Testing the selectiveness of electric harps: a mitigation method for reducing Asian hornet impact at beehives

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ABSTRACT

The Asian hornet (*Vespa velutina*) has rapidly become a source of stress for the beekeeping sector. Several methods have been developed to control its impact and spread, though some of these impose a high risk for native insects. Among these methods are electric harps, which are physical barriers that electrocute hornets passing through two wires powered by a current generator. However, the risk to local fauna of electric harps has not previously been tested. Here we evaluated the selectiveness and risk of damage for local entomofauna of the electric harps in a study carried out over three years and four locations in Girona province (NE Catalonia, Spain). The electric harps showed a high selectiveness, with 82.9% of all insects trapped (3,902 individuals) catalogued as Asian hornets, although this greatly varied over years and locations with values ranging from 20.5% to 94.3%. The risk damage of electric harps for local entomofauna was very low in all surveyed areas and years. Native insects accounted for, as a mean, 1.7% of all insects trapped over the study period (range 0-4.5%). Accordingly, the electric harps imply a low risk for the native European hornet *Vespa crabro*, since only 0.1% of the captures belonged to that species. Our results suggest that electric harps might be a useful method to reduce predation pressure of the Asian hornet at beehives while imposing a low risk for local entomofauna. The employment of standardised techniques, such as the placement of electric harps, may be useful to assess inter-annual variations or site-specific differences on the predation pressure of the Asian hornet at beehives. Further research should evaluate whether the placement of electric harps improves bee colony survival or vigour parameters (i.e. honey production, amount of brood, pollen, etc.).

Keywords: apiculture, *Apis mellifera*, biological invasions, electric harp, IAS, *Vespa velutina*.

INTRODUCTION

Biological invasions threaten biodiversity and the maintenance of ecosystem services, but they are also responsible for substantial economic losses and management expenses (Simberloff et al. 2013, Bellard et al. 2016, Diagne et al. 2020). Indeed, the introduction of invasive alien species may have disastrous consequences for economic activities, as has occurred in the beekeeping industry with the introduction of the Asian hornet (*Vespa velutina*, Lepeletier 1836) (Rome et al. 2011). The Asian hornet is native to Southeast Asia, but has been introduced into non-native Asian countries (e.g. Choi et al. 2012). In Europe, it was first detected in France in 2004 and then rapidly spread into Spain, Portugal, Belgium, Germany, Holland, Italy, Switzerland and United Kingdom (Keeling et al. 2017).

In the invaded range, the Asian hornet rapidly became a source of stress and negative impacts for beekeepers (see review in Laurino et al. 2020). Nonetheless, the impact of the Asian hornet is not restricted to the beekeeping industry, but can also have negative consequences on entomofauna, the economy (e.g. costs related to mitigation activities and monitoring, Barbet-Massin et al. 2020) and human health, including death (Rome et al. 2011). For these reasons, the European Union added the species to the list of IAS of Union Concern (European Commission 2016), and it has also been catalogued as a major threat to European biodiversity (Monceau and Thiéry 2017). Asian hornets feed on sugar and on many pollinators, but the species shows a noticeable preference for the European honey bee (*Apis mellifera* Linnaeus, 1758), which are its principal source of protein (Villemant et al. 2006, Perrard et al. 2009). Predation pressure of the Asian hornet at beehives is at a maximum during early autumn (October-November, Monceau et al. 2014, 2017, Villemant et al. 2014). This is a critical period for honey bee colonies, as at this time honey bees store honey and breed before winter (Winston 1994). Thus, the attacks of the Asian hornet go beyond the direct predation on honey bees producing paralysis of foraging activity for long periods of time and may have a major impact on honey bee colony dynamics and winter survival (Leza et al., 2019, Requier et al. 2019, Laurino et al. 2020). Despite warnings from the beekeeping industry and the scientific community, our current knowledge about their impact in the beekeeping sector and how to manage the invasion of the species is limited and with mixed results (but see Monceau and Thiéry 2017, Requier et al. 2019, Barbet-Massin et al. 2020).

