Surveillance and sampling of disease vectors

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Summary

Improving the surveillance and sampling of vectors is associated with many issues, including: the relative merits of laboratory studies as against field studies of vector behaviour; the ability to track individual vectors; the cost-effectiveness of traps and confident interpretation of sampling data. In this paper, the authors offer examples of recent progress in these matters and suggestions for future progress, with an emphasis on the need for analytical approaches to be adopted more widely.

Keywords

Analytical approach – Fly – Host – Odour – Radar – Sampling – Surveillance – Tick – Trap – Vector – Video.

Introduction

How many vectors are hereabouts? What is their condition and what are they doing? Answers to such types of question are essential for gauging the present risks of disease, predicting future threats, and formulating methods for monitoring and control. Certain types of question, such as whether vectors are present or absent, can sometimes be answered indirectly by reference to the incidence of disease, as with tsetse-transmitted trypanosomosis in sub-Saharan Africa (1). However, it is more usual and potentially more informative to study the vector itself, especially when dealing with new epidemics in which the precise roles of various species of vector are not yet fully elucidated, as, for example, with bluetongue disease transmitted by midges in northern Europe (2). Vector surveillance is sometimes easy, as when counting the ticks that attach themselves to hosts for extended periods (3). In other cases, as with most flies, the vectors cannot be readily counted or watched since they are too small and move too rapidly and far, in many cases at night. Moreover, many vectors can be attracted or repelled by observers, so biasing the results (4).

The upshot is that, for most studies, it is usually necessary to employ specialised procedures and equipment, either to observe the vectors or to catch them, and then attempt to make pertinent deductions from the magnitude and composition of the samples obtained. The methods available for such work are about as many and varied as the vector biologists and the topics to address (5, 6). In such circumstances much of the attention of the biologist is often directed to selecting, modifying or creating a technique that produces abundant data as quickly, conveniently and cheaply as possible, in a form that relates as far as possible to data produced elsewhere. Hence, it can be easy to give only fleeting attention to the most important matter of all: the ability to interpret confidently the meaning of the data produced. Often institutes possess stacks of data that cannot be translated into pertinent information. The problems of interpretation, together with improving the cost-effectiveness and relevance of sampling techniques, depend largely on understanding the way in which vectors in various physiological states respond to host animals (5) and traps (6).

The present essay cannot cover all of the recent progress and recommendations made in every pertinent aspect of sampling each vector species. For this, the reader must refer to specialised reviews (e.g. 7, 8, 9). All that is provided now is an outline of the main sampling topics of general interest, with a few examples of how the important principles in such topics have been advanced in the last two decades. Attention is given to deserving fields for new or continued research.

Laboratory studies versus field studies

Experiments to elucidate the bait-orientated responses of vectors are usually simpler, quicker and cheaper when performed in laboratories instead of in the field. The main advantage that laboratory scientists have is the ability to control or assess the number and condition of the vectors being studied. This is especially important when investigating the quantitative aspects of vector behaviour, since it is possible to ensure that all of the vectors are exposed to stimuli and to measure the proportion that respond in various ways. Against this, there is often substantial doubt that the laboratory population and its situation are fair simulations of nature. Field work rarely suffers from the latter anxiety, but there are commonly worries over what the field samples mean about the numbers, condition and behaviour of insects in the sampled area and it is often unclear what constitutes the sampled area.

The dilemma as to whether to work in the field or laboratory can sometimes be eased by using semi-field conditions, consisting of what is, in principle, a large cage placed in the field, often populated by wild flies that have been lured or placed inside. Such techniques have continued to be used effectively, as in studies of the responses of laboratory-reared mosquitoes to different types of trap producing various plumes of CO_2, placed in a large wind-tunnel, 6.2 m long, in the field (10, 11). One of the largest field cages has been the so-called 'screen house', 11.2 m long, 7.1 m wide and 4.4 m high, provided with a hut and garden inside, and used to assess the effects of attractant and repellent chemicals on adult mosquitoes reared inside the screen house or introduced from a laboratory colony (12).

While these sorts of semi-field conditions can be helpful, the ideal strategy is to create in the field what is, in effect, a cage full of counted wild flies that have entered the cage naturally without being aware of it, and have then been categorised as having responded or not responded to stimuli inside. With tsetse flies, this type of procedure has frequently been attempted by various arrangements of fine electrocuting grids. Such grids might not catch absolutely all of the insects that touch them (13), but the technique has led to important indications for feeding success (14), trap performance (15) and attraction to visual baits (16). The general principles of the technique are applicable to many other insects, as confirmed by recent studies of feeding success and trap performance with horse flies (17), as well as measurements of the readiness with which mosquitoes enter traps and huts (18), but the scope for this technology remains far from fully exploited.

