Could *Vespa velutina nigrithorax* be included in the World Organisation for Animal Health list of diseases, infections and infestations?

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Summary

Vespa velutina nigrithorax is an invasive alien organism that has raised concerns in all beekeeping communities of invaded countries including the Republic of Korea, European countries and Japan. Known also as

the yellow-legged hornet (or the 'Asian hornet'), it is native to Northern India, Eastern Nepal, Bhutan and the People's Republic of China. Given its climatic and biological characteristics and the effects of climate change, some coastal areas of North America, Argentina, South Africa, Australia and New Zealand are also susceptible to invasion. *Vespa velutina nigrithorax* notably affects managed honey bee colonies by predation on foragers and causing a reduction in the collection of food resources. Being a generalist predator, the yellow-legged hornet also preys on other managed and wild pollinators, and therefore its impacts are not limited to the beekeeping sector but also represent a biodiversity concern.

The purpose of this paper is to provide an assessment of *V. v. nigrithorax* against the four criteria established in Chapter 1.2. of the World Organisation for Animal Health (OIE) *Terrestrial Animal Health Code* for the inclusion of a disease, infection or infestation in the OIE list. The work was requested by the OIE Scientific Commission for Animal Diseases and presented to this Commission and to the OIE Terrestrial Animal Health Standards Commission in September 2017. Owing to the lack of effective measures to prevent its spread, the fact that its legal situation in some countries is under the mandate of environmental authorities rather than Veterinary Services, and because it is not considered a disease or parasite, *V. v. nigrithorax* is not currently being proposed for inclusion in the OIE list. At the end of the text, the statements from the two commissions are included and discussed.

Keywords

Assessment – Honey bee – Invasive alien species – OIE criteria – OIE list – Pollinators – Predator – Threat – *Vespa velutina nigrithorax* – Yellow-legged hornet.

Introduction

Honey bees are currently facing numerous threats that include infectious agents (viruses, bacteria, fungi and parasites), pesticides and nutritional stress due to the diminution of foraging resources available

(1, 2, 3, 4). Free-living predators can also constitute an important stress factor for bees. One example is the small hive beetle *Aethina tumida*, which may be considered a parasite when viewing the bee colony as a super-organism (5, 6, 7, 8). More recently, another arthropod predator has been added to the list of *Apis mellifera* stressors and health risks for international trade: *Vespa velutina nigrithorax*.

The World Organisation for Animal Health (OIE) has as a primary aim the improvement of animal health, animal welfare and veterinary public health worldwide. To support Member Countries in preventing the transboundary spread of important animal diseases, including zoonoses, the OIE created a list of notifiable terrestrial and aquatic animal diseases, infections or infestations. In order to be included in the list, a pathogenic agent has to fulfil four criteria, which are published in Chapter 1.2. of the OIE *Terrestrial and Aquatic Animal Health Codes*. Briefly, in the case of terrestrial animals, the criteria refer to the international (but not ubiquitous) spread of the pathogenic agent, the existence of reliable means of detection and diagnosis, a precise case definition available, and its relevant impact on the health of humans, domestic animals or wildlife (9).

Once a disease, infection or infestation is included in the list, Member Countries shall provide periodic or immediate information to the OIE Headquarters, in Paris, France (10), enhancing the transparency of the situation at international level. The inclusion also stimulates the development of standards for harmonising the detection, prevention and control of the pathogenic agent, and for safe international trade in animals and their products, along with the establishment of world reference centres of scientific expertise.

Vespa velutina nigrithorax was first observed outside its native range in 2003 in the Republic of Korea, and since then it has continued to spread throughout Asia and Europe, affecting an increasing number of honey bee colonies (see Criterion 1 in the assessment section). In light of the current situation, in February 2017 the OIE Scientific Commission for Animal Diseases requested an assessment, the aim being to gather more information on *V. v. nigrithorax* and especially to

evaluate whether it fulfilled the criteria for being included in the OIE list of diseases, infections and infestations. The document was presented to this Commission and to the OIE Terrestrial Animal Health Standards Commission in September 2017. The objective of this paper is to present the above-mentioned assessment, including background on the biology and behaviour of the yellow-legged hornet, and to discuss the statements of the two OIE Commissions made after its consideration.