A series of physical and chemical control methods have been developed to mitigate the impact of the Asian hornet (Rome 2011, Turchi and Derijard 2018, Rojas-

Nossa et al. 2018, Rodríguez-Flores et al. 2019). Among the mitigation methods most commonly applied are the use of baited traps and nest eradication. Baited traps use proteins or sugar—the most common baits—and are placed at strategic points to capture the largest number of Asian hornets. This method is usually aimed at capturing colony-founding queens during the early spring to reduce the number of colonies in the summer months, although baited traps are also used for trapping Asian hornet workers during the hunting season (Turchi and Derijard 2018). However, this method has shown to kill many non-target insects and few Asian hornets (ca. 1-3% of the total trapped insects are Asian hornets, see Rojas-Nossa et al. 2018, Rodríguez-Flores et al. 2019, Lioy et al. 2020, Sánchez and Arias 2021) and has been catalogued as an inefficient method to limit the distribution of the species (Rome et al. 2011, Monceau and Thiéry 2017). Nest destruction has been declared the best way to control the spread of the hornet (Rome et al. 2011), but its detection through visual observation or remote control (i.e. using drones) is costly. The use of trojans (i.e. capture and release of hornets previously covered with insecticides) to destroy the nests can also have negative consequences for the environment depending on the chemical used and are forbidden in many countries (Poidatz et al., 2018).

Among the current methods available for the control of the Asian hornet at beehives, it is worth highlighting beehive muzzles and electric harps. Both methods can be home-made by beekeepers, which facilitates their use (Turchi and Derijard 2018). The beehive muzzles are a physical barrier that blocks the entry of Asian hornets into the hive while allowing the bees to pass through (see e.g. Bonnefond et al. 2020, Requier et al. 2020). Electric harps are physical barriers that electrocute hornets passing through two wires powered by a current generator (Turchi and Derijard 2018). Ideally, an electric harp should be placed among two hives to capture hornets while circulating between hives (Turchi and Derijard 2018). Theoretically, the space amongst wires is such that bees can pass through without being electrocuted, whereas hornets touch both wires and are electrocuted. For baited traps, there are several studies evaluating the selectiveness of the method (i.e. Lioy et al. 2020, Sánchez and Arias 2021). However, to the best of our knowledge, the selectiveness of electric harps in capturing Asian hornets has never been evaluated. Thus, while electric harps have already been proposed as an alternative method to reduce predation pressure from hornets at beehives (Turchi and Derijard 2018), they may impose an extra risk to native entomofauna.

In this work we aim to: 1) assess the selectiveness of electric harps, and 2) use data collected from electric harps to describe the seasonal pattern of Asian hornet appearance at beehives in north-eastern Spain. Identifying the period of maximum predation pressure of Asian hornets at beehives, together with the knowledge acquired about the selectiveness of the electric harps, will be useful for beekeepers and policy makers to implement a management programme based on the most adequate and environmental-friendly mitigation measures, and to increase their mitigation effort at critical dates. Additionally, we aim to provide some recommendations based on our personal experience working with different types of electric harps at beehives over three years.

MATERIAL AND METHODS

Study area and electric harps employed

The study was conducted during 2018-2020 and at four separate sites in Girona province (NE Catalonia, Spain). Apiaries were separated by a maximum distance of 15 km. During the year 2018, we monitored two different apiaries located in the villages of Begudà and Santa Pau. Each apiary was monitored weekly over five weeks, from 24 September to 30 October, and in both apiaries we placed two "dry electric harps" and two "wet electric harps" (Fig. 1, see below). The electric harps and electronic system were developed by a local Spanish company (Velzapper). The electric harps were squared PVC frames of 75 cm height and 50 cm width, which supported a series of electric wires separated by 1.8 cm. That separation was designed so that bees can pass without touching two wires at the same time, but due to their larger wing span, hornets should always touch two cables simultaneously causing electrocution. Unlike other models of electric harps, the wires were formed from the consecutive winding of two acer cables. The two cable lines were connected to a different pole of an electric battery so that the harps were electrified. The original electric harp from Velzapper, herein named "dry electric harps", included a container that collects the animals that collide with the wires after electrocution. The container is a mesh through which small insects (including honey bees) can exit without difficulty, unlike larger insects like the Asian hornets. The hornets leave the container through two holes in the centre and are accumulated in a plastic trap. The use of this container was considered an improvement over previous models of electric harps, which instead of the container had a water receptacle into which electrocuted animals fall without the possibility of getting out (“wet electric harp”). This harp model has the disadvantage, a priori, that any insect that touches the threads, whether or not it gets electrocuted, can fall into the water container. Moreover, the water itself can be an attraction for certain insects, acting as a fall trap. In this sense and to minimise the attracting effect, the containers were painted on neutral grey. The Velzapper electronic system was powered by a solar panel, with a 6V battery plugged to ensure the functioning of the electric harps during less sunny times. It distributed the current to two different channels, which had four or five electric harps connected in a series.

