New mosquito traps improve the monitoring of disease vectors

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Introduction

Despite the considerable progress made in our understanding of the biological and molecular basis of mosquitoes-transmitted diseases, their insidence over recent decades has increased world-wide. Some 50% of the world's population still lives under the threat of vector borne diseases such as malaria or dengue. Although these diseases are largely restricted to resource-poor tropical parts of the world, the rapid spread of the West Nile virus in North America since 1999 demonstrates that diseases transmitted by mosquitoes can spread even through industrialised resource-rich nations as well.

The reasons for the growing risk from mosquitoes worldwide are diverse and are summarized in Table 1. What is generally agreed is that socio-economic factors play a major role but that there is little hope of changing them. Conventional control strategies also have little impact on mosquitoes in urban environments. Experience demonstrates that lasting protection against many vector-associated diseases can only be achieved through an effective control of the vectors.

Importance of effective monitoring of vectors

One of the essential preconditions for effective disease prevention is the availability of monitoring systems that enable the incidence, distribution and density of vectors to be measured quickly, accurately and at low cost. It is crucially important that this information is recorded for a number of reasons:

1. Effective focus of control measures both in terms of time and location

2. Measuring the effectiveness of control measures

3. Determining the risk of infection in any particular area

4. Modeling of epidemiological forecasts and risk management

5. Monitoring of genetically modified strains of mosquitoes in controlled field experiments

Methods for the monitoring of mosquitoes

Currently there is a wide range of different methods used to monitor vector populations, as summarized below.

Recording of larvae and pupae

If the locations of breeding sites are known, samples can easily be taken from the water to determine the number of larvae and/or pupae present. This form of mosquito monitoring has been deployed in the fight against dengue fever. Staff at the dengue control authorities visit private households several times a year, check the house and backyard for potential breeding containers and determine the number of larvae (Fig. 1). This method is costly in terms of human resources and is

Fig.1: Monitoring of mosquito populations in Brazil: Search for water containers populated by eggs, larvae or pupae (Photo: Á.E. Eiras, University of Minas Gerais, Belo Horizonte, Brazil).

not always popular with the house-holders. The more numerous the breeding waters the more difficult the survey becomes. In an urban environment, breeding locations are constantly being created, disappear again and are almost impossible to control, e.g. discarded bottles, cups and cans, old car tyres, flower pots with water left over from watering, blocked roof gutters, soak-away pits and drains, uncovered drinking water containers and storage tanks.

Experience over recent years in places where cases of dengue have been increasing has shown that this method does not provide an up-to-date indication of the actual risks of dengue fever. Larval density estimates correlate very poorly with subsequent adult vector densities.

Traps for egg-carrying females

Another method involves the use of small containers or cups that are half-filled with hay infusions and from which small wooden strips project. Attracted by the smell of the hay infusions, certain species of Aedes lay their eggs on these strips.

Fig. 2: Photograph of the BG Sentinel®. The yellow arrows show the direction of the drawn-in air, the red arrows the air loaded with the attractants which are emitted through the permeable fabric.

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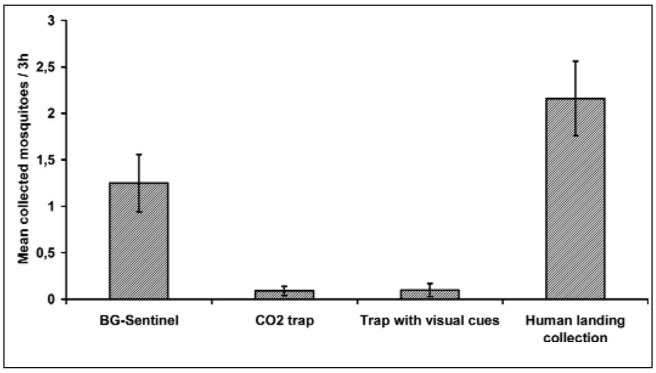

Fig. 3: Mean values (± standard error) for caught Aedes aegypti (syn. Stegomyia aegypti) from all three-hour catching periods over an eight week period. BG-Sentinel trap with lure dispenser BG Lure (n=32). Carbon dioxide: Mosquito Magnet Liberty generates moist-warm CO2 (n=32). Trap with visual lures: Fay Prince trap with black and white contrast (n=30). Person: Voluntary test person as a mosquito catcher (n=32).

These containers, also known as Ovitraps, are set out in large numbers and checked on a weekly basis. To find out exactly which species of mosquito laid the eggs, however, larvae have to be hatched from the eggs, which is both time-consuming and requires trained personnel.

