are potential habitat for the Asian hornet (Fig. 6). However, a more detailed assessment of the habitat requirements of <i>V. velutina</i> has shown that urban and peri-urban habitat, together with agricultural landscape characterised by carbohydrate-rich sources (eg fruit crops), along with deciduous woodland is required by queens seeking to establish primary nests in spring (Fournier et al., 2017). Ireland has very little of such landscape, particularly very little soft fruit production. Further, grassland, which dominates the agricultural landcover in Ireland (Fig. 6) is unsuitable for the reproduction of <i>V. velutina</i>, as it lacks sufficient readily-available protein or carbohydrate energy sources (Fournier, 2017).</p>

Pathway 1 – Natural dispersal by flight				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				 <p>Figure. 6: CORINE land cover map of Ireland (2018). Red = artificial surfaces, yellow/orange = Agricultural (largely improved grassland), green = Forest and semi-natural, blue = wetlands and bogs. Source: Copernicus.eu</p>

Pathway 1 – Natural dispersal by flight				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	<u>Unlikely</u>	High	Currently the likelihood of the Asian hornet entering Ireland via flight is low. The distance between landmasses (Ireland, GB and mainland Europe) is too large for the hornet to cross readily from areas where it is currently present, unless assisted by very strong easterly winds. Large bodies of water i.e., the Celtic Sea and Irish Sea, may thus act as a barrier for dispersal. The risk of entry through this pathway will increase if the Asian hornet successfully establishes in England and spreads into Wales and north to Scotland.
1.10	Do other pathways need to be considered?	YES	High	The habitat of mated queens actively seeking overwintering sites, including those found in freight containers, imported goods and industrial and domestic vehicles, and remaining quiescent for long periods, makes human-assisted dispersal into Ireland very much more likely than natural dispersal by flight.

Pathway 2 – Movement of wood and wood products				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	Accidental	High	Entry of the species via this pathway is accidental. Fertilised queens overwinter in small crevices in wood or under bark, or in other small dry spaces (eg in horticultural goods, ceramic goods, camping equipment etc.) and as such can be accidentally transported to new areas (Monceau et al., 2014). Under Regulation (EU) 1143/2014 it is illegal to keep, import, sell or breed Asian hornets in the European Union.

1.04	How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?	Unlikely	Medium	<p>Hibernating queens can cluster in groups of up to three individuals, but concentration of overwintering hornets in a single imported wooden product, or wooden container, depends on its size (Mollet and Torre, 2006; Marris et al. 2011). Preference for tree species has not been reported in this species. Ireland imports a range of wood and wood-products (e.g., raw and processed timber, wooden pallets, wooden agricultural and horticultural equipment) many of which originate in <i>Vespa</i>-invaded countries (eg France, Spain, Portugal) or in regions where <i>Vespa</i> naturally occurs (eg China), and so this pathway has multiple potential points of origin. The concentration of the organism along this pathway in a single year depends on the <i>V. velutina</i> population size in any given area associated with the exporting pathway and on the frequency and volume of trade between the infested range and Ireland.</p> <p><u>Frequency:</u> Wood and wood-based commodities may be transported into Ireland at any time of the year. In 2018, €642 million of forest products were imported into Ireland, dominated by the importation of pulp, paper and paper-board products, representing 61% of forest product imports by value (O’Driscoll and Moore, 2019).</p> <p><u>Volume and origin:</u> In 2018, the majority of sawn softwood for the construction industry was imported from European or Scandinavian countries. Although the main suppliers of softwood to the Irish market are Sweden, Latvia, Finland (hence currently outside the <i>Vespa</i>-invaded European region), Germany and Great Britain, sawn softwood was also imported from <i>Vespa velutina</i> invaded and native ranges, including the Netherlands (12,000 m³), France (5,000m³) and Belgium (4,000 m³) (O’Driscoll and Moore, 2019). In the same year, Ireland imported 16,000 m³ of tropical sawn hardwood and 29,000 m³ of sawn hardwood - of which 1,000m³ came from Great Britain and Germany respectively (O’Driscoll and Moore, 2019). Furthermore, 275,000 m³ of wood-based panels, 41,000 tonnes of pulp products and 388,000 tonnes of paper and</p>
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Pathway 2 – Movement of wood and wood products

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				particle board products were imported into Ireland in 2018 (DAFM, 2021).

1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	Likely	High	<p>Import regulations and detection measures depend on the tree species, country of origin and the nature of wood product. The Department of Agriculture, Food and the Marine Forestry Inspectorate is responsible for overseeing aspects of the EU Plant Health Regulation 2016/2031, FAO, and IPPC International Standard for Phytosanitary Measures (ISPM) 15. Ireland's Forests -Statistics 2021 report and DAFM's Forestry webpage detail the legislation and regulations in place for the movement of wood within the EU and outside of the EU (https://www.gov.ie/en/publication/642e6-forestry/ and https://www.gov.ie/en/publication/a2c8d-new-plant-health-legislation-december-2019/). Under the EU Plant Health regime, Ireland is considered as a whole and as such there is close co-operation with Northern Ireland's Department of Agriculture, Environment and Rural Affairs (DAERA).</p> <p><u>Imports from third countries (including the UK):</u> In the case of imports of regulated commodities from third countries, importers are required to register with DAFM and include official documents depending on the type of commodity. Sawn wood with bark, roundwood with bark, isolated bark, cut Christmas trees over 3 metres, forestry plants for planting and sawdust/ wood shavings with bark require official document (Phytosanitary Certificate) to show that it complies with Commission implementing Regulation 2019/2072 (DAFM Import Requirements). Inspections of wood and wood products from third countries are regularly carried out under the EU Plant Health Regulation to prevent the introduction and spread of plant pests into the European Union. In 2020, 675 third country consignments received a documentary check where a follow-up physical inspection was required. Of these, 27 (coming from USA and Canada) were found to be regulatory non-compliant. Regulated commodities include conifer tree species, sawn wood and roundwood with bark and certain hardwood species (sweet chestnut, plane trees, and ash). Under Commission Implementing Decision (2018/1127/EU) wood packaging material associated with certain stone commodities and wood (e.g., fuel wood, logs, twigs, wood chips, sawdust and scrap, packaging cases, crates, pallets)</p>
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Pathway 2 – Movement of wood and wood products

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				<p>imported into the EU from China (relevant Asian hornet range) are also inspected (DAFM, 2021). Of the 53 wood packaging inspections carried out in 2020, all were compliant. Wood packaging material must comply with ISPM 15 requirements and be stamped with the ISPM 15 mark.</p> <p><u>Imports from EU member states:</u> Under the EU single market, free movement of goods is assured. As such, wood and wood products are not subject to the same level of custom clearances as non-EU consignments, but wood and wood products are monitored to ensure EPPO protected zone requirement are met. Each protected zone is defined in relation to a particular harmful organism. The relevant EU country must ensure that the harmful organism(s) remain absent from the protected zones by only importing plant species from areas free from said harmful organism. Aside from protected zone measurements, a plant passport is required for the movement of certain plants, plant products and other objects (packaging) within the EU territory: this includes all plants intended for planting, wood which has been obtained in whole or in part from sweet chestnut (except debarked wood) and plane trees including wood that has not been kept in its natural round surface, and isolated sweet chestnut bark. Inspectorate also monitor Portuguese wood packaging material (due to threat of pine wood nematode) and wood packaging from other countries.</p> <p><u>Key Points</u> <i>Vespa velutina</i> is not a quarantine plant pest or priority pest and as such is not targeted in inspections of regulated wood commodities. Moreover, the majority of wood entering Ireland is not subject to physical inspections. Hornets could thus easily escape detection both at country of origin and in Ireland, given its behaviour of seeking overwintering sites in small cryptic spaces and crevices, such as under bark.</p>

Pathway 2 – Movement of wood and wood products

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION

1.06	How likely is the organism to survive during passage along the pathway?	Likely	High	<p>The arrival of a single overwintering mated queen into France from China in 2004 shows empirically that <i>V. velutina</i> can survive a long time in transported goods, and can be transported over very long distances.</p> <p>Overwintering of <i>V. velutina</i> begins in late autumn/winter and ends in early spring in temperate zones (ie 4-6 months), but duration is highly dependent on abiotic conditions, chiefly temperature, light and humidity (Monceau et al., 2014). The duration of transportation of wood and wood products from <i>V. velutina</i> invaded and native regions to Ireland is unlikely to exceed the overwintering period. If conditions are ideal during transportation and storage, overwintering queens can survive along this pathway.</p> <p>Survival along this pathway will also depend on the existing pest management practices and intended use of the wood. Breakdown of treatment by species, commodity and country of origin can be obtained from Commission Implementing Regulation (EU) 2019/2072 Annex VII (non-EU origin) and Annex XIII (commodities that require plant passport within EU territory). Treatments used to kill tree pests (heat treatment, fumigation etc.) are likely to be fatal to hornets. For example, wood packaging imported from non-EU states and Portugal must follow ISPM guidelines. ISPM 15 requires wood packaging material to be manufactured from debarked wood, and be either heat treated, fumigated with methyl bromide or heat treated using dielectric heat. Conventional steam or dry kiln heat treatment requires a minimum temperature of 56°C for a minimum duration of 30 minutes and dielectric heating consists of 60°C for one continuous minute (FAO, 2019). This is likely to be fatal for <i>Vespa velutina</i>, as hornets will die when trapped in the lethal honeybee thermal-balling defence, which reaches maximum of 44-45°C (Chauzat and Martin, 2009; Arca et al., 2014). Conifer wood packaging from EU states and Switzerland, excluding Portugal, must either be bark free, have a plant passport or be kiln dried to 20% moisture content. No action is required for hardwood unless it is made from sweet chestnut, plane wood or ash. Other exceptions include wood that is 6mm thick, made from processed wood made using glue, heat and pressure, sawdust,</p>
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Pathway 2 – Movement of wood and wood products				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				<p>wood shavings and wood wool and barrels that have been heat treated during manufacturing.</p> <p>Key points <i>Vespa velutina</i> is not a quarantine plant pest or priority pest and as such is not targeted by existing treatments of regulated wood commodities. However, such wood treatments are likely to be fatal to stowaway hornets. It is of course possible for hornet queens to seek overwintering locations in wood and wood products (e.g., crates, sawn and slabs of timber) after the wood has already been treated and is awaiting transport to a new area.</p>
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	Likely	High	Wood and wood-based commodities may be transported into Ireland at any time, including those months of the year most appropriate for establishment (spring/summer). The greatest risk for imports is in spring when queens are beginning to emerge from their overwintering refugia, and are seeking to build a nest. Hornets may still overwinter in commodities imported between October – March, emerging in spring, but this would depend on storage and intended use of commodity.

