Risk Assessment and Recommendations for Foresters Exposure to Hymenoptera

by

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Ants, bees, hornets, wasps, and yellow jackets, collectively in the Order Hymenoptera, are a serious concern to outdoor workers as their stings have the potential to cause life-threatening allergic reactions. This study assessed current training regimes and impacts of Hymenoptera stings on forestry workers across the United States (US). A survey was distributed to nearly 2,000 outdoor workers in four US regions (South, West, Northeast, Midwest). Results show that ants are a primary concern in the South with over 75% of participants reporting ant stings within the last five years. Bees, hornets, wasps, and yellow jackets are a concern in all US regions with 60-70% and 75-93% of participants, respectively, having been stung by bees or hornets/wasps/yellow jackets within the last five years. Despite such a large number of participants experiencing stings, nearly 75% of participants are not concerned about being stung or their reaction to such stings. Approximately 70% of participants in the survey reported not having received any safety training related to Hymenoptera from their employers. There was no significant difference found in the proportion of those being stung at work between safety trained and non-safety trained participants (p = 0.230). However, it was significantly more likely for participants to carry a medical first

aid kit if they had received Hymenoptera safety training ($p < 0.05$). Consequently, a Hymenoptera educational brochure was developed as a potential tool to train outdoor workers and reduce risk. Based on the results, more comprehensive and more frequent training is recommended to help reduce risk of exposure of Hymenoptera to foresters.

Risk Assessment and Recommendations for Foresters Exposure to Hymenoptera

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CHAPTER I - INTRODUCTION AND PURPOSE OF THE STUDY

Risks Associated with Hymenoptera. Many of the insects that constitute the Order Hymenoptera are considered beneficial; however, venom from stings may cause sensitization or allergic reactions in sensitized individuals. The Vital Statistics database of the United States (US) Department of Health and Human Services (DHHS) showed that between 1979 and 1990, 527 people died from hornet, bee, or wasp-related injuries, and 57 people died from exposure to other venomous arthropods (Langley and Morrow, 1997). Therefore, the average number of fatalities per year between 1979 and 1990 from hornet, bee, or wasp-related injuries was 43.9 deaths per year, and the average number of fatalities per year for other venomous arthropods during this time period was 4.75 deaths per year (Langley and Morrow, 1997). Because occupational exposure to Hymenoptera occurs at a higher rate in outdoor workers compared to the general public, foresters and other outdoor workers may be at a greater risk of stings. The Centers for Disease Control and Prevention Wide-Ranging Online Data for Epidemiologic Research (CDC WONDER) database identified that, during 1999-2015, 987 people in the US died from interactions with hornets, wasps, and bees (CDC WONDER Database, 2017). Of these 987 deaths, 144 occurred in the Northeast region, 202 occurred in the Midwest region, 497 occurred in the South region, and 144 occurred in the West region (CDC WONDER Database, 2017).

Stings may result in a variety of symptoms including generalized (itching or swelling in a small area), local (affecting a larger area such as an entire arm or leg), and systemic or generalized reactions (such as anaphylaxis) that can be life threatening. Hayashi et al. (2014) found the following types of reactions in Japanese foresters who experienced either hornet or wasp stings: 62% (N = 621) experienced a local reaction, 20% (N = 198) experienced a large local reaction, and 21% (N = 210) of participants experienced a systemic reaction to Hymenoptera stings. These numbers in the study conducted by Hayashi et al. (2014) were derived from testing blood samples of the participants for serum antibodies to Hymenoptera venom specifically from hornets and wasps. Hayashi et al. (2014) estimates that about 40 people per year in the US are killed from Hymenoptera stings. Given the potential for negative reactions, the study of Hymenoptera stings in foresters throughout the US bears significant potential for improvements in occupational preventive measures that protect worker health, safety and productivity.

Occupational Hazards. Many research studies highlight the negative effects of Hymenoptera envenomation, e.g., the Lee at al. (2014) case report of 21-year-old male developing hemolytic-uremic syndrome after sustaining fire ant bites; Demain et al. (2009) discuss the increase in insect reactions such as fatal anaphylaxis from Hymenoptera stings in Alaska; Gupta et al. (2016) case report of a 55-year-old man who suffered more than 50 bee stings at one time and then developed cardiac issues roughly three weeks later. Pegula and Kato (2014) analyzed data collected by the U.S. Bureau of Labor Statistics between 2003-2010 on fatalities caused by hymenoptera related injuries. This study found that of 83 fatal occupational injuries during this time period, most of them (N=52) were caused by bee stings. In addition to the fatal bee stings, 11 workers were killed from wasp-related injuries, with three of these 11 deaths involving yellow jacks (Pegula and Kato, 2014). In contrast, there are no known published studies focusing specifically on occupational risk assessment of Hymenoptera exposure in foresters in the US. It is theorized that the proportion of foresters who encounter Hymenoptera stings varies in different parts of the US. The increased occupational hazard of encountering multiple Hymenoptera stings, coupled with a lack of immediate medical resources to respond to envenomation, could lead to extremely dangerous situations for foresters working at remote locations. A worker does not have to have a history of reactions to Hymenoptera stings as it is possible for fatal allergic reactions to occur as the first generalized reaction to a Hymenoptera sting (Park, 2017). It is also important to note that symptoms can have a very rapid onset once a worker is exposed to a Hymenoptera sting. If a person stung by Hymenoptera does experience a severe reaction then 50% of deaths occur within 30 minutes, and 75% of deaths occur within 4 hours of the sting (Park, 2017). Therefore, it is essential for foresters working in rural, remote locations to have access to necessary medical supplies when the risk of encountering Hymenoptera is present. We anticipate that trends will demonstrate foresters experiencing high incidence of Hymenoptera stings perform high risk jobs, and their exposure would vary by region.

Despite a high potential occupational hazard, it is suspected that a low percentage of foresters undergo employer-provided worker training related to Hymenopteran exposure risk and prevention, and training likely varies by region and employer. This study seeks to identify trends in risks of Hymenoptera exposure faced by foresters and similar outdoor workers and utilize these findings to develop occupational training, educational programs, and protective worksite measures for those with identified risk.

Study Objectives. The results of this study will assist in assessing risk of exposure of foresters to Hymenoptera and provide a basis for recommendations for occupational health and safety training. The study incorporates the following specific aims:

1) Quantify the history and knowledge of Hymenoptera stings and allergic reactions in foresters working in the US.
2) Assess the extent to which the frequency of Hymenoptera stings experienced by foresters differs between regions.
3) Assess the extent to which employer-provided worker training (e.g. to identify Hymenoptera nests and other dangers related to Hymenoptera exposure risk and prevention) given to foresters differs between regions.
4) Develop an informational brochure about Hymenoptera that can be distributed to foresters in the US.

CHAPTER II - LITERATURE REVIEW

Hymenoptera in the Occupational Setting. There are more than 17,000 species of Hymenoptera from 70 families in North America (Meyer, 2009) (Fig.1). One study estimates that up to 94% of the population has been stung by a wasp at least once during their lifetime (Ittyachen et al., 2015). There is currently no standardized reporting system for occupational occurrence or history of stings and sting reactions to Hymenoptera in outdoor workers, such as foresters. There has been some attention given as to which occupations have increased risk of contact and stings from Hymenoptera. Moscato et al. (2014) identified that working in occupations such as bee keeping, greenhouse maintenance, bumblebee farming, agriculture, parks, forestry, gardening, landscaping and groundskeeping, construction, transportation, or aquaculture increased the risk of anaphylaxis due to the increased potential exposure to Hymenoptera and other insect bites/stings. Other studies have shown that outdoor occupations, hobbies and even rural residency increase the risk of allergy to bee and vespid venom (e.g. Moos et al., 2013). Perez-Pimiento et al. (2007) examined hospital medical records for wasp stings in Spain (N = 98) and found that, of 18 patients experiencing anaphylaxis, gardeners (N = 7) ranked highest in frequency for medical complications. However, foresters were not included in the study (Perez-Pimiento et al., 2007).

High Risk Work Activities. Foresters and workers in similar outdoor occupations engage in a variety of activities that can result in unintended exposure to Hymenoptera. Their work, which is primarily conducted outdoors, elevates the likelihood they will come into contact with Hymenoptera species. Forestry work requires specific focus in other areas, either to avoid a perceived greater occupational safety hazard or to fulfill required duties. For example, a forester may be concentrating on maintaining footing on uneven terrain and fail to notice a wasp nest that is located five feet above ground level. S/he may also be distracted by handling equipment such as saws and/or heavy machinery. There also may be nests hiding in areas where the foresters are working, so they must remain vigilant at all times not to disturb these nests. To complicate physical distractions, some foresters must also contend with musculoskeletal issues including back, neck, and shoulder pain; depression, and stress that are associated with outdoor manual labor (Tribble et al., 2015). A large number of foresters work outdoors year round; however, even foresters who are able to work indoors during winter months still may face risks associated with Hymenoptera during spring and summer when these insects are most active, as well as risks associated with Hymenoptera whose nesting habits allow them to find their way indoors during winter.

Localized Sting Reactions. Reactions to stings can vary depending on a person's immune response and the type of Hymenoptera sting they receive. Data support the varied effect of different stings on individuals ranging from local swelling and redness to life-threatening anaphylaxis (Ruëff et al, 2013). Local allergic reactions can have delayed onset and last up to 10 days (Golden, 2007). Approximately 25% of the population experiences large local reactions to stings (Przybilla and Ruëff, 2012). Large local reactions associated with stings can cause swelling of extremities that may negatively impact work activities (Ruëff et al., 2011). Even one sting has the potential to reduce work productivity, health, and morale of foresters. Hymenoptera deliver between 50 ng (fire ants) and 50 μg (bees) of venom with each sting; these venoms contain vasoactive amines, including histamine and dopamine, as well as norepinephrine and kinins, which cause the painful, erythematous swelling and itching at the site of the sting (Solomon et al., 2015). Pesek and Lockey (2013) offer evidence of the potential occupational impact through their explanation of localized reaction to fire ant envenomation resulting in painful pustules on the skin that are hard to treat with medical treatment and often accompanied by nausea and vomiting. These local reactions do not usually require treatment other than symptomatic therapy with cold compresses or ice, analgesic agents, oral antihistamines, or topical glucocorticoid creams or ointments to reduce local pain swelling (Solomon et al., 2015). These simple treatments could easily be kept in a first aid kit and administered in the field if a forester was stung while working.

Generalized Sting Reactions. Generalized reactions to envenomation can be acute or chronic, and are more serious than localized reactions due to their systemic effect. These systemic reactions affect multiple organ systems including skin, gastrointestinal, respiratory, and cardiovascular systems (Pesek and Lockey, 2013). The major allergens leading to systemic reactions in allergic persons are primarily protein enzymes such as phospholipase, hyaluronidase, and acid phosphatase (Solomon et al., 2015). The greater the number of lifetime stings a worker experiences, the greater the likelihood their next sting reaction will be generalized. The increased likelihood of generalized reaction may also be related to the number of stings experienced in a single envenomation exposure (Pesek and Lockey, 2013). It is accepted that outdoor workers are at increased risk of anaphylactic reactions due to their increased exposure risk (Forrester et al., 2012). According to Golden (2007), generalized reactions can lead to severe impacts such as development of chronic urticaria, purpura, rhabdomyolysis, bradycardia, arrhythmias, angina, myocardial infarction, neurological issues, and nephropathy. Przybilla and Ruëff (2012) confirm that anaphylaxis is not an uncommon reaction to bee and wasp envenomation.

