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INSECT SPOTLIGHT

Asian giant hornet (*Vespa mandarinia*)

Figure 1. Asian giant hornet workers. Source: USDA-APHIS.

Summary

- Asian giant hornet (AGH) is a large hornet native to eastern Asia.
- AGH has the potential to impact North American apiculture due to their tendency to attack honeybee hives to loot young and worker bees.
- A new invasive, AGH was first sighted in 2019 in Washington and British Columbia, Canada.
- Establishment of AGH in the US is tentative and may have been eradicated.
- Tentative risk assessments do not place AGH as a major threat to the US, although inconclusive.
- AGH is unlikely to pose a threat to Kansas or arrive in the state for many years, if at all.

Introduction

As many readers are probably already aware, earlier in May news of the discovery of Asian giant hornet (*Vespa mandarinia*) circulated through the media and took on a life of its own through social media.

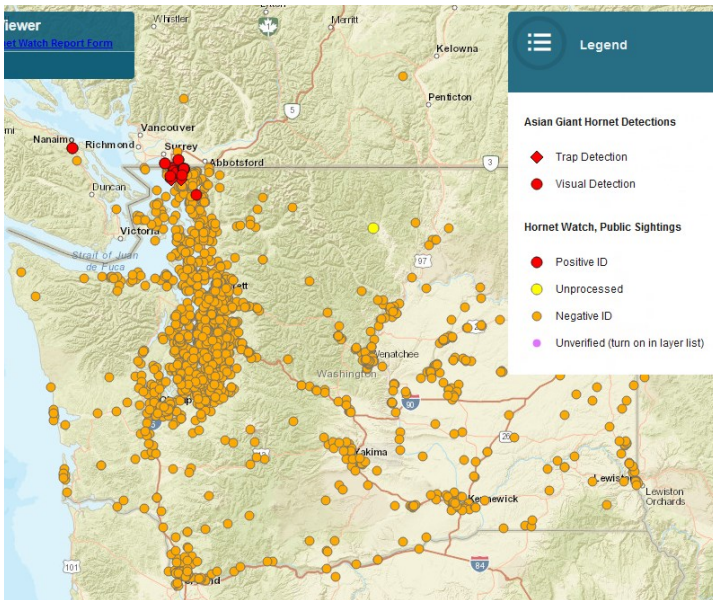


Figure 2. Survey and detections of AGH in the US. Source: WSDA.

Asian giant hornet (AGH) (Fig. 1) was first discovered in British Columbia, Canada, and nearby Blaine in the state of Washington in 2019. Additional AGH sightings have continued to accumulate through 2020 (Fig. 2), culminating in the discovery and eradication of a mature nest in Blaine, Washington. The nest contained many ready-to-emerge queens, all having the potential catalyze establishment of more nests the following year.

Since news of AGH in the US, KDA has received many calls and emails concerning the insect. Here, we will attempt to summarize what is known about AGH within the context of the US, potential threat to KS and how to distinguish AGH from other native look-alikes readers may encounter in KS.

Asian Giant Hornet Goes Viral

It all began with a New York Times (NYT) article published May 2, 2020 (Baker 2020a). Amidst the country's pandemic lockdown, a seemingly casual article about the confirmed sightings of Asian giant hornets (*Vespa mandariania*) in western North America, almost a year prior in 2019, took the internet by storm. Citing the Asian giant hornet (AGH) colloquially as "murder hornet", people quickly shared the article and its digital spawn through social media, consequently literally creating an online frenzy. A simple Google Trends query for "murder hornet" shows that, proportionally speaking, Google searches for the term spiked soon after the release of the NYT article to unprecedented levels, peaking on May 4th (Fig. 3). What this means is that relatively speaking, no one had been Google-ing "murder hornet" or "Asian giant hornet" until the sudden spike in searches following the release of the NYT article.

All of this internet activity inevitably spilled over into the physical realm, with many entomologists across the country getting bombarded with emails and phone calls from friends, family and the public concerning AGH. Some inquiries were questions regarding the insect, but the majority consisted of images taken on phones being submitted by people wondering whether the image was one of a "murder hornet". For some entomologists, inquiries and the fear-based language was so intense that many formed coalitions on social media condemning the NYTs for their sensationalist coverage and outright misappropriation and abuse of the subject by using the term "murder hornet". In reality, the article was actually quite benign, and the single use of the term "murder hornet" is not without context nor precedence, with Japanese news outlets frequently sensationalizing AGHs, which are native to Japan to spark attention: especially leading up to summer vacation season. However, this does not excuse media outlets from using sensationalistic rhetoric and it is important to honor the term "Asian giant hornet" instead, which is preferred by the scientific community.

