The Mosquito Problem, Attempted Solutions, and *Drosophila* as a Similar Olfactory Organism

Literature Review

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Abstract

Mosquitoes are vectors of deadly diseases that cause millions of fatalities each year and leave people with health complications for the rest of their lives. Every year, hundreds of thousands of people lose their lives to diseases, such as malaria. In addition, the variety of diseases mosquitoes carry can be transmitted to the host, which can lead to disabilities. Furthermore, for the individuals fortunate enough to not receive a disease from mosquitoes, their bites are unpleasant, leading to inflammation and itching (the body's response to foreign invaders). There are three phases of the host-seeking process, occurring at different distances. Currently, many attempts at producing a mosquito-controlling method have been based on sight or taste, which often leads to at least one flaw. For example, DEET has been proven harmful to the environment. Since DEET is hard to remove as a waste product, it eventually seeps back into the ecosystem, disrupting the growth of smaller insects and microorganisms. There has not been conclusive evidence stating which bite-preventing method is the most effective. However, the importance of prevention is undeniable. Studies have found that by maintaining a low mosquito population in an area, it reduces the probability of a vector transmitting a disease into a host. Therefore, a more safe but effective method to attract and remove mosquitoes in an area is needed. *Drosophila* are a great model organism to utilize when conducting olfactory experiments. This is because *Drosophila* are easy to handle and acquire, as well as easily genetically mutated for specific purposed.

Keywords: *mosquito attractant, trap, vector control, Drosophila*

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Literature Review

Behind humans, mosquitoes are the deadliest animal on the planet. Although they may not look terrifying or invoke fear in humans, they cause hundreds of thousands of deaths every year, as well as leave people with life-long disabilities (Bustamante, 2019). Most species of mosquitoes lay their eggs in still water, preferably sheltered from wind and poor weather (AMCA, n.d.). In a short amount of time, around two weeks (varies among different species), a mosquito egg hatches, turns into larva, then a pupa, and finally an adult (AMCA, n.d.). The adult phase of the mosquito is the most dangerous. However, only female mosquitoes bite warm- or cold-blooded animals, as they require a blood meal for egg production. Many female mosquitoes feed during nighttime or in shady/cloudy regions (AMCA, n.d.). Male mosquitoes are not a threat to humans, as they feed on nectars (AMCA, n.d.). When mosquitoes bite their host, any disease or harmful material carried by mosquitoes may be transferred to the host. For example, malaria, dengue fever, chikungunya, zika, and countless other diseases are carried by mosquitoes and could be transmitted into the host when bit (Bustamante, 2019). 500 million medical cases each year are caused by mosquito-borne diseases (Bustamante, 2019). Of the 500 million, over 2.7 million humans lose their lives (Bustamante, 2019). Poorer regions of the world are not able to control mosquito populations as effectively, and therefore suffer heavily from these diseases (Bustamante, 2019). In addition, mosquito bites also cause infection, caused by when blood from a previous host is spread into the new host. Certain areas of the world are more affected than others, especially poorer regions, where there may not be enough money to limit mosquito populations, or the inaccessibility to treatment or vaccines. However annoying and dangerous mosquitoes are, they are essential for ecosystems, meaning they cannot be erased from the face of the earth (Peach, 2019). There are thousands of mosquito species in the world, many of which do not target humans (Peach, 2019). There are two vital roles mosquitoes play in ecosystems: pollination and food chains (Peach, 2019). First, male and female mosquitoes feed on plant sugar and related nutrients (Peach, 2019). Many plants mainly rely on mosquitoes for pollination (Peach, 2019). Secondly, mosquitoes are at the bottom of the food chain. Larval mosquitoes are consumed by larger organisms a part of aquatic ecosystems. Adult mosquitoes are also fed on by many creatures, a part of terrestrial and avian ecosystems (Peach, 2019). When these deceased mosquitoes are then digested and released back into the world, the nutrients they consumed provide valuable nutrients for plants.

