

Mosquitoes (Diptera: Culicidae) in New Zealand: reverting to the traditional *Aedes* nomenclature

José G. B. Derraik*

Ecology and Health Laboratory, Wellington School of Medicine & Health Sciences, University of Otago, PO Box 7343, Wellington, New Zealand

**Address for correspondence: derraik@gmail.com*

Abstract

Mosquito-borne diseases are one of the main causes of death and morbidity among humans worldwide. Globalisation is facilitating the spread of mosquitoes to new areas, and vigilance at international borders combined with ongoing surveillance are paramount to prevent the spread of mosquito vectors. This must be underpinned by prompt identification of species, and international consensus on the application of nomenclature is therefore essential. There have been a number of proposed reclassifications of mosquitoes in recent years, which would lead to name changes to some of the most important mosquito vectors worldwide. Considerable controversy has since erupted. The issues surrounding the controversy are briefly discussed here. Following discussions with a number of scientists in Oceania, it is therefore suggested that New Zealand (and other countries) retain mosquito nomenclature as per the traditional genus *Aedes*. Currently, this seems to be the most appropriate course of action until some agreement on this issue is reached at an international level.

Mosquitoes, human health and the need for clarity

Mosquitoes are insects in the family Culicidae (Order Diptera) and there are approximately 3200 known species and subspecies distributed among 37 genera worldwide (Service 2000). The adoption of a blood (protein) feeding mode by females in most culicid genera has provided the means to both greatly enhance mosquito productivity, and to transmit blood-borne pathogens/parasites between terrestrial vertebrate hosts. While there is a relatively small number of species of major concern in this regard, the impact on human health is disproportionately significant.

Malaria, caused by *Plasmodium* spp. (Protozoa) and transmitted by *Anopheles* mosquitoes, is endemic in 91 countries and threatens *ca* 40% of the world's population (WHO 2007). It is estimated to have killed nearly one million children under five in 2000 (Murray *et al.* 2001). In the African region, malaria is the third most frequent cause of death, behind HIV/AIDS and lower respiratory system infections (Murray *et al.* 2001). Moreover, it causes 300-500 million acute illnesses per year and is responsible for 30-50% of inpatient admissions in Africa (WHO 2002, 2007).

Dengue fever, transmitted primarily by *Aedes aegypti*, is the world's most widely distributed arboviral disease (Gratz 1997, WHO 1997, Solomon & Mallewa 2001). It causes an estimated 20 million infections and 24,000 deaths annually, with 2.5 billion people worldwide living in risk areas (WHO 1997, Gibbons & Vaughn 2002). In addition to the burden on human health from these and more localised mosquito-borne diseases, mosquitoes are also involved in the transmission of numerous diseases affecting both domesticated and wild animals (Labarthe *et al.* 1998, Dobson & Fofopoulos 2001).

Modern transport and the unprecedented movement on a global scale of people, animals and goods are facilitating the spread of mosquitoes to new areas (Derraik 2004). The probability of mosquito establishment and subsequent spread are likely to be enhanced by the warmer and wetter climates predicted for many areas under a global warming scenario (Reiter 2001).

Vigilance at international borders combined with ongoing surveillance within individual countries is one of the best lines of defense available. This must be underpinned by prompt identification by health protection and biosecurity agencies of species that may pose a threat. International consensus on the application of nomenclature is therefore essential to avoid confusion in this regard.

The proposed changes to mosquito taxonomy and the consequent controversy

The International Code of Zoological Nomenclature was developed “to promote stability and universality of scientific names in taxonomy” (Weaver 2005). This is fundamental to create a universal language that overcomes linguistic and cultural barriers.