Background

The yellow-legged hornet *Vespa velutina nigrithorax* (also called the 'Asian hornet') is one of the known subspecies of *Vespa velutina* Lepeletier (genus *Vespa*, family Vespidae and order Hymenoptera) (11, 12, 13). It is between 17 and 32 mm long, and the head is black with an orange–yellow face. The thorax is velvety black/dark brown, and the brown abdominal segments are bordered dorsally with a fine yellow band except for the 4th segment, which is almost entirely orange–yellow. The legs are brown with yellow ends and the wings are brownish hyaline. *Vespa velutina nigrithorax* can be clearly differentiated from other species of hornets and wasps in Europe because of its unique dark colour pattern, which is mostly black (13) (Fig. 1).

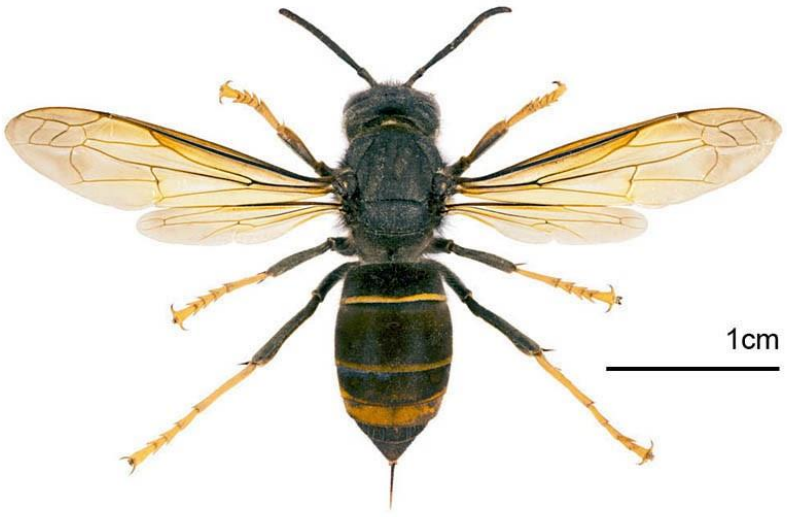

Fig. 1.1 (dorsal view)

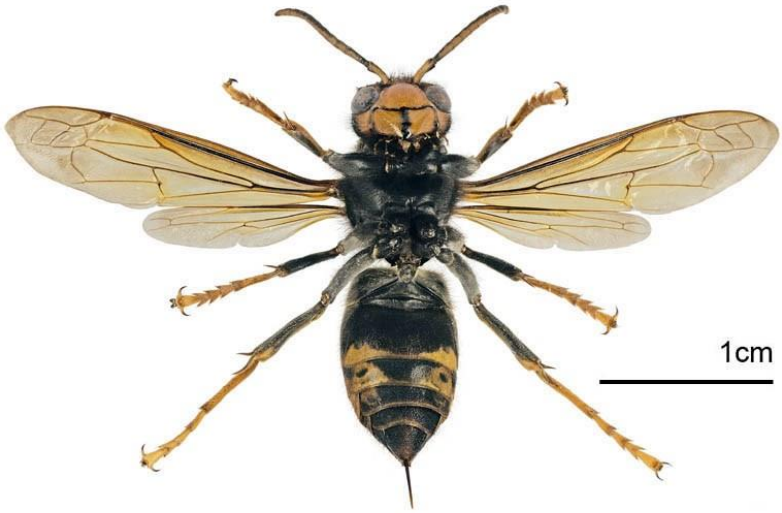

Fig. 1.2 (ventral view)

Fig. 1

Dorsal (above) and ventral (below) views of *Vespa velutina nigrithorax*

Source: © Toulouse Museum / Didier Descouens – 2013 - CC BY- SA 4.0, with permission

Besides the males, two female castes can be distinguished: the queen and workers (infertile females). Males lack a sting apparatus and have longer and thicker antennae. Discrimination between queen and workers is more difficult, although inside the colony the laying queen can be recognised by her distended abdomen and at the end of the season by her damaged wings (13, 14).

