Bed Bugs (Cimex lectularius):
Biology, Control Methods, & Their Role as Pests

Dreann Nicole Fedor

Cimex lectularius, more commonly known as bed bugs, are ectoparasites that feed on the blood of their mammalian or avian hosts (Harlan, 2006; Koganemaru & Miller, 2013). The ancestor of bed bugs presumably evolved 145-165 million years ago, during the Cretaceous and Jurassic periods (Koganemaru & Miller, 2013). It is hypothesized that human bed bugs transitioned from bat hosts to humans during the Pleistocence, Paleolithic and Neolithic periods when humans began sleeping in caves. There are records as early as 400 B.C that document bed bugs pestering humans and there is evidence of bed bugs in North America in the 1600's.According to Delaunay (2012), heat, carbon dioxide and possibly human kairomones attract bed bugs to humans during resting periods where they are most vulnerable. Bed bugs are nocturnal insects that bite their hosts at night on regions of the skin that are exposed (Delaunay *et al.*, 2011). The bites are often painless due to the anesthetic compounds in the bed bugs' saliva along with vasodilatory and anticoagulant factors. Adult bed bugs typically feed every three to five days, and require a blood meal in order to reproduce (Harlan, 2006). Bed bugs feed approximately five to ten minutes and consume a blood quantity that is many times larger than their body weight (Pest West Environmental, 2014; Williams & Willis, 2012). Bed bugs use two separate elongate stylets where one draws the blood without clotting and the second injects saliva to prevent any pain the host would feel during the feeding process (Williams & Willis, 2012).

The most common side effect of bed bug bites are skin lesions that are often mistaken for mosquito or spider bites (Williams & Willis, 2012). Bed bug bites may range from a few to many lesions due to the degree of infestation (Delaunay *et al.*, 2011). There is often localized inflammation and itchiness as a side effect of the bites which will usually heal after one week (Harlan, 2006; Williams & Willis, 2012). Secondary bacterial skin infections can occur from scratching, as well as anaphylactic reactions due to a severe allergic reaction (Koganemaru & Miller, 2013). Cases of severe infestation have reported anemia and iron deficiencies in infants and the elderly. The physical lesions left by bed bugs can lead to psychological problems such as: worrying, reduced self esteem and self isolation, especially if the lesions are on the neck or face (Williams & Willis, 2012). Work performance can be affected because beg bugs are associated with poor hygiene. Some people develop delusions of bed bugs crawling on their skin. A study conducted by Susser *et al*. (2012) concluded that levels of anxiety and sleep disturbances were considerably elevated in groups plagued by bed bug infestations. Mild to severe forms of anxiety, depression and stress are

common psychological side effects as well (Williams & Willis, 2012). There has been considerable speculation that bed bugs have the potential to transmit infectious diseases, such as HIV, to humans (Koganemaru & Miller, 2013). Studies found that bed bugs that were injected with HIV did not pass the disease onto their offspring and no replicated virus was found in the bed bugs; therefore, the bed bug is not a candidate for HIV transmission (Delaunay, 2012; Koganemaru & Miller, 2013). Currently, there are no known infectious diseases or pathogens that humans can acquire from bed bugs serving as a vector (Adelman *et al*., 2013; Williams & Willis, 2012). Adelman *et al.,* (2013) speculates that if there is a potential for bed bugs to carry an unknown infectious disease, poor and underdeveloped parts of the world will be most heavily affected; particularly, refugee camps, homeless shelters, migrant camps in close contact to bat and bird populations. The potential for bed bugs to transmit diseases exists because inside male intromittent organs of bed bugs, molds, bacteria and fungi have been found (Williams & Willis, 2012). Bed bug bites can lead to numerous health problems and should be carefully monitored because their role as a vector carrying infectious diseases is still currently unknown and under investigation.

Active dispersal is the most common method for spreading bed bugs short distances, such as room to room (Delaunay *et al.,* 2011). Areas with high turnover of people such as hotels, trains, cruise ships, and apartments are highly susceptible to bed bug infestations (Delaunay *et al*., 2011; Delaunay, 2012). Economically poor regions with overcrowding and poor hygiene are also a risk factor for bed bug infestations (Delaunay *et al*., 2011). Places such as clothes, mattresses, wall paper, cracks and crevices are common hiding places that house bed bugs in close proximity to their hosts. Bed bugs can also travel thousands of kilometers in luggage, clothing or furniture, which is referred to as passive dispersal. Because bed bugs secrete a distinctive oil from their dorsal abdominal glands that consists of aldehydes and other chemicals (Williams & Willis, 2012), when infestations are severe, a sour smell will be apparent and then control methods should be administered (Delaunay, 2012).

After World War II, bed bugs were no longer a common nuisance due to the development of insecticides such as DDT in economically prospering countries, however, bed bugs were still an issue in poor countries (Delaunay *et al*., 2011). The cosmopolitan reemergence of bed bugs in the last couple of decades is hypothesized to be the result of resistance to DDT and parathyroid insecticides (Koganemaru & Miller, 2013). However, there are several other hypotheses, such as increased travel, changes in frequency of pest control, lack of awareness, and modifications in pesticide application that support the reemergence as well. Zhu *et al*. (2013) found that bed bugs have developed resistance genes in the epidermal layer of the integument that slows down or prevents toxins from reaching nerve cells. Other mutations enhance metabolic detoxification or change the binding compatibility of insecticides to their target protein, thus

leading to pyrethroid resistance. Williams & Willis (2012) report that mutations in the voltage gated sodium channels has created pyrethroid resistance in many insect species. There is a new type of insecticide, called Pyrroles, that are stomach poisons that hinder the production of ATP in the mitochondria (Koganemaru & Miller, 2013). These may become the pesticides of choice to treat bed bug infestations. Future studies on insecticide resistance must enhance the penetration of insecticides or locate different target sites that do not yet have resistance gene mutations (Zhu *et al.*, 2013). Other control methods to eradicate bed bug infestations include: vacuuming, steaming, laundering, disposal, and exposure to extreme temperatures (Koganemaru & Miller, 2013). Dogs have even been trained to detect the odour produced by bed bugs (Williams & Willis, 2012). Washing linens and other infested material at temperatures above 60^0C are likely to kill eggs and nymphs (Delaunay *et al.*, 2011). Freezing infested items for four days is an option when the infestation is small (Williams & Willis, 2012). A combination of chemical and non-chemical control methods are the most efficient way to remove bed bugs as a long term solution.