Recently, Reinert (2000) proposed the elevation of the *Aedes* subgenus *Ochlerotatus* to a generic rank. Reinert's proposed changes also transferred 22 other *Aedes* subgenera into the new genus *Ochlerotatus* (Reinert 2000, Russell 2006). In the context of New Zealand, for example, two exotic species of human health significance *Aedes (Finlaya) notoscriptus* and *Aedes (Ochlerotatus) camptorhynchus* were consequently renamed as *Ochlerotatus (Finlaya) notoscriptus* and *Ochlerotatus (Ochlerotatus) camptorhynchus*, respectively. Later Reinert *et al.* (2004) raised another 32 existing subgenera of *Aedes* and *Ochlerotatus* to generic rank (Reinert *et al.* 2004, Russell 2006). As a result, the names of some of the most important mosquito vectors of human disease were changed, including *Aedes (Stegomyia) aegypti* and *Aedes (Stegomyia) albopictus*, which became *Stegomyia aegypti* and *Stegomyia albopicta*, respectively.

Savage & Strickman (2004) raised key criticisms against the change in the generic status of *Ochlerotatus*. For example, under the traditional nomenclature the three

most common mosquito genera (*Aedes*, *Anopheles* and *Culex*) can be easily distinguished by field personnel, based on simple morphological characters, and biological and behavioral characteristics. The authors emphasized that female adult specimens (the stage most commonly encountered during mosquito surveillance or monitoring) of *Ochlerotatus* and *Aedes* (as defined by Reinert 2000) cannot be identified morphologically without the aid of a microscope, and no major features of biology, behavior and ecology can clearly distinguish these taxa (Savage & Strickman 2004). Savage & Strickman (2004) defended the view that the best way to advance the nomenclature of Culicidae based on phylogenetic analysis is to focus on the subgenera, and Savage (2005) provided an in-depth analysis of the reasons for doing so, while extensively criticizing the approach taken by Reinert (2000) and Reinert *et al.* (2004). On the other hand, according to the work of Shepard *et al.* (2006) on ribosomal DNA, *Aedes* and *Ochlerotatus* formed two separate and distinct clades, providing phylogenetic data consistent with the elevation of *Ochlerotatus* to the generic level as proposed by Reinert (2000).

There is still no consensus on the appropriateness of the proposed changes by Reinert (2000) and Reinert *et al.* (2004) (see Weaver 2005). There has been considerable controversy on this topic, with numerous experts debating the issue, for example via the Walter Reed Biosystematics Unit website, which hosts the online *Systematic Catalogue of Culicidae*. Although taxonomic changes may be necessary, such nomenclature changes of important mosquito vectors of human disease have extensive implications, potentially creating considerable confusion and financial cost (*e.g.*, republishing educational materials, keys and catalogues, as well as updating databases) (Weaver 2005). A succinct and relatively comprehensive discussion of the pros and cons of the reclassifications proposed by Reinert (2000) and Reinert *et al.* (2004) has recently been provided by Russell (2006).

Indications are that at present, irrespective of the appropriateness of the nomenclatural changes suggested by Reinert (2000) and Reinert *et al.* (2004), they will not be incorporated by some of the most important journals covering the field of medical entomology (Weaver 2005), at least not until further work has been carried out. The journals that have agreed to adopt the traditional nomenclature are *The American Journal of Tropical Medicine and Hygiene*, *Annals of Tropical Medicine and Parasitology*, *Emerging Infectious Diseases*, *Journal of the American Mosquito Control Association*, *Journal of Vector Ecology*, *Medical and Veterinary Entomology*, *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *Vector-Borne and Zoonotic Diseases*, and *PROMED* (Weaver 2005).

The mosquito nomenclature issue in New Zealand

New Zealand scientists working with culicids had unofficially accepted Reinert's (2000) recommendations, with the elevation of the *Aedes* subgenus *Ochlerotatus* to a generic

rank. However, few have subsequently adopted Reinert *et al.*'s (2004) further reclassifications, in particular the controversial elevation of the subgenus *Stegomyia* to generic rank. Those working with mosquitoes in New Zealand tend to do so in close association with colleagues and other experts overseas, particularly with those in the South Pacific. Australia, in particular, is the origin of not only three of the four exotic mosquitoes established in New Zealand, but also of most species being regularly intercepted at our national entry ports (Derraik 2004). Furthermore, this taxonomic controversy is of relevance to New Zealand as the exotic *Aedes camptorhynchus* is the subject of a government-funded eradication programme.

