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Mosquitoes

Identification, Ecology and Control

Third Edition

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The title of the first and second edition of this book is “Mosquitoes and Their Control”.

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Cover illustration: Asian tiger mosquito (female) sitting on a privet twig. Courtesy by Björn Pluskota (IfD)

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Foreword

The first edition of this book has been a well-thumbed member of my bookshelf for many years. I remember the relief I felt when I first looked at the volume and realised that I finally had a single work that covered all the basics about mosquitoes, from biology to control. The third edition is equally and even more useful. Anyone interested in mosquitoes as insects, pests or vectors of pathogens could read this entire volume easily and come away with a firm foundation for further study, for practical control or simply to understand what Culicidae means in nature and to people.

The forewords of the previous two editions were written by one of the giants of entomology, Yoel Margalit (1933–2011). Dr. Margalit was best known for his discovery with Leonard Goldberg of a bacterium that produces protein toxins with remarkably specific toxicity to mosquitoes and some other nematoceran flies. Now known as *B.t.i.* (*Bacillus thuringiensis israelensis*), this product has revolutionised mosquito control because of its effectiveness at killing aquatic larvae, its ability to avoid resistance because of its mode of action and its wonderful safety in the environment and for humans. It is also a great lesson in product development, as the potential of the new toxicant was recognised from the beginning, and it took less than 10 years to translate it into reliable, widely used materials. Innovation takes methodical patience, a quality that Dr. Margalit demonstrated during his work with a wide circle of students and fellow entomologists. He was one of the important mosquito professionals who came out of the mid-twentieth century, including William Horsfall, John Belkin, Ken Knight, Alan Stone and Bruce Harrison. Those people shared an appreciation for the variety of mosquito species, the need to use information to guide control efforts and a sense of personal responsibility for the lives of people who depended on their work.

The study of mosquitoes was slow to start and gradual in progress until the revolution in biology took place in the 1860s. Charles Darwin and Alfred Russel Wallace finally provided an outline of how the variety of life came to be, while luminaries like Robert Koch, Louis Pasteur and Claude Bernard made practical connections between biology and medicine. Soon after, in the late 1870s, Theobald Smith showed transmission of the cattle fever pathogen by ticks in Texas, USA, and Patrick Manson showed transmission of filariae by mosquitoes. Twenty years later, Ronald Ross demonstrated transmission of malaria pathogens by *Anopheles*, and Walter Reed's team showed yellow fever virus transmission by *Aedes aegypti*. Suddenly, the world realised that mosquitoes were responsible for a significant part of the suffering in the world. Researchers turned their attentions to this group of insects, with major reviews by F.V. Theobald, L.O. Howard, H.G. Dyar and F. Knab published in the first decade of the 1900s. The general interest in mosquitoes and their control was reflected in E.G. Mitchell and J.W. Dupree's *Mosquito Life*, which addressed a similar audience in 1907 as *Mosquitoes: Identification, Ecology and Control* does in 2019. By 1932, F.O. Edwards had outlined modern mosquito taxonomy by examining less than half of the species we know about now. The stage was set for the gigantic

progress in mosquito biology and control, in which Yoel Margalit participated and summarised in this volume.

For opposite reasons, this book's treatments of taxonomy and mosquito control deserve comment. It seems that mosquito taxonomy is lacking new researchers, to the point that younger scientists have limited familiarity with morphology and with the complete fauna of their regions. This volume summarises the field of systematics in a way that will inform those who have not had much consideration for this important aspect. The chapter on systematics gives a detailed account of how to translate phylogenetic considerations into names and identification. Descriptions and keys not only have utility for identification; they also show how morphology can be used in many situations to distinguish one species from another. All the species of Europe are presented, but a reader can get a firm idea of the fauna of any region in chapters dedicated to each continent where mosquitoes occur. The discussions make it clear that the recent disagreements about nomenclature of aedine genera are not merely pedantic—getting phylogeny and nomenclature right makes a big difference for accurate understanding by a wide audience.

The part of the book about mosquito control reflects a field experiencing great participation by scientists, product developers and public health professionals around the world. The chapters provide clear explanations of all current mosquito control techniques, leaving the sense that we are living during a period of intense innovation. The development of new chemistries, new ways to deliver those chemistries, new means of information management and surveillance and entirely novel genetically based interventions are evidence that we are in something of a golden age of mosquito control. We may not have seen such a rush of improvements since Herman Müller won the Nobel Prize for public health applications of DDT in 1948.

