THE ASIAN GIANT HORNET—WHAT THE PUBLIC AND BEEKEEPERS NEED TO KNOW

Introduction

The Asian giant hornet (AGH) or Japanese giant hornet, *Vespa mandarinia*, recently found in British Columbia, Canada, (B. C. Ministry of Agriculture 2019) and in Washington State (McGann 2019), poses a significant threat to European honey bee (EHB), *Apis mellifera*, colonies and is a public health issue. The AGH is the world's largest species of hornet (Figure 1; Ono et al. 2003), native to temperate and tropical low mountains and forests of eastern Asia (Matsuura 1991). It appears the hornet is well adapted to conditions in the Pacific Northwest.

If this hornet becomes established, it will have a severe and damaging impact on the honey bee population, the beekeeping industry, the environment, public health, and the economy. It is critical that we identify, trap, and attempt to eliminate this new pest before it becomes established and widespread. Attempts to contain the spread and eradication of this invasive insect will be most effective by trapping queens during early spring before their nests become established. Another strategy is to locate and destroy nests prior to development of virgin queens and drones in the late summer and fall.

It is critical that surveying and trapping occur before the fall reproductive and dispersal phase of the hornet. Beekeepers in the field are a crucial line of defense in locating, identifying, and trapping the hornets. Yet, everyone should be on the lookout and report any sightings to local authorities and the Washington State Department of Agriculture.

Here, we will cover how the AGH will impact the honey bee, give the reader a better understanding of the hornet, outline precautions to take, and first aid if attacked by the hornet.

Figure 1. Asian giant hornet macerating a honey bee into a meat ball for transport back to the nest. (Photo courtesy of Scott Camazine.)

Impact on Honey Bees

This invasive hornet is a voracious predator of EHBs late in the season (late summer to early fall). Honey bee colonies provide a rich, plentiful, and easily attainable food source. The AGH also preys on other hornets and social wasps, yet its impact on honey bee colonies is the biggest concern. An easy target, EHBs lack the defense mechanisms developed by Asian honey bees, *Apis cerana*, which coevolved with the hornets. Honey bee pupae and larvae are rich in protein and fat and are plentiful, making it the preferred food for the hornet's developing queens and drones (Matsuura and Sakagami 1973).

To acquire this protein food base, the hornet attack on a honey bee colony occurs in three phases: hunting, slaughter, and occupation (Matsuura and Sakagami 1973).

Hunting: Foraging hornets wait and seize individual bees near the entrance. A meaty ball is made from the thorax of the adult bee and carried back to the hornet's nest (Matsuura and Sakagami 1973). Hornet scouts locate and mark a source colony during the hunting phase (Ono et al. 1995). A food-site marking pheromone is produced in a gland located on the last abdominal segment of the hornet. The pheromone recruits additional hornet nest-mates, then the slaughter phase occurs.

Slaughter: The slaughter phase is a relatively rare occurrence (Matsuura and Sakagami 1973), but when it does occur, it is devastating to the honey bee hive. Several hornets will relentlessly attack and kill nearly all of the adult worker bees as they attempt to defend their colony (Matsuura and Sakagami 1973). Within a few hours, a strong, healthy, and populous honey bee colony of 30,000 to 50,000 workers can be slaughtered by a group of hornets. The number of hornets engaged in a slaughter can range from 2 to 50 (Barth et al. 2013). The slaughter phase generally will not occur until late July or August, with the peak in September through late October.

Occupation: After eliminating the adult honey bees, the hornets occupy the colony and guard the entrance to protect their food source. During the occupation phase, their behavior changes and becomes very defensive, attacking nearby animals and humans. They harvest and transport the bee brood over the next ten to fourteen days, until it becomes rancid, feeding the hornet larvae back in their nest (Matsuura and Sakagami 1973).

Prior to transport, the hornets chew the bee brood into a paste and take this back to the nest. The adult hornets do not eat the paste; all is given to the developing hornet larvae to promote their growth. After consuming and digesting the bee brood paste, the larvae drool a high energy mash, which the adult hornets consume. The larval secretion provides the adults with the nutrients needed for their survival (Matsuura and Sakagami 1973).