Australian scientists have previously adopted Reinert's (2000) suggested nomenclature (Russell 2006). However, at the 2006 meeting of the Mosquito Control Association of Australia (MCAA) it was agreed that the nomenclature would revert back to the traditional genus *Aedes* (Russell 2006). It is important that New Zealand maintains an approach to nomenclature that is consistent with the one adopted overseas. As a result, until the controversy surrounding the issues proposed by Reinert (2000) and Reinert *et al.* (2004) are adequately agreed upon at an international level, it seems appropriate for New Zealand to revert to the traditional nomenclature prior to Reinert (2000). Discussions with others working with culicids or closely related species in New Zealand and Australia indicate that there is some agreement on this proposed move, as put forward to the author by a number of researchers in the field*.

The two main government departments dealing with mosquito-related issues in New Zealand (the Ministry of Health and the Ministry of Agriculture and Forestry) have accepted this recommendation following the MCAA's move. This article does not support or reject the taxonomic changes of Reinert (2000) and Reinert *et al.* (2004). However, it is here suggested that Culicidae nomenclature in New Zealand is retained as per the traditional genus *Aedes* used prior to Reinert (2000) (see Table 1). This seems to be the most appropriate action to take, at least until some agreement on this issue is reached at an international level.

* In alphabetical order: Mark Disbury (NZ Biosecure, NZ); Dr Allen Heath (Animal Research Centre, AgResearch, Wallaceville, NZ); Dr Mary McIntyre (Wellington School of Medicine & Health Sciences, University of Otago, NZ); Assoc. Prof. Ted Nye (Dunedin School of Medicine, University of Otago, NZ); Dr Ricardo L. Palma (Museum of New Zealand Te Papa Tongarewa, NZ); Dr Scott Ritchie (School of Public Health, James Cook University, AUS); Prof. Richard Russell (Department of Medical Entomology, University of Sydney, AUS); Dr David Slaney (Institute of Environmental Science & Research Ltd, NZ); Dr Amy Snell (AUS); Dr Craig Williams (School of Pharmacy & Medical Sciences, University of South Australia, AUS).

Table 1. List of mosquito species in New Zealand as per their traditional generic and subgeneric status.

Origin	Species
Endemic	<i>Aedes (Ochlerotatus) subalbirostris</i> Klein and Marks
	<i>Aedes (Nothoskusea) chathamicus</i> Dumbleton ¹
	<i>Aedes (Ochlerotatus) antipodeus</i> Edwards
	<i>Coquillettidia (Coquillettidia) iracunda</i> (Walker)
	<i>Coquillettidia (Austromansonia) tenuipalpis</i> (Edwards)
	<i>Culex (Culex) asteliae</i> Belkin
	<i>Culex (Culex) pervigilans</i> Bergroth
	<i>Culex (Culex) rotoruae</i> Belkin
	<i>Culiseta (Climacura) novaezealandiae</i> Pillai
	<i>Culiseta (Climacura) tonnoiri</i> (Edwards)
	<i>Maorigoeldia argyropus</i> (Walker)
	<i>Opifex fuscus</i> Hutton
Exotic	<i>Aedes (Ochlerotatus) camptorhynchus</i> Thomson
	<i>Aedes (Finlaya) notoscriptus</i> (Skuse)
	<i>Aedes (Halaedes) australis</i> Erichson
	<i>Culex (Culex) quinquefasciatus</i> Say

¹Reinert *et al.* (2004) proposed the placement of this endemic New Zealand species into the genus *Opifex*, renaming it as *Opifex chathamicus* (Dumbleton). Although this issue has not yet been widely discussed, the suggested re-classification may be appropriate (Amy Snell, *personal communication* 2006).

Acknowledgements

Special thanks to Dr Mary McIntyre (Wellington School of Medicine and Health Sciences, University of Otago) for her very valuable amendments and suggestions. I would also like to thank Dr Dave Slaney (Institute of Environmental Science and Research Ltd), Sarah Clinehens (MAF Biosecurity New Zealand) and Dr Amy Snell for feedback on previous versions of this manuscript.

