

# Olfaction in vector-host interactions



**edited by:**

**Willem Takken and Bart G.J. Knols**

**Ecology and control of vector-borne diseases**  
**Volume 2**

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## Ecology and control of vector-borne diseases

In the past century, many advances were made in the control of vector-borne diseases. Malaria disappeared from the northern hemisphere, diseases such as typhus, Bartonella and yellow fever were seriously reduced in prevalence and in many countries effective methods of disease control contributed to a greatly reduced incidence of such diseases. Most of these advances were beneficial to the industrialised world, whereas underdeveloped countries continued to suffer much as before. Indeed, several diseases such as malaria, Rift Valley fever and African sleeping sickness are still highly prevalent in specific countries. 'New' vector-borne diseases such as dengue, chikungunya fever and West Nile fever, have emerged and are invading previously disease-free regions. The discovery of new drugs and vaccines has made great advances and allows for the effective treatment and control of many diseases. In contrast, vector control has lagged behind in development, even though it is realised that effective vector control would allow for an immediate interruption of the transmission of disease, and aid in disease control and eradication. In the last 20 years new initiatives on vector control have been undertaken, leading to a rapid development of effective and lasting methods of vector control. The development of molecular genetics has provided new insight in vector biology and behaviour, which is being used for developing new strategies of vector control. Advances in geographic information systems allow for precision targeting of interventions. The collective information on new developments in Vector Ecology and Control of Vector-borne Diseases is scattered over numerous periodicals and electronic databases. This book series intends to bring together this information in sequential volumes arranged around selected themes that are currently of interest. Forthcoming themes will include 'Surveillance methods of vectors of infectious diseases', 'Recent advances in biological control of mosquitoes', 'Transgenic tools for vector management' and 'Integrated vector management', but also fundamental biological topics such as 'Mating behaviour of disease vectors', 'Oviposition behaviour of disease vectors' and 'Parasite-vector interactions'. Other topics will be added as perceived relevant.

Willem Takken and Bart Knols are well-known experts in the field of Medical and Veterinary Entomology. Both have extensive experience from field work in the tropics and ecological studies in the laboratory and field. They also have a wide experience in publishing and other methods of research dissemination. Willem Takken is Professor in Medical and Veterinary Entomology at Wageningen University. Bart Knols is visiting scientist at the Division of Infectious Diseases, Tropical Medicine & AIDS of the Academic Medical Centre in Amsterdam, the Netherlands, as well as director of K&S Consulting, a company engaged in the global dissemination of medical information, organisation building, and consultancies in infectious disease control.



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## Preface

The series Ecology and Control of Vector-borne Diseases was launched in 2007 with Volume I providing an overview on the emergence of pests and vector-borne diseases in Europe. This first volume has been well received, and was the starting point of an overview of the state of the art of various topics that are relevant for this field of science. In the past decade the world has witnessed an increasing number of outbreaks of vector-borne diseases as well as invasions of vectors and/or pathogens. Whereas in the previous century many of these diseases were eliminated from the temperate climate zones, some of them are found to expand their distribution, with invasions of Europe, North America and Australia. Many of these events are associated with environmental change and find their explanation by the often complex ecological processes that drive the transmission of the pathogens. The prevention and control of these diseases requires in-depth knowledge of the arthropods that transmit the pathogens. This book series aims for highlighting specific aspects of the ecology of these vectors that can be exploited for the prevention and control of these diseases.

The current volume addresses the topic of how blood-feeding arthropods interact with their vertebrate hosts. As the transmission of infectious vector-borne pathogens is much dependent on the contact between vector and host, the efficacy of host location is of profound importance. Interruption of vector-host contact is considered one of the most effective means of vector-borne disease control, as is currently witnessed by the successful use of insecticide-treated bed nets for malaria prevention in sub-Saharan Africa.