Sting Hypersensitivity. In the US, reports of sting hypersensitivity vary. Golden (2007) approximates 50 fatal sting reactions occur each year in the US, with half of those never having shown an allergic reaction to stings in the past. The National Institute for Occupational Safety and Health (NIOSH) (2012) asserts greater incidence of fatal sting reactions ranging from 90-100 US cases per year, and suggests that these numbers are largely underreported. Solomon et al. (2015) estimate that anaphylaxis due to a hymenopteran sting causes at least 40 deaths per year in the US but also suggest this number is underestimated. For foresters who often work individually in remote areas, the lack of rapid medical attention for serious sting reactions presents a unique problem. Medical response to anaphylaxis must be immediate, even following use of self-administered adrenaline or epinephrine (Knight and Jeebhay, 2008). Despite the need for swift response following medication, it is recommended that people at risk of systemic reactions such as anaphylaxis should consider keeping a field kit containing oral antihistamines and corticosteroids, as well as (injectable) adrenaline/epinephrine, if needed (Ruëff et al. 2011). Medications such as epinephrine are not available over the counter and therefore require a prescription from a doctor to obtain. This can present its own set of challenges as prescriptions for such medications are generally only written for patients who have previously suffered a severe reaction or have a history of life threatening allergies, so a person may not have access to needed medications the first time a severe allergic reaction occurs. These prescriptions can also be very costly depending on the specific type of medication prescribed and the insurance coverage the worker may have. Therefore, even if prescribed medication, the forester may not be able to afford the needed medication. Under Session Law 2009-363 from House Bill 878, exceptions to this may include specific occupational workers, such as some Master Bee Keepers, public school officials, or others who have gone through a special certification process to administer treatment in the event of a medical emergency (North Carolina General Assembly, 2009). The Occupational Health and Safety Administration (OSHA) (2015) does not provide specific guidance on anaphylaxis response training in their Agricultural section of training requirements; however, general requirements for occupational first aid training is clear that in the absence of a medical facility, at least one person shall be adequately trained to provide first aid, and that adequate first aid supplies will be readily available.

Anaphylaxis symptoms have acute onset and occur within minutes to hours of Hymenoptera exposure. Symptoms can include abnormalities in skin and/or mucosal tissues such as hives, swollen lips, swollen tongue, respiratory issues, reduced blood pressure less than 90 mmHg or an approximate 30% decrease from baseline blood pressure, persistent gastrointestinal symptoms such as abdominal pain or vomiting (Moscato et al. 2014). Severe, painful cramps are also common (Knight and Jeebhay, 2008). The sensitization process is well recognized with regards to sting reactions and, even if a worker has not experienced a severe reaction in the past, the risk for such a reaction increases with the frequency of stings received. Furthermore, prior envenomation increases the risk of subsequent reactions to stings (Rueff et al., 2011, Siracusa et al., 2015).

Sting Precautions. Recommended preventive measures vary depending on the insects to which the workers are at risk of being exposed. Issues of recognition, prevention and reporting may be complicated by the various Hymenoptera species distributed throughout different regions, and lack of standardized reporting requirements for occupational sting events between various agencies. Knight and Jeebhay (2008) emphasize the importance of primary prevention in the form of focusing efforts on reducing exposure. The National Institute of Occupational Safety and Health (2016) recommends workers to wear light-colored, smooth-finished clothing, avoid perfumed soaps, shampoos, and deodorant, not wear cologne or perfume, wear clean clothing and bathe daily, and to wear clothing that covers as much of the body as possible (long sleeve pants and shirts). They also recommend to keep work areas clean, remain calm and still if a single stinging insect is flying around, run away if attacked by multiple stinging insects at once, and using awareness and caution near ant mounds and when lifting items off the ground where ants may be present (NIOSH, 2016).

Secondary preventative measures should also be considered so workers may respond effectively to avoid or minimize reactive response to Hymenoptera envenomation. For example, first aid measures after a sting or bite vary by insect, but most often include washing the site of sting or bite with soap and water, applying ice to reduce swelling, and taking antihistamines (NIOSH, 2016). Workers should have knowledge of the potential for allergic response in their field, and the ability to recognize symptoms (Knight and Jeebhay, 2008). It is also advisable for workers to alert others to the potential reaction they may have so medical help can be provided immediately, if necessary. One of the most important precautions for those that are severely allergic to Hymenoptera venom is to carry their self-injectable epinephrine medication with them at all times. Knight and Jeebhay (2008) also identify tertiary prevention measures including first aid training for all workers, and wearing a medical alert bracelet if a worker has a known allergy.

Venom Immunotherapy. Workers with known anaphylaxis reactions to venom should consider the risk from exposure in areas prone to Hymenoptera incidence, and should consider venom immunotherapy (Siracusa et al., 2015). As a safety precaution before going into the field, workers could choose to visit an allergist-immunologist for skin testing; extracts available for skin testing include venom from honeybee, yellow jacket, white-faced hornet (also called bald-faced hornet), yellow hornet, and wasp (Solomon et al., 2015). This is not a necessity without prior history of an allergic reaction to Hymenoptera exposure, but it is a valid option available to outdoor workers. After getting the results from this test, workers could decide on immunotherapy if they experience severe enough reactions to the test. Moos et al. (2013) recommend venom immunotherapy for patients at high risk of a severe sting reaction. Typically conducted for *Apis* spp. and *Vespula* spp. reactivity, venom immunotherapy is an established practice of providing low doses of venom to those who experience severe reaction when exposed naturally via insect sting. According to Paolocci et al. (2014), workers who have Hymenoptera venom allergy coupled with a high-risk job for exposure to Hymenoptera also have higher risk of work disability due to stings. The same study found that participants undergoing venom immunotherapy experienced a positive effect on their ability to work. A combination of preventative anti-allergic drugs and venom immunotherapy may be associated with a higher protection rate (Ruëff et al., 2013).

This enhances the health and longevity of workers who suffer from sensitization to stings and have high-risk careers, such as foresters. Venom immunotherapy can lessen the severity of a reaction to envenomation, hence reducing the acute distress in a victim of Hymenoptera stings. Approximately 80-90% of patients who undergo immunotherapy for three to five years do not have a systemic reaction to a future insect sting, so undergoing immunotherapy for this length of time could be very beneficial to foresters, especially coupled with wearing protective clothing (Solomon et al., 2015). Despite this effectiveness, Ruëff et al. (2012) urge that those who experience even a large local reaction must protect themselves through avoiding situations where they may get stung again. This finding is supported by Stoevesandt et al. (2013) who acknowledged that envenomation relapse rate for double (reactive to both honey bee and *Vespula* venom) and single (reactive to one or the other) reactivity occurs in 6%-8% of patients who undergo venom immunotherapy. Solomon et al. (2015) suggest that patients at higher risk, such as foresters, should consider continuing venom immunotherapy indefinitely. For foresters, not following advice to avoid situations that may result in a sting could mean the end of their career.

Occupational Training. There are no known published reports regarding occupational exposure to stings from Hymenoptera in foresters in the US; therefore, the occupational implications of Hymenoptera hazard-related training for each region are unclear at this time. Knight and Jeebhay (2008) identify the absence of a universal definition of work related anaphylaxis. Given the dangers of Hymenoptera exposure, it is important that employers provide adequate training to employees about risk of exposure to stinging and biting insects. Training should include topics such as how to reduce risks through proper identification of insects and their nests or hives, preventative measures available, how to use preventive measures for protection from stings and bites, what measures workers should take if they are stung or bitten, and first aid/CPR training for workers (NIOSH, 2016; Siracusa et al., 2015).

Regional US Presence. There are several different families of Hymenoptera found throughout the four major US regions: West, South, Midwest and Northeast (Fig. 2). Hymenoptera are the third largest order of insects with 70 different families and nearly 18,000 different species found in North America (Meyer, 2016). The most easily recognized families belong to Apidae (bumblebees and honeybees), Vespidae (yellow jackets, hornets, paper and potter wasps), and Formicidae (ants). Vespidae, Formicidae, and Apidae species are responsible for the highest number of stings (Pesek and Lockey, 2013). Depending on which region of the US, there are different types of native species of Hymenoptera that are of concern. For example, “fire ants” are the ants of the greatest medical concern in the US, yet these ants are only found in southern, southwestern, and western states (Purdue University, 2008). There are various non-native species found in each region as well that can pose a significant threat to ecosystem stability, the economy, and human health. Factors, such as climate change, capable of creating ecosystem boundary shifts support invasive species migration to new areas (Wiezik et al., 2015). Whether working in wooded areas, or open fields, foresters in the US are likely to encounter bees, yellow jackets, wasps, or ants.

Native Bees. There are over 4,000 different types of native bees that can be found throughout the entire US (Moisset and Buchmann, 2011). Native bees are beneficial pollinators that are responsible for pollinating 75% of the fruits, nuts, and vegetables grown in the US (Moisset and Buchmann, 2011). Foresters should take care not to disturb native Apidae as they pollinate approximately 80% of flowering plants which makes this species very important (Moisset and Buchmann, 2011). The ability to quickly distinguish between species to assess a threat level is a key component in maintaining personal safety against Hymenoptera species. For example, the southeastern blueberry bee, *Habropoda laboriosa* (Fabricius), is a solitary, ground nesting bee that is highly unlikely to sting, but it is very important because each female bee is capable of pollinating enough blueberry flowers to produce 6,000 blueberries (Moisset and Buchmann, 2011). If foresters were to come in contact with this type of bee, the threat of being stung would be very low, so there would be no need to disturb these bees. Many Hymenoptera species mimic others in appearance, hence the need for foresters to have Hymenoptera-related behavioral knowledge is important. For example, carpenter bees and bumblebees are similar enough in appearance that they could be mistaken for one another by a novice; yet their behaviors are clearly distinct (Flowers et al., 2015). For example, carpenter bees are solitary and are seen above ground burrowing into wood. Male carpenter bees, who do not have a stinger and pose no threat of envenomation, are known to defend their territory by aggressively harassing trespassers, while females, who are capable of stinging, rarely do so (Flowers et al., 2015). In contrast, bumblebees are social insects (live in groups up to 200) capable of stinging, and nest predominately in the ground (Flowers et al., 2015).

Yellow Jackets. *Vespula* spp. yellow jackets have distinctly different behaviors than that of *Dolichovespula* spp, yet both types of yellow jackets nest in large colonies of 600-800 insects (Flowers et al., 2015). A main difference between the two is their nesting habits; *Vespula* spp. are known to make paper-like nest in concealed areas, possibly even underground, to prevent detection, but *Dolichovespula* spp. are known for living near human populations (Pesek and Lockey, 2013). Yellow jackets are extremely protective of their nest and will swarm to defend it; however, once an invader (e.g., human) is away from the nest, the likelihood of stings is reduced (Flowers et al., 2015). Human hypersensitivity response to yellow jacket envenomation is common as half of the identified allergens within their venom are known to be major allergens (Pesek and Lockey, 2013) (Fig. 3). Due to the likelihood of reactivity to stings, it is vital that foresters be educated about the preferred nest site locations, and tendency of yellow jackets to group near inhabited areas that provide a food source.