References

- Derraik JGB. 2004. Exotic mosquitoes in New Zealand: a review of species intercepted, their pathways and ports of entry. *Australian and New Zealand Journal of Public Health* 28: 433-444.
- Dobson A, Foufopoulos J. 2001. Emerging infectious pathogens of wildlife. *Philosophical Transactions of the Royal Society of London Series B - Biological Sciences* 356: 1001-1012.

- Gibbons RV, Vaughn DW. 2002. Dengue: an escalating problem. *British Medical Journal* 324: 1563-1566.
- Gratz NG. 1997. Dengue and Dengue hemorrhagic fever: a spreading pandemic. *Public Health* 14: 20-29.
- Labarthe N, Serrão ML, Melo YF, de Oliveira SJ, Lourenço de Oliveira R. 1998. Mosquito frequency and feeding habits in an enzootic canine dirofilariasis area in Niterói, state of Rio de Janeiro, Brazil. *Memórias do Instituto Oswaldo Cruz* 93: 145-154.
- Murray CJL, Lopez AD, Mathers CD, Stein C. 2001. *The Global Burden of Disease 2000 Project: Aims, Methods and Data Sources*. World Health Organization, Geneva. [online] URL: <http://www.who.int/healthinfo/paper36.pdf>
- Reinert JF. 2000. New classification for the composite genus *Aedes* (Diptera : Culicidae: Aedini), elevation of subgenus *Ochlerotatus* to generic rank, reclassification of the other subgenera, and notes on certain subgenera and species. *Journal of the American Mosquito Control Association* 16: 175-188.
- Reinert JF, Harbach RE, Kitching IJ. 2004. Phylogeny and classification of Aedini (Diptera: Culicidae), based on morphological characters of all life stages. *Zoological Journal of the Linnean Society* 142: 289-368.
- Reiter P. 2001. Climate change and mosquito-borne disease. *Environmental Health Perspectives* 109(Suppl 1): 141-161.
- Russell RC. 2006. Mosquito name changes: 'An *Aedes* by any other name will bite as bad!' *Mosquito Bites* 1: 37-40.
- Savage HM. 2005. Classification of mosquitoes in tribe Aedini (Diptera: Culicidae): paraphylyphobia, and classification versus cladistic analysis. *Journal of Medical Entomology* 42: 923-927.
- Savage HM, Strickman D. 2004. The genus and subgenus categories within Culicidae and placement of *Ochlerotatus* as a subgenus of *Aedes*. *Journal of the American Mosquito Control Association* 20: 208-214.
- Service MW. 2000. *Medical Entomology for Students*, 2nd edn. Cambridge University Press, Cambridge.
- Shepard JJ, Andreadis TG, Vossbrinck CR. 2006. Molecular phylogeny and evolutionary

relationships among mosquitoes (Diptera: Culicidae) from the northeastern United States based on small subunit ribosomal DNA (18S rDNA) sequences. *Journal of Medical Entomology* 43: 443-454.

Solomon T, Mallewa M. 2001. Dengue and other emerging flaviviruses. *Journal of Infection* 42: 104-115.

Weaver S. 2005. Journal policy on names of aedine mosquito genera and subgenera. *American Journal of Tropical Medicine and Hygiene* 73: 481.

WHO. 1997. *Dengue Haemorrhagic Fever - Diagnosis, Treatment, Prevention and Control*, 2nd edn. World Health Organization, Geneva. [online] URL: <http://www.who.int/csr/resources/publications/dengue/Denguepublication/en/>

WHO. 2002. *Scaling Up the Responses to Infectious Diseases - A Way Out of Poverty*. World Health Organization, Geneva. [online] URL: http://whqlibdoc.who.int/hq/2002/WHO_CDS_2002.7.pdf

WHO. 2007. *What is Malaria? Roll Back Malaria Partnership Secretariat*. World Health Organization, Geneva. [online] URL: http://www.rollbackmalaria.org/cmc_upload/0/000/015/372/RBMInfosheet_1.pdf