Recording movement

Even when the vectors are held in cages, it can be difficult to watch and record the speed and direction of their movements, especially the often tortuous flight paths of insects responding to olfactory stimuli in poor illumination. Infra-red video recording can help to overcome these problems, as illustrated by its recent use in studying the flight patterns of various mosquitoes reacting to odours and traps in the laboratory (19) and semi-field conditions (11). Some time ago, the daylight video recording of wild tsetse gave important information about the ways in which the insects moved in response to odours and catching devices in small field arenas, a few metres across (13, 20). Since then, however, little has been done with videos of tsetse in the field, mainly because the fly travels quickly out of video range. For this reason, movement has been studied primarily by the ancient expedient of mark, release and recapture (21). While this has indubitably delivered much useful information on the general extent of tsetse movement, the technique tells us only where the flies started and ended their travels. Details of the number, speed and direction of their flights, constituting the overall displacement, remain unknown, to the detriment of a fuller understanding of important matters such as the range of odour perception, the flight pattern in odour plumes, the objects visited and the routes of insect invasion.

It was therefore encouraging, in the early 1990s, when Riley and his colleagues developed harmonic radar (22), to allow the detailed tracking of individual tagged tsetse for many metres. The authors of the present paper were treated to a small demonstration of the system working effectively, but a change in the funding of tsetse research meant that the system was transferred from tsetse to other insects, such as bees, butterflies and beetles (22). The work with such insects has been stunningly effective, indicating important things such as flight paths and speed (22). It is particularly exciting that radar can be used to show how the flight of insects is affected by experimental manipulations of the 'furniture' (e.g. trees, shrubs and large logs) (23) and bait stimuli (24) in the environment. Thus, it seems that, for the last 20 years, a powerful and exciting tool has existed, suitable for studying the movement of tsetse and other flies of about the same size. It is high time for vector biology to take advantage of this tool.

Meanwhile, there have been steady improvements in knowledge due to refinements in marking procedures. For example, by feeding a rubidium marker to rodents, it was possible to assess the proportion of adult flies that fed on these hosts, so indicating the scope for controlling sandflies by treating such hosts with insecticide (25).

Cost-effectiveness of field catches

In field sampling, the catchers often go in active search of vectors as, for example, when a cloth is dragged through grass to collect ticks (3). However, it is often more productive and convenient to rely on vectors coming to the catching systems, especially when the availability of vectors to the devices is enhanced by visual or olfactory attractants (6). The principles on which attractive traps operate vary widely, involving great differences in cost-effectiveness and convenience. At one extreme is the light trap from the Centers for Disease Control and Prevention (CDC) (7), often baited with CO_2 and other chemicals, which is widely used for mosquitoes and midges. As a routine sampling device this trap and others like it suffer from the need for electrical power to run the light, and also for the fan that sucks insects into the trap. An additional problem is that CO_2 can be costly and complicated to dispense by the usual methods, involving gas cylinders, dry ice or fuel-gas burners. The constraints of electricity and CO_2 can be particularly difficult for long-term sampling of veterinary pests that often occur in remote locations. Furthermore, light and CO_2 commonly attract a wide range of insects (5, 6), so that catches of the insects of interest can be swamped with many other creatures. At the other extreme are the traps commonly used to sample tsetse. These traps require no light or fan, and are usually employed without CO_2 since cheaper alternative attractants have been identified (9). Moreover, some of the traps for tsetse have been designed specifically to minimise catches of other insects (26, 27).

One approach to improving the cost-effectiveness of traps for other insects has been to see how well the tsetse traps and attractants perform against the other insects, and broadening, where necessary, the range of insects caught. This was exemplified by testing the traps against horse flies, stable flies and mosquitoes in North America (28), eventually leading to a trapping system that improved catches of certain horse flies by up to about 100 times (29). Another approach has been to start with light traps and to try to make them more cost effective. At its simplest, this procedure involves comparing a range of light traps, and has shown, for example, that the Onderstepoort trap can catch two to ten times more midges than other light traps (30). It has also shown that, when CO_2 is required, it can be provided cheaply and simply by fermenting molasses in a bottle beside the trap (31). However, the more effective policy in the longer term may be to rely entirely on attractants other than CO_2. Several of the attractants used with tsetse, such as 1-octen-3-ol, have long been known as effective for certain species of mosquito and midge (32), but more recently a wide range of other potentially useful chemicals has been identified, including 3-heptanol, 2-methylpropanal and 4,5-dimethylthiazole for mosquitoes (33). With midges, interest has largely been in developing repellents (34). However, when looking for candidate attractants, it is appropriate to keep watch on all work that identifies any sort of olfactory stimulant since a repellent used at a certain dose for one vector can be an attractant when used at another dose or with another vector (35).

A further advance has been the proven efficacy of traps that require no light, such as the commercially produced BioGents-Sentinel™ and Zumba™ traps. These can catch many times more mosquitoes than the standard CDC light trap, especially when combined with proprietary odour baits (36). Unfortunately, however, these traps still require a fan and can still need CO_2. The potentially more important development is a new range of 'passive' traps that involve neither a fan nor a light to ensure that large numbers of mosquitoes are caught, but even these traps require CO_2 (37). Thus, although much has been done to provide a more cost-effective alternative to the CDC light trap, there is still much to do to achieve a fully passive, CO_2-free trap for vectors other than tsetse and certain horse flies.