So, what is going on? We can't be certain, but there is probably a tight link to the COVID-19 lockdown that occurred prior to the initial NYT article. With the nation entering a lockdown under circumstances unseen since the 1918 Spanish influenza, many people were stuck at home with idle time being spent on the internet. Many people were also likely knowingly or not looking for other news to distract from the pandemic. Combining these two factors likely catalyzed the rapid and extreme public response to the NYT reporting on the AGH. On top of which, many people started spending more time outdoors (Scientific American 2020), maybe even gardening for the first time and becoming more aware of backyard entomofauna (CNYCentral 2020), contributing to the high volume of citizen AGH reports across the nation.

None of this is necessarily a bad thing. It is a blessing in disguise that more people are spending time out of doors and noticing their local insect neighbors for the first time. However, it is important to contextualize this new potentially invasive species and understand what it is, what the threats may or may not be, and learn to spot and identify any unfounded sensationalism. Readers will hopefully come away with a more informed and nuanced understanding of AGH

What is the Asian giant hornet?

Among the diverse Hymenoptera (ants, bees, sawflies, and wasps), hornets specifically refer to species in the genus *Vespa*. A natively Old World genus of large social "wasps", *Vespa* includes 22 species that are most diverse in Asia (Beggs *et al*. 2011, Smith-Pardo 2020).