The Bill and Melinda Gates Foundation is the largest private philanthropy in the world, dedicated to the principle that all lives have equal value. One of its goals is to eradicate malaria from the planet by the year 2040. The Gates Foundation clearly recognises that controlling mosquitoes will be a big part of accomplishing that goal. Investments range from basic development to stimulation of markets, but all in the direction of lowering vector mosquito populations, lowering their life expectancy or keeping them from biting humans. Malaria in Africa decreased by about half between 2000 and 2015, with most of that improvement caused by using insecticide-treated bed nets. That is a trend we cannot afford to lose and that we would like to improve further. *Mosquitoes: Identification, Ecology and Control* will be a powerful tool for those improvements, informing and inspiring the generation that will accomplish audacious goals.

Fellow Entomological Society of America, Bill
& Melinda Gates Foundation, Seattle, WA,
USA
March, 2019

Daniel Strickman

Preface to the Third Edition

Mosquitoes have always presented a potentially severe threat to the health and well-being of humans and animals. In order to understand and alleviate this threat, mosquitoes have been and continue to be an important focus of research worldwide. Following the first Edition (2003, 17 years ago) and the second Edition (2010, 10 years ago), the authors have now included the most recent information on the identification, biology and management of these important pests and vectors in this third Edition (2020). There has been a steady flow of new publications, with a particularly rapid growth in information on novel molecular techniques and control tools and on the influence of globalisation and climate change on the spread of mosquitoes. To include these new topics and information, we have undertaken an intensive revision of all chapters. This edition now covers the most important invasive species, not only in the description of their biology but has also incorporated them into the keys. As a result of the number of new references, and in contrast to the previous two editions, the references in this new edition are given at the end of each chapter.

The first edition of this book (Becker et al. 2003) included comprehensive and globally relevant chapters on mosquito systematics, biology, morphology, medical importance, research techniques and control. However, the identification keys and descriptions were limited to European mosquito species only. Nonetheless, the reviews and the rapid sale of this first edition indicated that the book was widely appreciated and accepted by both scientists and professionals. The authors therefore realised the need for a second as well as a third edition and agreed that the scope required widening to include an overview of selected important vector and nuisance mosquito species worldwide. The new editions needed to be useful not only to readers in Europe but to readers around the world. The incorporation of invasive mosquitoes into this third edition now makes the text more comprehensive still.

The nomenclature used in the first and second editions reflected the work of Reinert (2000) and Reinert et al. (2004, 2006, 2008) in revising and establishing monophyletic genera in the tribe Aedini.

However, several groups of mosquito taxonomists and editors of major professional journals have not accepted the latest nomenclature proposed by Reinert et al. (2004, 2006, 2008) and have returned *Ochlerotatus* (Reinert 2000) to the subgeneric rank after several years of extensive usage. In this third edition, we therefore follow the nomenclature before Reinert (2000) and proposed by Wilkerson et al. (2015). The main reason is the utility of the old nomenclature for colleagues working in the field.

We sincerely hope that this extensively updated third edition will be useful and interesting both to entomologists in general and particularly to professionals in public health battling the scourges of mosquito nuisance and mosquito-borne disease.

Just prior to completion of the manuscript for this third edition of our Mosquito book, our friend and colleague Minoo B. Madon passed away, following infection with Covid-19. We have lost not only a great scientist who devoted his life to mosquito control in Los Angeles, California, but also a friend with whom we shared many enjoyable hours at field excursions and SOVE, AMCA and EMCA conferences over decades. He was part of the author team from the beginning and contributed extensively to the success of our book. We will miss Minoo in so many ways, and will fondly remember those educational, stimulating and so often amusing times, that we spent in his company.

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Preface to the Second Edition

The first edition of this book (Becker et al. 2003) included comprehensive chapters on mosquito systematics, biology, medical importance, research, morphology and biological and other tools for their control, globally, but was limited to only the identification keys and descriptions of European mosquito species. Based upon reviews, it appears that this text has been well appreciated and academically accepted by both scientists and professionals considering the rapid sale of the number of copies of this edition.

In the course of time, when the authors generated discussions about the need for a second edition, we envisioned that the contents of the scope needed to be widened by providing an overview and an arbitrary list of the most important vector and nuisance mosquito species worldwide and to provide a complete text which could be useful to the readers not only in Europe but on a global basis.

The additional list of mosquito species we have chosen to include was based not only upon our experience but was also contributed by the expertise of many of our colleagues in various regions, including the vast number of literature citations.