During 2019 and 2020, we placed an experimental apiary in the municipalities of Batet de la Serra and Falgons, respectively. The apiary was surveyed weekly over 13 weeks in 2019 (28 August to 21 November) and 10 weeks (23 September to 24 November) in 2020. Both apiaries were composed of 36 beehives, forming a total of 12 groups composed of 3 beehives each. Four of these groups were equipped with two dry electric harps, for a total of eight electric harps monitored each year. These four groups of beehives are the only ones being considered in this study. The electric harps employed in 2019 and 2020 were an adaptation of the “dry” prototype employed in 2018, in which we exchanged the PVC structure for a squared iron frame (76 cm height and 74 cm width) and changed the separation of the wires to 2 cm. The electric harps from 2019 had weatherproof wood bars at the top and bottom of the structure to fix the wires, while those from 2020 had PVC bars to ameliorate the transmission of electricity.

Data collection

During 2018, we evaluated the effectiveness of the electric harps by performing a total of 32 surveys (16 surveys in Begudà and 16 in Santa Pau) in which we collected the total number of insects trapped over four consecutive hours. The surveys were conducted during the period of maximum insolation of the monitored sites (between 10:00 and 15:00 CET), and were restricted to this duration (four hours) to ensure that the electric harps worked properly. During 2019 and 2020, we made a weekly visit to each of the electric harps, during which we collected the total number of insects trapped during that day (ca. 8 working hours) (Table 1). The fauna trapped by the electric harps were identified and divided into the following four categories: 1) honey bees, 2) Asian hornets, 3) European hornets (*Vespa crabro*, Linnaeus, 1758), and 4) native insects. We counted the number of European hornets trapped separately from native insects because the former is a native species closely related and presenting a similar size to the invasive

Asian hornet, and we aimed to assess specifically the potential impact that electric harps have on the native hornet. All native insects trapped in 2018 were described at the Order level. Due to the low number of native insects trapped in the preceding two years, in 2020 we did not annotate in the field the specific number of native insects trapped on each survey. However, we remember that around eight native insects were trapped during 2020. For statistical purposes, we multiplied this factor by five, as a conservative measure, to include the assessment for the 2020 year.

Statistical analyses

We estimated the selectiveness and risk damage for local entomofauna of the electric harps employed for capturing the Asian hornet. For these analyses, we pooled the data for each type of electric harp from the same location and year. We defined selectiveness as the proportion of Asian hornets trapped in comparison to the total number of insects trapped in the electric harps, for which we used the following equation:

Selectiveness = (Total number of Asian hornet trapped / Total number of insects trapped) * 100

Risk damage for local entomofauna was estimated as the proportion of native insects trapped (categories *European hornet* and *Native insects)* in respect to the total number of insects trapped, for which we used the following equation:

Risk damage = (Total number of native insects trapped / Total number of insects trapped) * 100.

To describe the seasonal pattern of appearance of the Asian hornet at beehives in north-eastern Spain, we used the standardised data collected over 2019 and 2020 (one visit per week), since the data collected in 2018 was much restricted in time and used a different electric harp. To do this, we estimated the mean number of Asian hornets trapped per electric harp and day over the survey period. Data were analysed separately for each of the years surveyed.

RESULTS

During 2018, a total of 710 insects were trapped in the two surveyed locations, with a mean selectiveness of 46.5%. In both locations the risk damage of electric harps for local entomofauna was low and ranged from 0 to 4.5%. The analyses at the Order level of the native insects, which was carried out only during that year, identified Diptera as the Order most commonly trapped in the electric harps (12 of 24 insects, 50% of the total), followed by Hymenoptera (7 individuals, 29.2%), Mecoptera and Orthoptera (two individuals each, 8.3% each) and Hemiptera (1 individual, 4.2%). In both of the surveyed locations the dry electric harps showed high selectiveness and lower risk damage for the local entomofauna (Table 2), and thus, during the subsequent years we only tested this model.

During 2019 and 2020, a total of 167 and 3,025 insects were trapped over the whole survey period, respectively. The selectiveness of the electric harps greatly varied among years—in 2019 it was 29.9% while in 2020 it reached a value of 94.3%. However, the risk damage of electric harps for local entomofauna was low in both years. Native insects accounted for, as a mean, 2.4% and 1.3% of all insects trapped over the years 2019 and 2020, respectively (Table 2). In all sites and years, the electric harps captured a much higher number of Asian hornets than native insects. Moreover, electric harps trapped a much lower proportion of the native European hornet (0.10% of the total) when compared to *V. velutina* (82.9% of the total, Table 2).