Within its native range, *V. velutina* lives essentially in the forests of tropical and subtropical regions throughout most of Indochina, Indonesia and Chinese Taipei (15). The subspecies *V. v. nigrithorax* specifically can be found in Northern India, Eastern Nepal, Bhutan and the People's Republic of China (China) (16). In France, *V. v. nigrithorax* seems to take advantage of river valleys and major roads for spreading, but tends to avoid pure stands of conifers. *Vespa velutina nigrithorax* builds its nest by mixing plant fibres with water

and saliva, therefore easy access to suitable wood fibres and water sources is crucial (16, 17, 18).

In tropical regions *V. velutina* colonies can be found in all stages of development at any given time of the year, whereas in temperate zones colonies have an annual cycle, with newly produced queens overwintering in a diapause state (19). The development cycle in temperate regions involves the following sequence: a mated queen, known as the foundress, emerges during the first warm days of spring and quickly builds a small round nest in an enclosed and protected place, to raise the first generation of female workers (Fig. 2). Four to six weeks later, the first batch of workers emerges (16). As the population grows, the majority of colonies abandon the primary nest, because it is either in a confined site or too close to the ground, to build a new, much larger secondary nest, spherical to pear-shaped with a small side entrance, in an open space (in more than 70% of cases in branches of trees over 10 m tall [20]) (Fig. 2).

Fig. 2.1

Fig. 2.2

Fig. 2.3

Fig. 2

Primary (Fig. 2.1) and secondary (Figs 2.2 and 2.3) nests of *Vespa velutina nigrithorax*

Source: Anses (French Agency for Food, Environmental and Occupational Health & Safety), Sophia Antipolis Laboratory (Figs 2.1 and 2.3); © Quentin Rome / MNHN– CC 4.0 : BY-NC-SA (Fig. 2.2)

Gradually, the queen becomes confined to egg laying and the workers take over the duties of foraging and nest building. Throughout the summer the colony and nest undergo a period of expansion until the beginning of autumn, when the colony can reach a maximum size of 1,000–2,000 workers, with hundreds to thousands of new queens and drones (15, 16). At this stage, the nest can be very large (approximately 60 × 80 cm). After mating, new foundresses disperse, and individually or in clusters of two to three individuals find a suitable location, small and dark (e.g. under the bark of trees, stones or leaf litter) to go into hibernation during the winter months. During this hibernation period the mortality among foundresses is high (21). The queen lives for about one year and usually dies before her sexual offspring emerge, whereas the rest of the colony dies of starvation at the onset of winter (13, 16). The secondary nest is then empty and inactive, and will never be used again, although the same nest sites can be used year after year (22, 23). Finally, the fertilised foundresses will emerge the following spring and initiate new colonies, starting the cycle again (14).

Carbohydrates are the main source of energy for adult vespids, and are provided by flower nectar, tree sap or ripening fruits (14). The brood, on the other hand, requires animal proteins for its development. In order to provide the larvae with the necessary protein requirements, *V. velutina* preys on a diverse group of arthropods, including honey bees, but also feeds on carrion as well as waste from the stalls of butchers and fishmongers (16, 17). *Vespa velutina* is much faster and more agile than other hornet species in Europe (13). While other vespid species land on a hive and grab bees that try and attack them, the hunting behaviour of *V. velutina* consists of catching bees in flight: it hovers over the entrance to a hive at a distance of 20–40 cm and swoops

down, trying repeatedly to catch foraging bees (13) (Fig. 3). Once a prey organism has been captured, *V. velutina* usually flies to a tree branch, from which it hangs while it cuts off the head, wings, legs and abdomen, keeping only the prey thorax that contains the nutritious flight muscles for feeding the larvae back in the nest. The foraging range is still uncertain, but different experiments suggest that queens are able to fly up to 30–40 km per day (17, 24, 25).

