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# *VESPA VELUTINA*: CURRENT SITUATION AND PERSPECTIVES

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Vespa velutina*: Current situation and perspectives*

*Vespa velutina* is an invasive honeybee predator introduced more than a decade ago in southwest France, followed by an impressive colonization of several areas within mainland Europe (France, Spain, Portugal, Italy, Germany, Belgium) and overseas (UK, Mallorca). The purpose of this short review is to give an overview of the basic historic of this biological invasion, to expose the current situation and to propose perspectives based on the French experience.

KEY WORDS: Alien species, domestic honeybee predator, Yellow-legged hornet.

## INTRODUCTION

In the last century, the increase of human trade worldwide has largely contributed to the introduction of invasive species that are considered one of the major threats to biodiversity (VITOUSEK *et al.,* 1997; CHAPIN *et al.,* 2000). Alien species are usually characterized by their overall flexibility especially when facing disturbance (LEE & GELEMBIUK, 2008). Social hymenopteran are such highly flexible species due to eusociality: they exhibit behavioural plasticity due to their organization in castes; they also have high reproductive rates, demonstrate efficient competitive and dispersal abilities and are opportunistic foragers (MOLLER, 1996). This explains why several social hymenopterans have been successful at colonization worldwide in the last century. Vespids are of special concern because there are particularly difficult to contain when introduced; thus they have colonized several places worldwide and especially in America, Australia and New-Zealand (BEGGS *et al.,* 2011). Europe was spared until the introduction of *Vespa velutina*.

## BACK TO *VESPA VELUTINA* INTRODUCTION HISTORY AND SPREAD IN EUROPE

*Vespa velutina* was first seen in 2004 in southwest France near Agen (RORTAIS *et al.,* 2010). The yellow-legged hornet (also called improperly Asian hornet) has been most probably introduced close to Agen (France) *via* boat and truck transport from China. A recent population genetic study determined that the invasive population originated from Zhejiang or Jiangsu provinces and that a single female mated with four males was responsible for the European invasion (ARCA *et al.*, 2015). *V. velutina* has now colonized the two-third of the French territory and has reached several neighbouring countries such as Spain (LÓPEZ *et al.,* 2011) including Mallorca in Balearic Islands (GOVERN DE LES ILLES BALEARS, 2015), Portugal (Grosso-Silva & Maia, 2012), Italy (DEMICHELIS *et al.,* 2013), Germany (WITT, 2015), and more recently Belgium and United Kingdom (including Channel islands such as Jersey and Alderney, UK Government, 2016).

## WHY *VESPA VELUTINA* IS A MAJOR CONCERN?

*V. velutina* forms large colony, headed by one queen that can produce thousand individuals a year. During the growth of the colony from early July to late October, a huge amount of proteins is required to feed the brood (Fig. 1). A large part of the required proteins are obtained from honeybees that explains why *V. velutina* is known in its native range as a pest for beekeeping (MATSUURA & YAMANE, 1990; SHAH & SHAH, 1991). Following the first observations in France, the predation on beehives was soon noticed. Typically, *V. velutina* workers stay in stationary flight, back to the hive entrance to catch honeybee foragers coming back to the hive (TAN *et al.,* 2007; MONCEAU *et al.,* 2013a). In Asia, *V. velutina* prey on Asian honeybees, *Apis cerana*, but also on *A. mellifera*, the European honeybee, which has been introduced into Asia

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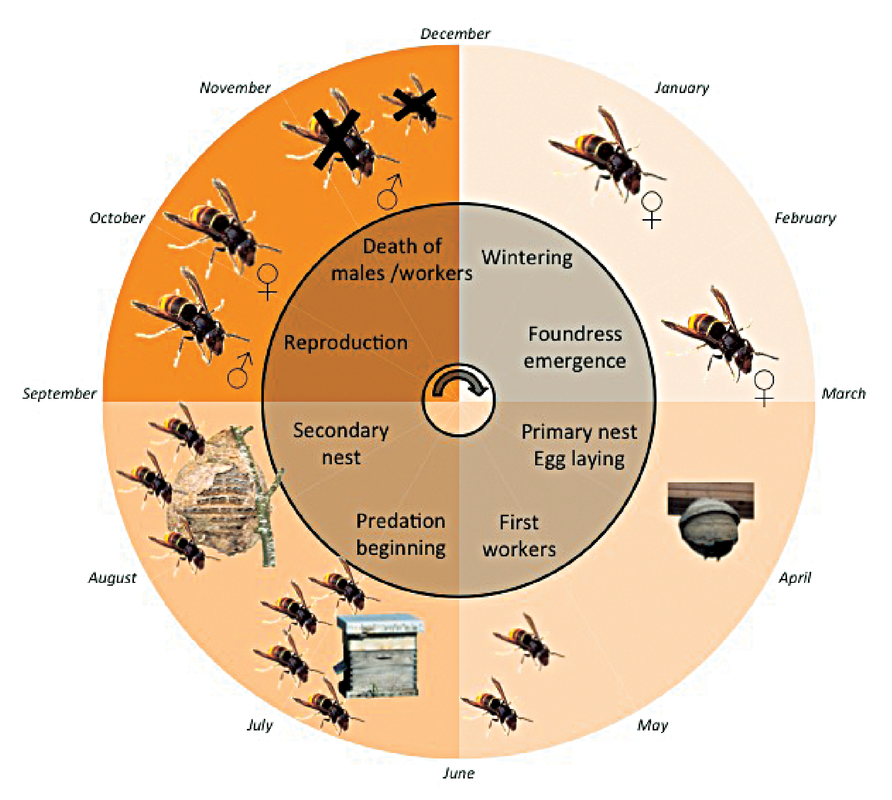