The number of Asian hornets trapped daily varied among the survey period. The seasonal pattern of captures also varied by year of survey (Fig. 2). The seasonal pattern of appearance during the year 2019 showed a unimodal pattern, with most of the individuals trapped during the month of October, and very few Asian hornets trapped during the months before or after this month (Fig. 2). Indeed, during August (one survey) and September (four surveys) of the year 2019 the capture rate was very low (three individuals trapped, 0.07 Asian hornets per trap and day). However, the number of captures increased afterwards and reached its maximum during the last fortnight of October (from 17th to 30th), with a mean number of 1.2 individuals trapped per harp and day. During 2020 the number of individuals trapped over weeks showed a more erratic pattern, although the number of Asian hornets trapped also acquired its maximum from the middle of October onwards (Fig. 2). However, while in 2019 there was a decreasing pattern of captures during the month of November, during 2020 the number of captures reached its maximum in mid-November, with a mean value of 72.5 Asian hornets trapped per electric harp and day during the surveys on the 10th and 17th of November (Fig. 2).

DISCUSSION

Electric harps are a mitigation method commonly used in the invaded area by beekeepers to reduce the impact of the Asian hornet at beehives (Turchi and Derijard

2018). Here, we provide the first assessment of the selectiveness of electric harps for trapping the Asian hornet. Our findings prove that electric harps are a very selective tool and impose a very low risk to the local entomofauna in contrast to other mitigation measures often applied for controlling the Asian hornet, such as baited traps where only 1-3% of the trapped insects were Asian hornets (Rojas-Nossa et al. 2018, Rodríguez-Flores et al. 2019, Lioy et al. 2020, Sánchez and Arias 2021). The selectiveness of the electric harps (% of Asian hornets trapped in respect to the total number of insects trapped) was 82.9%, and the Asian hornet capture rate was seven times higher than for the honey bee, the second most commonly trapped insect (3,235 hornets trapped against 599 honey bees trapped). The low risk that the electric harps appear to have for honey bees makes it an effective method for reducing the impact of Asian hornets on beehives minimizing impact on honey bees.

Our results suggest that electric harps help reduce the abundance of Asian hornets at beehives. For example, in 2018 we estimated a mean capture rate of 0.64 Asian hornets per trap and hour (surveys were carried out during four consecutive hours in the morning), while in 2020 we estimated a mean capture rate of 4.46 Asian hornets per trap and hour (surveys were carried out over eight consecutive hours during the day). Nonetheless, in 2019, when the abundance of the species was very low (pers. obs.) the estimated mean capture rate was 0.06 *V. velutina* per trap and hour (surveys were carried out over eight consecutive hours during the day). Besides the high capture rate of *V. velutina* in 2020, it is notable that most of the beehives monitored over that year collapsed in part due to the high pressure of the Asian hornet. Therefore, our findings suggest that electric harps might be a useful tool to reduce the abundance of the invasive species at beehives, but further research should evaluate the density at which electric harps should be placed in the apiaries to achieve a positive impact on beehive survival or colony parameters (i.e. honey production, brood amount).

Our study also proved that the use of electric harps imposes a very low risk to the local entomofauna, since only 1.7% of the total fauna trapped were native insects. These values are totally opposite to those found using baited traps for capturing the Asian hornet, when only around 1-3% of the total fauna trapped was Asian hornets (Rojas-Nossa et al. 2018, Rodríguez-Flores et al. 2019, Lioy et al. 2020, Sánchez and Arias 2021). Moreover, the electric harps impose a very low risk to the native European hornet (4 individuals, 0.1% of the total), even though the native species is significantly larger than the Asian hornet (Monceau et al. 2014, Kwon and Choi 2020). For this reason, we would have expected a large impact of electric harps on the native hornet. We should note that the abundance of the European hornet in the surveyed areas is relatively low compared to Asian hornets, which may contribute greatly to explaining the low impact of electric harps on the native hornet. Therefore, further research should evaluate the potential impact of electric harps on the native *V. crabro*, in areas of higher suitability for the species before any generalisation can be made.