Section I: Host-seeking process

Scientists have found three major steps, as shown in figure 1, that are based upon the distance from a host in a mosquito's host seeking process (Raji & Degennaro, 2017). The first stimulus that draws the attention of a mosquito is odor and CO_2, which occurs at the farthest distance (Caltech, 2015). As there are thousands of species of mosquitoes, this first phase occurs at around 10 to 50 meters (Caltech, 2015). Next, a combination of CO_2, as well as the odor, and sight continue to lure the mosquito to its host (Caltech, 2015). This middle step occurs at around 5 to 15 meters (Caltech, 2015). Finally, when the mosquito is close enough, CO_2, odor, visual signals, and the host's body heat, taste, and moisture cues if the host can be fed on (Mathew et al., 2013). The last phase happens within 1 meter of the host or during physical contact (Caltech, 2015). Different chemicals may attract or repel mosquitoes. Mosquito-control methods may never be 100% effective, but there are mechanisms part of the different methods that are the most ideal at preventing humans from being bitten. The only way to prevent mosquito bites, thereby preventing mosquito-transmitted diseases, is to exterminate all blood-sucking mosquito species, which is highly impractical, or by not breathing, which would be very effective since CO2 would not be emitted by the human, but even then, it would not be 100% effective. By targeting a mosquito's olfactory senses, the first phase, a hypothetical trap should be the most effective, as the attractant functions at the farthest range during the mosquito's host-seeking process. For example, DEET primarily serves at minimal distance, the last phase of the host-seeking process, because DEET tastes bad for mosquitoes.

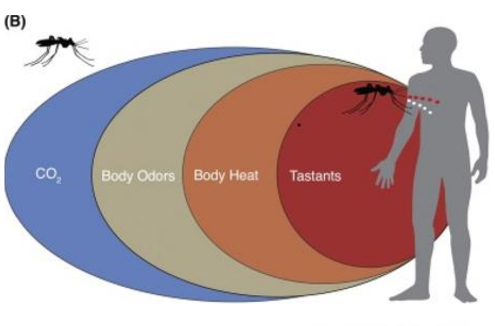

Figure 1: Diagram of distances of the occurrences of different stimuli in the host-seeking process of mosquitoes by Raji & Degennaro, 2017. Mosquitoes first sense CO2 and Body Odors (chemicals) of the host, then see the host and its heat. Finally, after physical contact, the mosquito may taste the host.

Section II: Drosophila

A research paper done by Vosshall in 2000 indicated *Drosophilae*, more commonly known as fruit flies, are great model organisms to use for odor experiments. *Drosophilae* are able to recognize hundreds of different odorants (Vosshall 2000). In addition, *Drosophilae* has been proven to adapt to simple olfactory-based tests (Vosshall 2000). Finally, because *Drosophilae* are able to be easily mutated, they may be easily adapted for an experiment. Another study conducted by Raji and Degennaro in 2017 found that mosquitoes and *Drosophilae* are attracted to similar chemicals. A mosquito's and *Drosophila's* brain was found to incorporate both odor and taste when feeding (Raji & Degennaro, 2017). Also, both organisms can sense heat through Ionotropic Receptors (Raji & Degennaro, 2017). They also found that combining a chemical attractants with others the resulted compound usually is more attractive. An experiment conducted by Mathew et al in 2013 used *Aedes Aegypti* and a choice chamber to test different compounds for their attractancy or repellency. To decide the attractancy or repellency of the compound, Mathew et al implemented the attractancy and repellency index. They found that 1-octen-3-ol had the highest attractancy rating for *Aedes Aegypti* individually, at around 58, while a combination of myristic acid, lactic acid, and carbon dioxide had the highest attractancy rating as a synthesized compound, at around 62. In addition, three other synthesized compounds also had a higher attractancy rating compared to 1-octen-3-ol individually (Mathew et al., 2013).