Fig. 1 – *Vespa velutina* life cycle (from Monceau *et al.*, 2014).

(Ken *et al.*, 2005; Yang, 2005). The predation on *A. cerana* is less intense than in *A. mellifera* because the former is able to efficiently defend its colony against *V. velutina* due to coevolution. *A. cerana* is able to display the so-called "beecarpet", the heat-balling and shimmering behaviours while *A. mellifera* only displays the beecarpet and balling behaviours (Ken *et al.*, 2005; Tan *et al.*, 2010, 2012, 2013). In Europe, where *V. velutina* is the invasive and *A. mellifera* the native species, the situation is similar and the European honeybee does not defend efficiently against its predator (Arca *et al.*, 2014).

## Impact of *Vespa velutina*

The impact of *V. velutina* should be viewed at three different levels: i) the ecological impact on biodiversity, ii) the economic impact on beekeepers and citizens and iii) the sanitary impact.

### *The ecological impact*

As previously said, the major impact of *V. velutina* is the predation on hives and other insects (Monceau *et al.*, 2013a, b). Direct impact on the entomofauna and indirect impact on plant biodiversity by reducing pollinator populations are thus expected. Hornet workers prey on honeybee foragers but the presence of the hornets by itself is also an important stressor for the bee colony in reducing the number of exit for the foragers, thus decreasing the opportunity to collect food for storage and thus leading to the collapse of the hive during winter (Arca, 2012). Additionally, studies realized in China have shown that the predation pressures of the hornet impact the learning ability of the honeybees (Wang *et al.*, 2016) and that neonicotinoid pesticides reduce predator avoidance (Tan *et al.*, 2014). The effects on domestic honeybees are probably the most conspicuous part of the impact of *V. velutina* on biodiversity but they represent only one to two-third of its diet depending on the environment (Villemant *et al.*, 2011). So the impact of the huge predation on honeybee hives should be analogous on wild pollinators and other insects and should be investigated soon.

Finally, *V. velutina* is potentially a direct competitor of the native European hornet species, *V. crabro* which is considered a beneficial insect in agriculture. First studies, however, did not clearly evidence any negative impact of *V. velutina* on this species (Monceau *et al.*, 2015a, b) but investigations should be pushed forward.

### *The economic impact*

Beekeeping activities have been challenged for a long time with different threats targeting honeybees such as parasites, virus, pesticides, habitat loss and/or fragmentation that weakened bee colonies (Goulson *et al.*, 2015). *V. velutina* is an additional source of stress but its effects are difficult to dissociate from the others. According to the local section of the beekeeper union in southwest France

(Union Nationale pour l'Apiculture Française), 30% of the hives were destroyed/weakened in Gironde in 2010 due to *V. velutina*. No real assessment of the overall impact on honey production exists at this point but should be necessary.

From the citizen point of view, *V. velutina* could also represent a cost. Although French beekeepers are able and largely contribute to the destruction of nests for free, some private companies destroy nest for a cost up to several hundreds of euros depending of the conditions.

*The sanitary impact*

The last level to consider in this biological invasion is the sanitary problems. First of all, *V. velutina* is a venomous animal that can sting several times and thus injecting venom at each sting contrary to honeybees. In its native range, this hornet species is considered highly aggressive (Martin, 1995). A first assessment of the number of envenomation due to *V. velutina* was realized from 2007 to 2010 but the authors concluded that the number of accidents did not increase during this period corresponding to the proliferation of the hornet in southwest France (de Haro *et al.,* 2010). There are, however, several accidents that ended dramatically by the death of the patient but the number of cases (although it is always too much) is low (less than 20 in 12 years). The frenzy surrounding each accident contributes to increase the phenomenon and also reinforces the fear of hornets (native and invasive species).