Electric harps appear to be a useful tool for reducing predation pressure of the Asian hornet at beehives, the main purpose for which they were designed, but they can also be used for monitoring seasonal changes of predation pressure, as has been shown in this study. In 2019, the species showed a unimodal pattern with a maximum number of captures in late October. However, in 2020, a year with higher predation pressure, we found that the species' activity increased over the whole survey period, with few exceptions, and reached its maximum in mid-November. However, most of the colonies monitored in 2020 collapsed and this may have biased our results, since Asian hornets enter beehives after collapse in large numbers possibly explaining the higher number of hornets in the apiaries in mid-November. Despite small differences among years, the seasonal patterns described in our study for NE Catalonia (Spain) agree with those already proposed for the Asian hornet in France, with the species' activity increasing through the summer and reaching a peak in early autumn (October-November, Monceau et al., 2013, 2017). Differences found among years suggest that continued long-term surveys of the species are desirable to understand the mechanisms behind the temporal and spatial changes in predation pressure of the invasive species. For accurate knowledge about the seasonal pattern of appearance of the Asian hornet at beehives, efficient management strategies or focussed efforts at specific times could be proposed (Monceau et al., 2017).

Electric harps are usually built or customised by beekeepers (Turchi and Derijard 2018). Indeed, we employed different customised models of electric harps each year. This may pose an extra challenge when extrapolating the results obtained using a specified electric harp to different models. However, the risk of damage for all models of electric harps employed in our study was very low, since native insects accounted for 0% (using dry electric harps in 2018 in Begudá) to 4.5% (using wet electric harps in 2018 in Santa Pau) of captured species. Therefore, we believe that the use of different models and methodologies provides robustness to our main finding of low impact of electric harps on native insects. Native insects play important roles in biodiversity and ecosystem functioning as pollinators, predators and decomposers, among other functions, and therefore it is important to implement effective and selective traps to control the Asian hornet. The need for eco-friendly mitigation measures is enhanced in the modern era due to prominent insect decline (see Sánchez-Bayo and Wyckhuys 2019, Wagner et al., 2021). Future studies should evaluate whether the electric harps lead to an improvement in honey bee colony survival rate, colony health status or honey production. In this way, we can elucidate whether the application of such mitigation measures is useful not only to mitigating the impact of the Asian hornet at beehives but also to improving honey bee population dynamics.

ACKNOWLEDGEMENTS

This study was funded by Diputació de Girona and a grant for demonstration activities, call 2018 (expedient number 56 30071 2018 P4), financed through the operation 01.02.01 of Technology Transfer of the Rural Development Program of Catalonia 2014-2020. CPG acknowledges the support from Ministerio de Educación y Formación Profesional through the Beatriz Galindo Fellowship (Beatriz Galindo – Convocatoria 2020). Finally, we would like to thank the Solà-Morales family (Batet de la Serra) and Manel Simón (Falgons) for letting us install the hives on their properties.

REFERENCES

Barbet-Massin, M., Salles, J. M., & Courchamp, F. (2020). The economic cost of control of the invasive yellow-legged Asian hornet. NeoBiota, 55, 11.

Bellard, C., Cassey, P., & Blackburn, T. M. (2016). Alien species as a driver of recent extinctions. *Biology Letters*, *12*(2), 20150623.

Bonnefond, L., Paute, S., & Andalo, C. (2020). Testing muzzle and ploy devices to reduce predation of bees by Asian hornets. Journal of Applied Entomology. DOI: 10.1111/jen.12808.

Choi, M. B., Martin, S. J., & Lee, J. W. (2012). Distribution, spread, and impact of the invasive hornet Vespa velutina in South Korea. Journal of Asia-Pacific Entomology, 15(3), 473-477.

Diagne, C., Leroy, B., Gozlan, R. E., Vaissière, A. C., Assailly, C., Nuninger, L., ... & Courchamp, F. (2020). InvaCost, a public database of the economic costs of biological invasions worldwide. Scientific data, 7(1), 1-12.

European Commission. (2016). Commission Implementing Regulation (EU) 2016/1141 of 13 July 2016. Adopting a list of invasive alien species of Union concern pursuant to Regulation (EU) No 1143/2014 of the European Parliament of the Council. Official Journal of the European Union. L 189/4.

Keeling, M. J., Franklin, D. N., Datta, S., Brown, M. A., & Budge, G. E. (2017). Predicting the spread of the Asian hornet (Vespa velutina) following its incursion into Great Britain. *Scientific reports*, *7*(1), 6240.

Kwon, O., & Choi, M. B. (2020). Interspecific hierarchies from aggressiveness and body size among the invasive alien hornet, Vespa velutina nigrithorax, and five native hornets in South Korea. *PloS one*, *15*(7), e0226934.