Wasps and Hornets. Many different types of wasps and hornets are common to the US and knowledge of area-specific species is necessary for appropriate response. Some wasps, such as paper wasps, nest high in the trees or under limbs, while others, such as cicada killers also known as ground digger wasps, lead solitary lives in underground burrows (Flowers et al., 2015). Not all hornets build hanging nests. For example, the European hornet, an introduced species, builds its nest hidden in tree cavities that are difficult to spot until disturbed (Flowers et al., 2015). Another example are mud wasps, found throughout all of the US, which are named such due to their ability to construct nests out of mud (Terro, 2016). Wasps and hornets are not usually aggressive until they perceive a threat; however, the challenge for foresters involves avoiding this threat all together.

Fire Ants. There are two types of non-native fire ants in the US that are important to note: red imported fire ants and black imported fire ants (Orkin, 2017). Red imported fire ants, *Solenopsis invicta* (Buren), are now common throughout the US, particularly in the southeast states, but are native in South America, specifically Brazil, and were imported into the US (Texas Invasive Species Institute, 2014). These are small ants that live in colonies of various sizes which consist of three types of adult ants: winged males or reproductives, worker ants, and the queen ant, and they are known for their very painful sting (Texas Invasive Species Institute, 2014). The black imported fire ant, *Solenopsis richteri* (Buren), is also originally from South America but can now be found in many parts of the US (Texas Invasive Species Institute, 2014). The black imported fire ants prefer open grasslands, specifically pastures and lawns, so foresters working in these types of areas should take extra precaution not to disturb these ants (Texas Invasive Species Institute, 2014).

There are also several native species of fire ants that are important to note: native southern fire ants, tropical fire ants, desert fire ants, and little fire ants (Orkin, 2017). The native species of fire ants are not considered as hostile as the imported fire ants, but their stings can cause just as much pain (Orkin, 2017). The native southern fire ants, *Solenopsis xyloni* (McCook), are very similar to the red imported fire ants but can be distinguished by their brown to black color; these ants are found widespread throughout the southern part of the US from Texas to North Carolina and in the southwestern states, including California and Hawaii (Orkin, 2017). The tropical fire ants, *Solenopsis geminata* (Fabricius), prefer open spaces and are known for easily overtaking homes and farms in hot climates; these ants are also found predominately in the southern part of the US (Orkin, 2017). The desert fire ants, *Solenopsis aurea* (Wheeler) and *Solenopsis amblychila* (Wheeler), are found in the southwest areas of the US, particularly in Arizona and west Texas (Orkin, 2017). The little fire ants, *Wasmannia auropunctata* (Roger), are small, slow moving ants that generally go undetected until their painful sting is felt; these ants are found in the southeastern states of the US as well as in California and Hawaii (Orkin, 2017).

Nonnative Species. There are several invasive Hymenoptera species in the US. *Pachycondyla chinensis* (Emery) (Asian needle ant) is an introduced species that could have lethal sting reaction consequences for foresters (Guenard and Dunn, 2010). It can be easily recognized by its inability to climb smooth surfaces. This ant nests with minimal cover, but it is not known to be aggressive if given the opportunity to run (Guenard and Dunn, 2010). Haddad and Larsson (2015) illustrate how dangerous some invasive Hymenoptera can be when they describe *Solenopsis* spp., such as the red imported fire ant, tendency to “massively” attack in effort to defend nests. Invasive species in the US are not limited to ants, and can include Africanized bee species for example. Hall et al. (2015) notes African honeybees’ aggressive survival behavior of attacking from over 45 meters away in an effort to defend their hives.

Hymenoptera Nest Recognition Training. Since native and invasive species may defend their nest by swarming and stinging, it is important that foresters be well prepared to recognize and avoid nests. The focus of Hymenoptera nest training should center on knowledge of Apidae, Vespidae, and Formicidae common to the area, as well as invasive or imported species that may also be encountered. All Hymenoptera in the

US build nests, with the exception of various species of cuckoo bees who lay eggs in the nests of other bees (Moisset and Buchmann, 2011). Hymenoptera nest sites can occur above or below ground, hence they may be easily visible or hidden from view. Likely places for aerial nesting Hymenoptera hives include the underside of leaves, tree branches, or inside hollow cavities. Depending on the species, hives may be well camouflaged or exposed to the elements. Flowers et al. (2015) note some species' hives may be identified by an unpleasant odor, or papery hive appearance. Hall et al. (2015) remarks on the importance of looking and listening for hive activity such as buzzing or humming.

Hole-nesting bees including mason and leafcutter bees create nests from existing crevices and holes while carpenter bees excavate their own individual holes using their jaws (Moisset and Buchmann, 2011). Nesting holes are likely to be visible to foresters if they remain aware of their surroundings. Ground dwelling bees may create small but visible mounds of excavated earth outside of their individual nests, which are usually located in well-draining soil with minimal vegetation (Bambara and Brandenburg, 2011). Because miner bees are usually solitary, they generally do not pose a threat of swarming (Moisset and Buchmann, 2011). Yellow jackets are well known for nesting underground, particularly in rodent burrows, so foresters need to be constantly aware of holes in the ground (DeJohn, 2018).

This does not exclude foresters' risk of swarms from the ground level as most ant colonies are recognized as displaying the pinnacle of social hymenoptera behavior. Ant nests may be large and unsightly as with red imported fire ants, or they may be well hidden within in leaf litter or under debris as with dark rover ants (Haddad and Larsson, 2015; Tribble, 2015). No matter the species, foresters must remain vigilant in their observation for ants, mounds, and possible cover.

Worker Training. Workers should be trained in the importance of conducting work at times of day when nests and hives are least likely to be full. For example, if a hive of bees is known to be in a particular area, the area may be avoided at times including dusk and evening hours when the greatest amount of bees will be in the hive. Most bees do not fly at night; however, if disturbed, some wasps, such as yellow jackets, will attack a flashlight (Flowers et al., 2008). European hornets remain active at night, and are known to pursue lights (Flowers et al., 2008). In some instances, knowledge of this behavior is critical because safety recommendations must be adjusted. For example, if chemicals are being used at night to control a European hornet nest, NIOSH's (2016) safety recommendations for light colored clothing would be inappropriate, and dark clothing would need to be substituted so as not to attract the hornets (Flowers et al., 2008). NIOSH's (2016) safety recommendations also note the importance of workers maintaining a clean work environment; meaning, wrappers, old food, drink containers, and the like should be disposed of promptly so as not to attack insect activity. Ant species may demonstrate an initial subdued response; however, the threat of swarm remains no matter the time of day. It is also important that outdoor workers recognize how their own activity may stimulate defensive behavior of Hymenoptera. Loud noises and vibrations may be viewed as a threat and provoke an attack (Hall et al., 2015). Workers should receive training that illustrates the benefits of scanning an area prior to commencing work activity.

Physical Hazard Reduction Training. The danger of swarming cannot always be reduced, but there are physical barriers that may reduce the effectiveness of attack from Hymenoptera. Flying Hymenoptera are often attracted to carbon dioxide that is exhaled from the mouth while breathing, so it is useful to cover the head and neck with netting that will prevent contact with these sensitive areas if swarmed (Hall et al., 2015). The NIOSH (2016) also recommends long sleeves, pants, and gloves as barriers to stings. The use of N, N-diethyl-meta-toluamide (DEET) and other repellants to protect against ants may also be part of a useful strategy (OSHA, 2005). Hymenoptera that exhibit swarm behaviors may be attracted to human inhabited areas where food and shelter are readily available. To reduce physical hazards associated with human contact, proper sanitary practices should be implemented. Without a welcoming habitat, colonies are likely to move on to more hospitable areas (Hall et al., 2015).

Avoidance and Escape. Once a nest is suspected, identified, or confirmed as Hymenoptera, it is best to avoid disturbing the nest and surrounding area. If the nest has been disturbed, workers should bear in mind that many species of Hymenoptera apply a swarm defense tactic to protect themselves from a perceived threat (Pesek and Lockey, 2013; OSHA, 2005). Hymenoptera communicate danger through advanced pheromone placement and movements (Heinze and d'Ettorre, 2009). If swarmed, it is essential to move as far away from the nest as possible to minimize the number of stings. Workers should leave the area as quickly as possible, but without panic. Hall et al. (2015) recommends the following evasive strategy: run in a straight line away from the hive while covering the face and neck area. Hymenoptera have a strong sense of smell and are not deterred by hiding behind objects, water, or running in a zigzag pattern (Hall et al., 2015).

Once away from the attacking insects, any stingers in the skin should be carefully removed with gauze or by scraping with a fingernail. According to NIOSH (2016) tweezers should never be used since the stinger may still contain venom, which can be inadvertently squeezed into the skin. Various ant species are known for holding on with their jaws and stinging repeatedly; therefore, OSHA (2005) recommends using gloves or a cloth to immediately brush ants off the skin. NIOSH (2016) also recommends washing with soap and water, application of ice, and use of over-the-counter antihistamines to reduce immediate symptoms in cases where a history of allergic reactions is present.

Environmental Awareness Training. Workers may further protect themselves by remaining abreast of new species of Hymenoptera in their area. This is particularly true with ant species, some of which may not have been previously identified as being in that area of the US (MacGowen et al., 2007). Wiezik et al. (2015) discuss how there are different sampling methods available used to quantify the composition, richness, and abundance (or activity) of various ant assemblages throughout the US. This is important as Wiezik et al. (2015) goes on to mention that "habitat specificity of sampling methods affects our ability to discern patterns present in ant assemblages." There is potential for a new study to be conducted using this information in which the information would be analyzed and used in training materials given to foresters and other outdoor workers as a tool to map out where various kinds of ants are found throughout the US. Sampling may also bring heightened awareness of the ecosystems and seasonal influences on hymenoptera behavior that supports increased application of knowledge-based Hymenoptera training (Wiezik et al., 2015).

Medical Intervention Training. The most common medical conditions seen with Hymenoptera stings are itching and swelling at the site of the sting, but generalized systemic reactions are possible which can lead to symptoms of anaphylaxis such as severe respiratory distress (Golden, 2007). Employees with greater occupational exposure to Hymenoptera would benefit from learning how to assist coworkers known to experience several allergic reactions in properly utilizing their epinephrine, if they carry it, should they be stung and require support. To do so, workers would need to learn the importance of discussing the existence of allergies with coworkers, and know how to identify a coworker in distress, how to locate and prime the coworker's epinephrine, place the epinephrine auto injector in the coworker's hand, and then assist the coworker with self-administering their medication. If someone must assist a coworker in administering their auto injector (EpiPen), 911 needs to be called immediately because only a healthcare professional should give additional doses of epinephrine (EpiPen, 2015). Cardiopulmonary resuscitation and first aid training are also advisable trainings since 60% of adults who have severe reactions experience hypotension leading to loss of consciousness and stoppage of cardiac rhythm (Golden, 2007). Przybilla and Ruëff (2012) identify an allergic response leading to anaphylaxis as so severe that it requires long term treatment to avoid future episodes.