*V. velutina* can also be a vector of different parasites species. For example, it can host the Israeli Acute Paralysis Virus (IAPV), which infects *A. mellifera* in China but also in France (Blanchard *et al.,* 2008; Yañez *et al.,* 2012). However to date, no report of such virus has been done in *V. velutina*. It could also be a host for the parasitoid *Conops vesicularis* (Darrouzet *et al.,* 2015a) and the nematode *Pheromermis vesparum* (Villemant *et al.,* 2015) which are both quite generalists and rare (see below).

The invasion by *V. velutina* poses several problems. Thus, it is urgent to control its expansion to a larger extent within Europe.

## What to do against *Vespa velutina*?

Several techniques have been used to contain invasive vespids during past experiences in New Zealand for instance (Beggs *et al.,* 2011). However, to date, there is no plug-and-play method that allows controlling efficiently *V. velutina* expansion. Different ways have been considered; some of them are potentially of major interest but this is not the case for all of them.

*Trapping*

Trapping is probably the first method that has ever been used to fight against invasive vespids. It can be performed at different step of the life cycle of *V. velutina* (Fig. 1): during the spring for catching foundresses and during the summer and autumn to catch workers and new emerging gynes (Monceau *et al.,* 2014). To date, only traps baited with food have been used. This is quite controversial for queen spring trapping for instance because of the lack of specificity, *V. velutina* foundresses representing a small percentage of the overall catches (Monceau *et al.,* 2012). Side effect on local entomofauna is sometimes impressive with the obvious potential consequences on population dynamics for non-target species. Additionally, there is a lack of evidence of the efficiency of such method as a mean of regulation of the invasive hornet species (Monceau & Thiéry, 2016). An acute assessment of the real impact and efficiency of queen spring trapping should be done.

During the growth of the hornet colony, trapping can be used to locally decrease the predation pressure in apiaries. Three phases could be observed (Fig. 2): in June/July the late phase of the gynes, followed in early August by the dramatic increase of the predation due to the need of proteins to feed the brood and lastly in late October, the emergence of the gynes and males and the end of the colony. For these three phases, different food baits are efficient: the sugar-based baits for the first and last, and protein-based baits (fish) for the intermediate part (Monceau *et al.,* 2013b, 2015b). This kind of trapping has limited side effect on local entomofauna because most of the insects in apiaries at this time are either honeybees (that avoid these traps) or invasive hornets.

Toxic baits (growth inhibitor, insecticide) have also been used unofficially but the release of such molecules is problematic especially in regard to honeybee health and the current concerns about pesticides.

*Inbreeding depression*

As suggested by the population genetic study by Arca *et al.* (2015), a single queen mated by four males is at the origin of the invasive population in Europe, thus with high level of inbreeding, as expected in most biological invasion. As a result, diploid males have been observed in several colonies of *V. velutina* (Arca 2012; Darrouzet *et al.,* 2015b). Basically, in hymenopterans, females are diploid and males are haploid (haplodiploidy). However, sex is also determined by a locus, a phenomenon called complementary sex determination (CSD, see Liebert *et al.,* 2010). By definition, inbreeding increases the probability of an individual to be homozygous for a given locus.