Laurino, D., Lioy, S., Carisio, L., Manino, A., & Porporato, M. (2020). Vespa velutina: An Alien Driver of Honey Bee Colony Losses. *Diversity*, *12*(1), 5.

Leza, M., Herrera, C., Marques, A., Roca, P., Sastre-Serra, J., & Pons, D. G. (2019). The impact of the invasive species Vespa velutina on honeybees: A new approach based on oxidative stress. *Science of The Total Environment*, *689*, 709-715.

Lioy, S., Laurino, D., Capello, M., Romano, A., Manino, A., & Porporato, M. (2020). Effectiveness and Selectiveness of Traps and Baits for Catching the Invasive Hornet Vespa velutina. Insects, 11(10), 706.

Monceau, K., & Thiéry, D. (2017). Vespa velutina nest distribution at a local scale: An 8-year survey of the invasive honeybee predator. *Insect science*, *24*(4), 663-674.

Monceau, K., Bonnard, O., & Thiéry, D. (2014). Vespa velutina: a new invasive predator of honeybees in Europe. *Journal of Pest Science*, *87*(1), 1-16.

Monceau, K., Maher, N., Bonnard, O., & Thiéry, D. (2013). Predation pressure dynamics study of the recently introduced honeybee killer Vespa velutina: learning from the enemy. *Apidologie*, *44*(2), 209-221.

Monceau, K., Tourat, A., Arca, M., Bonnard, O., Arnold, G., & Thiéry, D. (2017). Daily and seasonal extranidal behaviour variations in the invasive yellow-legged hornet, Vespa velutina Lepeletier (Hymenoptera: Vespidae). *Journal of insect behavior*, *30*(2), 220-230.

Perrard, A., Haxaire, J., Rortais, A., & Villemant, C. (2009). Observations on the colony activity of the Asian hornet Vespa velutina Lepeletier 1836 (Hymenoptera: Vespidae: Vespinae) in France. Annales de la Société entomologique de France, 45(1): 119-127.

Poidatz, J., Plantey, R. L., & Thiery, D. (2018). Indigenous strains of Beauveria and Metharizium as potential biological control agents against the invasive hornet Vespa velutina. Journal of invertebrate pathology, 153, 180-185.

Requier, F., Rome, Q., Chiron, G., Decante, D., Marion, S., Menard, M., Muller, F., Villemant, C., Henry, M. (2019). Predation of the invasive Asian hornet affects foraging activity and survival probability of honey bees in Western Europe. *Journal of pest science*, *92*(2), 567-578.

Requier, F., Rome, Q., Villemant, C., & Henry, M. (2020). A biodiversity-friendly method to mitigate the invasive Asian hornet's impact on European honey bees. *Journal of Pest Science*, 93(1), 1-9.

Rodríguez-Flores, M. S., Seijo-Rodríguez, A., Escuredo, O., & del Carmen Seijo-Coello, M. (2019). Spreading of Vespa velutina in northwestern Spain: influence of elevation and meteorological factors and effect of bait trapping on target and non-target living organisms. *Journal of Pest Science*, *92*(2), 557-565.

Rojas-Nossa, S. V., Novoa, N., Serrano, A., & Calviño-Cancela, M. (2018). Performance of baited traps used as control tools for the invasive hornet Vespa velutina and their impact on non-target insects. *Apidologie*, *49*(6), 872-885.

Rome, Q., Perrard, A., Muller, F., & Villemant, C. (2011). Monitoring and control modalities of a honeybee predator, the yellow-legged hornet Vespa velutina nigrithorax (Hymenoptera: Vespidae). *Aliens*, *31*(31), 7-15.

Sánchez, O. & Arias, A. 2021. All That Glitters Is Not Gold: The Other Insects That Fall into the Asian Yellow-Legged Hornet Vespa velutina 'Specific' Traps. *Biology*, 10(5):448.

Sánchez-Bayo, F., & Wyckhuys, K. A. (2019). Worldwide decline of the entomofauna: A review of its drivers. *Biological conservation*, *232*, 8-27.

Simberloff, D., Martin, J. L., Genovesi, P., Maris, V., Wardle, D. A., Aronson, J., ... & Pyšek, P. (2013). Impacts of biological invasions: what's what and the way forward. Trends in ecology & evolution, 28(1), 58-66.

Turchi, L., & Derijard, B. (2018). Options for the biological and physical control of Vespa velutina nigrithorax (Hym.: Vespidae) in Europe: A review. Journal of Applied Entomology, 142(6), 553-562.