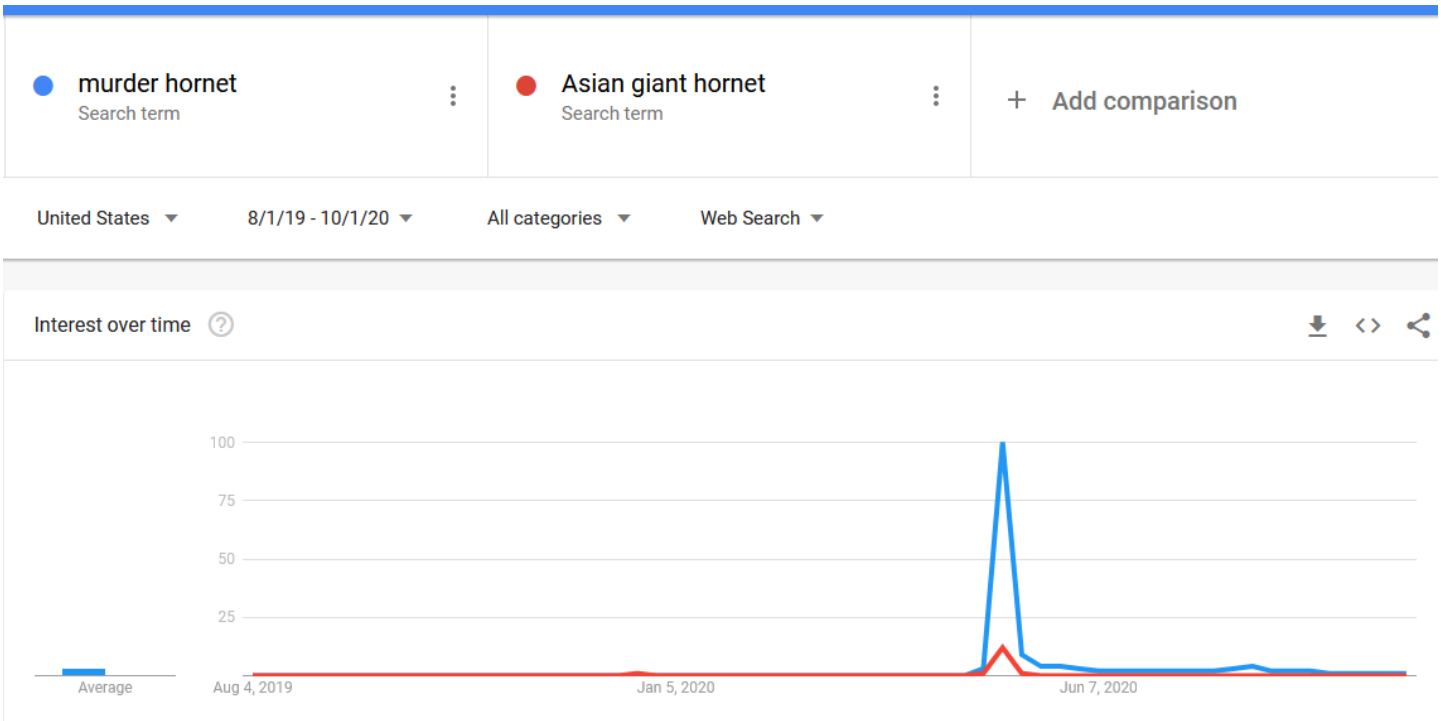


Figure 3. Google Trends search for "murder hornet" and "Asian giant hornet.

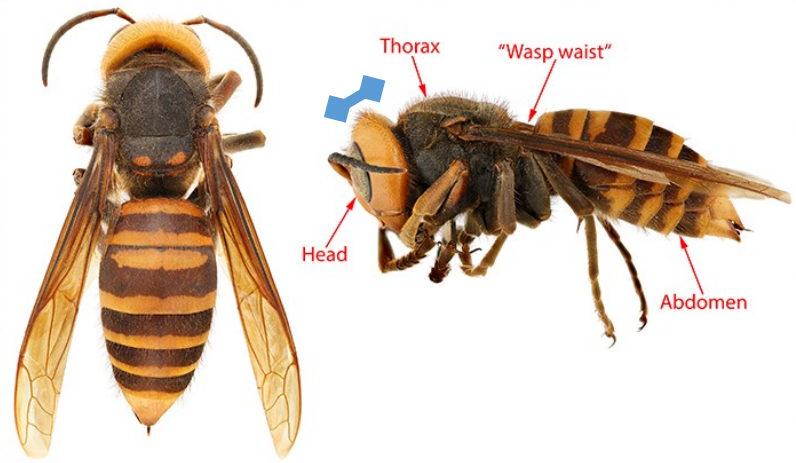


Figure 4. AGH. Characteristically wide gena highlighted by blue line. Source: USDA-APHIS.

Asian giant hornet (AGH) is the largest known species of hornet (*Vespa*) native primarily to eastern Asia. AGH can be distinguished from all other known *Vespa* by the genae (cheeks) being x1.7 wider than the eyes in lateral view and the distinctive abdominal color pattern (Fig. 4). The genae house the mandibular adductor muscles and contribute to AGH's strong biteforce, which it uses to overpower prey (Matsuura & Sakagami 1973, Smith-Pardo 2020).

AGH prefers to live in forests and urban greenways and are poorly suited to disturbed or human-altered areas. AGH typically nest in naturally occurring underground cavities such as holes at the bases of trees—although the nest intercepted in Blaine, Washington was unusual in that it was located above ground on the trunk of a tree (USDA 2020a).

Colonies, similar to other social bees and wasps are founded by a single queen in the spring. Queens will seek out a suitable nesting site and begin building a nest in the form of an inverted vase. Comb-shaped brood chambers are stacked in multiple tiers which in turn is entirely enveloped by sheets of pulp (Fig. 5). Queens are solely responsible for procuring food until the first generation of workers emerge. After the first batch of workers emerge, queens cooperate with workers for some time, foraging and taking care of young. Later in the summer, roles completely change with queens dedicating her time to egg-laying and workers taking up the role of foraging for food and taking care of brood. Adults feed primarily on tree sap and other sugary sources, foraging for insects as a primary food source for young in the nest. In the fall, queens begin to lay eggs destined to develop into the future generation of reproductives (males and queens). Males emerge first and wait outside nests in order to mate with newly emerged queens. Mated queens will seek out a site to hibernate, typically in soil or rotting wood, emerge in the spring to restart the lifecycle. It is in late summer and into fall, when food begins to become scarce that AGH workers will notoriously begin attacking honeybee nests, which is a major concern regarding the establishment of AGH in North America (Matsuura & Sakagami 1973, USDA 2020a).

Figure 4. AGH. AGH nest after exhumation from soil. Source: USDA 2020a.