Interpretation of catches

The interpretation of catches is simplest when it has already been possible to establish directly the relationship between catch levels and the issue that the catches are required to clarify. The easiest relationship to establish is that between trap catches and the numbers of insects pestering hosts. Work on this type of relationship has continued steadily; for example, by comparing the numbers of midges caught by light traps and from sheep (38) or horses (39), but the scope for more work of this type with all vector species is enormous. Unfortunately, it is also complex since the availability of insects to traps and hosts can vary greatly, depending on many factors, such as the environmental furniture nearby (40, 41), or the way that the numbers of insects on hosts are scored (38, 42). It can be especially important to establish the extent to which the physiological condition and age structure of catches represent these features of the insects attacking hosts. For example, using standard fly-round methods of catching tsetse produces a misleading impression of the species, sex, age and physiological status of tsetse attracted to livestock (4). If the age structure of catches is biased, then so too can be the perceived infection rate of the insects and hence the apparent risk of disease transmission (43).

The worst interpretive problems occur when catches have been the sole means of assessing the point of interest. For instance, it is only rarely that trap catches have been calibrated against absolute measures of the local population density at various seasons (44). Hence, in most cases, the catches can be no more than indices of relative abundance – and not very reliable indices, since the responsiveness to traps is likely to change over time and space, as exemplified by the varied effects of lunar phases on catches of light traps and truck-traps (6). Moreover, catches can also be of limited use if they are themselves the only clues for how well the traps are performing. This problem occurs in the common type of pragmatic experiment that makes a straight comparison between catches in a variety of traps (28, 36). Such experiments are of immediate practical importance in deciding which of the existing types of trap is best for routine sampling. However, such experiments tend to be short-sighted, being unable to expose what scope exists for improving the best trap since they offer no in-depth analysis of its current performance. Such an analysis should recognise that to be caught by a trap the flies must go through a sequence of responses to it, including the approach to the trap, entering it and then remaining inside. The capture of vectors at each stage of response is essential to assess such important matters as which trap attracts most insects to its vicinity and whether that trap now catches 5% or 95% of the attracted insects (26). Some important progress has recently been made in these matters, as exemplified by studies of trap efficiency (11, 13, 18) and the ways in which insects respond to hosts and trap-like objects (19, 42, 45). In general, however, there has been little widespread heed to the long-standing encouragement that Muirhead-Thompson gave towards transforming vector sampling from a largely *ad hoc* empiricism to an analytical science (5, 6).

Conclusion

In a nutshell, an important means of improving the science of sampling is not only to ask what happens to the magnitude and composition of catches when we try different sampling procedures, but also to explain why various things happen. The explanations must be partly found in continued attention to matters such as where bait stimuli can be perceived, and the details of the vector's response (10, 20, 46). We also need to understand the multiplicity of environmental factors that affect these matters, such as the recently noted effect of habitat geometry on the performance of visual and olfactory baits for tsetse (47). These various aspects of the improvement of sampling science are some of the main things that must be tackled before we can reach, with each vector and surveillance topic, the ultimate goal of a sampling technology that is economical, universally accepted, and produces pertinent data that can be interpreted with confidence.

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La surveillance des vecteurs de maladies et la collecte d'échantillons

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Résumé

Pour améliorer la surveillance et la collecte d'échantillons de vecteurs, il convient de progresser sur un certain nombre d'aspects très divers, entre autres l'intérêt relatif des études effectuées au laboratoire sur le comportement des vecteurs, par rapport aux études réalisées sur le terrain ; la capacité d'assurer un suivi individuel des vecteurs ; le rapport efficacité-coût des pièges à vecteurs ; et les questions de fiabilité au moment d'interpréter les données obtenues suite à la collecte d'échantillons. Les auteurs présentent quelques exemples des avancées récentes dans ces domaines et formulent des propositions pour continuer à avancer à l'avenir, en insistant particulièrement sur la nécessité d'appliquer des méthodes analytiques à plus grande échelle.

Mots-clés

Échantillon – Hôte – Méthode analytique – Mouche – Piège – Puanteur – Radar – Surveillance – Tique – Vecteur – Vidéo.

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Vigilancia y obtención de muestras de vectores que transmiten enfermedades

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Resumen

Para mejorar la vigilancia y la obtención de muestras de vectores hay que progresar en muy diversos aspectos, entre ellos: el interés relativo que revisten los estudios de laboratorio sobre el comportamiento de los vectores, en comparación con los estudios realizados sobre el terreno; la capacidad de seguir individualmente a los vectores; la relación eficacia-costo de las trampas; y la fiabilidad a la hora de interpretar los datos resultantes de la obtención de muestras. Los autores presentan ejemplos de recientes avances en estos ámbitos y formulan propuestas para seguir progresando en el futuro, insistiendo especialmente en la necesidad de aplicar métodos analíticos a mayor escala.

Palabras clave

Anfitrión – Garrapata – Hedor – Método analítico – Mosca – Muestreo – Radar – Trampa – Vector – Vídeo – Vigilancia.

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