Fig. 3

Photo showing the hunting behaviour of *Vespa velutina nigrithorax* and the size difference between the hornets and honeybee workers

Source: Anses (French Agency for Food, Environmental and Occupational Health & Safety), Sophia Antipolis Laboratory

Assessment against the World Organisation for Animal Health criteria for listing a disease/infection/infestation

The following section is structured as follows: for each of the four criteria detailed in Chapter 1.2. of the OIE *Terrestrial Animal Health Code* for the inclusion of a disease, infection or infestation in the OIE

list (9), a corresponding rationale for the specific case of *V. v. nigrithorax* is provided. All the information in the criteria below has been extracted from the relevant references cited in this review.

Criterion 1: International spread of the pathogenic agent (via live animals or their products, vectors or fomites) has been proven

International spread has indeed been proven; below is presented a chronological list of countries affected by *V. v nigrithorax*:

– Republic of Korea (2003); France (2004); Spain (2010); Portugal (2011); Belgium (observed in 2011, and again in 2016–2017 [26]); Italy (2012); Tsushima island (2012) and Kyushu island (2015–2016 [27, 28]), Japan; south-west Germany (2014); southern Great Britain (2016 [29, 30]); Fregiécourt, Switzerland (2017); the Netherlands (2017 [31, 32]) (Fig. 4).

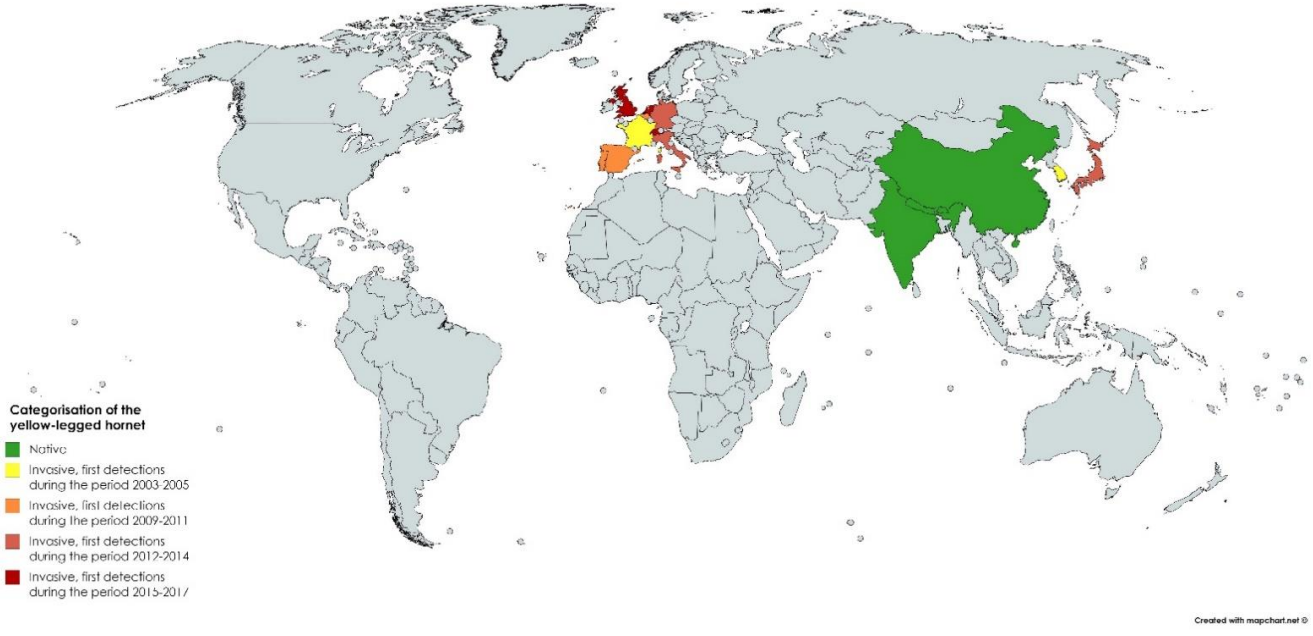

Fig. 4

Current distribution of *Vespa velutina nigrithorax* (as of 2018)