Potential Impact of AGH in North America

In their native range, AGH is a significant pest for apiculture. Beginning in early August and peaking in the fall, presumably when desired food starts to become scarce, AGH will begin actively targeting honeybee colonies. During honeybee nest attack, AGH go through three phases: hunting phase -> slaughter phase -> occupation phase. In the hunting phase, worker AGHs will attack multiple nests, killing honeybees, biting off their mesosoma ("thorax"), process the honeybee mesosoma into meatballs that are brought back to the nest to feed young. When a threshold is reached, AGH hunting phase attacks may transition to the slaughter phase. In the slaughter phase numerous AGH workers will target a single nest, slaughtering honeybee workers without processing the killed workers into meatballs. After the honeybee colony is decimated, AGH workers will occupy the hive. While several AGH workers guard the bounty, other workers enter the nest to raid young in the following order of preference: pupae > mature larvae > successively smaller/younger larvae > previously slaughtered worker bees. AGH rarely partake in available honey and is not a primary target for attacking honeybee hives. AGH can be quite detrimental, with 20–30 AGH workers able to slaughter 25,000–30,000 honeybees in the span of 1–6 hrs (Matsuura & Sakagami 1973).

The vast majority of AGH impact on apiculture in their native range is due to damage to European honeybee (*Apis melifera*). Contrastingly, AGH has far less of an impact on eastern honeybee (*Apis cerana*), which has coevolved in the presence of AGH. This is due to eastern honeybee's adaptive defense strategy. While European honeybees fail to react to the presence of AGH, eastern honeybees will recognize AGH presence and actively defend the hive. Eastern honeybees uniquely defend their hives by swarming individual AGH workers and forming a mass of honeybees, decoupling their wings and vibrating their flight muscles, actively raising the internal temperature of the AGH worker. Due to the higher temperature tolerance of eastern honeybees, the shivering behavior can raise the mass's temperature to 47 °C (116.6 °F) but under the lethal tempera-

temperature of 48–50 °C (118.4–122 °F), effectively cooking AGH workers to death (Baker 2020b, Matsuura & Sakagami 1973) (Fig. 6). Eastern honeybee-keeping has a long history in their native range but has become largely replaced by European honeybees with their introduction through trade. While eastern honeybee-keeping is seeing a resurgence, the fact of the matter is that European honeybees form larger colonies and are more prolific honey producers. Therefore, while keeping eastern honeybees may be a potential solution, in terms of honey production, European honeybee-keeping is unlikely to be replaced.

Figure 6. A defensive ball of Eastern honeybees. Source: Wikimedia Commons.

Recently, Asian hornet (*Vespa velutina*) has become established in France after accidentally getting introduced in 2003. Similar to AGH, Asian hornets are also well known to similarly attack honeybee hives. Three nests were recorded in 2004 and quickly increased to 1,637 confirmed nests in 2009. French apiarists have observed Asian hornet attacking hives, but degree of damage and the exact impact on the apiculture industry is unknown. However, the cost of nest removal has been estimated to cost ~€23 million (~$28.3 million) annually between 2006–2015 and potentially increasing as the hornets increase in range (Barbet-Massin *et al*. 2020). Going forward, the effect of Asian hornet on French apiculture may serve as a reference for the impact AGH may have in North America.

In addition to their impact on apiculture, AGH has the potential to disrupt native ecosystems. Previously, lesser banded hornet (*Vespa affinis*), yellow hornet (*V. simillima*) and European hornet (*V. crabro*) have been detected in the United States (Kimsey & Carpenter 2012), of which European hornet has been well established in North America since the 1850s (some sources indicate that the species was intentionally introduced for pest management, source for this information is unclear). European hornet is widely established in North American east of the Mississippi, have slowly spread westward over that last 150+ years. European hornets are largely insectivorous but are also known to occasionally girdle nursery saplings in spring to acquire sap. European hornets are rarely known to attack honeybees and require forest habitats to survive (Beggs *et al*. 2011, Kimsey & Carpenter 2012. While the environmental impact of European hornets in North America is unknown, invasive paper wasps (*Polistes*) in New Zealand are known to adversely impact native entomofauna by preying on 478,000 prey loads/ha/season (~191,200 prey loads/acre/season) (Beggs *et al*. 2011). Therefore, while not a direct comparison, there is the potential for AGH having an adverse environmental impact in North America once established.