Villemant, C., Haxaire, J. & Streito, J. C. 2006. The discovery of the Asian hornet *Vespa velutina* in France. *Insectes* 143, 3–7.

Villemant, C., Muller, F., Rome, Q., Perrard, A., Barbet-Massin, M., Jiguet, F. (2014) Estimating the potential range expansion and environmental impact of the invasive bee-hawking hornet, Vespa velutina nigrithorax. In: In Silico Bees, CRC Press. James Devillers, Boca Raton, FL, USA, pp 269–287

Wagner, D. L., Grames, E. M., Forister, M. L., Berenbaum, M. R., & Stopak, D. (2021). Insect decline in the Anthropocene: Death by a thousand cuts. *Proceedings of the National Academy of Sciences, 118*(2).

Winston ML (1994) The biology of the honeybee. Harvard University Press, Cambridge. United Kingdom.

Table 1: Monitoring protocol followed during each year. It includes location, type of electric harps monitored, survey period, total number of surveys and hours of survey per site and hours of survey. It is also shown whether or not we counted the total number of *Apis mellifera*, *Vespa velutina*, *Vespa crabro* and native insects. *Native insects identified at Order level.

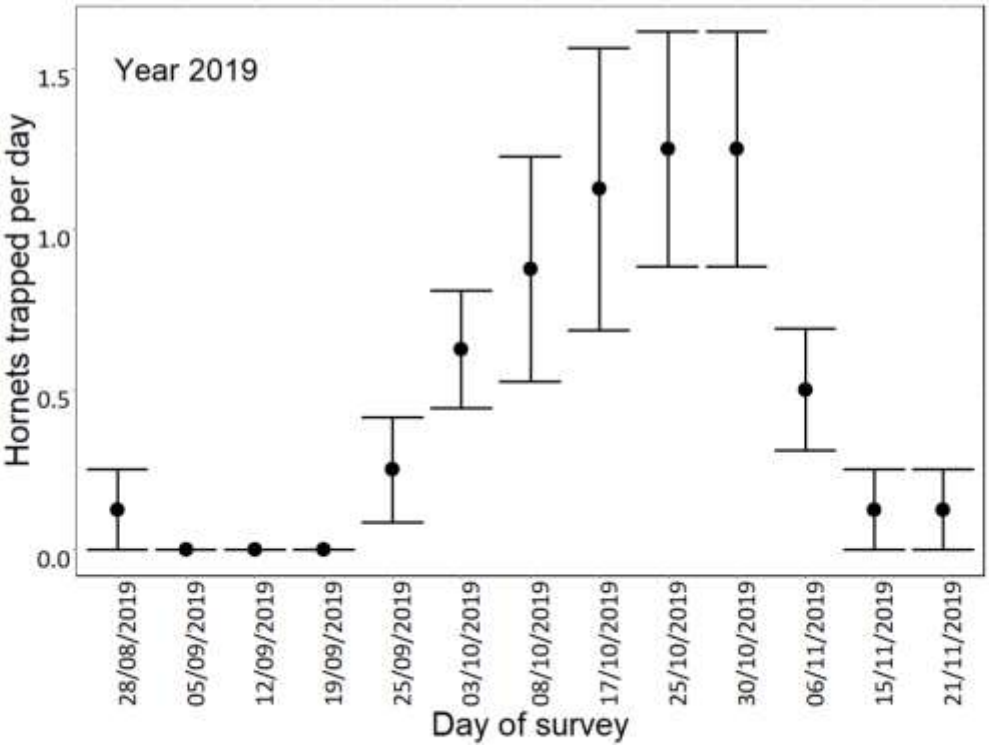
Year	**Location**	**Type harps uses**	***Survey period***	***Number of surveys***	***Hours of survey***	***A. mellifera***	***V. velutina***	***V. crabro***	**Native insects**
2018	Begudà & Santa Pau	Dry & Wet	24 Sept- 30 Oct	16	4	X	X	X	X*
2019	Batet de la Serra	Dry	28 Aug- 21 Nov	13	8	X	X	X	X
2020	Falgons	Dry	23 Sept - 24 Nov	10	8	X	X	X	-