Pathway 2 – Movement of wood and wood products

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	likely	High	<p>This depends on i) where a commodity enters Ireland, ii) the type of commodity iii) storage and use of commodity.</p> <p>i) DAFM operates two designated Border Inspection posts in Dublin and Cork (Belfast in NI) for imports arriving from third countries. Non-regulated consignments and EU-shipments can arrive via multiple seaports and airports across Ireland. There are approximately fifteen commercial ports in the Republic of Ireland, although Dublin port alone handles over 50% of imports into Republic of Ireland (Central Statistics Office, Ireland, 2020). There are five commercial ports in Northern Ireland. Pre-Brexit, Warrenpoint harbour was the biggest timber importer in Ireland, with approximately 70% of imports moving to ROI and 30% staying in NI. More timber is now likely to be imported into the south of Ireland, due to post-Brexit regulation changes. Regardless, <i>V. velutina</i> could easily transfer from the pathway of wood imports to a suitable habitat as they are highly adaptable to novel environments. ii) Provided a queen survives overwintering and remains undisturbed (i.e., concealed in wood that is not processed for the duration of her hibernation), she can then emerge to establish a colony, iii) Some commodities, such as whole trees, sawn wood and pallets are placed outside, directly into or near suitable habitats e.g., woodland, tall trees, buildings and other man-made structures, particularly if near a food source. Transfer will be much more likely in this situation, where the hornet is not confined on emergence from its overwintering site. Some commodities may be stored in warehouses or garages (e.g., fire logs) where hornets may be restricted and detected more easily. However, it is evident that emerging queens can establish primary nests in garages and buildings where there is access to resources for survival and nest building e.g., water, pulp, and food.</p>

Pathway 2 – Movement of wood and wood products				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	Likely	High	Entry of this species along this pathway at some time in the future is likely, based on the fact that hornets typically build nests in trees and are known to hibernate under bark and in crevices in wood products. Additionally, wood and wood products are routinely imported from invaded ranges like Germany, France and Belgium year-round and only certain commodities must be treated and inspected for tree pests.
1.10	Do other pathways need to be considered?	YES	Very high	Although queens will overwinter in locations associated with wood and wood products, this is by no means the only habitat in which this will occur. Thus, other pathways must be considered.

Pathway 3 – Movement of fruit/cut flowers				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	Accidental	Very high	Entry of <i>V. velutina</i> via this pathway is accidental, as for all other pathways. Under Regulation (EU) 1143/2014 it is illegal to keep, import, sell or breed Asian hornets in the European Union. Adult <i>V. velutina</i> exploit a variety of fruits and flowers as a food source in their native and invaded ranges (Kishi and Goka, 2017). Foundresses leaving the nest in October/November will seek out carbohydrate-rich food sources, as will queens emerging from hibernation, to provide energy for overwintering and for nest building. Adult workers also consume carbohydrates from fruits and nectar.

1.04	How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?	Unlikely	High	<p>More hornets are likely to be associated with this pathway in autumn when workers, no longer able to consume carbohydrate-rich secretions from their larvae, must go in search of carbohydrates outside the nest. Unlike, <i>Apis mellifera</i> and other Hymenoptera, <i>V. velutina</i> does not store food within nests, and so needs a constant supply (Rojas-Nossa et al., 2021). The concentration of the organism along this pathway in a single year depends on <i>V. velutina</i> population density in any given area associated with the pathway and on the frequency and volume of trade between the infested range and zone of interest. <i>V. velutina</i> individuals may be brought into Ireland within consignments of fruit and flowers, but the majority of these are likely to be sterile workers which are inadvertently captured when fruit and flowers are harvested and packaged for export. Active queens foraging on fruit and flowers are much rarer than workers. In addition, actively foraging and flying individuals in summer are much less likely to be inadvertently retained in harvested fresh fruit and flowers, compared to quiescent queens in overwintering sites.</p> <p>Due to the relatively small size of the flower industry in Ireland, there is a lack of information about trade frequency, however from examining the Dutch and UK market, it is clear that flowers are imported to these areas year-round due to a high demand (Burke, 2012). Fruit is also imported year-round into Ireland, chiefly bananas, apples, pears and citrus fruits, with most apples, pears and citrus imports coming from <i>Vespa</i>-invaded Spain and the Netherlands. Bananas are mostly imported from Costa-Rica, a non-<i>Vespa</i> invaded region.</p> <p>EU Regulation 2016/2031 sets out a framework of protective measures against the introduction into the EU Community of organisms harmful to plant and plant products, and against their spread within the Community. It provides for a harmonized policy for the 27 members of the EU to prevent the introduction and spread of such organisms. Plants, including flowers and fruits imported into Ireland must be accompanied by a phytosanitary certificate, which documents the origin of the shipment and confirms inspection in the</p>
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Pathway 3 – Movement of fruit/cut flowers				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				country of origin by a member of that country's national plant protection organization. As <i>V.velutina</i> is not a recognised pest of plants or fruits, it would not be regulated under these statutory control.
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	Likely	High	<p>The type of fruit and flowers visited by <i>V. velutina</i> is dependent on locality and season (Monceau et al., 2014). In South Korea, Adult. <i>V. velutina</i> were recorded feeding on floral nectar of 27 plant species within 15 families (Ueno, 2015). Furthermore, <i>V. velutina</i> was discovered to consume floral nectar from plants with short corolla or small tubulars due to their small tongue size (Monceau et al., 2014, Rojas-Nossa et al., 2021). Overall, <i>V. velutina</i> is an opportunistic generalist feeder and is not associated strongly with one plant type or species. This makes it more difficult for the relevant authorities to detect the species in inbound shipments.</p> <p>Fruit and flowers are not inspected specifically for <i>V.velutina</i>, as this species is not a recognised pest of agricultural or horticultural plant material (fruit, flowers and vegetables). However, the large size and vigorous activity of individual <i>V. velutina</i> may make it more likely that individuals may be noticed by customs officials and other importing stakeholders. This would depend both on the vigilance of importing officials, and their ability to recognise <i>V. velutina</i> individuals.</p>

Pathway 3 – Movement of fruit/cut flowers				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.06	How likely is the organism to survive during passage along the pathway?	Likely	Medium	<p>Survival along this passageway depends on the processes used to preserve fruit and cut flowers during transport and storage.</p> <p>Adult <i>V. velutina</i> could survive for the transit periods if transported and/or stored with a suitable fruit/flower food source (e.g., grapes). In 2017, a single hornet was identified at a retail fruit/vegetable warehouse in Scotland, and it is assumed that this was transported in imported fruit/vegetables (Scottish Beekeepers' Association, 2017). The majority of specimens likely to be imported within fruit and/or flowers during the summer growing months are likely to be sterile worker hornets, and not overwintering queens and as such would need ready access to food and water during and after transit.</p>
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	Likely	Medium	<p>Hornets are attracted to ripe fruit which is imported year-round. The large majority of hornets likely to be found on or around ripe fruit in invaded countries (France, Spain etc) are sterile worker hornets. Sterile worker hornets cannot reproduce, thus do not pose a threat of establishing a new population. Mated queens emerging from overwintering sites and searching for carbo-hydrate-rich energy sources pose the greatest risk of establishment in Ireland. Spring months are therefore key for invasion and subsequent establishment via this pathway. Fruit and cut flowers are imported year-round, with greater quantities imported in spring and summer.</p>
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	Likely	Medium	<p>The transfer from pathway to a suitable habitat depends on: i) where a commodity enters Ireland, ii) the type of commodity iii) storage and use of commodity. Cut flowers and fruit are associated with big and small retailers and as such could be transported anywhere in Ireland.</p>

Pathway 3 – Movement of fruit/cut flowers				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	Likely	Medium	It is likely that individual hornets will arrive in Ireland via this pathway over the coming decades, given the high propagule pressure in fruit and flower exporting countries. The individual found in Scotland likely entered via this pathway. However, the large majority of these individuals are likely to be sterile workers, as these are more likely to visit flowers and fruit in summer months in invaded countries. Harvesting of flowers and fruit in spring, when mated queens are searching for food sources, is quantitatively less than in summer, and the numbers of individual hornets (albeit queens) likely to be accidentally transported also somewhat less than in summer.
1.10	Do other pathways need to be considered?	YES	High	

Pathway 4 – Movement of Man-made Goods				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	Accidental	High	Entry of the species via this pathway is accidental, as for all pathways (under Regulation (EU) 1143/2014 it is illegal to keep, import, sell or breed Asian hornets in the European Union). Gynes (mated queens) will search out areas to overwinter that provide shelter from inclement weather and potential predators. This includes man-made goods, stored in such a way to allow ready access for <i>V. velutina</i> queens (e.g., agricultural, construction and horticultural equipment, durable domestic goods such as ceramics, large wooden goods). The foundress responsible for the entire European invasion is thought to have been transported to France in a pottery consignment from China.

Pathway 4 – Movement of Man-made Goods				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.04	How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?	Unlikely	MEDIUM	Hibernating queens can cluster in small groups (Mollet et al., 2006; Chauzat and Martin, 2009), although the number of hornets in any one commodity depends on the commodity's size. Since the range of potential commodities suitable for hibernation is great, it is impossible to determine the likely concentration of the species along this pathway. Entry of individual <i>V.velutina</i> queens into Ireland along this pathway is, however, very likely over the coming decades, given the volume of imported goods of this kind from invaded areas. The numbers of such imported individuals is however likely to be low, as the likelihood of a mated queen being imported in any single consignment, or in any individual year is low.
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	Very likely	High	This pathway involves a wide range of commodities that are likely subject to an array of corresponding inspection procedures. As <i>V. velutina</i> is not currently a notifiable pest species in the EU (EU Reg 2019 1702 Priority Pests), and thus it is not mandatory to report the presence of this species in imported goods. Overwintering <i>V.velutina</i> gynes tend to be hidden in cryptic locations, and are quiescent, and as such are likely to remain undetected in consignments of man-made goods, unless these are inspected explicitly for <i>V.velutina</i> gynes. At present, this is not mandatory within the EU.