The intensity of attacks is dependent upon the distance of the food source. The hunting phase's shift to the slaughter phase usually occurs when the hornet nest is close to the beehive, within 0.5 to 1.5 miles, and hornet visits are constant. If a greater distance, up to five miles, the hunting phase can continue indefinitely without ever shifting to a slaughter phase (Matsuura and Sakagami 1973). Attacks generally focus on a particular honey bee hive within an apiary, and typically near the AGH nest.

The EHB is easy and bountiful prey for the hornets, with no inherent defense mechanisms. As the bees rush out to defend their colony, they are slaughtered by the hornets, most of the adult workers are decapitated and discarded, the few remaining bees are ignored as the hornets collect and transport the bee brood back to their nest. The smaller *A. cerana* has coevolved with wasp and hornet predators and has developed several behavioral defense mechanisms and counter-attack strategies against them (Figure 2).

Figure 2. The Japanese honey bees (*Apis cerana japonica*) forming a "bee ball" in which hornets are engulfed and heated. Yokohama, Kanagawa prefecture, Honshu Island, Japan. (Photo courtesy of Takahashi Wikimedia Commons.)

The hornet's marking pheromone is recognized by the *A. cerana* and stimulates defensive behaviors. The hornets mark a colony by rubbing the basal gland at the tip of the abdomen. EHBs do not react and apparently do not recognize the hornet's marking pheromone, making them more susceptible to attack by the AGH. The *A. cerana* recognizes this pheromone and alerts the colony. No single bee attacks alone, the defense is collective. EHBs rush out as individuals and are slaughtered one after another (Ono et al. 1995; Sugahara and Sakamoto 2009).

The Asian honey bees successfully repel hornets and eliminate the scouts before a mass attack can be started. When a hornet is detected, the *A. cerana* colony becomes very alert with raised antennae and heavy fanning. The workers also begin emitting a warning sound that tends to repel the hornet. Workers stop foraging and retreat into the colony. Aggregating near the entrance, a group of about 50 *A. cerana* guards display a warning behavior, lifting and shaking their abdomens simultaneously (McClenaghan et al. 2019). This warning behavior is often effective in driving away a hunting hornet.

If the hornet persists, an *A. cerana* guard bee will grasp the hornet with its mandibles (jaws). Several hundred bees will follow suit and engulf the hornet in a ball in an immediate, synchronized rush, superheating the hornet to a lethal temperature. The center of the *A. cerana* heat ball reaches 117°F (47°C) with high levels of carbon dioxide (Sugahara and Sakamoto 2009; Yamaguchi et al. 2018). The bees are able to hold this position for about 20 minutes, since they are tolerant of temperatures a few degrees higher than temperatures lethal to the hornet (McClenaghan et al. 2019). The defensive heat ball temperature extremes can kill 25% of the honey bees and shorten the longevity of those exposed, though the colony survives (Yamaguchi et al. 2018; McClenaghan et al. 2019).

The *A. cerana* colony defense is highly effective in interrupting the initial hunting phase of the hornet by eliminating the scout hornet, preventing recruitment and mass attack. However, the importation of *A. cerana* is *not* an option to counter the AGH.

There are two Asian mites, *Tropilaelaps clareae* and *T. mercedesae*, which coevolved with the *A. cerana* and are minor pests. The EHB is defenseless, and the impact of these mites may be much worse than the *Varroa* mite, the current major parasite of EHB in the United States and throughout the world where it has spread. We cannot risk the possible importation of these mites. Also, the *A. cerana* would not serve well in US agricultural systems.

Vespa mandarinia—What Beekeepers Need to Know

Beekeepers in the Pacific Northwest should be very concerned with the hornet's discovery in British Columbia and northwest Washington State. The Washington State Department of Agriculture is distributing sap-baited sticky boards aimed at attracting inseminated queens emerging from hibernation. Queens emerge in late March or early April and begin seeking a suitable site for establishing nests. During this time, the queen has a high carbohydrate diet; oak sap is one of the preferred sources. Sticky traps may be an effective way to capture AGH queens and prevent their establishment of new nests.