Section III: Comparison of Mosquito-Controlling Methods

Humans already knew the diseases carried by mosquitoes were the cause of hundreds of thousands of fatalities each year. To counteract this, numerous inventions have been developed, and numerous more are being invented. However, there has not been a method guaranteeing 100% safety from mosquito bites. Although scientists have found DEET to be the most effective repellent at preventing mosquito bites, there are still several flaws. Firstly, the effectivity of DEET is not permanent. DEET must be applied repeatedly to ensure safety from mosquito bites, and even then, unlucky hosts may still be bitten. Secondly, the more pressing issue is DEET negatively affects the environment. Because DEET in insect repellents (has other uses too) functions as a spray, it is physically introduced into the environment. Other mosquito repellent methods include mechanical ways of dealing with them, such as using light to attract mosquitoes. These methods do not damage the environment, but they present a danger to other insects attracted to light in addition to not being effective at controlling mosquitoes, especially since they function most efficiently during dark hours. DEET must be treated at wastewater treatment plants (WWTP) because the chemical is not biodegradable. However, these WWTP are not able to remove 100% of all DEET (Aronson et al., 2011).

A study conducted by Aronson et al in 2011 found that DEET contamination in aquatic environments largely come from WWTP. The presence of DEET in water negatively affects both microorganisms as well as small aquatic bugs (Aronson et al., 2011). The methods mentioned above may not even be available for use in poverty-stricken areas, as they may be area specific or too expensive. In the end, humans have greatly advanced mosquito-repellency methods, but more research and testing needs to be done to finally put an end to the mosquito pandemic.

Another type of mosquito control humans have developed is an attempt to prevent mosquitoes from growing up into adults. As previously mentioned, mosquitoes prefer to lay their eggs in safe, still water. This may be exploited against them by spraying chemicals into the water to disrupt their process. One other method relating to mosquito control is utilizing infrared light. Many typical designs involve a power source, an electrical grid where mosquitoes are electrocuted, and some protective material surrounding the electrical grid. Part of the electrical grid includes the light which mosquitoes are attracted to. However, mosquitoes are not the only insect attracted to light. Countless other insects, such as moths, fall victim to the trap designed for mosquitoes. Moths are not even a threat to humans. A different type of a mosquito controlling method is relatively new (CDC, 2020). The technique involves utilizing male mosquitoes (CDC, 2020). Mosquitoes are hatched in a lab, where male and female pupae are separated (CDC, 2020). Next, the male mosquitoes are sterilized, using radiation (CDC, 2020). These irradiated male mosquitoes are released back into the wild, and when they mate with wild female mosquitoes, the eggs will not hatch (CDC, 2020). This approach at mosquito control takes time to go into effect, but over time, mosquito populations will drop in a given area (CDC, 2020).

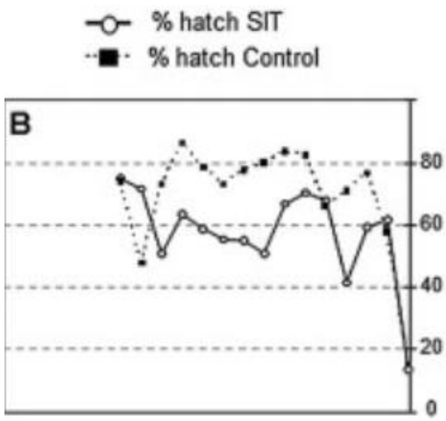

Figure 2: Graph showing the percentage of mosquitoes hatching from eggs with and without sterilized males. SIT stands for sterile male release areas. Based on the graph, less than 20% of all mosquito eggs hatched while around 60% of mosquito eggs hatched without sterilization of the males (Bellini et al., 2013).

This technique is effective and does not have many drawbacks, but two significant flaws are that the method is not commercially available and it does not provide immediate safety for the consumer. Therefore, one wanting protection from mosquitoes is not able to employ this process because it is impractical. Also, this method is not sustainable, because this process has to be repeated by professionals every year or the mosquito population in the area will return to normal.

Conclusion

Mosquitoes pose a huge threat to humans from all regions. However, poorer nations may not have enough wealth and material to implement resources to fight mosquito populations. Therefore, future research should be conducted to design the most effective mosquito-controlling device. This developed method does not need to be specified towards repellency or attractancy, as the end goal should be to create a cheap, environmentally friendly, and as effective as possible in regard to preventing mosquito bites. This literature review examined current methods of mosquito control and what areas to further research relating to a mosquito's biology to prevent as many mosquito bites as possible.

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