Pathway 4 – Movement of Man-made Goods				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.06	How likely is the organism to survive during passage along the pathway?	Very likely	High	The likelihood of survival of <i>V.velutina</i> individuals arriving into Ireland via any single pathway is difficult to quantify, due to the wide array of potential commodities in this pathway. Survival will depend on the type of commodity, duration of transport and life stage of the hornet. However, given the volume of goods transported into Ireland from infected areas, it is likely that individual <i>V.velutina</i> will be unwittingly imported into Ireland in the coming decades. Eventually, this may include a live, quiescent mated queen. A single Asian hornet was introduced to France in 2004 via a ceramic goods (pottery) consignment from China, resulting in the widespread establishment of the species in Western Europe. This demonstrates that the Asian hornet was able to be transported a long distance and over a long period, as it is likely that these goods were imported into Europe via sea freight, rather than air freight.
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	Very likely	High	Commodities may be brought in at any time of the year, including months most suitable for establishment. Quiescent queens transported during winter months will be capable of potential establishment once they emerge in spring.
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	Likely	Medium	This depends on i) where a commodity enters Ireland, ii) the type of commodity iii) storage and use of commodity. For example, commodities used for garden or horticultural trades, such as ceramic containers, plant pots, etc. will be placed outdoors into suitable habitat for <i>V. velutina</i> . Other commodities will be placed indoors where queens may be confined on emergence (eg food warehouses), making transfer to suitable habitat more difficult but likely not impossible in many cases.
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	Likely	Medium	Given the volume of goods transported into Ireland from infected areas, it is likely that individual <i>V.velutina</i> will be accidentally imported into Ireland in the coming decades. Although the majority of these individuals would be sterile workers, it is likely that, eventually, a quiescent mated queen will arrive in transported goods from infected regions in Europe, or even from its native range in China. The chances of this happening in any one year is, however, low.

Pathway 4 – Movement of Man-made Goods				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.10	Do other pathways need to be considered?	Yes	High	The high density of <i>V. velutina</i> colonies now present in the EU, coupled with the adaptability of the species, and the association with human settlements and activities, means that all potential pathways by which a quiescent queen may be brought into Ireland must be considered.

Pathway 5 – Movement of Soil and Soil Associated with Plant Trade				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	Accidental	Very high	Entry of the species via this pathway is accidental. <i>V. velutina</i> will construct nests underground, typically at the base of trees and shrubs, and entire nests or parts of a nest could be accidentally excavated and transported with soil taken from countries where the species is present (for example in specimen rooted ornamental trees in large pots). Further, mated queens are known to overwinter in soil or leaf litter (Villemant and Haxaire, 2007), so may be imported in smaller volumes of spoil associated with plant trade.
1.04	How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?	Unlikely	High	The concentration of hornets along this pathway depends on the volume of soil / rooted plants imported, and also the vigilance of exporting countries in detecting <i>V. velutina</i> . Overwintering adult queens can cluster in small groups of up to 3 individuals and so a relatively small volume of soil could harbour several fertilised queens. An entire living nest would only be concealed by a large volume of soil. As above, the likelihood of mated queens arriving in large numbers via this pathway in any one year is very low, but the likelihood of a single individual queen arriving via this pathway over the course of several decades is high.

Pathway 5 – Movement of Soil and Soil Associated with Plant Trade				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	Likely	High	As above: <i>V. velutina</i> is not currently a notifiable pest species in the EU (EU Reg 2019 1702 Priority Pests), and thus it is not mandatory to report the presence of this species in imported goods. Overwintering <i>V. velutina</i> gynes tend to be hidden in cryptic locations, and are quiescent, and as such are likely to remain undetected in consignments of soil and rooted plants, unless these are inspected explicitly for <i>V. velutina</i> gynes. At present, this is not mandatory within the EU.
1.06	How likely is the organism to survive during passage along the pathway?	Likely	High	Individual adults in nests are unlikely to survive for very long, as they would need a constant supply of food and water from sources outside of the nest. Larvae and pupae, however, could survive for considerable periods within nests contained in soil. Quiescent overwintering queens can also survive extended periods along this pathway.
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	Likely	High	Soil may potentially be brought in at any time, including months most suitable for establishment.
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	Likely	High	As above, this depends on i) where a plant and/or soil enters Ireland, ii) the nature of the imported good and iii) the storage conditions and location of the goods. Imported plants will typically be stored outdoors, or in locations with ready access to outdoors (eg polytunnels) directly in or near suitable habitat.
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	Likely	High	Entry of this species along this pathway at some time in the future is likely, based on the fact that hornets, at various life stages, may find harborage in horticultural products containing soil. Much of the imports of soil associated with the plant trade comes from invaded areas of Europe, notably the Netherlands.
1.10	Do other pathways need to be considered?	YES	High	The high density of <i>V. velutina</i> colonies now present in the EU, coupled with the adaptability of the species, and the association with human settlements and activities, means that all potential pathways by which a quiescent queen may be brought into Ireland must be considered.

Pathway 6 – Movement of freight containers and vehicles themselves				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	Accidental	Very high	Entry of the species via this pathway is accidental, as for all pathways (under Regulation (EU) 1143/2014 it is illegal to keep, import, sell or breed Asian hornets in the European Union).
1.04	How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?	Unlikely	High	It is unlikely that a large number of <i>V. velutina</i> will travel along this pathway in any one year. Although there has been a very large population of <i>V. velutina</i> in Europe since at least the last ten years, there has been only one reported instance of a single <i>V. velutina</i> imported into Ireland. However, it is likely that an individual will arrive in Ireland (either sterile worker or mated queen) via this pathway in coming years, given both the density of the species in countries where freight originates from, and the increasing volume of imported goods from these countries.
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	Very likely	High	There are no known management practices on this pathway. Detection will likely be associated with the life stage in question. Swarms or active individuals are more likely to be detected. Hibernating queens are less likely to be detected as they often hide in small, discrete spaces for protection.
1.06	How likely is the organism to survive during passage along the pathway?	Very likely	High	The arrival of an overwintering mated queen from China into Europe in 2004, via this pathway, shows the high potential for this to occur within Europe, as well as from repeated introductions from its native range. Quiescent queens hitchhiking on imported goods and freight not only present the sole danger for establishment of a <i>V. velutina</i> population in Ireland, they are much more likely to survive extended time periods greater than a few days, than active sterile workers.

Pathway 6 – Movement of freight containers and vehicles themselves				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	Likely	high	Freight containers and vehicles travel between the risk assessment area and the invaded range of <i>V. velutina</i> throughout the year, particularly of goods and freight in which overwintering queens may occur.
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	VERY LIKELY	HIGH	The ability of the species to transfer from the pathway to a suitable habitat depends on the destination of the freight container or vehicle. Freight containers and vehicles arriving to Ireland will move through major and minor ports. If the pathway ends here or the hornet escapes at this junction, it is likely that it will find potentially suitable habitat near to the port. Major ports are located in urban areas (e.g, Dublin City, Cork Harbour, Belfast City), and the Asian hornet is strongly associated with urban habitats in its invaded range. If the container or vehicle's destination is outside the port, then it is possible for <i>V. velutina</i> to be transported anywhere in Ireland.
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	Likely over longer timescales, unlikely in any one year.	High	As above. Entry of this species along this pathway at some time in the future is likely, given that hornets, at various life stages, may enter freight containers directly, or indirectly, within the freighted goods themselves. The original invasion into Europe from China was via this pathway. In addition to commercial freight traffic, tourist vehicles traveling to Ireland from infected areas also represent a potential invasion pathway. Such traffic would not be subject to the same biosecurity protocols as commercial freight, either by custom officials or the individual tourists themselves. Melly and Hanrahan (2019,2020) show the lack of biosecurity (public awareness and planning) within Ireland's tourism and outdoor recreation sector, leaving the Island exposed to introductions of new species and diseases.
1.10	Do other pathways need to be considered?	YES	High	As above, the high density of <i>V. velutina</i> colonies now present in the EU, coupled with the adaptability of the species, and the association with human settlements and activities, means that all potential pathways by which a quiescent queen may be brought into Ireland must be considered.

Pathway 7 – Movement of Honeybees				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	ACCIDENTAL	HIGH	As above, under Regulation (EU) 1143/2014 it is illegal to keep, import, sell or breed Asian hornets in the European Union. Entry of the species via this pathway is therefore accidental. Imports of honeybees into Ireland from other European Union member states is highly regulated, due to the risks of importing diseases and pest of honeybees. Much of the population of honeybees was wiped out in Ireland in the 1920's due to an Acarapisosis outbreak originating from within Europe (Kidd, 1919). Any importation of honeybees (honeybee queens, packages of bees, nucleus colonies, honeybee colonies) into Ireland must be notified to the Department of Agriculture at least 24 hours before the consignment's arrival in the Republic of Ireland. A health certificate which has been issued by the competent authority in the member state of origin must accompany each consignment of bees. If a consignment is subsequently sub-divided for delivery to two or more recipients, a copy of the health certificate must accompany each partial consignment to its final destination. The health certificates is aimed at ensuring that any bees imported do not carry any diseases or pathogens, and have been visually inspected to ensure the health and disease-free status of the imported bees. It is thus very unlikely that adult queen <i>V.velutina</i> may be imported accidentally or deliberately along with live honeybees.