Sticky boards can be used throughout the season to reduce the number of hornets. One trick that Japanese beekeepers use is to "bait" the sticky board with a dead AGH. The pheromone they release attracts additional hornets who, in turn, attract more hornets. Individual hornets can often be seen in honey bee apiaries in areas heavily infested with the AGH. In Japan, beekeepers use sticks or badminton rackets to knock them out of the air. Care should be taken whenever coming into direct contact with hornets, but they are not overly aggressive away from their nest or when they are not "occupying" a honey bee hive and harvesting the pupae or larvae. The Japanese beekeepers have also developed a couple of hive attachments to control the AGH. One is a trap that allows the hornet into a chamber containing bait at the bottom of the trap. A second opening at the top of the bait chamber leads into a capture trap. This takes advantage of the hornet's tendency to fly up and away once it has taken the bait (Figure 3). These traps do work, but hornets can escape and eventually learn to avoid the trap and wait outside to catch bees. Another method is to attach a screen loosely over the full front of the hive that allows honey bees to come and go, but inhibits the hornet's approach to the colony. These two methods are often used in tandem at a ratio of 1:5, screens-to-traps, to keep costs down while still disrupting the hornets (Matsuura and Sakagami 1973).

The USDA suggests some trap designs that may also work to capture queens and workers in the spring and fall. For a list of traps that may work, see the USDA's [New Pest Response Guidelines: *Vespa mandarinia*, Asian Giant Hornet] (Tripodi and Hardin 2020).

Finding the nests can be a bit of a challenge. Their nests are almost always in the ground though they can occasionally be found under overhangs and within wall voids. The AGH is a strong flier, and they likely have an extensive flight range. Often flying high and away from apiaries, this makes tracking the AGH difficult. If you can locate a nest, proceed with extreme caution and contact the WSDA immediately. Do not try to exterminate the nest yourself.

Figure 3. Japanese AGH trap on honey bee hive. (Photo courtesy of Inoue Haruko.)

For smaller non-migratory and hobby beekeepers, a hornet trap that fits on the front of the colony and works well in Japan may help limit the potential for an all-out attack by the AGH. Simply screening the hive, for example, using honey bee queen excluders will not protect colonies from an AGH attack. The Japanese traps are designed to capture the hornet away from the entrance and allow honey bees to forage with less disturbance. These traps may not be practical for commercial or migratory beekeepers. The commercial beekeepers' best option to control the hornet may be to use the sticky traps, either baited with sap or a captured hornet. Another option may be to move colonies out of heavily infested areas before the hornets begin rearing queens and drones in late August through November or until the first heavy frost.

Public Health Issue

The AGH tends not to be aggressive toward people, though they will attack when their nest or food source is threatened. Stumbling upon or disturbing a nest can be dangerous, especially for the unaware. Hornets patrol the nest entrance day and night and are highly defensive. The hornet sting is excruciating, and individual hornets can sting repeatedly, unlike honey bees that lose their stinger in the process. Dr. Justin Schmidt, in his book *The Sting of the Wild* (2016), refers to the AGH as "the most intimidating insect on earth." The AGH has earned this designation due to its size, the intensity of the pain of its sting, and the amount of venom it can deliver. The stinger is also about a quarter inch long and can penetrate through a standard beekeeper's suit or coveralls. When eliminating nests, professionals wear double layers of smooth, slippery fabrics to reduce the likelihood of being stung. A protective face mask is also recommended as the hornets can spray venom. Stings can cause anaphylactic shock in allergic victims but can also be lethal to people who are not allergic if a sufficient dose is received, although this is rare in countries where the hornet is native. If a nest is encountered, leave the area immediately and contact local authorities or the Washington Department of Agriculture. Do not attempt to eliminate the colony yourself.

Avoidance and First Aid

If you find yourself in a situation where you are being attacked by any bees, wasps, or hornets, get away from them as quickly as possible. Move quickly, but do not panic! Bees, wasps, and hornets tend to give a warning signal before they begin an attack. In the case of the AGH, they snap their mandibles (jaws) together, and you will hear a loud clicking noise. But by the time you hear this, it may be too late. The best strategy is to run far away. Do not necessarily run in a straight line. If there are trees or bushes, it is best to weave your way around them to elude the pursuing hornets. If possible, retreat inside a vehicle or structure. The AGH reportedly can fly up to 25 mph (Strom 2001). Outrunning them will be difficult, it is best to elude them and avoid their defensive territory. If stung, seek medical attention. Also, report the incident to the Washington State Department of Agriculture or local authorities as soon as possible.

