Journal of Tropical Diseases

Tabbabi et al., J Trop Dis 2017, 5:5
DOI: 10.4172/2329-891X.1000250

Review Article Open Access

A Review of Entomological Surveillance and Vector Control, with Concrete Examples that Discuss the Use of Indicators in Monitoring and Evaluation

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Received date: September 16, 2017; **Accepted date: October** 27, 2017; **Published date:** November 06, 2017

Abstract

The emergence of diseases or vectors is not a new phenomenon but for the last few decades, it seems to be accelerating. The subject of this article was to review the surveillance and response to disease emergence, in particular entomological surveillance. The available published and unpublished reports on entomological surveillance and vector control were collected and reviewed. The relevant entomological indicators target the presence/absence, density or longevity of vector populations, or even the presence of pathogens in the vectors. The role of research is to fill gaps and limit uncertainties that may affect the efficiency of an entomological surveillance program, including vector competence and environmental conditions favorable to emergence and outbreaks.

Keywords: Entomological surveillance; Disease emergence; Vectors; Monitoring; Evaluation

Introduction

The news of infectious diseases whose agents are transmitted by vectors regularly makes headlines. For the year 2014, the first epidemic due to the chikungunya virus in the New World [1], epidemics due to chikungunya and zika viruses in the Pacific Islands [2], epidemics of dengue around the world [3], and the first outbreak of indigenous cases of chikungunya in France (Montpellier) [4].

The invasive vectors are not left behind. *Anopheles* allochthonous species of mosquito Ochlerotatus notoscriptus, an Australasian species, has been detected in the United States [5]. The area of distribution of the tiger mosquito (*Aedes albopictus*) continues to expand in Europe, particularly in metropolitan France [6]. *Anopheles stephensi*, a major vector of the malaria agent in Asia, was observed for the first time on the African continent where it is clearly well established in Djibouti [7].

These examples are not intended to be exhaustive, but only to illustrate the extent to which the reality of the globalization of trade, in particular the speed and volume of intercontinental transport of goods and people, affects Epidemiology of vector-borne diseases. The emergence of diseases or vectors is not a new phenomenon; Charles Nicolle has long considered its changing, even opportunistic nature. But for the last few decades, it seems to be accelerating [8].

Faced with this somewhat worrying observation, is there an appropriate response? In part yes: surveillance is an element of response, in particular entomological surveillance, the subject of this article. Some concepts, organization, monitoring, issues, tools, and examples are addressed in turn.

Methods

The available published and unpublished reports on entomological surveillance and vector control were collected and reviewed. Concrete examples that discuss the use of indicators in monitoring and evaluation were added and discussed. Several articles were searched of which some published articles were selected and reviewed on the basis of the news of infectious diseases whose agents are transmitted by vectors.

Results and Discussion

The two notions of observation (monitoring) and surveillance are often differentiated in the field of epidemiology. Monitoring generally refers to the set of processes established, punctual or routine, in a defined perimeter, to observe a phenomenon. It involves compilation and compilation of data, without including analysis, interpretation, dissemination and use of the information produced for the action, which is under surveillance. Surveillance, on the other hand, incorporates strict observation, and goes beyond that. Surveillance can be defined as all processes: i) put in place in response to a risk to allow description and tracking in time and space; and ii) carried out to support various actions.

Entomological surveillance is a device for collecting and tracking data in time and space on vectors. It is a tool for detecting anomalies in the evaluation of entomological parameters. Subsequent actions can be very varied; Such as the decision to change the alert level, the launch of a mandatory vaccination campaign, the initiation of vector control, the use of a different insecticide by its mode of action, etc. A surveillance system includes active surveillance aspects, based on a predefined protocol for data production, such as observation of the presence of a vector, a critical vector density, monitoring of susceptibility to Insecticides in target vectors, of the circulation of a pathogen within a population of vectors. This monitoring should be considered as part of a more comprehensive surveillance system that takes into account the entire circulation cycle of a pathogen: human and/or animal epidemiological surveillance, monitoring of reservoirs (wildlife and/or domestic), Monitoring the circulation of pathogens in these compartments, and monitoring environmental conditions favorable to vector proliferation or transmission [9]. In these instances, the concept of indicator is, of course, fundamental.

Thus, in a context of high circulation of the West-Nile virus in Colorado (3,800 human cases) and on the basis of a major effort to collect and thus observe (265,000 mosquitoes crops over 5 years) a "vector index" has been elaborated. This index alerted the risk of transmission three months before the first human cases. This index was based on positive batches of mosquitoes but also took into account other indicators such as abundance and trophic preferences [10].

The internal structure of the continuum (observation-response (s)) should not be improvised in an emergency. This is why strategic and practical reflections are put in place upstream, in the form of case studies. Reflecting before the health crisis is triggered facilitates consultation among all stakeholders and facilitates the identification of the most appropriate response, taking into account operational, sociological, economic and political aspects. Prior consultation is essential for the distribution of the tasks to be carried out and the deployment of the means to be implemented. The multiplicity of actors involved is a constraint to be taken into account. Several ministries, several regions and even more departments, many operators are stakeholders.