Pathway 7 – Movement of Honeybees				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.04	How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?	UNLIKELY	High	<p>To date, there have been no reports of <i>Vespa velutina</i> being accidentally or intentionally imported into Ireland along with honeybees. Hornets are strongly attracted to honey and pollen odours which help them locate hives (Couto et al., 2014; Wang et al., 2014), and worker hornets can occasionally enter weakened hives in search of pollen, pupae, and honey. If trapped within a transported hive, these sterile workers may potentially be accidentally transported into Ireland, but will not be able to establish new colonies. Queens may also potentially (although very unlikely) overwinter under the rooves of beehives and be transported to new areas where they can create a founding population, although there are no confirmed reports of this happening. Concentration of organisms along this pathway depends on the size of <i>Vespa velutina</i> population in an area where bees are exported from and the volume of trade along this pathway.</p> <p>Ireland has a long history of importing bees from Europe, particularly from the Netherland, Italy, Germany, and France (relevant <i>Vespa velutina</i> range). On average, 115 queens per year were imported into the Republic of Ireland c. 2012- 2017 (Hassett et al., 2018). The current volume of trade and origin of imports is unknown. It is unlikely that a large number of hornets will travel along this pathway.</p>
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	UNLIKELY	High	<p>In relation to the importation of honeybees into Ireland, this is allowed under regulations governing intra-community trade with other EU Member States. Requirements for trading honeybees are laid out in Council Directive 92/65/EEC and Regulation (EU) 2016/429. Bees can only be imported into Ireland under strict conditions, one of which is that bees must be imported in such a way that they can be visually inspected by customs/DAFM officials, usually in small mesh cages. It is highly unlikely that the <i>V. velutina</i> could enter Ireland undetected or without the knowledge of competent authorities through this pathway.</p>

Pathway 7 – Movement of Honeybees				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.06	How likely is the organism to survive during passage along the pathway?	VERY LIKELY	MEDIUM	If honeybees can survive passage along this pathway then, in the unlikely case that an individual <i>V. velutina</i> is able to hitchhike along with honeybees and escapes detection, hornets should also be able to survive on this pathway. Adult hornets require sweet carbohydrates for energy: fondant or sugar is supplied to bees in transit and so would be potentially available to Asian hornets as well.
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	VERY LIKELY	MEDIUM	Bees can be imported any time throughout the year but are most likely to be imported during the active season (March to September). Demand is typically highest at the start of the season (March/April - depending on when bees start flying regularly). Queen hornets emerge from hibernation and begin establishing nests in spring. In the very unlikely event that <i>V. velutina</i> individuals are imported along with honeybees, via this pathway, they are likely to arrive during the months appropriate for establishment.
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	VERY LIKELY	MEDIUM	Hives and apiaries are typically situated in countryside or urban areas, providing suitable habitat for <i>Vespa velutina</i> , as well as ample food sources (honeybees). Transfer to suitable habitat from this pathway is likely as beekeeping is widely practiced across Ireland. County Cork, Dublin, Tipperary, Wexford and Waterford account for 44% of all bee colonies in 2019 (Bord Bia, 2019).
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	VERY UNLIKELY	HIGH	Hornets are much bigger than <i>Apis mellifera</i> in size and are of a distinct colour and pattern that makes them stand out. Additionally, the final destination of bees will be to a beekeeper or beekeeping business who are generally knowledgeable about the species. As such the species is likely to be spotted before entering the risk assessment area. Imported bees must have a phytosanitary certificate prior to importation and must be imported in such a way that they can be visually inspected by customs/DAFM officials, usually in small mesh cages. This makes it very unlikely that a hornet will go unnoticed.
1.10	Do other pathways need to be considered?	YES		N/A

Overall likelihood				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.11	Estimate the overall likelihood of entry into Ireland based on all pathways (comment on the key issues that lead to this conclusion).	Likely	High	The rapid growth of the <i>Vespa velutina</i> population in several other EU states has resulted in high densities of <i>Vespa</i> colonies across countries with which Ireland has extensive trade and cultural links, including France, Spain, Portugal and the Netherlands. The pressure of potential <i>Vespa velutina</i> colonists is likely to remain high for the foreseeable future, and in fact is likely to increase as a result of economic growth (bringing with it an increase in traded goods and the flow of tourist traffic) and climate change. <i>Vespa velutina</i> individuals have now been found in many regions where the species has not established populations (including northern England, Germany, Scotland and Ireland), and these individuals presumably arrived via human-mediated means. It is thus very likely that Asian hornet individuals will continue to be transported between countries and regions via human-mediated means, unless strict protocols targeting <i>Vespa</i> are introduced EU-wide. There is no indication that such protocols are planned. As such, we can expect more <i>V. velutina</i> individuals to arrive in Ireland in the coming years. However, a critical difference exists between the much more common sterile workers, which may be imported accidentally in summer months along with freight and vehicular traffic, and the rarer mated queens, which are likely to be imported in spring and winter months. Queens, although rare, can be imported in a quiescent state and are therefore much more likely to survive extended periods of transport and in cold temperatures (such as that found in refrigerated conditions) that would normally result in the death of active hornets. Only queens can establish an Asian hornet population in Ireland.

Stage 2 - Detailed assessment: Section B - Establishment				
<i>This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.</i>				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
2.01	Is the organism well established in Ireland (if there is any uncertainty answer 'unsure')	NO	HIGH	<i>Vespa velutina</i> does not presently occur in Ireland. Only one record for this species exists for Ireland (National Biodiversity Data Centre, 2021). A single sterile worker hornet was reported and caught in Dublin, in a location near to the commercial docks, in 2021. Additional individuals and/or nests were not detected during rapid response monitoring and no new records have been reported.
2.02	How likely is it that the organism will be able to establish in Ireland based on the similarity between local <u>climatic conditions</u> and the organism's current global distribution?	Unlikely	Medium	<p>Based on best-estimate climate models, Ireland as a country falls within the hypothetical suitable climate range for <i>V. velutina</i> establishment (Villemant et al., 2011; Barbet-Massin et al., 2013; Nguyen et al., 2019).). However, Ireland has an unusually (compared to the rest of Europe) extreme oceanic climate with cooler, windier and cloudier summers than mainland Europe. There are in fact several indicators that the Irish climate is <u>unsuitable</u> for the widespread establishment of <i>V. velutina</i>:</p> <p>(1) Although climate models may describe Ireland as a country potentially suitable for <i>V. velutina</i> (e.g Ibáñez-Justicia & Loomans 2011; Barbet-Massin et al., 2019), the extent of suitable area within Ireland is relatively small and is confined to southern and eastern coastal areas (Figs. 7 & 8). Keeling et al (2017) have modelled the potential spread of <i>V. velutina</i> within Great Britain, assuming colonists arriving in southern England in 2016 had managed to establish and expand into other areas (Fig. 9). The authors parsimoniously assumed a linear decrease in reproductive potential with latitude (although climate change in north west Europe is more related to oceanic impacts, which run in a north-west direction, rather than N-S latitude), and their model showed zero reproduction potential above northern England (Keeling et al., 2017).</p> <p>The restricted climate zone of Ireland at the furthest extreme of European climate suitability would therefore likely greatly restrict (i) the geographical extent of any <i>V. velutina</i> invasion in Ireland, (ii) the</p>

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N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				<p>density of any established <i>V. velutina</i> population and (ii) the likely stability of such a population over time.</p> <p>(2) Lioy et al (2023) has recently described the niche overlap between <i>V. velutina</i> and the European native hornet <i>V. crabro</i>. Although the two species overlap considerably in mainland Europe, <i>V. crabro</i> is adapted to somewhat colder climates than <i>V. velutina</i> (Lioy et al., 2023). <i>V. crabro</i> does not occur in Ireland, in common with most other members of the Vespinae that are found in England and continental Europe (Edwards, 1997; Irish National Biodiversity Data Centre). Notably, the Median wasp, <i>Dolichovespula media</i>, which has colonised the UK naturally since 1980, is also much more common in southern England and is rarely recorded in northern England, Scotland and Wales. <i>D. media</i> does not occur in Ireland (Phillips and Roberts, Hymettus information sheet no. 9 , 2010). Vespid wasps, including <i>V. crabro</i> have invaded many regions around the globe, facilitated by their wide dietary habits, their association with human habitation, social habits and the behaviour of mated queens to overwinter in a quiescent state in cryptic, easily transported locations, such as in imported wood and wood products (Beggs et al., 2011).</p> <p>The European hornet, <i>V. crabro</i> was unintentionally introduced into the United States in the 19th century and has now become invasive there (Shaw and Weidhaas, 1956). Despite the multiple likely introduction opportunities of <i>V. crabro</i> into Ireland over the centuries, as a function of the large volume of traded goods between the two countries, it is noteworthy that this species has not succeeded in establishing in Ireland. <i>V. crabro</i> queens would seek out the same overwintering places as other vespid queens in autumn.</p> <p>Ireland has fewer species across a wide range of floral and faunal groups compared both to England and continental Europe, including</p>

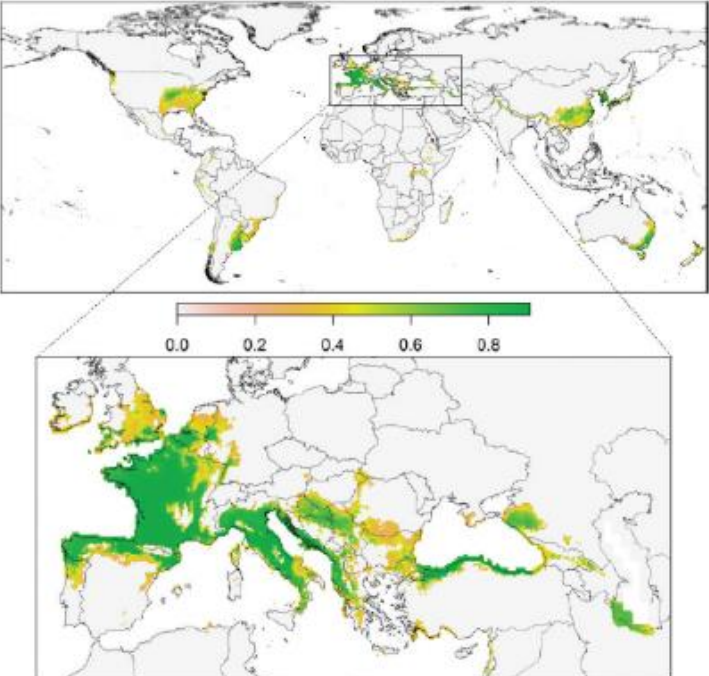
Stage 2 - Detailed assessment: Section B - Establishment

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				<p>flighted groups, due to <i>inter alia</i>, the cool, cloudy and humid Irish climate (Harrison, 2014). The lack of large thermophilic vespids in Ireland is thus likely a function of the lower summer temperatures and higher year-round humidity of Ireland compared to southern England and continental Europe, rather than a lack of opportunities to reach here due to Ireland's island status.</p> <p>(3) <i>V.velutina</i> colonies discovered in southern England have all been shown to be derived from queens colonising from France, rather than descended from queens from previous years (Jones et al., 2021). The UK nests are also smaller than those found in France and Jones et al (2021) have suggested that the environment and climate in the UK are unsuitable for sustaining large, highly productive nests. The Irish climate over most of the island is likely to be even less suitable, than southern England, for the establishment of <i>V.velutina</i>.</p>