The type of damage that venom from bees, wasps, and hornets inflict varies from very mild to quite severe. It is estimated that about one to five percent of individuals stung by bees or wasps will develop a systemic allergic reaction, which can be life-threatening (Steen et al. 2005). Persons experiencing difficulty breathing following a sting should seek medical attention immediately. Most people receiving one to a few stings will develop a localized reaction, such as swelling and itching of the area of the sting(s). Localized reactions can be significant and painful, with some relief in the use of oral antihistamines. An ice pack can also help to reduce swelling (Laskowski-Jones 2006).

In summary, first aid suggestions for stings include:

- Monitoring swelling and removing any tight-fitting jewelry or clothing constricted by swelling.
- Taking an antihistamine.
- Applying ice or a cold compress.
- Monitoring for any severe reactions following a sting, especially respiratory distress.
- Calling 911 or seeking immediate medical care if experiencing respiratory distress or anaphylactic shock.
- Washing the site of the sting thoroughly using soap and water.
- Additional information on first aid is available at the Washington State Department of Health website.

Additional complications from stings noted in the literature include an anaphylactic reaction (can lead to airway closure or cardiac arrest), necrosis (death of tissue), destruction of red blood cells, kidney failure, other organ failures, and death. Seek medical attention and call 911 for difficulties breathing or any other life-threatening symptoms.

What Is a Hornet?

A hornet is simply a large wasp. Generally, wasps of the class or genus known as *Vespa* are considered hornets. Interestingly, there are no true hornets (*Vespa*) native to North America. The European hornet (*Vespa crabro*) is well established in much of the eastern half of the United States. The European hornet is not a major threat to honey bees.

Hornets are part of a large order of insects known as Hymenoptera that include bees, wasps, ants, and sawflies. Worldwide, there are more than 115,000 species belonging to the order Hymenoptera (Hunt and Toth 2017). Most of this group of insects are beneficial for pollination and pest control. There are two types of hornets, solitary and social (Lee et al. 2016). Solitary hornets hunt various insects and spiders. Their "stinger" is primarily used to paralyze their prey. They often lay an egg on the immobilized victim, and when the egg hatches, the larvae consume the still-living host. Solitary wasps generally do not sting humans and usually are not aggressive unless provoked.

Social wasps, on the other hand, do use their stingers to defend their nests and can be very aggressive and will readily sting. The most common social wasp in the United States is the yellowjacket. The four most common yellowjacket species in Washington are the western yellowjacket (*Paravespula pensylvanica*), the common yellowjacket (*Paravespula vulgaris*), the aerial yellowjacket (*Dolichovespula arenaria*), and the German yellowjacket (*Paravespula germanica*) (Berry and Mooney 1998; Landolt and Antonelli 2003).

The recently introduced Asian giant hornet (AGH) is also a social wasp. When foraging for food in spring, the AGH is not highly aggressive—unless its nest is disturbed. Late summer and fall, with the high demand for protein, they become very aggressive when attacking or occupying a honey bee colony.

Life Cycle of the Asian Giant Hornet

The inseminated AGH queens emerge in late April to early May (Figure 4). The queen begins to forage for carbohydrate sources, such as tree sap, while looking for a suitable nest site. With few exceptions, she will establish her new nest in the ground. It may take days or weeks for the queen to find and construct a suitable nest site and begin rearing workers. Until the emergence of the first workers, the queen performs all the nest's functions, including nest construction, egg-laying, care of the young, and foraging for food. The first workers begin to emerge as early as June and take over nest and foraging activity within two to four