As with Volume I, this book is a collaboration of a large number of scientists, each experts in their specific field, who have written comprehensive overviews of specific aspects of olfaction-mediated arthropod behaviour. Each chapter was reviewed by independent reviewers, and subsequently adjusted as needed. We are grateful to the anonymous reviewers, as we realise that this takes time and effort. We thank Mike Jacobs and Marijn van der Gaag of Wageningen Academic Publishers for their patience and useful advice. We thank Hans Smid for once more having contributed to the cover design. Special thanks to Françoise Kaminker, who has language-edited several chapters, and provided useful advice.

Wageningen, 8 March 2010

*Willem Takken and Bart Knols*



# 1. Strategic use of chemical ecology for vector-borne disease control

Willem Takken and Bart G.J. Knols

## Abstract

In the epidemiology and control of vector-borne diseases an accurate estimate of parasite and pathogen transmission is required. This can be achieved by monitoring the vector population using traps provided with attractive cues. Volatile chemicals are the principle cues with which the disease vectors locate their vertebrate hosts. Natural and synthetic blends of such chemicals can be used to manipulate the vectors, so that transmission risk can be determined and, in some cases, the vector population can be killed. Novel scientific developments, including molecular genetics, analytic chemistry and odour-release technologies provide opportunities for the effective use of chemical ecology in vector-borne disease control.

**Keywords:** olfaction, insects, ticks, behaviour, disease transmission, nuisance, attractant, repellent

## Introduction

In the last decade nuisance insects and disease vectors have received increasing attention because of their continuing and devastating effects on human and animal health. Examples are recent outbreaks of chikungunya fever in the Indian Ocean, SE India and Italy (Erin Staples *et al.* 2009), the large number of recorded dengue outbreaks in South America (Barclay 2008) and the arrival of bluetongue virus in NW Europe (Carpenter *et al.* 2009). In addition, the rapid growth of the world population coupled with increasing poverty in resource-poor countries is the cause of much suffering from neglected vector-borne diseases such as malaria, leishmaniasis and trypanosomiasis (Mathers *et al.* 2007). Lastly, the current debate on climate change and its potential effects on human health is causing global concern about emerging diseases such as West Nile virus, Lyme disease and other tick-borne diseases (Epstein 2001, Gould and Higgs 2009, Jones *et al.* 2008). Whereas for several of these diseases effective intervention strategies are available, and hence their control can be implemented, for many of them the current control strategy is inadequate. With some exceptions, effective vaccines are lacking, parasites have developed resistance against drugs, and vector control efforts are hampered by insecticide resistance, technologically inadequate tools and lack of resources.

It is widely agreed that the first step in monitoring vector-borne disease is accurate risk assessment (Hay *et al.* 2004, Mathers *et al.* 2007). This information is needed to study the epidemiology of the disease, and to predict its course in time and space. The basic reproductive number ( $R_0$ ) (Hartemink *et al.* 2008, Smith *et al.* 2007) is used to express disease risk, and as the biting rate of disease vectors is one of the critical parameters in  $R_0$ , tools to accurately measure this are essential. Examples in which these data are being widely used are malaria and dengue control programmes: in endemic situations vector densities provide knowledge on spatial and temporal distribution of biting intensities, while in epidemic situations, vector populations are measured so that the course of the outbreak can be monitored. Also, the outcome of vector-targeted interventions, aimed at the interruption of parasite/pathogen transmission, can be assessed when accurate data on vector densities are available. Vectors are also collected to determine their infections with disease agents: the intensity of disease transmission the product of vector density and parasite/pathogen infection rate. In spite of the importance of accurate sampling of disease vectors, the methodologies used for insect collection are in many cases based on perception rather than on

accurate knowledge of vector behaviour. This is because information on vector-host interactions (at which level the parasites/pathogens are being transferred) is in many cases poor or lacking. It is therefore of relevance that this knowledge be expanded in order to obtain better, more precise, data on vector biting density and intensity of parasite transmission.