Occupational Implications of Training. Even one Hymenoptera sting can evoke a systemic reaction. Occurrence of systemic reaction takes place in approximately 70% of adults who experience stings, making occupational training focusing on protective attire, recognition, and avoidance of contact with Hymenoptera species essential to the health and well-being of workers (Ittyachen et al., 2015). Foresters' ability to correctly identify and respond to Hymenoptera dangers can directly translate to reduced injuries, increased productivity, and increased morale in the workplace. Further study of the risk of Hymenoptera stings in foresters in the US is needed as it has potential for dramatic improvements in occupational preventive measures that protect worker health, safety, longevity, and productivity.

CHAPTER III - MATERIALS AND METHODS

Participant Recruitment. Subjects for this study included consulting/state foresters, Parks/Recreation employees, and/or National Parks Service employees who have access to phone or email and who are/were employed in one of 39 states throughout the US in one of four regions: South: North Carolina, South Carolina, Virginia, West Virginia, Florida, Georgia, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana; West: Washington, Oregon, California, Idaho, Arizona, Montana, Utah, Colorado, New Mexico, Wyoming; Northeast: New York, Pennsylvania, New Jersey, Maine, Connecticut, Rhode Island, Massachusetts, New Hampshire, Vermont; and Midwest: North Dakota, South Dakota, Iowa, Kansas, Nebraska, Ohio, Michigan, and Illinois. These states represent each region and division of the US as it has been split into boundaries by the US Census (Fig. 2). Candidate selection was generated through online research of forestry employees and members of major government, public corporations, private corporations, clubs, service organizations, and professional organizations.

A total of 1,999 subjects were invited to participate in the study. Participants were placed into 4 groups (West, Midwest, Northeast, and South) based on the US region in which they were employed. Participants were offered incentive for their involvement in the form of entry into a drawing for a $50 gift card. Informed consent was obtained from all candidates who volunteered to participate in the study (ECU Institutional Review Board #15-001105).

Survey Development and Distribution. A list of potential participants and contact information was generated in an Excel spreadsheet. A potential participant was defined as a candidate chosen to be asked to participate in the study due to their outdoor job related functions. Table 1 shows the number of potential participants per region. Their information was obtained online through the aforementioned process.

A 29-question survey was developed (Appendix A) in Qualtrics and distributed to participants via email. Participants were provided a description of the study and asked to give consent to participate prior to completing the survey; when a participant opened the link to the survey, they could not begin the survey without first reading and agreeing to a consent form on the first page of the survey. Participants were also advised that their participation in the study was voluntary and provided with contact information for the investigators and the ECU Institutional Review Board (IRB) Office should they wish to ask questions. Two weeks after the initial email was sent, the same participants were emailed a reminder to complete the survey. Four weeks after the initial distribution, the survey was closed. To choose a winner for the $50 gift card, each name and address, 373 total from the participants' responses, were put into an Excel spreadsheet which gave each address a numerical number. A random number generator from mathgoodies.com was used to select a number from 1-373 as the winner which was number 269.

Development of Educational Materials. An educational brochure was developed as a potential tool for employers to give to their employees on how to avoid Hymenoptera (Appendix B). NIOSH (2016) recommendations were included in the brochure as well as information on the various Hymenoptera types (ants, bees, hornets/wasps/yellow jackets). It is the goal of this brochure to aid foresters with a quick visual representation with information pertaining to what to look out for and how to avoid Hymenoptera as best as they possibly can so that they can perform their job duties in a safer manner. The brochure could be incorporated into the training the foresters should receive from their employers before they begin their job duties.

Data Analyses. We utilized a retrospective cohort analysis method. Statistical analysis software SPSS (IBM, Armonk, New York) was used to conduct chi-square tests of independence to assess: 1) differences between safety trained and non-safety trained employees in sting incidence at work 2) differences between safety trained and non-safety trained employees in carrying a medical first aid kit, and 3) differences between allergic and non-allergic employees in carrying a medical first aid kit. *P*-values less than 0.05 were considered significant. The rate of occurrence and type of Hymenoptera stings was analyzed between regions using descriptive comparisons. Types of stings (ant, bee, hornet/wasp/yellow jacket stings) within each region were identified by percentage (total reports of specific type of sting/total responses within the region) and compared to one another to assess where each type of Hymenoptera stings are most prevalent and therefore of greatest concern in each region of the US.

CHAPTER IV – RESULTS

Email Results. The survey was initially emailed to 1,999 participants on March 21, 2017. Of the 1,999 emails sent, 121 bounced back for one of three reasons: email address error (95), automated response (22), or the person responded that they had retired (4). The second (reminder) email was sent on April 6, 2017. Before sending this email, the 99 email addresses that were associated with either an error or a retired person from the first email were deleted from the list. Therefore, 1,900 emails were sent on April 6, 2017 and of these, 35 bounced back for either error (7), an automated response (26), or retired (2). The survey was closed to responses on April 14, 2017.

There were initially 552 responses to the survey. However, 78 responses were deleted and excluded from the study because the response was either blank or only had one question answered. These were deemed unusable because surveys were incomplete. Therefore, 474 participants were included in the retrospective cohort study (24% response rate).

Demographics of Participants. Of the 474 participants included in the cohort study, 433 were men (91.7%), 39 were women (8.2%), and 2 (<1%) did not answer the question (Table 2). Where the participants work/live was classified into 4 regions: South, West, Northeast, and Midwest. Participants were from the following regions: 198 (41.8%) South, 94 (19.8%) West, 132 (27.9%) Northeast, and 60 (12.7%) Midwest. It is important to note that 31 participants did not specify the geographic location of where they work, so these participants were labeled as “unknown” in calculations regarding geographic location. If a participant worked in more than one region, they were counted as an individual person for each region and not just one region. Therefore, for some calculations, the total number of participants exceeded 474 since some participants were counted multiple times if they worked in more than one region. The ethnicity and age of participants was also recorded and can be found in Table 3.

Hymenoptera Stings. A significant portion of the participants had been stung by Hymenoptera (e.g. ant, bee, hornet, wasp, yellow jacket) while at work. Specifically, 436 (92.0%) participants reported to have been stung by Hymenoptera while at work with only 27 (5.7%) participants reporting to have not been stung, and 11 (2.3%) participants did not specify whether or not they had been stung while at work. However, despite a large portion of the participants experiencing Hymenoptera stings, most of them (N=428, 90.3%) reported that being stung did not cause them to change their job tasks. There were 34 (7.2%) participants that did report changing their job tasks due to a Hymenoptera sting; they reported changing their job tasks by either going to the hospital/doctor or leaving the area where the Hymenoptera were and coming back later to complete their task once the Hymenoptera settled back down. Only one participant changed his career focus due to Hymenoptera stings; however, this participant remained in forestry, but started buying and selling timber instead of cruising timber regularly. A small portion of participants (N=14, 3.0%) reported suffering economic loss due to Hymenoptera stings. This economic loss was mainly due to having to leave work early because of pain/swelling from the Hymenoptera sting. Two of the participants had to visit a doctor/hospital due to the sting; one of these two participants reported having to go to the hospital on two separate occasions due to stings. Fewer participants reported being stung by Hymenoptera during recreational activities (N=354, 76.5%).

Participants were asked to specify how many times they had been stung by an ant, bee, or hornet/wasp/yellow jacket within the last five years. These questions refer to the actual number of times the participant had been stung by each type of Hymenoptera and not the rate (number of days) stings occurred. In regards to being stung by an ant, 239 (51.7%) participants reported to have not been stung at all within the last five years, 130 (28.1%) reported to have been stung 1-5 times, 36 (7.8%) reported to have been stung 6-10 times, and 57 (12.3%) reported to have been stung more than 10 times; 12 participants did not specify the number of times they had been stung (Fig. 4). Of the participants that reported being stung by an ant, 122 (35.1%) reported being at work when stung. In regards to being stung by a bee, 154 (33.5%) participants reported to have not been stung at all within the last five years, 232 (50.4%) reported to being stung 1-5 times, 38 (8.3%) reported to have been stung 6-10 times, and 36 (7.8%) reported to have been stung more than 10 times; 14 participants did not specify details of the number of stings they experienced (Fig. 5). Of the participants that reported being stung by a bee, 192 (52.5%) reported to have been at work when the sting occurred. In regards to being stung by a hornet, wasp, or yellow jacket, 79 (17.2%) participants had not been stung at all within the last five years, 282 (61.4%) reported to have been stung 1-5 times, 50 (10.9%) reported to have been stung 6-10 times, and 48 (10.5%) reported to have been stung more than 10 times; 15 participants did not specify the number of stings they experienced (Fig. 6). The majority of these types of stings (hornet/wasp/yellow jacket stings) occurred while at work (N=292, 69.7%).

The Hymenoptera of greatest concern by region was determined by calculating which type of Hymenoptera was responsible for the most reported stings per region. Table 4 shows the regional data for participants' reports of being stung by an ant, bee, or hornet/wasp/yellow jacket. Ant stings were primarily a major concern in the South region with 76.9% of participants reporting having been stung by an ant within the last five years while in the West, Northeast, and Midwest regions, at least 65% of participants of each region reported not having been stung by an ant in the last five years. In contrast, bee stings were an issue in all four regions as 68.4% of participants in the South, 60.7% of participants in the West, 70.5% of participants in the Northeast, and 61.4% of participants in the Midwest reported having been stung by a bee within the last five years. Similarly, hornet/wasp/yellow jacket stings were also reported as an issue in all four regions with stings occurring in the last five years (83.2% South, 79.8% West, 92.2% Northeast, and 75.4% Midwest). Figure 8 shows these data as a visual comparison of the various types of Hymenoptera stings per region.

Participants were asked to report what type of immune response(s) they experienced if they were stung by an ant, bee, hornet, wasp, or yellow jacket (Table 5). The options given were no reaction, local skin reaction (e.g. minor swelling, redness, itching), large local reaction (e.g. swollen appendage [e.g. arm]), gastrointestinal reaction (stomach pain, nausea, vomiting), respiratory reaction (e.g. difficulty swallowing, hoarseness), cardiovascular reaction (e.g. hypotension), and other. The most common reported symptom for all kinds of Hymenoptera stings was a local skin reaction with 198 (N=289, 68.5%) participants reporting a local skin reaction from an ant sting, 277 (N=364, 76.1%) participants reporting a local skin reaction from a bee sting, and 357 (N=468, 76.3%) participants reporting a local skin reaction from a hornet, wasp, or yellow jacket sting.

Training and Safety. The foresters were asked if they received any type of Hymenoptera safety training from their employers. This training should have generally involved education on the risk of exposure to Hymenoptera, how to protect oneself from Hymenoptera, and what to do if stung/exposed to various types of Hymenoptera. A majority of the participants (N=329, 69.4%) reported to not having had this type of safety training with only 132 participants (27.8%) reporting to have had this type of safety training; 13 participants (2.7%) did not specify whether or not training had been provided by their employer. Participants were also asked to specify the topics that were mentioned in their safety training (if they did have training) and how long the training lasted. Of the 132 participants that reported having had Hymenoptera related safety training, 122 (95.3%) reported the training lasted less than 1 day, 4 (3.1%) reported the training lasted 1 day, and 2 (1.6%) reported the training lasted more than 2 days. Topics covered in the training and the number of participants that reported covering each topic (Fig. 7) included: risk of exposure to Hymenoptera (N=102, 21.8%), insect identification (N=54, 11.5%), adverse effects of Hymenoptera stings (N=99, 21.2%), what should be done when stung/bitten (113, 24.1%), what should be done to prevent stings/bites (N=88, 18.8%), and other (N=12, 2.6%).