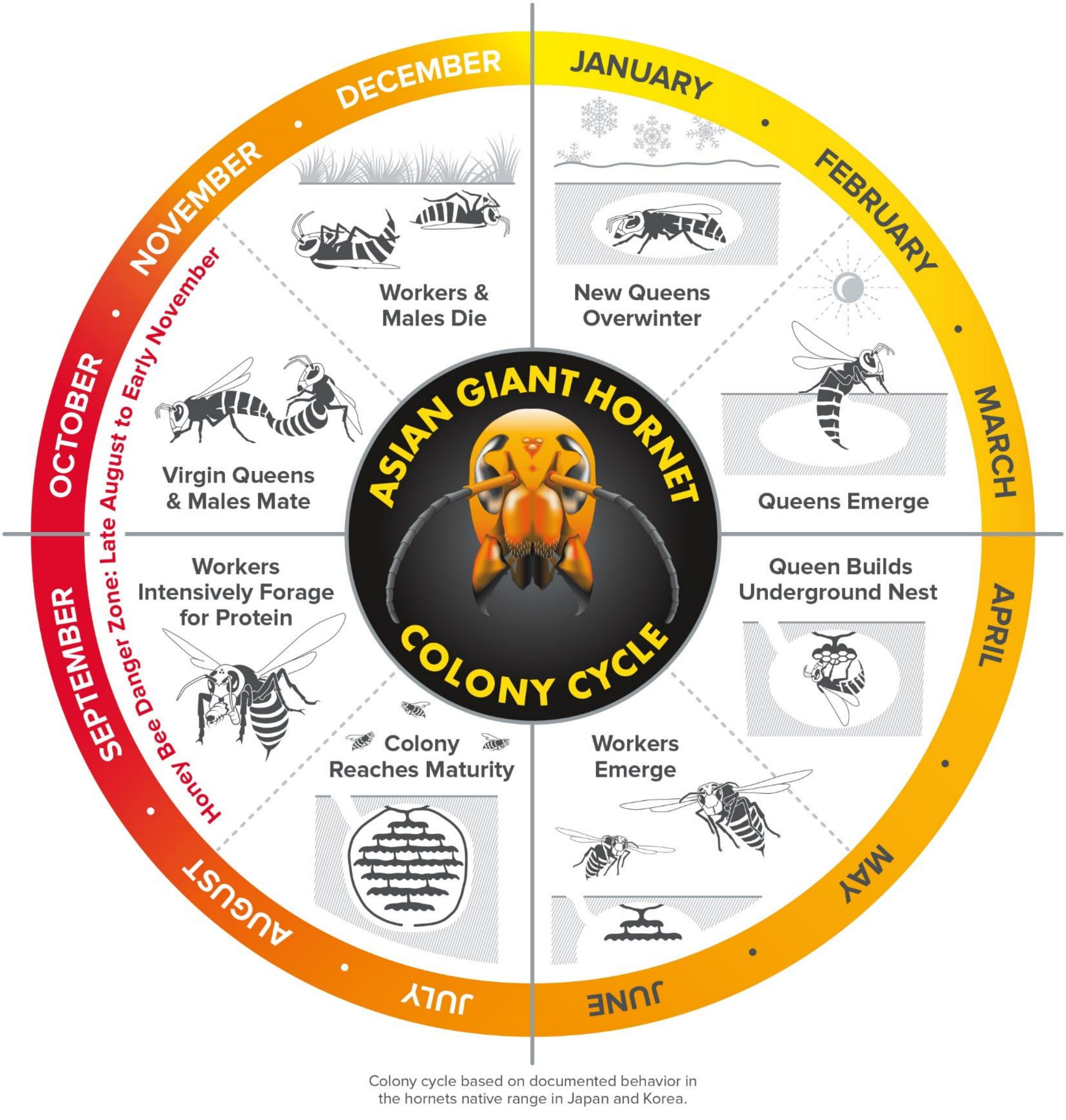

Figure 4. Asian giant hornet colony cycle.

days. After the emergence of the first workers, the queen will continue foraging and nest activities for a short period. Eventually, the queen will focus solely on egg-laying, while the workers perform foraging, nest construction, and care for the developing brood. For the next couple of months, the nest grows exponentially in size, and the workers begin to focus more attention on the queen, forming a court of attendants very similar to what we see in honey bee colonies. The workers also start to construct larger cells for the rearing of new queens and males (drones) (Matsuura 1984).

Toward the end of August through October, only queens and drones are reared. It is at this stage in the hornet's lifecycle when workers will start attacking honey bee colonies and other social bee and wasp nests to meet the growing demand for protein to feed the queen and drone larvae. The newly emerged queens and drones will remain in the nest for 10–20 days, continually feeding, but do not participate in any nest maintenance activities. When these new queens and drones exit the nest, they will never return (Matsuura 1984). The virgin queens emerging from the nest are seized by the drones in midair near the hive entrance, causing both to fall to the ground. Mating takes 8 to 45 seconds to complete (Barth et al. 2013). Late emerging virgin queens may not receive sufficient nutrition, may not mate, and will die near the nest. Towards the end of October, the founding queen of the nest dies, and, with no new workers emerging, the nest degenerates and dies out. Inseminated queens will seek a suitable location to overwinter, and the life cycle will begin again in spring (Matsuura 1984).