Since the discovery of the role of arthropods in disease transmission, entomologists have worked on the development of tools for vector surveillance, and a wide range of traps is available with which the vector population can be monitored (Qiu *et al.* 2007, Service 1993). Traps are designed to attract the target insect(s) using sensory cues such as sound, colour and odour. As chemical signals are the principal cues with which arthropods identify their blood hosts, many traps employ odorants to lure the vectors to the trap. The odorants used vary from natural host odours, synthetic blends of compounds mimicking host odours, or non-host related chemical compounds that have been found to be attractive to the vectors. Harris (1938) and Van Thiel (1935) were among the first to report on the use of host odours to trap tsetse flies and mosquitoes, respectively. It was also established that carbon dioxide (CO<sub>2</sub>) acts as a universal attractant for many blood-feeding insects, and many traps are baited with this compound. For example, the Centre for Disease Control miniature light trap (CDC light trap) (Sudia and Chamberlain 1962) was reported to produce significantly-enhanced catches of mosquitoes when baited with dry ice (Newhouse *et al.* 1966). The CO<sub>2</sub>-baited CDC trap was the gold standard for establishing mosquito densities for many years. In the tropics, CO<sub>2</sub> was replaced by natural human emanations by operating the CDC trap next to a bed net under which a human spent the night (Garrett-Jones and Magayuka 1975). Although these odour-baited traps collected disease vectors, the trap collections represented only crude data on vector densities, and more accurate measurements were needed.

In the 1970s, Vale (1974), dissatisfied with the variable results of odour-baited traps, began to experiment with natural host odours to investigate the behaviour of tsetse flies in Zimbabwe. By using an elegant design of electrified grids and artificial host models, Vale demonstrated that natural host odours were the principle cues that led tsetse flies to the vicinity of their blood hosts (Vale 1993). The studies on tsetse olfactory behaviour are still considered to be classic methods for investigating insect behaviour with respect to their vertebrate hosts. Gillies and Wilkes (1968) demonstrated that mosquitoes could also be manipulated with host odours, and it was soon found that synthetic blends of odorants could be used to manipulate mosquito populations (Takken and Kline 1989). These behavioural studies were gradually augmented with physiological studies to reveal the sensory processes that made the insects respond to the odorants (Cork 1996, Davis and Sokolove 1976). The advent of molecular genetics has allowed for detailed insight in the genetics and molecular regulation of insect olfaction, which provides fundamental knowledge on the regulation of insect behaviour (Jacquin Joly and Merlin 2004, Lessing and Carlson 1999, Touhara and Vosshall 2009). This, in turn is being used for the identification of chemical compounds that affect vector-host interactions, so that the target vectors can be more effectively lured to sampling devices and/or removed from the environment as a tool for disease control.

In future, odorants will increasingly be used for the monitoring of vector-borne disease transmission risk as well as for vector control. It is therefore appropriate that the current volume of the Ecology and Control of Vector-borne Diseases has brought together reviews of the state-of-the-art of this topic, from the molecular regulation of olfactory senses (Chapter 2) to field applications of odorants for disease control (Chapter 17). As many disease vectors belong to the insect order of Diptera, this group of insects is discussed in detail, with mosquitoes being the example for detailed explanation of olfactory regulation. Chapters on blood-feeding bugs, vectors of Chagas disease, and blood-feeding ticks, vectors of a variety of parasites and pathogens, are

included as well. Finally, as it is increasingly becoming apparent that the olfactory behaviour of insects and ticks is often mediated by parasites, a chapter on the latest knowledge of this field of science is also included. Odorants are not only used to attract insects and ticks, but they can also be used to protect blood hosts from being attacked (Katz *et al.* 2008). In many cases odorants act as deterrents or repellents, and where applicable, this aspect of olfaction is discussed as well.

The ecology of vector-borne diseases is much determined by the association between vectors, parasites and hosts, which is in turn strongly mediated by chemical cues. The chapters in this volume demonstrate that detailed studies on insect olfaction contribute to our understanding of the individual components regulating this process, and contribute to finding effective solutions for disease control.

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