Ovitraps can be sensitive instruments, however, and are ideally suitable for determining whether certain species of mosquito are present in an area and whether they are multiplying. On the other hand they do not give an accurate estimate of the number of female mosquitoes which have laid their eggs because such females distribute their eggs across a wide number of different breeding waters.

Traps for host-seeking females

Trapping adult host-seeking female mosquitoes is the most effective means of gaining an accurate picture of the risk of infection in any specified area. To collect this data, voluntary human volunteers are used that spend several hours in a test area catching all female mosquitoes that land on them (human bait catch). This technique, however, puts the mosquito catchers at a greater risk of infection, making the method highly questionable on ethical grounds. Additionally, it is very difficult to standardise the catch rates because each mosquito catcher varies in his/her degree of attraction, enthusiasm and skill.

Fig. 4: Percentage of catching periods in which at least one female Aedes aegypti was caught. Descriptions of the catching methods as in Fig. 3.

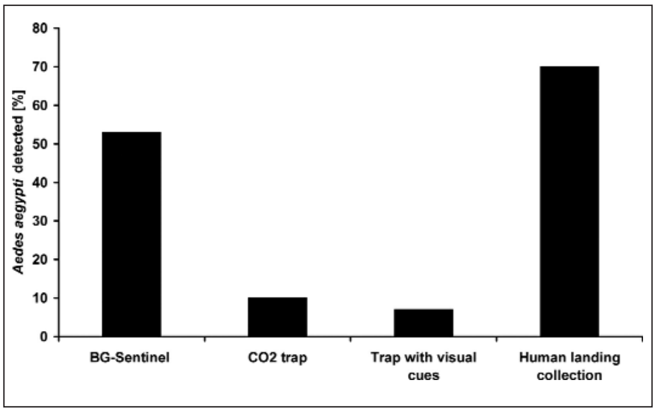

Table 1: Factors influencing the increasing risk of diseases transmitted by mosquitoes.

Socio-economic factors

- Uncontrolled population growth
- Increasing urbanisation and high population densities in conurbations
- Poor infrastructure (e.g. waste disposal, lack of sewage systems)
- High population mobility
- Floods of refugees
- Increasing transportation networks and traffic levels, nationally and internationally
- Air traffic
- International trade in used tyres
- Renaturalization measures and the creation of new wet areas

Way of life and biology of the vectors

- Close socialization with man
- Host preference: Man is the preferred host species for the most dangerous vectors
- Adaptation of the mosquitoes to the areas in which man lives and to man's way of life
- Slums in the megacities offer ideal living conditions for the vectors
- Adaptation to temperate climatic zones

Variability of the pathogens

- Resistance against medications
- Development of new variants of viruses
- Slow development of new medications and vaccines

Climate change

- Medium-term and long-term changes in climate are creating new areas in which mosquitoes can live

Inadequate means of combating the vectors

- Resistance of the vectors to insecticides
- Lack of highly effective, specific insecticides which pose only a minimum risk to man and the environment
- Extreme difficulty of co-ordinated control efforts against vectors in cities

One solution to the problem is to use alternative catching systems which attract mosquitoes using visual cues, scent signals or heat, and then catching them with a fan, adhesive surfaces or a high-voltage electric mesh. A wide variety of these kinds of traps are available, the most common being the CDC traps developed by the Center for Disease Control and Prevention in the USA. These use carbon dioxide and/or light to attract the mosquitoes, which are then sucked in by a fan. However, since neither light nor carbon dioxide are specific stimulants with which mosquitoes can distinguish a human host from any other animal, traps such as these mainly attract opportunistic mosquitoes with no specific host preference. The catch rates of these traps for dengue or malaria vectors are in the order of 10 – 1000 times lower than human mosquito catchers.

Backpack aspirators

An alternative method of collecting adults is to search systematically through homes and vacuum up all mosquitoes found using special back-pack aspirators. This method is especially efficient for mosquito species that remain in the

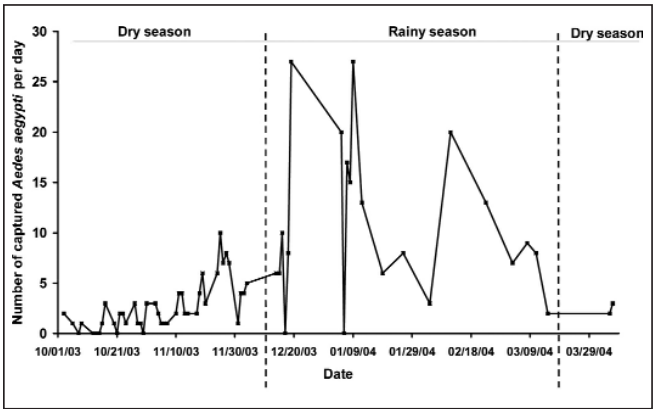

Fig. 5: Number of female Aedes aegypti caught by a BG-Sentinel trap in a certain location in Belo Horizonte over several months. The trap was kept at the same location for the whole time and the catch was recorded at irregular intervals. The wettest months are between the beginning of December and the end of March.

building even after they have sucked blood (endophil mosquitoes). The number of mosquitoes caught, however, depends on the experience and enthusiasm of the catchers and is therefore difficult to standardize. Other disadvantages include the relatively high cost and low level of acceptance on the part of the human population, since there is a reluctance to allow strangers into their homes.