Figure 5. Stinger of *V. mandarinia*. A close-up of the stinger is shown in the top photo. (Photo courtesy of kobunny Flickr.)

The Stinger

The stingers of bees and social wasps (including hornets) have evolved to attack, immobilize prey, defend their nest, and deliver venom that inflicts pain on the victim (Figure 5). Because the stinger is a modified egg-laying device, it only occurs in females. The males or drones may look and sound intimidating, but they cannot deliver a sting. The males do not participate in food collection or defense of the nest. It can be challenging to distinguish between a male and female bee or wasp—so use caution and avoid any contact with the AGH.

Hornets and wasps have curved stingers and have smaller and fewer barbs compared to the honey bee. The smaller barbs allow for the tearing of flesh, which helps the stinger puncture the skin of the victim and deliver venom. The fewer and smaller barbs of wasp and hornet stingers allow them to sting repeatedly. The curved stinger helps with the insertion into the target. Wasps are able to deliver the stinger at a force that is 40 to 225 percent greater than that of the honey bee. In addition, wasps are able to sting both above (dorsally) and below (ventrally), giving them much greater flexibility in delivering a sting (Zhao et al. 2015). Given this greater flexibility and force of the sting, extra precaution is warranted.

The stingers of hornets and wasps are different from that of the honey bee. The honey bee stinger is heavily barbed, with lancets that ride on rails on the main hollow shaft of the stinger. Their stinger is straight and can only sting under their bodies (ventrally). Muscular action works the lancets as they alternate their downward movement and tear into the flesh of the victim. As the stinger works its way into the victim, it alternates back and forth, digging deeper at the same time two diaphragms within the venom sac facilitate a pumping action, delivering venom through the hollow main shaft. When the bee flies away, the barbs on the stinger keep it lodged in the victim, leaving the stinger, venom sac, and some of the internal abdomen behind.

Venom

The primary purpose of honey bee and hornet venom is defense against predators by inflicting pain and damage. *Vespa mandarinia* is one of the two most venomous, known insects in the world. The other is another large hornet *V. tropica* (Schmidt et al. 1986). The amount of venom a wasp has (4.1 µl/wasp) contributes to the designation of *V. mandarinia* as the most venomous insect (Schmidt et al. 1986). In comparison, the honey bee has about 0.6 µl/bee (Schmidt 2020). Bee and wasp venoms contain a cocktail of substances (Postma 2009); most of these are primarily proteins, but the type of proteins differ between bees, wasps, and hornets (Fitzgerald and Flood 2006). Milligram to milligram, the honey bee is more toxic than that of the AGH (Schmidt 2019), but given that the AGH can deliver more venom and sting repeatedly, they are far more dangerous than the honey bee. Histamine is a common ingredient in bee, wasp, and hornet venom, which causes dilatation of blood vessels and thus is responsible for localized swelling, redness, and some itching. However, histamine does not cause pain; acetylcholine, found only in hornet venom, does cause a sharp pain (Schmidt 2016). Most beekeepers are aware of this difference and can readily tell the difference between a honey bee sting and that of a wasp or hornet, which is more intense and longer lasting than the honey bee sting.

To Report Asian Giant Hornet Sightings

- Report using the [Hornet Watch Report Form]
- Email PestProgram@agr.wa.gov
- Call 1-800-443-6684

References

Barth, Z., T. Kearns, and E. Wason. 2013. Animal Diversity Web.

B. C. Ministry of Agriculture. 2019. Pest Alert: Asian Giant Hornet.

Berry, R.E., and P. Mooney. 1998. *Insects and Mites of Economic Importance in the Northwest*. Department of Entomology, Oregon State University.

Fitzgerald, K.T., and A.A. Flood. 2006. Hymenoptera Stings. *Clinical Techniques in Small Animal Practice* 21:194–204.

Hunt, J.H., and A.L. Toth. 2017. Sociality in Wasps. Cambridge University Press.

