Foreword

Mosquitoes. The term is generic in nature, yet it is eminently practical for encompassing a vast array of biological, ecological, health, social, economic and historical diversity. Mosquitoes, or *Culicidae* to use their scientific name, refers to the 3,700 species described here on earth, in addition to an unknown number yet to be described. If nature abhors a vacuum, then so do mosquitoes. They are ubiquitous, occurring on every continent and across all ecosystems, and have been around for far longer than humans.

This is something which our human readers often forget. You might only think about mosquitoes if they're keeping you awake at night, stopping you from enjoying an evening outdoors, or, depending on where you live, for causing an illness in the family or to one of your livestock or pets.

Emergence. This has become a trendy word in recent years. Humans have become aware that diseases can emerge. The French microbiologist Charles Nicolle, in his 1933 work *Destin des maladies infectieuses*, already predicted that "there will be new [infectious] diseases. It's a fatal fact". Some of these diseases, emerging from the wild as a consequence of environmental, climatic, demographic, societal, cultural, health, and economic changes, among other factors, are vectorial diseases, and sometimes mosquitoes are responsible for this transmission through the inoculation of viruses and parasites.

Mosquitoes are insects, but their study and control go well beyond entomology (from *entoma*, meaning insect in ancient Greek). A multitude of complementary disciplines are involved, ranging from taxonomy to public health. Remote sensing and spatial modelling are counted among these, and they have become indispensable tools in medical and veterinary entomology, as well as agricultural entomology.

By the 5th century BC, the Greek philosopher and physician Hippocrates had already established the link between environmental factors and the aetiology of disease. He described fevers with the same set of symptoms as malaria, and noted a connection between the wetlands and these fevers in his treatise *On Airs, Waters, and Places*. Of course, at the time, even though people likely complained about mosquitoes, it was not feasible to form a causal relationship with malaria. In the not-so-distant past and closer to home, in France the inhabitants of the regions now known as Vendée, Sologne, Dombes and Camargue were invaded by mosquitoes, and fevers were commonplace in these areas until the beginning of the 20th century. The construction site of the Palace of Versailles was the site of numerous fatalities, likely attributable to malaria, before the surface water was channelled.

It is only in our recent past, following the formulation of modern germ theory by Louis Pasteur, that causal relationships have been established between the environment, climate, mosquitoes, microbes and diseases. Over the past two decades, significant progress in our understanding of these relationships have been made, thanks in part to novel genomic techniques, but also due to the emergence of sophisticated remote sensing technologies, spatial analysis tools for biological phenomena (mosquitoes included) and advances in health risk modelling.

The biological diversity of mosquitoes is extraordinary. These 3,700 species are particularly well adapted to specific environments and biotopes. Some mosquito larvae are only found in very specific larval habitats, such as small, water-filled cavities in trees, known as phytotelmata, or the pitchers of carnivorous plants like Nepenthes. Others are less picky and are able to thrive in lakes, marshes or on riverbanks; yet others are almost exclusively found in areas where water has collected due to human activities. Certain species are endemic to a single region (*Aedes pia* on the island of Mayotte), whereas others, which have adapted to urban environments, can be found on every continent (*Aedes albopictus*). Some of these can take blood meals from many different animals, including humans (*Anopheles arabiensis*), whereas others have very strict diets (ant regurgitate for *Malaya* sp.). Some species can survive periods of drought or cold by their eggs entering diapause (*Aedes*), or their adult form resting in sheltered sites such as houses and stables. It is, however, essential that they have access to water in order to lay their eggs and for the development of larvae and pupae. Water plays a vital role in mosquito biology, exerting influence through its presence, quality, physical and chemical properties, as well as biotic factors (plants, food, predators). Any approach that seeks to ascertain, analyse and correlate water-related parameters (rainfall, development, vegetation, etc.) is capable of more accurately estimating, or even predicting, the presence or abundance of different mosquito species and populations, as well as the associated risks.

These risks are not trivial. History is replete with examples of fates being decided by mosquitoes, from the death of Alexander the Great attributed to malaria (*Anopheles*) or West Nile disease (*Culex*), and the excavation of the Panama canal being halted by malaria and yellow fever (*Aedes*), to the more recent example of the "vertical forest" buildings in China being abandoned by their inhabitants due to an invasion by Asian tiger mosquitoes. The list of infectious diseases transmitted to humans by different mosquito species is impressive. Nearly 100 human diseases can be attributed to mosquitoes. Some are still rare, such as Mayaro fever in South America. Yet others are much more common, such as malaria, which kills nearly 400,000 children every year in Africa, or dengue fever, which affects more than 300 million people each year and is present on every continent according to the World Health Organization (WHO).

The health, social and economic challenges associated with mosquitoes are therefore immense, without considering the ecological challenges. Although mosquitoes play an important role in the food chain and contribute to biodiversity, it is nevertheless essential to control species that are responsible for major human and animal diseases. This control must be rationalised, integrated, adapted, sustainable accepted and generate the least environmental impact. The era of the intensive use of insecticides is coming to an end. Other more targeted methods, including geographically targeted campaigns, are currently being developed. Approaches such as remote sensing, spatial analysis and modelling have become indispensable tools for achieving these goals, yet they remain underutilised in the decision-making process.

The examples provided in this publication—*Anopheles* and malaria risk in Camargue, French Guiana, Asia and Madagascar; *Aedes* and dengue risk in Thailand, Brazil and the Indian Ocean—show that remote sensing and spatial modelling applied to mosquitoes and mosquito-borne diseases play a crucial role in these efforts. They also show that interdisciplinary collaboration is required. Models based on inadequate documentation of biological data are not only devoid of meaning, but they can also foster false expectations among those that use them. Conversely, rigorous sampling in the field cannot be used to its full potential without good spatial modelling.

Each scientific community has its own concepts and language. Attending a specialist symposium can be a real ordeal if one is unable to decipher the code. Set an entomologist loose in a remote sensing convention, or a geomatics expert in the annual conference of the Society for Vector Ecology, and they may be unable to correctly interpret the words or acronyms being used, such as reflectance, scanning swath, exophilic, sternite, univoltine, raster mode, diapause, spectral signature, gonotrophic, Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI). Only the word vector can be understood by all, but with two very different meanings: one taken from the field of biology and the other from the field of geomatics. The idea behind this publication, authored by specialists who have worked with or even belong to both communities, is to make these concepts accessible to all with the help of well-documented and concrete examples. My sincerest thanks and best wishes go out to all the contributors. This publication will serve as an invaluable reference for those who recognise the need to adopt a global, spatial and environmental approach for the study of mosquitoes (and other vectors) and the documentation of their biology, distribution, impact and control. It will also prove beneficial to those seeking examples of the application of remote sensing and spatial modelling.

This book acts as a bridge between communities, inviting entomologists to more abstractions and macroscopic perspectives, and those working in the field of remote sensing and geomatics to discover the fascinating world of mosquitoes.

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