The categorisation of *Vespa velutina nigrithorax* is at country level, no differences are made at regional level

The introduction of *V. v. nigrithorax* to the first countries affected (Republic of Korea and France) was accidental, probably through trade with China [14, 17, 18]. In Japan it is also thought that the introduction of this hornet was through trade, with the Republic of Korea. However, for most European countries affected, the entry pathway was presumably by natural spread from France. In fact, different studies have shown that *V. v. nigrithorax* is spreading at a rate of 10–20 km per year in the Republic of Korea (15), where six other hornet species are present, and at 60 km per year in Europe (33), where there are only two species: *Vespa crabro* and *Vespa orientalis* (although the latter species is restricted to Mediterranean areas) (14, 16). Moreover, fertilised queens can survive long periods of time in hibernation, making *V. v. nigrithorax* an ideal candidate for long distance transport in shipments of goods (13).

Predictive models (34, 35) taking into account the effects of climate change point to the most suitable areas for invasion by *V. v. nigrithorax*:

- In Europe, the areas along the Atlantic coast, the Mediterranean coast and the southern coasts of the Black and Caspian Seas, however the south-eastern part of the Mediterranean basin appears less suitable
- Outside Europe, the eastern and western coasts of North America, southern Argentina, the south coasts of South Africa and of Australia, and New Zealand.

In addition, another recent predictive model (36) demonstrated the high suitability of anthropised environments for the hornet. This finding could be explained by the protection that human constructions offer for building primary nests and the availability of nutritional resources such as food scraps found in bins, markets, and butchers' and fishmongers' shops.

Criterion 2: At least one country has demonstrated freedom or impending freedom from the disease, infection or infestation in populations of susceptible animals, based on the provisions of Chapter 1.4.

According to the published data, in addition to the European and Asian countries not mentioned under Criterion 1, *V. v. nigrithorax* has not been reported in any country in the Americas, Africa and Oceania.

Criterion 3: Reliable means of detection and diagnosis exist and a precise case definition is available to clearly identify cases and allow them to be distinguished from other diseases, infections or infestations

From its physical appearance, hunting behaviour and nest characteristics *V. v. nigrithorax* can be clearly differentiated from other species of hornets and wasps (Figs 1 and 2). Detection and diagnosis are made through direct observation and morphological identification: in apiaries, *V. v. nigrithorax* specimens stand out as dark spots in front of beehives at a distance of 20–40 cm and, as a consequence, many honey bee workers remain at the hive entrance without taking flight. Predatory behaviour can be observed as well. Apart from direct observation, if their presence is suspected the hornets can be detected using traps (14, 15). Finally, *V. v. nigrithorax* can also be recognised if their nests are found, although spotting them is often difficult because they remain hidden until leaf fall in autumn and winter reveals their position. For a more exact diagnosis, specimens must be collected and submitted to laboratories, where accredited morphological identification methods exist.

Criterion 4

a) Natural transmission to humans has been proven, and human infection is associated with severe consequences

As mentioned, *V. v. nigrithorax* is adapted to urban and peri-urban areas, and therefore it may become a public nuisance in some populated areas because of its size and appearance, and the occasional presence of

extremely large nests. In addition, the hornet can be dangerous for humans by inducing a life-threatening allergic reaction or inflicting multiple stings.

Within its native range this subspecies is considered particularly aggressive with little provocation. However, in Europe *V. v. nigrithorax* is not aggressive when chasing or foraging, and severe attacks occur only when colonies are disturbed.

OR

b) The disease has been shown to have a significant impact on the health of domestic animals at the level of a country or a zone, taking into account the occurrence and severity of the clinical signs, including direct production losses and mortality

The presence and attacks of *V. v. nigrithorax* can lead to death of honey bee colonies. A single hornet can catch up to 25–50 bees per day, and if the entrance of the hive is not sufficiently narrow they attempt to enter the nest, especially at the end of the season when their energy requirements are higher (13). After attacking the honey bee guards, the hornets can remove the brood and take the honey reserves. In addition to direct predation, the presence of *V. v. nigrithorax* in front of a hive stresses honey bees and decreases their foraging activity, thus reducing pollen and nectar collection, along with water and propolis foraging. This reduction in foraging is particularly important in late summer and early autumn when long-lived winter bees are raised and when the colony needs to store sufficient food supplies for overwintering (16, 23).