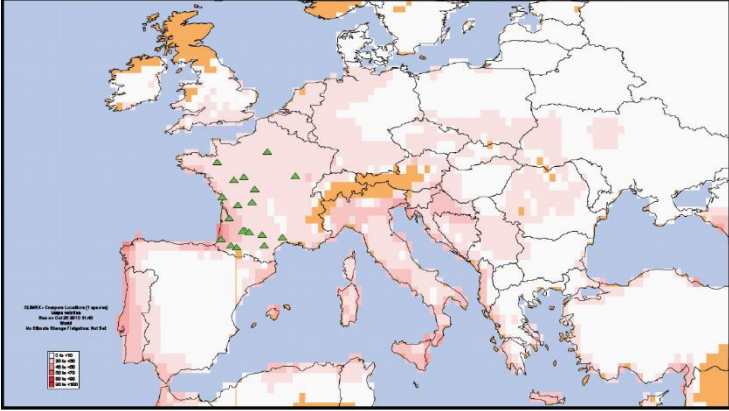
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N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				 <p data-bbox="1276 1109 2016 1197">Fig. 7. Consensus climate suitability of the yellow-legged hornet predicted from species distribution modelling. Figure adapted from Barbet-Massin et al (2019).</p>

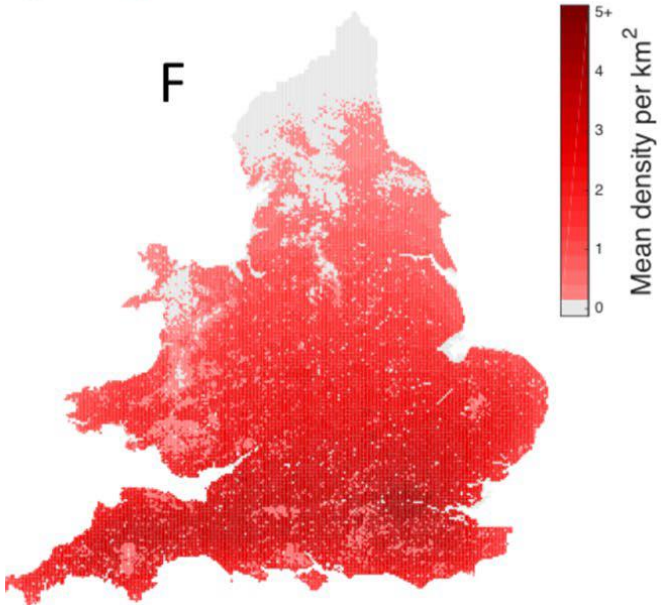
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N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				 <p data-bbox="1285 874 2018 1002">Fig. 8. Model <i>Vespa velutina nigrithorax</i> (0.5° world grid meteorological data) Europe. Triangles: Locations <i>V. velutina</i>, Red gradation: EI values. Figure adapted from Ibáñez-Justicia & Loomans (2011).</p>

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N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				 <p data-bbox="1276 1037 2027 1157">Fig. 9. Estimated modelled spread of <i>V. velutina</i> 20 years following invasion into Great Britain. Adapted from Keeling et al., (2017). Note the limit to <i>V. velutina</i> in northern England – a function of climatic suitability for reproduction of the Asian hornet.</p>
2.03	How likely is it that the organism will be able to establish in Ireland based on the similarity between other local <u>abiotic conditions</u> and the organism's current global distribution?	Unlikely at present	Medium	The establishment of <i>V. velutina</i> in continental Europe has been facilitated by the availability of human-supplied food, such as discarded protein-rich fish and seafood in the vicinity of fish processing plants, ripe fruit from the abundant fruit cultivation business, discarded food waste in urban and peri-urban areas (including holiday campsites) and from the abundant supply of their honeybee prey. The

Stage 2 - Detailed assessment: Section B - Establishment

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N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				supply of food of human origin in Ireland is very low compared to continental Europe, due both to climate limitations and to the lower human population density. <i>V. vespa</i> is significantly more associated with artificial urban land surface than natural or agricultural land use in invaded areas in Europe, and hornets will make ready use of human dwellings, such as sheds, outhouses, barns etc., to build their nests (Fournier et al., 2017). The supply and location of suitable artificial urban and peri-urban habitat is likely much lower in Ireland than continental Europe due to the lower human population density, and the relatively small percentage area of urban habitat in Ireland.
2.04	How likely is the organism to encounter habitats necessary for the survival, development and multiplication of the organism in Ireland?	Unlikely	Medium	Habitats that the species occupies within its native and introduced ranges occur across Ireland e.g., woodland and scrub, cultivated and built land, sea cliffs (Lydon and Smith, 2012; Fossitt, 2000). <i>V. velutina</i> is most likely to be introduced via human agency and so could be introduced anywhere in Ireland depending on the destination of the pathway. Furthermore, queen <i>V. velutina</i> hornets can fly long distances in search of suitable habitat. The amount and location of built land, and urban fabric, is however lower in Ireland than in much of European continental regions and this may limit the potential distribution of <i>V. velutina</i> to areas associated with larger towns and cities along the southern and eastern coasts.
2.05	How likely is it that establishment will occur despite competition from existing species in Ireland?	Very unlikely	MEDIUM	Competition has been reported between <i>Vespa velutina</i> and other <i>Vespa</i> species in its invaded range of Japan and Korea (Ikegami et al., 2020, Kwon and Choi et al., 2020). Europe has two native hornets, however only <i>Vespa crabro</i> , the European hornet, is found in <i>V. velutina</i> invaded range. <i>Vespa crabro</i> and <i>Vespa velutina</i> have an overlapping nesting and prey preference in Europe, but there is little evidence that <i>V. crabro</i> is outcompeted by <i>V. velutina</i> or vice versa (Lioy et al., 2023). Similarly, the social vespid wasps <i>Paravespula germanica</i> and <i>P. vulgaris</i> show considerable spatial overlap with <i>V. velutina</i> in invaded areas and competition between native Vespidae and <i>V. velutina</i> is likely to be minimal in continental Europe (Carisio et al.,

Stage 2 - Detailed assessment: Section B - Establishment

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N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				<p>2020). The species richness of Vespidae in general is much lower in Ireland than the UK and continental Europe and no other <i>Vespa</i> species is present in Ireland, and there are fewer large vespids in Ireland compared to elsewhere in Europe (Edwards, 1997). This likely reflects the sub-optimal climatic conditions for these large thermophilic active insects in Ireland, and indicates that there would be very low competitive pressure from other vespids, or indeed other species, in Ireland should <i>V. velutina</i> succeed in establishing a population here.</p>
2.06	How likely is it that establishment will occur despite predators, parasites or pathogens already present in Ireland?	Very unlikely	MEDIUM	<p>i) Predators: The European Honey buzzard, <i>Pernis apivorus</i>, reportedly feed on Asian hornets in France. They can destroy hornet nests to take combs with larvae back to their offspring (Macià et al., 2019). Shrike, woodpeckers, magpies, honey buzzard and the European Bee-eater predate the European hornets and so may attack <i>V. velutina</i>. Of these, only the Greater Spotted Woodpecker (an Irish colonist since 2005) and magpies are resident in Ireland and only the latter is common. The European badger <i>Meles meles</i> (native to Ireland) will dig up wasp nests to feed on larvae and adults and thus could be a potential predator for ground nesting Asian hornets in Ireland. Hymenoptera make up a part of pine marten and stoat diet (Lynch and McCann, 2007), although there are no known reports of these mustelids consuming <i>V. velutina</i> in their invaded or native ranges. Predatory activity by native species would therefore likely be sporadic and not enough to deter <i>V. velutina</i> establishment.</p> <p>ii) Pathogens and Parasites The degree of infection in any nest depends on the proximity of the wasp nest to an abundant source of parasitic hosts (Villemant et al., 2015). In the native range of <i>V. velutina</i>, <i>Bareogonalos jezoensis</i> is a well-known parasite used in biological control methods. The species is not native to Europe. In France, the parasitoid dipteran <i>Conops</i></p>

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				<i>vesicularis</i> (also found in Ireland) and the nematode <i>Pheromermis vesparum</i> have been reported to be pathogens of Asian hornets on occasion, however the impact of these species on establishment is limited (Villemant et al., 2015; Darrouzet et al., 2015; Laurino et al., 2020). It is unlikely therefore that parasites or pathogens will prevent the establishment of <i>V.velutina</i> in Ireland.
2.07	How likely is it that establishment will occur despite existing management practices?	Unlikely	Medium	Currently, the Island of Ireland does not have an overall guiding policy for IAS management and the Republic of Ireland does not have an official <i>V. velutina</i> contingency plan in place. Northern Ireland does have a <i>V. velutina</i> Rapid Response Contingency Plan, which provides information on how management may move from monitoring to control if eradication can no longer be achieved. Ireland operates a Sentinel Apiary Programme, which acts as an early detection and warning system for <i>V. velutina</i> across Ireland. Higher concentration of traps are placed in major ports where introduction is most likely to occur and near honeybee apiaries which are known to attract hornets. It is recognised, however, that the Asian hornet could appear anywhere in the country due to the movement of goods and people.
2.08	How likely is it that management practices in Ireland will facilitate the establishment of the organism?	Unlikely	Medium	There are few management practices that would facilitate the establishment of <i>V.velutina</i> in Ireland, other than beekeeping. The high density of honeybees in invaded areas of Europe has likely facilitated the spread of <i>V. velutina</i> , as honeybees form a major part of their diet (Rome et al., 2011). However, Ireland has the lowest density of honeybee hives within Europe, outside of Scandinavia (De La Rua et al., 2009; Chauzat et al., 2013), reflecting both the sub-optimal climate for honeybees in Ireland and the low human population density. It is therefore unlikely that the beekeeping industry would facilitate the establishment of <i>V.velutina</i> in Ireland, as it may have done in Europe. In addition, industries that may provide carbohydrate- and protein-rich food for <i>V.velutina</i> , (facilitating invasion in Europe – Monceau et al., 2014) including commercial fruit growers, fruit processing factories, sea-food processing factories and industries that generate high food

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N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				waste, such as campsites and other tourism industries are much less common in Ireland than in invaded areas in Europe.
2.09	How likely is it that the biological characteristics of the organism would allow it to survive eradication campaigns in Ireland?	LIKELY	High	Once populations are established, Asian hornets have proven to be extremely difficult to eradicate. Five years after its introduction in France, eradication of the invasive species was no longer feasible there (Rortais et al., 2010). Islands, such as Majorca and Great Britain, have had initial success controlling introductions through rapid, early response measures (Budge et al., 2017; Leza et al., 2018). Based on the size of Ireland and its isolation from mainland Europe, eradication campaigns could be successful if implemented in the early stage of invasion. If an Asian hornet population was to go undetected it is unlikely that eradication would be possible at later stages of invasion.
2.10	How likely is it that the biological characteristics of the organism will facilitate its establishment?	Unlikely	High	Like many of the other social wasps of the family Vespidae, <i>V. velutina</i> is a highly adaptable generalist predator/detritivore, which can thrive in close proximity to human settlements, making its nests in buildings and feeding off carbohydrate- and protein-rich food associated with humans, including cultivated fruit, discarded food, fish and seafood processing waste, and cultivated honeybees (Monceau et al., 2014; Fournier et al., 2017). These traits have led to several species of the genera <i>Vespa</i> and <i>Vespula</i> having become invasive around the world. Ireland, however, has very little of suitable habitat/resources for successful establishment at present.
2.11	How likely is it that the organism's capacity to spread will facilitate its establishment?	Unlikely	HIGH	The species is vagile, with the ability to fly long distances in search of resources and suitable habitat. Sterile workers are typically found within 500-700 metres of their nest, but do not pose a threat of establishment. Queens and fertilised gynes can however fly much longer distances in search of a suitable nest site or hibernating spot (Robinet et al., 2017). The behaviour of quiescent overwintering of mated queens in locations and habitats often associated with humans, such as wood and wood products, agricultural and horticultural products and equipment, will likely facilitate its spread around the