It is unclear how AGH was first introduced into North America, but from what is known from Asian hornet introduction into France, it has been established a single mated queen is sufficient for establishment (Barbet-Massin *et al*. 2020). However, recent genetic analysis utilizing the mitochondrial genome has established that at least two maternal lineages have been identified between Canadian and US AGH interceptions, suggesting that at least two introductions have occurred in Canada and the US (Wilson *et al*. 2020). According to the USDA's Domestic Pathway Analysis for the Asian Giant Hornet, due to overwintering and nesting tendencies, the artificial spread of AGH is unlikely. Therefore, any AGH spread is likely going to be the result of natural spread by dispersal (USDA 2020a). However, if AGH spread will be similar to European hornet after establishment, we can expect spread to be slow and gradual as it took >150 yrs for European hornet to cross the Mississippi from its initial inception in New York state. However, AGH young, similar to other social wasps are a delicacy in parts of Asia and any illicit import/export activity could be a means to spread AGH into and within the US (USDA 2020a). In fact, there is one recorded incident of an entire AGH nest having been intercepted from China, which is believed to have been motivated by consumption (Smith-Pardo *et al*. 2020).

While there is a legitimate concern that AGH will have an adverse economic impact on North American apiculture, east Asian beekeepers have been able to quell AGH impact through the implementation of exclusion cages (Fig. 7) and commercially available drop-floor entryways. In addition, due to the unlikeliness of AGH to be spread artificially and expected slow natural spread similar to European hornet in North America, AGH will likely to be less negatively impactful than the most extreme projections that have been initially made.

Figure 7. An exclusion cage designed to prevent AGH entry into beehives. Source: NBC-K5 news.

Medical Impact

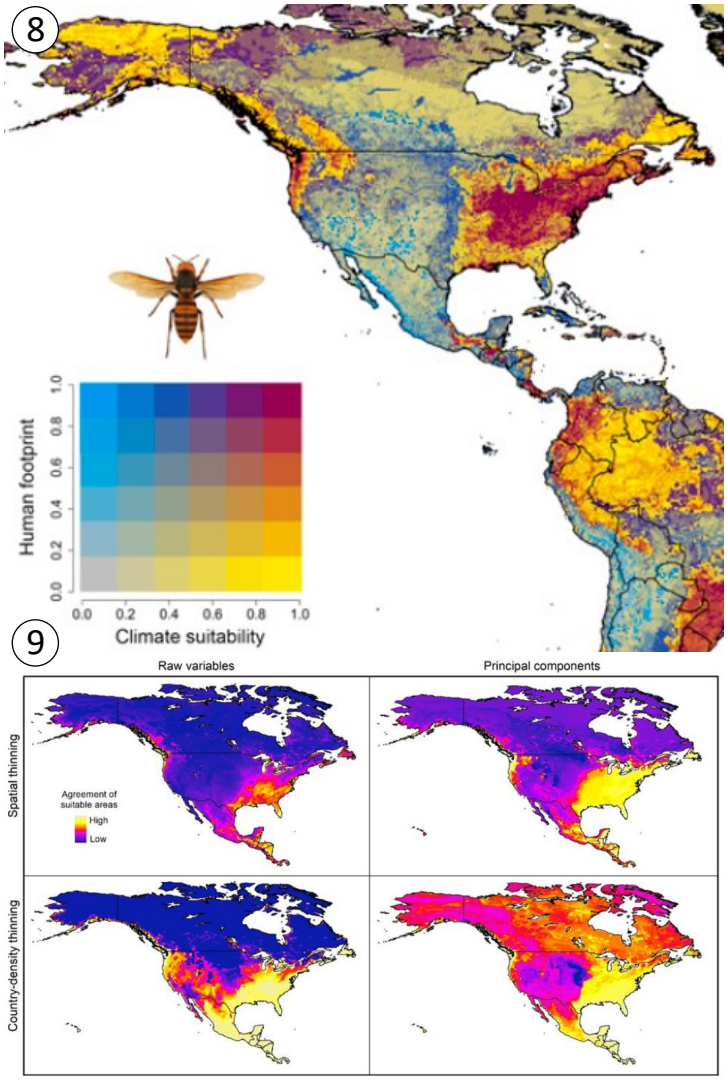
There is no doubt that AGH has a very painful sting. Beginning in the 1980's Justin O. Schmidt, a research entomologist out of Arizona began publishing on what has subsequently been coined the Schmidt Sting Pain Index. The Index is a somewhat subjective ranking of pain from 1–4, with 4 being the most painful. For reference, honeybees rank as a pain level of 2, and the warrior wasp (*Synoeca septentrionalis*) (widely considered to be the most painful wasp sting in the world) is a pain level of 4, with Schmidt describing it as "(t)orture. You are chained in the flow of an active volcano. Why did I start this list?" (Schmidt 2016) While Schmidt himself has done toxicological research on AGH, he has never been stung, but Coyote Peterson, a YouTube character has taken up the mantle and has ranked AGH stings as a 4 (Greenspan 2020). Pain aside, interestingly, honeybees are in fact more toxic than AGHs, with a LD_{50} of 2.8–3.5 mg/kg compared to the 4.1 mg/kg for AGHs (Pucca *et al*. 2019, Schmidt *et al*. 1986). However, it should be noted that honeybees can only sting once and are much smaller, so effectively the volume of venom per sting may be comparatively larger enough to counter LD_{50} discrepancies between honeybees and AGHs. Another important fact to note is that medically speaking, there is no link between the pain of a venom and its toxicity (Patel, M.D. personal communication).