Foresters were asked how, if at all, they protect themselves from being stung by Hymenoptera (Table 6). The options included wearing long-sleeved shirts, long pants, light-colored clothing, gloves, applying insect repellant, avoiding wearing cologne or perfume, or other. Most of the responses to the other category involved watching for and avoiding nests, being hyperaware of surroundings, or not taking any precautions to prevent being stung. The most common protective measure taken by over 70% of participants to limit exposure to Hymenoptera was to wear long pants, and the second most common protective measure taken by over 50% of participants was to wear long-sleeved shirts. To determine foresters' preparedness in dealing with a sting after it has occurred, foresters were asked if they carried a medical first aid kit with them that included supplies to treat Hymenoptera stings. More than half of the participants reported that they do not carry a first aid kit with them. The foresters that did report carrying a first aid kit with supplies to treat Hymenoptera stings (N=221, 47.7% of participants) reported the most common supplies they used to treat Hymenoptera stings were antihistamines, an epi-pen, and sting relief cream.

Participants were also asked to choose whether they strongly agree, agree, neutral, disagree, or strongly disagree with a series of questions regarding their opinions on Hymenoptera exposure in their lives (Table 7). The questions included the following: Hymenoptera are a nuisance where I live; Hymenoptera are a nuisance where I work; I am concerned about my physical reaction to Hymenoptera stings; I am anxious about Hymenoptera stings; and I would like to learn more about how to identify Hymenoptera and their habitats' in the field. The largest percentage of participants (34.9%) agree that Hymenoptera are a nuisance where they live as well as where they work (38.6%). Also, the largest percentage of participants (32.7%) disagree in their concern about their physical reaction to Hymenoptera stings, and (34.0%) disagree about being anxious about Hymenoptera stings. Lastly, the largest percentage of participants (40.9%) were neutral in regards to wanting to know more about how to identify Hymenoptera and their habitats in the field.

Chi-Square Tests. A Chi-Square Test was conducted to determine if there was a difference between the incidence of a participant being stung by some type of Hymenoptera while at work and whether or not the participant received any Hymenoptera safety related training from their employer. The null hypothesis is that if a participant received Hymenoptera safety related training, then the participant would be less likely to be stung by the various types of Hymenoptera due to a better understanding/knowledge of the Hymenoptera and their habits. The alternative hypothesis was that participants' training history had no impact on whether or not they would experience Hymenoptera stings. There was no significant difference found in the proportion of those being stung at work between safety training and non-safety trained participants (X^2 = 1.436, p = 0.230, see Appendix C).

We tested the null hypothesis which is that if a participant received Hymenoptera safety related training from their employer, then the participant would be more likely to carry a medical first aid kit that includes supplies to treat Hymenoptera stings since they should have a better understanding/knowledge of how to handle Hymenoptera stings after they have occurred and a medical first aid kit would be necessary to handle such stings. There was a significant difference found between participants receiving or not receiving Hymenoptera safety in that they carried a medical first aid kit that included supplies to treat Hymenoptera stings (X^2 = 30.367, $p < 0.001$ as $p < 0.05$, see Appendix C). Hence, it is statistically more likely for a participant to carry a medical first aid kit for Hymenoptera stings if they have had Hymenoptera safety training from their employer than for a participant to not carry a medical first aid kit after receiving training from their employer.

We also tested the null hypothesis that if a participant has a known allergy to Hymenoptera, that participant would be more likely to carry a medical first aid kit that includes supplies to treat Hymenoptera stings. There was a significant difference found in allergic and non-allergic individuals related to carrying a medical first aid kit that includes supplies to treat Hymenoptera stings ($X^2 = 8.685$, $p < 0.001$ as $p < 0.05$, see Appendix C). Hence, it is statistically more likely for a participant that has a known allergy to Hymenoptera to carry a medical first aid kit that includes supplies to treat Hymenoptera stings than for a participant with a known allergy to Hymenoptera to not carry a medical first aid kit.

CHAPTER V - DISCUSSION

Extent of Hymenoptera Concern. It is evident that each type of Hymenopteran (ants, bees, hornets/wasps/yellow jackets) is a problem throughout the US regions we studied (Fig. 8). The data suggest that the South region experiences the highest rate of incidence of Hymenoptera stings (nearly 70% or above for each type of Hymenoptera surveyed), but this may be skewed due to a higher volume of participants being from the South region. Also, forestry is a large industry in the South region of the US compared to other regions of the country. However, foresters throughout the US (surveyed here) experienced negative side effects from Hymenoptera stings which suggests that there is no specific region that needs to be pinpointed to focus on outreaching to the foresters working in this area on how to better prevent Hymenoptera stings. All US regions are lacking in education of the foresters that work in these areas on Hymenoptera safety. Due to this, the educational brochure (Appendix B) developed from this study could be distributed to all the companies from which participants from this study came; the employers could distribute the brochure to their employees which would aid the foresters in knowing how to identify Hymenoptera and avoid stings. NIOSH (2016) recommendations are also a good reference for employers to print material off of to give to their employees for training purposes.

Training Related Concerns. A large number of participants in this study reported that they did not receive any kind of training from their employers about Hymenoptera safety related topics. The relatively few participants that did report receiving training from their employers spent less than a day on this topic. This is one area where change needs to take place. There are a very large number of various types of Hymenoptera that foresters have the potential to come in contact with on a regular basis, so these foresters really need to be able to identify the different types of Hymenoptera. This study did not specifically address how well foresters can correctly identify the various types of Hymenoptera, but it is crucial for them to be able to do so. A study conducted by Baker et al. (2014) showed that in general adults are poor discriminators in distinguishing stinging insects and their nests correctly with the exception of the honeybee. Although the Baker et al. (2014) study looked at 640 adults from the general population and not specifically foresters, it is plausible that many of the participants in this study also cannot correctly identify many of the different types of Hymenoptera since many of the foresters that participated in this study reported to not have received proper training on how to identify the different types of Hymenoptera. Along with being able to identify them, the different types of Hymenoptera also have very different nesting habits and behavioral characteristics. Due to this, some Hymenoptera pose a much more significant threat to foresters than others do. Foresters being able to differentiate between different Hymenoptera may be lifesaving as some people who are exposed to Hymenoptera stings suffer severe immune responses that could lead to death if left untreated. It is recommended that at least one day per year be devoted to training employees on Hymenoptera related safety.

The ability to treat Hymenoptera stings on site when they occur is another area that may require improvement for worker safety. A study by Hayashi et al. (2014) showed that of 62.2% of forester workers in Japan experienced local reactions to Hymenoptera stings which is similar to the nearly 70% or higher (depending on the type of Hymenoptera sting; table 5) of foresters in this study who experienced local reactions to stings. Therefore, it is necessary for the foresters to have the supplies needed to treat these reactions. Most of the participants in this study reported to not carry a medical first aid kit, and of the ones that did report to carrying a medical first aid kit, not all of them reported carrying supplies necessary for treating Hymenoptera stings such as Benadryl, anti-itch cream, or an epi-pen. Medical supplies can be expensive, so employers may be hesitant to purchase these supplies. Training on administration of epi-pens is another area that needs improvement. There is a great potential here for someone to help save someone else's life, so the benefit of training everyone on how to use an epi-pen far outweighs the cost of having the training.

Attitude Changes. A majority of participants (more than 50%) in this study reported to not be concerned about their physical reaction to Hymenoptera stings and to not be anxious about future Hymenoptera stings. While this could possibly be due to the participants feeling experienced enough to know how to avoid the Hymenoptera, the general attitude towards the seriousness of Hymenoptera stings should change. As previously stated, just because a forester does not experience serious side effects from being stung the first time or even multiple times after, the likelihood that these serious side effects will occur increases with each sting. It is possible that foresters do not understand this.

One way to address overall attitude change is for employers to change their attitude towards Hymenoptera safety-related training. Considering the small number of participants that reported having had Hymenoptera safety-related training from their employers, it is clear that employers themselves do not take the risk of Hymenoptera stings seriously. It would be beneficial for employers to also undergo some form of training on safety related to Hymenoptera stings so that they too understand the importance and seriousness of what could potentially and very well may happen if one of their employees were to be stung by the various types of Hymenoptera.

Strengths and Limitations of the Study. One important strength of this study is that the study analyzes data from participants that live in different US regions. This is helpful in determining trends about various Hymenoptera that may vary between regions. However, one limitation of this study is that the number of responses was not distributed equally for all regions. Obtaining contact information online for foresters was difficult as some states had databases with all the foresters in that state available to the public while other states were much harder to find information.

Other limitations of the study include the age and gender of participants represented as well as participants' ability to correctly ID the various types of Hymenoptera. Two-thirds (67%) of the participants were between 50-69 years old; their age and experience could have caused their opinions to be different than those of newer, younger foresters who may not have as much knowledge. Only 48 (10.1%) of the participants were women, hence this is an underrepresented group. This study did not assess participants' ability to correctly identify Hymenoptera, so, it is possible the reported number of stings could be inaccurate if a participant confused the different types of Hymenoptera.

CHAPTER VI – CONCLUSIONS

Hymenoptera such as ants, bees, hornets, wasps, and yellow jackets are found throughout the US and pose a threat to outdoor workers such as foresters. This potential for serious harm due to life-threatening allergic responses to Hymenoptera stings prompted this study. This study found employers across the nation have not adequately trained their employees for how to identify and handle exposure to various Hymenoptera. Due to this, an educational brochure was developed for employers to disburse to their employees as a way to train them on Hymenoptera safety. Specifically, employees need to carry a medical first aid kit to handle Hymenoptera stings, learn how to identify the various Hymenoptera and their nesting habits, as well as learn how to administer an epi-pen in case of an emergency situation.

Future studies could be conducted that address specific regions of the US instead of the entire US so as to better identify specific issues in the various regions across the nation. It would also be beneficial to focus more on specific contributing factors when the Hymenoptera stings occurred so that specific training could be done on how to avoid these types of situations. All Hymenoptera sting events cannot be avoided as they will always be found in nature, but the more training that is taught, the less likely these events will occur.

Table 1. Number of potential participants per region.

Region	# of participants	Total (%)
South	889	44.5
West	438	21.9
Northeast	483	24.2
Midwest	189	9.5
TOTAL	1999	100.0

Table 2. Participant gender per region.

	South	West	Northeast	Midwest	Total (%)
Men	185	79	131	45	440 (90.2)
Women	19	12	5	12	48 (9.8)

Table 3. Age and ethnicity of participants.

Age Range	Identified Ethnicity
18-29 years old (N=13, 2.7%)	Caucasian (N=448, 94.5%)
30-39 years old (N=38, 8.0%)	African American (N=1, 0.2%)
40-49 years old (N=70, 14.8%)	Native American (N=2, 0.4%)
50-59 years old (N=130, 27.4%)	Multiracial (N=5, 1.1%)
60-69 years old (N=188, 39.7%)	Other (N=14, 3.0%)
70 years or older (N=35, 7.4%)	Unknown (N=4, 0.8%)

Table 4. Regional reports of ant, bee, and hornet/wasp/yellow jacket stings.