Despite the natural division of the mosquito fauna of the world to zoogeographical regions in our work, we adopted a continental approach to present a simpler overview of the current situation to provide an understanding of the global distribution of important nuisance and disease mosquito vectors to those removed from the science of zoogeography.

It is well known that the tribe Aedini is the largest and most polyphyletic group of mosquitoes; therefore we support the approach of Reinert (2000) and Reinert et al. (2004, 2006, 2008) to revise it and establish monophyletic genera. There should be a trend towards establishing genera as “monophyletic” groups of species: monophyletic groups include an ancestor and all of its descendants—i.e., a natural system.

However, several mosquito taxonomic groups and editors of major professional journals did not accept the latest nomenclature proposed by Reinert et al. (2004, 2006, 2008) and even returned *Ochlerotatus* (Reinert 2000) to the subgeneric rank after several years of extensive usage.

As a compromise, the generic placement within the tribe Aedini in this edition is based on “traditional” generic and subgeneric affiliations recognised prior to and including the separation of *Aedes* and *Ochlerotatus* by Reinert (2000). In this text, the “latest” generic placement proposed by Reinert et al. (2004, 2006, 2008) is indicated in square brackets following “traditional” generic names. For those who would like to follow the nomenclature before Reinert (2000) can choose to treat the name *Ochlerotatus* equivalent to *Aedes*. Finally, for those species whose status did not change after Reinert (2000), we have not provided any additional information.

We have attempted to restructure and reorganise chapters as “Mosquito Research Techniques” or “Medical Importance” to better adapt to the global aspects and to make this text more acceptable for our colleagues outside of Europe.

In general, we sincerely hope that we have produced a text that includes valid and useful information to satisfy public health professionals battling the scourge of nuisance mosquitoes and mosquito-borne diseases globally.

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Preface to the First Edition

Throughout the world, mosquitoes interact with man in many different ways. However, despite the very extensive research on these interactions, there remains much that is not yet fully understood. The attempt by the authors of this volume is to highlight the importance of a basic knowledge of mosquito biology as a basis for successful control operations.

When compared to the Curculionidae, the largest family in the animal kingdom, with 35,000 known species, the Culicidae, numbering more than 3200 species, could be ranked as a family of only small to moderate size. Even though yield losses caused by weevils could be estimated in billions of dollars, mosquitoes are able to carry many lethal diseases in their bodies. By the time you have read this Preface (5 min), ten human lives will have been lost due to plasmodian infections. Apart from being the well-known vectors of life-threatening diseases, in some parts of the world, mosquitoes may also occur in enormous numbers, thus causing a significant reduction in human life quality and serious economic damage for instance in livestock.

Ramsdale and Snow (1999) published a list of currently recognised European mosquito taxa with synonyms. They included 98 species in 7 genera and 17 subgenera. The authors of this volume, in deciding upon the species which should be covered, have come to the conclusion that the pertinent species are those which were recorded on more than one occasion at least, where type specimens have been deposited, where identification material has been available and where the position regarding the validity of the species is satisfactory. In addition to these requirements, information about geographical distribution with substantiating references was considered. According to this, 92 species and subspecies belonging to 8 genera and 18 subgenera are described and included in the keys.

The following species or subspecies previously reported from Europe are not included in the list: *Oc. gilcolladoi* (Villa et al. 1985) was named from a form from central Spain differing in certain features of larval chaetotaxy from both *Oc. echinus* and *Oc. geniculatus*. The position regarding the validity of this species is unsatisfactory. Type specimens were not deposited, and material is not available for examination (Ramsdale and Snow 1999). *Oc. thibaulti* (Dyar and Knab 1909) is a Nearctic species, in Europe recorded from the river Dnieper, Ukraine (Gutsevitch and Goritskaya 1970), but no longer found there according to Gutsevitch and Dubitzkiy (1987). *Oc. atropalpus* (Coquillett 1902) is not considered here because it was only once reported from Italy, and it is not considered as a permanent species in the European area.

For the species *Oc. krymmontanus* Alekseev 1989; *Oc. coluzzii* Rioux, Guilvard and Pasteur 1998; *Oc. duplex* Martini 1926; and *Cx. deserticola*, short notes are given in the description of the species.