C. lectularius are included in the family Cimicidae, which is a blood feeding group of insects (Williams & Willis, 2012). The Cimicidae are one of the only two families in the order Hemiptera that feed on blood, the other non-blood feeding members feed on fluids from plant tissues (Koganemaru & Miller, 2013).There are at least eight species of the genus *Cimex* that feed on humans when their bird or bat hosts live in close proximity to people (Adelman *et al.*, 2013). Birds, bats and domestic animals can be infested by cimicids (Williams & Willis, 2012). Bed bugs are related to the only other blood feeding hemipterans, kissing bugs (family, Reduviidae) which transmit (*Trypanosoma cruzi*), the cause of Chagas' disease (Williams & Willis, 2012). There are two species of bed bugs that commonly infect humans: *Cimex lectularius* and *Cimex hemipterus* (Williams & Willis, 2012). *C. lectularius* is common in temperate zones and *C. hemipterus* is found in tropical parts of the world; however, both species can be found anywhere across the globe. The common bed bug (*C. lectularius*) flourishes in temperatures and humidity that is comfortable for humans (Harlan, 2006).

The size of adult *C. lectularius* ranges from five to seven mm, with reddish brown, oval-shaped bodies (Williams & Willis, 2012). A female bed bug can lay 200 to 500 eggs in her life time, following a blood meal. Eggs are roughly 1mm long by 0.5 mm wide and vary from a translucent appearance to a pearl white color (Pest West Environmental, 2014). At room temperature eggs hatch in four to ten days. Five nymph stages follow until adulthood is reached (Williams & Willis, 2012). Juvenile bed bugs are approximately 1.5 mm and are yellow or translucent before feeding and bright red following a blood meal. A blood meal is required to move onto the next nymphal stage, which is passed every three to seven days depending on food resources.The stages of a bed bugs' life cycle

can be passed every three to seven days; therefore, an infestation can escalate rapidly without intervention. Adult bed bugs can survive for twelve months without a blood meal and nymphs can survive over three months (Delaunay, 2012; Harlan, 2006). Bed bugs can also survive in cold environments for 1.5 to 2 years (Delaunay,*et al.*,2011).

Male bed bugs are attracted to female bed bugs that have had a recent blood meal (Williams & Willis, 2012). Male bed bugs do not use the genital opening of the female during copulation; rather fertilization is achieved by traumatic insemination (Morrow & Arnqvist, 2003). The male uses its intromittent organ to pierce the female's abdominal wall to bypass the genital tract and add sperm into the female's mesospermagele (Morrow & Arnqvist, 2003; Williams & Willis, 2012). The mesospermagele is an organ inside the female bed bug that conducts the movement of sperm (Williams & Willis, 2012). The genital tract is solely used for egg laying in cimicids (Alastair & Siva-Jothy, 2001). Females will undergo as many as five traumatic inseminations after feeding; consequently, death is common after copulation (Williams & Willis, 2012). Some costs as a result of traumatic insemination are infection in the puncture wound, cuticle repair, immune system defense against sperm or other fluids in the blood stream and leakage of haemolymph (Morrow & Arnqvist, 2003). Studies conducted by Morrow & Arnqvist (2003) found that increased rates of traumatic insemination do not significantly reduce fitness of female bed bugs, but rather increases the reproductive rate. Despite the costs associated with traumatic insemination, the female's life span is only reduced by 30% since the spermalege provides a counter adaption in the female. The mesospermagele is thought to have evolved in the female bed bugs to reduce the costs associated with traumatic insemination. The mesospermagele provides protection to the female in several ways: localizing the injury in the abdomen, decreasing the diffusion of ejaculate inside the female, lessening the leakage of blood from the injury site and narrowing the entry of pathogens into the bloodstream (Morrow & Arnqvist, 2003). Female bed bugs need to copulate once every four blood meals in order to reach their normal reproductive rate and peak their reproductive success in their lifetime (Alastair & Siva-Jothy, 2001).

Conclusion

There are numerous hypotheses such as increased immigration, resistance to pesticides, and modified control methods explaining the reemergence of bed bugs as serious pests in the past couple of decades. Future research is needed to develop an insecticide that bed bugs are not resistant to, in order for efficient control. Infestations can escalate quickly due to the high reproductive potential of female bed bugs and also the relatively short time span to reach adulthood. Bed bug populations are hard to eradicate because they hide in crevices and cracks during the day and are able to survive harsh environmental conditions as well as, long periods without a blood meal. The nocturnal activities of bed bugs

make humans susceptible to bites when they are sleeping causing side effects such as itching and inflammation. Bed bugs can travel several meters to thousands of kilometers therefore creating a worldwide problem. Having some common knowledge regarding bed bugs can decrease their spread to new ranges if travelers are informed about cautionary measures they can take. Bed bugs are a unique blood-feeding insect that have evolved to a human host and will continue to be a nuisance until more efficient control methods are discovered.

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