The prey spectrum of *V. velutina* is varied, but the analysis of flesh pellets from a few nests in France indicated that bees (Apidae) represented one-third to two-thirds of their dietary protein. The actual proportion of protein from bees was suggested to depend on the nest location and environment (14). For the hornets, apiaries, where hives (with up to 50,000 bees each) are gathered in a relatively small area, represent an abundant, easy, and accessible source of food.

Not all honey bee species are equally susceptible to *V. velutina*. *Apis cerana*, which has co-evolved with *V. velutina*, shows a spectrum of defensive strategies such as heat-balling, wing shimmering, increased guard bees and changed flying behaviour (22). Nevertheless, despite these defence mechanisms, *V. velutina* is able to destroy up to 30% of a colony population of *A. cerana* (13). The western honey bee *Apis mellifera*, in contrast, does not exhibit these defensive mechanisms, or when displayed they are less effective (14, 17, 22). This means that *A. mellifera*, present in almost every country in the world, is much more vulnerable to *V. velutina* attacks.

Furthermore, the honey bee viruses sacbrood virus (SBV), black queen cell virus (BQCV) and deformed wing virus (DWV) have been detected in *V. v. nigrithorax* adults, larvae and pupae (37), and more recently the Moku virus was also detected in some specimens in Belgium (38). Although the role of the hornet as reservoir and disseminator of honey bee pathogens is still not clear, the findings create an additional concern for honey bee populations.

As a consequence, *V. velutina*, and specifically *V. v. nigrithorax*, has impacts at two levels: on the beekeeping sector and on pollination:

– Beekeeping sector: currently, the impacts on beekeeping have been assessed only by beekeepers' organisations, and therefore the information should be interpreted carefully. In south-west France, *V. v. nigrithorax* has destroyed and weakened hives. Weakened colonies were subsequently more vulnerable to diseases, infestations, robbing and collapse during winter. Although there are few quantitative data available, the impact of this hornet on the beekeeping sector is undeniable. Proof of these concerns is provided by the many different initiatives set up in affected countries to combat this hornet species:

  - In Europe it is noteworthy to mention that the European Union (EU) has included *V. v. nigrithorax* in the list of invasive alien species of Union concern. Furthermore, some National Apiculture Programmes co-funded by the EU and the 28 Member States (with a total budget of €216 million

for the period 2017–2019) include lines of funding for the surveillance and control of the yellow-legged hornet (39, 40, 41);

- France: Association Action Anti Frelon Asiatique (AAAFA). *Vespa velutina nigrithorax* is classified as a sanitary hazard for *A. mellifera* in French regulations. A national strategy of prevention, surveillance and control has been established involving different groups within the beekeeping sector, research and technical institutes, and the national museum of natural history;

- Italy: Project Life STOP VESPA (LIFE14/NAT/IT/001128 STOPVESPA 'Spatial containment of *Vespa velutina* in Italy and establishment of an Early Warning and Rapid Response System') (42), and Project Stop Velutina (monitoring and management activities) (43);

- Spain: Stop *Vespa velutina* (platform to raise awareness), and Vespaap (online georeferencing of *V. v. nigrithorax* nests and specimens) (44);

- Portugal: Platform SOS–Vespa (online georeferencing of *V. v. nigrithorax* nests) (45).

– Pollination: there is no accurate assessment yet of the consequences of *V. v. nigrithorax* predation on pollination. However, in economic terms, the value of pollinators in the United Kingdom (UK) alone is estimated at £440 million per year (46). Worldwide, the amount rises to €153 billion (47).