The principal objective, regarding the taxonomy and morphology chapters, is to provide an identification key to both adult females and males as well as to fourth-instar larvae, which incorporate all 92 species. At the beginning of Chaps. 6–8, keys for the identification of genera

are given. Recently, Reinert (2000) divided the composite genus *Aedes* Meigen into 2 genera, *Ochlerotatus* Lynch Arribalzaga and *Aedes*. Adults of these genera are distinguished primarily on the basis of genitalic characters that require dissection. For this reason, the species belonging to these genera are treated in a single key. The illustrated keys are followed by a detailed description of the morphology, biology and distribution of each species. The morphological terms engaged in this volume are somewhat changed from those used by Harbach and Knight (1980, 1981), taking into consideration homology, phylogeny and their general use among the dipterous insects.

When a specimen has been keyed out, it should be compared with the description of that species to use the additional information as a cross-check. The description of the species is given according to the examination of the Peus collection, as well as a considerable number of species sampled in different European regions and various literature sources.

Characters of fourth-instar larvae are often clearer than those of the adults, and many taxonomists prefer to identify mosquitoes in this stage. Since there is a certain degree of variation among larvae of a species, it is best to identify, if possible, from a series of specimens. Rare exceptions to key characters can almost always be found. More important variations and their relative frequency are indicated in the systematic section of the species.

In the keys, the larval chaetotaxy of the thorax and abdomen is not used to such an extent as by other authors. This seems to be a little bit "old fashioned", but on the other hand, quite often setae may be broken off, lying in a misleading or barely visible position in slide preparations or, in the worst case, are totally missing. If the latter occurs, an experienced eye is needed to see the alveola or tubercle of the missing seta.

Although eggs, early instar larvae and pupae of most European species are known, they are more difficult to identify than adults and fourth-instar larvae. Rearing eggs to fourth-instar larvae and pupae to adults is easier and less time-consuming than to identify them in the early stages.

The authors suggest that the user should study the sections on general morphology before starting to identify specimens. The user should also be familiar with the proper sampling and mounting techniques of adults and larvae, because the presence of a full set of scales, setae and other features is essential for identification. Updated mosquito distribution throughout Europe, together with the bioecological conditions to be met for each species, should also help in the species identification. The territory of Europe, despite not being a distinct zoogeographical region, is chosen in an attempt to provide for the first time a unique key for the whole European region.

The authors' intention is to encourage and give support to every person who intends to start, or already has some experience in, mosquito control. The concept of the book is also based on several fields of knowledge which are important for everyone who deals with mosquitoes. Overviews on mosquito taxonomy, morphology, biology and biological and chemical control measures are given, to complete the information needed for a comprehensive approach to both studying and controlling mosquitoes.

Mosquito control measures are dependent on many complex and interacting factors ranging from biological (species dependent), abiotic and physical factors influencing the phenology and abundance of mosquitoes (terrain features, climate, types of breeding sites, etc.) to administrative, organisational and most certainly economical conditions. A decision to use one or another mosquito control measure is highly dependent on a basic knowledge of all aspects of the target species and the impact of a chosen control method on the target and non-target organisms, as well as on the environment. A professional control programme should combine cost-effectiveness, acceptable level of mosquito population suppression and an environmentally sensitive approach. In some situations, it is possible to rely on inexpensive and simple methods such as applying fragments of copper wire into flower pots for the control of *Ae. albopictus* larvae (Bellini, pers. comm.), while in others, only pure biological, highly selective control measures are allowed, such as in the Upper Rhine Valley where almost the entire mosquito control programme in the river flood plains has relied solely on *B. thuringiensis israelensis* larviciding for several decades. Sections on different approaches in mosquito control (chemical, biological, integrated or personal protection) provide basic information about different methods of using products with different

formulation and toxicological features, effectiveness on target species as well as their impact on non-target organisms. Information from this part of the volume attempts to serve as a basis for an appropriate mosquito control operation, allowing the user to live in relative security from some vector-borne diseases, to alleviate the effects of abundant nuisance populations, to re-establish wetlands and to share and enjoy nature by conserving the biodiversity, by using environmentally friendly control tools.

Up to now a comprehensive book in which the taxonomy, biology and dispersal of all currently known European mosquito species are described, as well as the options for their control, has been missing. This volume should fill the gap and be a valuable help to scientists and indeed all those interested in or working in any of the fields related to the Culicidae. It should provide guidance to field workers concerned with mosquito control and who wish, for example, to learn more about the behaviour of the species in their region, about mosquito breeding sites or about the mosquito control techniques and options that may be suitable for each specific environment. Since there is still much information which for some, despite greatly increased access to the Internet, may be difficult to acquire, we have tried to include and summarise all available information, so that entomologists can apply it to their own situations.