Regardless of the limit between observation, surveillance and control, the most important is the effectiveness of the action undertaken, itself being the culmination of the process that begins with observation. The main thing is to ask the following questions and to define methods to answer them. What to watch? How to monitor? And most importantly, why monitor, which amounts to asking how to react according to the results of surveillance?

The issues of vector surveillance are crucial for public health, human medicine or veterinary medicine. An example, from the recent history of Madagascar, will illustrate the importance of the stakes. Following independence in Madagascar, in the 1960s, the malaria had done wonders on the central highlands. The major vector, *An. Funestus*, had virtually disappeared as a result of vector control based on intra-domiciliary spraying of DDT. The human reservoir of parasites had itself greatly decreased under the effects of chloroquine treatments and chemoprevention. In the end, the transmission of the malaria agent was practically nil, the new cases observed were so few in number that they were difficult to quantify in comparison with non-indigenous cases, particularly contracted in the coastal regions. Malaria was no longer a public health problem. Over the years, what happened almost everywhere in such cases. Concerns have shifted, surveillance has been relaxed, other emergencies have become self-evident, the means previously devoted to malaria control have been mobilized elsewhere. Everything went well until a phenomenon occurred, later identified as being the reconstitution of the endophilic populations of *Anopheles funestus* on the Central Highlands. In the absence of appropriate supervision, this phenomenon has gone unnoticed, contrary to the consequences which have been dramatic. As the transmission potential is restored, the parasite prevalence has gradually reached a threshold terrible epidemic (more precisely, a restoration of malaria endemic) to *Plasmodium falciparum*, by far the most deadly agent of malaria, occurred during the years 1985-1988 [11,12]. The ex-post evaluations vary according to the sources indicating a total of 40,000, 120,000 or 400,000 deaths. This example illustrates the difficulty of maintaining an effective surveillance system, including the material aspects, but more importantly the individual know-how and expertise of the people involved.

This example emphasizes the importance of the production and dissemination of information. It is crucial for a public health official to be informed of the evolution of the major indicators that are part of the risk assessment.

From this perspective, entomological surveillance makes an essential contribution to the assessment of the basic reproductive rate (R0) of a communicable disease, defined as the average number of secondary cases generated by a person during the infectious period, Symptomatic or not, introduced into a fully sensitive population. It is this rate that makes it possible to make forecasts and thus to assess the risk. A large part of the surveillance issues crystallizes in this rate, and in the reliability of its evaluation.

According to the incriminating vector, it is a qualitative variable, presence/absence, which is considered essential (as for triatom bugs, vector of the agent of Chagas disease). These presence/absence data are particularly relevant in the case of invasive species which, by their presence, constitute a necessary factor for emergence. Thus, newly colonized areas by *Aedes albopictus* become at risk of arboviruses, which requires prevention measures and adapted responses. For other vectors, the density (tick Ixodes vector of the agent of Lyme disease) is preferred, or a combination of the density and longevity of the vectors (culicoides vector of the agent of bluetongue). The vector density may also be coupled with the prevalence of a pathogen in the vector in question to determine the level of risk, since: (i) in some cases the circulation of a pathogen can be detected in the Vector before its circulation in humans or in domestic animals (case of the West Nile virus in Colorado) and (ii) in other cases, the geographical distribution of a vector does not coincide with the area of circulation of a pathogen (e.g. ticks and encephalitis), but such a situation is evolve. Sometimes the larval stages are the subject of surveillance (in the case of aquatic larvae of *Aedes* mosquitoes which are vectors in the adult stage of dengue viruses) or it is the adult stages (the case of trypanosome trypanosome vectors in sub-Saharan Africa).

On the margins of these technical aspects, an important dimension of maintaining effective surveillance is the motivation of the people who perform it. This is why one of the objectives of the scheme concerns communication in order to maintain the motivation of the actors involved in this surveillance. They must be able to find recognition of their activity and perceive the collective benefit of the data they collect, format, or transmit.

The tools used in entomological surveillance are as varied as vectors and even entomologists. The question of the sampling of insects, whether vectors or not, is a matter of great concern to specialists. Several books exist now, entirely devoted to the sampling of mosquitoes alone, at all stages (egg, larva, nymph, adult male, adult female). Interestingly, unexpected applications have emerged in this context; In fact, methods of collecting insects originally envisaged to respond to sampling problems have sometimes proved to be so successful that they were immediately used in control; This is what happened to the tsetse trap, which was originally conceived as a means of sampling and which, now simplified, is now one of the pillars of tsetse control.

The multiplication of vector sampling methods is a real problem for surveillance, which requires a minimum of homogeneity in the apparatus and procedures for comparing data from different sources.

So the entomological monitoring plans set out in great detail the aspects of materials and methods.