Region	Ant stings (%)	Bee stings (%)	Hornet/wasp/yellow jacket stings (%)
South	133 (76.9)	119 (68.4)	144 (83.2)
West	31 (35.2)	54 (60.7)	71 (79.8)
Northeast	33 (25.6)	91 (70.5)	118 (92.2)
Midwest	20 (33.9)	35 (61.4)	43 (75.4)

Table 5. Reported symptoms associated with various types of Hymenoptera stings.

Symptom	Ant Sting (% out of 289 responses)	Bee Sting (% out of 364 responses)	Hornet/Wasp/Yellow Jacket Sting (% out of 468 responses)
No Reaction	74 (25.6)	40 (11.0)	27 (5.8)
Local Skin Reaction	198 (68.5)	277 (76.1)	357 (76.3)
Large Local Reaction	5 (1.7)	24 (6.6)	47 (10.0)
Gastrointestinal Reaction	0 (0)	2 (0.6)	5 (1.1)
Respiratory Reaction	1 (0.4)	3 (0.8)	5 (1.1)
Cardiovascular Reaction	0 (0)	1 (0.3)	4 (0.9)
Other	11 (3.8)	17 (4.7)	23 (4.9)

Table 6. Protective measures taken by participants to limit exposure to Hymenoptera.

Protective measure taken	Total (% out of 474 participants)
Wear long-sleeved shirts	251 (53.0)
Wear long pants	333 (70.3)
Wear light-colored clothing	96 (20.3)
Wear gloves	102 (21.5)
Apply insect repellant	159 (33.5)
Avoid wearing cologne or perfume	122 (25.7)
Other	161 (34.0)

Table 7. Participants' opinions on Hymenoptera.

	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly disagree (%)
Hymenoptera are a nuisance where I live	29 (6.1)	163 (34.9)	126 (26.6)	115 (24.3)	26 (5.5)
Hymenoptera are a nuisance where I work	37 (7.8)	183 (38.6)	109 (23.0)	104 (21.9)	26 (5.5)
I am concerned about my physical reaction to Hymenoptera stings	19 (4.0)	86 (18.1)	127 (26.8)	155 (32.7)	69 (14.6)
I am anxious about Hymenoptera stings	11 (2.3)	56 (11.8)	109 (23.0)	161 (34.0)	118 (24.9)
I would like to learn more about how to identify Hymenoptera and their habitats in the field	18 (3.8)	122 (25.7)	194 (40.9)	87 (18.4)	36 (7.6)

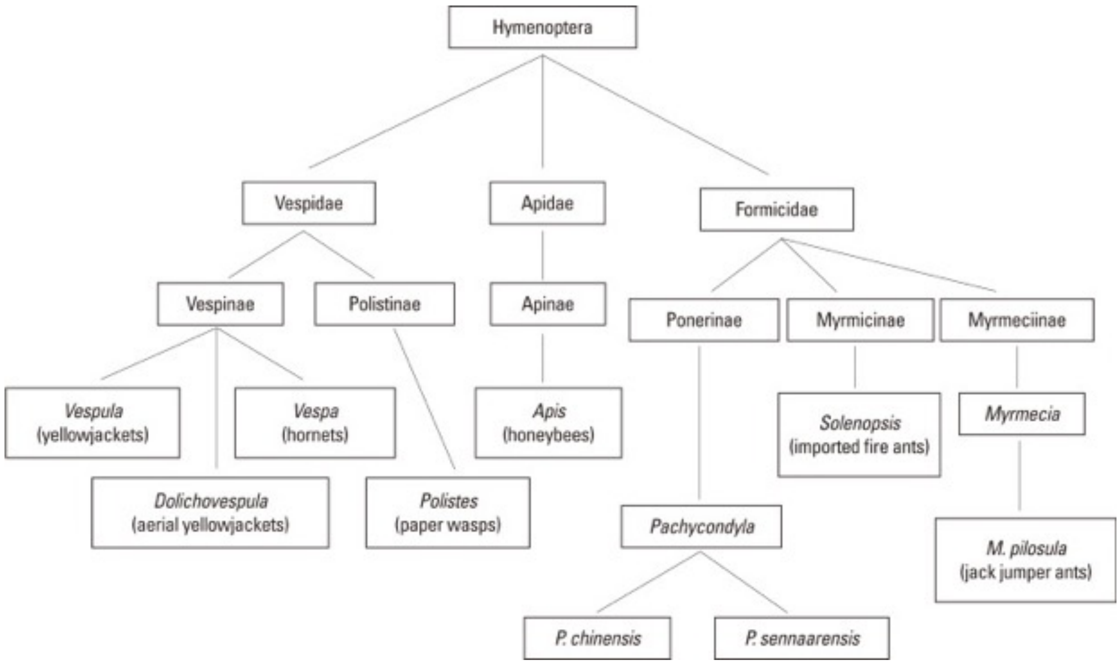

Figure 1. Taxonomy of Hymenoptera.
(Pesek, R.D. and Lockey, R.F. 2013)

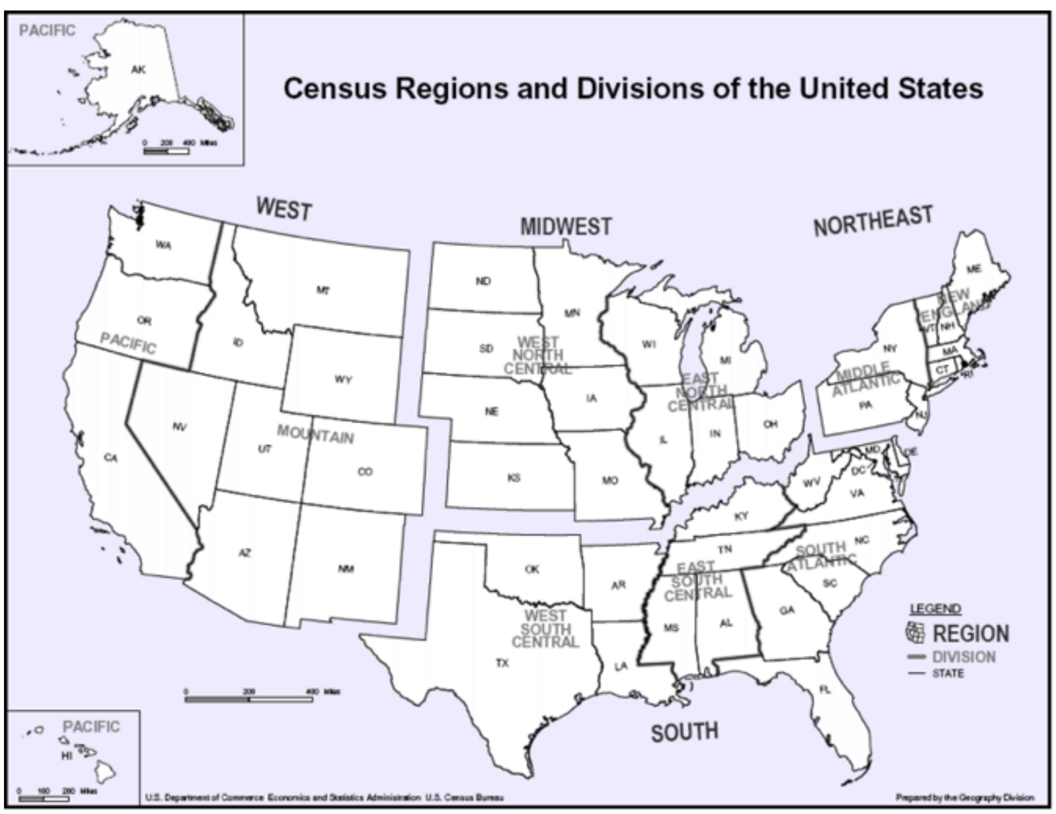

Figure 2. U.S. census regions and divisions.
(U.S. Census Bureau, 2015)

Venom	Allergen	Common name	Molecular Wt. (kDa)
Apis mellifera (honeybee)	**Api m 1**	**Phospholipase A2**	**16**
	Api m 2	**Hyaluronidase**	**39**
	Api m 3	**Acid phosphatase**	**43**
	Api m 4	Melittin	3
	Api m 5	Dipeptidylpeptidase IV	100
	Api m 6	N/A	8
	Api m 7	**Protease**	**39**
	Api m 8	Carboxylesterase	70
	Api m 9	Carboxypeptidase	60
	Api m 10	Incarapin variant 2	50-55
	Api m 11	Major royal jelly protein	50
	Api m 12	Vitellogenin	200
Vespula vulgaris (yellowjacket)	**Ves v 1**	**Phospholipase A1B**	**34**
	Ves v 2	**Hyaluronidase**	**38**
	Ves v 3	Dipeptidylpeptidase IV	100
	Ves v 5	**Antigen 5**	**23**
	Ves v 6	Vitellogenin	200
Dolichovespula arenaria (yellow hornet)	**Dol a 5**	**Antigen 5**	**23**
Dolichovespula maculate (white face hornet)	**Dol m 1**	**Phospholipase A1B**	**34**
	Dol m 2	**Hyaluronidase**	**42**
	Dol m 5	**Antigen 5**	**23**
Vespa crabro (European hornet)	**Vesp c 1**	**Phospholipase A1B**	**34**
	Vesp c 5	**Antigen 5**	**23**
Polistes annularis	**Pol a 1**	**Phospholipase A1B**	**34**
	Pol a 2	**Hyaluronidase**	**38**
	Pol a 5	**Antigen 5**	**23**
Solenopsis invicta (imported fire ant)	**Sol i 1**	**Phospholipase A1B**	**18**
	Sol i 2	N/A	14
	Sol i 3	**Antigen 5**	**26**
	Sol i 4	N/A	12
Myrmecia pilosula (jack jumper ant)	Myr p 1	Pilosulin-1	5.5/7.5
	Myr p 2	**Pilosulin-3**	**2-4/8.5**
	Myr p 3	Pilosulin-4.1	8.1
Pachycondyla chinensis (Asian needle ant)	**Pac c 3**	**Antigen 5**	**21**

Figure 3. Common Hymenoptera venoms with major allergens in bold. (Pesek, R.D. and Lockey, R.F. 2013)

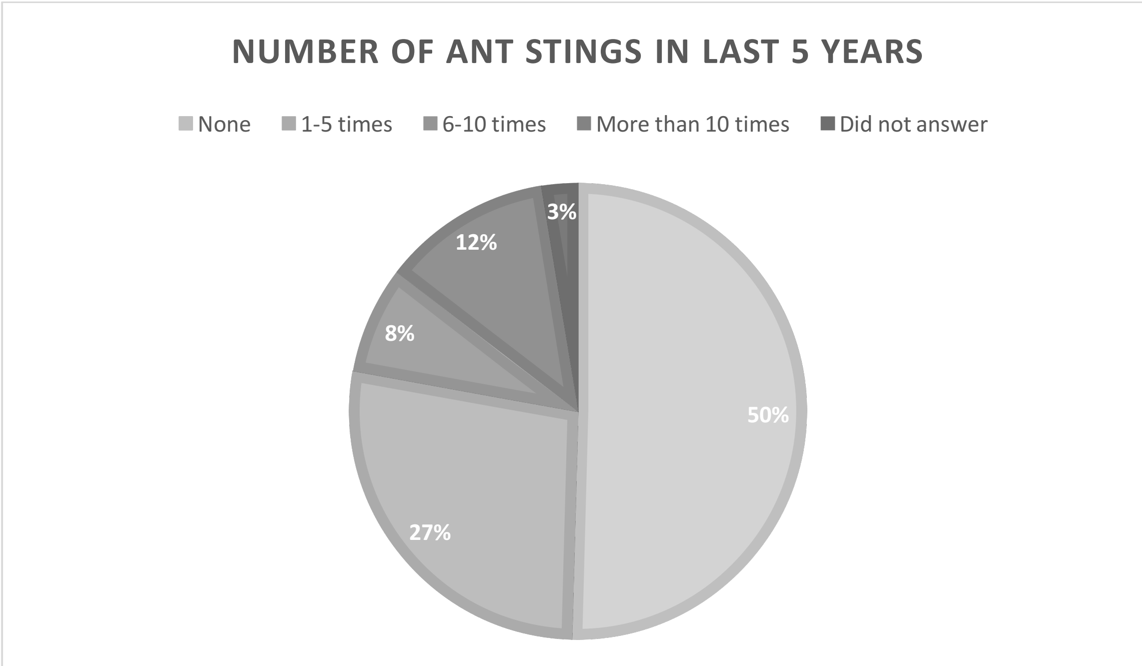

Figure 4. Number of reported times participants were stung by an ant over the last 5 years (all regions).