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Introduction

The mosquitoes (family Culicidae) are at the centre of worldwide entomological research primarily because of their medical importance as vectors of dangerous diseases, such as malaria, yellow, dengue, Zika, West Nile, chikungunya fever and other encephalitides, including Japanese encephalitis and lymphatic filariasis. More than half of the world's population lives under the risk of becoming infected by mosquitoes that carry the causative agents of these diseases. Estimates made by the World Health Organization (WHO) show that 247 million people became ill in 2006 and about 1 million people died (WHO 2008). Despite all efforts and significant reduction of malaria cases in 2018 still 228 million malaria cases occurred world-wide with more than 400.000 deaths (94% in Africa) (WHO 2019). Although approximately three quarters of all mosquito species occur in the humid tropics and subtropics, mosquitoes are not just a problem in these regions. They also cause a considerable nuisance or occasionally can transmit pathogens to humans in temperate latitudes, for example, West Nile virus epidemic in the United States or chikungunya virus, occurring in many states of Africa and Asia and first autochthonous cases were also reported from Italy 2007 (Depoortere et al. 2008).

The floodwater mosquitoes, such as *Aedes vexans* and *Ae. sticticus*, are most commonly a nuisance species in river valleys that routinely flood; the snow-melt mosquitoes, e.g. *Ae. cantans*, *Ae. communis*, *Ae. punctor* and *Ae. hexodontus*, which occur in swampy woodlands and tundra areas; the halophilous species, *Ae. caspius* and *Ae. detritus*, which breed particularly in the shallow lagoons found along the coasts of southern Europe, Asia Minor and North Africa; and the rock pool mosquito *Ae. mariaae* found along parts of the Mediterranean rocky coasts, where mass occurrences can become a great nuisance. *Culex pipiens* biotype *molestus*, which is commonly known as the “house mosquito” because of its presence within close proximity to human settlements, can be a nuisance in temperate zones. *Culex pipiens* is also the major vector for West Nile virus which caused recently significant WNV outbreaks in Europe (ECDC 2019a). Mosquitoes are extremely successful organisms due to their ability to adapt to a wide range of habitats. They are found throughout the world, except in permanently frozen areas. Mosquito larvae colonise a wide range of waterbodies, temporary and permanent, highly polluted as well as clean, large or small, stagnant or slowly flowing, even in the smallest accumulations such as water-filled buckets, flower vases, old tyres, bromeliads, hoof prints or leaf axils, for example. Adult mosquitoes vary greatly in their bionomics, e.g. concerning the host-seeking, biting and migration behaviour and strategy for reproduction. Their significant medical importance and their troublesome behaviour have historically aroused the interest of scientists. Their importance as vectors of malaria and yellow fever were suspected by Joseph Nott in 1848. In 1878 Sir Patrick Manson showed that the roundworm *Wuchereria bancrofti* is transmitted by *Culex quinquefasciatus*. Only 3 years later, Carlos Finley postulated that yellow fever was transmitted by mosquitoes and was later proven by Walter Reed and his co-workers in 1901. Sir Ronald Ross made a further pioneering discovery in Hyderabad, India, in 1897, when he recognised the importance of the

anophelines as vectors of malaria. The discovery of the transmission cycles of most vector-borne diseases eventually led to being able to successfully suppress this dreaded scourge to humanity. The foundations for the control of mosquitoes were established at the beginning of the twentieth century, which included source reduction as a means to lessen the human-vector contact. William C. Gorgas, a member of the Army Medical Corps, USA, dedicated most of his professional life to the control of yellow fever, with special focus on control of the vector mosquito, *Aedes aegypti* (*Stegomyia aegypti*). By the turn of the nineteenth century, he succeeded in fighting yellow fever in Panama and set the basis for the realisation of this project. Gorgas was the first in recognising that only by the implementation of an integrated control programme the burden of severity of vector-borne diseases could be reduced. His approach comprised of draining the breeding sites, brush and grass cutting to reduce favourite sites for resting adult mosquitoes, larviciding with oil derivatives to kill mosquito development stages, prophylactic quinine administration to kill the pathogens in humans, screening and quarantine of infected people to interrupt the transmission as well as killing the adult mosquitoes to reduce the vector density and vector-human contact (Le Prince and Orenstein 1910, 1916).