Various values for annual deaths due to AGHs have been presented in the media, but the source of these numbers is rather unclear. Looking at census data by the Japanese Ministry of Health, Labor and Welfare there is an average of 26 deaths due to Hymenoptera stings between 1983–2015, much fewer compared to the 40 or so often presented by the media. It is noteworthy that while the mean value of 26 is mostly attributable to AGH, this value also includes stings from other bee and wasp species. In comparison, in the US an average of 62 deaths are attributable to Hymenoptera stings between 2000–2017. Relative to total national population sizes, 18.9 x 10^{-6} % and 20.6 x 10^{-6} % of the population dies due to Hymenoptera stings in the US and Japan respectively, which is not very different comparatively despite the presence of AGH in Japan.

AGH deaths in Japan are mostly due to anaphylactic (allergic) symptoms and are not due to innate lethality to humans (Main 2020). When death does occur due to AGH without anaphylactic shock, death is attributable to the sheer number of stings and resultant hemorrhaging and organ failure, and kidney failure in particular. On average patients that have died received 59 ± 12 stings, significantly more compared to 28 ± 4 stings in patients that survived (± standard error, p = 0.01) (Yanagawa *et al*. 2007). While AGH stings are undoubtedly painful due to acetycholine and histamine within the venom causes pain and swelling; kinin causing blood vessel dilation; mastoparan (not found in bee venom) and phospholipase synergistically act to degrade immune cells and cause widespread inflammation. Together, these venom components cause blood and muscle cell death, and the release of macromolecules like hemoglobin in extreme cases can lead to renal failure due to their role in filtering out rogue macromolecules in the blood stream (Main 2020). Therefore, a sting by AGH is highly unlikely to cause death unless ~50 stings are experienced in the absence of an allergic reaction.

Potential Spread of AGH in North America

Several suitability studies have been published since AGH has been discovered in North America (Nunez-Penichet *et al*. 2020, USDA 2020b, Zhu *et al*. 2020). All studies have used an ecological niche modeling approach in their studies but due to methodological differences, results are variable to a degree. However, the overall results indicate that a narrow coastal margin of the West Coast and a relatively large portion of the East Coast is suitable. Most models explored indicate that Kansas demonstrates poor to moderate environmental suitability (Nunez-Penichet *et al*. 2020, USDA 2020b, Zhu *et al*. 2020) (Figs. 8–10). It is difficult to predict the ecological impacts of invasive species. Many invasive Vespidae have minimal impacts on the environment, but some have been known to displace congeners and disrupt native environments (Zhu *et al*. 2020). However, due to substantial overlap between potential AGH suitability in North



Figures 8–9. AGH habitat suitability for North America. Source: Nunez-Penichet *et al*. 2020 & Zhu *et al*. 2020.