New techniques for attracting and catching mosquitoes

Recently, new techniques have been developed with the objective of simplifying and improving the monitoring of mosquitoes. Fundamental research in the area of chemical and sensory ecology of mosquitoes at the University of Regensburg resulted in the design of a new lure and trapping system. The new suction trap, the BioGents-Sentinel trap (BG-Sentinel) mimics convection currents created by a human body, employs attractive visual cues, and releases attractants over a large surface area.

The trap is used in combination with a novel attractant lure, the BioGents-Lure, which consists of a combination of non-toxic substances that have been identified from human skin. The upward moving convection flows, typical of scent emitted from a human, are imitated by the trap through the use of a fan that blows the scent upwards through a fabric gauze. Any mosquitoes following a scent trail emitting from the trap are then drawn visually to the edge of a suction column and forced into a net by the downward suction of the fan. The patented trap is shown in Fig. 2.

Efficient monitoring using the example of mosquitoes that transmit dengue fever

This new system is currently being tested in Cairns in Australia and a number of cities in Brazil to monitor mosquitoes in urban environments that transmit dengue. The female mosquitoes are active during the day and are almost impossible to catch using conventional traps with carbon dioxide. Field experiments have demonstrated that the BG-Sentinel trap is far superior to other trap systems and catches almost as many mosquitoes per hour as a human mosquito catcher (Fig. 3).

The BG-Sentinel is not only efficient in terms of the absolute number of mosquitoes caught but also in terms of its sensitivity. Yellow fever mosquitoes are normally found in relatively low population densities. Day-feeding mosquitoes are frequently disturbed while sucking blood and therefore need several blood feeds to mature their eggs. It only requires a very small population therefore to spread disease and trigger epidemics.

Fig. 4 shows the percentage of positive verifications of yellow fever mosquitoes on the site of the Institute for Biology at the University of Belo Horizonte, Brazil. In spite of the usual presence of students and staff and therefore a large number of competing hosts, the BG-Sentinel caught at least one yellow fever mosquito in over 50% of all catching periods, whereas the other two types of traps failed to catch any for most of the time.

With the help of the BG-Sentinel it is also possible to monitor the effectiveness of any control measures that are implemented. Plans are being developed to install an early warning system based on this technology for dengue fever in several cities in Brazil. This will also permit the mosquitoes that are caught to be examined for dengue viruses and the number of dengue cases in the population to be correlated with the catch rates. The goal of these investigations is to calibrate these monitoring systems to a level that catch rates can determine the risk of an epidemic. Additionally, these investigations will determine the number of traps required in any area to detect even small breeding population.

Fig. 5 shows the catch rates of a BG-Sentinel at a single location in Belo Horizonte over several months. It is apparent that the catch rate rises noticeably at the beginning of the wet season, but in the dry months too, the trap is sensitive enough to enable lower populations to be measured.

Up until now, city monitoring authorities have only been able to carry out a maximum of four mosquito larval surveys in any one district per year. In these surveys, homes were inspected on a random sample basis to determine the number of mosquito larvae/eggs present. However, given that mosquitoes have development cycles of less than two weeks, this kind of monitoring is incapable of providing an up-to-date picture of risk. Using the new methods described here it will be possible, with the same human resources, to determine the density of adult mosquitoes on a weekly basis, thereby achieving a much higher temporal and spatial resolution of the degree of risk.

Future prospects

The BG Sentinel is not only a trap for use in tropical conditions. In Italy the trap produced very encouraging results for catching the tiger mosquito Aedes albopictus, and in North America it has been used to catch Culex pipiens, one of the carriers of the West Nile virus. In the near future the BG-Sentinel will be tested not just as a monitoring tool but also for control purposes by investigating its capacity to reduce disease transmission by direct reduction of the female population.

In field tests in Mali and Ghana, sand flies (phlebotominae), the leishmaniasis vectors, were also caught in high numbers. This opens up the possibility that the BG Sentinel might be useful for many other biting insect pests.

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