Stage 2 - Detailed assessment: Section B - Establishment

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N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				country, due to human-mediated transport of these materials around the country.
2.12	How likely is it that the organism's adaptability will facilitate its establishment?	Unlikely	MEDIUM	As above for section 2.10. <i>V. velutina</i> is a highly adaptable species, and inhabits a wide range of environmental conditions, but – critically - it is unclear if the species can adapt to Ireland's oceanic climate, largely agricultural landscape and relatively low human urban density, which will impose energetic constraints on the species. Ireland has fewer vespids than continental Europe (and does not have <i>V. crabro</i>), and has one of the lowest honeybee hive densities in Europe (De La Rua et al., 2009; Chauzat et al., 2013). In the UK, transient <i>V. velutina</i> nests are reportedly much smaller than those in its invaded and native range, which may indicate that the UK has fewer resources or a less favourable climate (the two being related, of course) to facilitate large colonies.
2.13	How likely is it that the organism could establish despite low genetic diversity in the founder population?	HIGH	HIGH	This is very likely. In comparison to native <i>V. velutina</i> populations, invasive populations from France and Korea are less genetically diverse, indicating that <i>V. velutina</i> suffered a genetic bottleneck during these two independent introduction events (France and Korea). However, low genetic diversity has not prevented its expansion in Europe, Korea and Japan (Choi et al., 2013; Arca et al., 2015; Takeuchi et al., 2017). A single foundress, which mated with an estimated 3.6 haploid males, established the original population in France that quickly spread across western Europe (Arca et al., 2015; Dillane et al., 2022).
2.14	Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Ireland? If possible, specify the instances of invasion elsewhere in the justification box	Unlikely	Medium	As detailed earlier in the risk assessment (Stage 1: Q7 + Q8), <i>V. velutina</i> is a highly successful invader in western Europe, South Korea, and Japan. However, as detailed above, the risk of establishment in Ireland will be reduced by the oceanic climate, limiting both food resource availability and constraining the foraging abilities of <i>Vespa</i> on cool, humid cloudy days in summer, as for honeybees and other vespid wasps (Stabentheiner and Kovac, 2016). Further, the low percentage landcover of urban habitats, coupled with the low cultivated honeybee

Stage 2 - Detailed assessment: Section B - Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				density, will likely further reduce the likelihood of establishment of <i>V.vespa</i> in Ireland. However, changing human and land use patterns, and climate change in coming decades/centuries will likely increase the risk of <i>V.velutina</i> establishment in the future. Considerable uncertainty surrounds the potential of <i>V. velutina</i> to establish in Ireland in the future.
2.15	If the organism does not establish, then how likely is it that transient populations will continue to occur?	Very likely	HIGH	Transient populations are likely to re-occur in Ireland, due to the increase in movement of traded goods, vehicles and people. In particular, the UK leaving the EU has resulted in more direct transport routes from mainland Europe to Ireland. England has had a number of transient nests reported since 2017 when the first Asian hornet was reported in southern England. Genetic analysis of the UK nests to date has shown that each nest was the result of a separate incursion from the continent (Jones et al., 2020). These UK colonies are thought to have originated through human mediated transport of individual mated queen from invaded areas in Europe, via wood products and camping equipment (Budge et al., 2017). It is thus likely that similar transport pathways from invaded European regions into Ireland will result in <i>V. velutina</i> individuals continuing to arrive into Ireland. However, the risk of overwintering mated queens subsequently establishing secondary colonies over successive generations is likely lower than the UK (where this phenomenon has not yet been observed), due to the less favourable climate in Ireland.
2.16	Estimate the overall likelihood of establishment. Mention any key issues in the comments box	Unlikely	Medium	(1) <i>V.velutina</i> has successfully established in at least three non-native regions, including Japan, Korea and western Europe. Other vespidae wasps have also become invasive aliens around the world (Beggs et al., 2011). The invasive potential of the Vespidae may be largely attributed to the potential for fertilised overwintering queens to gain assisted passage from humans via a sheltered location in human goods, which may then be transported to new locations, coupled with the intrinsic ability of predatory social insects to readily adapt to

Stage 2 - Detailed assessment: Section B - Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				<p>novel surroundings and food resources (Beggs et al., 2011). The increasing trade in freighted goods and the movement of domestic vehicular traffic, between Ireland and invaded areas of Europe is likely to increase the risk of mated queens arriving into Ireland.</p> <p>(2) The risk of establishment of colonies is less than the risk of initial invasion. In common with other large vespine wasps, Asian hornets are large thermophilic and endothermic apex predators that require a lot of protein to rear their young (Rome et al., 2022), and need high temperatures to forage successfully. Temperature is the key environmental factor that controls foraging activity in vespine wasps (Canevazzi and Noll, 2011), and Ireland's mean daily summer temperatures are among the lowest in western Europe (Current Results). Faunal and floral species richness is lower in Ireland than the UK and continental Europe (Harrison, 2014), largely reflecting these climatic differences, rather than Ireland's insularity.</p> <p>(3) Food resources for hornets, in terms of honeybees, other invertebrate prey and human-associated food, is also likely much lower in Ireland, due both to climatic differences compared to Europe and the lower human density in Ireland.</p> <p>(4) The density of urban/peri-urban landscape which favours <i>V. velutina</i> in continental Europe is much lower in Ireland, with Dublin, Cork, Wexford and Waterford being the only large urban settlements along the eastern and southern coasts where the climate is more suitable for <i>Vespa velutina</i>.</p>

Stage 2 - Detailed assessment: Section C - Spread				
<i>This section evaluates the probability of spread of an organism within Ireland. Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.</i>				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
3.01	What area (given in % or 10km squares) in Ireland could the organism establish (0% - 10%, 11% - 33%, 34% - 67%, 68% - 90% or 91% - 100%)?	0-10%	Medium	Based on climate models above, only the eastern and southern coastal areas of Ireland would be suitable climatically for the establishment of <i>V. velutina</i> . Further, the urban/peri/urban habitat favoured by <i>V. velutina</i> on the continent (Fournier et al., 2017) is largely found in only four urban centres within this climatic zone – Cork, Waterford, Wexford and Dublin.
3.02	How important is the expected spread of this organism in Ireland by <u>natural</u> means (minimal, minor, moderate, major or massive)?	Minimal	Low	This species has a high potential dispersal rate in favoured habitats and climates. In general, within experimental trials a queen can fly up to 40km a day and gynes can fly up to 18 km a day (Robinet et al., 2017). However, it is now believed that foundresses may stay close to their original nest, resulting in a high nest density in any one area, following foundation of initial colony (Carvalho et al., 2020). Rate of spread differs by region, making it difficult to predict its expected rate of spread in Ireland. For example, in Portugal the species is spreading at a rate of 45 km/yr North to South, but 20km/yr from west to east (Verdasca et al., 2021). In Northern Italy (characterised by the Alp mountain range) spread is much slower at 18.3 km/yr, whereas in France rate of spread is 78 km/y (Robinet et al., 2017). Spread is likely impacted by several abiotic and biotic factors such as topography, climate and food/habitat availability. Suitable areas in Ireland for colonisation will be limited by climate, habitat and food resources and likely centred in southern and eastern coastal areas, particularly focused around urban centres.
3.03	How important is the expected spread of this organism in Ireland by <u>human assistance</u> (minimal, minor, moderate, major or massive)?	Moderate	High	Within Ireland, the spread of the species may be assisted by humans, as for when queens may stowaway on goods transported within Ireland, or in freight trucks carrying same. <i>V. velutina</i> has likely spread along roads in Portugal, showing that the species can be spread by human intervention within a region as well as between regions (Verdasca et al., 2021).
3.04	Within Ireland, how difficult would it be to contain the organism (minimal, minor, moderate, major or massive)?	MAJOR	MEDIUM	In the initial phases of invasion, early detection is crucial to managing outbreaks. Ireland's responsible government agencies already have an Invasive species rapid alert system and Sentinel Apiary Programme in

Stage 2 - Detailed assessment: Section C - Spread

This section evaluates the probability of spread of an organism within Ireland. Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				place to aid early detection of <i>V. velutina</i> . However, if once established in a region, it will be very difficult to contain the species due to their large number of offspring, ability to spread quickly and far, and ability to adapt to novel environments. In the case of the UK, where they have had transient invasions since 2017, the UK government has been very successful in tracking and eradicating nests, with the aid of beekeepers and the public reporting sightings. Majorca has also had great success controlling the species since 2015 (Leza et al., 2021), but the island is significantly smaller than Ireland.
3.05	What proportion (%) of the area in Ireland suitable for establishment, if any, has already been colonised by the organism?	N/A	N/A	To date, the species is not established in Ireland.
3.06	What proportion of the area in Ireland suitable for establishment, if any, do you expect to have been invaded by the organism five years from now (including any current presence)?	0-1%	Low	The species is not found in Ireland presently. To estimate the spread of the species in Ireland five years from now, it is most pertinent to refer to the invasion of <i>V. velutina</i> in the UK. Despite multiple incursions of mated queens from invaded areas in the continent, nests have all been located and destroyed. More importantly, nests were smaller than those found on the continent, containing fewer individual hornets, and none was thought to be founded by queens from previous nests established in England (ie none were found of succeeding generations), indicating that establishment is much slower in the UK than continental Europe, due to climatic constraints (Jones et al. 2020). The potential invasion of Ireland is very likely to be slower and less intense than in England.
3.07	What other timeframe would be appropriate to estimate any significant further spread of the organism (10, 20, 40, 80 or 160 years)? Please comment on why this timeframe is chosen.	10-160 year	Very low	The time frame for significant spread would have to start at the date of successful establishment of <i>V. velutina</i> in Ireland. As this has not yet occurred, the timeframe for further spread cannot be estimated with any certainty. This has not yet occurred. Should the hornet successfully arrive and establish in Ireland, however, four main factors may influence the estimation of <i>V. velutina</i> establishment and spread in Ireland – i) climate change, ii) landuse change (inc urbanisation) within