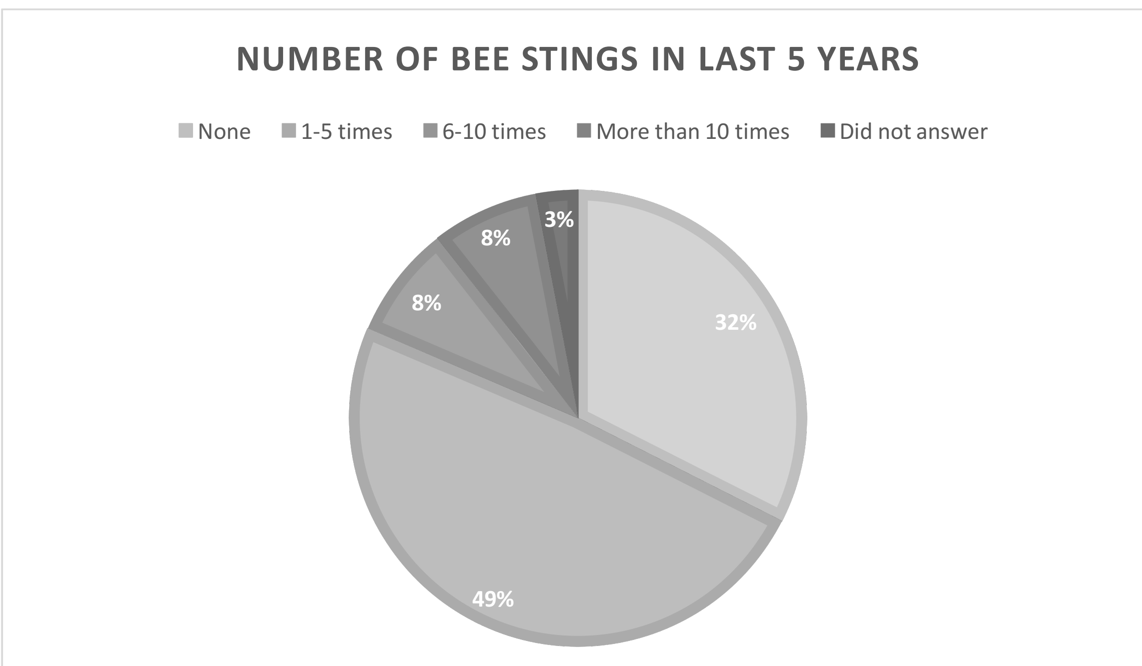

Figure 5. Number of reported times participants were stung by a bee over the last 5 years (all regions).

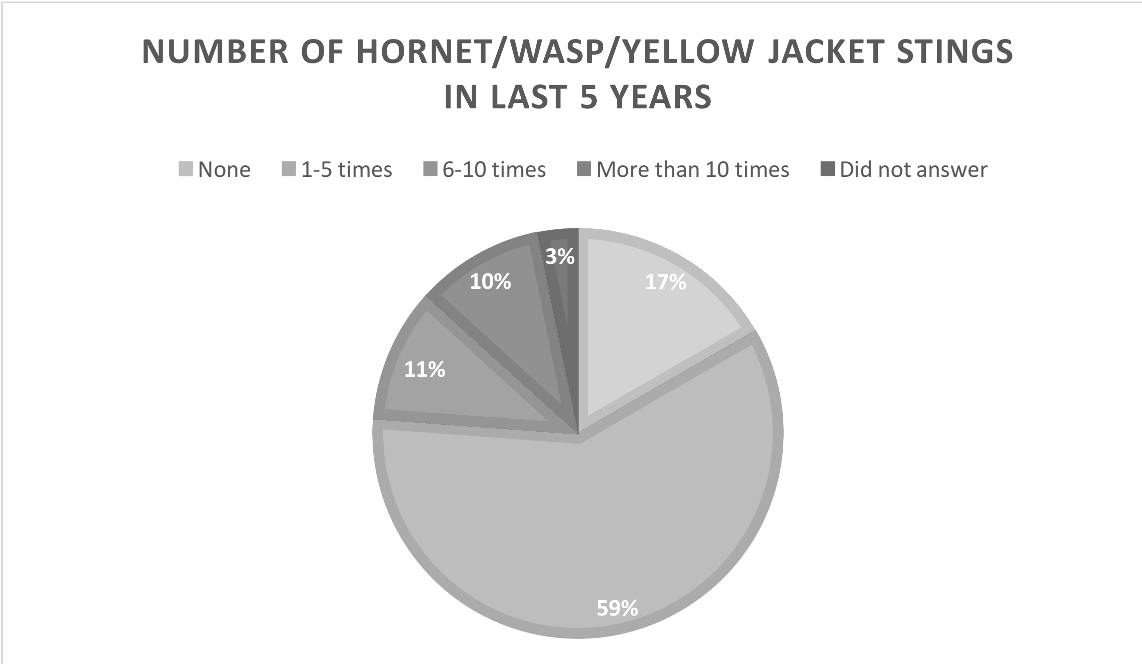

Figure 6. Number of reported times participants were stung by a hornet/wasp/yellow jacket over the last 5 years (all regions).

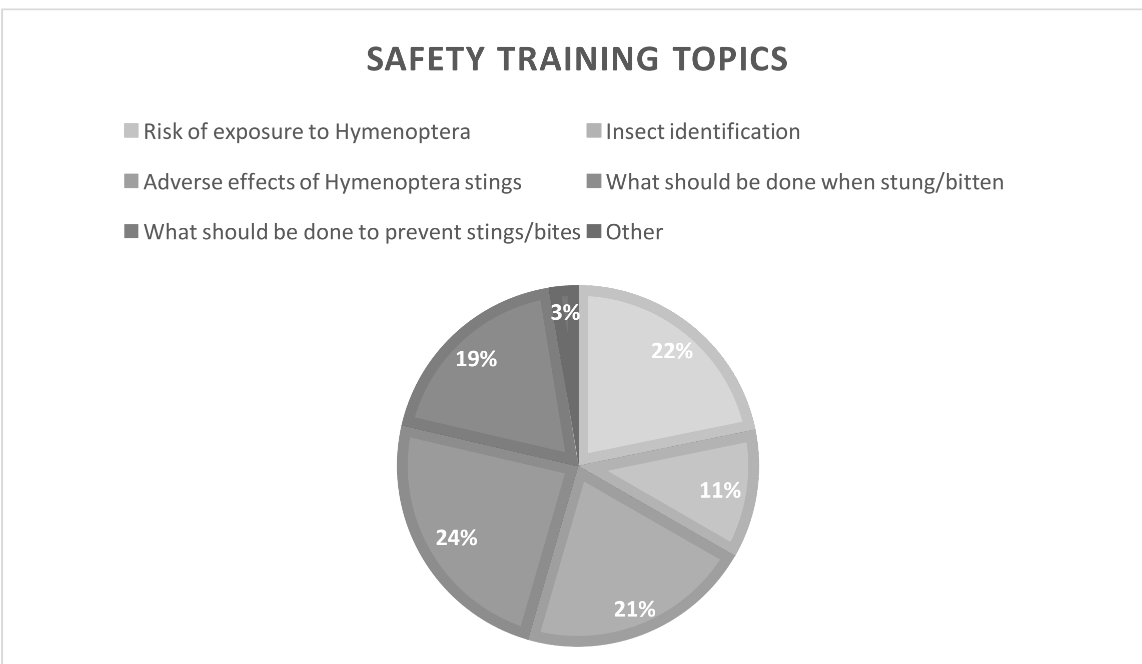

Figure 7. Topics covered in Hymenoptera related safety training provided by employers (all regions).

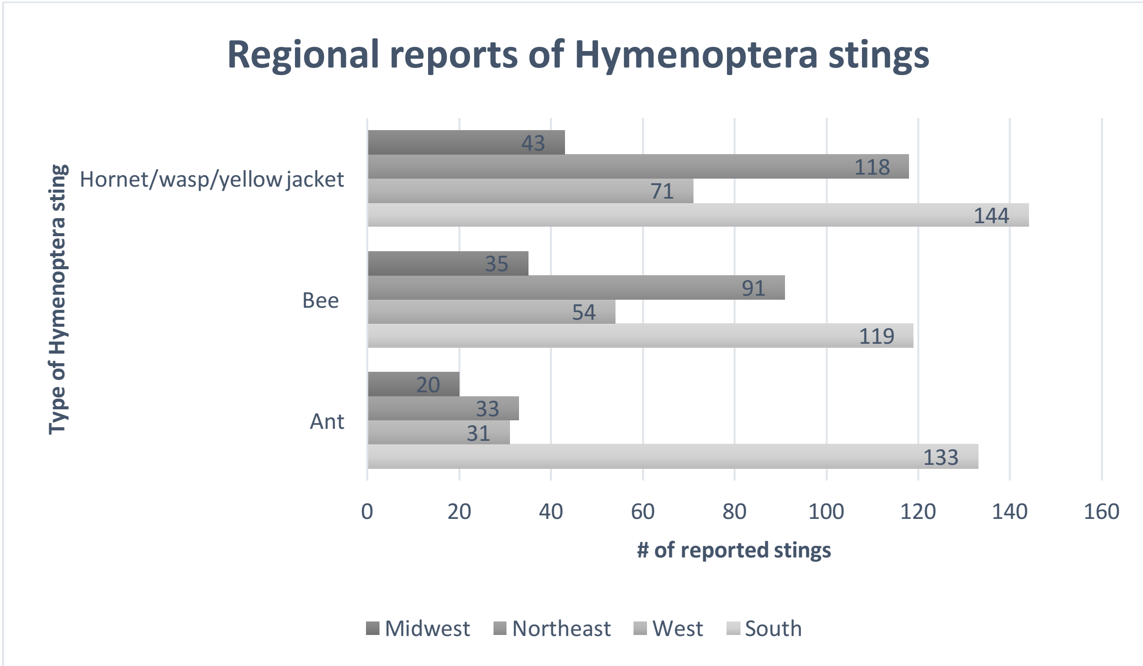

Figure 8. Comparison of types of Hymenoptera stings by region.