The development and use of DDT as a residual as well as a broad-spectrum insecticide initially achieved phenomenal success in the control of mosquitoes. In the 1950s, it was believed that malaria would be “exterminated” by the use of DDT and chloroquine, but disillusionment quickly followed, because mosquitoes eventually became resistant to the insecticide in many areas. In addition, the control efforts against the vectors were not consistent. Toxicological and eco-toxicological problems resulted in undesirable disadvantages caused by the use of unspecific and highly persistent insecticides. Despite considerable efforts of national and international organisations like the WHO, prevention of a more dramatic increase in vector-borne diseases is mainly what has been achieved up to date. The Roll Back Malaria (RBM) partnership—an international alliance of over 90 organisations and foundations which includes organisations such as WHO, UNICEF and the World Bank or foundations as the Bill & Melinda Gates Foundation, was set up in 1998 to highlight the existence of low-cost and effective interventions for malaria and low levels of spending for this disease. RBM is the main instrument through which African leaders were hoping to achieve the goals of the Abuja Declaration of 2000—where 53 African heads of state pledged to reduce the malaria burden significantly. The RBM programme is mainly based on insecticide-treated bed nets (long-lasting nets), indoor residual spraying (e.g. DDT-bendiocarb, pyrethroids) and effective diagnosis and treatment of malaria cases.

Urgent actions are necessary to meet the ambitious goal to reduce malaria by 90% the next decade. It is imperative that additional integrated vector control/management approaches have to be incorporated into the programme such as larviciding and significant reduction of breeding sites or new control techniques and strategies such as the recombinant DNA technology which has revolutionized biological sciences and has a practical impact on new control strategies (Antonelli et al. 2016).

Not only do the vectors and pathogens have tremendous adaptability, but also new types of diseases continue to occur, such as dengue haemorrhagic fever that was observed for the first time in Southeast Asia in 1954. Altogether, the greater mobility of people from endemic areas by modern means of transport, the intensified international trade and the fluctuations in climate have resulted in a wider distribution of vector mosquitoes such as *Aedes albopictus* (*Stegomyia albopicta*) and disease-causing agents. The risk of becoming infected with a vector-borne disease has increased again not only in the tropics but also in Europe, such as the outbreak of chikungunya virus in Italy in 2007 (Angelini et al. 2007). Special vigilance is needed in countries where the Asian tiger mosquito, *Aedes albopictus*, is present because of its high vector capacity for arboviruses. Italy’s outbreak of chikungunya in 2007 is the first known transmission by this efficient vector species, to be confirmed in Europe, and the risk increased with the changing climatic conditions and anthropogenic activities such as increasing mobility and trade which favoured the spread and development of mosquitoes and pathogens. This phenomenon is well

documented by the recent autochthonous dengue cases in Spain and Southern France as well as the first autochthonous Zika case in Southern France in 2019 (Aranda et al. 2018; ECDC 2019b, c).

The essential foundation for successful action against the vectors requires not only an integrated mosquito management (IMM) concept, in which all appropriate methods for control are used, but also including knowledge of the biology and ecology of the target organisms. The importance of a vector or nuisance species is determined above all by its physiological characteristics, such as reproduction, migration and host-seeking and biting behaviour. Accurate identification is a basic prerequisite to a study of the autoecology of a species as well as its biocoenotic relationship in the ecosystem. All these efforts should result in an improvement of the quality of life for humans by reducing the mosquito abundance by enhancing control measures based on integrated vector management (IVM) principles. All approaches should favour effective methods with low toxicological profile and low environmental impact to contribute to the preservation of wetland biodiversity. Exchange of information and knowledge in the broadest sense should support sound mosquito control programmes worldwide.

The exciting achievements in molecular biology such as the sequencing of the genomes of the malaria parasite, *Plasmodium falciparum*, and the mosquito vector *Anopheles gambiae* give hope for the development of new drugs, vaccines and genetic engineering of malaria-resistant mosquitoes. However, these new tools should not lead to neglect the already developed strategies in vector control/management which are still in stages of development and can be implemented quickly if the necessary infrastructure is provided.

Scientists and the public are concerned about an increasing risk of vector-borne diseases, both from the entomological, medical and epidemiological point of view. Changing climatic conditions cause a resurgence in diseases which have already been eradicated or which may appear as a threat to human health.

Improved techniques like the geographic information system (GIS) integrated with digital mobile collection systems supported by a Global Positioning System (GPS) and modern information technology can significantly contribute to improving the planning, realisation and documentation of mosquito control/management operations and allow a more effective effort to reducing mosquito-borne diseases.

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