Stage 2 - Detailed assessment: Section C - Spread

This section evaluates the probability of spread of an organism within Ireland. Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				Ireland iii) changes in volume of freighted trade and vehicular traffic between Ireland and invaded areas of the continent and iv) adaptation by <i>V. velutina</i> to novel climates and habitats in its invaded range. The first three of these changes are occurring currently, the fourth may occur in the future. Keeling et al. (2017) modelled the hypothetical spread of <i>V. velutina</i> within the UK, and estimated that the hornet could colonise all of England within 20 years if nests were not located and destroyed immediately upon discovery. It is noteworthy that reproductive success of the hornets was modelled to drop to zero in northern England, assuming a linear decrease in the number of queens produced per nest with latitude, so greatly limiting the spread within Great Britain. The future colonisation of <i>V. velutina</i> Ireland is likely to be more similar to Scotland, which shares a similar oceanic climate with Ireland, than England. Jones (2020) found that <i>V. velutina</i> failed to establish nests in years succeeding the first year of a nest being established in an area, such that Keeling's models likely paint an unrealistic estimate of the potential spread of <i>V. velutina</i> within the UK.
3.08	In this timeframe, what proportion of the area (including any currently occupied areas) is likely to have been invaded by this organism?	0-1%	Low	As for answer 3.06. The spread of <i>V. velutina</i> in Ireland is likely to be constrained by climate, food resources and land use. Spread is most likely to occur in southern and eastern coastal areas, in proximity to urban settlements (mainly Cork, Watreford, Wexford and Dublin).
3.09	Based on the answers to questions on the potential for establishment and spread in Ireland, define the area endangered by the organism. Be as specific as possible. If available, provide a map showing the area most likely to be endangered.	southern and eastern coastal areas, in proximity to urban settlements (mainly Cork, Waterford, Wexford and Dublin)	Medium	As for answer 3.06. The spread of <i>V. velutina</i> in Ireland is likely to be constrained by climate, food resources and land use. Spread is most likely to occur in southern and eastern coastal areas, in proximity to urban settlements (mainly Cork, Waterford, Wexford and Dublin).

Stage 2 - Detailed assessment: Section C - Spread				
<i>This section evaluates the probability of spread of an organism within Ireland. Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.</i>				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
3.10	Estimate the overall potential for future spread for this organism in (very slowly, slowly, moderately, rapidly or very rapidly). Use the justification box to indicate any key issues .	Low	Medium	The overall potential for spread of this organism within Ireland is low. Modelling of the spread of the species within Great Britain (Keeling et al., 2017) has shown that reproductive success falls to zero in northern England due to climate-mediated effects. Jones (2020) found that <i>V. velutina</i> did not establish new nests in years succeeding initial colony founding, likely due to climatic constraints on reproduction and growth of colonies in the south of England. Taken together, these two lines of evidence point to <i>V. velutina</i> being able to colonise Ireland only slowly, if at all, under current climates and with current known ecology of <i>V. velutina</i> .

Stage 2 - Detailed assessment: Section D - Impact				
<i>This section evaluates the probability of impact of an organism within Ireland.</i>				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.01	How great is the economic loss caused by the organism within its global distribution (excluding Ireland), including the cost of any current management?	High	High	The economic loss caused by <i>V. velutina</i> can be grouped into three categories: losses to the honey industry, damage to fruit and vegetable crops and costs associated with monitoring and control measures, i) Loss of honey bee colonies and subsequent decrease in honey production. In parts of France, beekeepers have reported colony losses of between 30-50% (Laurino et al., 2020). Broadly speaking, if <i>V. velutina</i> caused a decline of 5% in honey production in France, it would have a yearly cost of €3.3 million (Barbet-Massin et al. 2020). ii) Damage to crops/fruit and subsequent decrease in sellable fruit. Hornets feed on ripening fruits that are high in sweet carbohydrates. Investigation into the extent of damage and cost to fruit production is underway. iii) Costs associated with monitoring and control measures, including removing nests. Nest destruction in France cost an estimated €23 million between 2005 to 2015 and is expected to increase to €11.9 million

Stage 2 - Detailed assessment: Section D - Impact				
<i>This section evaluates the probability of impact of an organism within Ireland.</i>				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				million per year if the species colonises all the suitable climates in France. In Japan and South Korea, yearly nest removal is estimated at €19.5 m and €11.9 m respectively (Barbet-Massin, 2020). Costs associated with implementing monitoring and educational campaigns if more difficult to quantify. More work is still needed to fully understand the economic impact of this species in its global range.
4.02	How great has the economic cost of the organism been in Ireland from the <u>time of introduction to the present</u> ? Exclude any costs associated with managing the organism from your answer.	N/A	N/A	To-date, the species is not known to be established in Ireland. Costs are limited to increased time by apiarists in vigilance and inspection measures for <i>V. velutina</i> , which are likely to be moderate.
4.03	How great is the economic cost of the organism likely to be in the <u>future</u> in Ireland? Exclude any costs associated with managing the organism from your answer.	Low	Medium	The future economic cost of the species in Ireland depends on the scale of establishment i.e., spread, abundance and nest density. Based on reported economic impacts in Europe, impacts to beekeeping and fruit production are of major concern. Overall, the impact of <i>V. velutina</i> on honey production could be great at a local and national scale depending on species spread and density. The Republic of Ireland has over 4,462 beekeepers and 27,040 bee colonies (Beekeeper Census report, 2019). The Department of Agriculture, Food and the Marine estimated honey production to be €4,296,000 in 2019, at 205 tonnes (Flanagan, 2020). The largest concentration of colonies are located in Cork (15%) and Dublin (11%), however beekeeping is generally well dispersed across the island. Overall, the impact of <i>V. velutina</i> on fruit production is less likely to be significant as horticulture represents less than 1% of agricultural land area in Ireland (6000ha) (DAFM, 2020). Protected crops (fruit grown in greenhouses and polytunnels) are the second largest fruit and vegetable output (446,000 tonnes) valued at €77.8 million in 2016. In comparison, outdoor fruit crops (the most vulnerable to <i>V. velutina</i> damage) only account for 4% of fruit and vegetable output, at 45,000 tonnes in 2016, valued at €11.1 m. Moreover, the number of outdoor fruit producers halved between 2007 to 2016 (DAFM, 2017).

Stage 2 - Detailed assessment: Section D - Impact				
<i>This section evaluates the probability of impact of an organism within Ireland.</i>				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.04	How great have the economic costs of managing this organism been in Ireland from the <u>time of introduction to the present</u> ?	N/A	N/A	To-date, the species is not known to be established in Ireland.
4.05	How great is the economic cost of managing this organism likely to be in the <u>future</u> in Ireland?	Low	Medium	The cost of managing <i>V. velutina</i> rises exponentially as the species spreads (Refer to 4.01). If the species becomes established, it will be extremely difficult and expensive to control due to the species life history traits (e.g., high dispersal rate, large number of reproductive offspring).
4.06	How important is environmental harm caused by the organism within its global distribution?	Important	High	<i>V. velutina</i> is an active predator of invertebrates other than honeybees, although the latter constitute the dominant prey item. It may also be a strong competitor with other species, notably other vespids, and through these two effects, it can have indirect impacts on pollination services (Lioy et al., 2022). Rojas-Nossa and Calviño-Cancela (2022) found that <i>V. velutina</i> had indirect negative impacts on pollination of a single plant species, through its impacts on the numbers and flower visitation behaviour of other insect pollinators. Carisio et al., (2022) however, found that <i>V. velutina</i> had little impact on the abundance of other vespid wasps in invaded areas. Rome et al. (2021) investigated the impact that <i>V. velutina</i> has on other animals in France. They estimated that a single hornet nest could consume some 11 kg of insect biomass in one season, targeting mostly locally abundant prey. The opportunistic predation on locally-abundant insects, however, suggested a minor impact on wild invertebrate species. Notably, suggested that attempts to manage this species using non-selective traps could have a much greater impact on wild and domesticated entomofauna than the hornet itself (Rome et al., 2021).
4.07	How important has the impact of the organism on biodiversity* been in	N/A	N/A	To-date, the species is not known to be established in Ireland.

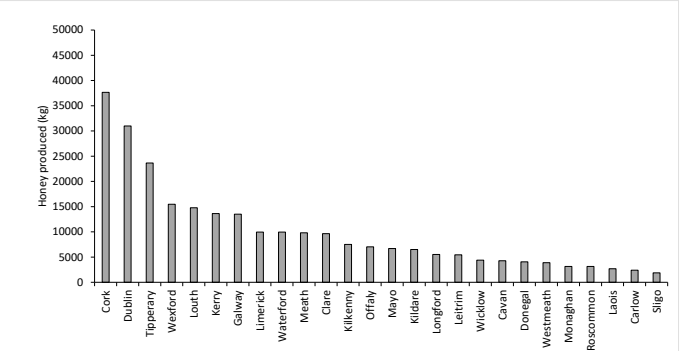
Stage 2 - Detailed assessment: Section D - Impact				
<i>This section evaluates the probability of impact of an organism within Ireland.</i>				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
	Ireland from the time of introduction to the present? *e.g. decline in native species, changes in community structure, hybridisation			
4.08	How important is the impact of the organism on biodiversity likely to be in the <u>future</u> in Ireland?	Somewhat important	Low	This is very difficult to estimate, as there is no information on the impact of <i>V. velutina</i> on biodiversity in Ireland, nor in the UK, the nearest biogeographic zone to Ireland. However, given the restricted likely spatial extent of any invasion of the Asian hornet in Ireland, the low potential abundance in any one area, and the lower insect biodiversity in Ireland in general, it is likely that the future impact on biodiversity is low.
4.09	How important has alteration of ecosystem function* caused by the organism been in Ireland from the time of introduction to the present? *e.g. habitat change, nutrient cycling, trophic interactions	N/A	N/A	To-date, the species is not known to be established in Ireland.
4.10	How important is alteration of ecosystem function caused by the organism likely to be in Ireland in the <u>future</u> ?	Low	Low	A potential reduction in pollination services may be observed in the future under a scenario where <i>V. velutina</i> (a) becomes established in Ireland (b) achieves a high population density (c) preys heavily on honeybees AND native insect pollinators. Further research will be needed to establish any potential effect on ecosystem function, both in Ireland, the UK and continental invaded countries, before this question can be answered.
4.11	How important has decline in conservation status* caused by the organism been in Ireland from the time of introduction to the present? *e.g. sites of nature conservation value, WFD classification, etc.	N/A	N/A	To-date, the species is not known to be established in Ireland.
4.12	How important is decline in conservation status caused by the	Possible	MEDIUM	Possible decline in conservation status would be as a result of a reduction in endangered pollinators, or plants depending on same.