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Appendix A

(ECU UMCIRB Approval #15-001105)

Survey Instrument

1) What is your household street address and city where your gift card should be mailed?

____

2) Please list the county or counties and state(s) where you primarily carry out forestry work?

____

3) What is your age?
    a. 18-29
    b. 30-39
    c. 40-49
    d. 50-59
    e. 60-69
    f. ≥ 70

4) What is your gender?
    a. Male
    b. Female
    c. Other

5) What is your ethnicity?
    a. Caucasian
    b. African American
    c. Latino
    d. Asian American
    e. Pacific Islander
    f. Native American
    g. Multiracial
    h. Other, please list________________

6) Please list types of work activities you commonly carry out.

____

7) Do you have any known allergies to Hymenoptera (e.g. ant, bee, hornet, wasp, yellow jacket)?
    a. Yes

b. No (skip to Question 9)
c. If yes, please specify. ___________________________________

8) If you answered yes to Question 7, when (e.g. as an adult or as a child) and how (e.g. at home or at work) did you discover this allergy?
____

9) Have you ever been stung by Hymenoptera (e.g. ant, bee, hornet, wasp, yellow jacket) at work?
   a. Yes
   b. No
   c. If you answered yes, what work activity were you doing when the sting occurred? ____

10) Did you change your job tasks because of Hymenoptera sting reaction? If so, please explain. ____

11) Did you change your career focus because of Hymenoptera sting reaction? If so, please explain. ____

12) Did you suffer economic loss because of Hymenoptera sting reaction? If so, please explain. ____

13) Please list types of outdoor recreational activities in which you commonly participate.
____

14) Have you ever been stung by Hymenoptera (e.g. ant, bee, hornet, wasp, yellow jacket) during recreational activities (home or vacation)?
   a. Yes
   b. No
   c. If you answered yes, what recreational activity were you doing when the sting occurred? ____

15) Within the last five years, how many times have you been stung by an ant?
   a. None
   b. 1-5 times
   c. 6-10 times
   d. > 10 times

16) If you have been stung by an ant within the last five years, did the sting occur while you were at work?
   a. Yes
   b. No

c. If yes, please describe the activity you were doing at the time of the sting.
____

17) If stung by an ant, your symptoms included: (Check all that apply)

a. No reaction
b. Local skin reaction (e.g. minor swelling, redness, itching)
c. Large local reaction (e.g. swollen appendage [e.g. arm, leg])
d. Gastrointestinal reaction (stomach pain, nausea, vomiting)
e. Respiratory reaction (e.g. difficulty swallowing, hoarseness)
f. Cardiovascular reaction (e.g. hypotension)
g. Other. Describe____________________________________

18) Within the last five years, how many times have you been stung by a bee?

a. None
b. 1-5 times
c. 6-10 times
d. > 10 times

19) If you have been stung by a bee within the last five years, did the sting occur while you were at work?

a. Yes
b. No
c. If yes, please describe the activity you were doing at the time of the sting.
____

20) If stung by a bee, your symptoms included: (Check all that apply)

a. No reaction
b. Local skin reaction (e.g. minor swelling, redness, itching)
c. Large local reaction (e.g. swollen appendage [e.g. arm])
d. Gastrointestinal reaction (stomach pain, nausea, vomiting)
e. Respiratory reaction (e.g. difficulty swallowing, hoarseness)
f. Cardiovascular reaction (e.g. hypotension)
g. Other. Describe____________________________________

21) Within the last five years, how many times have you been stung by a hornet, wasp, or yellow jacket?

a. None
b. 1-5 times
c. 6-10 times
d. > 10 times

22) If you have been stung by a hornet, wasp, or yellow jacket within the last five years, did the sting occur while you were at work?

a. Yes
b. No

c. If yes, please describe the activity you were doing at the time of the sting. ____

23) If stung by a hornet, wasp, or yellow jacket, your symptoms included: (Check all that apply)
   a. No reaction
   b. Local skin reaction (e.g. minor swelling, redness, itching)
   c. Large local reaction (e.g. swollen appendage [e.g. arm])
   d. Gastrointestinal reaction (stomach pain, nausea, vomiting)
   e. Respiratory reaction (e.g. difficulty swallowing, hoarseness)
   f. Cardiovascular reaction (e.g. hypotension)
   g. Other. Describe__________________________________

24) How do you protect yourself from stings from Hymenoptera? Check all that apply.
   a. Wear long-sleeved shirt
   b. Wear long pants.
   c. Wear light-colored clothing.
   d. Wear gloves.
   e. Apply insect repellant.
   f. Avoid wearing cologne or perfume.
   g. Other. Please specify. ________________

25) While at work, do you carry a first aid kit or other medical supplies to treat Hymenoptera bites/stings if they were to occur?
   a. Yes
   b. No
   c. If yes, please describe the types of medical supplies. ____

26) Did you undergo any training from your employer related to risk of exposure to Hymenoptera and/or how to protect yourself from them at work?
   a. Yes
   b. No (skip to Question 29)

27) If you answered yes to Question 26, how long was your Hymenoptera-related training?
   a. Less than 1 day
   b. 1 day
   c. 2 days
   d. More than 2 days

28) If you answered yes to Question 26, what topics were covered in your Hymenoptera-related training?
   a. Risk of exposure to Hymenoptera (e.g. how you get exposed)
   b. Insect identification
   c. Adverse effects of Hymenoptera stings

d. What you should do when you get stung or bitten
e. What you should do to prevent getting stung or bitten
f. Others. Please specify. ________________________

29) Indicate your level of agreement or disagreement for the following statements:

a. Hymenoptera are a nuisance where I live.
   Strongly Agree Agree Neutral Disagree Strongly Disagree
b. Hymenoptera are a nuisance where I work.
   Strongly Agree Agree Neutral Disagree Strongly Disagree
c. I am concerned about my physical reaction to Hymenoptera stings.
   Strongly Agree Agree Neutral Disagree Strongly Disagree
d. I am anxious about Hymenoptera stings.
   Strongly Agree Agree Neutral Disagree Strongly Disagree
e. I would like to learn more about how to identify Hymenoptera and their habitats in the field.
   Strongly Agree Agree Neutral Disagree Strongly Disagree

Appendix B – Educational Brochure

Hymenoptera Safety Tactics for Foresters

What are Hymenoptera? Why do they matter?

Hymenoptera is a order of insects including bees, ants, wasps, yellow jackets and hornets. These stinging insects can cause serious health issues and should be avoided as much as possible.

Photos above are by: Danielle Carter

Hymenoptera to Avoid & How

Photo by: Maciej A Czyewski at https://www.vice.com/en_us/article/wd74d9/the-earth-index-829

#1: BEES!

Bees can be our friends because they are incredibly important pollinators, but their stings can cause various immune responses aside from being fairly painful. Bumblebees are of the most concern and should be avoided as much as possible because they are social insects and will sting if provoked.

#2: ANTS!

Fire ants are the main concern when it comes to adverse effects that could happen from an ant sting. Fire ants can be both red or black – so be careful around all ants and don't just avoid the red ones. Be aware of your surroundings so as not to disturb ant mounds.

Photo from: www.hgtv.com/outdoors/gardens/planting-and-maintenance/how-to-keep-yellow-jackets-away

Photo from: https://www.thinglink.com/scene/717785273718538240

#3: HORNETS/WASPS/YELLOW JACKETS!

These flying stinging insects are most dangerous when in groups and when their nests are disturbed. Some species nest underground and others build nests in hidden places such as in tree cavities for example. Be cautious when inspecting and cruising timber so as not to disturb the nests.

NIOSH Recommendations for avoiding exposure to Hymenoptera: (https://www.cdc.gov/niosh/topics/insects/default.html)

- Wear light-colored, smooth-finished clothing
- Avoid perfume, cologne, and perfumed soaps/shampoos/deodorant
- Cover as much as the body as possible – wear long sleeved shirts and long pants
- Wear clean clothing and bathe daily

Appendix C – Chi-Square Test Results

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.436[a]	1	.231		
Continuity Correction[b]	.958	1	.328		
Likelihood Ratio	1.558	1	.212		
Fisher's Exact Test				.278	.164
Linear-by-Linear Association	1.433	1	.231		
N of Valid Cases	461				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 7.73.

b. Computed only for a 2x2 table

Test 1. Chi-Square Test of Association results from SPSS for testing to establish an association between participants being stung at work and receiving Hymenoptera safety training from employer.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	30.367[a]	1	.000		
Continuity Correction[b]	29.242	1	.000		
Likelihood Ratio	30.818	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	30.302	1	.000		
N of Valid Cases	461				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 63.28.

b. Computed only for a 2x2 table

Test 2. Chi-Square Test of Association results from SPSS for testing to establish an association between participants receiving Hymenoptera safety training from their employers and carrying a medical first aid kit that includes supplies to treat Hymenoptera stings.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	8.685[a]	1	.003		
Continuity Correction[b]	7.801	1	.005		
Likelihood Ratio	8.814	1	.003		
Fisher's Exact Test				.003	.002
Linear-by-Linear Association	8.667	1	.003		
N of Valid Cases	463				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 22.43.

b. Computed only for a 2x2 table

Test 3. Chi-Square Test of Association results from SPSS for testing to establish an association between participants with known allergies to Hymenoptera and carrying a medical first aid kit that includes supplies to treat Hymenoptera stings.

Appendix D – IRB Approval Letter

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
4N-70 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** · www.ecu.edu/irb

Notification of Continuing Review Approval: Expedited

From: Social/Behavioral IRB
To: Stephanie Richards
CC:

Date: 6/3/2016
Re: CR00004481
UMCIRB 15-001105
Risk Assessment of Forester Exposure to Hymenoptera

The continuing review of your expedited study was approved. Approval of the study and any consent form(s) is for the period of 5/31/2016 to 5/30/2017. This research study is eligible for review under expedited category # 7. The Chairperson (or designee) deemed this study no more than minimal risk.

Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The Investigator must adhere to all reporting requirements for this study.

Approved consent documents with the IRB approval date stamped on the document should be used to consent participants (consent documents with the IRB approval date stamp are found under the Documents tab in the study workspace).

The approval includes the following items:

Document	Description
Consent letter - Hymenoptera (English).docx(0.01)	Consent Forms
Consent letter - Hymenoptera (Spanish).docx(0.01)	Consent Forms
Recruitment statement - online survey (English).docx(0.01)	Recruitment Documents/Scripts
Recruitment statement - online survey (Spanish).docx(0.01)	Recruitment Documents/Scripts
Recruitment statement - telephone survey.docx(0.01)	Recruitment Documents/Scripts
Study protocol - Hymenoptera.docx(0.01)	Study Protocol or Grant Application
Survey questionnaire (English).docx(0.01)	Surveys and Questionnaires
Survey questionnaire (Spanish).docx(0.01)	Surveys and Questionnaires

The Chairperson (or designee) does not have a potential for conflict of interest on this study.