Abstract

Vector-borne diseases are a major threat to human health. Diseases caused by viruses and parasites carried by mosquitoes kill millions of people every year. How can we control these diseases? One of the methods scientists have tried to develop recently is biocontrol – the use of natural enemies to control mosquito populations and thus the diseases they carry. We wanted to try a slightly different approach: using bacteria that reduce the mosquitoes’ ability to transmit viruses. We introduced these bacteria in local Australian mosquitoes and then released them back into a town where a lot of dengue outbreaks have occurred to breed with wild mosquitoes. Soon enough the majority of the mosquitoes in the area carried the bacteria. This has led to a drastic reduction of human dengue cases.

Introduction

You probably already know what the deadliest animal in the world is. It’s not sharks or spiders – it’s mosquitoes. They contribute to the deaths of millions of people every year because they transmit viruses and parasites that cause diseases such as malaria, dengue, Zika, chikungunya and yellow fever, each of which can be deadly. Preventing these diseases is hard: vaccines are scarce, and so are drugs. Mosquito population control is not easy either: usually it involves insecticides, which can be effective but requires the constant spread of chemicals that are usually at least slightly toxic to the environment. Biocontrol is another method of reducing mosquito populations: an example of effective biocontrol agents are some predatory fish which feed on mosquito larvae. We wanted to try a different approach though – what if we use another natural enemy to mosquito populations: bacteria?

Methods

First we had to raise and release mosquitoes with Wolbachia. Using a tiny needle we introduced Wolbachia in local Aedes aegypti mosquitoes. This step fortunately only needs to be done once. We looked after the mosquitoes for several generations and divided them into two colonies: one for reproducing inside the lab and one for releasing.
At the end of 2014 we released mosquitoes with *Wolbachia* in Townsville (a small city in northeastern Australia) in four stages. Our prediction was that the mosquitoes with *Wolbachia* would then breed with wild mosquitoes and over time the majority of insects would carry the bacteria (See Fig. 1.)

We then monitored two things weekly: 1. how many mosquitoes carried *Wolbachia* and 2. the number of dengue cases among people in the area. We trapped some of the mosquitoes in the areas where we released the *Wolbachia*-carrying insects and we performed qPCR on them to look for *Wolbachia* presence. Queensland Health Communicable Diseases Branch provided us with information regarding all human dengue cases in the town between January 2000 and October 2018.

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**Figure 1:**

This diagram explains a process called Cytoplasmic Incompatibility, which allows *Wolbachia* to increase in the mosquito population.

Source: World Mosquito Program
Results

The areas of release showed a relatively quick increase in the percentage of mosquitoes carrying *Wolbachia* (Fig. 2). And while the percentage of *Wolbachia*-carrying mosquitoes was increasing, the number of human dengue cases in the area was decreasing (Fig. 3). So, even when a person carried dengue to Townsville from another location, the virus wasn't spread by the local mosquito population.

**Figure 2:**
Percentage of *Wolbachia*-carrying mosquitoes over time in Hermit Park, one of the areas of release. The yellow shading shows the release times and the green line shows the percent of mosquitoes carrying the bacteria.

**Figure 3:**
Dengue cases in Townsville between 2000 and 2018. The top graph shows dengue cases that people caught locally, while the bottom graph shows the dengue cases brought in from somewhere else. The green shading indicates the coverage of *Wolbachia*-carrying mosquitoes.

How quickly did the percentage of mosquitoes carrying *Wolbachia* reach 80%?

How did the number of locally acquired dengue cases in Townsville change after the release of *Wolbachia*-carrying mosquitoes?
Discussion

Our method showed promising results. In almost every area of release the bacteria spread among the mosquito population very quickly – in a matter of months the percent of Wolbachia-carrying mosquitoes had risen to above 80% at almost every area we checked. This means that the insect population is capable of maintaining the bacteria by itself, without the need for us to release any more mosquitoes carrying Wolbachia.

But does our success spreading Wolbachia among mosquitoes have an effect on dengue cases? Our results showed a clear correlation between the increasing percent of Wolbachia-carrying mosquitoes and decreasing number of human dengue cases. Townsville has had some serious dengue outbreaks since 2001. But ever since the introduction of Wolbachia in mosquito populations, dengue cases have been sporadic – nearly all of the locally acquired dengue cases were in areas where we haven’t released our mosquitoes. Moreover, the number of imported dengue cases hasn’t shown a similar decrease over the years, further supporting the efficiency of our method in reducing dengue transmission.

Conclusion

Governments and health organizations are trying various methods to control vector-borne diseases, a major problem for public health. Nevertheless, the best prevention against these diseases is to avoid mosquito bites - after all, a mosquito can’t infect you if it doesn’t take a bite!

- Use insect repellents
- Wear long sleeves and trousers
- Take precautions during the day, not only in the evening - some mosquitoes (like the Aedes aegypti we mentioned before) bite during the daytime!

Glossary of Key Terms

- **Aedes aegypti** – species of mosquitoes, the primary vector of Zika, dengue, chikungunya and yellow fever.
- **Biocontrol** (or biological control) – the control of a pest (like mosquitoes) by the introduction of a natural enemy such as a predator, parasite, etc.
- **Dengue** – a mosquito-borne viral disease, causing fever and severe joint and muscle pains. Sometimes it is lethal, especially to children under 5.
- **Insecticides** – chemicals which kill insects.
- **Larva** – an active immature form of an insect (and some other animals as well).
- **qPCR = quantitative polymerase chain reaction** – a method for creating multiple copies of a specific part of the genetic material. By making a lot of copies, we can visualize them and eventually identify them.
- **Repellent** – a chemical (or natural substance) which deters insects from approaching and biting.
- **Transmission** – the passing of a bacteria/virus or other pathogen from one person to another.
- **Vector-borne diseases** – diseases for which insects (such as mosquitoes or some flies) and ticks transmit the disease-causing viruses or parasites to people.
- **Wolbachia** – a genus of bacteria which infects many different insects, some other arthropods and some nematodes.
Check your understanding

1. If you use an insecticide to kill greenflies (aphids – pests on cultivated plants) what kind of control is this? And what about if you use parasitic wasps? Which is less harmful to the environment?

2. How are Wolbachia-carrying mosquitoes maintaining Wolbachia in their population after the initial release?

3. What does this bacterium do inside the mosquito’s body?

4. Did the high percentage of Wolbachia-carrying mosquitoes achieved have any impact on dengue cases in the area where we released them?

5. What are some vector-borne diseases control strategies mentioned in the article?

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