In France, an assessment of health hazards for honey bees was conducted in 2014 by the French Agency for Food, Environment and Occupational Health and Safety (Anses) (48). Taking into account the impacts on public health, the economy, the environment and society, as well as the availability and viability of disease control measures, *V. v. nigrithorax* was ranked third out of the 18 hazards present in the French territory. Therefore, the hornet comes before *Melissococcus*

plutonius and *Acarapis woodi*, two of the six pathogens listed by the OIE, and only just after *Paenibacillus larvae* (first), and *Varroa destructor* (second).

OR

c) The disease has been shown to, or scientific evidence indicates that it would, have a significant impact on the health of wildlife taking into account the occurrence and severity of the clinical signs, including direct economic losses and mortality, and any threat to the viability of a wildlife population

As mentioned above, although hives represent an easy and abundant source of food, *V. v. nigrithorax* can attack a broad range of prey, mainly Hymenoptera, including bumble bees, other wild bees and wasps, and Diptera, such as hoverflies and houseflies (13, 16). As some of these species are wild pollinators, *V. v. nigrithorax* could pose additional risks and have further negative effects on crop production as well as on biodiversity (24, 28).

Moreover, *V. v. nigrithorax* has displaced native hornet species. In some regions of the Republic of Korea, for instance, it has become one of the most abundant species, causing a drop in *Vespa simillina* (20%) and *Vespa mandarinia* (10%) populations (15). In Europe, the effect on the native *V. crabro* populations is still not known (14).

The World Organisation for Animal Health Commissions statement and discussion

As mentioned in the introduction, this assessment was initially requested by the OIE Scientific Commission for Animal Diseases in February 2017 and presented to this Commission and to the OIE Terrestrial Animal Health Standards Commission in September 2017. After consideration, the final conclusion was that *V. v. nigrithorax* cannot be proposed for inclusion in the OIE list of diseases, infections and infestations for the following reasons:

– its nature as an invasive alien organism rather than a disease or parasite

– its legal situation in some countries, where it is more likely to be under the responsibility of environmental authorities rather than Veterinary Services, and finally

– the lack of useful control measures to support Member Countries in preventing its transboundary spread, which is the primary reason why pathogenic agents are listed.

The full report can be consulted on the OIE website (www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/A_TAHSC_Sept__2017_Report.pdf [p. 40]). While it is indeed true that *V. v. nigrithorax* is not a disease, it is apposite to remember the definition of the term 'infestation' in the OIE *Terrestrial Animal Health Code*; as of 2018, it 'means the external invasion or colonisation of animals or their immediate surroundings by arthropods, which may cause clinical signs or are potential vectors of pathogenic agents'. Therefore, *V. v. nigrithorax* could fall under the term 'infestation' if the specimens invade a colony of honey bees, removing the brood and taking the honey reserves. Moreover, it would be beneficial to consider carefully the exact meaning of 'immediate surroundings', because even without invading the colony the close proximity of hornets to the hive entrance might also fall under this term. Second, it should be taken into account that, although *V. v. nigrithorax* is categorised as an invasive alien organism (28, 49) and affects wild ecosystems, it also has an impact on managed honey bees. Honey bees are considered as livestock and therefore within the remit of Veterinary Services. Nevertheless, what is beyond any doubt is the lack of effective control measures to prevent its spread. As mentioned, the primary aim of listing diseases, infections and infestations by the OIE is to support Member Countries in preventing the transboundary spread of important animal diseases, including zoonoses, and in the case of *V. v. nigrithorax* this condition is not currently met.

In conclusion, the assessment has provided information to allow serious consideration of the fulfilment of each of the four criteria for including

V. v. nigrithorax in the OIE list. Nevertheless, the three above-mentioned reasons (its categorisation as an invasive alien organism; its legal situation in some countries, outside the mandate of Veterinary Services; the lack of means to prevent its spread) make it unfeasible to include *V. v. nigrithorax* under the current mandate of the OIE. Future efforts should focus on the research and implementation of effective and practical control measures, as well as obtaining robust quantitative data about the impact of this hornet on the beekeeping sector and on other managed bees. This information may encourage a change in its situation at national and international levels, and it may then be appropriate to re-evaluate the possible inclusion of *Vespa velutina nigrithorax* in the OIE list.

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