With regard to the surveillance of larval mosquitoes, three larval indicators are mainly used. These are indicators developed between 1920 and 1950 in South America as part of the control of *Aedes aegypti*, vector of the yellow fever virus. These indicators are currently being used in the surveillance and vector control of other arboviruses such as dengue and chikungunya (*Aedes aegypti* and *Aedes albopictus*): Index of house (proportion of houses or larvae or nymphs were shown, expressed in %); Container index (proportion of larval instars in water or larvae or nymphs were shown, expressed in %); Breteau index (from the name of its inventor, number of larval instars or larvae or nymphs were found for 100 houses examined). In practice, these indicators are somewhat redundant, but they are useful for inter-site and inter-period comparisons, allowing for the definition of action triggering thresholds for contexts [13].

Other mosquito sampling methods, particularly for mosquito surveillance, including *Aedes albopictus* in metropolitan France, permit the collection of eggs or adult mosquitoes. The purpose of the nest trap is to provide spawning support for mosquito species that breed in small water collections (water reservoirs, tree troughs). The regular rotation of these traps makes it possible to identify the species thanks to the eggs harvested. The CO_2 trap has for its purpose to attract adult mosquitoes in search of a blood meal. Attracted by the discontinuous blast of CO_2 mimicking the production of carbon dioxide through breathing, mosquitoes are caught in a net falling regularly. The capture of adult mosquitoes allows the evaluation of the density of biting mosquitoes and the identification of many species. Other adult mosquito traps use as bait a light source (combined or not with a release of CO_2), as in the conventional "CDC light traps". These light traps are also used in the monitoring of culicidae in Europe.

In some cases, when the vector is also a nuisance in itself (case of *Aedes albopictus*), it is advisable to be attentive to the complaints of the populations, usually relayed by the town halls and possibly by the media; The inhabitants, disturbed in their habits by a recent nuisance, easily question their mayor to ask for an explanation and to demand a solution. It is often this complaint that is the first indicator of the implantation of this mosquito in a new locality.

The evaluation of the density of hard ticks, such as *Ixodes ricinus* vector Borrelia burgdorferi in Europe, Lyme disease agent, is usually carried out according to the "flag" method. A person drags behind her, in the low vegetation, walking slowly, a white or ecru fabric, of square form, a meter of coast, acting as a lure. Ticks are mistaken and cling to the tissue, as if it were the coat of a host mammal. After 10 meters, a sampled area of 10 m^2, the person stops and takes the ticks on the tissue, providing information on the species collected and on the density of the various stasis (larvae, nymphs, males and female) to monitor population dynamics.

Another aspect, sometimes neglected, of entomological surveillance is the monitoring of the sensitivity of the vectors to the insecticides of the target populations. This type of monitoring is essential to ensure the effectiveness of an insecticide treatment undertaken at the time when the epidemiological risk is important or even proven.

In addition to strictly entomological data, the contribution of Regional Health Agencies (ARS) is essential. It is the virological analysis of blood samples that allowed the identification of the first outbreak of indigenous cases of chikungunyaa Montpellier at the end of summer 2014. These cases were reported while the presence of the vector was known in the department of the Hérault since 2011. All the forecasters, in relation to the concomitant epidemic, had precisely evaluated the high risk of occurrence of indigenous cases of chikungunya in metropolitan France, especially on the Mediterranean rim. In view of these data, it is legitimate to ask whether entomological surveillance Somewhat flawed, the cases having been revealed only at the end of the chain? But no, here surveillance did not contemplate the search for the Chikungunya virus in the vector, a task that would require considerable resources.

Example of Entomological Surveillance of Vectors

Bluetongue is a viral disease whose agent is transmitted by culicoides. It is subject in France to a mandatory declaration to the veterinary services. Any infected or vaccinated area is subject to special regulations. The movement of animals from these restricted areas to pest free areas is prohibited. The States of Europe are authorized to take measures to try to circumscribe the infection in space and time. Indeed, they can declare a part of their territory only as an infected area, and they can declare a so-called "vector inactivity" period (actually a period during which the risk of transmission is low). To do this, European regulations require monitoring of the activity of culicoides populations using a network of light traps using an ultraviolet light source [14]. Culicoides populations are declared inactive if weekly catches are less than five pares/trap/night females. It should be noted that this threshold is based on statements of experts rather than on specific studies. The number of females per trap is easy to measure. And the parity also, since it is assumed that the signature of the Culicoides parex is revealed by the examination of the pigmentation of the abdomen, the nulliparous females having the abdomen not pigmented. This particular regulation has necessitated the setting up of trapping networks throughout Europe. This network continues to provide unprecedented information on European Culicoides in terms of species diversity, distribution and seasonal dynamics.

Conclusion

The few examples set out above show how hazardous it is to propose a generic framework for entomological surveillance. This monitoring depends on a large number of parameters: context, geographical area, time period envisaged, knowledge of the biology of the target vector and possible methods of vector control, as well as available tools and resources. The role of research is to fill gaps and limit uncertainties that may affect the efficiency of an entomological surveillance program, including vector competence and environmental conditions favourable to emergence and outbreaks. Entomological surveillance activities are often large-scale and therefore very expensive. They are justified by the underlying human or veterinary health issues, providing essential information for health decision-makers.

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