Landolt, P.J., and A.L. Antonelli. 2003. *Yellowjackets and Paper Wasps*, rev. *Washington State University Extension Publication* EB0643. Washington State University.

Laskowski-Jones, L. 2006. First Aid for Bee, Wasp & Hornet Stings: Learn How to Protect the Victim—and Yourself—from the Potentially Dangerous Effects of Their Venom. *Nursing* 36:58–59.

Lee, S.H., J.H. Baek, and K.A. Yoon. 2016. Differential Properties of Venom Peptides and Proteins in Solitary vs. Social Hunting Wasps. *Toxins* 8(2):32.

Matsuura, M. 1984. Comparative Biology of the Five Japanese Species of the Genus Vespa (Hymenoptera, Vespidae). *Bulletin of the Faculty of Agriculture—Mie University* 69:1–131.

Matsuura, M. 1991. Vespa and Provespa. In *The Social Biology of Wasps*, edited by K.G. Ross and R.W. Matthews, 232. Ithaca; London: Cornell University Press.

Matsuura, M., and S.F. Sakagami. 1973. Bionomic Sketch of the Giant Hornet, *Vespa mandarinia*, a Serious Pest for Japanese Apiculture. *Journal. Series 6. Zoology* 19(1):125–162.

McClenaghan, B., M. Schlaf, M. Geddes, J. Mazza, G. Pitman, K. McCallum, S. Rawluk, K. Hand, and G.W. Otis. 2019. Behavioral Responses of Honey Bees, *Apis cerana* and *Apis mellifera*, to *Vespa mandarinia* Marking and Alarm Pheromones. *Journal of Apicultural Research* 58:141–148.

McGann, C. 2019. Pest Alert: Asian Giant Hornet. Washington Department of Agriculture Ag Briefs.

Ono, M., T. Igarashi, E. Ohno, and M. Sasaki. 1995. Unusual Thermal Defence by a Honeybee against Mass Attack by Hornets. *Nature* 377:334–336.

Ono, M., H. Terabe, H. Hori, and M. Sasaki. 2003. Insect Signalling: Components of Giant Hornet Alarm Pheromone. *Nature* 424: 637–638.

Postma, T.L. 2009. Neurotoxic Animal Poisons and Venoms. In *Clinical Neurotoxicology: Syndromes, Substances, Environments* pp. 463–489. Saunders, Philadelphia, PA.

Schmidt, J.O. 2016. *The Sting of the Wild*. Johns Hopkins University Press, Baltimore.

Schmidt, J.O. 2019. Pain and Lethality Induced by Insect Stings: An Exploratory and Correlational Study. *Toxins* 11(7):427.

Schmidt, J.O. 2020. personal communication.

Schmidt, J.O., S. Yamane, M. Matsuura, and C.K. Starr. 1986. Hornet Venoms: Lethalities and Lethal Capacities. *Toxicon: Official Journal of the International Society on Toxinology* 24:950–954.

Steen, C.J., C.K. Janniger, S.E. Schutzer, and R.A. Schwartz. 2005. Insect Sting Reactions to Bees, Wasps, and Ants. *International Journal of Dermatology* 44:91–94.

Strom, S. 2001. Faster than a Speeding Hornet. *The New York Times*, January 3, pp. F1.

Sugahara, M., and F. Sakamoto. 2009. Heat and Carbon Dioxide Generated by Honeybees Jointly Act to Kill Hornets. *Naturwissenschaften* 96:1133–1136.

Tripodi, A., and T. Hardin. 2020. New Pest Response Guidelines: *Vespa mandarinia* Asian Giant Hornet. United States Department of Agriculture.

Yamaguchi, Y., A. Ugajin, S. Utagawa, M. Nishimura, M. Hattori, and M. Ono. 2018. Double-Edged Heat: Honeybee Participation in a Hot Defensive Bee Ball Reduces Life Expectancy with an Increased Likelihood of Engaging in Future Defense. *Behavioral Ecology and Sociobiology* 72:1–8.

Zhao, Z., H. Zhao, G. Ma, C.W. Wu, K. Yang, and X. Feng. 2015. Structures, Properties, and Functions of the Stings of Honey Bees and Paper Wasps: A Comparative Study. *Biology Open* 4:921–928.

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