Stage 2 - Detailed assessment: Section D - Impact				
<i>This section evaluates the probability of impact of an organism within Ireland.</i>				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
	organism likely to be in the <u>future</u> in Ireland?			
4.13	How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within its global distribution?	Potentially high	HIGH	Asian hornets favour urban and semi-urban environments (Fournier et al., 2017). Primary nests have been reported in both man-made structures such as garages, light fixtures, and bird boxes, whereas secondary nests are typically found in more predator-free locations such as in tall trees, as well as underground. Hornets also target apiaries for hunting. As such, the species has close proximity to human activity (Villemant et al., 2011). Hornets are equipped with highly poisonous venoms that they use to overcome prey. In extreme cases, envenomation of <i>V. velutina</i> can induce severe allergic reactions or toxic reactions resulting in organ failure and death, however it is unusual for stings to cause fatality (Liu et al., 2015); death occurs rarely, when victims receive multiple stings or as a result of anaphylactic shock (Lubrano et al., 1985; Korman et al., 1990; Vetter et al., 1999; Kularatne et al., 2003, Lee et al., 2005). Human fatalities from hornet stings have been reported in European countries but often don't distinguish between species (Feas,2020). <i>V. velutina</i> is not believed to be outwardly aggressive, only when they perceive a threat to the nest (Villemant et al., 2011).
4.14	How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within Ireland?	N/A	N/A	To-date, the species is not known to be established in Ireland. Honey production is small-scale in Ireland compared to other EU countries and so the species is more likely to negatively impact amateur/hobbyist beekeepers.
4.15	How important is it that genetic traits of the organism could be carried to other organisms / species, modifying their genetic nature and making their economic, environmental or social effects more serious?	MINIMAL	HIGH	This species will not breed with any other species presently found in Ireland.

Stage 2 - Detailed assessment: Section D - Impact				
<i>This section evaluates the probability of impact of an organism within Ireland.</i>				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.16	How important is the impact of the organism as food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)?	Minimal	Medium	That have been no reported instances, as far as we are aware of <i>V.velutina</i> having an impact on other species indirectly, as food, host, symbiont or disease vector, in invaded areas of Europe.
4.17	How important might other impacts not already covered by previous questions be resulting from introduction of the organism? Specify in the justification box.	N/A	Medium	We are not aware of other impacts not already covered by previous questions
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 Ireland?	Low	High	See above 2.06. It is unlikely that predators, parasites or pathogens will prevent the establishment of <i>V.velutina</i> in Ireland, nor is it likely that any natural biological control agent would limit its impact in Ireland.
4.19	Indicate any parts of where economic, environmental and social impacts are particularly likely to occur. Provide as much detail as possible, where possible include a map showing vulnerable areas.	N/A	Medium	<p>The economic, environmental and social impacts of <i>V.velutina</i>, should it successively establish in Ireland, would largely be restricted to those occurring on the honeybee industry, and possibly the soft fruit industry. <i>V.velutina</i> can have significant economic impacts on honeybees and honey production in invaded areas of Europe (Laurino et al., 2019; Liroy et al., 2022) and may impact soft fruit production via the potential risk of harm (stinging) to people working in the industry. Strawberries and raspberries are the two most commercially important soft fruit species, but most of the production is under protective cover, which is likely to reduce the impact of <i>V.velutina</i> on fruit workers.</p> <p>Honey production is heavily focused in Counties Cork, Dublin and Tipperary Ireland, reflecting both climatic conditions favourable for honeybees, and human population density (Beekeeper Census, 2019, Bord Bia) (Fig. 10 below). Soft fruit production is concentrated in counties Dublin and Wexford (Bord Bia).</p>

Stage 2 - Detailed assessment: Section D - Impact

This section evaluates the probability of impact of an organism within Ireland.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				<p>Both honey and soft fruit production is centred in southern and eastern coastal regions in Ireland, reflecting both climatic conditions and human population density. These regions are also likely to be most likely to be colonised by a successful <i>V. velutina</i> invasion, for the same reasons.</p>  <p>Fig. 10. Honey production (kg) per county in Ireland, 2019 (data taken from Beekeeper Census 2019, Bord Bia)</p>
4.20	Estimate the overall potential impact of this organism in Ireland. Use the justification box to indicate any key issues.	Low-medium impact	Medium	<p>The overall impact of <i>V. velutina</i> is likely to be lower than Great Britain and continental Europe for the following reasons:</p> <ol style="list-style-type: none"> 1) As above, the likelihood of a successful establishment of <i>V. velutina</i> is low in Ireland, due to climatic constraints, the lower availability of food (insect prey, discarded human food and flowers/fruit) resources and relative paucity of urban/peri-urban habitat. 2) Should <i>V. velutina</i> establish in Ireland, the geographic spread will likely be limited to southern and eastern coastal regions, where climate is somewhat more favourable for the hornet and where there is a higher density of food production and urban habitat.

Stage 2 - Detailed assessment: Section D - Impact				
<i>This section evaluates the probability of impact of an organism within Ireland.</i>				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				<p>3) In these regions more likely to be colonised by <i>V.velutina</i>, density and overall abundance of hornets is also likely to be lower than in invaded areas of the continent. Altitude imposes a climatic constraint on the distribution and density of <i>V. velutina</i> in invaded regions of Europe (Lioy et al., 2019), and sub-optimal climates for the species, such as that found in Ireland, is also likely to reduce densities, and activities of <i>V. velutina</i>, relative to ontinental invaded areas.</p> <p>4) The relatively (likely) low density, spread, activity and local abundance of <i>V.velutina</i> in Ireland, compared to the continent is also therefore likely to reduce concomitant impacts on native species that are naturally adapted to the Irish climate and habitat.</p> <p>5) Honeybee production is lower in Ireland than all other continental countries, other than Scandinavia. The economic losses nationally are thus likely to be lower in Ireland, should <i>V.velutina</i> successfully colonise and establish here.</p>

Stage 2 - Detailed assessment: Section E - Conclusion				
<i>This section requires the assessor to provide a score for the overall risk posed by an organism, taking into account previous answers to entry, establishment, spread and impact questions.</i>				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
5.01	Estimate the overall risk of this organism in Ireland. Noting answers given in 1.11, 2.16, 3.10 & 4.20	Low	Medium	<p>1. Entry of <i>V.velutina</i> into Ireland is highly likely via accidental introduction by human assisted means, from invaded areas of Europe, or (less likely) its native range in East Asia.</p> <p>2. Future accidental introductions may likely be of quiescent overwintering queen, which could be foundresses of future Irish populations.</p> <p>3. Climatic constraints have been shown to be a strong controlling factor in the potential spread, abundance and long-term invasion success of <i>V. velutina</i> in Great Britain</p>

				<p>(Keeling et al., 2017; Jones et al., 2021). Ireland is likely to be markedly sub-optimal for the Asian hornet compared to England, and is thus less likely to be successfully invaded by this species than southern England.</p> <p>4. Despite the European hornet, <i>V. crabro</i>, being native to the UK, it does not occur in Ireland, along with many other vespids found in the UK, due to climatic constraints. This ecological pattern of the distribution of European vespids is further evidence to the lower risk of <i>V. velutina</i> invasion into Ireland compared to the UK and continental Europe.</p> <p>5. In conclusion, the risk of <i>V. velutina</i> individuals, including mated quiescent queens, being introduced into Ireland via human means is high over coming decades. The risk of successful establishment of a <i>V. velutina</i> population is however much lower. Further, in the event of a population of <i>V. velutina</i> establishing in Ireland, the likely geographic spread, abundance and overall environmental, social and economic impact of the species is likely to be much lower than in invaded areas of continental Europe.</p>
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Stage 2 - Detailed assessment: Section F – Additional questions				
<i>This section is used to gather information about the potential effects of climate change on the risk posed by an organism. It is also an opportunity for the risk assessor to highlight high priority research that could help improve the risk assessment.</i>				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
6.01	What aspects of climate change, if any, are most likely to affect the risk assessment for this organism?	Pattern of temperature, wind and rainfall	High	High spring temperatures, coupled with low rainfall are associated with reproductive success in large social wasps and hornets in Europe (Nadolski, 2013). Such conditions favour the establishment of primary nests by overwintering queens. It is noteworthy that the primary nests of <i>V. velutina</i> in its invaded range in Europe, along with other large social wasps, are most often found in buildings in urban and peri-urban areas, which protects nests from inclement weather (Diéguez-Antón et al., 2022). In general, the multiple aspects of climate change are likely to increase the rate of establishment of alien terrestrial arthropods in Great Britain (the nearest geographic land mass to Ireland, and also the region with the closest climate and habitat to

Stage 2 - Detailed assessment: Section F – Additional questions

This section is used to gather information about the potential effects of climate change on the risk posed by an organism. It is also an opportunity for the risk assessor to highlight high priority research that could help improve the risk assessment.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				Ireland), as a result of their physiological dependence on temperature, high dispersal rate and their strong association with trade as well as commensal relationships with human environments (Hulme, 2017). However, modelling using an ensemble of climate models indicates that the geographic climatic suitability for <i>V. velutina</i> is not expected to change within Great Britain (and, by extension, into Ireland), by 2050, under likely climate change scenarios (Hulme, 2017).
6.02	What is the likely timeframe for such changes (5, 10, 15, 20, 50 or 100 years)?			Refer to Question 6.01
6.03	What aspects of the risk assessment are most likely to change as a result of climate change			Refer to Question 6.01
6.04	If there is any research that would significantly strengthen confidence in the risk assessment, please note this here. If more than one research area is provided, please list in order of priority.			Further research is clearly needed to strengthen confidence in this risk assessment of the likelihood of <i>V. velutina</i> establishing in Ireland. This would largely include empirical research into the physiological tolerance of <i>V. velutina</i> to realistic, ecologically-relevant, climate – and weather – conditions in Ireland. In addition, the likely change in abundance of <i>V. velutina</i> 's major food resources under the same climate scenarios should also be explored.

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