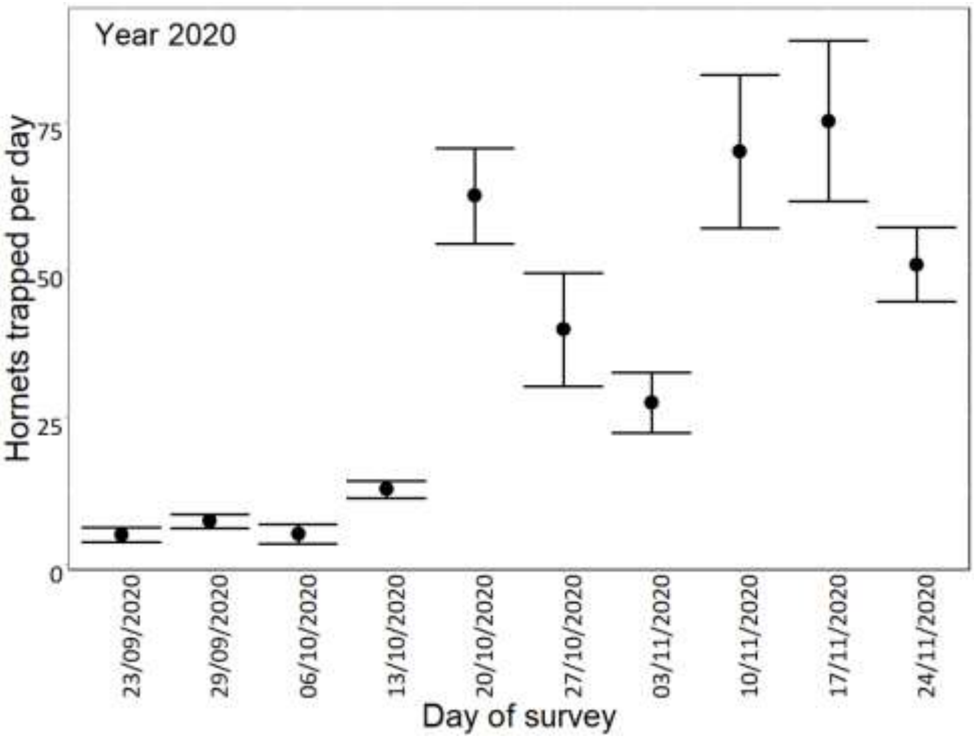
Table 2: Total number of individual *Apis mellifera*, *Vespa velutina*, *Vespa crabro* and native insects captured using electric harps at beehives in Girona province. Data are shown separately for each year of the survey, location and type of electric harp employed. Data for 2018 is based on the number of insects trapped over 4 h (mainly in the morning), while the surveys carried out during 2019 and 2020 extended over 8 h during the whole day. Selectiveness was calculated as the number of Asian hornets trapped/total number of insects trapped, while risk damage of electric harps for local entomofauna was estimated as the total number of native insects (including *V. crabro*)/total number of insects trapped. *Due to low numbers of native insects trapped in previous years we did not annotate this variable during 2020. We recall that around eight insects were trapped during the whole survey. We multiplied this factor by five, as a conservative measure, to include this assessment for the 2020 year.

Year	**Location**	**Type**	***A. mellifera***	***V. velutina***	***V. crabro***	**Native insects**	**Selectiveness (%)**	**Risk damage (%)**
2018	Begudà	Wet	178	48	0	8	20.5	3.4
2018	Begudà	Dry	12	26	0	0	68.4	0.0
2018	Santa Pau	Wet	151	171	1	14	50.7	4.5
2018	Santa Pau	Dry	13	87	0	1	86.1	1.0
2019	Batet de la Serra	Dry	113	50	3	1	29.9	2.4
2020	Falgons	Dry	132	2853	0	40*	94.3	1.3
TOTAL			**599**	**3235**	**4**	**64**	**82.9**	**1.7**

Figure 1. Examples of the dry (left) and wet (right) electric harps used to mitigate the impact of the Asian hornet at beehives.

Figure 2. Seasonal pattern of Asian hornets trapped in the study area (Girona province, north-eastern Spain) using electric harps during 2019 (top) and 2020 (below). Boxplots showing the Mean and SD of the number of Asian hornets trapped per electric harp and day (i.e. approximately 8 hours).


Year 2019
Hornets trapped per day
0.0
0.5
1.0
1.5
28/08/2019
05/09/2019
12/09/2019
19/09/2019
25/09/2019
03/10/2019
08/10/2019
17/10/2019
25/10/2019
30/10/2019
06/11/2019
15/11/2019
21/11/2019
Day of survey


Year 2020
Hornets trapped per day
0
25
50
75
23/09/2020
29/09/2020
06/10/2020
13/10/2020
20/10/2020
27/10/2020
03/11/2020
10/11/2020
17/11/2020
24/11/2020
Day of survey