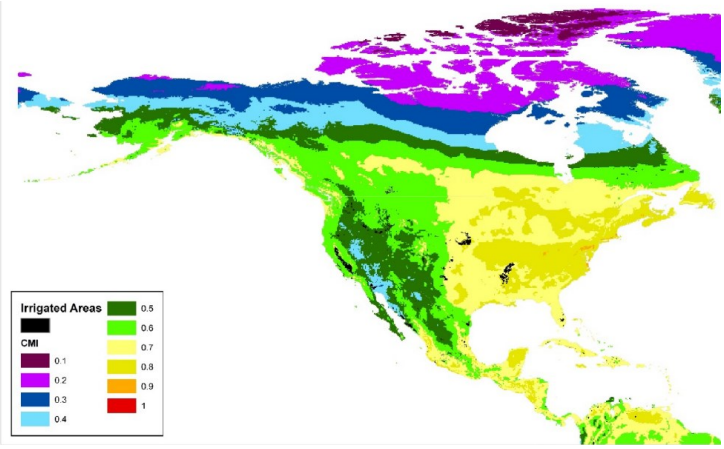


Figure 10. AGH habitat suitability for North America. Source: USDA 2020b.

America, honey production, bumblebee (*Bombus*) and stingless bee (*Melipona*) diversity (Nunez-Penichet *et al*. 2020), it is important that folks are aware of what AGH looks like and how to appropriately respond if they spread to new locations (Fig. 11). That being said, it is important to note that many obstacles appear to exist for a strong establishment and subsequent spread of AGH in North America. In addition, it is noteworthy that the first mature nest to have been eradicated in the United States was aerial (Washington Department of Agriculture 2020)—atypical behavior—potentially indicative that AGH may already be demonstrating non-native-atypical behavior in the US. Regardless, as we currently understand, there is little evidence that AGH will pose any immediate threat to the continent.

Distinguishing AGH from other Natives

There are several natives that folks have trouble distinguishing from AGH. However, the most commonly confused species in Kansas is eastern cicada killer (Hymeoptera: Crabronidae: *Sphecius speciosus*) (Fig. 11). These large solitary wasps paralyze and provision their burrows specifically with cicadas onto which they lay their eggs and young develop into the following season. Eastern cicada killers are a common native that can be distinguished from AGH by their smaller size, large eyes that occupy the majority of their head in lateral view, and overall black to black-ish body—AGH will be a deep orange color overall with dark black bands as opposed to a black ground color with pale-yellow bands as in eastern cicada killers. Western cicada killers, less common in Kansas, will be more orange but also differ in color pattern significantly enough that an image comparison will distinguish the two. Cicada killers are benign natives that will have no impact on people. While they may nest in open grounds of yards, undisturbed pose no consequence to people.

The most interesting inquiry we received at Kansas Department of Agriculture was a mydas fly (Diptera: Mydidae). These flies are the largest flies in the world and very rare. Larvae typically develop in sandy soils as predators and adults imbibe nectar and are harmless. Adults will often mimic wasps and hornets as a defense mechanism but are harmless. These rare flies require quality natural habitat and are rarely encountered and was a surprise to receive this report. The author has spent decades in entomology and is still to see one alive.

The following link to North Carolina State University is a fantastic resource for distinguishing AGH from look-alike natives and should be consulted when you believe you've made a sighting:

https://www.ces.ncsu.edu/2020/05/a-visual-guide-to-asian-giant-hornets-and-similar-insects/

Figure 11. Eastern cicada killer female. Source: BugGuide © Jeff Jarrett.

Final Remarks

While AGH does pose a threat to North American apiculture, current potential distributional models and modes of spread indicate that they are not going to be an immediate issue for most of the US. Generally, Kansas is likely not to be a major stronghold for this hornet if it ever arrives.

AGH has a powerful sting that is painful, but its venom's toxicity is less compared to honeybees. While it may be argued that AGH is capable of multiple stings compared to honeybees and has a higher venom load, threat lies in anaphylaxis which also applies to honeybees. Threat of death by AGH stings occur in cases of extreme numbers of successive stings in the >50 range: mostly a rare occurance.

Several sightings of AGH in the US have been the result of citizen scientists, including a young girl in Washington. Accordingly, recognizing the importance of being able to identify AGH from other native insects will be paramount in monitoring spread and novel establishment of AGH in the US.

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