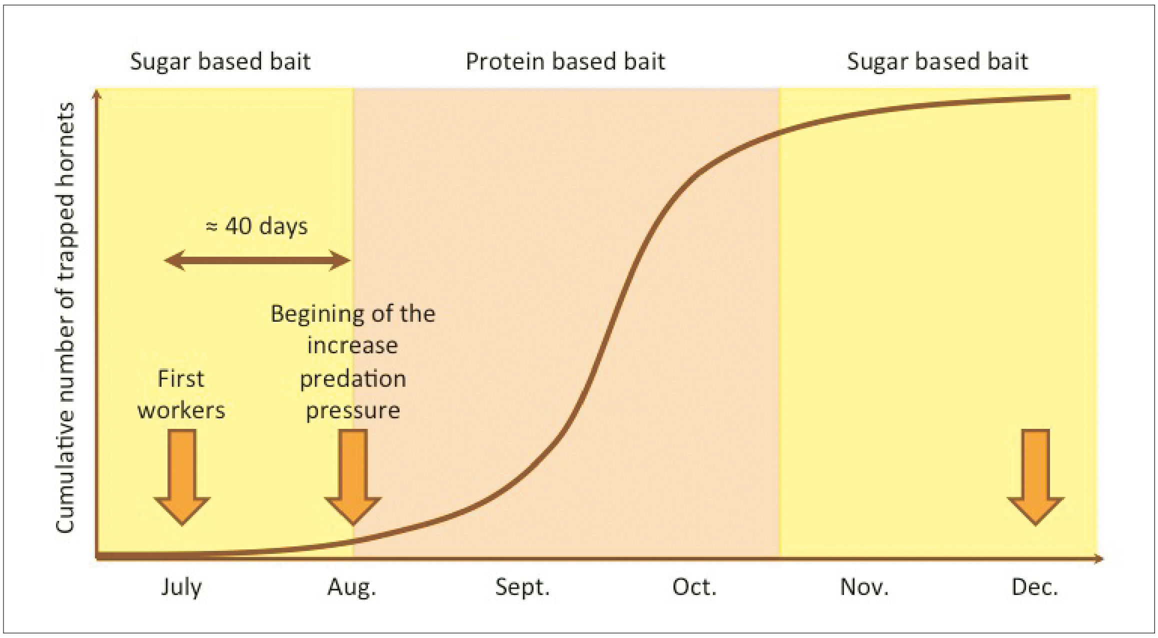


Fig. 2 – The three phases of trapping from July to December (from MONCEAU *et al.,* 2013b, 2015b).

Thus, in inbred populations like in the case of *V. velutina*, diploid females can be homozygous at CSD locus that is perceived like haploid individuals and are thus males. These diploid males represent a cost for the colonies because of their sterility and could lead to a vortex of extinction (ZAYED & PACKER, 2005). In the case of *V. velutina*, inbreeding is present since the introduction and did not seem to limit the expansion of the population through Europe, so it is unlikely that this could naturally drive the extinction of the invasive hornet. Moreover, *V. velutina* gynes are polyandrous and this mating system is known in social insects to be advantageous to increase offspring genetic diversity (JENNIONS & PETRIE, 2000) that could counteract the effect of inbreeding.

*Natural enemies*

As above, *V. velutina* can host different pathogens. Those recently described (DARROUZET *et al.,* 2015a; VILLEMANT *et al.,* 2015) are however unlikely to be involved in biological control because they are generalist pathogens. One predator species has been identified too, the honey buzzard, *Pernis apivorus*. Although this species is a potential predator of hymenopterans, a single observation of an individual feeding on a *V. velutina* nest has been done to date (see details in MONCEAU *et al.,* 2014).

The potential for natural enemies in a biological control context is quite restricted but some interesting perspectives from the side of entomopathogenic fungus that are often used for controlling insect pests may arise.

*Nest destruction*

Systematic nest destruction is probably the most effective method to control social insects (THOMAS, 1960; SPRADBERY, 1973) because the nest ensures the survival of the colony (HÖLLDOBLER & WILSON, 2008). During the queen colony phase (i.e., before the emergence of the first workers, Fig. 1), the nest is of the size of a gulf ball. Therefore, finding these little nests is often like searching for a needle in a haystack. Then, later in the cycle, the huge nests are often at the top of the trees but remain cryptic until leaves fall. Some methods are currently under development to increase our ability to detect early with harmonic radar (MILANESIO *et al.,* 2016) and nest destruction with drones for instance.

*Pheromones*

Due to their involvement in intraspecific communication, pheromones are probably the major way to investigate. Indeed, exploiting these naturally emitted molecules would be a clean way to enhance the specificity and attractiveness of the traps. For example, sex pheromones are used to disrupt mating in several agricultural pests like the grapevine pest, *Lobesia botrana* (IORATTI *et al.,* 2011). Recent neurobiological works on *V. velutina* showed the presence of several macrostructures in the antennal lobe of the males, which are probably linked to sex pheromones (COUTO *et al.,* 2016). To date, no sex pheromone has been clearly identified in hornets although a biological activity has been demonstrated in different *Vespa* sp. (ONO & SASAKI, 1987; SPIEWOK *et al.,* 2006). Future researches are thus required to identify candidate molecules in this way.

## Conclusion and perspectives

*Vespa velutina* has become of major concern in the last decades, but it took ca. eight years before the French government legislated on this species. However, eradication was not possible anymore at this time. Early warning such as the system proposed by UK seems to work, as the reaction to the first observation of *V. velutina* in September 2016 lead to the destruction of the nest (although nobody at this time cannot know if there was only one nest). The main problem with biological invasion is that since the eradication step is exceeded, the establishment of a management program will be costlier and costlier as in several other examples (Simberloff *et al.,* 2013). Now, *V. velutina* has been implemented on the European alien list with 36 other invasive species but it still questions how and who will be mandated to coordinate the efforts of all the European research teams, beekeeper unions and citizens involved in the fight against the invasive bee predator.

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